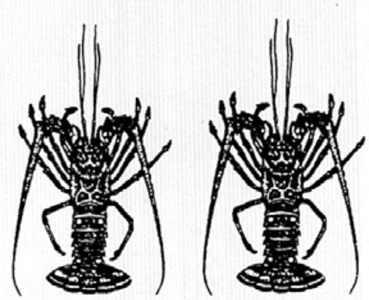
STOCK ASSESSMENT AND FISHERY EVALUATION REPORT FOR SPINY LOBSTER

FISHERY MANAGEMENT PLAN FOR THE SPINY LOBSTER FISHERY

VOLUME I



MAY 1999

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This is a publication of the South Atlantic Fishery Management Council pursuant to National Oceanic and Atmospheric Administration Award No. NA97FC0018

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prepared by the
South Atlantic Fishery Management Council

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Financial assistance for producing this document was provided by grant funds from the National Marine Fisheries Service, National Oceanic and Atmospheric Administration, under Public law 104-208, the Magnuson-Stevens Fishery Conservation and Management Act.

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1.0 INTRODUCTION

The *Guidelines for Fishery Management Plans (602 Guidelines)* published by the National Marine Fisheries Service (NMFS) require that a stock assessment and fishery evaluation (SAFE) report be prepared and reviewed annually for each fishery management plan (FMP). The SAFE reports are intended to summarize the best available scientific information concerning the past, present, and possible future condition of the stocks and fisheries under federal management. Appendix A to the *Guidelines* lists the desired components of SAFE reports as follows: 1) information on which to base harvest specifications; 2) information on which to assess the economic and social condition of persons and businesses that rely on recreational and commercial use of fish resources, including fish processing industries; and 3) any additional economic, social, and ecological information pertinent to the success of management or the achievement of objectives of each FMP.

The SAFE report for the Spiny Lobster fishery managed under the Fishery Management Plan for Spiny Lobster in the Gulf of Mexico and South Atlantic was compiled by South Atlantic Council staff with input from NMFS SERO, NMFS SEFSC, and State of Florida scientists. Our goal was to include the most recent information on issues that have been raised or are likely to be raised during the Council's review of the spiny lobster stock and fishery. The detailed information is found in the attached reports and we have only attempted to extract a very brief overview for inclusion in Sections 2, 3 and 4.

A very summary overview of stock status is presented in Section 2.0 Overview of Stock Assessment. Overviews of economic and social status of the fishery are presented in Section 3.0 Fishery Evaluation. This section contains material from the Council's Sustainable Fisheries Act Amendment describing fishing communities. Ecosystem considerations are presented in Section 4.0 Ecosystem Considerations using material from the Council's Habitat Plan and Habitat Amendment. These sections rely very heavily on the identified Council documents and the following appendixes:

Appendix A. Results of Literature Search.

A computer search of published literature was conducted. These results, along with the literature cited sections of the papers included in Appendix A through Appendix K, should provide most if not all of the pertinent literature.

Appendix B. List of Contributions to SAFE as Provided by NMFS SERO.

This list includes suggested documents for the SAFE report.

Appendix C. Florida's Spiny Lobster Fisheries (SERO-ECON-98-23).

This report analyses Florida's spiny lobster fisheries with data through 1997 and was prepared by John Vondruska (NMFS Fisheries Economics Office) in September 1998.

Appendix D. The Developing Live Spiny Lobster Industry (NMFS-SEFSC-395).

The developing live spiny lobster fishery was described by William Antozzi (NMFS Fisheries Economics Office) in 1996.

Appendix E. The 1995 Spiny Lobster Update of Trends in Landings, CPUE, and Size of Harvested Lobster (NMFS-SEFSC-MIA-94/95-47).

Landings, CPUE, and size of harvested lobsters were reported through the 1994/95 fishing season by Douglas E. Harper (NMFS Southeast Fisheries Science Center) and made available in September 1995.

Appendix F. National Report - Spiny Lobster Fisheries of the United States of America (Spiny Lobster Assessment Workshop, Belize City, Belize).

An overview of the spiny lobster fishery prepared by Robert G. Muller (Florida Department of Environmental Protection) was presented at a recent lobster symposium

Appendix G. Status of Spiny Lobster Fishery in Florida, 1998 (FL DEP).

The status of the spiny lobster fishery through the 1997/98 fishing year was prepared by John H. Hunt, William C. Sharp, Thomas R. Matthews, Robert G. Muller, Rodney D. Bertelsen, and Carrollyn Cox (Florida Department of Environmental Protection) in November 1998. This represents the most recent information on the fishery itself versus the stock assessment results in Appendix H.

Appendix H. Evaluation of Effort Reduction in the Florida Keys Spiny Lobster , *Panulirus argus*, Fishery using An Age-Structured Population Analysis (FL DEP).

The trap reduction program and stock status were analyzed by Robert G. Muller, John H. Hunt, Thomas R. Matthews, and William C. Sharp (Florida Department of Environmental Protection) using data through the 1995/96 fishing season and published in 1997.

Appendix I. By-Catch in Florida's Spiny Lobster Trap Fishery and the Impact of Wire Traps (FL DEP).

The issue of by-catch in the spiny lobster fishery was reported on by Thomas R. Matthews and Scott Donahue (Florida Department of Environmental Protection) at the June 13, 1996 South Atlantic Council meeting in Key West, Florida.

Appendix J. Nocturnal Foraging of the Caribbean Spiny Lobster, *Panulirus argus*, At Offshore Reefs of Florida, USA (FL DEP).

Feeding behavior is described by Carrollyn Cox, John H. Hunt, William G. Lyons, and Gary E. Davis (Florida Department of Environmental Protection and United States National Parks Service) and published in 1997.

Appendix K. Life History of the Spotted Spiny Lobster, *Panulirus guttatus*, an Obligate Reef-Dweller: Settlement, Population Structure, Reproduction, and Interactions With Other Lobsters (FL DEP).

Information on the spotted spiny lobster are described by William C. Sharp, John A. Hunt, and William G. Lyons (Florida Department of Environmental Protection) and published in 1997.

2.0 OVERVIEW OF STOCK ASSESSMENT

2.1 Stock Identification

Spiny lobster are known from Bermuda, the Bahamas, the Caribbean, and the East Coast of the American continent from North Carolina, U.S.A. to Rio de Janeiro, Brazil. The origin of phyllosoma larvae in Florida is unsolved. These two statements are taken directly from the original Spiny Lobster Fishery Management Plan (GMFMC and SAFMC, 1982). More recent work has been completed examining current patterns and settlement patterns. The issue remains unresolved, however, it is generally recognized there is local recruitment. This issue should be examined in a future amendment to the fishery management plan.

2.2 Biology

The following is taken directly from Appendix F which includes the cited references: "The biology of spiny lobsters in Florida has been studied extensively for more than 30 years (see last year's report for references). More recently, Cox et al. (1997) investigated the foraging behavior of spiny lobsters and prey densities in the Florida Keys and found that lobster gut contents contained a predominance of molluscs especially in rubble areas. Butler et al . (1997) used mesocosms and field observations to examine the spatial scales of "postalgal" juveniles. They found that aggregated juveniles had higher mortality than non-aggregated ones. Butler and Herrnkind (In press) examined the efficacy of adding artificial shelters. Acosta et al. (1997) found that puerulus settlement increases during the first quarter of the moon phase, the highest settlement during the year centered on March, and they found a correlation between puerulus settlement and winds from the Northeast. Donahue et al. (1998) gave the equation for the numbers of eggs in a batch (E) as a function of carapace length (CL) as

$$E = 88.7\ CL^2 - 219\ 200.$$

An on-going study is looking at the growth of spiny lobsters in the wild from settlement at 6-7 mm using micro-coded wire tags. Based on the 59 lobsters that have been recaptured, the size of lobsters a year after settlement was 37-53 mm CL."

2.3 Available Data

The following is taken directly from Appendix F which contains the cited references:
"4.1 Fishery dependent

Commercial effort and landings information is collected through trip tickets. Wholesale dealers provide the Department of Environmental Protection with copies of their landing receipts that includes the dealer number, Saltwater Product license number of the fisher, date of sale, county landed, area fished, water depth, time away from the dock, gear used on the trip, soak time for traps, number or traps, species landed, size category, and ex-vessel price paid. Catch rates from trip tickets are standardized with a general linear model and show a marked decline as the season progresses (Figure 2). Standardized catch rates from a general linear model are used as a tuning index in the stock assessment. In the past four seasons, there have been an average of 27 800 trips in the Florida Keys and those trips landed an average of 3 000 tonnes per fishing season. Data from the 1997-98 season are not complete but the landings reported to date are 3 056 tonnes from 28 205 trips with a value of $29 300 000.

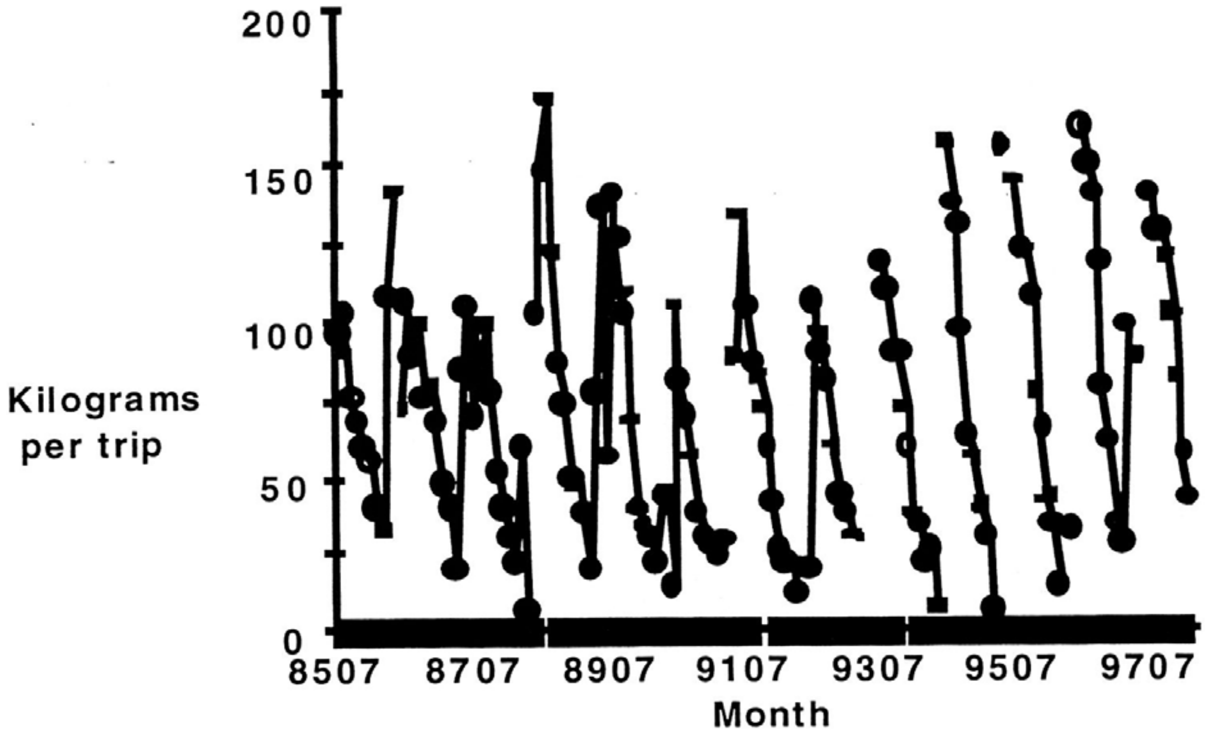


Figure 2. Monthly commercial catch per trip in the Florida Keys.

Beginning in July 1991, the recreational harvest in numbers of spiny lobster for the Florida Keys and the rest of the state for the Sport have been estimated using a mail survey of persons possessing a crawfish stamp on their Saltwater Fishing license. In the past four seasons, recreational participants have caught an average of 1 100 000 lobsters in July and August. A survey estimated the landings for the entire 1994-95 season and showed that 95% of the recreational harvests occurs between the Sport Season in July and the first Monday in September.

The final fishery dependent program is the on-board observer program that began in August 1993 and measures the total catch from between 100 and 150 traps per commercial trip. This program produces catch per trap and an independent measure of catch per trip. The catch per trap from the observer program is also used to as a check to ensure that the catch per trip from trip tickets reflects the dynamics in the fishery (Figure 3). Also, this program provides a recruitment index as the number of lobsters between 76 mm and 80 mm that will be incorporated into future stock assessments. Lastly, this program identifies the number of under-sized lobsters that are used as bait.

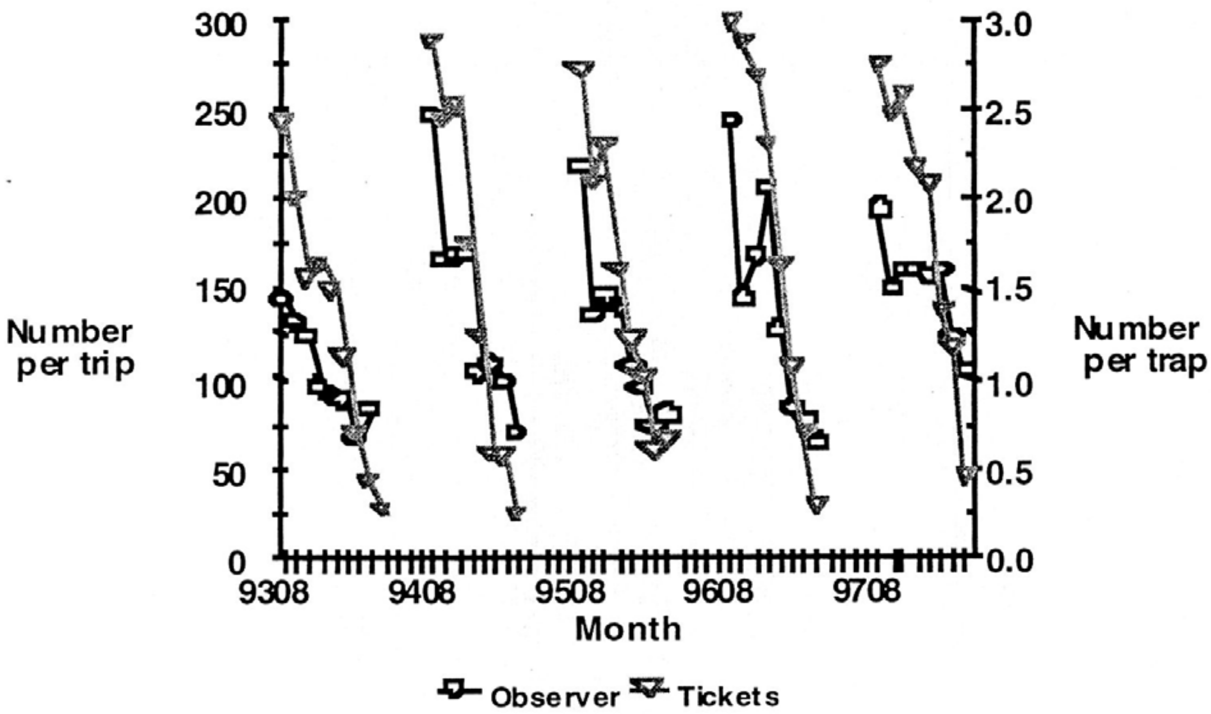


Figure 3. Comparison on commercial catch per trip from trip tickets with number of lobster per trap from the observer program.

4.2 Fishery independent

Beginning in April 1987, puerulus collectors were established at two locations in the Florida Keys. In 1992, sampling frequency changed from weekly samples to monthly sampling during the first quarter of the lunar phase after analyzing the first five year's of data. The monthly number of recruits estimated from the onboard observer program was highly correlated with the number pueruli collected 21 and 32 months earlier. These times were similar to those Muller et al. (1997) estimated using probabilistic growth simulations of the time from settlement to recruitment as 23 months for males and 30 months for females. A new program is evaluating the efficacy of Special Protection Areas (SPA) that do not allow harvesting of any marine resources including spiny lobsters. Beginning in July 1997, divers have been collecting information to compare the density, sizes, and sex ratio of lobsters inside of the spas and outside. Those data are not available at this time but they have the potential for providing an independent tuning index for future stock assessments."

2.4 Stock Status

The following is taken directly from Appendix F which contains the cited references:
"Stock Status

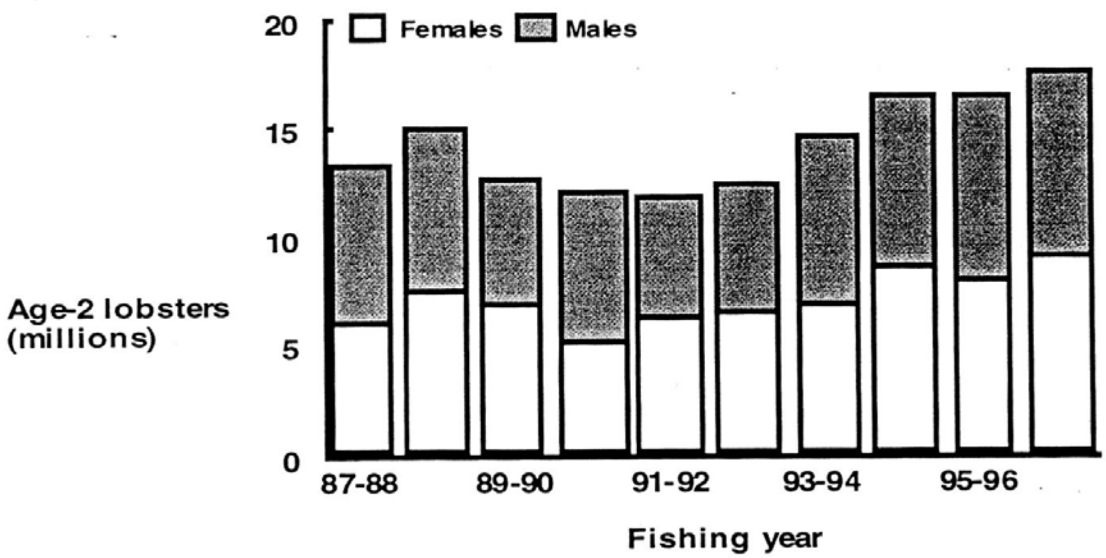


Figure 4. Recruitment expressed as number of age-2 lobsters as estimated by sex from the age-structured population analyses.

An age-structured stock assessment was developed for spiny lobster in the Florida Keys in 1996 with a probabilistic growth model (Muller et al. 1997) and again in 1997 using the same procedures (Integrated Catch at Age, version 1.2, Patterson and Melvin 1996). Higher landings in recent seasons reflect larger population sizes rather than higher fishing mortality rates. Recruitment began increasing after the number of traps was reduced beginning in 1993 (Figure 4). A possible explanation lies with the use of under-sized lobsters as attractants in traps. With fewer traps in the fishery, fewer small lobsters were used for bait."

Additional detailed stock assessment information is included in Appendix H.

3.0 FISHERY EVALUATION

3.1 Economic Status of The Fishery

This section describes economic aspects of the commercial and recreational harvest of spiny lobster (*Panulirus agrus*) in the South Atlantic and Gulf. The latest landings data for 1997 indicate that just over 7 million pounds are harvested by the commercial sector and over 90% of spiny lobsters consumed in the United States are imported. It was estimated that recreational harvests were about one fourth that of the total commercial landings in 1997 (Vondruska, 1998; Appendix C).

Commercial Fishery

The commercial fishery for spiny lobsters is a small boat fishery, where the majority of vessels are in the 20-40 foot range. These craft make one day trips primarily in waters within and off the state of Florida. Most of the commercial harvest is taken using traps, and about 3% of landings is attributed to bully nets and commercial divers. The ex-vessel value of commercial landings was just over $29 million in 1997, the year for which the most recent landings information is available. The principal commercial harvest region is the West Coast of Florida as indicated in Illustration 1.

Table 1: Landings, Ex-Vessel Value, and Real Prices in the U.S. Commercial Spiny Lobster Industry (Vondruska, 1998).

Year	Region	Landings (Pounds)	Ex-Vessel Landings Value $(1997)	Real Ex-Vessel Price per pound
1992	Florida East Coast	481,510	1,767,142	3.67
1992	Florida West Coast	4,004,911	15,338,809	3.83
1992	**Total**	**4,486,421**	**17,105,951**	
1993	Florida East Coast	884,021	3,138,275	3.55
1993	Florida West Coast	4,494,786	14,473,211	3.22
1993	**Total**	**5,378,807**	**17,611,485**	
1994	Florida East Coast	809,572	3,367,820	4.16
1994	Florida West Coast	6,294,632	25,933,884	4.12
1994	**Total**	**7,104,204**	**29,301,703**	
1995	Florida East Coast	695,627	2,845,114	4.09
1995	Florida West Coast	6,328,311	26,325,774	4.16
1995	**Total**	**7,023,938**	**29,170,888**	
1996	Florida East Coast	670,684	2,401,049	3.58
1996	Florida West Coast	7,196,075	24,754,498	3.44
1996	**Total**	**7,866,759**	**27,155,547**	
1997	Florida East Coast	613,000	2,507,170	4.09
1997	Florida West Coast	6,490,000	24,402,400	3.76
1997	**Total**	**7,103,000**	**26,909,570**	

Landings in 1996 were the highest during the period from 1976 to 1997. However, it is not clear whether this is due to the reduction in excess harvesting capacity or stock fluctuations (Vondruska, 1998). Ex-vessel price reached a peak in the 1995-1996 season and declined thereafter. There is a strong indication that prices have rebounded in the 1997-1998 season (Muller, 1998; Appendix F).

Live lobsters harvested in this fishery have been shipped to overseas markets in recent years. The main export markets have been in Asia, Europe and Canada , and in fact a large proportion of domestic landings is shipped abroad. Over the past two years the downturn in the Asian economy has had an impact on this export market. It may even account for the drop in the real ex-vessel price of Florida spiny lobsters between 1996 and 1997 (Vondruska, 1998). Domestic consumption of spiny lobsters fell from 120 million pounds in 1970 to its current level of about 70 million pounds (round weight). Nearly 90% of the product sold in the U.S. is imported, primarily as frozen tails from Latin America and The Caribbean.

<u>Harvesting Capacity</u>

Prior to 1976 U.S. vessels fished extensively in Bahamian waters and landed their catch in Florida. This activity was prohibited in 1977, which resulted in the shifting of additional effort to the spiny lobster fishery in the United States. Consequently, this fishery became over capitalized and there was excess harvesting capacity beyond what was needed to harvest the resource. The fishery off Florida continued its growth until 1991 when crowding on the fishing grounds and declines in average productivity prompted Florida's trap certificate program in 1992. During the 1991/1992 fishing season commercial lobster fishermen made 38,628 trips and deployed 939,000 traps in this fishery. Data from the Florida Department of Environmental Protection shows that the number of trap tags issued was progressively reduced to 568,000 by the 1995/96 season. During this time period even though the number of fishing trips and craft in use in the fishery have declined, landings have continuously increased reaching a peak in 1996.

The number of tags issued for the 1998/1999 season was reduced to 540,000. The planned number of traps for the 2001/2002 fishing season will be about half the number of traps employed in the 1991/92 fishery (Vondruska, 1998, Appendix C).

Prior to the trap reduction program an average of 1,838 fishers reported landing spiny lobsters, and 76 wholesale dealers purchased lobsters. After the trap reduction program was implemented this number was reduced to 1,100. However, now 216 commercial fishermen produce 73% of the harvest and 20 wholesale dealers distribute 84% of the landings.

With the advent of the trap reduction program there was concern that a shift in harvest allocation would occur from commercial trap fishermen to commercial divers. Commercial divers' landings have increased from 184,000 pounds in 1993/1994 season to 400,000 pounds during the 1997/1998 season. This represents a shift of 2% in total commercial landings towards the commercial diving sector.

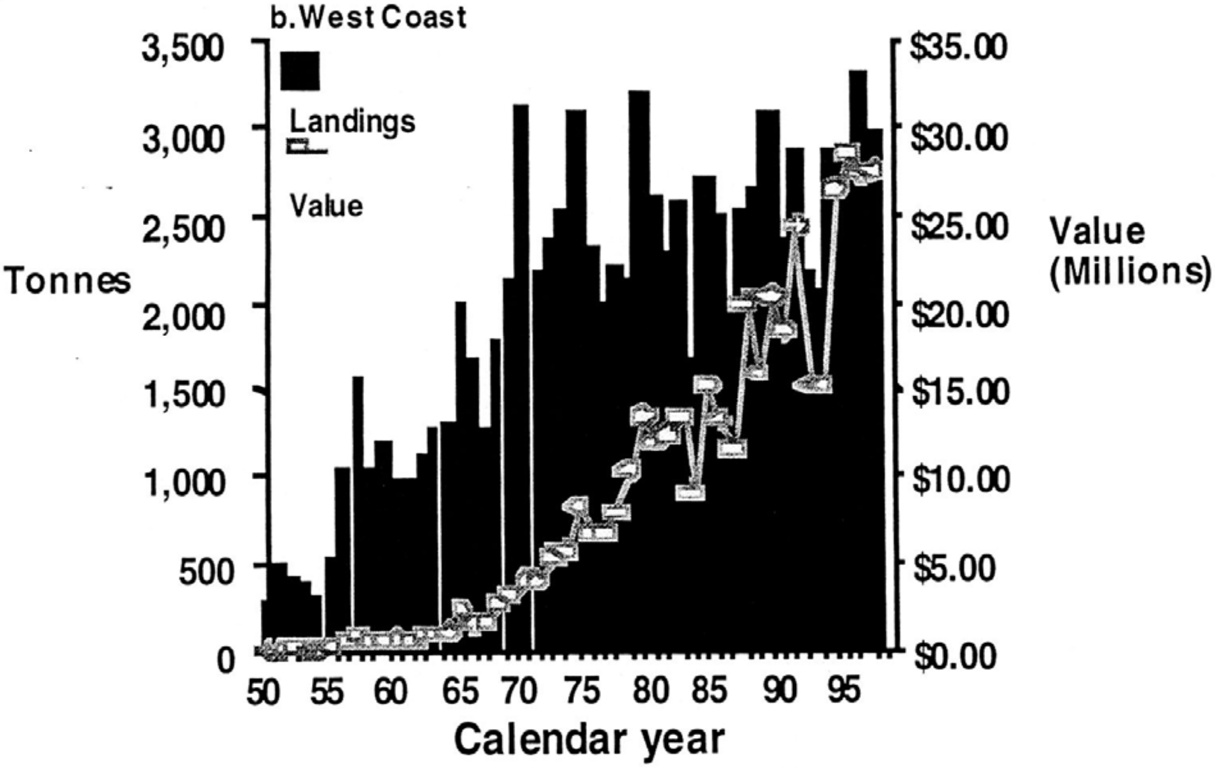
The Recreational Sector

Recreational diving for lobsters is extremely popular, about 110,000 recreational saltwater license holders purchase the crawfish stamp in Florida. It has been estimated that spiny lobster recreational divers' harvest amounts to at least 25% of the commercial catch annually. This estimate was derived from a mail survey of Florida saltwater license holders who purchased a crawfish stamp in 1991 (Appendix H). Surveys in the following three years indicate that the level of recreational diving effort and harvest have remained constant. Most of this recreational activity is concentrated in the Florida Keys, and the majority of the catch is taken between the start of the two day special sport season in July and Labor Day. There is a little information on recreational diving in states North of Florida, however from earlier studies it appears that most of the spiny lobster recreational harvest occurs in Florida.

The following is taken directly from Appendix F which contains the cited references:

"2. Description of fisheries

Florida's fishery for spiny lobsters began in Key West area of the Florida Keys in nineteenth century (Labisky et al. 1980) and developed until by the early 1960s the fishery was producing approximately 1 250 tonnes per year (Figure 1). When the minimum size of lobster was reduced to 76.2 mm (3.0 in) carapace length (CL) in 1968, the fishery expanded to the Middle and Upper Keys and the resulting harvest increased to an average of 2 500 tonnes. In addition, the smaller size allowed fishers on Florida's East Coast to land lobsters from Grand Bahamas Bank until the Bahamian government closed their waters to foreign fleets in 1977. Ninety percent of the landings in Florida come from the Florida Keys (Monroe county) and most of the following discussion will focus on that area. The commercial fishery primarily harvests spiny lobsters with traps. As the number of traps increased in the fishery, landings increased, but landings leveled off as the numbers of traps exceeded 250 000 traps. In 1993, Florida's Legislature instituted a Trap Reduction Program. The number of traps has been reduced from 939 000 traps to 582 000 traps with another reduction of 61 000 traps scheduled for July 1998. Spiny lobsters are also captured by diving and with bully nets. Increasingly, spiny lobsters are being landed and shipped live primarily to Taiwan and Japan with a few being shipped to Europe (Antozzi 1996)."



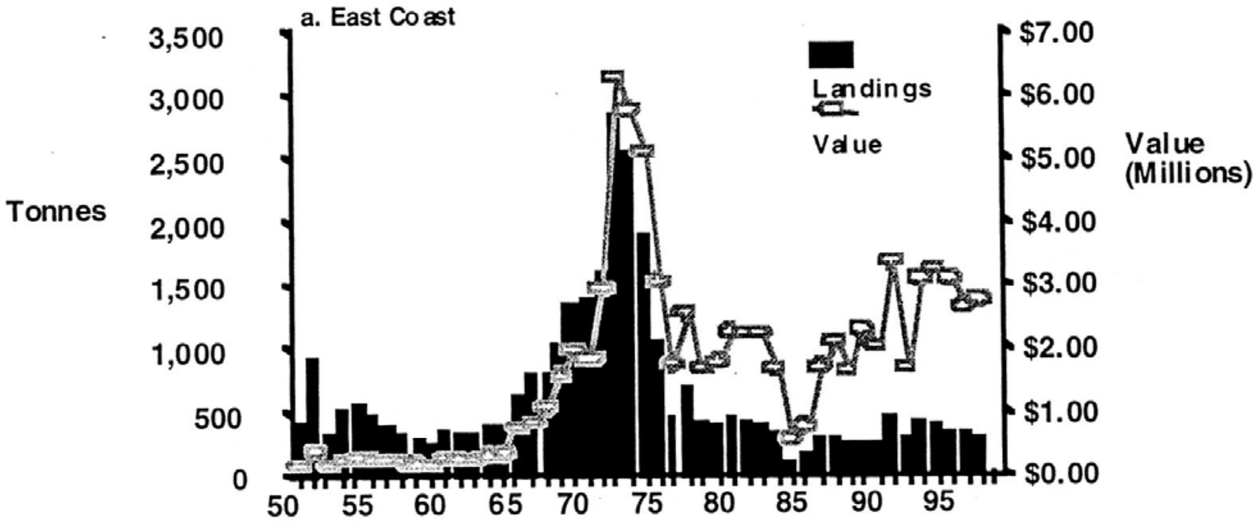


Figure 1. Annual landings and value of spiny lobster in the US by calendar year and coast.

3.2 Social Evaluation - South Atlantic Fishing Communities as Defined in the Sustainable Fisheries Act Amendment (SAFMC, 1998a)

"4.3.3 Fishing Communities - Identify and define fishing communities

Identifying fishing communities provides a basis for analyzing impacts of management measures on fishing communities rather than on a fishery-wide basis. This would be more relevant in situations where impacts are differential because of the location, level of activity and dependency on fishing, availability of alternative job opportunities, etc. in different fishing communities. This measure would allow fishery managers to obtain information on the impacts of future management measures on different fishing communities. It could make for the formulation of management measures that would minimize impacts on fishing communities that have less opportunities to adapt to changes imposed by the measures.

Identification and definition of fishing communities would normally have a positive impact, except that, for the South Atlantic, there are no data collected on fishing communities. National Standard 8 imposes requirements on the council and the fishery management regulatory process that cannot be satisfied given existing data. Current data available do not allow for a meaningful definition of fishing community, moreover, do not provide a measure of dependence upon fishing and will not contribute to useful impact analysis.

At its March meeting, the Gulf of Mexico Fishery Management Council's Socio-economic Panel recommended that further research be initiated and funded by National Marine Fisheries Service as soon as possible to aid in the identification and definition of fishing communities in the Southeast. The panel also recommended the scope of this problem be addressed at a national level, such that impacts upon fishing communities can be analyzed across regions as well as within. A key area for expanded research is ethnographic and survey research to identify, not only communities, but those who provide supporting services to the economy and culture of fishing communities. Especially important in the Southeast is the need to provide a realistic portrayal of recreational fishing, diving, and eco-tourism and their importance to a fishing community.

The Council concluded incorporating all available information at this time will meet the mandates of the recent Magnuson-Stevens Act amendments relative to fishing communities.

With the addition of National Standard 8, FMPs must now identify and consider the impacts upon fishing communities to assure their sustainable participation and minimize adverse economic impacts [MSFCMA section 301 (a) (8)].

The proposed guidelines for this new standard state: *"... fishing communities are considered geographic areas encompassing a specific locale where residents are dependent on fishery resources or are engaged in the harvesting or processing of those resources. The geographic area is not necessarily limited to the boundaries of a particular city or town. No minimum size for a community is specified, and the degree to which the community is 'substantially engaged in' or 'substantially dependent on' the fishery resources must be defined within the context of the geographical area of the FMP. Those residents in the area engaged in the fisheries include not only those actively working in the harvesting or processing sectors, but also ``fishery-support services or industries," such as boat yards, ice suppliers, or tackle shops, and other fishery-dependent industries, such as ecotourism, marine education, and recreational diving."* [Federal Register Volume 62, Number 149 (August 4, 1997)]

"The term 'sustained participation' does not mandate maintenance of any particular level or distribution of participation in one or more fisheries or fishing activities. Changes are inevitable in fisheries, whether they relate to species targeted, gear utilized, or the mix of seasonal fisheries during the year. This standard implies the maintenance of continued access to

fishery resources in general by the community. As a result, national standard 8 does not ensure that fishermen would be able to continue to use a particular gear type, to target a particular species, or to fish during a particular time of the year." [Federal Register Volume 62, Number 149 (August 4, 1997)]

"The term 'fishing community' means a community that is substantially dependent on or substantially engaged in the harvest or processing of fishery resources to meet social and economic needs, and includes fishing vessel owners, operators, and crew, and fish processors that are based in such communities. A fishing community is a social or economic group whose members reside in a specific location and share a common dependency on commercial, recreational, or subsistence fishing or on directly related fisheries-dependent services and industries (for example, boatyards, ice suppliers, tackle shops)." [Federal Register Volume 62, Number 149 (August 4, 1997)]

In order to determine a community's "substantial dependence" or "sustained participation" on fishing, those communities must first be identified. Presently, the NMFS has not identified fishing communities, nor their dependence upon fishing in the South Atlantic. Moreover, there are no ongoing data collection programs to gather the necessary information that would allow for the identification of fishing communities in the South Atlantic or other regions. Also, there are no future plans to implement any such data collection program that would determine dependence upon fishing in order to provide the Councils with important information necessary for social and economic impact analysis of fishing communities. This leaves the councils with existing data collected through other agencies, not always specific to fisheries management, i.e., census data, regional economic census, and previous research on specific fisheries. Although this data can be useful, it is often not specific enough to identify or provide a clear representation of a community and its dependence upon fishing. One reason for this difficulty is that fishermen in a specific fishery often do not reside within one particular municipality that can easily be identified as a fishing community or one that is substantially dependent upon fishing. Also, that information is often not provided at the municipality level, but more often at the county level.

Commercial fishermen may have a domicile (home) in one community and dock their boat in another. They may sell their fish in either place or an entirely different location. Recreational fishermen often do not live on the coast, but drive from inland counties and may launch their boats or fish from several different sites. For these reasons, identifying a "fishing community" becomes problematic in that such a community does not fit the normal geographic boundaries or fall within the metes and bounds that would surround a normal incorporated municipality.

The impacts of fisheries management may be minimal in a single community, but, when taken overall may be substantial to an entire county or several county area. Those same measures may have a small impact on a large metropolitan area, but, to a neighborhood where most fishing families live or most fishing activity originates it could be substantial. Therefore, a "fishing community" may encompass a single municipality, a county, several counties or one neighborhood within a major metropolitan area depending upon a variety of demographic, social, economic and ecological factors that one must consider.

One important circumstance to consider when assessing the impacts upon fishing communities is the difference between rural and urban areas, as many fishing communities exist in rural areas on the Southeast coast. There are several ways in which rural areas differ from the more urban or metropolitan as illustrated in *Understanding Rural America* (ERS-USDA, 1993).

Rural areas have consistently lagged behind urban areas with respect to real earnings per job and education levels. Rural areas have also seen a rise in subgroups who are prone to economic disadvantage--families headed by single mothers and minorities. However, these differences vary across the country and are influenced by several factors, one of which is the availability of natural resources. In order to explain and examine some of these differences, counties within the U.S. have been classified as either metropolitan or non-metropolitan. A further subdivision of non-metro counties provides a more clear understanding into each subtype's dependence upon certain economic specialization and the importance of those differences to the residents of those counties (ERS-USDA, 1993). The following classification system may also suggest a possible method for defining an area's dependence upon fishing using the appropriate criteria.

Six types of non-metro counties have been classified, three of which are based upon economic specialization - farming, manufacturing and services. The other three county classifications are based upon their relevance to policy -- retirement-destination; Federal lands; and persistent poverty. Using earned income as a measure of dependence, the classification for counties based upon economic specialization is as follows:

Farming counties - 20% or more earned income from farming
Manufacturing - 30% or more earned income from manufacturing
Services - 50% or more earned income from services industries

Those counties whose classification is based upon economic specialization are mutually exclusive; the other three classification types are not mutually exclusive (ERS-USDA, 1993).

This type of classification system, based upon a percentage of earned income or other measure, might be used to determine a community, county or region's dependence upon fishing. However, like farming counties, those dependent upon fishing have likely seen a decline in the dependence upon fishing over time. This is probably due to significant increases in the population of coastal areas since the 1970's. Much of the population growth has been in the form of immigration of people 60 and older who seek coastal areas for retirement destinations. The increase in this population sector, in turn, brings a greater dependence upon service industries. Choosing such a measure of dependence is not possible at this time and would have to be developed through further analysis and/or research.

Griffith and Dyer developed a typology of fishing community dependence for the Northeast Multi-species Groundfish Fishery (MGF) (Aguirre, 1996). In that typology, they identified critical indicators of dependence which included specific physical-cultural and general social-geographic indicators, i.e., number of repair/supply facilities; number of fish dealers/processors; presence of religious art/architecture dedicated to fishing; presence of secular art/architecture dedcicated to fishing; number of MGF permits; and number of MGF vessels. Using previous results and supplemental research of their own, they were able to develop a fishery dependence index score for the five primary ports in the MGF.

From their research Griffith and Dyer were able to document five variables which best predicted dependence upon the MGF:

1. Relative isolation or integration of fishers into alternative economic sectors, including political participation. To what extent have the fleets involved in the MGF enclaved themselves from other parts of the local political economy or other fisheries? How much have the MGF fleets become, similar to an ethnic enclave, closed communities?

2. Vessel types within the port's fishery. Is there a predominance of large vessels or small vessels, or a mix of small, medium, and large?

3. Degree of specialization. To what extent do fishers move among different fisheries? Clearly, those fishers who would have difficulty moving into alternative fisheries or modifying their vessels with alternative gears are more dependent on the MGF than those who have histories of moving among several fisheries in an opportunistic fashion.

4. Percentage of population involved in fishery or fishery-related industries. Those communities where between five and ten percent of the population are directly employed in MGF fishing or fishing-related industries are more dependent on the MGF than those where fewer than five percent are so employed.

5. Competition and conflict within the port, between different components of the MGF. Extensive competition and conflict between fishers within the same port--as well as between different actors in the MGF, such as boat owners and captains--seem to be associated with intensive fishing effort and consequent high levels of dependence on the MGF. In this case, dependence may have a strong perceptual dimension, with fishers perceiving the resources they are harvesting to be scarce and that one fleet's gain is another fleet's loss.

It is important to understand that these factors are appropriate for the MGF and are not necessarily the best predictors for all fishing communities. Fisheries in the Southeast will differ markedly from those in other regions of the country, especially with regard to their integration into other economies and notably the tourist economy. Recreational fishing is an integral part of the tourism and service economy that has developed for coastal communities in the South Atlantic. For these communities, dependence upon fishing will undoubtedly be tied to commercial and recreational fishing and their associated businesses. Therefore, it is important for fishery dependence models to be developed specifically for the South Atlantic.

Griffith and Dyer (Aguirre 1996) also discuss their description of fishing communities as it relates to the term Natural Resource Community (NRC). Dyer et. al define a NRC as "a population of individuals living within a bounded area whose primary cultural existence is based upon the utilization of renewable natural resources" (1992:106). Natural Resource Communities possess an elementary connection between biological cycles within the physical environment and socio-economic interactions within the community. An adaptation to working on the water by fishermen has important implications for the community as a whole because of the necessary support activities that take place on land, i.e., net hanging & mending; fish handling & preparation; boat building & repair. This important tie to the physical environment not only dictates occupational participation, but structures community interaction and defines social values for those living in Natural Resource Communities. While fishing communities in the MGF are not bounded or set apart from the larger community in which they reside, they still manifest certain recognizable features that would classify them as NRCs (Aguirre 1996). Fishing communities in the South Atlantic will also show signs of being integrated into the larger economy, but may still maintain certain vestiges of an NRC. Fishermen in the South Atlantic, like those in the Northeast MGF, will not likely see their ecological systems being closed, but affected by a host of other forces, both globally and locally. Far more detailed research will need to be conducted among South Atlantic fishing communities to determine changes in integration of the larger economy. One of the most likely changes will be an increasing dependence upon the service sectors as recreational fishing and other recreational activities play an increasing role in the economies of coastal communities. While there will continue to be a connection between the social and physical environments, the nature of that interaction will undoubtedly change.

At this time there is insufficient data to completely identify and define fishing communities in the South Atlantic. The following description of fishing communities provides information to explore ways of defining fishing communities that range from geographical regions to a well bounded municipality. With varied levels of research or data available for each state, descriptions of fishing communities will depend upon the amount of data available and the specific nature and timeliness of that data. In some cases, it may be possible to find a municipality that will clearly fit a definition of fishing community and meet a criterion for dependence upon fishing. In others, it may be a series of communities or counties designated a "fishing community" or possibly a particular sector of a large metropolitan area.

Readily available data will be discussed to allow for public input on the best way to identify fishing communities and determine their dependence upon fishing. Following the discussion of fishing communities in the South Atlantic a discussion of data needs and format will provide possible directions for data collection and analysis. The Council welcomes comments on all aspects of incorporating this new national standard, in order to devise a classification system which will assist in assessing the impacts of fishery management upon fishing communities.

4.3.3.1.1 South Atlantic Fishing Communities

According to NMFS, South Atlantic commercial fishermen have harvested well over 250,000 pounds of seafood in each of the years 1995 and 1996 (Table 1). Those landings have represented over $200,000,000 in harvest value. The value of those landings can become even greater once it diffuses throughout South Atlantic fishing communities as it provides employment and other benefits to other sectors within each community's economic base.

Table 1. U.S. Domestic Commercial Fishing Landings by Region, 1995 and 1996.
Source Fisheries of the United States, 1996

	1995		1996	
Region	**Thousand pounds**	**Thousand dollars**	**Thousand pounds**	**Thousand dollars**
New England	592,665	580,957	641,821	564,169
Middle Atlantic	240,413	179,747	241,936	181,869
Chesapeake	845,632	174,229	728,830	158,736
South Atlantic	**277,035**	**238,112**	**268,990**	**209,407**
Gulf of Mexico	1,464,718	724,619	1,496,875	680,304

Commercial seafood landings also represent other forms of expenditure which have an impact upon fishing communities, such as: fuel, gear, groceries, etc. Support industries like, gas stations, tackle shops, grocery stores all have an investment in the harvesting capability of the local fishing fleet.

As with commercial fishing, recreational fishing activity will also contribute to the economic base of a fishing community as fishermen buy fuel, bait, tackle and food & beverage for fishing trips. Figure 1 demonstrates an increasing trend in recreational fishing trips for most

South Atlantic states, but, also substantial variation in the number of trips over time. Such variation can mean significant economic impacts for those communities that rely upon recreational fishing.

South Atlantic fishing communities will depend upon both recreational fishing and commercial fishing for determining the importance of fishing to their economic base. The supporting role of associated businesses will also need to be incorporated into any measure of dependence. Such businesses as: seafood dealers and processors, marinas, gas stations, bait and tackle shops, dive shops, trucking firms, restaurants and many others, all have some role in determining dependence upon fishing. Unfortunately, data that is robust and/or specific enough does not exist to include in such a determination.

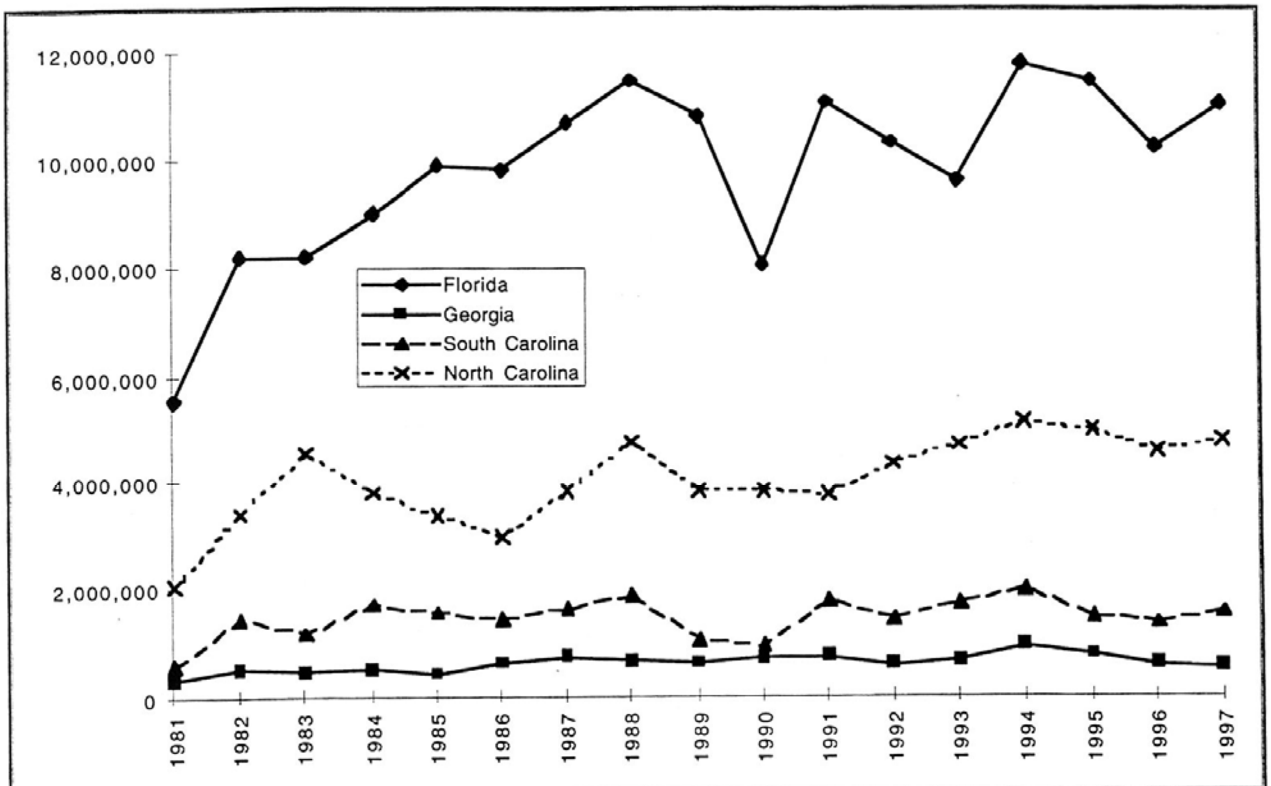


Figure 1. Estimated Number of Marine Recreational Fishing Trips by State and Year for the South Atlantic. Source: Personal communication from the National Marine Fisheries Service, Fisheries Statistics and Economics Division.

To identify fishing communities in the South Atlantic one might begin with the National Oceanic and Atmospheric Administrations publication *Fisheries of the United States* (1996). Among the various statistics listed are commercial landings of major U.S. ports. These ports could be considered to be substantially dependent upon fishing. Table 2 lists the major ports for the South Atlantic in 1996 and 1995 for quantity and value of landings. Some ports are listed as individual communities while others are a combination of several communities over a limited geographical range. This characterization may be useful as we attempt to further delineate fishing communities in each state. Other sources of information helpful in defining fishing communities include the United States Census and Bureau of Economic Research, which include economic information for many areas of the U.S.

Table 2. Quantity, Value and Rank of Commercial Landings for South Atlantic Ports among Major U.S. Ports Source: Fisheries of the United States, 1996.

Port	1995 Quantity*	1995 Rank	1995 Value*	1995 Rank	1996 Quantity*	1996 Rank	1996 Value*	1996 Rank
Key West	23.4	32	66.7	5	23.7	37	62.8	4
Beaufort-Morehead City, NC	87.0	16	35.0	15	75.4	18	20.3	34
Wanchese-Stumpy Point, NC	39.0	25	25.0	24	43.4	24	24.6	27
Charleston-Mt.Pleasant, SC	11.0	58	19.0	32	---	--	---	--
Cape Canaveral, FL	10.1	--	16.9	35	21.2	43	17.7	42
Darien-Bellville, GA	---	--	11.0	50	---	--	---	--
Beaufort, SC	---	--	11.0	51	---	--	---	--
Englehard-Swanquarter, NC	11.0	58	---	--	15.0	50	---	--
Oriental-Vandemere, NC	9.0	--	10.0	--	14.0	53	13.3	50
Bellhaven-Washington, NC	---	--	6.0	--	---	--	11.5	58

*Value and quantity are in millions of dollars and pounds respectively.

4.3.3.1.2 North Carolina

The 1990 Census of Population and Housing provides the following information for North Carolina regarding individuals who reported their occupation as fisher in Table 3. This data will likely include those individuals who commercially fish fresh water areas and others who are not impacted by fisheries management of marine fisheries at the council level. This information does provide data for comparison and could help set parameters for a measure of dependency upon fishing. It is not recommended that these figures be used to determine dependency upon fishing, however. The 1990 Census classifies year-round full-time workers as all persons 16 years old and over who usually worked 35 hours or more per week for 50 to 52 weeks in 1989.

Table 3. Number of Fishers and Mean Annual Income for North Carolina in 1990. Source: U.S. Bureau of the Census.

	Year Round/Full Time	Other	Total
Number of fishers			
Male	989	1,271	2,260
Female	47	105	152
Total	1,036	1,376	2,412
Mean Annual Income ($)			
Male	16,315	13,069	14,489
Female	11,518	4,489	6,662
Total	16,097	12,414	13,996

The 1990 Census also provides the following information for North Carolina regarding individuals who reported their occupation as captain of a fishing vessel in Table 4. It is interesting to note that there were no females listed as captain of fishing vessels. This concurs with the much of the research on the occupation of fishing which finds very few women in this role. Although women often play an important role in the fishing operation, they are rarely in the position of captain of fishing vessels.

Table 4. Number of Captains of Fishing Vessels and other officers and Mean Annual Income for North Carolina in 1990. Source: U.S. Bureau of the Census.

	Year Round/Full Time	Other	Total
Number of Captains			
Male	102	141	243
Female	0	0	0
Total	102	141	243
Mean Annual Income ($)			
Male	26,917	33,640	30,818
Female	0	0	0
Total	26,917	33,640	30,818

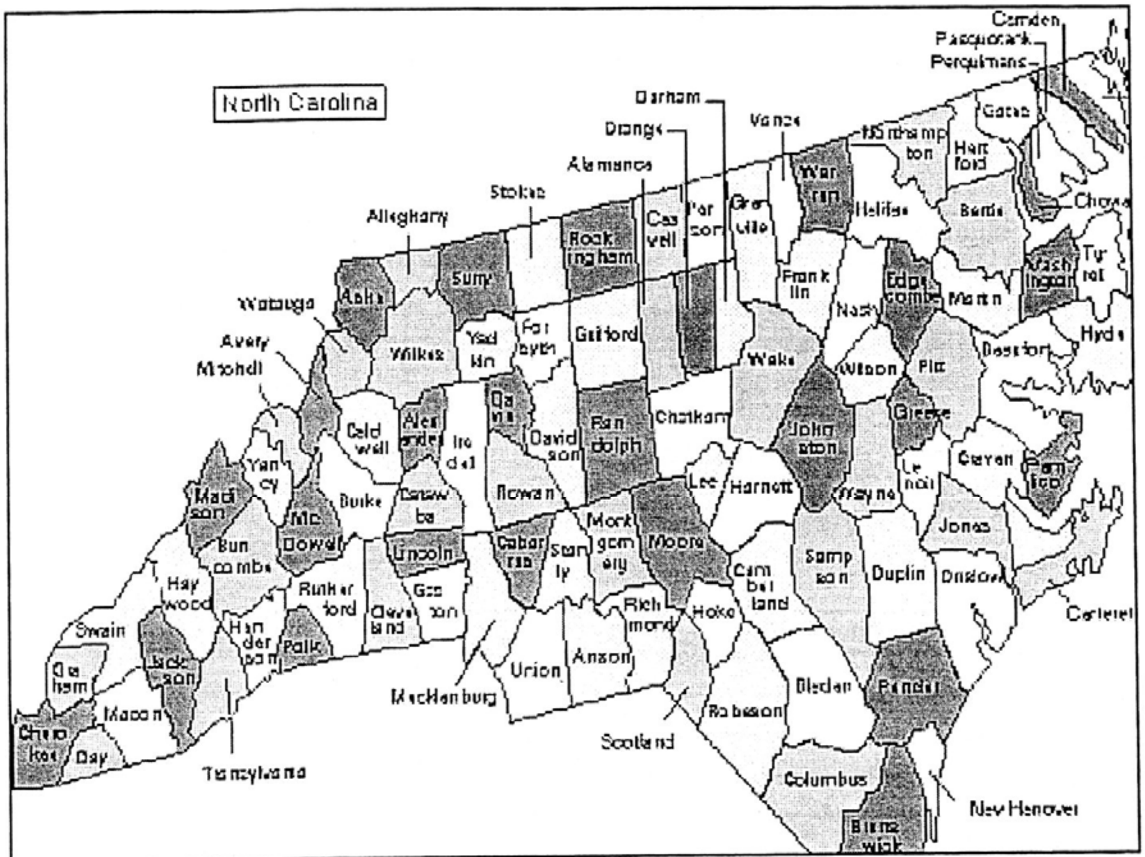


Figure 2. North Carolina Counties. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

Johnson and Orbach (1996) have divided North Carolina into six areas for their research on effort management of North Carolina commercial fisheries. Those areas were determined to be distinct with regard to species/gear combinations in addition to sociological, ecological and environmental differences. The areas defined are as follows:

- Area 1: Albermarle Area - Currituck, Camden, Pasquotank, Perquimans, Chowan, Bertie, Washington, and Tyrell Counties.
- Area 2: Dare County
- Area 3: Southern Area - Brunswick, Pender, New Hanover, and Onslow Counties
- Area 4: Pamlico Area - Craven, Pamlico, Beaufort, and Hyde Counties.
- Area 5: Carteret County

Area 6: Inland Counties.

Area 1: Albermarle Area

The Albermarle area includes the following counties: Currituck, Camden, Pasquotank, Perquimans, Chowan, Bertie, Washington and Tyrell. Johnson and Orbach (1997) found that commercial fishermen in this area had two primary gear types, pots and gill nets. They also concluded that fishermen here move in and out of gill netting on an annual basis.

Table 5. Population and Economic Information for Counties included in Area 1. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

Area 1-County		1993	1994	1995
Bertie	Population	20,631	20,665	20,745
	Personal Income (Thousands of $)	291,226	303,292	328,227
	Per Capita Pers Income ($)	14,116	14,677	15,822
	Personal Income Fishing (Thousands of $)	71	75	84
Camden	Population	6,211	6,370	6,399
	Personal Income (Thousands of $)	92,875	100,012	105,636
	Per Capita Pers Income ($)	14,953	15,700	16,508
	Personal Income Fishing (Thousands of $)	0	0	0
Chowan	Population	13,815	13,909	13,958
	Personal Income (Thousands of $)	226,563	234,453	247,428
	Per Capita Pers Income ($)	16,400	16,856	17,727
	Personal Income Fishing (Thousands of $)	128	134	151
Currituck	Population	15,215	15,831	16,285
	Personal Income (Thousands of $)	251,885	269,871	291,055
	Per Capita Pers Income ($)	16,555	17,047	17,873
	Personal Income Fishing (Thousands of $)	358	376	423
Pasquotank	Population	33,220	33,488	33,759
	Personal Income (Thousands of $)	510,623	534,860	574,433
	Per Capita Pers Income ($)	15,371	15,972	17,016
	Personal Income Fishing (Thousands of $)	----	----	----
Perquimans	Population	10,644	10,692	10,737
	Personal Income (Thousands of $)	148,365	162,627	160,912
	Per Capita Pers Income ($)	13,939	15,210	14,987
	Personal Income Fishing (Thousands of $)	----	0	----
Tyrell	Population	3,918	3,875	3,846
	Personal Income (Thousands of $)	56,056	58,138	52,738
	Per Capita Pers Income ($)	14,307	15,003	13,712
	Personal Income Fishing (Thousands of $)	476	500	562
Washington	Population	14,136	14,276	14,138
	Personal Income (Thousands of $)	220,429	229,038	238,124
	Per Capita Pers Income ($)	15,593	16,044	16,843
	Personal Income Fishing (Thousands of $)	225	236	266

Using multidimensional scaling, Johnson and Orbach were able to examine the spatial relationship of various types of fishing in each area. For Area 1, crab potting was the most central fishery. In other words most fishermen in the area do some crab potting. Referring to cliques, they found that for this area fishermen who peeler pot, eel pot, crab pot and gill net flounder differ from those that long haul. Fishermen that long haul will crab pot and gill net flounder but do not engage in peeler pots or eel pots.

In examining the categories which would include fishermen for Area 1 (Table 6) there seems to be no trend regarding either those in Farm/Fish/Forest occupations or the Agriculture, Fishing, Mining Industries. There are both increases and decreases in the number of those within each categories from 1970 to 1990 which varies by county.

Table 6. Number within Farm/Fish/Forest Occupation and Agriculture, Fishing, Mining Industry for North Carolina Coastal Counties included in Area 1 for 1970, 1980, and 1990 Census. Source: MARFIN Sociodemographic Database

County	**Occupation/Industry**	**1970**	**1980**	**1990**
Bertie County	Farm/Fish/Forest	923	1035	839
	Agri.,Fishing,Mining	1050	1038	884
Camden County	Farm/Fish/Forest	203	220	114
	Agri.,Fishing,Mining	220	181	137
Chatham County	Farm/Fish/Forest	740	904	832
	Agri.,Fishing,Mining	927	934	1286
Currituck County	Farm/Fish/Forest	194	247	316
	Agri.,Fishing,Mining	215	296	309
Pasquotank County	Farm/Fish/Forest	444	491	469
	Agri.,Fishing,Mining	552	478	508
Perquimans County	Farm/Fish/Forest	417	513	299
	Agri.,Fishing,Mining	445	524	316
Tyrrell County	Farm/Fish/Forest	197	249	208
	Agri.,Fishing,Mining	225	273	233
Washington County	Farm/Fish/Forest	408	511	551
	Agri.,Fishing,Mining	462	557	526

Area 2 : Dare County

Within Dare county the following communities have been described through recent research of the snapper grouper fishery and might be considered fishing communities: Manns Harbor, Manteo, Wanchese, Hatteras, Stumpy Point (Iverson 1997). Johnson and Orbach (1997) found that commercial fishermen in this area had two primary gear types, pots and gill nets. In their analysis of fishery networks for Area 2 they again found crab pots to be central. Another interesting difference revealed was that fishermen who shrimp trawl in this area will gillnet for sharks but do not engage in crab potting.

Dare County shows a higher personal income from fishing over the three years listed (Table 7) than most other coastal counties in North Carolina.

Table 7. Population and Economic Information for Counties included in Area 2. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

Area 2 County		**1993**	**1994**	**1995**
Dare				
	Population	24,300	25,106	26,074
	Personal Income (Thousands of $)	429,564	465,011	502,474
	Per Capita Pers Income ($)	17,678	18,522	19,271
	Personal Income Fishing (Thousands of $)	5,426	5,688	6,392

Dare County (Table 8) shows a general increase in the number of individuals in the listed occupations and industries over the twenty years from 1970 to 1990.

Table 8. Number within Farm/Fish/Forest Occupation and Agriculture, Fishing, Mining Industry for Dare County (Area 2) for 1970, 1980, and 1990 Census. Source: MARFIN Sociodemographic Database

County	Occupation/Industry	1970	1980	1990
Dare County	Farm/Fish/Forest	11	376	637
	Agri.,Fishing,Mining	181	446	655

Snapper Grouper Fishing

Most of the snapper grouper permit holders in Area 2 work out of Hatteras and only a small portion of their annual commercial fishing activity is devoted to targeting snapper grouper species. Black sea bass, snowy grouper, and blueline tilefish are the most frequently targeted species by commercial snapper grouper fishermen from this area. Surface longlining for tuna and swordfish is apparently the most productive and profitable style of commercial fishing in the area, and the small towns of Manteo and Wanchese serve as refuge for a large number of both local and non-local longlining boats (Iverson, 1997).

Area 3: Southern Area

The Southern Area includes the following counties and communities (in parenthesis): Brunswick (Southport). Pender, New Hanover, Onslow (Sneads Ferry). Johnson and Orbach (1997) found that commercial fishermen in this area had four primary gear types: hook-and-line, gill net, hand harvest of shellfish, and trawling. Pot fishing was classified as secondary gear but they report that increasing usage over time could possibly make it a primary gear. It is interesting to note that they also reported that pot fishing showed an increase in all five areas over time. Area 3 showed much more complexity in annual rounds of fishing than Areas 1 or 2 with shrimp trawling, hand clamming and crab potting all central to the network (Johnson and Orbach 1997).

Table 9. Population and Economic Information for Counties included in Area 3. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

Area 3				
County		**1993**	**1994**	**1995**
Brunswick				
	Population	56,350	58,386	60,697
	Personal Income (Thousands of $)	878,453	941,247	1,024,954
	Per Capita Pers Income ($)	15,589	16,121	16,886
	Personal Income Fishing (Thousands of $)	1,595	1,674	1,885
Pender				
	Population	32,554	33,894	33,759
	Personal Income (Thousands of $)	510,623	534,860	574,433
	Per Capita Pers Income ($)	15,681	16,341	17,253
	Personal Income Fishing (Thousands of $)	----	----	----
New Hanover				
	Population	131,091	135,317	139,906
	Personal Income (Thousands of $)	2,620,539	2,800,024	3,036,665
	Per Capita Pers Income ($)	19,990	20,692	21,705
	Personal Income Fishing (Thousands of $)	----	----	693
Onslow				
	Population	145,638	144,951	144,259
	Personal Income (Thousands of $)	1,962,312	2,030,075	2,149,074
	Per Capita Pers Income ($)	13,474	14,005	14,897
	Personal Income Fishing (Thousands of $)	667	700	787

Counties included in Area 3 (Table 10.) show a general increase in numbers of individuals within the selected occupations and industries, with the exception of Pender County which shows a decline from 1970-1990.

Table 10. Number within Farm/Fish/Forest Occupation and Agriculture, Fishing, Mining Industry for North Carolina Coastal Counties included in Area 3 for 1970, 1980, and 1990 Census. Source: MARFIN Sociodemographic Database.

County	Occupation/Industry	1970	1980	1990
Brunswick County	Farm/Fish/Forest	370	668	1028
	Agri.,Fishing,Mining	505	645	971
Pender County	Farm/Fish/Forest	772	562	627
	Agri.,Fishing,Mining	892	669	690
New Hanover County	Farm/Fish/Forest	289	550	782
	Agri.,Fishing,Mining	564	615	984
Onslow County	Farm/Fish/Forest	754	869	996
	Agri.,Fishing,Mining	906	800	987

Snapper Grouper Fishing

For Area 3, the small community of Sneads Ferry, is unique in that the majority of the commercial reef fishermen fish with sea bass pots. According to the 1993 federal permit list for the South Atlantic region, there were 58 permit holders who indicated that sea bass pots were their primary gear type. Of those, 13 permit holders worked out of Sneads Ferry (Iverson, 1997).

Overall, 72% of fishermen using sea bass pots as their primary gear work out of home ports in North Carolina.

Area 4: Pamlico Area.

The Pamlico area includes these counties and communities (in parenthesis): Craven, Pamlico (Vandemere, Oriental), Beaufort (Bellhaven, Washington), Hyde (Ocracoke, Swanquarter, Englehard). Johnson and Orbach (1997) found that commercial fishermen in this area had three primary gear types, pots, gill nets, and trawls. In terms of annual fishing rounds Area 4 is the simplest to understand where two strategies are employed: gill netting and crab potting or trawling and crab potting. They go on to note that this simple strategy may signify few choices for fishermen in this area in the case of environmental or regulatory change (Johnson and Orbach 1997). Possible fishing communities within Area 4 might be: Vandemere and Oriental.

Table 11. Population and Economic Information for Counties included in Area 4.
Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

Area 4				
County		**1993**	**1994**	**1995**
Craven				
	Population	83,595	83,851	85,163
	Personal Income (Thousands of $)	1,450,296	1,508,353	1,626,657
	Per Capita Pers Income ($)	17,349	17,988	19,101
	Personal Income Fishing (Thousands of $)	386	405	- - - -
Pamlico				
	Population	11,772	11,948	12,064
	Personal Income (Thousands of $)	179,384	186,131	199,576
	Per Capita Pers Income ($)	15,238	15,578	16,543
	Personal Income Fishing (Thousands of $)	2,714	2,851	3,211
Beaufort				
	Population	43,446	43,815	43,998
	Personal Income (Thousands of $)	674,788	711,961	756,048
	Per Capita Pers Income ($)	15,532	16,249	17,184
	Personal Income Fishing (Thousands of $)	1,339	1,406	1,580
Hyde				
	Population	5,374	5,339	5,362
	Personal Income (Thousands of $)	80,982	90,101	80,300
	Per Capita Pers Income ($)	15,069	16,876	14,976
	Personal Income Fishing (Thousands of $)	1,860	1,973	2,215

Pamlico county had the highest personal income from fishing for Area 4 from 1993 to 1995 with a steady increase over those three years (Table 11). Hyde county followed with Beaufort next; both showing an increase over time. For most counties in Area 4 (Table 12) the general trend seems to be an increase from 1970 to 1980 and then a decrease from 1980 to 1990 within these occupation and industry categories. Beaufort County shows an overall decrease from 1970-1990.

Table 12. Number within Farm/Fish/Forest Occupation and Agriculture, Fishing, Mining Industry for North Carolina Coastal Counties included in Area 4 for 1970, 1980, and 1990 Census. Source: MARFIN Sociodemographic Database

County	Occupation/Industry	1970	1980	1990
Craven County	Farm/Fish/Forest	873	1136	832
	Agri.,Fishing,Mining	1129	1222	860
Pamlico County	Farm/Fish/Forest	245	498	442
	Agri.,Fishing,Mining	502	662	477
Beaufort County	Farm/Fish/Forest	1452	1393	1024
	Agri.,Fishing,Mining	2169	2123	1190
Hyde County	Farm/Fish/Forest	295	509	454
	Agri.,Fishing,Mining	442	579	511

Area 5: Carteret County

In Area 5 Johnson and Orbach (1997) found that commercial fishermen had three primary gear types, gill nets, trawls and hand harvest of shell fish. In terms of annual fishing rounds Area 5 did not show the clear gear stratification found in other areas. Shrimp trawling is the most central fishery, but pound netting, crab potting, and mechanized clamming also occur with shrimp trawling. (Johnson and Orbach 1997). Possible fishing communities within Area 5: Morehead City and Beaufort.

Table 13. Population and Economic Information for Counties included in Area 5. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

Area 5				
County		**1993**	**1994**	**1995**
Carteret				
	Population	55,747	56,381	57,690
	Personal Income (Thousands of $)	935,032	985,484	1,076,753
	Per Capita Pers Income ($)	16,773	17,479	18,664
	Personal Income Fishing (Thousands of $)	2,783	2,871	3,207

Among North Carolina's coastal counties, Carteret county was second to Dare county (Table 13) in terms of personal income from fishing. In addition, Carteret County (Table 14) shows an marked increase from 1970 to 1980, then a decrease from 1980 to 1990, within the occupations of Farm/Fish/Forest and an overall increase in the number of Agriculture, Fishing and Mining industries.

Table 14. Number within Farm/Fish/Forest Occupation and Agriculture, Fishing, Mining Industry for Carteret County (Area 5) for 1970, 1980, and 1990 Census. Source: MARFIN Sociodemographic Database.

County	Occupation/Industry	1970	1980	1990
Carteret County	Farm/Fish/Forest	225	1200	1158
	Agri.,Fishing,Mining	731	1234	1260

In a recent report on the importance of commercial fishing in Carteret county, Diaby (1997) found that Carteret county ranked first in poundage (96,652,314 lb) and second in dockside value ($20,618,486) in terms of commercial landings for North Carolina coastal counties. Finfish represented the 91% of total landings and 46% of total ex-vessel value. The most important species of finfish were: menhaden, flounder, croaker, weakfish and spot. Shellfish and crustaceans accounted for only 9% of all commercial landings but, represented over half of the value of landings during the period from 1974-1994. Employment by the commercial fishing industry, both full and part time for Carteret county was estimated to be 3,232 people for 1994 (Diaby, 1997). This number varies from those reported in the census data and emphasizes the problems in comparing these types of data. Since 1981 there have been about 105 to 140 licensed seafood dealers in Carteret county. The value of processed seafood peaked for the county in 1981 when scallops accounted for almost half of the value with a total value of $19,737,126. Since that time there has been a general decline in total value of processed seafood attributable to a decline in scallop landings. Menhaden was the most important single processed product over a fifteen year period from 1980 to 1994 (Diaby, 1997).

In estimating the economic impact of Carteret county commercial harvesting sector Diaby (1997) estimated $27 million in sales of goods and services and $11.66 million in value added. Total employment from commercial harvesting activities was estimated to be 3,371.

Sales of goods and services for the wholesaling and processing sector were estimated at $19 million, with $11 million n value added. There were an estimated 1,563 full and part time jobs created earning $6.55 million in wages (Diaby, 1997).

Overall, the activities of the commercial fishing industry created $46 million in sales of goods and services and $24 million in value added. There were 4,934 full and part time jobs which earned $14 million in wages (Diaby, 1997).

The recreational fishery spent approximately $70 million on fishing trips in Carteret county with $25.23 million in employ compensation and $47.61 in value added. There were 1,821 full and part time jobs associated with the recreational fishing industry in Carteret County.

The total impact of the coastal fishing industry on the economy of Carteret County was estimated to be $120.74 million with $71.32 million in value added. The total number of full and part time jobs was estimated at 6,755 with earnings of $38.94 (Diaby, 1997).

Snapper Grouper Fishing

The Morehead City/Beaufort area is located approximately 50 miles south of Ocracoke in Carteret County. This area is known for its sportfishing activity including several major tournaments each year. There is a small population of full time commercial reef fishermen in Morehead, however the majority of fishermen holding commercial permits are primarily part timers. Many of these fishermen divide their time between charter fishing during the peak tourist season (April through September) and commercial fishing in the winter months. Full time fishermen in this area reported fishing approximately 50 miles straight offshore and fishing from Hatteras to as far south as the South Carolina/Georgia line. Trip lengths vary with the size of the vessel, but the average trip length is 7 days and the larger boats carried up to 3 crew members (Iverson, 1997).

King Mackerel Fishery

The king mackerel fishery in North Carolina has grown steadily since 1980 and has leveled with catches repeatedly around one million pounds in recent years. From 1986 to 1990 the number of permits for Atlantic group king mackerel issued in North Carolina ranged from a low of 325 in 1987/88 to a high of 533 in 1989/90. Again, the majority of those permits were granted to hook and line fishermen. Present data indicates there were 448 commercial vessels permitted for king and Spanish mackerel in North Carolina (Vondruska, 1997).

4.3.3.1.3 South Carolina

Figure 3. South Carolina Counties Source: Roger Pugliese, SAFMC Staff.

The 1990 Census of Population and Housing provides the following information for South Carolina regarding individuals who reported their occupation as fisher in Table 15. A total of 401 individuals claimed Fisher as their occupational title with less than half indicating it was a year round full time employment. There were few females who indicated such and they had a far lower mean annual income than males in this occupation.

Table 15. Number of Fishers and Mean Annual Income for South Carolina Fishers in 1990. Source: U.S. Bureau of the Census.

	Year Round/Full Time	**Other**	**Total**
Number of fishers			
Male	188	193	381
Female	6	14	20
Total	194	207	401
Mean Annual Income ($)			
Male	28,842	14,489	18,946
Female	750	5,000	2,403
Total	23,710	14,269	18,390

There were a total of 69 individuals who indicated their occupation as captain of a fishing vessel in the 1990 census of population and housing. and 7 of them were female according to Table 16 Again, females had a much lower mean annual income when compared to males.

Table 16. Number of Captains of Fishing Vessels and other officers and Mean Annual Income for South Carolina in 1990. Source: U.S. Bureau of the Census

	Year Round/Full Time	**Other**	**Total**
Number of Captains			
Male	17	45	62
Female	7	0	7
Total	24	45	69
Mean Annual Income ($)			
Male	18,765	15,022	16,048
Female	9,000	0	9,000
Total	15,917	15,022	15,333

Horry County

The following descriptions for fishing communities in South Carolina are notes from Kim Iverson of South Carolina Department of Natural Resources. Kim has spent many months interviewing both commercial and recreational fishermen in South Carolina and other parts of the South Atlantic region as part of several research projects. Although the research was not intended to identify fishing communities, her notes represent the best available information on fishing communities for South Carolina.

Little River has a long history of fishing activity, both commercial and recreationally. The headboat operations date back to the 1940's. As of 1996, there were headboats operating in Little River. There are approximately 4 vessels that actively run charters and also commercial fish. Several full time snapper/grouper vessels operate out of the area. Little River also hosts an annual Blue Crab Festival each spring (Kim Iverson, SCDNR pers. comm., 1998).

Murrells Inlet has a large fleet of charter and headboats, with one marina hosting one of the Governor's Cup Billfishing Tournaments. There are several smaller fishing tournaments held in the area. There are fish houses in the community that deal primarily with finfish. There are no shrimp dealers. This area is also noted for it's large number of seafood restaurants that target the tourist market from Myrtle Beach (Kim Iverson, SCDNR pers. comm., 1998).

Major fishing tournaments held in Murrells Inlet are: March of Dimes Annual Flounder Tournament - Voyagers View Marina. Registration was by angler with approximately 200 anglers participating. Local tournament with many family participants. Primarily smaller boats < 25' participating. Tournament date May 17.; and the Marlin Quay Governor's Cup Billfish Tournament - Marlin Quay Marina. The last in the series of SC Gov. Cup. Total of 31 boats registered. July 23-26 (Kim Iverson, SCDNR pers. comm., 1998).

Major tournaments in North Myrtle Beach: Dock Holidays Governor's Cup Billfish Tournament - Dock Holiday's Marina. The first tournament in a series of 6 for the SC Governor's Cup. April 30 - May 3. Total of 25 boats entered; Frantic Atlantic King Mackerel Tournaments - North Myrtle Beach - Blue Marlin Yacht & Fishing Club. A two tournament series consisting of the Spring and Fall Classics. Total purse of $250,000 for the series. Total of 392 paid boat entries with an average of 4.09 anglers per boat. Tournament dates May 9-11, September 26-28; Evinrude Outboard King Mackerel Tournament - Oct. 11-12, Weigh-in stations at Dock Holidays Marina, Marlin Quay Marina and Georgetown Landing. 147 boats were registered; Yamaha Contender King Mackerel Classic - Weigh in stations at Dock Holidays Marina, Marlin Quay Marina and Georgetown Landing. 125 boats registered; Fall Pier King Tournament - September 19-21 (Kim Iverson, SCDNR pers. comm., 1998).

One of the largest concentration of snapper grouper vessels is located in Murrells Inlet, SC. Most of the reef fishermen in this area are full time commercial fishermen and consider bandit reels to be the most effective way of catching snapper grouper. There is a wide variety of snapper grouper species off of Murrells Inlet, with gag grouper, scamp grouper and vermilion snapper being highly targeted. The average trip length is 5 days with some of the larger boats (>40 ft.) fishing up to 10 days. A few smaller bandit boats may stay out for 2-3- days. The Gulf Stream is approximately 62 miles offshore from Murrells Inlet. Most bandit boats fish between the 20-50 fathom line, concentrating on the 25 fathom curve. Winter weather dictates that fishermen fish shallow, in waters 60-90' deep. Several fishermen switch to sea bass trapping during the winter months (Iverson, 1997).

Horry County has shown a small increase in personal income from fishing that follows the general increase in personal income overall (Table 17).

Table 17. Population and Economic Information for Horry County, South Carolina.
Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Horry				
	Population	148,385	152,435	157,834
	Personal Income (Thousands of $)	2,543,793	2,744,260	3,013,059
	Per Capita Pers Income ($)	17,143	18,177	19,220
	Personal Income Fishing (Thousands of $)	81	129	169

Vessels in Murrells Inlet will fish an area from Frying Pan Shoals off southern NC, south to Savannah. The average boat has two crew members. It is interesting to note that fishermen stated a crew of 3 plus the captain was ideal for this area, but decreasing catches and increased costs have made it necessary to cut back on crew members (Iverson, 1997).

Georgetown County

The community of Georgetown has shrimp dealers who also deal in finfish and shellfish. Georgetown is host to the one of the SC Governor's Cup Billfish Tournaments along with several other smaller fishing tournaments. There are no headboats operating from the area and charter activity is limited. Georgetown is known for it's historic waterfront district (Kim Iverson, SCDNR pers. comm., 1998).

Major fishing tournaments in Georgetown County: Georgetown Landing Governor's Cup Billfishing Tournament - May 21-24, Georgetown Landing Marina. The oldest of the series tournaments with 45 boats participating.

Georgetown County shows an increasing personal income from fishing like Horry County in Table 18 but, personal income from fishing tends to be a larger percentage of overall personal income than in Horry County.

Table 18. Population and Economic Information for Georgetown County, South Carolina. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Georgetown				
	Population	49,371	49,966	50,835
	Personal Income (Thousands of $)	822,317	885,024	946,898
	Per Capita Pers Income ($)	16,656	17,713	18,627
	Personal Income Fishing (Thousands of $)	246	388	399

Charleston County

McClellanville is a small community with a long history of commercial shrimping. McClellanville has a large shrimp fleet. At any given time (dependent upon the season) there can be as many as 20 shrimp boats at the docks. Shrimp wholesale dealers are also present within the community. McClellanville hosts an annual Blessing of the Fleet Festival each spring. Shem Creek (Mt. Pleasant) hosts a mixture of commercial and recreational fishing activity along with a number of seafood restaurants, a retail seafood market and a waterfront hotel. There are also headboats operating out of Shem Creek along with charter operations. There is a large permanent shrimp fleet and many shrimp boats visit seasonally. At any give time there are an average of 30 shrimp boats along the creek. Shrimp dealers along the creek also buy and sell finfish from the trawlers. There are several offshore fishing boats including longline and snapper/grouper boats. Several shellfishermen and crabbers do business along the creek. Each spring, Mt. Pleasant hosts an Annual Blessing of the Fleet for the shrimp boats.

In Folly Beach there is a concentration of commercial fishing vessels and several fish houses who handle offshore finfish, shellfish, shrimp and crabs. Rockville is a historical small community located at the south end of Wadmalaw Island. There are commercial dealers who handle shrimp, inshore fish, offshore finfish and some shellfish. On Edisto Island there are several commercial seafood dealers. There are approximately 10 shrimp boats that operate there, fluctuating with the season. The dealers handle primarily shrimp and in-shore species along with shellfish and blue crabs. There is also a large "harvest" of horseshoe crabs. These crabs are "bled" for their blood that is used in cancer research and returned to the water. Edisto Island is also host to the annual SC Governor's Cup Billfish Tournament. Charter activity here is limited. Bennett's Point is a small community south of Edisto with shrimping operations in the community. There are 10-15 small boat shrimpers that live in Walterboro and fish out of Bennett's Point (Kim Iverson, SCDNR pers. comm., 1998).

Table 19. Population and Economic Information for Charleston County, South Carolina. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Charleston	Population	297,888	287,139	281,068
	Personal Income (Thousands of $)	5,653,489	5,879,506	6,083,636
	Per Capita Pers Income ($)	18,979	20,476	21,645
	Personal Income Fishing (Thousands of $)	3,188	3,809	----

Charleston County (Table 19) has a higher personal income from fishing than the previous two counties, but has a much larger overall dollar value for personal income overall.

Major fishing tournaments in the Charleston County area: SCSSA (South Carolina Saltwater Sportfishing Assoc.) Early Bird - Ashley Marina. Approximately 25 registered boats. April 19. Multi-species tournament; James Island King Mackerel Tournament - James Island

Yacht Club, May 24; Wild Dunes Governor's Cup Billfish - June 11-14. Total of 46 registered boats; Bohicket Invitational Governor's Cup Billfish - June 25-28. Total of 48 registered boats. Bohicket Marina on John's Island; Lowcountry Angler's Inshore Tournament - June 28. Multi-species tournament held at the East Cooper Outboard Motor Club on Gold Bug Island in Mt. Pleasant. Registration by angler, with approximately 200 anglers registered; SCSSA Sailfish XV - Ashley Marina in Charleston. Club sponsored tournament with approximately 25 boats registered. Sailfish, tuna, dolphin & wahoo. August 8-10; Fishing For Miracles King Mackerel Tournament - Ripley's Light Marina. Large King tournament with over 200 boats entered. August 14-16; Alison Oswald, Sr. Memorial Tournament - James Island Yacht Club. Local tournament with approximately 75 boats participating. Multi-species. Aug. 23; Edisto Marina Governor's Cup Billfish Tournament - July 16-19. One of the oldest and largest of the Billfish Series. 46 Boats registered. Edisto Island (Kim Iverson, SCDNR pers. comm., 1998).

Beaufort County

In Frogmore there are 8 commercial dealers which are home to over 50 shrimpers. This does not include the many individuals with shrimp boats in their back yards. The dealers primarily handle shrimp but others may also handle crabs and shellfish. There is a large blue crab industry on nearby Lady's Island. There are several commercial seafood dealers in the Port Royal area with over 30 shrimp boats. There are also commercial crabbers, shad fishermen and offshore finfishermen here. There are a small number of charter vessels operating out of this area also. Hilton Head Island primarily caters to the tourist trade. There are several headboats operating on Hilton Head. These boats make half-day trips and night trips for shark fishing. There are four major marinas that offer charter fishing. Commercially, Hilton Head had 4 seafood dealers and approximately 12-15 shrimp boats (Kim Iverson, SCDNR pers. comm., 1998).

Data on personal income from fishing in Table 20 for Beaufort County may have been excluded due to confidentiality issues.

Table 20. Population and Economic Information for Beaufort County, South Carolina. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Beaufort				
	Population	94,375	97,293	100,017
	Personal Income (Thousands of $)	2,057,250	2,194,774	2,373,921
	Per Capita Pers Income ($)	21,799	22,558	23,774
	Personal Income Fishing (Thousands of $)	----	----	----

Major fishing tournaments in Beaufort County: 42nd Annual Beaufort County Water Festival Fishing Tournament - June 28. Held in conjunction with the annual Beaufort Water Festival; Hilton Head Kingfish Classic - Schillings Marina, Hilton Head Island. July 10-12. Registration by angler with a total of 49 registered; Dottie Dunbar Women's Tournament - Palmetto Bay Marina, Hilton Head. Women's only multi-species inshore tournament. Total of 49 anglers registered. October 4 (Kim Iverson, SCDNR pers. comm., 1998).

Possible fishing communities in South Carolina: Charleston, Mt. Pleasant, Hilton Head, Port Royal, Frogmore (St. Helena), Bennett's Point, Edisto Beach, Rockville, Folly Beach, Shem Creek, McClellanville, Georgetown Waterfront, Murrell's Inlet, Little River (most of these locations are designated ports of landing)

Counties in South Carolina have seen a general increase in these occupations and industries over the past three decades (Table 21), with the exception of Horry County which has seen a slight decreasing trend.

Table 21. Number within Farm/Fish/Forest Occupation and Agriculture, Fishing, Mining Industry for South Carolina Coastal Counties for 1970, 1980, and 1990 Census. Source: MARFIN Sociodemographic Database

County	Occupation/Industry	1970	1980	1990
Horry County	Farm/Fish/Forest	2627	2542	2310
	Agri.,Fishing,Mining	2843	2653	2110
Georgetown County	Farm/Fish/Forest	403	558	597
	Agri.,Fishing,Mining	552	856	690
Charleston County	Farm/Fish/Forest	810	1697	2056
	Agri.,Fishing,Mining	1256	1938	2316
Beaufort County	Farm/Fish/Forest	436	938	966
	Agri.,Fishing,Mining	698	1087	1111
Colleton County	Farm/Fish/Forest	532	614	730
	Agri.,Fishing,Mining	787	705	782

For the Charleston, South Carolina MSA (Table 22) there are 113 individuals who indicated fishing as their year round occupation . Another 102 individuals indicated that it is a part time or seasonal occupation for them. This represents over half of those individuals in South Carolina who indicated the occupation as fishing from Table 15. The Charleston, SC MSA includes Berkely, Charleston and Dorchester counties.

Table 22. Number of Individuals in Occupation of Fishing By Work Status and Gender for the Charleston, SC MSA in 1989. Source: 1990 Census Of Population And Housing.

	Year Round Full Time	Other	Total
Male	102	102	204
Female	11	0	11
Total	113	102	215

4.3.3.1.4 Georgia

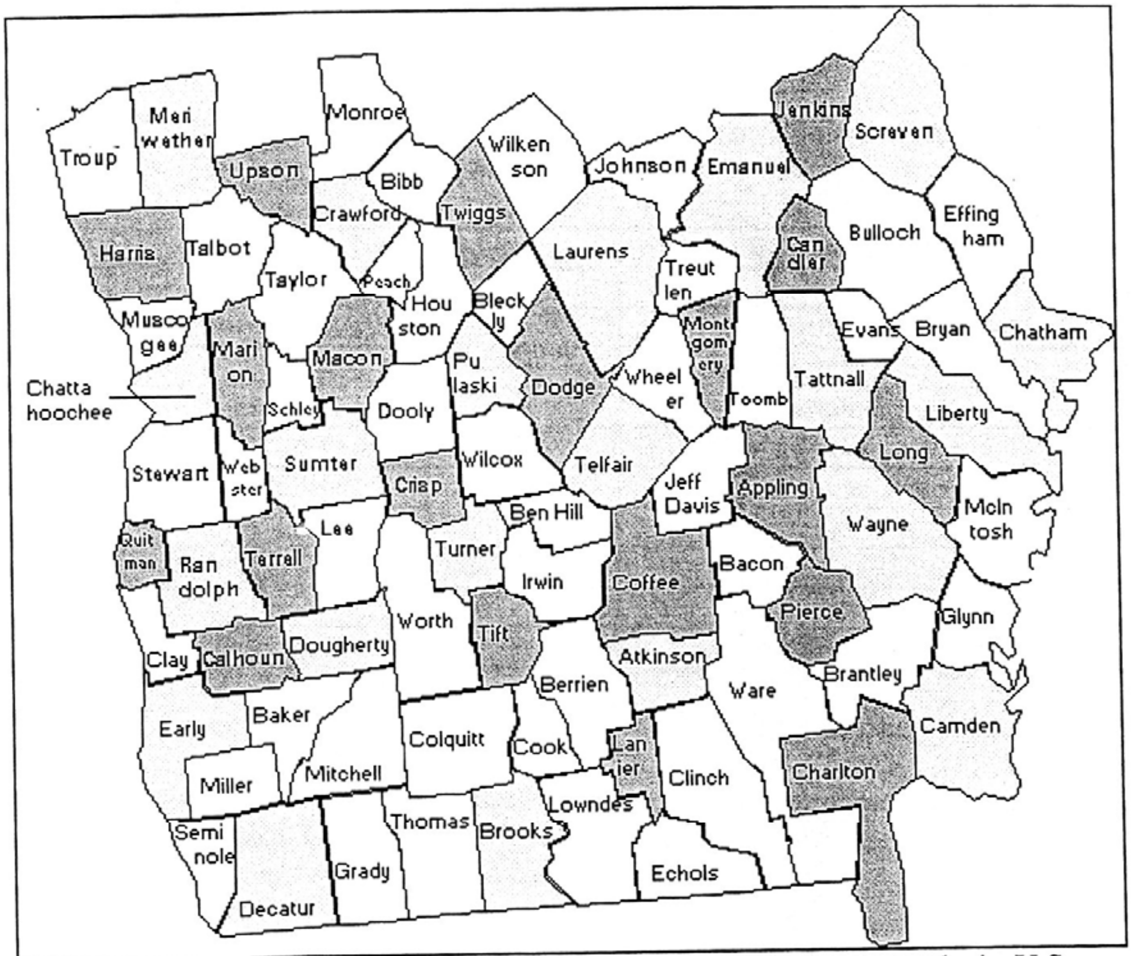


Figure 4. Georgia Coastal Counties. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

The 1990 Census of Population and Housing provides the following information for Georgia regarding individuals who reported their occupation as fisher in Table 23. A total of 536 individuals claimed Fisher as their occupational title with less than half indicating it was a year round full time employment. There were few females who indicated such and they had a far lower mean annual income than males who indicated it was a full time occupation. However, females who indicated it was other than full time had a much higher mean income than any other category. This may be due to a low sample size, however.

Table 23. Number of Fishers and Mean Annual Income for Georgia in 1990. Source: U.S. Bureau of the Census.

	Year Round/Full Time	Other	Total
Number of fishers			
Male	222	295	518
Female	11	7	18
Total	234	302	536
Mean Annual Income ($)			
Male	19,139	11,082	15,058
Female	8,600	25,000	20,080
Total	18,813	12,024	15,308

Shrimping

In their 1975 report, Nix et. al., found a total of 32 commercial docks in six Georgia coastal counties. Those docks and shrimp trawlers were distributed as follows: Camden Co. - 5 docks and 33 trawlers; Glynn Co. - 5 docks and 74 trawlers; McIntosh Co. - 12 docks and 111 trawlers; Liberty Co. - 1 dock and 18 trawlers; Bryan Co. - 1 dock and 2 trawlers; and finally Chatham Co. - 8 docks and 69 trawlers. This information is outdated and certainly does not represent the current status and location of shrimp trawlers in Georgia. However, the report does represent the kinds of information that can be extremely helpful in identifying fishing communities.

Snapper Grouper Fishing

The coast of Georgia contains a small concentration of full-time reef fishermen that fish primarily with bandit reels. Their fishing patterns are similar to those found in SC with vessels fishing from northern Florida north to the SC/NC line (Iverson, 1997).

Possible fishing communities in Georgia: Savannah, Brunswick, St. Marys, Jekyll Island, and Darien.

Table 24. Number of Captains of Fishing Vessels and other officers and Mean Annual Income for Georgia in 1990. Source: U.S. Bureau of the Census.

	Year Round/Full Time	Other	Total
Number of Captains			
Male	17	21	38
Female	0	0	0
Total	17	21	38
Mean Annual Income ($)			
Male	25,706	1,976	12,592
Female	0	0	0
Total	25,706	1,976	12,592

Table 25. Population and Economic Information for Chatham County, Georgia. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Chatham	Population (number of persons)	224,050	225,779	226,554
	Personal income (thousands of dollar	4,569,113	4,810,530	5,087,638
	Per capita personal income (dollars)	20,393	21,306	22,457
	Personal Income Fishing (Thousands of $)	650	(D)	25

Table 26. Population and Economic Information for Bryan County, Georgia. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Bryan				
	Population	18,827	20,008	21,212
	Personal Income (Thousands of $)	274,738	307,258	342,128
	Per Capita Pers Income ($)	14,593	15,357	16,129
	Personal Income Fishing (Thousands of $)	251	359	----

Table 27. Population and Economic Information for Liberty County, Georgia. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Liberty				
	Population	56,625	58,827	58,571
	Personal Income (Thousands of $)	636,042	669,454	709,468
	Per Capita Pers Income ($)	11,233	11,380	12,113
	Personal Income Fishing (Thousands of $)	----	90	97

Table 28. Population and Economic Information for McIntosh County, Georgia. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
McIntosh				
	Population	8,985	9,153	9,372
	Personal Income (Thousands of $)	110,187	116,171	125,645
	Per Capita Pers Income ($)	12,263	12,692	13,406
	Personal Income Fishing (Thousands of $)	3,619	4,486	----

Table 29. Population and Economic Information for Glynn County, Georgia. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Glynn				
	Population	64,759	64,956	65,450
	Personal Income (Thousands of $)	1,322,745	1,400,544	1,505,337
	Per Capita Pers Income ($)	20,426	21,558	23,000
	Personal Income Fishing (Thousands of $)	328	343	351

Table 30. Population and Economic Information for Camden County, Georgia. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Camden				
	Population	39,712	41,262	40,819
	Personal Income (Thousands of $)	502,639	542,385	556,622
	Per Capita Pers Income ($)	12,657	13,145	13,636
	Personal Income Fishing (Thousands of $)	1,889	2,431	2,484

Georgia coastal counties have seen a general increase in these occupations and industries with the exception of Liberty County which has shown a decrease from 1970-1990.

Table 31. Number within Farm/Fish/Forest Occupation and Agriculture, Fishing, Mining Industry for Georgia Coastal Counties for 1970, 1980, and 1990 Census. Source: MARFIN Sociodemographic Database

County	Occupation/Industry	1970	1980	1990
Bryan County	Agri.,Fishing,Mining	161	100	200
	Farm/Fish/Forest	121	135	136
Chatham County	Agri.,Fishing,Mining	558	686	1103
	Farm/Fish/Forest	228	704	1062
Liberty County	Agri.,Fishing,Mining	332	146	152
	Farm/Fish/Forest	242	205	157
McIntosh County	Agri.,Fishing,Mining	233	266	169
	Farm/Fish/Forest	27	260	193
Glynn County	Agri.,Fishing,Mining	261	482	593
	Farm/Fish/Forest	84	581	712
Camden County	Agri.,Fishing,Mining	209	126	176
	Farm/Fish/Forest	106	110	205

4.3.3.1.5 Florida

Florida's eastern coastline is made up largely of metropolitan counties. This is primarily due to the increases in population for Florida's coastal counties over the past 50 years. Florida's coastline has become a very popular retirement destination and tourist attraction. Because they are largely metropolitan, fishing communities here may be subsumed into these larger metropolitan areas and difficult to identify. Data presented from the most recent Census will also show that in relation to the larger economy, fishing will contribute very little at the county level for most coastal counties. Over the years, with the demographic changes following the inmigration of retirees and tourists and the subsequent economic transition, few fishing communities will have survived as distinct communities.

The data presented in Table 32 shows Florida as having almost 6,000 individuals claiming fisher as their occupation in the 1990 census; 381 of those individuals were female. Mean annual income is highest for those reporting fishing as a full time occupation with women reporting a lower mean annual income in all categories.

Table 32. Number of Fishers and Mean Annual Income for Florida in 1990. Source: U.S. Bureau of the Census.

	Year Round/Full Time	Other	Total
Number of fishers			
Male	2,698	2,844	5,544
Female	111	270	381
Total	2,809	3,116	5,925
Mean Annual Income ($)			
Male	23,288	11,794	17,388
Female	17,285	11,511	13,193
Total	23,051	11,770	17,118

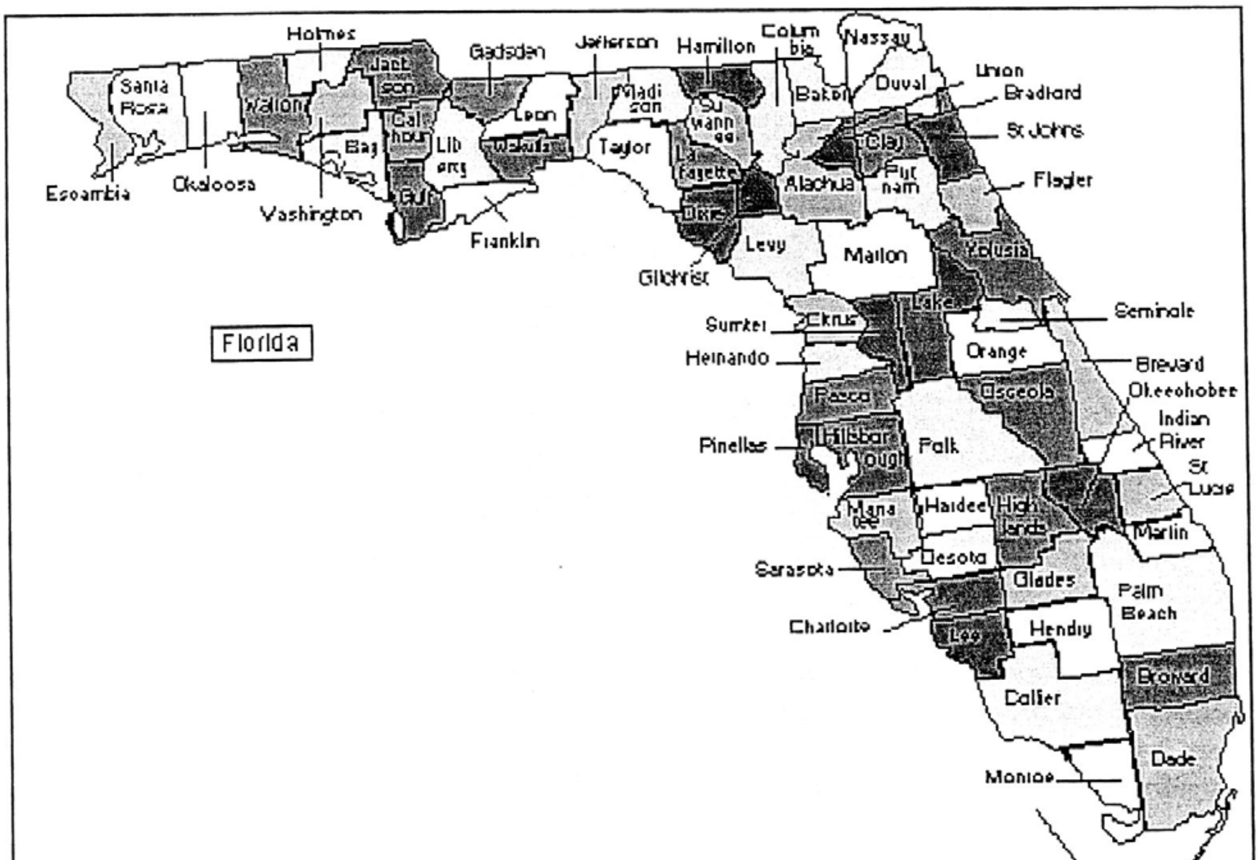


Figure 5. Florida Coastal Counties. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

There were over 1100 individuals from Florida who reported their occupation as captain of a fishing vessel during the 1990 census, with 51 of them being female (Table 33). Again, mean annual income was highest for full time workers and females reported lower mean annual income for both full time and other work.

Table 33. Number of Captains of Fishing Vessels and other officers and Mean Annual Income for Florida in 1990 Source: U.S. Bureau of the Census.

	Year Round/Full Time	Other	Total
Number of Captains			
Male	430	633	1,063
Female	26	25	51
Total	456	658	1,114
Mean Annual Income ($)			
Male	25,993	21,274	23,183
Female	8,487	15,420	11,885
Total	24,995	21,052	22,666

Nassau County (Table 34) showed an increase in personal income from fishing over the time period from 1993 to 1995 which reflects the general increase in population and personal income overall for the county.

Table 34. Population and Economic Information for Nassau County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Nassau				
	Population	48,355	49,565	50,717
	Personal Income (Thousands of $)	954,342	1,003,920	1,089,793
	Per Capita Pers Income ($)	19,736	20,255	21,488
	Personal Income Fishing (Thousands of $)	1,540	1,918	2,068

Duval County (Table 35) shows slow growth in population over the three years listed, but does show growth in personal income from fishing from 1993 to 1994. There was a slight decrease in personal income from fishing reported from 1994 to 1995.

Table 35. Population and Economic Information for Duval County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Duval				
	Population	701,267	703,152	705,014
	Personal Income (Thousands of $)	14,111,822	14,724,897	15,748,121
	Per Capita Pers Income ($)	20,123	20,941	22,337
	Personal Income Fishing (Thousands of $)	2,272	3,658	3,335

St John's County (Table 36) had some growth in personal income from fishing from 1993 to 1994 but no data were available for 1995 to indicate whether that trend continued.

Table 36. Population and Economic Information for St. John's County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
St. Johns				
	Population	94,480	98,377	101,966
	Personal Income (Thousands of $)	2,394,764	2,612,557	2,869,300
	Per Capita Pers Income ($)	25,347	26,557	28,140
	Personal Income Fishing (Thousands of $)	432	502	----

According to Table 37, Flagler County had no individuals reporting personal income from fishing for the time period 1993 to 1995. Volusia County also has no personal income from fishing listed in Table 38, but data were not included due to confidentiality issues.

Table 37. Population and Economic Information for Flagler County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Flagler				
	Population	35,868	37,894	40,260
	Personal Income (Thousands of $)	571,528	631,959	692,269
	Per Capita Pers Income ($)	15,934	16,677	17,195
	Personal Income Fishing (Thousands of $)	0	0	0

Table 38. Population and Economic Information for Volusia County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Volusia				
	Population	397,372	405,515	410,115
	Personal Income (Thousands of $)	6,845,402	7,235,060	7,772,063
	Per Capita Pers Income ($)	17,227	17,842	18,951
	Personal Income Fishing (Thousands of $)	- - - -	- - - -	- - - -

Indian River County saw an increase in personal income from fishing from 1993 to 1994 according to Table 39, but saw a decrease from 1994 to 1995. St. Lucie County (Table 40) may have had a similar trend although data from 1993 are missing and the trend is not clear.

Table 39. Population and Economic Information for Indian River County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Indian River				
	Population	94,184	95,374	96,263
	Personal Income (Thousands of $)	2,686,514	2,827,427	3,065,533
	Per Capita Pers Income ($)	28,524	29,646	31,845
	Personal Income Fishing (Thousands of $)	1,340	1,826	1,707

Table 40. Population and Economic Information for St. Lucie County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
St. Lucie				
	Population	165,120	169,284	171,914
	Personal Income (Thousands of $)	2,719,602	2,840,752	3,051,018
	Per Capita Pers Income ($)	16,470	16,781	17,747
	Personal Income Fishing (Thousands of $)	- - - -	1,855	1,303

Table 41. Population and Economic Information for Broward County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce

County		1993	1994	1995
Broward				
	Population	1,353,279	1,358,585	1,412,942
	Personal Income (Thousands of $)	32,716,045	34,273,950	37,007,667
	Per Capita Pers Income ($)	24,175	24,736	26,192
	Personal Income Fishing (Thousands of $)	658	816	- - - -

The trend in personal income from fishing for Broward County is not clear as data from 1995 are missing from Table 41 because of confidentiality. Brevard County (Table 42) shows a decrease in personal income from fishing during 1994 to 1995, but overall shows a much larger percentage of personal income coming from fishing than most counties previous.

Table 42. Population and Economic Information for Brevard County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Brevard				
	Population	435,546	443,337	450,238
	Personal Income (Thousands of $)	8,564,204	8,938,218	9,341,030
	Per Capita Pers Income ($)	19,663	20,161	20,747
	Personal Income Fishing (Thousands of $)	3,600	4,690	3,797

Martin County has one of the highest per capita incomes reported over the three year period according to Table 43. There was also a significant increase in personal income from fishing from 1993 to 1994 which decreased in 1995. Palm Beach County, with an even higher per capita income, showed an increase in personal income from fishing from 1993 to 1994 with no data available for 1995 (Table 44).

Table 43. Population and Economic Information for Martin County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Martin				
	Population	107,238	109,194	110,495
	Personal Income (Thousands of $)	3,406,064	3,521,665	3,815,294
	Per Capita Pers Income ($)	31,762	32,251	34,529
	Personal Income Fishing (Thousands of $)	270	1,658	819

Table 44. Population and Economic Information for Palm Beach County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Palm Beach				
	Population	933,644	957,522	976,358
	Personal Income (Thousands of $)	30,994,531	32,423,719	35,204,121
	Per Capita Pers Income ($)	33,197	33,862	36,057
	Personal Income Fishing (Thousands of $)	1,464	1,902	- - - -

Dade County shows a steady growth in personal income from fishing for the time period listed in Table 45. Monroe County shows, by far, the highest personal income from fishing for any Florida county and most likely any county in the South Atlantic according to Table 46.

Table 45. Population and Economic Information for Dade County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Dade				
	Population	1,985,373	2,011,571	2,046,078
	Personal Income (Thousands of $)	39,110,301	40,344,476	43,087,320
	Per Capita Pers Income ($)	19,699	20,056	21,058
	Personal Income Fishing (Thousands of $)	1,247	1,479	1,897

Table 46. Population and Economic Information for Monroe County, Florida. Source: Bureau of Economic Analysis, U.S. Dept. of Commerce.

County		1993	1994	1995
Monroe				
	Population	81,737	81,461	81,152
	Personal Income (Thousands of $)	1,982,209	2,054,326	2,208,152
	Per Capita Pers Income ($)	24,251	25,219	27,210
	Personal Income Fishing (Thousands of $)	13,506	15,558	16,723

Recently, data were compiled from the last three census and placed into a user friendly interface through a MARFIN grant by the Louisiana Population Data Center, Louisiana State University (C. M. Tolbert, et al. 1998). Those data provide a time series of information from the last three census with the ability to compare several variables at the state,. county and place level. Census places are incorporated and Census designated places of 2500 or more persons. The tables presented below incorporate the data included in the MARFIN SocioDemographic Database for the coastal counties outlined above with a focus on the occupational classification of Farm/Fish/Forest and the industry classification of Agriculture, Fishing, and Mining. These classifications are inclusive of those within the occupation and industry of fishing, but not exclusive of others, therefore it is difficult to know the exact number of individuals who have indicated their occupation or business is fishing. We can only assume that whatever trend appears over the time corresponds to the occupation of fishing as well as the others.

Data covering Metropolitan Statistical Areas are provided because it includes a more detailed occupational breakdown, but unfortunately geographic boundaries expand as most MSAs encompass more than one county. In some cases, MSAs were not used because the area covered did not correspond with the coastal areas within the South Atlantic region. As mentioned earlier, these data are what is currently available. Further analysis is constrained by variety of issues relating to data computability and availability at each place level of analysis. As mentioned before more research on fishing communities will be required before a more complete definition and identification can be accomplished.

Examining census data at the level of Metropolitan Statistical area reveals greater detail for occupation, but the scale changes as MSAs often times encompass more than one county. Metropolitan area (MA) is a large population nucleus, together with adjacent communities that have a high degree of economic and social integration with that nucleus. Metropolitan Areas must contain either a place with a minimum population of 50,000 or a Census Bureau-defined urbanized area and a total MA population of at least 100,000. An MA comprises one or more central counties and also may include one or more outlying counties that have close economic and social relationships with the central county. Metropolitan statistical areas (MSA's) are relatively freestanding MA's and are not closely associated with other MA's. These areas typically are surrounded by nonmetropolitan counties. See Appendix ?? for details on the parameters for the coastal MSAs included in this discussion.

When you look at the occupations of farming, fishing and forestry for Florida coastal counties in Table 47, over the past 20 years there is, in general, a steady increase in the number of individuals within these occupations and industries.

Table 47. Number within Farm/Fish/Forest Occupation and Agriculture, Fishing, Mining Industry for East Florida Coastal Counties from 1970, 1980, and 1990 Census. Source: MARFIN Sociodemographic Database

County	**Occupation/Industry**	**1970**	**1980**	**1990**
Nassau County	Farm/Fish/Forest	371	427	559
	Agri.,Fishing,Mining	501	462	606
Duval County	Farm/Fish/Forest	1237	2782	3729
	Agri.,Fishing,Mining	2536	2959	4324
St.Johns County	Farm/Fish/Forest	794	813	1002
	Agri.,Fishing,Mining	1012	883	976
Flagler County	Farm/Fish/Forest	145	314	408
	Agri.,Fishing,Mining	186	298	403
Volusia County	Farm/Fish/Forest	1308	3150	4917
	Agri.,Fishing,Mining	2511	3407	5606
Indian River County	Farm/Fish/Forest	991	1907	2042
	Agri.,Fishing,Mining	1454	2361	2217
St. Lucie County	Farm/Fish/Forest	2602	2710	3147
	Agri.,Fishing,Mining	3253	3252	3342
Broward County	Farm/Fish/Forest	1982	7358	9425
	Agri.,Fishing,Mining	5354	7756	10317
Brevard County	Farm/Fish/Forest	764	1772	3369
	Agri.,Fishing,Mining	1394	2279	3585
Martin County	Farm/Fish/Forest	964	1838	1983
	Agri.,Fishing,Mining	1268	2032	2086
Palm Beach County	Farm/Fish/Forest	6552	9676	13261
	Agri.,Fishing,Mining	9791	11780	15155
Dade County	Farm/Fish/Forest	4804	11257	14894
	Agri.,Fishing,Mining	9682	13708	16926
Monroe County	Farm/Fish/Forest	163	1769	1729
	Agri.,Fishing,Mining	920	1932	1860

The following table includes only those individuals who reported their occupation as fishing for the following Metropolitan Statistical Areas (MSA) within Florida.

Table 48. Number of Individuals in Occupation of Fishing By Work Status and Gender for Florida MSA in 1989. Source: 1990 Census Of Population And Housing.

Jacksonville		Year Round Full Time	Other	Total
	Male	151	210	361
	Female	15	49	64
	Total	166	259	425
West Palm Beach		Year Round Full Time	Other	Total
	Male	94	47	141
	Female	0	0	0
	Total	94	47	141
Miami		Year Round Full Time	Other	Total
	Male	254	254	508
	Female	0	30	0
	Total	254	284	538

Snapper Grouper Fishery Profile

Concentrations of reef fishermen can be found in the communities of Mayport, Port Orange and New Smyrna, north of Cape Canaveral. Bandit reels are the primary gear used for reef fishing in these areas, although a few bottom longline vessels are present. In northern Florida, bandit fishermen report trips lasting 5-6 days and fish 30-50 miles offshore. They average between 2 to 3 crew members depending on vessel size and gear. Vessels from the Mayport area reported fishing from the Georgia line south to the Daytona area. The larger longline vessels are required by regulations to fish past the 50 fathom line and reported trip lengths of up to 10 days, fishing as far as 100 miles from shore. These bottom long line vessels fish for deep water species such as tilefish in water 600 - 900' deep (Iverson, 1997).

King Mackerel Fishery Profile

McKenna (1994) identified the number of fishermen in Florida reporting landings of king mackerel (based on Saltwater Products Licenses) from 1987 to 1993 as varying from 1,500 to 2,222. From 1986 to 1990 the number of commercial permits for Atlantic migratory group king mackerel ranged from a high of 888 in 1989/90 fishing season to low of 785 in the 1987/88 fishing year. The percentage of those permits which were hook and line fishermen for those years ranged from 89% in 86/87 to 78% in 1990. There were 1654 vessels permitted for commercial king mackerel and Spanish mackerel in Florida for the 1993-94 fishing year. The number of permitted vessels was divided with 846 and 808 allocated to the East and West coasts respectively. How many of those vessels landed king mackerel is unknown at this time. Catch per unit of effort data seems fairly consistent for the southeastern region of the Atlantic group king mackerel with an average CPUE of between 200-300 lbs/trip (McKenna, 1994). Most of the commercial landings of Atlantic group king mackerel are made by hook and line fishermen. In addition, because most landings of Atlantic group king mackerel are in Florida and the most information that exists is on the Florida fishery, the following description will focus primarily on the Florida fishery unless noted otherwise.

King Mackerel Hook and Line Fleet

There were approximately 203 full and part time vessels in the hook and line mackerel fleet in 1980. Vessel size ranged from 22-44 feet in length. Today, the Florida South Atlantic troll fishery is composed of about 100 full-time and 100 part-time operations, about 150 of them are dependent upon king mackerel. Full-time fishermen operate primarily out of Jupiter, Port Salerno, Fort Pierce, Sebastian, and Rivera Beach. Normally, there is one fisherman to a boat. Part-time fishermen operate mostly out of Palm Beach, frequently two or three fishermen per boat. Approximately 40 percent of the full time trollers switch to bottom fishing for various reef fish after the Gulf king mackerel season. The remainder of these full time trollers tie up their boats when the Gulf king mackerel season ends. Some engage in various non-fishing jobs, while the majority reportedly wait for the opening of the Atlantic king mackerel season (GMFMC & SAFMC, 1994).

During the peak season about 75 to 100 troll vessels and 16 to 20 net vessels target king mackerel in the Keys. Net vessels usually start fishing late December, although some of these vessels troll for mackerel before net fishing becomes more practicable. Most king mackerel fishermen in the Keys target other species such as stone crab, spiny lobster, and reef fish throughout the year.

King Mackerel Net Fishing Fleet

There were approximately 89 large gill net vessels in Florida including full and part time in 1980. The vessels ranged in size from 30-65 feet. These vessels fished Spanish and king mackerel during the winter, but also targeted lobster, swordfish and bait fish during other times of the year. Vessels over 40 feet usually employed a power roller to haul nets. The large gill net fleet was primarily located from Florida's central east coast in Ft. Pierce, throughout the Florida Keys to the central west coast as far north as Cortez. There were also a few large boats in the Panhandle area of Port St. Joseph (Centaur Associates, 1981).

Approximately 87% of captains in the large gill net fleet at that time depended entirely upon fishing for their income. Net fishermen, then as they do today, have the options of participating in the Spanish mackerel fishery, trolling for king mackerel, and fishing with nets or hook and line for Atlantic group king mackerel after March (Centaur Associates 1981).

Today, there are twelve large net boats located in the Keys that may fish Atlantic group king mackerel occasionally. These vessels have a capacity of up to 40,000 pounds per trip and have had large catches of king mackerel in the past. There does not seem to be a small gill net boat sector for Atlantic king mackerel. In Monroe County there are 16 to 20 large net boats currently participating in the king mackerel fishery, some with capacity to land up to 50,000 pounds. There are another 6 to 12 small net boats in south-west Florida ready to enter the fishery when the opportunity arises. These vessels are 30 to 40 feet in length with capacities of 5,000 to 10,000 pounds.

There has been a general decline in net catches along the Florida east coast. This may be attributed to regulations like the prohibition of drift nets and purse seines, but also stems from the recent net ban in Florida state waters.

King Mackerel Dealers

McKenna (1994) identified over 200 dealers in Florida who had handled king mackerel since 1987. In 1992 there were 240 who reported landings of king mackerel. Most of those dealers purchased king mackerel ten or fewer times per season and handled less than 5000 pounds. There were over twenty dealers who handled 100,000 pounds or more during the 1992 season (McKenna, 1994) .

Possible fishing communities in Florida: Mayport, Port Orange, New Smyrna, Sebastian, Port Salerno, Rivera Beach, Ft. Pierce, Jupiter, West Palm Beach, Boyton Beaches, The Keys -- Upper Keys: Key Largo, Tavernier; Middle Keys - Islamorada, Marathon; Lower Keys; and Key West.

4.3.3.1.6 Other Community related Analysis

In a recent survey of snapper grouper fishermen in the South Atlantic questions were posed concerning a fishermen's tenure within a community and attitudes towards community change. The results in Table 49 show that the majority of fishermen feel their community has stayed the same or has changed for the better. A larger percentage of inactive than active snapper grouper fishermen feel that their community has changed for the worse. Well over half of fishermen interviewed had been in their present community for twenty years or more. Over sixty percent of inactive fishermen have lived in their community for twenty years or more, while over fifty percent of active fishermen have lived in their communities for 19 years or less. The mean number of years a fishermen had resided in their present community was twenty years or more for North Carolina, South Carolina and Florida. In comparison Georgia snapper grouper fishermen had an average tenure in their communities of 6.5 years. This may be an artifact of the small sample size in Georgia as only seven fishermen from that state were interviewed, but could also be reflective of the nature of snapper grouper fishing in Georgia (Rhodes et al., 1997).

Table 49. Snapper Grouper Fishermen's Tenure and Attitude toward Change in their Present Community. Source: Socio-demographic Assessment of Commercial Reef Fishermen in the South Atlantic Region. 1997.

	Active (%)	Inactive (%)
Feel Your Community has changed?	(N=201)	(N=26)
For the better	41.8	30.8
For the worse	32.1	46.2
Stayed the same	25.9	23.1
	Active (Yrs)	Inactive (Yrs)
Number of Years in Present Community?	(N=201)	(N=26)
2-12	27.6	25.9
13-19	32.0	11.1
20-35	19.5	33.4
36 <	20.9	29.6

These perspectives on an individual's feelings toward a community become important when that person must face significant changes regarding his/her occupation, as is often the case when limited entry or some other form of fisheries management is implemented. An individual's commitment toward their community and sense of belonging will influence decisions on whether to stay in fishing or within a particular community. The impacts become important for the community if many individuals face the same decision. When active fishermen were asked what is the likelihood of moving to a new town in the next 2-3 years most responded that it is was unlikely, however, over 27% indicated they were not sure or it was likely. When both inactive and active fishermen were asked the likelihood of leaving commercial fishing altogether 46% of inactive fishermen said it was likely or very likely, while only 11% of active fishermen indicated such a likelihood. (Rhodes et al., 1997). These type of data at the community level would contribute much to the understanding of possible impacts of future fisheries management.

4.3.3.1.7 Data Needs

As mentioned earlier, the data presented here is what is currently available and readily accessible. It is very limiting and does not provide a sufficient amount of detail needed to define and identify fishing communities. Therefore, the likelihood of realistic impact assessment of future fishing regulations on fishing communities is not good.

At the present the NMFS does not collect data on fishing communities. Therefore, it is impossible to realistically identify fishing communities in this amendment. There is a tremendous need for research to be conducted on a continuous basis to collect this information. Both state and federal government agencies have access to current information which can inform the process of identifying fishing communities. Permit databases for fishing licenses, wholesale and retail licenses, boat registrations, marina permits, boat landing locations, and many others exist now. Putting that information into one database is a monumental task, but should be undertaken soon. Geographic Information System software is now available and being used to compile much of the data regarding habitat. The same type of databases need to be created regarding fishing communities. Spatial analysis of the variables that help identify and define fishing communities can give useful insight into the changes that affect these coastal communities.

It is unlikely that Council Staff would be able to gather these data. Council staff have in the past, with the cooperation of industry, been able to gather important information about a particular fishery, but were criticized for not following OMB guidelines. The difficulty with following OMB guidelines is that approval of data gathering tools is too time consuming. Councils are often on a timeline to develop FMPs which does not allow for a lengthy approval process. The South Atlantic Council staff has sufficient expertise with this type of data collection that design, implementation and analysis can often take place during an extremely short time period with little burden upon the public. In fact, industry is often eager to provide these type of data for consideration during development of an FMP, but don't have the expertise to offer data a form that can be used by Council staff.

Data collection is critical to the future of impact assessment of fishing communities. Standards must be set and data need to be collected. At present, the ACCSP is attempting to set those standards and has included social and economic data in that program. The ACCSP Technical Source Document IV contains detailed social and economic data needs and draft survey instruments. Social and economic data collection projects should at least collect the minimum data elements. Support of ACCSP can be an important step in meeting the future needs of the councils with regard to fishing communities. In addition, another guideline for the types of data needed can be found in the Southeast Social and Cultural Data Analysis Plan (NMFS, 1994). The plan was designed to address many of the current social and cultural information needs for the three councils in the Southeast."

4.0 ECOSYSTEM CONSIDERATIONS

4.1 Introduction

As a result of the Sustainable Fisheries Act Amendment to the Magnuson-Stevens Fishery Conservation and Management Act in 1996 the Councils and the NMFS have been mandated to use an ecosystem approach in managing the Nation's Fisheries. The Council has taken the first step with the submission of the Habitat Plan identifying and describing in detail essential fish habitat (EFH) for species managed by the South Atlantic Council and with the submission of the Comprehensive Habitat Amendment amending all existing FMP's to include descriptions of EFH and EFH-habitat areas of particular concern (EFH-HAPCs). By including an Ecosystems Considerations section in the required SAFE reports, existing data regarding the effects of a fishery on the ecosystem will be provided to the Council on a species by species basis while emphasizing the need for a new level of information. This section will also provide a forum in which to express ecosystem concerns for a specific fishery.

While incorporating ecosystem concerns into stock assessment reports is a new approach for this Council, this approach has been taken by the North Pacific Fishery Management Council for several years. A copy of their ecosystems chapter has been included as Appendix E and is an example of the way the ecosystem approach can be used in annual SAFE reports. Another supporting document detailing new ideas and approaches to holistic management is the report to Congress from the Ecosystem Principles Advisory Panel of the NMFS (Appendix F), appointed by the National Academy of Sciences. Congress charged NMFS with establishing this panel to assess the extent that ecosystem principles are used in fisheries management and research and to recommend how such principles can be used to improve our Nation's management of living marine resources.

Ecosystem considerations presented in the interim final rule to implement the essential fish habitat (EFH) provisions of the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act).

Overview of EFH FMP Amendment Guidelines

The themes of sustainability and risk-averse management are prevalent throughout the Magnuson-Stevens Act, both in the management of fishing practices (e.g., reduction of bycatch and overfishing and consideration of ecological factors in determining optimum yield [OY]) and in the protection of habitats (i.e., prevention of direct and indirect losses of habitats, including EFH). Management of fishing practices and habitat protection are both necessary to ensure long-term productivity of our Nation s fisheries. Mitigation of EFH losses and degradation will supplement the traditional management of marine fisheries. Councils and managers will be able to address a broader range of impacts that may be contributing to the reduction of fisheries resources. Habitats that have been severely altered or impacted may be unable to support populations adequately to maintain sustainable fisheries. Councils should recognize that fishery resources are dependent on healthy ecosystems; and that actions that alter the ecological structure and/or functions within the system can disturb the health or integrity of an ecosystem. Excess disturbance, including over-harvesting of key components (e.g., managed species) can alter ecosystems and reduce their productive capacity. Even though traditional fishery management and FMPs have been mostly based on yields of single-species or multi-species stocks, these regulations encourage a broader, ecosystem approach to meet the EFH requirements of the Magnuson-Stevens Act. Councils should strive to understand the ecological roles (e.g., prey, competitors, trophic *links within food webs, nutrient transfer between ecosystems, etc.) played by managed species within their ecosystems. They should protect, conserve, and enhance adequate quantities of EFH to support a fish population that is capable of fulfilling all of those other contributions that the managed species makes to maintaining a healthy ecosystem as well as supporting a sustainable fishery. Councils must identify in FMPs the habitats used by all life history stages of each managed species in their fishery management units (FMUs). Habitats that are necessary to the species for spawning, breeding, feeding, or growth to maturity will be described and identified as EFH. These habitats must be described in narratives (text and tables) and identified geographically (in text and maps) in the FMP. Mapping of EFH maximizes the ease with which the information can be shared with the public, affected parties, and Federal and state agencies to facilitate conservation and consultation. EFH that is judged to be particularly important to the long-term productivity of populations of one or more managed species, or to be particularly vulnerable to degradation, should be identified as "habitat areas of particular concern" (HAPC) to help provide additional focus for conservation efforts. After describing and identifying EFH, Councils must assess the potential adverse effects of all fishing-equipment types on EFH and must include management measures that minimize adverse effects, to the extent practicable, in FMPs. Councils are also directed to examine non-fishing sources of adverse impacts that may affect the quantity or quality of EFH and to consider actions to reduce or eliminate the effects.*

(ii) EFH determination.
(E) Ecological relationships among species and between the species and their habitat require, where possible, that an ecosystem approach be used in determining the EFH of a managed species or species assemblage. The extent of the EFH should be based on the judgment of the Secretary and the appropriate Council(s) regarding the quantity and quality of habitat that is necessary to maintain a sustainable fishery and the managed species' contribution to a healthy ecosystem.

(11) Review and revision of EFH components of FMPs.
This information should be reviewed as part of the annual Stock Assessment and Fishery Evaluation (SAFE) report prepared pursuant to § 600.315(e).

4.2 Essential Fish Habitat and Essential Fish Habitat -Habitat Areas of Particular Concern Designations

Essential fish habitat is defined in the Act as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." The definition for EFH may include habitat for an individual species or an assemblage of species, whichever is appropriate within each FMP.

For the purpose of interpreting the definition of essential fish habitat: "waters" includes aquatic areas and their associated physical, chemical, and biological properties that are utilized by fish. When appropriate this may include areas used historically. Water quality, including but not limited to nutrient levels, oxygen concentration and turbidity levels is also considered to be a component of this definition. Examples of "waters" that may be considered EFH, include open waters, wetlands, estuarine habitats, riverine habitats, and wetlands hydologically connected to productive water bodies.

"Necessary" , relative to the definition of essential fish habitat, means the habitat required to support a sustainable fishery and a healthy ecosystem. While "spawning, breeding, feeding, or growth to maturity" covers a species full life cycle.

In the context of this definition the term "substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities. These communities could encompass mangroves, tidal marshes, mussel beds, cobble with attached fauna, mud and clay burrows, coral reefs and submerged aquatic vegetation. Migratory routes such as rivers and passes serving as passageways to and from anadromous fish spawning grounds should also be considered EFH. Included in the interpretation of "substrate" are artificial reefs and shipwrecks (if providing EFH), and partially or entirely submerged structures such as jetties.

The Habitat Plan presents the habitat requirements (by life stage where information exists) for species managed by the Council. Available information on environmental and habitat variables that control or limit distribution, abundance, reproduction, growth, survival, and productivity of the managed species is included.

Essential Fish Habitat for Spiny Lobster

Essential fish habitat for spiny lobster includes nearshore shelf/oceanic waters; shallow subtidal bottom; seagrass habitat; unconsolidated bottom (soft sediments); coral and live/hard bottom habitat; sponges; algal communities (*Laurencia*); and mangrove habitat (prop roots). In addition the Gulf Stream is an essential fish habitat because it provides a mechanism to disperse spiny lobster larvae.

Essential Fish Habitat-Habitat Areas of Particular Concern for Spiny Lobster

Areas which meet the criteria for essential fish habitat-habitat areas of particular concern (EFH-HAPCs) for spiny lobster include Florida Bay, Biscayne Bay, Card Sound, and coral/hard bottom habitat from Jupiter Inlet, Florida through the Dry Tortugas, Florida

4.3 Description of Essential Fish Habitat and Essential Fish Habitat-Areas of Particular Concern

Description of the Species and Distribution

Spiny lobster begin their existence in the Keys as larvae that arrive oceanic currents. As planktonic larvae they pass through 11 life stages in more than six months (FKNMS 1995). They then metamorphose into a transitional swimming stage (puerulus) (Little and the Milano, 1980; Lyons, 1980) that is found along Florida's southeast coast all year-long (Hunt et al., 1991). Pueruli travel through channels between the Keys and enter nursery areas in Florida Bay and the Gulf, where they preferentially settle into clumps of red alga *Laurencia* (Herrnkind and Butler, 1986). In seven to nine days a metamorphose into juveniles and take a solitary residence in the algal clumps for two to three months (Marx and Herrkind, 1985b; Hunt et al., 1991).

When juvenile spiny lobster reach a carapace length of 15 to 16 mm they leave the algal clumps and reside individually within rocky holes, crevices, coral, and sponges. They remain solitary until carapace length reaches approximately 25 to 35 mm, when they begin congregating in rocky dens. They remain in these nurseries for 15 months to two years (Hunt et al., 1991).

Adult lobsters move to deeper waters in the coral reef environment, where they occupy dens or holes during daylight hours. They are nocturnal feeders and predominantly prey upon molluscs and crustacea, including hermit crabs and conch.

Adults move to the offshore reef to spawn, and larvae are swept up to the East Coast by the Florida Current, where many are lost due to the length of pelagic pueruli stage (9 months) (Marx and Herrnkind, 1985a; Hunt et al., 1985 a; Hunt et al., 1991).
The following abstract of Yeung, (1996) summarizes recent research efforts on transport and retention of spiny lobster larvae: Transport and Retention of Lobster Phyllosoma in the Florida Keys. Abstract of a doctoral dissertation at University of Miami. December 1996.

"Physical transport can significantly affect recruitment variability of marine species with planktonic larvae. This especially pertinent to the phyllosoma larvae of spiny lobsters (Palinuridae), which have an estimated planktonic duration of 6-12 months. A large population of spiny lobster, *Panulirus argus*, inhabits the reef offshore of the Florida Keys in the Straits of Florida, constituting one of Florida's most valuable fisheries. The hydrography of this region is dominated by the strong Florida Current, which links the Loop Current in the Gulf of Mexico with the Gulf Stream in the North Atlantic. This dynamic oceanography favors the entrainment and dispersal of locally-hatched phyllosoma larvae, leading to contention about the origin of recruits for Florida's population. In this study, the problem of lobster recruitment is approached from the perspective of transport. The main objective is to find the linkage between spatial variables of larval distribution and transport processes. The main physical processes likely to influence larval advection are the meanders and frontal modulations of the Loop Current - Florida Current, coastal gyres and countercurrents, and wind-driven onshore surface transport. The hypothesis is that, due to those processes, intra-regional spatial variability in the distribution and abundance of phyllosomata exists along the Florida Keys. Spatial variability of transport is established with empirical observations of associated physical parameters, e.g. wind vectors, wind-driven surface onshore transport, frequency of coastal countercurrent reversals, the mode of the Loop Current, and the configuration of the Florida Current. The physical data are related to the pattern of larval distribution derived from five years of sampling. Interspecific comparison of larval recruitment strategies between palinurid and scyllarid (Scyllaridae) lobsters, who also inhabit the region and possess the phyllosoma larva, lends insight to the mechanisms of larval transport. Simulation modeling of larval trajectories in an advective model of current-modified ageostrophic transport in the Straits of Florida further aids the conceptualizing of processes, and testing and formulation of hypotheses regarding the interaction between larval behavior and oceanography. Clarification of this biological-physical coupling will advance our understanding of spiny lobster population dynamics and promote effective management of the fishery stocks."

The South Atlantic Council's Habitat Plan

The Council, in developing the Habitat Plan, consolidated the best available information on habitat essential to species managed in the south Atlantic region. The description and distribution of essential fish habitat in this document includes estuarine inshore habitats, mainly focusing on North Carolina, South Carolina, Georgia, and the Florida east coast as well as adjacent offshore marine habitats (e.g. coral, coral reefs, and live/hard bottom habitat, artificial reefs, *Sargassum* habitat and the water column). The structural component of these habitats constitute the basis for the habitat distribution information presented in this document. A primary goal of this document is to relay information on the distribution of managed species and essential fish habitats and provide information to address fishing and non-fishing threats to the watershed or estuarine drainage area.

The Habitat Plan was prepared through a cooperative effort of State, Federal and regional habitat partners on the Councils' Habitat and Coral Advisory Panels, additional technical experts identified during Council EFH workshops, and Council staff. This approach was deemed appropriate and has resulted in a scientifically defensible product that describes the structural characteristics and function by habitat type and presents available information on distribution and use by managed species and their significant prey. The intent of this document is to serve as a source document for all species managed by the Council. It also represents an ecological characterization of the south Atlantic region describing essential fish habitat. The Council is therefore taking a risk-averse approach in describing and protecting essential fish habitat in its area of jurisdiction and making recommendations to protect essential habitat in state waters. The emphasis of the determination is on the interrelationships between habitat and State and Federally managed species and their prey and endangered and threatened species. The vast array of species using these habitats implies that the structural habitats serve such a wide variety of species at different times in different locations that these structural habitats (estuarine, palustrine, coral and live/hard bottom, artificial reefs, and *Sargassum*) are all inclusive as essential to the functioning of a healthy ecosystem in the south Atlantic region. In addition, the water column plays an important role in defining the nature of essential habitat by being the common link.

This document is a living document that will be revised as new information becomes available. New techniques such as Habitat Suitability Index (HSI) modeling being developed may be useful in better identifying these habitats and their use by managed species. In addition, more refined and accurate mapping techniques through geographical information systems (GIS), such as the ones being used in the Coastal Change Analysis Program (C-CAP), under development for south Atlantic states and continued refinement of the SEAMAP bottom mapping effort. These and other activities will provide even more refined information for future Habitat Plan versions.

Habitats Identified in the Habitat Plan Which Constitute the Ecosystem Used by Managed Species including Spiny Lobster

A. Estuarine/Inshore Essential Fish Habitat

Estuarine inshore habitats include estuarine emergent vegetation (salt marsh and brackish marsh), estuarine shrub/scrub (mangroves), seagrass, oyster reefs and shell banks, intertidal flats, palustrine emergent and forested (freshwater wetlands), and the estuarine water column. Section 3.1 presents individual detailed descriptions including species use of these habitats.

Estuarine Emergent

Estuarine marshes constitute a complex ecosystem that serves as essential fish habitat but also is vital to wildlife including endangered and threatened species, furbearers and other mammals, waterfowl, wading birds, shore and other birds, reptiles and amphibians, shellfish, and invertebrates. In contrast to freshwater marshes, salt marshes have low species diversity of the higher vertebrates, but high species diversity of invertebrates, including shellfish, and fishes. Optimal estuarine habitat conditions for managed species' spawning, survival, and growth is dependent on protecting the structural integrity as well as the environmental quality of these habitats. In North Carolina, South Carolina, Georgia and Florida, the marsh systems are of principal importance as nursery areas.

More detailed estimates of wetland by county are presented in Appendix A . This compilation of existing wetland habitat may, as refined to hydrological units, begin to serve as a baseline upon which to implement the policy directive and the long-term objective of a net gain of wetland habitats in the South Atlantic region. The Coastal Change Assessment Program (C-

CAP) is presently being developed in response to the National Wetlands Policy Forum recommendation to improve inventory, mapping, and monitoring programs by USFWS and NOAA. The program was implemented to develop a nationally standardized geographic information system using ground-based and remote sensing data. It assesses changes in land cover and habitat in US coastal regions to improve understanding of coastal uplands, wetlands, and seagrass beds and their links to distribution, abundance, and health of living marine resources. At this time only South Carolina coastal counties are complete and will represent essential wetland habitat as mapped in that state. The state of Georgia information is under review and as North Carolina and Florida are completed the mapping coverage will be incorporated into the Habitat Plan as the most accurate presentation of inshore essential fish habitat in the South Atlantic region. The ecological value, function and distribution of this essential fish habitat is described in Section 3.1.1.1.

Estuarine Shrub/Scrub Mangroves (from NOAA 1995)

The red mangrove (*Rhizophora mangle*), black mangrove (*Avincennia germinans*), and white mangroves (*Laguncularia erectus*) are the three "true" species found in South Florida (Tomlinson, 1986). Red mangroves have prop roots and viviparous cigar-shaped seedlings, while black mangroves have a pneumataphore root system and gray-green leaves, the undersides of which are encrusted with excreted salt. White mangroves have rounded leaves, with a pair of salt glands on each petiole. Buttonwood (*Conocarpus erectus*), an associated species occurring with mangroves, is found in transitional wetland areas between mangrove and upland areas.

A mangrove classification system has been developed that identifies six major forest types based on geological and hydrological process: riverine, overwash, fringe, basin, dwarf, and hammock (Lugo and Snedaker). Riverine forests do not occur in southeast Florida due to the lack of freshwater rivers and the associated floodplains (Davis, 1943: Minerals Management Service 1990). Fringe forests occur along shorelines inundated by high tides, dominated by red mangroves, and exposed to open water. Tidal flow follows the same directional path along the fringe forest, resulting in sediment and litter accumulation.

Mangrove-related fish communities can be organized along various environmental gradients including salinity, mangrove detritus dependence, and substrate (Odum et al., 1982). The ecological value, function and distribution of this essential fish habitat is described in Section 3.1.1.2

Seagrass Habitat

Seagrass beds in North Carolina and Florida are preferred habitat areas of many managed species including white, brown, and pink shrimp, red drum, and estuarine dependent snapper and grouper species in the larval, juvenile and adult phases of their life cycle. Seagrass meadows provide substrates and environmental conditions which are essential to the feeding, spawning and growth of several managed species. Seagrass meadows are complex ecosystems that are essential habitat because they provide primary productivity, structural complexity, modification of energy regimes, sediment and shoreline stabilization, and nutrient cycling. Section 3.1.1.3 describes the ecological value and function and distribution of this essential fish habitat. The states of North Carolina through CGIA and Florida through FMRI provided geographical information system (GIS) coverage of seagrass habitat. Subsequent reconfiguration of the data was conducted by NMFS SEFSC to create a uniform ArcView format for inclusion into the Councils' essential fish habitat distribution data base and GIS system.

Oyster Reefs and Shell Banks

Oyster and shell essential fish habitat in the South Atlantic can be defined as the natural structures found between (intertidal) and beneath (subtidal) tide lines, that are composed of oyster shell, live oysters and other organisms that are discrete, contiguous and clearly distinguishable from scattered oysters in marshes and mudflats, and from wave-formed shell windrows (Bahr and Lanier 1981). Both intertidal and subtidal populations are found in the tidal creeks and estuaries of the South Atlantic. On the Atlantic coast, the range of the American oyster, *Crassostrea virginica*, extends over a wide latitude (20° N to 54° N). The ecological conditions encountered are diverse and the oyster community is not uniform throughout this range. Where the tidal range is large the oyster builds massive, discrete reefs in the intertidal zone. North of Cape Lookout, in North Carolina, the oyster habitat is dominated by Pamlico Sound and its tributaries. In these wind-driven lagoonal systems, oyster assemblages consist mainly of subtidal beds. Throughout the South Atlantic, oysters are found at varying distances up major drainage basins depending upon typography, salinity, substrate, and other variables.

Several terms used to describe the oyster/shell essential fish habitat are oyster reef, bar, bed, rock, ground and planting. The habitat ranges in size from small scattered clumps to large mounds of living oysters and dead shells. Predation and siltation limit oyster densities at the lower portion and outer regions of the reefs. The vertical elevation of intertidal oyster reefs above mean low water is maximal within the central Georgia coastal zone, where mean tidal amplitude exceeds 2 m (Bahr and Lanier 1981).

Large shell banks or deposits of oyster valves generated by boat wakes are found throughout the South Atlantic, usually along the Atlantic Intracoastal Waterway and heavily traveled rivers. These shell accumulations are usually elongated and conform to the underlying bottom topography from mean low water into the supra littoral zone. Further build-up may result in ridge structures and washovers. In South Carolina, 998 "washed shell" deposits have been located predominantly in the central and southern portion of the State. Washed shell is less resilient, partially abraded oyster shell with a lower specific gravity than recently shucked shells (Anderson 1979).

Intertidal Flats

Variability in the tidal regime along the South Atlantic coast results in considerable regional variability in the distribution and character of the estimated 1 million acres of tidal flat habitat. The coasts of North Carolina and Florida are largely microtidal (0-2m tidal range) with extensive barrier islands and relatively few inlets to extensive sound systems. In these areas wind energy has a strong affect on intertidal flats. In contrast the coasts of South Carolina and Georgia are mesotidal (2-4m) with short barrier islands and numerous tidal inlets so that tidal currents are the primary force effecting the intertidal zone.

Tidal flats are critical structural components of coastal systems that serve as feeding grounds and refuges for a variety of animals. This constantly changing system provides essential fish habitat as; 1) nursery grounds for early stages of development of many benthically oriented estuarine dependent species. 2) refuges and feeding grounds for a variety of forage species of fishes 3) feeding grounds for a variety of specialized predators.

Palustrine Emergent and Forested

Palustrine emergent systems include tidal and non-tidal marshes. A large amount of the energy present in the palustrine emergent vegetation may be exported out of the system. Tidal currents, river currents, and wind energy all act to transport organic carbon downstream to the estuary, which is the nursery area for many of the Council-managed species. Migrating consumers, such as larval and juvenile fish and crustaceans, may feed within the habitat and then move on to the estuary or ocean. These links with managed species demonstrate the essential nature of this habitat type. Section 3.1.2.2 describes the ecological value, function and distribution of this essential fish habitat.

Aquatic Beds

Submersed rooted vascular vegetation in tidal fresh- or freshwater portions of estuaries and their tributaries performs the same functions as those described for seagrasses. Specifically, aquatic bed meadows possess the same four attributes: 1) primary productivity; 2) structural complexity; 3) modification of energy regimes and sediment stabilization; and 4) nutrient cycling. The ecological value, function and distribution of this essential fish habitat is described in Section 3.2.2.3.

Estaurine Water Column

This habitat traditionally comprises four salinity categories: oligohaline (< 8 ppt), mesohaline (8-18 ppt), and polyhaline waters (18-30 ppt) with some euhaline water (>30 ppt) around inlets. Alternatively, a three-tier salinity classification is presented by Schreiber and Gill (1995) in their prototype document developing approaches for identifying and assessing important fish habitats: tidal fresh (0-0.5 ppt), mixing (0.5-25 ppt), and sewater (>25 ppt). Saline environments have moving boundaries, but are generally maintained by sea water transported through inlets by tide and wind mixing with fresh water supplied by land runoff. Particulate materials settle from these mixing waters and accumulate as bottom sediments. Coarser-grained sediments, saline waters, and migrating organisms are introduced from the ocean, while finer-grained sediments, nutrients, organic matter, and fresh water are input from rivers and tidal creeks. The sea water component stabilizes the system, with its abundant supply of inorganic chemicals and its relatively conservative temperatures. Closer to the sea, rapid changes in variables such as temperature are moderate compared to shallow upstream waters. Without periodic additions of sea water, seasonal thermal extremes would reduce the biological capacity of the water column as well as reduce the recruitment of fauna from the ocean. While nearby wetlands contain some assimilative capacity abating nutrient enrichment, fresh water inflow and tidal flushing are primarily important for circulation and removal of nutrients and wastes from the estuary.

The water column is composed of horizontal and vertical components. Horizontaly, salinity gradients (decreasing landward) strongly influence the distribution of biota, both directly (physiologically) and indirectly (e.g., emergent vegetation distribution). Horizontal gradients of nutrients, decreasing seaward, affect primarily the distribution of phytoplankton and, secondarily, organisms utilizing this primary productivity. Vertically, the water column may be stratified by salinity (fresh water runoff overlaying heavier salt water), oxygen content (lower values at the bottom associated with high biological oxygen demand due to inadequate vertical mixing), and nutrients, pesticides, industrial wastes, and pathogens (build up to abnormal levels near the bottom from lack of vertical mixing).

B. Marine/Offshore Essential Fish Habitat

Marine offshore habitats include live/hard bottom, coral and coral reefs, artificial/manmade reefs, pelagic *Sargassum* and water column habitat. Section 3.2 presents individual detailed descriptions including species use of these habitats.

Live/Hard Bottom Habitat

Major fisheries habitats on the Continental Shelf along the southeastern United States from Cape Hatteras to Cape Canaveral (South Atlantic Bight) can be stratified into five general categories: coastal, open shelf, live/hard bottom, shelf edge, and lower shelf based on type of bottom and water temperature. Each of these habitats harbors a distinct association of demersal fishes (Struhsaker 1969) and invertebrates. The description of this essential fish habitat presented in Section 3.2.1.2, segregates the region into two sections: a) Cape Hatteras to Cape Canaveral; and b) Cape Canaveral to the Dry Tortugas. These regions represent temperate, wide-shelf systems and tropical, narrow-shelf systems, respectively. The zoogeographic break between these regions typically occurs between Cape Canaveral and Jupiter Inlet.

Covered by a vast plain of sand and mud underlain at depths of less than a meter by carbonate sandstone is relatively unattractive to fish. Live/hard bottom, usually found near outcropping shelves of sedimentary rock in the zone from 15 to 35 fathoms and at the shelf break, a zone from about 35 to 100 fathoms where the Continental Shelf adjoins the deep ocean basin and is often characterized by steep cliffs and ledges. The live bottom areas constitute essential habitat for warm-temperate and tropical species of snappers, groupers, and associated fishes including 113 species of reef fish representing 43 families of predominately tropical and subtropical fishes off the coasts of North Carolina and South Carolina.

The distribution of live/hard bottom habitat in the south Atlantic region is presented in the hardbottom maps in Section 3.2. These geographic coverage's are a compilation of the four state bottom mapping effort in the South East Monitoring and Assessment Program (SEAMAP). The Florida Marine Research Institute developed uniform ArcView coverage's of hard bottom habitat (including coral, coral reefs, live/hard bottom, and artificial reefs) as a 1998 SEAMAP program and provided it to the Council for inclusion into the south Atlantic essential fish habitat distribution data base and GIS system.

Coral and Coral Reefs

Coral reef communities or solitary specimens exist throughout the south Atlantic region from nearshore environments to continental slopes and canyons, including the intermediate shelf zones. Habitats supporting corals and coral-associated species are discussed below in groupings based on their physical and ecological characteristics. Dependent upon many variables, corals may dominate a habitat, be a significant component, or be individuals within a community characterized by other fauna. Geologically and ecologically, the range of coral assemblages and habitat types is equally diverse. The coral reefs of shallow warm waters are typically, though not always, built upon coralline rock and support a wide array of hermatypic and ahermatypic corals, finfish, invertebrates, plants, and microorganisms. Hard bottoms and hard banks, found on a wider bathymetric and geographic scale, often possess high species diversity but may lack hermatypic corals, the supporting coralline structure, or some of the associated biota. In deeper waters, large elongate mounds called deepwater banks, hundreds of meters in length, often support a rich fauna compared to adjacent areas. Lastly are communities including solitary corals. This category often lacks a topographic relief as its substrate, but instead may use a sandy bottom, for example. Coral habitats (i.e., habitats to which coral is a significant contributor) are divided into five categories - solitary corals, hard bottoms, deepwater banks, patch reefs, and outer bank reefs. The order of presentation approximates the ranking of habitat complexity based upon species diversity (e.g., zonation, topographic relief, and other factors). Although attempts have been made to generalize the discussion into definable types, it must be noted that the continuum of habitats includes many more than these five distinct varieties.

The ecological value, function and distribution of this essential fish habitat is described in Section 3.2.1.2. The distribution of live/hard bottom habitat in the south Atlantic region is presented in the hardbottom maps in Section 3.2.

Artificial/Manmade Reefs

Manmade reefs are defined for this document as any area within marine waters in which suitable structures or materials have intentionally been placed by man for the purpose of creating, restoring or improving long-term habitat for the eventual exploitation, conservation or preservation of the resulting marine ecosystems naturally established on these sites. Manmade hard bottom habitats are formed when a primary hard substrate is available for the attachment and development of epibenthic assemblages. This substrate is colonized when marine algae and larvae of epibenthic animals successfully settle and thrive. Concurrent with the development of the epibenthic assemblage, demersal reef-dwelling finfish recruit to the new hard bottom habitat. Juvenile life stages will use this habitat for protection from predators, orientation in the water column or on the reef itself and as a feeding area. Adult life stages of demersal reef-dwelling finfish including species managed in the snapper grouper plan, will use the habitat for protection from predation, feeding opportunities, orientation in the water column and on the reef and as spawning sites. Pelagic planktivores occur on hard bottom habitats in high densities and use these habitats for orientation in the water column and feeding opportunities. These species provide important food resources to snapper grouper species and coastal migratory pelagics including king and Spanish mackerel and cobia. The pelagic piscivores use the hard bottom habitats for feeding opportunistically. Most of these species do not take up residence on individual hard bottom outcrops, but will transit through hard bottom areas and feed for varying periods of time.

Manmade hard substrates are considered essential fish habitat in the south Atlantic region because of the use of these habitats by species in the snapper grouper complex, coastal migratory pelagics and prey important to those species. The ecological value, function and distribution of this essential fish habitat is described in Section 3.2.2

The State of Florida Marine Research Institute, as part of the 1998 deliverable, provided the Council with uniform Arc View coverage's for inclusion into the south Atlantic essential fish habitat distribution data base and GIS system.

Sargassum

Pelagic brown algae *Sargassum natans* and *S. fluitans* form a dynamic structural habitat within warm waters of the western North Atlantic. Most pelagic *Sargassum* circulates between 20°N and 40°N latitudes and 30°W longitude and the western edge of the Florida Current/Gulf Stream. The greatest concentrations are found within the North Atlantic Central Gyre in the Sargasso Sea. Large quantities of *Sargassum* frequently occur on the continental shelf off the southeastern United States. Depending on prevailing surface currents, this material may remain on the shelf for extended periods, be entrained into the Gulf Stream, or be cast ashore. During calm conditions *Sargassum* may form large irregular mats or simply be scattered in small clumps. Langmuir circulation, internal waves, and convergence zones along fronts aggregate the algae along with other flotsam into long linear or meandering rows collectively termed "windrows".

Pelagic *Sargassum* supports a diverse assemblage of marine organisms including fungi, micro-and macro-epiphytes, at least 145 species of invertebrates, over 100 species of fishes, four species of sea turtles, and numerous marine birds. The fishes associated with pelagic *Sargassum* in the western North Atlantic include juveniles as well as adults of a wide variety of species. The carangids and balistids are the most conspicuous, being represented by 21 and 15 species respectively. Therefore, this habitat is considered essential fish habitat because it provides protection, feeding opportunity and use as a spawning substrate to species managed by the Council. The ecological value, function and distribution of this essential fish habitat is described in Section 3.2.3.

Additional information is contained in the fishery management plan for pelagic *Sargassum* (SAFMC 1998d).

Water Column

Specific habitats in the water column can best be defined in terms of gradients and discontinuities in temperature, salinity, density, nutrients, light, etc. These "structural" components of the water column environment are not static, but change both in time and space. Therefore, there are numerous potentially distinct water column habitats for a broad array of managed species and life-stages within species.

The discussion of the ecological function of water column habitat and importance to managed species is presented in Section 3.2.3.2.

4.4 The Effects of Fishing Gear on the Ecosystem and Prior Council Action

Pursuant the guidelines implementing the essential fish habitat provisions of the Magnuson-Stevens Act, conservation and enhancement measures implemented by the Council may include ones that eliminate or minimize physical, chemical, or biological alterations of the substrate, and loss of, or injury to, benthic organisms, prey species and their habitat, and other components of the ecosystem. The Council has implemented restrictions on fisheries to the extent that no significant activities were identified in the review of gear impact conducted for the NMFS by Auster and Langton (1998) that presented available information on adverse effects of all fishing equipment types used in waters described as EFH. The Council has already prevented, mitigated, or minimized most adverse effects from most fisheries prosecuted in the South Atlantic EEZ.

The Council considered evidence that some fishing practices are having an identifiable adverse effect on habitat, and addressed these in the comprehensive habitat amendment. The Council has already used many of the options recommended in the essential fish habitat guidelines for managing adverse effects from fishing including: fishing equipment restrictions; seasonal and aerial restrictions on the use of specified equipment; equipment modifications to allow the escape of particular species or particular life stages (e.g., juveniles); prohibitions on the use of explosives and chemicals; prohibitions on anchoring or setting equipment in sensitive areas; prohibitions on fishing activities that cause significant physical damage in EFH; time/area closures including closing areas to all fishing or specific equipment types during spawning, migration, foraging, and nursery activities; designating zones for use as marine protected areas to limit adverse effects of fishing practices on certain vulnerable or rare areas/species/life history stages, such as those areas designated as habitat areas of particular concern; and harvest limits.

More specifically, the Council has protected habitat essential to managed species by regulating fisheries to reduce or eliminate the direct or indirect impacts of fishing. With the implementation of the Coral Fishery Management Plan and subsequent amendments to that plan, the Council has protected coral, coral reefs, and live/hard bottom habitat in the south Atlantic region by establishing an optimum yield of zero and prohibiting all harvest or possession of these resources which serve as essential fish habitat to many managed species. Another measure adopted by the

Council and implemented through the coral plan was the designation of the Oculina Bank Habitat Area of Particular Concern, a unique and fragile deepwater coral habitat off southeast Florida that is protected from all bottom tending fishing gear damage. The Council has also prohibited the use of the following gears in the snapper grouper fishery management plan to protect habitat: bottom longlines in the EEZ inside of 50 fathoms or anywhere south of St. Lucie Inlet Florida, fish traps, bottom tending (roller-rig) trawls on live bottom habitat, and entanglement gear. Also established under the snapper grouper plan is an Experimental Closed Area (experimental marine reserve) where the harvest or possession of all species in the snapper grouper complex is prohibited. Other actions taken by the Council that directly or indirectly protect habitat or ecosystem integrity include: the prohibition of rock shrimp trawling in a designated area around the Oculina Bank, mandatory use of bycatch reduction devices in the penaeid shrimp fishery, a prohibition of the use of drift gill nets in the coastal migratory pelagic fishery; and a mechanism that provides for the concurrent closure of the EEZ to penaeid shrimping if environmental conditions in state waters are such that the overwintering spawning stock is severely depleted.

4.5 Endangered Species and Marine Mammal Acts

The Sustainable Fisheries Act of 1996 established certain requirements and standards the Councils and the Secretary must meet in managing fisheries under the Magnuson-Stevens Act. Implementing the provisions in the SFA will not have any negative impacts on the listed and protected species under the Endangered Species Act (ESA) and Marine Mammals Protection Act (MMPA) including:

	Whales:	Date Listed
(1)	Northern right whale- *Eubalaena glacialis* (ENDANGERED)	12/2/70
(2)	Humpback whale- *Magaptera novaeangliae* (ENDANGERED)	12/2/70
(3)	Fin whale- *Balaenoptera physalus* (ENDANGERED)	12/2/70
(4)	Sei whale- *Balaenoptera borealis* (ENDANGERED)	12/2/70
(5)	Sperm whale- *Physeter macrocephalus* (ENDANGERED)	12/2/70
(6)	Blue whale- *Balaenoptera musculus* (ENDANGERED)	

	Sea Turtles:	Date Listed
(1)	Kemp's ridley turtle- *Lepidochelys kempii* (ENDANGERED)	12/2/70
(2)	Leatherback turtle- *Dermochelys coriacea* (ENDANGERED)	6/2/70
(3)	Hawksbill turtle- *Eretmochelys imbricata* (ENDANGERED)	6/2/70
(4)	Green turtle- *Chelonia mydas* (THREATENED/ENDANGERED)	7/28/78
(5)	Loggerhead turtle- *Caretta caretta* (THREATENED)	7/28/78

	Other Species Under U.S. Fish and Wildlife Service Jurisdiction:	Date Listed
(1)	West Indian manatee- *Trichechus manatus* (ENDANGERED)	3/67
	(Critical Habitat Designated)	1976
(2)	American crocodile - *Crocodulus acutus* (ENDANGERED)	9/75
	(Critical Habitat Designated)	12/79

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Gary E. Davis, US National Parks Service, also contributed to this SAFE report.

6.0 REFERENCES

[Note: Many of the references are contained in the Appendixes attached and in the Habitat Plan and Comprehensive Amendment.]

Adams, J. A. 1960. A contribution to the biology and post-larval development of the *Sargassum* fish, *Histrio histrio* (Linnaeus), with a discussion of the *Sargassum* complex. Bull. Mar. Sci. 10:55-82.

GMFMC and SAFMC. 1982. Fishery Management Plan, Environmental Impact Statement and Regulatory Impact Review for Spiny Lobster in the Gulf of Mexico and South Atlantic. South Atlantic Fishery Management Council, 1 Southpark Circle, Suite 306, Charleston, SC 29407-4699.

7.0 APPENDICES

Appendix A. Literature Search for species in the Spiny Lobster Management Plan

Panulirus argus

TI: Title
Aspects of chemoreception in marine crustacea
AU: Author
Ache, B.W. ; LeMagnen, J.; MacLeod. P (eds.)
AF: Author Affiliation
Dep. Biol. Sci., Florida Atlantic Univ., Boca Raton, FL 33431, USA
SO: Source
Olfaction and Taste VI.
PB: Publisher
IRL, 1 Falconberg Court, London W1V 5FG, UK
IB: ISBN
ISBN 0-904-14708-8
ER: Environmental Regime
Marine
AB: Abstract
Antennular chemoreceptors in the spiny lobster Panulirus argus are characterized as low threshold, amino acid-sensitive cells with possible restricted response spectra. The projection of this afference to the protocerebral lobes is verified physiologically and characterized as lacking apparent sensitivity to spatio-temporal parameters of antennular stimulation. These findings are discussed reltive to the understanding of crustacean chemosensitivity.

TI: Title
Mechanism of interaction between odorants at olfactory receptor cells.
AU: Author
Ache, BW; Gleeson, RA; Thompson, HD
AF: Author Affiliation
C.V. Whitney Lab., Univ. Florida, St. Augustine, FL 32086, USA
CF: Conference
8. Meeting ISOT IX/AChemS, Snowmass, CO (USA), 20-24 Jul 1986
SO: Source
Chemical Senses [CHEM. SENSES.], vol. 11, no. 4, p. 575, 1986
IS: ISSN
0379-864X
NT: Notes
Poster session; abstract only.
AB: Abstract
The authors earlier reported that mixture suppression is the dominant type of interaction found in the antennular (olfactory) pathway of the spiny lobster Panulirus argus , that it is due in part to odorants interacting at the receptor cells and that mixture suppression in one type of taurine-sensitive receptor cell suggests that odorant molecules of different efficacies compete for common receptor sites. The present study extends this latter observation by characterizing the dose-response function of other types of antennular chemoreceptors in the presence and absence of

suppressive odorants. The data show that both proline and arginine antagonize the action of taurine in a manner consistent with competitive inhibition (parallel slope, right-shift, equal maximum response).

TI: Title
Mechanisms for mixture suppression in olfactory receptors of the spiny lobster.
AU: Author
Ache, BW; Gleeson, RA; Thompson, HA
AF: Author Affiliation
Whitney Lab. and Dep. Zool. and Neurosci., Univ. Florida, St. Augustine, FL 32086, USA
SO: Source
Chemical Senses [CHEM. SENSES.], vol. 13, no. 3, pp. 425-434, 1988
IS: ISSN
0379-864X
AB: Abstract
The mechanisms by which the output of olfactory receptor cells is suppressed, as can happen, for example, when receptor cells are activated by stimulus mixtures, are ill defined. The authors show that subthreshold concentrations of some odorants suppress the responses of antennular (olfactory) chemoreceptors of the spiny lobster to stimulatory odorants in a manner indicative of competitive inhibition. The effect of these suppressive odorants on the response of other receptor cells is inconsistent with this hypothesis, allowing that non-competitive mechanisms also contribute to peripheral mixture suppression in the olfactory pathway of the spiny lobster.

TI: Title
Use of mangrove habitat by juvenile Caribbean spiny lobster
AU: Author
Acosta, CA; Butler, MJ
AF: Author Affiliation
Dep. Biol. Sci., Old Dominion Univ., Norfolk, VA 23529-0266, USA
CF: Conference
24. Annu. Benthic Ecology Meeting, Columbia, SC (USA), 7-10 Mar 1996
ED: Editor
Woodin, SA; Allen, DM; Stancyk, SE; Williams-Howze, J; Feller, RJ; Wethey, DS; Pentcheff, ND; Chandler, GT; Decho, AW; Coull, BC (eds)
SO: Source
TWENTY-FOURTH ANNUAL BENTHIC ECOLOGY MEETING, HELD IN COLUMBIA, SOUTH CAROLINA, MARCH 7-10, 1996., 1996, p. 16,
NT: Notes
Abstract only
AB: Abstract
Mangroves are considered important nursery habitats for juvenile fish and invertebrates, but the evidence is largely anecdotal. We

studied the population dynamics of juvenile Caribbean spiny lobsters, Panulirus argus, sheltering among prop roots and associated shelters near two types of mangrove islands with few alternative movement of lobsters did not differ among island types, but residency was greater on islands with few alternative shelters or those surrounded by deep water. Predation on small juveniles dwelling in mangroves was lower than in seagrass, whereas larger juveniles survived equally well in mangroves and patch reefs. While mangrove prop roots and associated communites can nurture juvenile lobsters, their significance as nurseries depends on the local availability of alternative shelter and, regionally, on the abundance of mangrove islands relative to other nursery habitats.

TI: Title

Temporal patterns and transport processes in recruitment of spiny lobster (Panulirus argus) postlarvae to south Florida

AU: Author

Acosta, CA; Matthews, TR; Butler IV, MJ*

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SO: Source

Marine biology. Berlin, Heidelberg [Mar. Biol.], vol. 129, no. 1, pp. 79-85, 1997

IS: ISSN

0025-3162

AB: Abstract

We used time-series analysis to identify weekly and annual patterns in the supply of spiny lobster, Panulirus argus, postlarvae to the Florida Keys, USA, over an 8 yr period. We also investigated the relationship between postlarval influx and wind forcing as a transport mechanism using the complex vector-scalar correlation analysis. Postlarval supply had a lunar phase periodicity at 4.5 wk intervals, with postlarval abundance peaking between the new moon and first-quarter lunar phases. A distinct annual cycle of postlarval supply with two peak periods was also apparent. Cross-correlation analysis between relative postlarval abundance and a 12 mo cycle showed that the annual peak occurs in spring, centered around March. With the 12 mo periodicity removed, a smaller peak at 5 mo intervals was also well defined. Wind-forcing for 7 d prior to the time of postlarval collection was marginally correlated with postlarval abundance through the entire time-series; the association was strongest during the late fall to early spring months. The analysis indicated that postlarval supply was correlated with winds from the northeast (ca. 45 degree), which are associated with winter atmospheric fronts. In contrast to results reported for other spiny lobster populations, these patterns suggest that recruitment of lobster postlarvae to south Florida is predictable only at a gross level and is presumably affected by the temporally inconsistent structure of regional oceanic gyres and variability in the timing of lobster spawning in the Caribbean.

TI: Title
Ecology of the Early Life History of the Caribbean Spiny Lobster, Panulirus argus: Recruitment, Predation, and Habitat Requirements
AU: Author
Acosta, Ca
AF: Author Affiliation
Old Dominion University
SO: Source
Dissertation Abstracts International Part B: Science and Engineering [Diss. Abst. Int. Pt. B - Sci. & Eng.], Apr 1998, vol. 58, no. 10, p. 4575
NT: Notes
Thesis publication date -- 1997. Number of pages -- 93. Available from UMI, 300 N Zeeb Rd, POB 1346, Ann Arbor, MI 48106-1346, USA (800.521.0600) or
http://www.umi.com/hp/Products/Dissertations.html.
NU: Other Numbers
AAT 9809880
AB: Abstract
Recruitment variability of the early life history stages of marine benthic organisms can have profound consequences on population dynamics. The author studied factors affecting recruitment success of postlarvae and early juveniles of the Caribbean spiny lobster (Panulirus argus). The authour examined patterns in postlarval supply, investigated wind forcing as a potential transport mechanism for recruiting postlarvae, and quantified predation on postlarvae in south Florida, USA. In an eight-year time series, spiny lobster postlarval supply occurred year-round between the new and first quarter lunar phases. The major annual peak occurred around March corresponding to spawning activity ten months earlier, and a smaller non-seasonal peak occurred with a five-month periodicity. Wind forcing of surface waters was correlated to postlarval supply only during winter months, but this accounted for a small proportion of the total variance. During new moon influx, predation on postlarvae tethered to floating arrays was highest over coral patch reefs and declined along a typical transport path over the coastal lagoon and leeward bay, especially near the surface. In contrast, predation during full moon was similar over reefs and the bay probably due to increased exposure to visual predators, whereas predation during

new moon was significantly lower in the bay. In laboratory mesocosms, predation was lower under new moon conditions when prey density was low. These results indicate the adaptive value of recruitment during the darkest lunar phase and use of surface waters for rapid transport pass concentrated predator assemblages near reefs. In benthic habitats, predation was highest in coral crevices than in nearshore seagrass or macroalgae. To compare the role of a possible alternative nursery habitat to that of the south Florida system, I studied the population dynamics of juvenile spiny lobsters in mangrove-associated habitats in Belize. Juveniles use mangrove habitats as nurseries, but usage patterns depend on available shelter and isolation of islands which acts to restrict migration of subadult and juvenile lobsters. Settlement presumably occurs in vegetation, but successful recruitment to benthic populations may depend on the proximity of settlers to crevice shelter associated with mangrove islands or patch reefs. The size of a local spiny lobster population may, thus, be influenced by factors affecting postlarval supply to coastal populations, abundance of predators at areas of concentration which postlarvae must traverse, and the availability of suitable settlement habitat.

TI: Title
Calcium ion effect on chitin characteristics in lobster.
OT: Original Title
Vliyanie ionov kal'tsiya v khitine omara na ego kharakteristiki
AU: Author
Alonso I., G; Vega D., O; Khenrikes, RD
AF: Author Affiliation
Inst. Exp. Chem. Biol., Havana, Cuba
SO: Source
BIOORG. KHIM., vol. 10, no. 9, pp. 1253-1255, 1984
IS: ISSN
0132-3423
AB: Abstract
A comparison was drawn between chitins from calcified cuticles and from elastic intersegmental tissues of the Panulirus argus shell. It is shown that Ca super(2+) ions affect both polysaccharide thermostability and chitin-protein binding.

TI: Title
(Meeting report of the permanent group of studies on pargo and spiny lobster held at Tamandare/PE, 21-24 June 1983.).
OT: Original Title
Relatorio da reuniao do grupo permanente de estudos sobre lagosta e pargo, realizada em Tamandare/PE, de 21-24 de Junho de 1983
AU: Author
Anon.
CF: Conference

Reuniao do grupo permanente de estudos sobre lagosta e pargo, Tamandare, PE (Brazil), 21 Jun 1983
SO: Source
DOC. TEC. INST. PESQUI. DESENVOLV. PESQ. BRAS., no. 33, pp. 129-173, 1985
IS: ISSN
0100-450
AB: Abstract
Statistical and biological data, were analyzed to gain information on red snapper and lobster in the Northeast and Northern regions of Brazil. Fishing legislation on the resources was discussed and the effects produced by the establishment of a production global quota to lobster were analyzed. The directrives to a fishing fiscalization effort were elaborated and evaluated. The research Programme was discussed. A fishing policy and resource management were recommended.

TI: Title
(Meeting report of the Permanent Group of Studies on Lobsters (Fortaleza, 13-15 December 1978).).
OT: Original Title
Relatorio da reuniao do Grupo Permanente de Estudos sobre Lagostas (Fortaleza, 13 a 15 de dezembro de 1978)
AU: Author
Anon.
CF: Conference
Meeting of the Permanent Group of Studies on Lobsters, Fortaleza (Brazil), 13 Dec 1978
SO: Source
DOC. TEC. INST. PESQUI. DESENVOLV. PESQ. BRAS., no. 32, pp. 163-189, 1985
IS: ISSN
0100-450
AB: Abstract
Available fishery, biological and environmental aspects data related to the lobster exploitation in Northeast Brazil, from 1965 to 1977 were analyzed. The maximum sustainable yield estimated was about 8.8 x 10 super(3) tons, corresponding to an optimum fishing effort of 18.8 x 10 super(6) traps per day. It was recommended that the minimum size of catch established previously should be followed.

TI: Title
The growout of spiny lobster juveniles in marine cages
OT: Original Title
Engorda de lagostas em viveiro no mar
AU: Author
Assad, LT; Gondim, DS; Ogawa, M
AF: Author Affiliation
Dep. Engenharia da pesca, Univ. Federal do Ceara, Ceara, Brazil
SO: Source
Arquivos de ciencias do mar. Fortaleza [Arq. Cienc. Mar], vol. 30, no. 1-2, pp. 13-19, Jan 1996

IS: ISSN
0374-5686
AB: Abstract
A 500 m super(2) marine nursery cage was laid down in nearshore waters at Ponta Grossa, Ceara State, Brazil,for the culturing, storage and trading of live individuals. About 15000 juvenile lobsters of the species Panulirus argus and few specimens of P. laevicauda and P. echinatus, were reared from June to August 1995. Tail weight presented a yielding of 1 g/day. The males had a bigger growth rate than females, both in length and weight.

TI: Title
A model to estimate the unrecorded catch based on recorded landings
AU: Author
Austin,C.B.; Waugh,G.T.; Chann,S.K. ; West,N. (ed.).
AF: Author Affiliation
Miami Univ., FL, USA
CF: Conference
Presented at: 5. Annu. Conference of the Coastal Society, Newport, RI (USA), 6 Nov 1979
SO: Source
In: Proceedings of fifth annual conference. Resource allocation issues in the coastal environment., Publ. by: The Coastal Society; Arlington, VA (USA)., 1980., p. 38-48., Proc. Annu. Conf. Coast. Soc.
ER: Environmental Regime
Marine
AB: Abstract
Work sponsored by the Ford Foundation to apply analytical and numerical models to marine resource management problems is described. A model is developed in this paper that can be utilized to estimate the magnitude of the unrecorded catch relative to recorded landings. The model implies that the unrecorded catch is slightly larger than the recorded catch of the Florida spiny lobster, Panulirus argus . While a percentage of the unrecorded catch can be attributed to the recreational harvest, it is expected (but still not verified) that the poaching of shorts by commercial fishermen while they are harvesting legal size lobsters is the major portion of the unrecorded catch.

TI: Title
Progress on assessment of recruitment of postlarval spiny lobsters, Panulirus argus , to Antigua, West Indies.
AU: Author
Bannerot, SP; Ryther, JH; Griffith, S
AF: Author Affiliation
P.O. Box 880, Tavernier, FL 33070, USA
CF: Conference
40. Annu. Gulf and Caribbean Fisheries Inst., Curacao (Netherlands Antilles), Nov 1987
ED: Editor
Waugh, GT; Goodwin, MH (eds)
SO: Source
PROCEEDINGS OF THE FORTIETH ANNUAL GULF AND CARIBBEAN FISHERIES

INSTITUTE, CURACAO NETHERLANDS ANTILLES, NOVEMBER 1987., 1991, pp.
482-488, Proceedings of the Gulf and Caribbean Fisheries Institute
[PROC. GULF CARIBB. FISH. INST.], vol. 40

IS: ISSN
0072-9019

AB: Abstract

Thirty-five floating collecting devices, constructed of PVC pipe and air conditioner filter material, were deployed around Antigua, West Indies 20-22 August and sampled weekly for postlarval spiny lobsters from 28 August to 5 November 1987. The samples are the beginning of a one year program designed to document periodicity, magnitude, and distribution of the recruitment of the postlarvae to nearshore waters. Total sample size after 11 weeks is 1,941 individuals. The majority settled on the collectors during the new moon and first quarter. Distribution of arriving pueruli is patchy. Several nearshore sites on the windward (east) coast have experienced the highest weekly settlement rates. Classification of sampled individuals into seven stages according to degree of pigmentation for pueruli and appearance following first molt for post-pueruli may allow accurate estimation of night of arrival to the collector.

TI: Title
Large-scale assessment of recruitment of postlarval spiny lobsters, Panulirus argus , to Antigua, West Indies.

AU: Author
Bannerot, SP; Ryther, JH; Clark, M

AF: Author Affiliation
P.O. Box 880, Tavernier, FL 33070, USA

CA: Corporate Author
Gulf and Caribbean Fisheries Inst., Charleston, SC (USA)

CF: Conference
41. Annu. Gulf and Caribbean Fisheries Inst., St. Thomas (USVI), Nov 1988

ED: Editor
Goodwin, MH; Kau, SM; Waugh, GT (eds)

SO: Source
PROCEEDINGS OF THE FORTY-FIRST ANNUAL GULF AND CARIBBEAN FISHERIES
INSTITUTE, ST. THOMAS, U.S.V.I., NOVEMBER 1988., 1992, pp.
471-486, Proceedings of the Gulf and Caribbean Fisheries Institute
[PROC. GULF CARIBB. FISH. INST.], vol. 41

IS: ISSN
0072-9019

AB: Abstract

Twenty-eight floating collecting devices, constructed of PVC pipe and air conditioner filter material, were deployed, maintained, and sampled weekly from 28 August 1987 to 29 July 1988 in Antigua, West Indies for the purpose of assessing periodicity, magnitude, and distribution of recruitment of postlarval spiny lobster to nearshore waters. Thirteen of these collectors were distributed randomly around the coastline within 50 m of shore to obtain unbiased estimates of relative abundance. Fifteen were deployed nonrandomly 1 m to 4.8 km from shore in order to increase area and number of habitat types sampled. Total sample size was 11,697.

Combined with additional field experiments, 22,817 postlarval lobsters were collected. Recruitment was strongly correlated with moon phase. Largest samples occurred during the new moon and first quarter throughout the year.

TI: Title
The structure of chemosensory centers in the brain of spiny lobsters and crayfish.
AU: Author
Blaustein, D; Derby, CD; Beall, AC
AF: Author Affiliation
Dep. Biol., Georgia State Univ., Atlanta, GA 30303, USA
CF: Conference
8. Meeting ISOT IX/AChemS, Snowmass, CO (USA), 20-24 Jul 1986
SO: Source
Chemical Senses [CHEM. SENSES.], vol. 11, no. 4, pp. 582-583, 1986
IS: ISSN
0379-864X
NT: Notes
Poster session; abstract only.
AB: Abstract
The authors are using the olfactory system of crustaceans to study sensory and integrative neural mechanisms. The authors have therefore undertaken this investigation of the olfactory pathways of two species commonly used in physiological studies - Panulirus argus (Florida spiny lobsters) and Procambarus clarkii (freshwater crayfish). The results are based on several staining methods, including silver, toluidine blue, horseradish peroxidase (HRP) and cobalt stains. The olfactory lobes (OL) are organized into discrete columns of chemical synapses. Each glomerulus has a distinct substructure of four region: (i) an outer region called the cap by Sandeman and Luff (this region contains terminals from the olfactory receptor cells, as well as interneurons whose fibers interconnect the cap regions of more than one glomerulus and project to the medulla terminais via the olfactory - globular tract); (ii) a subcap region composed of horizontal fiber; (iii) a layer of interglomerular horizontal fibers; and (iv) a tapered base of synapses. The accessory lobes (AL) are also glomerular in structure, although the AL glomeruli are smaller, spherical and more numerous than glomeruli in the OL, and are arranged into distinct regions. Interneurons with contralateral somata each synapse within more than one of the glomeruli of the AL.

TI: Title
The structure of chemosensory centers in the brain of spiny lobsters and crayfish.
AU: Author
Blaustein, D; Derby, CD; Beall, AC
AF: Author Affiliation
Dep. Biol., Georgia State Univ., Atlanta, GA 30303, USA
CF: Conference
9. International Symposium on Olfaction and Taste., Snowmass Village, CO (USA), 20-24 Jul 1986
ED: Editor
Roper, SD; Atema, J (eds)

SO: Source
TASTE AND OLFACTION., 1987, pp. 180-183, Annals of the New York Academy of Sciences [ANN. N.Y. ACAD. SCI.], vol. 510
IS: ISSN
0077-8923
AB: Abstract
The crustacean olfactory system has been used in recent years to investigate basic questions about the functional organization of the chemical senses. To provide a better understanding of the anatomical substrate upon which such chemosensory capabilities are based, the authors initiated this study of the morphology of the chemosensory pathways of two species of decapod crustaceans often used in physiological studies--Panulirus argus (Florida spiny lobster) and Procambarus clarkii (freshwater crayfish). The results are based on several staining methods including silver, toluidine blue, horseradish peroxidase, and hexammine cobalt chloride stains.

TI: Title
Effects of recreational and commercial fishing on spiny lobster abundance at Looe Key National Marine Sanctuary.
AU: Author
Blonder, BI; Hunt, JH; Forcucci, D; Lyons, WG
AF: Author Affiliation
Florida Mar. Res. Inst., 13365 Overseas Highw., Marathon, FL 33050, USA
CA: Corporate Author
Gulf and Caribbean Fisheries Inst., Charleston, SC (USA)
CF: Conference
41. Annu. Gulf and Caribbean Fisheries Inst., St. Thomas (USVI), Nov 1988
ED: Editor
Goodwin, MH; Kau, SM; Waugh, GT (eds)
SO: Source
PROCEEDINGS OF THE FORTY-FIRST ANNUAL GULF AND CARIBBEAN FISHERIES
INSTITUTE, ST. THOMAS, U.S.V.I., NOVEMBER 1988., 1992, pp. 487-491, Proceedings of the Gulf and Caribbean Fisheries Institute [PROC. GULF CARIBB. FISH. INST.], vol. 41
IS: ISSN
0072-9019
AB: Abstract
Impacts of recreational and commercial harvest on the abundance of spiny lobster, Panulirus argus , were studied at Looe Key National Marine Sanctuary, Florida. Spiny lobster abundance following the two-day sport diver season decreased by 55% in the reef flat in 1987, and in the fore reef by 33% in 1987 and 36% in 1988. However, no changes in P. argus abundance were observed in the patch reef either year, and lobster abundance in the reef flat increased 12% following the 1988 sport dive season. There were 3.8 times more recreational divers visiting the fore reef and reef flat during the 1987 sport dive season than there were in 1988; few visited the patch reefs. We conclude that spiny lobster abundance is adversely impacted by sport diver activity within the sanctuary. P. argus abundance in all zones decreased steadily over

the first 30 days following the open season, resulting from the combined effects of recreational diving and commercial trap fishing.

TI: Title
Spiny lobster recruitment in south Florida: Quantitative experiments and management implications.
AU: Author
Butler, MJ IV; Herrnkind, WF
AF: Author Affiliation
Dep. Biol. Sci., Old Dominion Univ., Norfolk, VA 23529-0266, USA
CA: Corporate Author
Gulf and Caribbean Fisheries Inst., Charleston, SC (USA)
CF: Conference
41. Annu. Gulf and Caribbean Fisheries Inst., St. Thomas (USVI), Nov 1988
ED: Editor
Goodwin, MH; Kau, SM; Waugh, GT (eds)
SO: Source
PROCEEDINGS OF THE FORTY-FIRST ANNUAL GULF AND CARIBBEAN FISHERIES
INSTITUTE, ST. THOMAS, U.S.V.I., NOVEMBER 1988., 1992, pp. 508-515, Proceedings of the Gulf and Caribbean Fisheries Institute [PROC. GULF CARIBB. FISH. INST.], vol. 41
IS: ISSN
0072-9019
AB: Abstract
Understanding recruitment and identifying factors critical to that process are imperative if adult spiny lobster Panulirus argus stocks are to be conserved and properly managed. The goal of our research has been to obtain ecological information linking inshore postlarval spiny lobster recruitment to later life stages, thereby providing the basic framework for assessing and predicting adult stock. The authors are conducting quantitative field experiments evaluating: the relationship between surface collector (a standard measure of recruitment), postlarval settlement in algal clumps, and benthic juvenile abundance, and the relative importance of settlement versus habitat carrying capacity in determining local lobster abundances. Preliminary results suggest that in Florida Bay: settlement is patchy and highest near the keys; surface collectors are poor indicators of local settlement or recruitment; and suitable habitat may limit recruitment to the postalgal juvenile stage more than settlement.

TI: Title
Cascading disturbances in Florida Bay, USA: Cyanobacteria blooms, sponge mortality, and implications for juvenile spiny lobsters Panulirus argus
AU: Author
Butler, MJIV; Hunt, JH; Herrnkind, WF; Childress, MJ; Bertelsen, R; Sharp, W; Matthews, T; Field, JM; Marshall, HG
AF: Author Affiliation
Department of Biological Sciences, Old Dominion University,

Norfolk, VA 23529-0266, USA

SO: Source

Marine ecology progress series. Oldendorf [MAR. ECOL. PROG. SER.], vol. 129, no. 1-3, pp. 119-125, 1995

IS: ISSN

0171-8630

NT: Notes

Bibliogr.: 44 ref.

AB: Abstract

Florida Bay, the shallow lagoon separating mainland Florida and the Florida Keys, USA, is experiencing an unprecedented series of ecological disturbances. In 1991, following reports of other ecosystem perturbations, we observed widespread and persistent blooms of cyanobacteria that coincided with the decimation of sponge communities over hundreds of square kilometers. Juvenile Caribbean spiny lobsters Panulirus argus, among other animals, rely on sponges for shelter; the impact of sponge loss on the abundance of lobsters and their use of shelter, in particular, has been dramatic. The loss of sponges on 27 experimental sites in hard bottom habitat in central Florida Bay resulted in the redistribution of juvenile lobsters among the remaining shelters, an influx of lobsters into sites where artificial shelters were present, and a decline in lobster abundances on sites without artificial shelters. Diver surveys of sponge damage at additional sites in central Florida Bay confirmed that the sponge die-off was widespread and its occurrence coincided with areas that had been exposed to the cyanobacteria bloom. This cascade of disturbances has dramatically altered the community structure of affected hard bottom areas and demonstrates the coupled dynamics of this shallow marine ecosystem.

TI: Title

A test of recruitment limitation and the potential for artificial enhancement of spiny lobster (Panulirus argus) populations in Florida

AU: Author

Butler, MJ IV; Herrnkind, WF

AF: Author Affiliation

Department Biological Sciences, Old Dominion University, Norfolk, VA 23529-0266, USA

SO: Source

Canadian Journal of Fisheries and Aquatic Sciences/Journal Canadien des Sciences Halieutiques et Aquatiques. Ottawa [CAN. J. FISH. AQUAT. SCI./J. CAN. SCI. HALIEUT. AQUAT.], vol. 54, no. 2, pp. 452-463, 1997

IS: ISSN

0706-652X

AB: Abstract

A field experiment was conducted in the Florida Keys in which Caribbean spiny lobster (Panulirus argus) settlement and shelter for juveniles was manipulated to 1) investigate how these factors influence local recruitment and 2) evaluate the efficacy of such practices proposed to enhance spiny lobster populations. The number of small juvenile lobsters significantly increased at six 0.05-ha sites where 12 artificial shelters were added, but was unchanged on three unmanipulated sites. Adding over 150 new settlers to three of the shelter-supplemented sites did not measurably increase juvenile lobster abundance above that attributable to shelter enhancement alone. Mark-recapture results confirmed that the observed increase in small juveniles on shelter-supplemented sites was not due to immigration. The addition of artificial structures to nursery sites appears to have reduced predation on the vulnerable small juveniles and led to their local retention. In contrast, larger, more mobile juveniles were no more abundant where shelter was added than on the unmanipulated sites. Results support the proposition that local recruitment of P. argus may be increased by augmenting natural shelter with appropriately designed artificial structures, but the broader implications of enhancing lobster populations on the surrounding natural communities are unknown.

TI: Title

Sponge mass mortality and Hurricane Andrew: Catastrophe for juvenile spiny lobsters in south Florida?

AU: Author

Butler, MJ; Herrnkind, WF; Hunt, JH

AF: Author Affiliation

Dep. Biol. Sci., Old Dominion Univ., Norfolk, VA 23508, USA

CF: Conference

Symp. on Florida Keys Regional Ecosystem, Miami, FL (USA), Nov 1992

ED: Editor

Prospero, JM; Harwell, CC (eds)

SO: Source

SYMPOSIUM ON FLORIDA KEYS REGIONAL ECOSYSTEM. NOVEMBER 1992., 1994, p. 1073, Bulletin of Marine Science [BULL. MAR. SCI.], vol: 54, no. 3

IS: ISSN

0007-4977

NT: Notes

Abstract only.

AB: Abstract

The hardbottom communities of Florida Bay and Biscayne Bay are dominated by sponges, macroalgae, and octocorals, and are prime

settlement and juvenile nursery habitat for south Florida's spiny lobster (Panulirus argus) population. We have been studying spiny lobster recruitment in south Florida for nearly a decade and, in 1991-1992, our ongoing field investigations provided us the opportunity to quantitatively assess the impact of two large-scale disturbances on hardbottom community structure and, consequently, juvenile spiny lobster population dynamics. From November 1991-January 1992, a massive sponge die-off occurred in south-central Florida Bay following an episodic phytoplankton bloom thought to have resulted from the nutrient flux emanating from a seagrass die-off event. nearly every species of sponge was impacted and over 90% of the sponges were dead or damaged in many areas. Sponges are the primary shelter for juvenile spiny lobsters and their loss precipitated dramatic shifts in lobster shelter use and abundance. Hurricane Andrew slammed into south Florida the following September and passed directly over Biscayne Bay, where we had completed surveys of juvenile spiny lobster abundance and hardbottom habitat structure only a month before. We are resurveying those sites to determine the effect of the storm on hardbottom community structure and the juvenile spiny lobster abundance and distribution. These two massive, but dissimilar disturbances have potentially important consequences for south Florida's hardbottom habitat and the juvenile spiny lobsters that reside there.

TI: Title
Factors affecting the recruitment of juvenile caribbean spiny lobsters dwelling in macroalgae

AU: Author
Butler, MJ IV; Herrnkind, WF; Hunt, JH

AF: Author Affiliation
Department of Biological Sciences, Old Dominion University, Norfolk, VA 23529-0266, USA

CF: Conference
Nemuro Workshop on Oceans and Fisheries '95. Spiny and Clawed Lobsters, Nemuro, Hokkaido (Japan), 18-22 Nov 1995

SO: Source
Bulletin of Marine Science, vol. 61, no. 1, pp. 3-19, Jul 1997

IS: ISSN
0007-4977

PB: Publisher
Rosenstiel School of Marine and Atmospheric Science

AB: Abstract
In south Florida, Caribbean spiny lobsters (Panulirus argus) settle and spend their first few months in macroalgae or seagrass. After a few months, these "algal-phase" juveniles emerge from vegetation and, as "postalgal-phase" juveniles, seek refuge in

crevices, often dwelling in groups. The importance of crevice shelters in determining the abundance of postalgal-phase juvenile spiny lobsters has been studied, but we know little about the processes affecting lobster distribution and survival during their cryptic algal-dwelling phase. We found that postlarval supply varied independently of changes in the structure of macroalgal settlement habitat. For this reason, postlarval supply alone can not reliably predict local settlement density. Changes in the size of macroalgal patches in particular tend to increase the variability in settlement density among locations and times. Field and mesocosm experiments indicate that social interactions and individual movements are unlikely to alter the general distribution of algal-phase lobsters established at settlement. But if algal-phase lobsters are aggregated at scales <1 m super(2) (e.g., due to patchy settlement), they experience higher mortality than non-aggregated lobsters, as revealed in field experiments where lobsters were tethered alone or in pairs and at varying inter-individual distances. Field manipulations of settlement density indicate that recapture (survival) of microwire tagged algal-phase juveniles is positively associated with features of the habitat that affect lobster density (e.g., site area, macroalgal patch size), but survival and growth of lobsters are unrelated to artificially manipulated settlement density. Collectively, these results imply that the population dynamics of juvenile P. argus dwelling in macroalgae are not typically regulated by density-dependent processes, although density-dependent predation may be locally important in patches when settlement is episodically high.

TI: Title
Artificial Reefs as Strategic Nursery Ground.
AU: Author
Calinski, M
AF: Author Affiliation
Florida Keys Community Coll., Key West, FL, USA
ED: Editor
Aska, DY (ed)
SO: Source
., pp. 209-210, .
AB: Abstract
Artificial habitats which have been designed and developed to protect the early life states (postlarval through 6th to 8th stage) of the Florida spiny lobster, Panulirus argus , have been shown to dramatically avail the survival rates (nearly 100% for the first month after postlarval settlement) of the animals, and theoretically, a total one square mile of habitats could double the total spiny lobster landings in the state of Florida. These habitats had to undergo several developmental changes, with the most functional design (which floats on the surface in shallow water) being focused at and used almost exclusively by spiny

lobsters. Present research strongly indicates that such habitats could be developed for the early life stages of other commercially important species (such as shrimp, snappers, stone crabs, and blue crabs) to step up their early survival rates, and thus provide an additional input into the fisheries.

TI: Title
Olfactory receptors of the spiny lobster: ATP-sensitive cells with similarities to P sub(2)-type purinocpetors of vertebrates.
AU: Author
Carr, WES; Gleeson, RA; Ache, BW; Milstead, ML
AF: Author Affiliation
C.V. Whitney Mar. Lab., Univ. Florida, St. Augustine, FL 32086, USA
SO: Source
Journal of Comparative Physiology, A [J. COMP. PHYSIOL., A.], vol. 158A, no. 3, pp. 331-338, 1986
IS: ISSN
0340-7594
AB: Abstract
A distinct population of ATP-sensitive cells, with response characteristics indicative of P sub(2)-type purinoceptors found in internal tissues of vertebrates, was identified among the antennular olfactory cells of the spiny lobster, Panulirus argus). Differences in structure-activity relationships, response duration, and response magnitude clearly distinguished the ATP-sensitive cells from another type of olfactory purinoceptor, the AMP-sensitive cells, also occurring in the antennules of the lobster.

TI: Title
Chemoreceptors of crustaceans: Similarities to receptors for neuroactive substances in internal tissues.
AU: Author
Carr, WES; Ache, BW; Gleeson, RA
AF: Author Affiliation
C.V. Whitney Lab., Univ. Florida, Rt. 1, Box 121, St. Augustine, FL 32086, USA
CF: Conference
Mechanisms of Pollutant Action in Aquatic Organisms, Research Triangle Park, NC (USA), 21-23 May 1986
ED: Editor
Pritchard, JB (ed)
SO: Source
MECHANISMS OF POLLUTANT ACTION IN AQUATIC ORGANISMS., 1987, pp. 31-46, Environmental Health Perspectives [ENVIRON. HEALTH PERSPECT.], vol. 71
IS: ISSN
0091-6765
AB: Abstract
A description is given of crustacean chemosensory systems and the neurophysiological procedures used to study them. Their response properties and tuning characteristics are discussed. A review is then provided of specific crustacean chemoreceptors that are stimulated selectively by either purine nucleotides, taurine,

glutamate, or glycine, all of which have neuroactive properties in internal tissues. Two distinctly different types of purinergic chemoreceptors occur on the antennules of the spiny lobster. Narrowly tuned taurinergic chemoreceptors are present on both the antennules and legs of lobsters. Crustacean chemoreceptors for glycine, ecdysteroids, gluatamate and pyridine are also described. The hypothesis that receptors for internal neuroactive agents may have originally evolved as external chemoreceptors of primitive aquatic organisms is discussed.

TI: Title
A tale of two tails: Behavioral and life history trait variation among sympatric spiny lobsters
AU: Author
Childress, M; Hunt, J; Herrnkind, W
AF: Author Affiliation
FL State Univ., Tallahassee, FL 32306, USA
CF: Conference
24. Annu. Benthic Ecology Meeting, Columbia, SC (USA), 7-10 Mar 1996
ED: Editor
Woodin, SA; Allen, DM; Stancyk, SE; Williams-Howze, J; Feller, RJ; Wethey, DS; Pentcheff, ND; Chandler, GT; Decho, AW; Coull, BC (eds)
SO: Source
TWENTY-FOURTH ANNUAL BENTHIC ECOLOGY MEETING, HELD IN COLUMBIA, SOUTH CAROLINA, MARCH 7-10, 1996., 1996, p. 26,
NT: Notes
Abstract only
AB: Abstract
Den sharing has been postulated as group defense to reduce predation, yet co-occupancy varies among species in the same habitat. We examined two sympatric lobsters at three life history stages to test hypotheses about why lobsters share dens. Post-puerulus stages are similarly asocial despite different settlement habitats. Adult stages on coral reefs share crevices with conspecifics in similar frequencies. However, juvenile P. argus are attracted to and share crevices with conspecifics more than juvenile P. guttatus. Juvenile P. argus must migrate from settlement to adult habitat whereas P. guttatus settle directly in adult habitat. Conspecific attraction can reduce exposure to predators when changing habitats and explain why juvenile P. argus share dens more often than P. guttatus in the same habitat. Such variation suggests that den sharing is initially a consequence of conspecific attraction.

TI: Title
Comparison of phenoloxidase activity from Florida spiny lobster and Western Australian lobster.

AU: Author
Chen, JS; Rolle, RS; Marshall, MR; Wei, CI
AF: Author Affiliation
Food Sci. and Hum. Nutr. Dep., Univ. Florida, Gainesville, FL 32611-0163, USA
SO: Source
Journal of Food Science [J. FOOD SCI.], vol. 56, no. 1, pp. 154-157, 1991
IS: ISSN
0022-1147
AB: Abstract
Polyphenoloxidase (PPO) isolated from cuticle of Western Australian lobster (Panulirus cygnus) and Florida spiny lobster (Panulirus argus) catalyzed oxidation of catechol and DL- beta -3,4-dihydroxyphenylalanine (DL-DOPA). The PPO from Florida lobster showed a higher substrate affinity than that from Australian lobster. They both showed higher affinity for catechol than for DL-DOPA, and optimal pH stability at 7.0. The enzymes differed with respect to activation energy and thermal stability. Electrophoretic patterns using SDS-PAGE indicated PPO from Western Australian lobster had two isoforms while Florida spiny PPO had three isoforms. These results suggest variations in enzyme activity may contribute to differences in susceptibility to melanosis between the two species.

TI: Title
Use of artificial shelters to enhance rock lobster fisheries.
AU: Author
Chubb, C; Brown, R
SO: Source
South Pacific Commission fisheries newsletter. Noumea [SPC FISH. NEWSL.], no. 59, pp. 24-26, 1991
IS: ISSN
0248-076X
AB: Abstract
Details are given of the spiny lobster (Panulirus argus) fisheries at Ascension Bay in Mexico, and in Batabano Gulf in Cuba, describing the artificial shelters used in both fisheries. The Mexican fishermen use "cassitas", which they lay out on seagrass beds, to accumulate the lobsters which are then caught in nets. The Cuban spiny lobster fishery is much more developed and 3 different methods are used to capture the spiny lobsters. As in Mexico, the principal method is the placement of artificial shelters, "pesqueros"; haul traps are used in the deeper waters of the fringing reef and shelf break and set net traps are used in shallower water during lobster migrations.

TI: Title
Effect of prolonged starvation in postlarvae and juveniles of the spiny lobster Panulirus argus.

OT: Original Title
Bioenergetica de juveniles de la langosta Panulirus argus (Latreille, 1804). Efectos del ayuno prolongado
AU: Author
Conceicao, RNL; Diaz Iglesia, E; Brito Perez, R; Baez Hidalgo, M
AF: Author Affiliation
Lab. Ciencias do Mar, Univ. Federal do Ceara, Fortaleza, Ceara, Brazil
SO: Source
Arquivos de ciencias do mar. Fortaleza [Arq. Cienc. Mar], vol. 30, no. 1-2, pp. 49-53, Jan 1996
IS: ISSN
0374-5686
AB: Abstract
An assay was realized to determine the effects of starvation on the oxygen consumption and nitrogen excretion of postlarvae and juveniles of the spiny lobster Panulirus argus. Results showed that after seven days of starvation there were no significative differences respect the measured parameters between the lobsters subnmitted to starvation respect to those under normal conditions.

TI: Title
Nocturnal foraging in the Caribbean spiny lobster, Panulirus argus
AU: Author
Cox, C; Hunt, JH; Lyons, WG; Davis, GE
AF: Author Affiliation
Florida DEP, Florida Mar. Res. Inst., Marathon, FL 33050, USA
CF: Conference
24. Annu. Benthic Ecology Meeting, Columbia, SC (USA), 7-10 Mar 1996
ED: Editor
Woodin, SA; Allen, DM; Stancyk, SE; Williams-Howze, J; Feller, RJ; Wethey, DS; Pentcheff, ND; Chandler, GT; Decho, AW; Coull, BC (eds)
SO: Source
TWENTY-FOURTH ANNUAL BENTHIC ECOLOGY MEETING, HELD IN COLUMBIA, SOUTH CAROLINA, MARCH 7-10, 1996., 1996, p. 30,
NT: Notes
Abstract only
AB: Abstract
Spiny lobsters (Panulirus argus) were observed during the night by diving along randomly selected transects across sand, seagrass, and rubble zones within the reef flat in the Looe Key National Marine Sanctuary. Lobsters from dens on the fore reef were repeatedly observed foraging on the reef flat during the night. Preferred foraging areas were extensive rubble ridges surrounding the reef flat. Subsequent sampling of the rubble area revealed

hundreds of species of potential prey items. Gut contents of 75 intermolt lobsters caught in Biscayne Bay and Dry Tortugas consisted of a myriad of prey items dominated by molluscs, especially gastropods (48%), chitons (14%) and bivalves (11%), and by crabs (11%). Abundance of Cerithium litteratum, a favored food item, was as high as 348 snails/sq. m in the rubble zone at Looe Key. Prey items were relatively scarce in sand and seagrass.

TI: Title
(Lobster fisheries and their relationships with the Fishery Management Units.).
OT: Original Title
Las pesquerias de langosta y su relacion con los Buroes de Captura
AU: Author
Cruz, R; Blanco, W
CA: Corporate Author
Ministerio de la Industria Pesquera, Havana (Cuba). Cent. Invest. Pesq
CF: Conference
2. Seminario sobre Buroes de Captura, (np) (Cuba), Sep 1986
SO: Source
(SECOND SEMINAR ON THE FISHING MANAGEMENT UNITS.)., SEGUNDO SEMINARIO SOBRE BUROES DE CAPTURA , (198, pp. 3.1-14
AB: Abstract
The lobster fishery in Cuba involves the species Panulirus argus . Details are given of fishery gear and methods used. Activities conducted by the Fishery Management Units are detailed. Sampling surveys investigated fishery productivity and biological aspects of the species such as size distribution, reproduction and mortality.

TI: Title
Mixture suppression in behavior: The antennular flick response in the spiny lobster towards binary odorant mixtures.
AU: Author
Daniel, PC; Derby, CD
AF: Author Affiliation
Dep. Biol., P.O. Box 4010, Georgia State Univ., Atlanta, GA 30302-4010, USA
SO: Source
Physiology & Behavior [PHYSIOL. BEHAV.], vol. 49, no. 3, pp. 591-601, 1991
IS: ISSN
0031-9384
AB: Abstract
The behavioral responses of Florida spiny lobsters (Panulirus argus) towards various concentrations of binary mixtures and their constituents (AMP, betaine, cysteine, succinate, and taurine) were measured using an antennular flicking assay. The rate of flicking increases with dose and has low thresholds: flick rates towards each of the 5 chemicals increased with concentration with thresholds between 1 nM and 100 mu M. A mixed receptor composition model, which incorporates knowledge of the composition

of receptor site types and their distribution across receptor cells (15), was used to predict responses to binary mixtures based on responses to the individual constituents. Nine of the 10 binary mixtures elicited response magnitudes which were less than predicted by this model, suggesting mixture suppression. These mixture interactions appear to be independent of the concentration of the mixture tested; rather, they occur with the same magnitude at all concentrations.

TI: Title
Juvenile spiny lobster management or how to make the most of what you get
AU: Author
Davis,G.E.
AF: Author Affiliation
Mar. Ecol. Res. Prog., US Natl. Park Serv. South Florida Res. Cent., Everglades Natl. Park, PO Box 279, Homestead, FL 33030, USA
SO: Source
Fisheries, 5(4), 57-59, (1980)
AB: Abstract
Larval production and survival, equitable allocation and efficient harvest among fishermen,and maximization of yield per postlarval recruit are identified as three major elements amenable to management actions in spiny lobster (Panulirus argus) fisheries. Minimum harvestable lobster size, habitat protection and enhancement, trap escape vents, and nursery sanctuaries are some of the means of improving yield per postlarval recruit.

TI: Title
Settlement of spiny lobster, Panulirus argus (Latreille, 1804), in Florida: Pattern without predictability?
AF: Author Affiliation
Dep. Biol. Sci., Florida State Univ., Tallahassee, FL 32306, USA
CF: Conference
4. Int. Workshop on Lobster Biology and Management, Sanriku (Japan), 25-31 Jul 1993
ED: Editor
Herrnkind, WF; Butler, MJ IV; Kittaka, J; Booth, JD; Phillips, BF; Cobb, JS; Quackenbush, LS; Kanazawa, A; Collin, R; Bannister, A; Addison, JT; Breen, PA (eds)
SO: Source
Crustaceana, vol. 66, no. 3, pp. 46-64, 1994
IS: ISSN
0011-216X
AB: Abstract
We used plankton nets, floating postlarval collectors, and arrays of benthic settling devices, along with diver surveys of juvenile lobster abundance and nursery habitat structure, to estimate the spatial pattern of settlement, abundance of settlers, and characteristics of postsettlement juvenile Panulirus argus populations in Florida Bay, the primary nursery for spiny lobsters

in Florida. Within a 200 km super(2) region of Florida Bay, settlement was patchy and locally unpredictable, although settlement occurred at most sites each lunar phase. However, the number of postlarvae entering inlets to the bay was significantly correlated with regional settlement, and areas with abundant red macroalgae (settlement substrate) and numerous sponges (benthic juvenile shelter) were the most productive sites, even though settlement within them varied widely during lunar influxes. Floating collector catches accurately estimated the number of postlarvae in the water column at inlets, but results from collectors deployed in the bay did not correlate with the number of postlarvae settling on benthic collectors nearby. Estimates of postsettlement mortality in the field yield a natural mortality of about 97% in the year following settlement.

TI: Title
Processing of olfactory information at three neuronal levels in the spiny lobster.
AU: Author
Derby, CD; Hamilton, KA; Ache, BW
AF: Author Affiliation
C.V. Whitney Lab., Univ. Florida, Rt. 1, Box 121, St. Augustine, FL 32086, USA
SO: Source
Brain Research [BRAIN RES.], vol. 300, no. 2, pp. 311-319, 1984
IS: ISSN
0006-8993
AB: Abstract
Odor quality coding was analyzed at three neuronal levels, receptor cells and two levels of chemosensory interneurons, in the olfactory system of the spiny lobster Panulirus argus . Responses to three of the most stimulatory compounds for this animal - taurine, glutamate and betaine - were recorded at each level in order to compare basic neuronal response properties, single cell and population response spectra, and across-neuron patterns. Mean response specificity increased for cells at each successive neuronal level. The increase in breadth of tuning between receptor cells and low-order interneurons was paralleled by an increase in interstimulus across-neuron correlations. However, in high-order interneurons, there was a relative decline in across-neuron correlations, indicating that the more broadly-tuned high-order interneurons are better able to discriminate between any two compounds than are the more narrowly-tuned low-order interneurons.

TI: Title
Processing of olfactory information at three neuronal levels in the spiny lobster.
AU: Author
Derby, CD; Hamilton, KA; Ache, BW
AF: Author Affiliation
C.V. Whitney Lab., Univ. Florida, Rt. 1, Box 121, St. Augustine, FL 32086, USA

SO: Source
Brain Research [BRAIN RES.], vol. 300, no. 2, pp. 311-319, 1984
IS: ISSN
0006-8993
AB: Abstract
Odor quality coding was analyzed at three neuronal levels, receptor cells and two levels of chemosensory interneurons, in the olfactory system of the spiny lobster Panulirus argus . Responses to three of the most stimulatory compounds for this animal - taurine, glutamate and betaine - were recorded at each level in order to compare basic neuronal response properties, single cell and population response spectra, and across-neuron patterns. Mean response specificity increased for cells at each successive neuronal level. The increase in breadth of tuning between receptor cells and low-order interneurons was paralleled by an increase in interstimulus across-neuron correlations. However, in high-order interneurons, there was a relative decline in across-neuron correlations, indicating that the more broadly-tuned high-order interneurons are better able to discriminate between any two compounds than are the more narrowly-tuned low-order interneurons.

TI: Title
AMP receptors of the spiny lobster: External receptors on the olfactory organs and internal receptors in the brain.
AU: Author
Derby, CD; Carr, WES; Ache, BW
AF: Author Affiliation
Dep. Biol., Georgia State Univ., Atlanta, GA 30303, USA
CF: Conference
8. Meeting ISOT IX/AChemS, Snowmass, CO (USA), 20-24 Jul 1986
SO: Source
Chemical Senses [CHEM. SENSES.], vol. 11, no. 4, p. 593, 1986
IS: ISSN
0379-864X
NT: Notes
Poster session; abstract only.
AB: Abstract
Electrophysiological recordings from single olfactory cells in the antennules of the spiny lobster (Panulirus argus) revealed the existence of receptors highly sensitive to the nucleotide, adenosine 5'-monophosphate (AMP). These receptors are most strongly activated by AMP, have a potency sequence of AMP > ADP > ATP > adenosine, are antagonized by theophylline and have responses that are most affected by changes in the ribose phosphate moiety. These olfactory purinoceptors closely resemble P1-type (or R-type) purinoceptors found in internal organs of vertebrates, including the brain. The authors have recently obtained electrophysiological evidence for the existence of related purinergic receptors within the brain of the spiny lobster. Addition of AMP into the saline perfusing the brain resulted in marked changes in the spontaneous activity and/or evoked responses of many of the studied brain interneurons. The modulatory effects of AMP were usually depressive, although examples of enhancement were also observed. Adenosine had modulatory effects similar to AMP in some of the neurons.

TI: Title
Purinergic receptors occur externally on the olfactory organs and internally in the brain of the spiny lobster.
AU: Author
Derby, CD; Carr,WES; Ache, BW
AF: Author Affiliation
Dep. Biol., Georgia State Univ., Atlanta, GA 30303, USA
CF: Conference
9. International Symposium on Olfaction and Taste., Snowmass Village, CO (USA), 20-24 Jul 1986
ED: Editor
Roper, SD; Atema, J (eds)
SO: Source
TASTE AND OLFACTION., 1987, pp. 250-253, Annals of the New York Academy of Sciences [ANN. N.Y. ACAD. SCI.], vol. 510
IS: ISSN
0077-8923
AB: Abstract
An electrophysiological characterization of purinergic chemoreceptor neurons on the olfactory organ (antennule) of a marine crustacean was performed using a larger species, the spiny lobster Panulirus argus . The responsiveness of the purinergic olfactory cells of lobsters correlated closely with the behavioral responses of shrimp. In both cases: (a) AMP was clearly the most effective purine tested; (b) there was a potency sequence of AMP > ADP > ATP > adenosine; (c) changes in the ribose phosphate moiety of the AMP molecule resulted in the greatest decrease in activity; and (d) the response to AMP was antagonized by theophylline. These results suggest that these marine crustaceans possess external purinergic receptors on olfactory receptor cells that are similar to the P sub(1)-type purinoceptors found internally in vertebrates.

TI: Title
Purinergic modulation in the brain of the spiny lobster.
AU: Author
Derby, CD; Ache, BW; Carr, WES
AF: Author Affiliation
Dep. Biol., Georgia State Univ., Atlanta, GA 30303, USA
SO: Source
Brain Research [BRAIN RES.], vol. 421, no. 1-2, pp. 57-64, 1987
IS: ISSN
0006-8993
AB: Abstract
Earlier studies identified purinergic chemoreceptors in the olfactory organ of the spiny lobster, Panulirus argus . In this study, electrophysiological experiments demonstrate that purinergic substances can modulate both the spontaneous activity and the evoked responses of neurons within the brain of this animal. Perfusion of the brain with 100 mu M adenosine 5'-monophosphate (AMP) modulated the spontaneous activity of 71% of the brain interneurons that were monitored. AMP also modulated the electrically or chemically evoked activity of 25% of the monitored interneurons. The authors believe this is the first

demonstration of modulatory effects of purinergic substances in the nervous system of any invertebrate.

TI: Title
Responses of olfactory receptor cells of spiny lobsters to binary mixtures. 2. Pattern mixture interactions.
AU: Author
Derby, CD; Girardot, M-N; Daniel, PC
AF: Author Affiliation
Dep. Biol., Georgia State Univ., P.O. Box 4010, Atlanta, GA 30302-4010, USA
SO: Source
Journal of Neurophysiology [J. NEUROPHYSIOL.], vol. 66, no. 1, pp. 131-138, 1991
IS: ISSN
0022-3077
AB: Abstract
The effect of mixture interactions in individual olfactory receptor cells of the spiny lobster (Panulirus argus) on neural coding of odorant quality of binary mixtures and their components is examined. Coding of odorant quality was evaluated by examining across neuron patterns (ANPs)--the relative response magnitudes across neuronal populations. Pattern mixture interactions (PMIs) occurred for most binary mixture, even those that did not produce statistically significant intensity mixture interactions (IMIs) for this same population of cells. The results suggest that PMIs can influence coding of stimulus quality, in some cases by causing an improvement of the contrast between the quality of mixtures and some of their components.

TI: Title
Predatory impact of Nassau grouper on reef fish and crustacean prey assemblages
AU: Author
Eggleston, D; Grover, J; Lipcius, R
AF: Author Affiliation
North Carolina State Univ., Raleigh, NC 27695, USA
CA: Corporate Author
Rutgers-the State Univ., New Brunswick, NJ (USA). Inst. Marine Coastal Sciences
CF: Conference
23. Benthic Ecology Meeting, New Brunswick, NJ (USA), 17-19 Mar 1995
ED: Editor
Grassle, JP; Kelsey, A; Oates, E; Snelgrove, PV (eds)
SO: Source
TWENTY-THIRD BENTHIC ECOLOGY MEETING., 1995, vp
NT: Notes
Abstract only.
AB: Abstract
We quantified species richness, abundance and size frequency of

reef fish (< 10 cm TL) and crustacean prey assemblages associated with artificial patch reefs of varying refuge scaling, with and without removal or predatory Nassau grouper (Epinephalus striatus) (> 15 cm TL), in a large seagrass bed off Lee Stocking Island, Bahamas. Our monthly censuses of reefs indicated that (1) there was no effect of shelter scaling or grouper predator abundance on the abundance of small, juvenile spiny lobster (Panulirus argus) and reef fish prey averaged over a seven month period prior to grouper removal from patch reefs; and (2) a negative relationship between grouper abundance, and small lobster and reef fish (4-10 cm TL only) prey abundance, as well as reef fish species richness, averaged over a 12 month period of grouper removal from certain patch reefs.

TI: Title
Isoelectric focusing in immobilized pH gradients of phosphoglucomutase and esterases from the spiny lobster.
AU: Author
Espinosa, G; Wenisch, E; Danner, H; Katinger, H; Righetti, PG
AF: Author Affiliation
Inst. Appl. Microbiol., Univ. Agric. and For., Peter-Jordan-Str. 82, A-1190 Vienna, Austria
SO: Source
Electrophoresis, vol. 11, no. 10, pp. 810-812, 1990
IS: ISSN
0170-0835
AB: Abstract
A method is described for detecting polymorphisms of cephalothorax and tail homogenates of 25 puerulus staged Panulirus argus in phosphoglucomutase (PGM) and esterases. Isoelectric focusing in immobilized pH gradients was used. In the pH 6.0-8.0 interval for phosphoglucomutase and in the pH 3.5-5.0 and 4.2-4.9 ranges for esterases, both enzymes appeared as polymorphic band patterns. These could be explained by one locus with 2 alleles for phosphoglucomutase and 2 loci with 2, 3 and 4 alleles for esterases. Esterases exhibit a more extensive polymorphism in immobilized pH gradients than in polyacrylamide gel electrophoresis.

TI: Title
Field studies of the reproductive biology of the spiny lobsters Panulirus argus (Latreille) and P. guttatus (Latreille) at Bermuda
AU: Author
Evans, CR; Lockwood, APM; Evans, AJ; Free, E
AF: Author Affiliation
Natl. Fish. Authority, P.O. Box 165, Konedobu, NCD, Papua New Guinea
SO: Source
Journal of Shellfish Research [J. SHELLFISH RES.], vol. 14, no. 2, pp. 371-381, 1995

IS: ISSN
0077-5711

AB: Abstract
A variant on the standard leg length assessment of the size at first physical maturity is described and applied to Panulirus argus and Panulirus guttatus at Bermuda. This is based on the relative length of the carapace and the longest segment of the second walking leg. Differential growth of this leg joint (meropodite) relative to the carapace is observed at maturity. The size at which maturity occurs is determined by intercept analysis of plots of meropodite length on carapace length (CL). For female P. argus the ratio changes in a negative direction at maturity. For male P. argus, the reverse occurs. For both female and male P. guttatus the ratio changes in a negative direction, but to a greater degree in females. Using the technique, first physical maturity for P. argus females captured at Bermuda in 1986 and 1987 was measured to be 86.0 mm carapace length, CL (standard deviation 5.1 mm CL), and for males was 97.4 mm CL (sd 5.0 mm CL). For P. guttatus, the comparative data were 59 mm (sd 4 mm CL) for females and 69.3 mm (sd 1.7 mm CL) for males. Field observations of trappable females beating eggs and/or spermatophores confirmed these values. Observations on sex ratio and distribution by depth of P. guttatus are described. Evidence of an inward migration of P. guttatus lobsters from the outer terraces and slopes to the reef-crest is presented.

TI: Title
Zooplankton associated to Panulirus argus (Latreille, 1804) larvae

OT: Original Title
Zooplancton asociado con larvas de Panulirus argus (Latreille, 1804)

AU: Author
Fabre, S; Alfonso, I; Gonzalez, G
AF: Author Affiliation
Instituto de Oceanologia, Playa, Cuba

SO: Source
Revista cubana de investigaciones pesqueras. Havana [REV. CUB. INVEST. PESQ.], vol. 17, no. 1, pp. 18-25, 1992
IS: ISSN
0138-8452

AB: Abstract
Details are given of the zooplankton associated with Panulirus argus in Cuban waters describing the composition, relative abundance and volume of seston. The most abundant and best distributed plankton in the area was the copepod Undinula vulgaris; molluscs occupied a second place in abundance and chaetognaths, siphonophores, ostracods and euphausids reached

remarkable concentrations. The copepods presented a negative correlation in relation with the molluscs, larvae and phyllosome larvae, a feature probably caused by the predatory or competitive effect which those groups exert on the copepods. With respect to the volume of seston, the oceanic waters in the Southern part of the Cuban archipelago may be considered oligotrophic and the zones with greater indexes in this parameter were those more influenced by upwelling or terrigenous contributions. A general relationship was noted between the magnitudes of the seston and the general pattern of circulation.

TI: Title
Activation, characterization, inhibition and seasonal variation in the phenoloxidase level of Florida spiny lobster (Panulirus argus)
AU: Author
Ferrer, OJ
CA: Corporate Author
Florida Univ., Gainesville (USA)
SO: Source
Dissertation Abstracts International Part B: Science and Engineering [DISS. ABST. INT. PT. B - SCI. & ENG.], Oct 1988, vol. 49, no. 4, 147 pp
NT: Notes
Diss. Ph.D.: Order No.: DA8809636.
AB: Abstract
Phenoloxidase (PO) was found in spiny lobster (Panulirus argus) shell as an inert enzyme that was activated by trypsin, producing two active PO forms with up to 120-fold increased PO activity. Phenoloxidase catalyzes the oxidation of phenolic compounds to melanin which leads to the darkening of many light fruits, vegetables and crustaceans. Pepsin, elastase, chymotrypsin, Triton X-100 and repeated freezing and thawing failed to activate PO. The inert PO became active during storage of a partially purified extract at 4 degree C; however, only one active PO form was demonstrated by electrophoresis. This activation was prevented by the addition of phenylmethyl sulfonyl fluoride and other protease inhibitors. Optimum pH of inert and trypsin-activated PO forms was neutral, while the self-active PO was approximately pH 8.0. Inert PO was most stable at pH 10.0-12.0. Trypsin-activated PO was stable from pH 7.0 to 9.0 while the self-active PO had the widest pH stability ranging from 6.0 to 10.0. For all PO forms, little activity was detected below pH 4.0. Apparent Michaelis-Menten constants were 0.81, 0.36 and 0.92 mM for inert, trypsin-activated and self-active PO, respectively. Energy of activation values were 12,193; 7,840; and 10,276 cal/mole also for inert, trypsin-activated and self-active POs, respectively. Sodium bisulfite inhibited the melanosis reactions by reacting with

intermediate quinones and by irreversibly inhibiting PO. Activation of inert PO in vivo appears to be related to the molting cycle of the lobster. High levels of active PO were found in lobsters ready to molt (late pre-molt stage) while high levels of inert PO and low levels of active PO were found in lobsters at the intermolt and premolt stages. Low levels of both inert and active POs were found in molt (newly molted) and postmolt lobsters. Phenoloxidase in the exuvia (cast-off cuticle) was the fully activated form. It appeared PO levels built up during intermolt and early premolt as inert forms which became activated when needed for sclerotization of the new forming cuticle or any other function (stress) associated with PO utilization (DBO).

TI: Title
The influence of temperature, salinity, and larval transport on the distribution of juvenile spiny lobsters, Panulirus argus, in Florida Bay
AU: Author
Field, JM; Butler, MJ
AF: Author Affiliation
Dep. Biol. Sci., Old Dominion Univ., Norfolk, VA 23508, USA
CF: Conference
Symp. on Florida Keys Regional Ecosystem, Miami, FL (USA), Nov 1992
ED: Editor
Prospero, JM; Harwell, CC (eds)
SO: Source
SYMPOSIUM ON FLORIDA KEYS REGIONAL ECOSYSTEM. NOVEMBER 1992., 1994, p. 1074, Bulletin of Marine Science [BULL. MAR. SCI.], vol. 54, no. 3
IS: ISSN
0007-4977
NT: Notes
Abstract only.
AB: Abstract
Florida Bay is the major nursery area for Florida's spiny lobster, Panulirus argus. It is characterized by a series of shallow hardbottom or seagrass covered basins separated by seagrass covered mud less than one meter in depth. Because these mud banks serve as barriers to circulation, the basins formed between the banks may experience extreme fluctuations in temperature and salinity due to reduced tidal influx and high rates of evaporation. Larval transport to areas of Florida Bay that experience these temperature/salinity fluctuations were monitored monthly (March 1992-July 1992) using artificial benthic collectors. Diver surveys to monitor new recruits and characterize lobster habitat were also conducted at eight sites along two

transects (four sites per transect) leading from the cuts between the Florida Keys and extending north and northwest to Twin Kay Bank and the subsequent basin. Concurrently, postlarval P. argus were reared in the laboratory, in a completely crossed design, at four temperatures (18 degree C, 22 degree C, 29 degree C, and 33 degree C) and four salinities (25, 35, 45 and 50 ppt). Survival, time to metamorphosis, and growth to first stage juvenile were measured. Results from monthly benthic collector censuses suggest that postlarvae are not regularly transported beyond Twin Key Bank, However, diver surveys indicate that some recruitment does occur in the western and central position of Twin Key basin, but not in the eastern portion of the same basin. During this study, temperature and salinity readings in this basin ranged from 21 degree C to 32 degree C and 35 ppt to 45 ppt, respectively. Laboratory results indicate that this range of temperature and salinities could be tolerated, however, mortality is greatest at high temperatures in conjunction with high salinities.

TI: Title
The influence of temperature, salinity, and postlarval transport on the distribution of juvenile spiny lobsters, Panulirus argus (Latreille, 1804), in Florida Bay
AF: Author Affiliation
Dep. Biol. Sci., Old Dominion Univ., Norfolk, VA 23529-0266, USA
CF: Conference
4. Int. Workshop on Lobster Biology and Management, Sanriku (Japan), 25-31 Jul 1993
ED: Editor
Field, JM; Butler, MJ IV*; Kittaka, J; Booth, JD; Phillips, BF; Cobb, JS; Quackenbush, LS; Kanazawa, A; Collin, R; Bannister, A; Addison, JT; Breen, PA (eds)
SO: Source
Crustaceana, vol. 66, no. 3, pp. 26-45, 1994
IS: ISSN
0011-216X
AB: Abstract
Florida Bay is the major nursery for the Caribbean spiny lobster, Panulirus argus, population in south Florida. This region is characterized by a series of shallow hardbottom or seagrass-covered basins separated by carbonate mudbanks that serve as barriers to water circulation and presumably to transport of planktonic larvae. Temperatures fluctuate dramatically in the bay and salinities there range from 35 ppt-50 ppt. In this study, we investigated the physiological tolerance of P. argus postlarvae to various combinations of temperature and salinity representative of the conditions found in Florida Bay and also determined the extent of postlarval recruitment into the interior of the bay. We

measured postlarval settlement, juvenile abundances, and postsettlement habitat availability monthly (March 1992-July 1992) along 5 transects extending north from the main Florida Keys into the interior of Florida Bay. Concurrently, P. argus postlarvae were reared in the laboratory, in a completely crossed design, at four temperatures (18 degree C, 22 degree C, 29 degree C and 33 degree C) and four salinities (25, 35, 45 and 50 ppt). Survival, time-to-metamorphosis, and growth to the first juvenile stage were measured. Few postlarvae settled at sites beyond the emergent banks ringing Florida Bay, and lobsters were only found in one basin (Twin Keys Basin) where habitat and environmental conditions were favorable. Laboratory results indicate that at high (33 degree C) and low temperatures (18 degree C) survival at salinities other than 35 ppt is greatly reduced. Our results indicate that postlarvae are not regularly transported into the interior of Florida Bay and that the lack of suitable nursery habitat and high salinity further limit recruitment, especially at extreme temperatures. Given the present conditions in Florida Bay, recruitment of P. argus is restricted to the southernmost reaches of Florida Bay nearest the Florida Keys.

TI: Title
Chemosensory discrimination: Behavioral abilities of the spiny lobster.
AU: Author
Fine-Levy, JB; Derby, CD
AF: Author Affiliation
Dep. Biol., Georgia State Univ., Atlanta, GA 30303, USA
CF: Conference
9. International Symposium on Olfaction and Taste., Snowmass Village, CO (USA), 20-24 Jul 1986
ED: Editor
Roper, SD; Atema, J (eds)
SO: Source
TASTE AND OLFACTION., 1987, pp. 280-283, Annals of the New York Academy of Sciences [ANN. N.Y. ACAD. SCI.], vol. 510
IS: ISSN
0077-8923
AB: Abstract
The authors are interested in the neural mechanisms by which organisms code the quality of chemical stimuli. This paper describes behavioral experiments that define the chemosensory discriminatory capabilities of spiny lobsters (Panulirus argus). The authors have used an aversive conditioning paradigm that relies on the relative changes in responses to the conditioned chemical and to nonconditioned chemicals following a series of conditioning trials as an indicator of the similarity between the conditioned chemical and each of the nonconditioned chemicals.

TI: Title
Effects of stimulus intensity and quality on discrimination of

odorant mixtures by spiny lobsters in an associative learning paradigm.

AU: Author

Fine-Levy, JB; Derby, CD

AF: Author Affiliation

Dep. Biol., P.O. Box 4010, Georgia State Univ., Atlanta, GA 30302-4010, USA

SO: Source

Physiology & Behavior [PHYSIOL. BEHAV.], vol. 49, no. 6, pp. 1163-1168, 1991

IS: ISSN

0031-9384

AB: Abstract

The Florida spiny lobster, Panulirus argus , can behaviorally discriminate between members of a set of four artificial odorant mixture types: crab, mullet, oyster, and shrimp. The present experiments were designed to examine the effects of both intensity and quality on discrimination of odorant mixtures. This was accomplished by conditioning lobsters to only one concentration (0.5 mM) of shrimp mixture and testing them with four concentrations (0.005, 0.05, and 0.5 and 5.0 mM) of shrimp mixtures and two concentrations (0.05 and 0.5 mM) of oyster mixture. For the two appetitive behaviors examined, lobsters did not discriminate the conditional mixture (0.5 mM shrimp) from any other of the same-type nonconditioned mixtures. For a third behavior, active avoidance, lobsters discriminated, to a significant degree, the 0.5 mM shrimp mixture from all of the nonconditioned mixtures. However, aversion values for the nonconditioned shrimp mixtures were markedly and consistently higher than those for the nonconditioned oyster mixtures for all three behaviors.

TI: Title

Report of the Joint Meeting of the Western Central Atlantic Fishery Commission, Working Party on Assessment of Fish Resources and Working Party on Stock Assessment of Shrimp and Lobster Resources. Cartagena, Colombia, 18-23 November 1977. Joint Meet. of the Western Central Atlantic Fishery Commission Working Party on Assessment of Fish Resources and Working Party on Stock Assessment of Shrimp and Lobster Resources; Cartagena (Colombia); 18 Nov 1977

OT: Original Title

Rapport de la Reunion Conjointe du Groupe de Travail de la COPACO sur l'Evaluation des Stocks de Poisson et du Groupe de Travail de la COPACO sur l'Evaluation des Stocks de Crevettes et de Langoustes. Cartagena, Colombie, 18-23 novembre 1977

CA: Corporate Author

FAO Western Central Atlantic Fishery Commission. Rome (Italy)

CF: Conference

Joint Meet. of the Western Central Atlantic Fishery Commission Working Party on Assessment of Fish Resources and Working Party on Stock Assessment of Shrimp and Lobster Resources, Cartagena (Colombia), 18 Nov 1977

SO: Source

Publ.by : FAO; Rome (Italy)., 1978., En ed. 103 p.; Fr ed. 109 p., FAO Fish. Rep., (no.211)

ER: Environmental Regime
Marine
AB: Abstract
The joint meeting discussed the extension of the WECAFC region, the statistical areas within the region and recommendations for regional activities. The working party on fish assessment discussed resource information and methods of improving it. The working party on the assessment of shrimp and lobster resources discussed shrimps and spiny lobsters, summarized the resource information on these species and gave a species list and standardization of common names.

TI: Title
On some cases of morphological anomalies in the spiny lobster, Panulirus argus (Latreille) and Panulirus laevicauda (Latreille) (Decapoda Palinuridae)
AU: Author
Fausto-Filho, J.; Da Costa, R.S.
AF: Author Affiliation
Lab. Ci Mar, Univ. Federal Ceara, Fortalenza, Ceara, Brazil
SO: Source
Crustaceana, 33(2), 215-218, (1977)
ER: Environmental Regime
Marine
AB: Abstract
Nine cases of morphological abnormalies in the P. argus and P. laevicauda, are reported. The observations were made on spiny lobsters principally at Macuripe Beach, Fotaleza, Ceara, northeastern Brazil, over a period of 10 years. Two previously reported cases are also recalled.

TI: Title
Bacteriological Study of Lobsters during Industrial Processing in Ceara State, Brazil.
OT: Original Title
Estudos Bacteriologicos da Lagosta nas Diversas Fases de Processamento
AU: Author
Fernandes Vieira, RHS; Soares Cardonha, AM
AF: Author Affiliation
Univ. Fed. do Ceara, Lab. Cienc. Mar., Fortaleza, Brazil
SO: Source
Arquivos de ciencias do mar. Fortaleza [ARQ. CIENC. MAR.], vol. 19, no. 1-2, pp. 81-85, 1979
IS: ISSN
0041-8854
AB: Abstract
The authors investigate the causes and agents of lobster tail contamination by bacteria throughout processing phases of the product, in fishing industries. The contamination indices by bacteria and MPN show an upward trend along the processing phases: reception, evisceration, washing and freezing. Some species of bacteria have been identified and there are signs of contamination, specially in the fourth phase. It must be emphasized that this process starts aboard the fishing boats due to careless handling of the caught lobsters. Care should be taken

at all production phases so that a better product is obtained and be conformed to international standards for export products.

TI: Title
Organoleptic and bacteriological studies of lobster tails stored in ice, in northeastern Brazil.
OT: Original Title
Estudo organoleptico e bacteriologico de caudas de lagostas estocadas em gelo
AU: Author
Fernandez Vierira, RHS; Fernandez Vieira, GH; Sobreira Rocha, CA; Saker-Sampaio, S; Holanda-Sampaio, A
AF: Author Affiliation
Univ. Fed. Ceara, Lab. Cienc. Mar, Fortaleza-Ceara, Brazil
SO: Source
Arquivos de ciencias do mar. Fortaleza [ARQ. CIENC. MAR.], vol. 25, pp. 63-75, 1986
IS: ISSN
0041-8854
AB: Abstract
The total number of bacteria were determined at 5, 25 and 35 degree C in Panulirus argus and P. laevicauda . Results showed that bacterial number at 35 degree C did not correlate with the sum of organoleptic characters (S.O.C.) during the storage period. At 5 and 25 degree C bacterial count correlates with S.O.C. showing an upward trend with storage time. The number of total and faecal coliforms did not grow during the experiment. Staphylococcus aureus occurred only in P. laevicauda . Salmonella was not registered during the analysis.

TI: Title
A proposed solution to a fine-structural puzzle: the organization of gill cuticle in a crayfish (Panulirus)
AU: Author
Filshie,B.K.; Smith,D.S.
AF: Author Affiliation
Div. Entomol., Commonw. Sci. and Ind. Res. Org., Canberra, Australia
SO: Source
Tissue and Cell, 12(1), 209-226, (1980)
AB: Abstract
Crayfish gill cuticle is approximately 2 m thick and comprises an epicuticle and an endocuticle, which is subdivided into outer and inner layers. Sections demonstrate indistinct lamellae in the outer endocuticle and vertically striated lamellae in the inner endocuticle. Microfibrils cannot be seen in sections. Difficulties in interpretation of the fibrous architecture of the cuticle from thin sections have been overcome by examining tilted series of micrographs of sections and also by making freeze-fracture replicas of the cuticle, which reveal the microfibrils clearly. A model for the endocuticle based on a helicoidal configuration of microfibrillar laminae is proposed and the vertically striated structures seen in sections of the outer layer are accounted for by including regular rows of particles oriented perpendicular to microfibrils. The model is compared with cuticles and coverings reported from other invertebrates.

TI: Title
Chemosensory discrimination: Behavioral abilities of the spiny lobster.
AU: Author
Fine, JB; Derby, CD; Daniel, PC
AF: Author Affiliation
Dep. Biol., Georgia State Univ., Atlanta, GA 30303, USA
CF: Conference
8. Meeting ISOT IX/AChemS, Snowmass, CO (USA), 20-24 Jul 1986
SO: Source
Chemical Senses [CHEM. SENSES.], vol. 11, no. 4, p. 597, 1986
IS: ISSN
0379-864X
NT: Notes
Poster session; abstract only.
AB: Abstract
The authors investigate how chemosensory systems code chemical quality by correlating behavioral and neurophysiological measures of the similarities among a set of behaviorally relevant chemicals. To extend this analysis to the behavioral, the authors have developed an aversive conditioning paradigm that uses a rapidly moving object ("pseudopredator") as the aversive stimulus to the spiny lobster (Panulirus argus). Aversion to a chemical stimulus was calculated as the probit of 1/(1 + exp(--(mean of preconditioning response--post-conditioning response))). Results of these experiments indicate that lobsters are capable of associative learning. They can discriminate between certain mixtures, with shrimp mixture being perceived as more similar to crab mixture (the conditioned chemical) than is either mullet mixture or oyster mixture.

TI: Title
Chemosensory discrimination: Behavioral abilities of the spiny lobster.
AU: Author
Fine-Levy, JB; Derby, CD
AF: Author Affiliation
Dep. Biol., Georgia State Univ., Atlanta, GA 30303, USA
CF: Conference
9. International Symposium on Olfaction and Taste., Snowmass Village, CO (USA), 20-24 Jul 1986
ED: Editor
Roper, SD; Atema, J (eds)
SO: Source
TASTE AND OLFACTION., 1987, pp. 280-283, Annals of the New York Academy of Sciences [ANN. N.Y. ACAD. SCI.], vol. 510
IS: ISSN
0077-8923
AB: Abstract
The authors are interested in the neural mechanisms by which organisms code the quality of chemical stimuli. This paper describes behavioral experiments that define the chemosensory discriminatory capabilities of spiny lobsters (Panulirus argus). The authors have used an aversive conditioning paradigm that

relies on the relative changes in responses to the conditioned chemical and to nonconditioned chemicals following a series of conditioning trials as an indicator of the similarity between the conditioned chemical and each of the nonconditioned chemicals.

TI: Title
Migratory behavior of spiny lobsters in the upper and middle Florida Keys
CA: Corporate Author
Florida Department of Natural Resources, Tallahassee (USA). Marine Research Lab
SO: Source
Compl. Rep. Fla. Dep. Nat. Resour
ER: Environmental Regime
Marine
AB: Abstract
Between April and October, 1978, 10,302 spiny lobsters, Panulirus argus (Latrielle), were tagged to study movement, population distribution, abundance, and other biological phenomena of adult and subadult spiny lobsters in the Upper and Middle Florida Keys. From late July (opening of the lobster season) through September, 1978, 948 tagged lobsters were returned by the fishing community. Those from commercial fishermen represented 85.9% of the total. Summaries of data and some preliminary analyses are presented. Computer analysis of data will be completed following termination of tagging March 31, 1979.

TI: Title
Evaluation of techniques to quantitatively monitor spiny lobster postlarval recruitment
CA: Corporate Author
Florida Department of Natural Resources, Key West (USA). Key West Field Lab
SO: Source
Compl. Rep. Fla. Dep. Nat. Resour
ER: Environmental Regime
Marine
AB: Abstract
Postlarval spiny lobsters, Panulirus argus, attracted to floating artificial habitats were counted to evaluate quantitative sampling techniques for lobster recruitment to the lower Florida Keys. Sampling was conducted from 27 March 1976 to 13 September 1978. Preliminary results on effects of moon phase, season, degree of habitat fouling, construction material and bottom type over which habitats float are presented. Data on associated invertebrates and their possible relationship to postlarvae abundance are examined.

TI: Title
Evaluation of techniques to quantitatively monitor spiny lobster postlarval recruitment
CA: Corporate Author
Florida Department of Natural Resources, Key West (USA). Key West Field Lab
SO: Source
Compl. Rep. Fla. Dep. Nat. Resour

ER: Environmental Regime
Marine
AB: Abstract
Postlarval spiny lobsters, Panulirus argus, attracted to floating artificial habitats were counted to evaluate quantitative sampling techniques for lobster recruitment to the lower Florida Keys. Sampling was conducted from 27 March 1976 to 13 September 1978. Preliminary results on effects of moon phase, season, degree of habitat fouling, construction material and bottom type over which habitats float are presented. Data on associated invertebrates and their possible relationship to postlarvae abundance are examined.

TI: Title
Techniques to monitor recruitment of postlarval spiny lobsters, Panulirus argus , to the Florida Keys
CA: Corporate Author
Florida Department of Natural Resources, St. Petersburg (USA). Marine Research Lab.
SO: Source
Publ. by: FDNR; St. Petersburg, FL (USA)., 1980., 18 p., Fla. Mar. Res. Publ.
ER: Environmental Regime
Brackish
AB: Abstract
Monitoring using floating artificial habitat collectors requires that collectors be pervious to fouling organisms for at least two months prior to deployment. Sampling is necessary during new moon and first quarter phases of each lunar month. Two collectors sampled as 2-3 day intervals should indicate peak recruitment and relative abundance at an appropriately selected station. Replacement of damaged or lost collectors with reserve fouled collectors should be immediate. Results obtained while testing monitoring techniques confirmed that significantly greater recruitment occurs during spring. Abnormally high recruitment followed a severe temperature drop (to 12.5 C) during one month; an apparently abnormal recruitment decline during one summer month is unexplained. No obvious effect of other collector-associated decapod crustaceans on postlarval lobster settlement was noted.

TI: Title
Preliminary considerations on artificial protection of spiny lobster eggs and larvae in natural environment.
OT: Original Title
Consideracoes preliminares sobre a protecao artificial de ovos e larvas de lagostas em ambiente natural
AU: Author
Fonseca Guimaraes, S
AF: Author Affiliation
Lab. Cienc. Mar, Univ. Fed. Ceara, Fortaleza, Ceara, Brazil
SO: Source
Boletim de ciencias do Mar. Fortaleza [BOL. CIENC. MAR.], no. 46, 1988, 11 pp
IS: ISSN
0067-9593
NU: Other Numbers

ISSN 0067-9593

AB: Abstract

The present work seeks possibilities and makes some preliminary considerations on the construction of a device to protect eggs and larvae of the spiny lobster (Panulirus sp.) in the natural environment, in an attempt to ensure egg hatching and larval survival. This device should be used during the period in which there is a notable incidence of ovigerous lobsters carrying eggs in advanced developmental stages in order to avoid the indiscriminate use of this device.

TI: Title

Technical parameters and yield indexes of the lobster fleet of Ceara State, Brazil.

OT: Original Title

Parametros tecnicos e indices de rendimiento da frota langosteira do estado do Ceara, Brasil

AU: Author

Fonteles-Filho, AA; Souza, ARde; Coelho, AS; Ximenes, MOC

AF: Author Affiliation

Lab. Cienc. Mar, Univ. Fed. Ceara, Fortaleza, Ceara, Brazil

SO: Source

Arquivos de ciencias do mar. Fortaleza [ARQ. CIENC. MAR.], vol. 24, pp. 89-100, 1985

IS: ISSN

0374-5686

AB: Abstract

The fishing effort and yield indexes of the fishing units were evaluated to learn the yield and structure of the lobster surface craft at Ceara State, Brazil. 458 motorboats of 699 fleet units were grouped and analyzed according the boats' total length: small 10 m; medium 11-15 m; large 16 m, in proportion of 41.8%; 41.9% and 16.3% respectively. The finest fishing effort unit (trap-day) follows this trend only for Panulirus argus , the inverse being true of P. laevicauda . Fulfillment index of the hold and freezer capacities decreased with boat size and tonnage. Boats yields by size were: small 62.6%; medium 48.2% and large 26.5%.

TI: Title

Population dynamics of juvenile Caribbean spiny lobster, Panulirus argus, in Florida Bay, Florida

AU: Author

Forcucci, D; Butler, MJ IV*; Hunt, JH

AF: Author Affiliation

Dep. Biol. Sci., Norfolk, VA 23529-0266, USA

CF: Conference

1992 Symp. on Florida Keys Regional Ecosystem, Miami, FL (USA), Nov 1992

ED: Editor

Prospero, JM; Harwell, CC (eds)

SO: Source

SYMPOSIUM ON FLORIDA KEYS REGIONAL ECOSYSTEM. NOVEMBER 1992., 1994, pp. 805-818, Bulletin of Marine Science [BULL. MAR. SCI.], vol. 54, no. 3

IS: ISSN
0007-4977

AB: Abstract

Despite a wealth of information on the growth and population dynamics of sub-adult and adult Caribbean spiny lobsters (Panulirus argus), there is far less information about younger juveniles under natural conditions. Here we describe growth and population dynamics of juvenile spiny lobsters (12-68 mm carapace length, CL) that we have studied for 14 months (October 1988-December 1989) using mark-recapture techniques in a hardbottom community in Florida Bay, Florida. We also monitored the supply of postlarvae into the region in 1988 and 1989 using Witham-type surface collectors in an effort to link peak periods of settlement of postlarvae with subsequent cohorts of juveniles. Field estimates of growth were the highest ever reported for this species, averaging 0.95 mm CL/wk (range: 0.35-1.25 mm Cl/wk for individuals 20-25 mm CL and 40-45 mm CL, respectively). These results indicate that lobsters in some areas in Florida Bay can reach Florida's legal harvestable size (76 mm CL) 1.5 years after settlement. Season and lobster size had significant effects on growth rates; slower growth occurred during the winter and among small individuals. Differences in growth among size classes resulted from changes in molt increment, whereas differences were a result of changes in intermolt interval. Using mark-recapture techniques, we estimate that the density of juvenile spiny lobsters < 45 mm CL in this prime nursery habitat was 454/ha, that the mean monthly probability of survival (reflecting actual mortality plus emigration) was 0.51, and that an average of 131 lobsters entered the population through recruitment and immigration each month. Recruitment of juveniles was significantly correlated (r = 0.83) with the supply of postlarvae to the region 8 months earlier. This relationship is stronger than was previously believed, and may only he manifested in areas with superior nursery habitat.

TI: Title
Social behavior and habitat use of captive juvenile spiny lobster, Panulirus argus (Latreille, 1804) (Decapoda, Palinuridea).

AU: Author
Glaholt, RD

AF: Author Affiliation
Dep. Renewable Resour., Gov. N.T., Inuvik, N.T. X0E 0T0, Canada

SO: Source
Crustaceana, vol. 58, no. 2, pp. 200-206, 1990

TI: Title
Purinergic receptors and dephosphorylating enzymes occur in both

the gustatory and olfactory systems of the spiny lobster.
AU: Author
Gleeson, RA; Trapido-Rosenthal, HG; Littleton, JT; Carr, WES
AF: Author Affiliation
Whitney Lab. and Dep. Zool., Univ. Florida, St. Augustine, FL 32086, USA
SO: Source
Comparative Biochemistry and Physiology, C [COMP. BIOCHEM. PHYSIOL., C.], vol. 92C, no. 2, pp. 413-417, 1989
IS: ISSN
0742-8413
AB: Abstract
1. Electrophysiological procedures demonstrated that sensilla on the walking legs of the spiny lobster, Panulirus argus , possess ATP- and AMP-sensitive cells. 2. The ATP-sensitive cells on these gustatory appendages exhibited similar structure-activity relationships, response properties and antagonistic effects as cell described earlier on the olfactory organ. 3. Biochemical procedures demonstrated that the walking legs, like the olfactory organ, also possess ectoenzymes that dephosphorylated the nucleotides ATP, ADP, and AMP.

TI: Title
Ovigerous setae as an indicator of reproductive maturity in the spiny lobster, Panulirus argus (Latreille).
AU: Author
Gregory, DR Jr; Labisky, RF
AF: Author Affiliation
Sch. Forest Resour. & Conserv., Univ. Florida, Gainesville, FL 32611, USA
SO: Source
NORTHEAST GULF SCI., vol. 4, no. 2, pp. 109-113, 1981
IS: ISSN
: 0148-9836
AB: Abstract
A comparative evaluation is presented of 3 external indicators of reproductive maturity - eggs, spermatophores and ovigerous setae - of female P. argus captured in the lower Florida Keys during the 1976 reproctive season. Data revealed that females with ovigerous setae were several-fold more abundant in trap samples than females bearing spermatophores or eggs or both, thereby indicating that the use of ovigerous setae, in conjunction with eggs and spermatophores as an indicator of reproductive maturity would enhance trap-sampling efficiency.

TI: Title
Catch efficiencies of live lobster decoys and other attractants in the Florida spiny lobster fishery.
AU: Author
Heatwole, DW; Hunt, JH; Kennedy, FS Jr
AF: Author Affiliation
Florida Dep. Nat. Resour., Bur. Mar. Res., Marathon Field Lab., 13365 Overseas Highw., Suite 103, Marathon, FL 33050, USA
SO: Source
Florida Marine Research Publications [FLA. MAR. RES. PUBL.], no.

44, 1988, 15 pp
IS: ISSN
0095-0157
AB: Abstract
Catch rates of spiny lobster, Panulirus argus , by traps individually baited with six natural or artificially produced baits were compared from 1566 trap pulls in the Florida Keys. Traps baited with live sublegal-sized lobsters (decoys) caught three times as many lobsters as did non-lobster-baited traps. Traps baited with cowhide, fish heads, cat food, liquified mullet, and a commercial bait made from herring caught fewer lobsters per unit effort than did unbaited traps; however, the differences were not significant. Traps containing decoys significantly reduced catch rates of adjacent (30-50 m distant) non-decoy traps, suggesting that spiny lobsters in traps facilitate aggregation of conspecifics by emitting a non-visual (acoustic or chemical) attractant. The powerful attraction of confined lobsters cannot be matched by food attractants at the present level of fishing effort.

TI: Title
Concentration-independence of mixture interactions in the antennular (olfactory) pathway of the spiny lobster.
AU: Author
Herder, TJ; Ache, BW; Carr, WES
AF: Author Affiliation
C.V. Whitney Lab., Univ. Florida, St. Augustine, FL 32086, USA
CF: Conference
8. Meeting ISOT IX/AChemS, Snowmass, CO (USA), 20-24 Jul 1986
SO: Source
Chemical Senses [CHEM. SENSES.], vol. 11, no. 4, p. 613, 1986
IS: ISSN
0379-864X
NT: Notes
Poster session; abstract only.
AB: Abstract
The authors previously reported physiological evidence for mixture interaction in the olfactory pathway of the spiny lobster, in which a high concentration of a mixture showed largely suppressive interaction. The present study extends this initial report by determining if the components identified as interactive at a high concentration change the nature of their interaction as a function of stimulus concentration. Evoked neural activity in high-order (post convergent) olfactory interneurons was used to quantify antennular (olfactory) chemosensitivity to the following: 31-component artificial crab mixture (ACM), eight individual components of ACM that were previously defined as interactive, and eight 30-component mixtures, each lacking one of the eight interactive components. Results suggest that if mixture synergism is common to the behavior of both shrimp and lobsters, then it must either be introduced at a higher level of the neural pathway than the one selected for testing, or be an emergent property of multimodal chemosensory integration, since chemoreceptors other than those on the antennules are stimulated in freely-behaving animals.

TI: Title
Evolution and mechanisms of mass single-file migration in spiny lobster: Synopsis.
AU: Author
Herrnkind, WF
AF: Author Affiliation
Dep. Biol. Sci., Florida State Univ., Tallahassee, FL 32306, USA
CF: Conference
Symposium on Migration, Port Aransas, TX (USA), 30 Oct-2 Nov 1983
ED: Editor
Rankin, MA; Checkley, D; Cullen, J; Kitting, C; Thomas, P (eds)
SO: Source
MIGRATION: MECHANISMS AND ADAPTIVE SIGNIFICANCE., 1985, pp. 197-211, Contributions in Marine Science [CONTRIB. MAR. SCI.], vol. 68, no. suppl.
IS: ISSN
0082-3449
AB: Abstract
This report summarizes two decades of research on all facets of the migration of the spiny lobster Panilirus argus (Crustacea: Palinuridae). Autumnal mass migrations in this species involve explosive, localized population movements which are triggered by polar front storms wherein the migrants walk continuously in parallel single-file queues for several days from shallow areas to the edge of oceanic channels. It is hypothesized that mass queuing emerged during past glacial cycles as a mechanism that allowed lobsters to evade the deleterious winter conditions in the food-rich shallows typically exploited by lobsters during warm seasons. Queuing probably evolved from antipredator formations but also serves mass migration by reducing hydrodynamic drag. Recent findings show that sharply increased water motion triggers mass queuing. Complex orientation to hydrodynamic guideposts is suggested to guide migration.

TI: Title
Factors regulating postlarval settlement and juvenile microhabitat use by spiny lobsters Panulirus argus .
AU: Author
Herrnkind, WF; Butler, MJ IV
AF: Author Affiliation
Dep. Biol. Sci., Florida State Univ., Tallahassee, FL 32306, USA
SO: Source
Marine ecology progress series. Oldendorf [MAR. ECOL. (PROG. SER.).], vol. 34, no. 1/2, pp. 23-30, 1986
IS: ISSN
0171-8603
NT: Notes
Incl. 29 ref.
AB: Abstract
Clumps of highly-branched red algae Laurencia spp. serve as important settling habitat for postlarval spiny lobsters P. argus and as residence for early benthic-stage juveniles. Given choice between the 2 most abundant macrophytes in Florida Bay, Laurencia spp. and the seagrass Thalassia testudinum postlarval and juvenile

lobsters chose Laurencia spp. Postlarvae apparently use intricate algal architecture as a cue for settlement, whereas juveniles use both architecture and food abundance in selecting habitat. In tethering experiments, predation on juvenile lobsters was very high on open sand, much reduced in algal clumps and seagrass, and lowest in dense algal meadows. Predation rates were similar day and night both on open sand and in vegetation. Most lobsters vacated algal clumps located within continuous algal meadows overnight, at a rate significantly higher than that from isolated algal clumps. The authors suggest that algal clump distribution, postlarval settling behavior, and juvenile interpatch movement and mortality contribute to the highly dispersed distribution and locally sparse abundances of early benthic juveniles.

TI: Title
Can artificial habitats that mimic natural structures enhance recruitment of Caribbean spiny lobster?
AU: Author
Herrnkind, WF; Butler, MJ IV; Hunt, JH
AF: Author Affiliation
Dep. Biol. Sci., Florida State Univ., Tallahassee, FL 32306, USA
SO: Source
Fisheries, vol. 22, no. 4, pp. 24-27, Apr 1997
IS: ISSN
0363-2415
NT: Notes
Special issue on artificial reefs.
AB: Abstract
The Caribbean spiny lobster (Panulirus argus) supports economically important fisheries throughout its range from Bermuda to southern Brazil; in south Florida, lobsters are the target of an intensive commercial trap and recreational sport-diving fishery. The species has a complex life cycle requiring three distinct habitats. Adult spiny lobsters can live for decades, inhabiting crevices within coral reefs. They mate and spawn on the reefs, but their larvae drift for several months in the open ocean before metamorphosing into a postlarval stage that moves onshore, seeking shallow, vegetated habitats in which to settle. Following settlement, the postlarvae metamorphose into early benthic-stage juveniles that remain hidden within vegetative cover, sheltered from predators and with a choice of abundant prey. Later, the juvenile lobsters emerge from settlement habitat and take up daytime refuge under crevices provided by rocks, sponges, octocorals, or other structures within the nearshore nursery. Artificial structures are now used to concentrate lobsters for ease of capture, but other designs might enhance recruitment.

TI: Title
Actions of adenylyl compounds in invertebrates from several phyla: Evidence for internal purinoceptors.

AU: Author
Hoyle, CHV; Greenberg, MJ
AF: Author Affiliation
Dep. Anat. and Embryol., University Coll. London, Gower St., London WC1E 6BT, UK
SO: Source
Comparative Biochemistry and Physiology, C [COMP. BIOCHEM. PHYSIOL., C.], vol. 90C, no. 1, pp. 113-122, 1988
IS: ISSN
0742-8413
AB: Abstract
The actions of adenylyl compounds on the internal structures of representative species from several invertebrate phyla were surveyed. Preparations taken from protostomous species were mostly unresponsive or inconsistently responsive. An exception was the terminal intestine of the spiny lobster Panulirus argus , in which ATP, ADP, AMP and adenosine could all potentiate the excitatory response to electrical field stimulation. Preparations isolated from deuterostomous species responded relatively consistently to the adenylyl compounds. There was evidence for ATP-specific, ATP-selective, adenosine-selective, and non-selective purinoceptors in the echinoderms Asterias forbesi, Thyone briareus , and Lytechinus variegatus , and in the urochordate tunicate Ciona intestinalis .

TI: Title
Status of the fishery for Panulirus argus in Florida
AU: Author
Hunt, JH
AF: Author Affiliation
Florida Dep., Mar. Res. Inst., South Florida Res. Lab., 2796 Overseas Highway, Suite 119, Marathon, FL 33050-2227, USA
ED: Editor
Phillips, BF; Cobb, JS; Kittaka, J (eds)
SO: Source
SPINY LOBSTER MANAGEMENT., BLACKWELL SCIENTIFIC PUBLICATIONS, LONDON (UK), 1994, pp. 158-168
IB: ISBN
0-85238-186-7
NT: Notes
AIC: SH380.865 1994.
PB: Publisher
BLACKWELL SCIENTIFIC PUBLICATIONS, LONDON (UK)
AB: Abstract
The fishery for Panulirus argus has evolved from a small undercapitalized fishery to a large, economically important, heavily capitalized fishery during the course of this century. This growth has evoked considerable management concern and controversy, especially since the early 1970s. In this chapter, I review two pivotal events in the development of the fishery,

pertinent research that has led to the newly instituted management plan, the Lobster Trap Certificate Program, and then describe this plan which will shape the course of spiny lobster management during the 1990s.

TI: Title
Isolation and characterization of the mitochondrial DNA from the Florida spiny lobster, Panulirus argus .
AU: Author
Komm, B; Michaels, A; Tsokos, J; Linton, J
AF: Author Affiliation
Dep. Biol., Univ. South Florida, Tampa, FL 33612, USA
SO: Source
Comparative Biochemistry and Physiology, B [COMP. BIOCHEM. PHYSIOL., B.], vol. 73B, no. 4, pp. 923-929, 1982
IS: ISSN
0305-0491
AB: Abstract
Mitochondria and mitochondrial DNA were isolated from the digestive gland of P. argus . The mitochondrial DNA has an average contour length of 5.13 mu m which corresponds to a molecular weight of 10.10 x 10 super(6) daltons. The molecular weight based on agarose gel electrophoresis of restricted individual DNA samples ranges from 10.04 to 10.4 x 10 super(6) daltons. Restriction endonuclease analysis with Bam H1 and Eco R1 demonstrate variation in nucleotide sequence between individual lobsters.

TI: Title
Florida's spiny lobster fishery: an historical perspective
AU: Author
Labisky,R.F.; Gregory,D.R.,Jr.; Conti,J.A.
AF: Author Affiliation
Sch. Forest Resour. and Conserv., Univ. Florida, Gainesville, FL, USA
SO: Source
Fisheries, 5(4), 28-37, (1980)
AB: Abstract
The Florida-based fishery accounts for 98% of the spiny lobsters landed commercially in the United States; this catch is comprised almost exclusively of the Florida spiny lobster, Panulirus argus . The commercial lobster industry began in the lower Florida Keys during the early 1800's, principally as a bait fishery that supported the local finfish industry. Subsequent developments in the lobster fishery have essentially mirrored the prosperity of Key West. In 1908, landings totalled about 53,000 pounds, valued at dollar 3,600. The fishery began to exhibit progressive expansion in the 1940's, a trend that continued through the 1970's. A sport (diver) fishery for lobsters, which began in the 1950's, has also gained prominence. Commercial landings in Florida, including catches from international waters, peaked in 1972 at 11.4 million pounds. The peak in ex-vessel landings value, dollar 13.4 million, was attained in 1974. The strong international fishery, which developed during the 1960's, was severely curtailed in 1975 by the closure of the Bahamian fishing grounds to foreign fishing. Domestic catches from Florida waters declined slightly during the 1970's, despite a substantial increase

in fishing effort. Retrospectively, the spiny lobster has not only strongly impacted the culture, sociology, and economics of south Florida, but has also emerged to rank second only to shrimp as Florida's leading fishing industry.

TI: Title
Handling of live lobsters in Cuba.
AU: Author
Lamadrid B., H; Blanco A., W
AF: Author Affiliation
Technol. Res. Cent., Minist. Fish. Ind., Havana, Cuba
SO: Source
INFOFISH MARK. DIG., no. 6, pp. 44-46. 1986
IS: ISSN
0127-2012
AB: Abstract
A brief account is given of the spiny lobster (Panulirus argus) fishery of Cuba, detailing storage centres and fixed bottom cages, floating cages and hoistable cages used and also transportation processes in operation.

TI: Title
Effect of temperature on survival, growth and feed intake of postlarval spiny lobsters, Panulirus argus
AU: Author
Lellis, WA; Russell, JA
AF: Author Affiliation
Div. Appl. Biol., Harbor Br. Oceanogr. Inst. Inc., Fort Pierce, FL 34946, USA
SO: Source
Aquaculture, vol. 90, no. 1, pp. 1-9, 1990
IS: ISSN
0044-8486
AB: Abstract
Ten-week growth of postlarval spiny lobsters (Panulirus argus) (initial live weight 0.22 g) was greater ($P < 0.01$) for animals reared at 30 degree C (final live weight 1.62 plus or minus 0.14 g) than for animals reared at 24, 27 or 33 degree C (final weights 0.60 plus or minus 0.04, 1.18 plus or minus 0.04 and 0.92 plus or minus 0.16 g, respectively). Suppressed growth among lobsters held at 24 degree C was due to prolonged intermolt periods and reduced size increments with each molt. Lobsters reared at 33 degree C had lower survival, smaller molting increments and lower feed conversion than lobsters held at 30 degree C. Data indicate that optimal growth of postlarval Panulirus argus occurs at water temperatures of 29-30 degree C, with optimal feed conversion occurring at slightly lower temperatures.

TI: Title

Age and growth update of the spiny lobster (Panulirus argus)
OT: Original Title
Actualizacion de la edad y el crecimiento de la langosta espinosa (Panulirus argus)
AU: Author
Leon, MEDe; Cruz, R; Puga, R
AF: Author Affiliation
Centro de Investigaciones Pesqueras. Ministerio de la Industria Pesquera, La Habana, Cuba
SO: Source
Revista cubana de investigaciones pesqueras. Havana [REV. CUB. INVEST. PESQ.], vol. 19, no. 2, pp. 3-8, 1995
IS: ISSN
0138-8452
AB: Abstract
From the frequencies of annual length per sex corresponding to the biological samplings carried out in the four areas of lobster (Panulirus argus) fishery at the Cuban archipielago from 1990-1993, the growth parameters of von Bertalanffy's growth equation for each area are determined through SLCA (Shepherd's Length Composition Analysis). Considering that the population of the species in that period is characterized by a decrease in the recruitment and an increase in the frequency of appearance of bigger size animals, it is concluded for the whole Cuban shelf that L infinity and k values for males are 184.77 mm (CL) and 0.232 year super(-1), while for females the values are 154.25 mm (CL) and 0.185 year super(-1). The parameters found by other authors for this species in the Great Caribbean area are also analyzed, comparing the different values by means of phi prima (Phi ') parameter.

TI: Title
Comparison of excitatory currents activated by different transmitters on crustacean muscle. 1. Acetylcholine-activated channels.
AU: Author
Lingle, C; Auerbach, A
AF: Author Affiliation
Dep. Biol. Sci., Florida State Univ., Tallahassee, FL 32306, USA
SO: Source
Journal of General Physiology [J. GEN. PHYSIOL.], vol. 81, no. 4, pp. 547-569, 1983
AB: Abstract
The properties of acetylcholine-activated excitatory currents on the gml muscle of three marine decapod crustaceans, the spiny lobsters Panulirus argus and P. interruptus , and the crab Cancer borealis , were examined using either noise analysis, analysis of synaptic current decays, or analysis of the voltage dependence of ionophoretically activated cholinergic conductance increases. The voltage dependence of the amplitude of steady-state cholinergic

currents suggests that the total conductance increase produced by cholinergic agonists is increased with hyperpolarization. Compared with glutamate channels found on similar decapod muscles, the acetylcholine channels stay open longer, conduct ions more slowly, and are more sensitive to changes in the membrane potential.

TI: Title
Comparison of excitatory currents activated by different transmitters on crustacean muscle. 2. Glutamate-activated currents and comparison with acetylcholine currents present on the same muscle.
AU: Author
Lingle, C; Auerbach, A
AF: Author Affiliation
Dep. Biol. Sci., Florida State Univ., Tallahassee, FL 32306, USA
SO: Source
Journal of General Physiology [J. GEN. PHYSIOL.], vol. 81, no. 4, pp. 571-588, 1983
AB: Abstract
The properties of glutamate-activated excitatory currents on the gm6 muscle from the foregut of the spiny lobsters Panulirus argus and interruptus and the crab Cancer borealis were examined using either noise analysis, analysis of synaptic current decays, or low iontophoretic currents. The properties of acetylcholine currents activated in nonjunctional regions of the gm6 muscle were also examined. The voltage dependence of the steady-state conductance increase activated by iontophoretic application of glutamate has the opposite direction of the steady-state conductance activated by cholinergic agonists when compared on the gm6 muscle. The glutamate-activated conductance increase is diminished with hyperpolarization.

TI: Title
Control and coordination of reproduction and molting in the spiny lobster Panulirus argus .
AU: Author
Lipcius, RN; Herrnkind, WF
AF: Author Affiliation
Virginia Inst. Mar. Sci., Sch. Mar. Sci., Coll. William and Mary, Gloucester Point, VA 23062, USA
SO: Source
Marine biology. Berlin, Heidelberg [MAR. BIOL.], vol. 96, no. 2, pp. 207-214, 1987
IS: ISSN
0025-3162
NT: Notes
Incl. 33 ref.
AB: Abstract
Behavioral and physiological correlates of vernal reproduction and molting were investigated experimentally in laboratory-held spiny lobsters (Panulirus argus Latreille) from Florida to determine their control by photoperiod and temperature. Behavioral measures included courtship, copulation and aggression; physiological measures included the timing and frequency of ecdysis, spermatophore emplacement, oviposition, egg hatching, and setal

(pleopod) and gonadal development. Behavior resembled that observed in nature, as evidenced in the expression of complete reproductive cycles. Long daylengths and warmer temperatures enhanced courtship, spawning frequencies, and female gonadal development, although gonadal recrudescence occurred in large females irrespective of photoperiod.

TI: Title
Hydrodynamic decoupling of recruitment, habitat quality and adult abundance in the Caribbean spiny lobster: source-sink dynamics?
AU: Author
Lipcius, RN; Stockhausen, WT; Eggleston, DB; Marshall, LS Jr; Hickey, B
AF: Author Affiliation
Virginia Institute of Marine Science, The College of William and Mary, Gloucester Point, VA 23062, USA
CF: Conference
5. Int. Conf. and Workshop on Lobster Biology and Management, Queenstown (New Zealand), 10-14 Feb 1997
SO: Source
Marine & Freshwater Research, vol. 48, no. 8, pp. 807-815, 1997
IS: ISSN
1323-1650
PB: Publisher
C.S.I.R.O. Publishing
AB: Abstract
Marine species possess dispersive stages that interconnect subpopulations, which may inhabit 'source' and 'sink' habitats, where reproduction and emigration either exceed or fall short of mortality and immigration, respectively. Postlarval supply, juvenile density and adult abundance of the Caribbean spiny lobster, Panulirus argus, were measured at four widely separated sites spanning >100 km in Exuma Sound, Bahamas. Adult abundance was lowest at a site with the highest postlarval supply and little nursery habitat; hence, it was tentatively classified as a sink. Circulation in Exuma Sound is dominated by large-scale gyres which apparently concentrate and advect postlarvae toward the nominal sink. The remaining three sites, including one marine reserve, had higher adult abundances despite lower postlarval supply, and are therefore tentatively classified as sources. Postlarval supply is probably decoupled from adult abundance by physical transport. Adult abundance is likely decoupled from postlarval supply by the effects of varying habitat quality upon postlarval and juvenile survival, as indicated by non-significant differences among sites in juvenile density. It appears that some sites with suitable settlement and nursery habitat are sources of spawning stock for Panulirus argus, whereas others with poor habitat are sinks despite sufficient postlarval influx.

TI: Title
Magnetic orientation of spiny lobsters in the ocean: Experiments with undersea coil systems
AU: Author
Lohmann, KJ; Pentcheff, ND; Nevitt, GA; Stetten, GD; Zimmer-Faust, RK; Jarrard, HE; Boles, LC
AF: Author Affiliation
Department of Biology, University of North Carolina, Chapel Hill, NC 27599, USA
SO: Source
Journal of Experimental Biology [J. EXP. BIOL.], vol. 198, no. 10, pp. 2041-2048, 1995
IS: ISSN
0022-0949
AB: Abstract
The western Atlantic spiny lobster Panulirus argus undergoes an annual migration and is also capable of homing to specific dens in its coral reef environment. Relatively little is known, however, about the orientation cues that lobsters use to guide their movements. To determine whether lobsters can orient to the earth's magnetic field, divers monitored the orientation of lobsters tethered inside magnetic coil systems submerged offshore in the Florida Keys, USA. Each coil could be used to reverse either the horizontal or vertical component of the earth's field. Tethered lobsters walking inside the coils often established and maintained consistent courses towards specific directions. After a lobster had established a course, it was exposed to one of three conditions: (1) a reversal of the horizontal component of the earth's field; (2) a reversal of the vertical component of the earth's field; or (3) no change in the ambient field (controls). Lobsters subjected to the horizontal field reversal deviated significantly from their initial courses. In contrast, control lobsters and those subjected to the reversed vertical field did not. These results demonstrate that spiny lobsters possess a magnetic compass sense. Because inverting the vertical component of the earth's field had no effect on orientation, the results suggest that the lobster compass is based on field polarity and thus differs from the inclination compasses of birds and sea turtles. The magnetic compass of lobsters may function in homing behavior, in guiding the autumn migration or in both.

TI: Title
Ongrowing of juvenile spiny lobsters, Panulirus argus (Latreille, 1804) (Decapoda, Palinuridae), in portable sea enclosures
AU: Author
Lozano-Alvarez, E

AF: Author Affiliation

Univ. Nac. Autonoma de Mexico, Inst. de Cienc. del Mar y Limnol., Estacion "Puerto Morelos", Ap. Postal 1152, Cancun, Q.R. 77500, Mexico

SO: Source

Crustaceana, vol. 69, no. 8, pp. 958-973, Dec 1996

IS: ISSN

0011-216X

AB: Abstract

The spiny lobster catch from Bahia de la Ascension, a large bay on the central coast of the Mexican Caribbean, is comprised mainly of young adults and large juveniles of Panulirus argus. The fishery in this bay is based on artificial shelters called "casitas". A substantial part of the lobsters found beneath the casitas is of sublegal size (minimum size limit approximately 74 mm carapace length, CL). The possibility of ongrowing sublegal juveniles in portable sea enclosures to maximize the harvestable biomass was explored. The enclosures (3 x 3 x 1 m) were installed in shallow depths in the bay. Juveniles taken from nearby casitas were introduced in the enclosures and kept for different periods. Lobsters were fed with live molluscs and fish remains and were provided with suitable shelters. Experiments were conducted in two stages, in 1992 and 1993. Growth in size (CL) and in harvestable biomass (weight of legal-size lobsters) was examined. Maximum growth rates, lower percentages of mortality, and higher increases in harvestable biomass of lobsters were obtained after about 45 days. Confinement periods longer than 45 days resulted in reduced growth and higher mortality. Observations on lobster behaviour showed an increased in aggressive encounters and dominance displays from the third week of captivity onwards, which could be the main cause for the increase in mortality. The alternative of ongrowing sublegal juveniles for short periods (45 days), in conjunction with the casita system, could help increase the unit value of the catch.

TI: Title

Behaviour and growth of captive spiny lobsters (Panulirus argus) under the risk of predation

AU: Author

Lozano-Alvarez, E; Spanier, E

AF: Author Affiliation

Instituto de Ciencias del Mar y Limnologia, Estacion Puerto Morelos, Universidad Nacional Autonoma de Mexico, PO Box 1152, Cancun, QR 77500, Mexico

CF: Conference

5. Int. Conf. and Workshop on Lobster Biology and Management, Queenstown (New Zealand), 10-14 Feb 1997

SO: Source
Marine & Freshwater Research, vol. 48, no. 8, pp. 707-713, 1997
IS: ISSN
1323-1650
PB: Publisher
C.S.I.R.O. Publishing
AB: Abstract
The behaviour and growth of captive spiny lobsters (Panulirus argus) under and not under the risk of predation was investigated in four 9-m super(2) sea enclosures: two 'predator enclosures' (P1 and P2) into which one predator, the triggerfish Balistes vetula, was introduced; and two 'nonpredator enclosures' (NP1 and NP2). Each enclosure contained a 1-m super(2) artificial shelter, and lobsters were provided with food ad libitum for 45 days, measured then left for a further 30 days with a reduced food supply. Inter- and intraspecific interactions and shelter use were recorded by means of underwater observations during day and night. Daytime shelter use by lobsters and fish was highest at noon and in the early morning. Activity of lobsters outside the shelters peaked around midnight in all four enclosures. Lobsters in P2 showed more activity and less shelter use than did those in all other enclosures. More predator-prey interactions were recorded in P1 than in P2, whereas intraspecific interactions were more prevalent in P2 than in the other three enclosures combined. Growth of lobsters was significantly higher only in NP1. The difference in lobster behaviour and survival between the two predator enclosures may be associated with the initial timing of shelter occupancy by the predators.

TI: Title
Effects of mate size on reproduction in spiny lobsters
AU: Author
MacDiarmid, A; Butler, M
AF: Author Affiliation
Natl. Inst. Water and Atmos. Res., Wellington, New Zealand
CF: Conference
24. Annu. Benthic Ecology Meeting, Columbia, SC (USA), 7-10 Mar 1996
ED: Editor
Woodin, SA; Allen, DM; Stancyk, SE; Williams-Howze, J; Feller, RJ; Wethey, DS; Pentcheff, ND; Chandler, GT; Decho, AW; Coull, BC (eds)
SO: Source
TWENTY-FOURTH ANNUAL BENTHIC ECOLOGY MEETING, HELD IN COLUMBIA, SOUTH CAROLINA, MARCH 7-10, 1996., 1996, p. 57,
NT: Notes
Abstract only

AB: Abstract

Preliminary field observations and laboratory experiments in New Zealand indicate that in the spiny lobster Jasus edwardsii small mature males, near the minimum legal size, have a lower probability than large males of successfully courting and copulating all sizes of mature females. Egg production in small male treatments was a third of that of large males. In protected spiny lobster populations mating is dominated by the numerous large males. In adjacent heavily fished populations, when large males are rare or absent, small males court and mate. Further laboratory experiments and field studies on J. edwardsii in New Zealand and Panulirus argus in the Florida Keys are currently underway to explore the consequences of mate size on egg production, fertilisation rates and the mating system.

TI: Title

Factors regulating microhabitat use by young juvenile spiny lobsters, Panulirus argus : Food and shelter.

AU: Author

Marx, J; Herrnkind, W

AF: Author Affiliation

Bur. Mar. Res., Florida Dep. Nat. Resour., 11400 Overseas Hwy., Suite 220, Marathon, FL 33050, USA

SO: Source

Journal of crustacean biology. Washington DC [J. CRUST. BIOL.], vol. 5, no. 4, pp. 650-657, 1985

IS: ISSN

0278-0372

AB: Abstract

Habitation patterns of algal-dwelling juvenile spiny lobsters, P. argus , are apparently regulated by (a) the availability of epifaunal prey, and/or (b) limited sheltering qualities provided by algal branching. Predictions derived from each hypothesis were tested by monitoring emigration from normal (prey abundant), rinsed (prey reduced), and rinsed but structurally enhanced clumps of red algae, Laurencia spp. Density dependent emigration from untreated clumps containing natural prey, and markedly increased emigration from clumps nearly void of potential prey, suggest that trophic pressures play an important role in regulating algal habitation. Solitary dwelling induced by agonistic behavior may function to reduce required foraging area, thus minimizing both exposure to predators and energetic expenditures.

TI: Title

Gastropod shells: A dynamic resource that helps shape benthic community structure.

AU: Author

McLean, R

AF: Author Affiliation

Energy Div., Oak Ridge Natl. Lab., Oak Ridge, TN 37830, USA

SO: Source

Journal of Experimental Marine Biology and Ecology [J. EXP. MAR. BIOL. ECOL.], vol. 69, no. 2, pp. 151-174, 1983

IS: ISSN
0022-0981
AB: Abstract
Empty gastropod shells are an important resources for many animals in shallow benthic marine communities. Shells provide shelter for hermit crabs, octopuses, and fishes, provide attachment substratum for hermit crab symbionts, and directly or indirectly modify hermit crab predation. Creation of an empty shell due to predation of one gastropod on another and acquisition of that shell by a hermit crab are two key events in the subsequent use of that shell. Certain shell types worn by the hermit crab, Pagurus pollicaris Say, are positively associated with the symbiotic sea anemone, Calliactis tricolor (Lesueur), which protects the hermit crab from predation by the crab, Calappa flammea (Herbst), and possibly from the octopus, Octopus joubini Robson. Shells of other species of gastropods are resistant to being crushed by the spiny lobster, Panulirus argus (Latreille). The potential of the shell to limit the size and distribution of animal populations demonstrates how this resource helps shape community structure.

TI: Title
Nonselective cation channel activated by patch excision from lobster olfactory receptor neurons.
AU: Author
McClintock, TS; Ache, BW
AF: Author Affiliation
Sect. Mol. Neurobiol., Yale Univ. Sch. Med., 333 Cedar St., New Haven, CT 06510, USA
SO: Source
Journal of Membrane Biology [J. MEMBR. BIOL.], vol. 113, no. 2, pp. 115-122, 1990
IS: ISSN
0022-2631
AB: Abstract
A nonselective cation channel activated by patch excision was characterized in inside-out patches from spiny lobster olfactory receptor neurons. The channel, which was permeable to Na super(+), K super(+) and Cs super(+), had a conductance of 320 pS and was weakly voltage dependent in the presence of micromolar divalent cations. Millimolar internal divalent cations caused a voltage- and concentration-dependent block of Na super(+) permeation. Analysis of the voltage dependence indicated that the proportion of the membrane's electric field sensed by Mg super(2+) was > 1, suggesting that the channel contains a multi-ion pore. Internal divalent cations also reduced the frequency of channel opening in a concentration-dependent, but not voltage-dependent, manner, indicating that different cation binding sites affect gating and conductance.

TI: Title
A recruitment index and population model for spiny lobster (Panulirus argus) using catch and effort data
AU: Author
Medley, PAH; Ninnes, CH

AF: Author Affiliation.
Department Environment & Coastal Resources, Turks and Caicos Islands, British West Indies
SO: Source
Canadian Journal of Fisheries and Aquatic Sciences/Journal Canadien des Sciences Halieutiques et Aquatiques. Ottawa [CAN. J. FISH. AQUAT. SCI./J. CAN. SCI. HALIEUT. AQUAT.], vol. 54, no. 6, pp. 1414-1421, 1997
IS: ISSN
0706-652X
AB: Abstract
Using only catch numbers and effort data, a recruitment index was developed that exploits underlying seasonal changes in lobster size frequencies in the Turks and Caicos Islands' spiny lobster (Panulirus argus) fishery. The recruitment index was successfully used to model the lobster population dynamics. An empirical bootstrap method to simulate observation errors suggests that the models are robust enough to form the basis of a management plan. A tentative stock-recruitment relationship between estimates of the spawning stock and recruitment has been identified that can be used to guide escapement levels from the fishery. If correct, the stock-recruitment relationship indicates that the lobster population is largely self-recruiting.

TI: Title
Studies on materials for traps for spiny lobsters.
AU: Author
Meenakumari, B; Rajan, KVM
AF: Author Affiliation
Cent. Inst. Fish. Tech., Cochin-682029, India
SO: Source
Fisheries research. Amsterdam [FISH. RES.], vol. 3, no. 4, pp. 309-321, 1985
IS: ISSN
0165-7836
AB: Abstract
Studies were conducted along the south-west coast of India in order to identify suitable materials and preservative treatments for the fabrication of spiny-lobster traps. Traps were fabricated in different designs using different materials, such as bamboo splinters, coconut leaf stalk fibres, wood, polyethylene twines, Polystrap binding tape, mild steel rod, welded mesh, chicken wire netting and galvanised iron wire. As measures of preservation, the traps fabricated of iron materials were plastic-coated or painted with anti-corrosive paints, and a bamboo traps were treated with ASCU (arsenic--copper--chrome composition) or creosote. To assess the performance of different materials and to recommend suitable materials and protective coatings, the traps were subjected to experimental fishing using an indigenous trap as a control. The results show that bamboo traps are weak and fragile and wooden traps are unwieldy and so are not favoured. Metal traps made of

mild steel rods and welded mesh covered by complete plastic coating were found to perform efficiently and last longer.

TI: Title
(Preliminary study of the proteins in the lobster shell.).
OT: Original Title
Estudio preliminar sobre las proteinas de carapacho de langosta
AU: Author
Mendez, A; Oviedo, D; Vallin, C; Henriques, RD
AF: Author Affiliation
Acad. Cie. de Cuba, Inst. de Quim. Biol. Exp., Habana, Cuba
SO: Source
INF. CIENT.-TEC. INST. QUIM. BIOL. EXPER. ACAD. CIENC. CUBA., no. 144, ACAD. CIENC. CUBA, HABANA (CUBA) , 1980, 15 pp
PB: Publisher
ACAD. CIENC. CUBA, HABANA (CUBA)
AB: Abstract
Lobster shells are wastes partially profitable for chitin production. Preliminary information about some biochemical properties of the shell proteins, as well as their purification and physicochemical characterization, intended to evaluate a more complete utilization of this waste, has been the aim of this work. Lobster (Panulirus argus) shells were used. Total nitrogen and chitin as N-acetil-glucosamine were determined. Proteins were extracted with aqueous solutions at different pH values. At pH 7, using 0,05M phosphate buffer, a relatively good extraction was attained. Protein fractionation through Sephadex G-100 was carried out. Polyacrilamide gel electrophoresis and the mean molecular weight were used as purity criteria. The aminoacid composition of the different fractions was determined. Some protein properties and considerations about the possible use of the shells as food protein source are given.

TI: Title
The larval recruitment problem of the spiny lobster
AU: Author
Menzies,R.A.; Kerrigan,J.M.
AF: Author Affiliation
Acad. Mar.Sci. Lab., Nova Univ., Fort Lauderdale, FL 33314, USA
SO: Source
Fisheries, 5(4), 42-46, (1980)
AB: Abstract
By studying protein variations as a reflection of genetic variation between populations and pueruli and postlarvae arriving in the Florida Keys the authors hope to be able to give a clear description or geographical definition of the 'spiny lobster (Panulirus argus) management unit' not only for the Florida fishery but for a variety of fisheries in the Caribbean.

TI: Title
Construction of shallow water habitat to increase lobster production in Mexico.
AU: Author
Miller, DL
AF: Author Affiliation

Dep. Geogr., Univ. Wisconsin-Milwaukee, Milwaukee, WI 53201, USA
CF: Conference
34. Annu. Gulf and Caribbean Fisheries Institute, Mayaguez, PR (USA), Nov 1981
SO: Source
PROCEEDINGS OF THE THIRTY-FOURTH ANNUAL GULF AND CARIBBEAN FISHERIES INSTITUTE, MAYAGUEZ, PUERTO RICO, NOVEMBER 1981., 1982, pp. 168-179, Proceedings of the Gulf and Caribbean Fisheries Institute [PROC. GULF CARIBB. FISH. INST.], no. 34
IS: ISSN
0072-9019
AB: Abstract
Many fishermen of the spiny lobster (Panulirus argus) in the state of Quintana Roo, Mexico have utilized artificial habitats in an effort to increase their catch. Members of fishing cooperatives in the north and central zones have constructed small shelters designed to provide refuge for lobsters. During the lobster season, fishermen periodically check the shelters and harvest the lobsters. In this paper, the author provides detailed information on the construction and use of habitats. In addition, the author discusses the limitations, advantages and special problems associated with this technology.

TI: Title
Summary of Bermuda spiny lobster workshop and workshop follow-up.
AU: Author
Miller, DL; Goodwin, MH
AF: Author Affiliation
Dep. Geog., SUNY, P.O. Box 2000, Cortland, NY 13045, USA
CA: Corporate Author
Gulf and Caribbean Fisheries Inst., Miami, FL (USA)
CF: Conference
39. Annu. Gulf and Caribbean Fisheries Institute, Hamilton (Bermuda), Nov 1986
ED: Editor
Waugh, GT; Goodwin, MH (eds)
SO: Source
PROCEEDINGS OF THE THIRTY-NINTH ANNUAL GULF AND CARIBBEAN FISHERIES INSTITUTE, HAMILTON, BERMUDA, NOVEMBER 1986., 1989, pp. 411-412, Proceedings of the Gulf and Caribbean Fisheries Institute [PROC. GULF CARIBB. FISH. INST.], vol. 39
IS: ISSN
0072-9019
NT: Notes
Rec'd July 1990.
AB: Abstract
The spiny lobster workshop at the Bermuda GCFI meeting was quite well attended, and much interest was evident with respect to getting a collaborative regional project underway. A principal objective of the workshop was to work out a uniform methodology for obtaining simultaneous estimates of puerulus/post larval recruitment. Much of the workshop discussion focused on spatial and temporal variables which may affect settlement on collectors. Location, habitat, and fouling were identified as potential contributors to spatial variation. Inter-annual variability,

seasonal variability, lunar periodicity, and recruitment patterns to certain collectors were identified as potential sources of temporal variation. Since the workshop, a number of individuals have been collating information from a variety of sources in order to provide specific guidelines and necessary related information to interested colleagues.

TI: Title
Investigations 1975 [including report of the Fisheries Division]
CA: Corporate Author
Ministry of Agriculture, Kingston (Jamaica).
SO: Source
1977., 216 p., Bull. Minist. Agric. (Jam.) (New Ser.), (no. 65)
ER: Environmental Regime
Marine
AB: Abstract
This issue covers agricultural crops produced in Jamaica, including a section on fisheries. Investigations described in the section cover spiny lobsters (Panulirus argus) collected by commercial fish traps along the south coast. These were examined from January 1974 to March 1976. Studies briefly described deal with the aspect of the biology and dynamics of the species, particularly reproduction, feeding, growth, population structure and conservation.

TI: Title
Mating frequency in spiny lobsters of genus Panulirus White (Decapoda, Palinuridae)
OT: Original Title
Frequencia de acasalamentos em lagostas do genero Panulirus White (Decapoda, Palinuridae)
AU: Author
Mota Alves,M.I.; Paiva,M.P.
AF: Author Affiliation
Lab. Cienc. Mar., Univ. Fed. Ceara, Fortaleza, Ceara, Brazil
SO: Source
Arq. Cienc. Mar., 16(2), 61-63, (1976)
ER: Environmental Regime
Marine
AB: Abstract
This paper deals with the spermatophoric mass structure of Panulirus trying to determine the number of matings by each female before spawning. Information was collected on the species P. argus and P. laevicauda . The females examind were caught off the State of Ceara, Brazil, during 1974 and 1975. Total length of females ranged from 23.5 to 31.8 cm for P. argus , and from 15.2 to 20.1 cm for P. laevicauda . The occurrence of two or three intermediate layers in the spermatophoric mass corresponded to the number of matings during the reproductive season. There is a direct relationship between the size of the female and the number of matings before spawning. As the number of egg increases with the size of the female, up to three matings are necessary before spawning for assuring the fertilization of the released eggs.

TI: Title

Evaluation of effort reduction in the Florida Keys spiny lobster, Panulirus argus, fishery using an age-structured population analysis

AU: Author

Muller, RG; Hunt, JH; Matthews, TR; Sharp, WC

AF: Author Affiliation

Department of Environmental Protection, Florida Marine Research Institute, 100 Eighth Avenue Southeast, St. Petersburg, FL 33701-5095, USA

CF: Conference

5. Int. Conf. and Workshop on Lobster Biology and Management, Queenstown (New Zealand), 10-14 Feb 1997

SO: Source

Marine & Freshwater Research, vol. 48, no. 8, pp. 1045-1058, 1997

IS: ISSN

1323-1650

PB: Publisher

C.S.I.R.O. Publishing

AB: Abstract

A management programme implemented in Florida in 1993 was designed to reduce the number of traps in the spiny lobster fishery in order to reduce gear conflicts, environmental damage and effort without reducing harvest. Traps in the commercial fishery were reduced from 939 000 in 1991 to 568 000 in 1995. Landings by fishing season, zone (upper Florida Keys and lower Florida Keys), sex, and time period (summer v. winter) were pro-rated into numbers by length that were assigned ages by using growth simulations. From tag-recapture data, moult interval was estimated by using a logistic regression with terms for zone, sex, time period, carapace length, and time at large. For lobsters that moulted, the moult increment was modelled with a multiple regression including the same terms. Standardized catch-per-trip and total landings increased as traps were reduced. Age-structured analysis of the catches-at-age indicated that fishing mortality decreased by 16%, even as landings increased. It is not known whether the increase in landings was due to natural population fluctuations or to positive results of trap reduction. Fishing mortality rates still exceed common benchmarks used in fishery management, and excessive traps remain in the fishery.

TI: Title

The biology, ecology and bionomics of spiny lobsters (Palinuridae), spider crabs (Majiidae) and other crustacean resources.

AU: Author

Munro, JL

CA: Corporate Author

International Cent. Living Aquatic Resources Management, Manila

(Philippines)
ED: Editor
Munro, JL (ed)
SO: Source
CARIBBEAN CORAL REEF FISHERY RESOURCES. A SECOND EDITION OF "THE BIOLOGY, ECOLOGY, EXPLOITATION AND MANAGEMENT OF CARIBBEAN REEF FISHES: SCIENTIFIC REPORT OF THE ODA/UWI FISHERIES ECOLOGY RESEARCH PROJECT 1969-1973: UNIVERSITY OF THE WEST INDIES, JAMAICA"., 1983, pp. 206-222, ICLARM studies and reviews. Manila [ICLARM STUD. REV.], no. 7
IS: ISSN
0115-4389
IB: ISBN
971-1022-01-X
AB: Abstract
An account is given of the taxonomy, distribution, bionomics, life history, population structure and dynamics of Panulirus argus, P. guttatus, Mithrax spinosissimus and other crustacean resources.

TI: Title
Evidence for hydrodynamic orientation by spiny lobsters in a patch reef environment
AU: Author
Nevitt, GA; Pentcheff, ND; Lohmann, KJ; Zimmer-Faust, RK
AF: Author Affiliation
Section of Neurobiology Physiology and Behavior, Department of Biology, University of California, Davis, CA 95616, USA
SO: Source
Journal of Experimental Biology [J. EXP. BIOL.], vol. 198, no. 10, pp. 2049-2054, 1995
IS: ISSN
0022-0949
AB: Abstract
Western Atlantic spiny lobsters (Panulirus argus) are superb underwater navigators. Spiny lobsters perform dramatic seasonal offshore migrations and have also been shown to locate and home to specific den sites within the elaborate coral reef environment in which they live. How these animals perform such complex orientation tasks is not known. The study reported here was designed to explore the sensory mechanisms that spiny lobsters use to orient in and around a familiar patch reef environment. Our results show that, in the absence of visual cues, lobsters displaced a short (50 m) distance off the reef do not initially (i.e. within 20 min) travel towards their dens or return to the patch reef where their dens are located. Instead, the headings lobsters follow are significantly correlated to the direction of local hydrodynamic cues and, specifically, to the direction of approaching wave surge. Results from ultrasonic tracking experiments over longer periods (24 h) suggest that displaced

lobsters are able to relocate the reef where they were captured, even without visual cues. These results suggest that hydrodynamic cues may provide useful and immediate directional information to lobsters within the local environment of the home reef.

TI: Title
Other crustacean species.
AU: Author
Oesterling, MJ; Provenzano, AJ
AF: Author Affiliation
Virginia Inst. Mar. Sci., Coll. William and Mary, Gloucester Point, VA 23062, USA
ED: Editor
Huner, JV; Brown, EE (eds)
SO: Source
CRUSTACEAN AND MOLLUSK AQUACULTURE IN THE UNITED STATES., 1985, pp. 203-234
IB: ISBN
0-87055-468-9
AB: Abstract
Each region of the United States has its locally caught crab, lobster, or prawn that finds favor with the residents of that area. Many fisheries for wild-caught species exhibit dramatic fluctuations in stock abundance or harvest. This phenomenon, more than any other, has prompted investigation of the possibilities for culturing regionally available species. The species discussed in detail in this chapter were chosen because of their potential for economic return or their current applications in commercial culturing operations. These species are the blue crab (Callinectes sapidus), spiny lobsters (Panulirus argus and P. interruptus), cancroid crabs (Cancer magister, C. irroratus , and C. borealis), the spot prawn (Pandalus platyceros), and carideans of the genus Palaemonetes . Brief remarks concerning other carideans and a few stenopidean shrimp are included. The techniques and procedures described in previous chapters on crustaceans may also be appropriate for the species discussed in this chapter.

TI: Title
Influence of storage conditions and quality evaluation of discolorated sic spiny lobster tails.
OT: Original Title
Iseebi no kokuhen hassei ni oyobosu hozo-joken to sendo no eikyo
AU: Author
Ogawa, M; Meneses, ACS; Perdigao, NB; Koxima, T
AF: Author Affiliation
Lab. Cienc. Mar., Univ. Federal do Ceara, C.P. 1072, Fortaleza, Ceara, Brazil
CF: Conference
Annual Spring Meeting of the Japanese Society of Scientific Fisheries, Tokyo (Japan), Apr 1981
SO: Source
BULL. JAP. SOC. SCI. FISH./NISSUISHI., vol. 49, no. 6, pp. 975-982, 1983
IS: ISSN

0021-5392
AB: Abstract
The circumstantal rate of black discolored tails has been surveyed on 2 ice-stored lobster species, namely Panulirus argus (Pa) and Panuliruss laevicauda (Pl) at 2 Brazilian fishing port, presevation test in ice storage on board has been researched under commercial practice of handling and quality evaluation of the discolored tails has been assessed on the basis of sample analysis at local plants. The incidence rate of black discoloration in Pl was 14.4%, an extremely high value. Black spots showed in 3 out of 671 samples of Pl and in 4 out of 1,207 samples of Pa after the preservation work on board. Black spots showed at the broken and bruised, hard and soft segments of the cuticle, but they did not reach the inner muscle. Only the K value was found to be a valid index of freshness, as supported by the comparison of means between the two species.

TI: Title
[Study of the lobster fishery of Ceara, during the year 1975]
OT: Original Title
Estudo sobre a pesca de lagostas no Ceara, durante o ano de 1975
AU: Author
Paiva Pinto, M.
AF: Author Affiliation
La. Cienc. Mar, Univ. Fed. Ceara, Fortaleza. Ceara, Brazil
SO: Source
Arq. Cienc. Mar., 16(1), 27-30, (1976)
ER: Environmental Regime
Marine
AB: Abstract
This paper deals with the spiny lobster fishery in the State of Ceara (Brazil) during 1975. The species Panulirus argus (Latreille) and Panulirus laevicauda (Latreille) are considered together. A total production of 1,873 tons of fresh tails was reached. Through the port of Fortaleza 1,697 tons of spiny lobster frozen tails were exported in 1975. The mean weight of spiny lobster tails for the State of Ceara during 1975 corresponded to 122 grams. The annual average relative density was 0 . 8 spiny lobster caught per trap/day. The fishing effort employed was very high, being equivalent to about 19.7 x 10 SUP-6 traps/day. Overfishing has been clearly characterized by the drop in production even though there was an increased fishing effort, and by the reduction in the mean weight of the fresh tails.

TI: Title
(Protection of the Cuban shelf fishery resources (2). Crustaceans: Lobster and shrimp.).
OT: Original Title
Proteccion de los recursos pesqueros de la plataforma cubana (2). Crustaceos: Langosta y el camaron
AU: Author
Perez Puentes, C
AF: Author Affiliation
Minist. Ind. Pesq., Dir. Regul. Pesq., La Habana, Cuba
SO: Source
MAR PESCA., no. 259, pp. 39-43, 1986

IS: ISSN
0025-2735
AB: Abstract
A brief review on the biology, reproductive cycle, spawning grounds, stock size and regulations of the fisheries of spiny lobster, and the white, pink and Chinese shrimps is presented.

TI: Title
(The fishery resources of the Archipelago of the Black Falcon National Park, Venezuela.).
OT: Original Title
Los recursos pesqueros del Parque Nacional Archipielago de Los Roques, Venezuela
AU: Author
Posada L., JM
AF: Author Affiliation
Fund. Cient. Los Roques, Apdo. 1139, Carmelitas, Caracas 1010-A, Venezuela
CA: Corporate Author
Gulf and Caribbean Fisheries Inst., Charleston, SC (USA)
CF: Conference
41. Annu. Gulf and Caribbean Fisheries Inst., St. Thomas (USVI), Nov 1988
ED: Editor
Goodwin, MH; Kau, SM; Waugh, GT (eds)
SO: Source
PROCEEDINGS OF THE FORTY-FIRST ANNUAL GULF AND CARIBBEAN FISHERIES
INSTITUTE, ST. THOMAS, U.S.V.I., NOVEMBER 1988., 1992, pp. 79-92, Proceedings of the Gulf and Caribbean Fisheries Institute [PROC. GULF CARIBB. FISH. INST.], vol. 41
IS: ISSN
0072-9019
AB: Abstract
The fishery resources of the national park are discussed. Included are methods and levels of production of the artesanal fishery, analysis of fish populations and possibilities for diversification and economic benefits.

TI: Title
An economic analysis of spiny lobster production by individual firms at optimum stock levels
AU: Author
Prochaska,F.J.; Williams,J.S.
AF: Author Affiliation
Florida Univ., Food and Resour. Econ., Gainesville, FL 32611, USA
SO: Source
South. J. Agric. Econ., 10(2), 93-100, (1978)
ER: Environmental Regime
Marine
AB: Abstract
Spiny lobster (Panulirus argus) landings in Florida increased from 1.9 million pounds in 1954 to 6.6 million pounds in 1974, a gain of 239%. Florida landings currently account for 94% of US spiny lobster landings. However total Florida spiny lobster landings have declined

since 1974. The purpose of this analysis was to provide information for decision making for individual lobster firms and to provide estimates of production relationships for use in the analysis of aggregate industry level management programs which might be imposed at current or optimum stock levels. A random stratified sample was taken, which consisted of 25 interviews of lobster fishermen (firms), to obtain information on production inputs, costs, landings, prices, fishing techniques and area fished.

TI: Title
Spiny Lobster, Stone Crab and Secondary Fishery Costs and Revenues in the Florida Keys, 1978-79 Season.
AU: Author
Prochaska, FJ; Landrum, PD
CA: Corporate Author
Florida Univ., Gainesville (USA). Food and Resource Economics Dep.
SO: Source
REP. FLA. SEA GRANT PROGRAM., FLORIDA SEA GRANT, GAINESVILLE, FL (USA) , 1981, 39 pp.
PB: Publisher
FLORIDA SEA GRANT, GAINESVILLE, FL (USA)
NU: Other Numbers
FSG-R-42
AB: Abstract
In 1979 6.3 million pounds of spiny lobster valued at $12.8 million were landed in the United States. Florida was the leading producing state with production at 5.95 million pounds for a value of $11.71 million. Within the state the value of spiny lobster production ranks second only to salt water shrimp. The Florida Keys in Monroe County is the principal producing area. Monroe County spiny lobster landings in 1979 were 5.48 million pounds valued at $10.95 million. In Monroe County the value of spiny lobster landings ranked second behind shrimp in 1979. The objective of this study was to analyze production, costs and revenues for the multiple species fisheries in which spiny lobster fishermen in the Florida Keys participate. Results of the analyses provide (1) individual fishermen a base with which they can compare their own lobster operations to determine if any changes in their fishing practices are warranted, (2) analysis of the profitability of fishery alternatives to lobster fishing, (3) an economic base on which alternative lobster fishery management programs can be analyzed, and (4) economic information to support industries such as credit institutions, boat builders, etc.

TI: Title
(Methods for Determining Fecundity in Spawning Crustaceans.).
OT: Original Title
Metodo Para Determinar la Fecundidad en Crustaceos con Freza Externa
AU: Author
Ros Pichss, RM
AF: Author Affiliation
Univ. de la Habana, Centro de Investigaciones Marinas, Cuba
CF: Conference
5. Evento Cientifico, Instituto de Oceanologia, La Habana (Cuba),

1979

SO: Source

(5th SCIENTIFIC EVENT. OCEANOLOGICAL INSTITUTE.)., 5o EVENTO CIENTIFICO. INSTITUTO DE OCEANOLOGIA. , 1979, p. 16

NT: Notes

Summary only.

AB: Abstract

A practical, simple and precise method for separating eggs from the crustaceans spawns is proposed. Experiments were carried out in the stone crab (Menippe mercenaria), the blue crab (Callinectes sapidus) and the Caribbean spiny lobster (Panulirus argus) using various preservation methods. A method for counting eggs is also described. The degree of precision for each species is discussed.

TI: Title

Mitochondrial DNA sequence evidence supporting the recognition of two subspecies or species of the Florida spiny lobster Panulirus argus

AU: Author

Sarver, SK; Silberman, JD; Walsh, PJ

AF: Author Affiliation

Department of Biology, Black Hills State University, Spearfish, South Dakota, USA

SO: Source

Journal of crustacean biology. Washington DC [J. Crust. Biol.], vol. 18, no. 1, pp. 177-186, 1998

IS: ISSN

0278-0372

AB: Abstract

Samples of the spiny lobster Panulirus argus from populations in the western Atlantic and Caribbean were compared with spiny lobsters from Brazil for DNA sequence variation for 2 mitochondrial genes. Phylogenetic analyses of 16S sequence data reveal 2 distinct clades of P. argus, a clade consisting of Caribbean populations and a second clade of samples from Brazil. Mean sequence divergence estimates between Brazilian and western Atlantic/Caribbean populations were 8.32% for the mitochondrial large subunit ribosomal RNA (16S) and 19.82% for the cytochrome oxidase I subunit (COI). Levels of sequence divergence among sister species of Panulirus in the japonicus-group were similar to that observed between Brazilian and Caribbean/western Atlantic P. argus. In addition to large mitochondrial DNA sequence differences between western Atlantic/Caribbean and Brazilian P. argus, characteristic color patterns also distinguish Brazilian P. argus. Based on the results presented here, Brazilian P. argus is distinct from populations in the Caribbean and western Atlantic and may represent a complex of 2 species or subspecies. The degree of differentiation between the Caribbean and Brazilian clades

indicates that formal recognition is warranted.

TI: Title
Antennular projections to the midbrain of the spiny lobster. 2. Sensory innervation of the olfactory lobe.
AU: Author
Schmidt, M; Ache, BW
AF: Author Affiliation
Inst. Biol., TU Berlin, Franklinstr. 28/29, 1000 Berlin 10, FRG
SO: Source
Journal of Comparative Neurology [J. COMP. NEUROL.], vol. 318, no. 3, pp. 291-303, 1992
IS: ISSN
0021-9967
AB: Abstract
The projection pattern of antennular sensory afferents in the olfactory lobe (OL) of the spiny lobster. Panulirus argus , was examined by backfilling axons in the antennular nerve (AN) with biocytin. Thin, presumptive olfactory afferents from the lateral division of the AN form a tract in the brain that diverges into a dense plexus that completely envelops the glomerular cortex of the OL. The results suggest that the majority of the OL innervation is provided by olfactory sensilla (aesthetascs), but that other types of sensilla provide additional, likely mechanosensory, input to the OL. The projection of olfactory afferents is not strictly uniglomerular. The columnar organization of crustacean olfactory glomeruli is functionally significant and may provide an evolutionary correlate of the recently proposed subdivision of the vertebrate olfactory bulb into "functional columns."

TI: Title
Antennular projections to the midbrain of the spiny lobster. 1. Sensory innervation of the lateral and medial antennular neuropils.
AU: Author
Schmidt, M; Ekeris, Lvan; Ache, BW
AF: Author Affiliation
Inst. Biol., TU Berlin, Franklinstr. 28/29, 1000 Berlin 10, FRG
SO: Source
Journal of Comparative Neurology [J. COMP. NEUROL.], vol. 318, no. 3, pp. 277-290, 1992
IS: ISSN
0021-9967
AB: Abstract
The organization of sensory afferents in the antennular nerve (AN) of the spiny lobster and the central arborization of the afferents in the lateral and medial antennular neuropils (LAN, MAN) were analyzed by backfilling the AN with biocytin. The MAN receives primarily thick afferents with a consistent pattern of arborization from the medial of the three major divisions of the AN. The LAN, in contrast, receives many thin to medium-sized afferents. The morphological findings are consistent with the idea that the MAN receives primarily mechanosensory (largely statocyst) input, as previously thought, but that the LAN receives

chemosensory as well as mechanosensory input.

TI: Title
Further investigations of the receptor potential in primary chemosensory neurons by intracellular recording.
AU: Author
Schmiedel-Jakob, I; Anderson, PAV; Ache, BW
AF: Author Affiliation
C.V. Whitney Lab., Rte. 1, Box 121, St. Augustine, FL 32086, USA
CF: Conference
9. International Symposium on Olfaction and Taste., Snowmass Village, CO (USA), 20-24 Jul 1986
ED: Editor
Roper, SD; Atema, J (eds)
SO: Source
TASTE AND OLFACTION., 1987, pp. 591-592, Annals of the New York Academy of Sciences [ANN. N.Y. ACAD. SCI.], vol. 510
IS: ISSN
0077-8923
AB: Abstract
Knowledge of the electrical events associated with olfactory transduction is limited. Fortunately, new techniques such as patch electrode recording and morphologically favorable preparations provide hope for rapid progress in this area. The olfactory organ (antennule) of one such organism, the spiny lobster (Panulirus argus), consists of tufts of hairlike sensilla (aesthetascs) that are innervated by bipolar sensory neurons. These neurons were exposed in a hemicylindrical preparation of the antennule and treated enzymatically with papain and trypsin for intracellular recording using patch pipettes in the whole-cell configuration. The input impedances for hyperpolarizing current pulses ranged from 120 to 580 Mohm; with depolarizing current steps this fell to 34 to 70 Mohm. Transiently depolarizing the membrane to -30 to 40 mV evoked fast action potentials that overshot zero by as much as + 33.3 mV. The rising phase of the action potential had a maximum slope of 71 V/sec; its repolarizing phase 50 V/sec.

TI: Title
Whole cell recording from lobster olfactory receptor cells: Responses to current and odor stimulation.
AU: Author
Schmiedel-Jakob, I; Anderson, PAV; Ache, BW
AF: Author Affiliation
Whitney Lab., 9505 Ocean Shore Blvd., St. Augustine, FL 32086, USA
SO: Source
Journal of Neurophysiology [J. NEUROPHYSIOL.], vol. 61, no. 5, pp. 994-1000, 1989
IS: ISSN
0022-3077
AB: Abstract
The basic electrical properties of olfactory (antennule) receptor cells were studied in an in situ preparation of the spiny lobster (Panulirus argus) using whole cell patch-clamp recording. Results indicate that lobster olfactory receptor cells have electrical properties similar to, but not necessarily identical with, those

currently envisaged for olfactory receptor cells in other species.

TI: Title
Olfaction: responses of a decapod crustacean are enhanced by flicking
AU: Author
Schmitt,B.C.; Ache,B.W.
AF: Author Affiliation
Dep. Biol. Sci., Florida Atlantic Univ., Boca Raton, FL 33431, USA
SO: Source
Science (Wash.), 205(4402), 204-206, (1979)
ER: Environmental Regime
Marine
AB: Abstract
Periodic movements of the olfactory organs, known as 'flicking,' temporally enhance the response of the olfactory receptors of the spiny lobster Panulirus argus to changes in stimulus concentration. This reflex provides the lobster with a physiological mechanism to compensate for the indiscrete temporal nature of chemical stimuli.

TI: Title
Morphology and function of the antennular joint and its strand organ, instrumental to gravity reactions in the spiny lobster Panulirus argus (Crustacea, Decapoda)
AU: Author
Schoene,H.; Schoene,H.
AF: Author Affiliation
Max-Planck-Inst. Verhaltensphysiol., 8131 Seewiesen, GFR
SO: Source
Zoomorphology, 96(3), 191-203, (1980)
AB: Abstract
The one-point joint linking the antennula with the carapace in P. argus is described. A strand organ is activated when the antennula is moved in the vertical plane. Its structure, function, and regeneration after severance were investigated. The implications of this system are discussed, starting from the findings that the strand organ counteracts the statocyst (located in the antennula) in such a way that gravity reactions occur only if the body changes its position with respect to gravity.

TI: Title
Factors affecting the selection of shelters for juveniles of lobster Panulirus argus (Latreille): Influence of nature, morphology and size of algal substrate
OT: Original Title
Seleccion del refugio por juveniles de la langosta espinosa (Panulirus argus Latreille): influencia de la naturaleza, morfologia y tamano del sustrato algal
AU: Author
Serpa-Madrigal, A; Areces, AJ
AF: Author Affiliation
Instituto de Oceanologia, La Habana, Cuba
SO: Source

Revista cubana de investigaciones pesqueras. Havana [REV. CUB. INVEST. PESQ.], vol. 19, no. 2, pp. 27-31, 1995

IS: ISSN

0138-8452

AB: Abstract

Six experiments were carried out along the Havana coast of Cuba to know the influence of nature, morphology and size of macrophytes on shelter selection by young juveniles of the spiny lobster Panulirus argus. Introduced carragenophytes of genus Kappaphycus were also compared with several native algae. Recently settled lobsters prefer algal substrates. During microhabitat selection they showed a remarkable affinity for laminar thalli. Biomass was less important than morphology as sorting attribute for juveniles sheltered on algae.

TI: Title

Species identification of spiny lobster phyllosome larvae via ribosomal DNA analysis.

AU: Author

Silberman, JD; Walsh, PJ

AF: Author Affiliation

Div. Mar. Biol. and Fish., Rosenstiel Sch. Mar. and Atmos. Sci., Univ. Miami, Miami, FL 33149, USA

SO: Source

Molecular Marine Biology and Biotechnology [MOL. MAR. BIOL. BIOTECHNOL.], vol. 1, no. 3, pp. 195-205, 1992

IS: ISSN

1053-6426

AB: Abstract

Within the tropical northwestern Atlantic, Panulirus argus, P. guttatus , and P. laevicauda (Palinuridae family), are sympatric. Numerous studies have examined the distribution and abundance of planktonic phyllosome larvae with respect to recruitment of spiny lobsters to the benthic population, but the data are of limited use because larvae of these species cannot yet be distinguished from one another by morphological characteristics. A simple molecular method that unambiguously differentiates adults or larvae of P. argus, P. guttatus , and P. laevicauda is described: a 5' region of 28s ribosomal DNA is amplified in vitro and then cut with a diagnostic restriction enzyme to identify each species. Data are also presented from the application of this method to representative plankton tows.

TI: Title

Population genetics of the spiny lobster, Panulirus argus

AU: Author

Silberman, JD; Walsh, PJ

AF: Author Affiliation

Univ. Miami, Rosenstiel Sch. Mar. and Atmos. Sci., Miami, FL, USA

CF: Conference

Symp. on Florida Keys Regional Ecosystem, Miami, FL (USA), Nov

1992
ED: Editor
Prospero, JM; Harwell, CC (eds)
SO: Source
SYMPOSIUM ON FLORIDA KEYS REGIONAL ECOSYSTEM. NOVEMBER 1992., 1994, p. 1084, Bulletin of Marine Science [BULL. MAR. SCI.], vol. 54, no. 3
IS: ISSN
0007-4977
NT: Notes
Abstract only.
AB: Abstract
Mitochondrial DNA sequence polymorphisms were assayed in 258 adult spiny lobsters (Panulirus argus) from locales throughout the Caribbean in order to test the null hypothesis of no genetic population subdivision. The P. argus mtDNA was found to be extremely polymorphic, with a large number of unique mtDNA haplotypes. The mean amount of mtDNA nucleotide diversity within and between locales was not statistically significant, with mean values of 1.46% and 1.45% respectively. Cluster analysis of distance measures and parsimony failed to detect genetic subdivision between lobsters from widely separated regions. These data are consistent with high levels of gene flow among populations. Although the proportion of local and foreign recruits cannot be estimated from these data, high levels of gene flow suggest long range larval dispersal and recruitment of lobsters from Caribbean sources. This work does not preclude the presence of genetic subdivision that may be cryptic to mtDNA analysis. Future research with other genetic markers and actual recruits may reveal patterns of local recruitment and specific settlement patterns of spiny lobster larvae. Thus, the contribution of new recruits to the Florida spiny lobster population by local adult breeding populations should continue to be protected by management regulations, and management of the spiny lobster on a pan-Caribbean scale should be considered.

TI: Title
Mitochondrial DNA variation and population structure in the spiny lobster Panulirus argus
AU: Author
Silberman, JD; Sarver, SK; Walsh, PJ
AF: Author Affiliation
Mar. Biol. Lab., Cent. Mol. Evol., Woods Hole, MA 02543, USA
SO: Source
Marine biology. Berlin, Heidelberg [MAR. BIOL.], vol. 120, no. 4, pp. 601-608, 1994
IS: ISSN

0025-3162

NT: Notes

Bibliogr.: 70 ref.

AB: Abstract

Adult spiny lobsters (Panulirus argus) were collected from nine locations throughout the tropical and subtropical Northwest Atlantic Ocean and examined for mitochondrial DNA (mtDNA) variation. 187 different mtDNA haplotypes were observed among the 259 lobsters sampled. Haplotype diversity was calculated to be 0.986 and mean nucleotide sequence-diversity was estimated to be 1.44 %; both of these values are among the highest reported values for a marine species. Analysis of molecular variance (AMOVA) and phenetic clustering both failed to reveal any evidence of genetic structure within and among populations of P. argus. The present data are consistent with high levels of gene flow among populations of P. argus resulting from an extended planktonic larval stage and strong prevailing ocean currents.

TI: Title

Mitochondrial DNA variation in seasonal cohorts of spiny lobster (Panulirus argus) postlarvae

AU: Author

Silberman, JD; Sarver, SK; Walsh, PJ*

AF: Author Affiliation

Div. Mar. Biol. Fish., Rosenstiel Sch. Mar. Atmos. Sci., Univ. Miami, Miami, FL 33149, USA

SO: Source

Molecular Marine Biology and Biotechnology [MOL. MAR. BIOL. BIOTECHNOL.], vol. 3, no. 3, pp. 165-170, 1994

IS: ISSN

1053-6426

AB: Abstract

Florida spiny lobster (Panulirus argus) postlarvae (pueruli) were collected over a 2-year period in the Florida Keys and tested for seasonal genetic differentiation. Mitochondrial DNA (mtDNA) haplotypes were determined for 160 spiny lobster postlarvae, and 61 different mtDNA haplotypes were revealed using nine restriction endonucleases. Mean nucleotide sequence diversity among pueruli was 1.99%. No heterogeneity in haplotype frequency was found among pueruli collected from different seasons. Estimated sequence diversity among pueruli from different seasons was essentially 0% after correcting for intraseason variation. Seasonally collected pueruli did not appear to cluster together either by genetic distance (UPGMA) or parsimony analysis. Analysis of molecular variance (AMOVA) also revealed no significant variation among pueruli collected from different seasons of the year ($p > 0.05$). The lack of genetic differentiation among seasonal cohorts of

spiny lobster postlarvae is most likely the result of (1) mixing of lobster larvae from different populations in the plankton, or (2) a lack of mtDNA differentiation among adult lobster populations.

TI: Title
Programmes for biological sampling of lobsters.
OT: Original Title
COMISION DE PESCA PARA EL ATLANTICO CENTRO-OCCIDENTAL.
AU: Author
Soares, CNC; Cavalcante, PPL
AF: Author Affiliation
SUDEPE, Reg. Coordination of Ceara, Rua Visconde de Maua, 685, Aldeota, Fortaleza, Ceara, Brazil
CA: Corporate Author
FAO/Western Cent. Atlantic Fishery Comm., Rome (Italy)
CF: Conference
5. Sess. of the WECAFC Working Party on Assessment of Marine Fishery Resources, Saint George (Bermuda), 3-7 Nov 1986
SO: Source
WESTERN CENTRAL ATLANTIC FISHERY COMMISSION. NATIONAL REPORTS AND
SELECTED PAPERS PRESENTED AT THE FIFTH SESSION OF THE WORKING PARTY ON ASSESSMENT OF MARINE FISHERY RESOURCES, SAINT GEORGE, BERMUDA 3-7 NOVEMBER 1986., COMISION DE PESCA PARA EL ATLANTICO CENTRO-OCCIDENTAL., 1988, pp. 60-72, FAO fisheries report. Rome [FAO FISH. REP.], no. 376,supp
IS: ISSN
0429-9337
IB: ISBN
92-5-002687
NT: Notes
FAO FIP/R376-Suppl/Supl(Tri).
AB: Abstract
This paper presents a detailed programme for biological sampling of lobster, Panulirus , prepared in order to study the reproductive dynamics of the genus. The methodology proposed reflects the experience acquired by the Regional Coordination Technical Group of the Superintendencia do Desenvolvimento da Pesca in Ceara, which has been conducting research of this type for more than 3 years on Panulirus argus and P. laevicauda . It is also in response to a recommendation of the Fourth Session of the Working Party on Assessment of Marine Fishery Resources of the Western Central Atlantic Fishery Commission (WECAFC), one of whose objectives is to standardize the working methodologies of the different countries in the region as far as the study of the reproductive dynamics of the lobsters is concerned.

TI: Title
A metapopulation comparison of the abundance of Caribbean spiny lobster and Nassau grouper in Exuma Sound, Bahamas
AU: Author
Stockhausen, WT; Lipcius, RN; Marshall, LS Jr; Hickey, BM;

Eggleston, DB
AF: Author Affiliation
Caribbean Mar. Res. Cent., Bahamas
CA: Corporate Author
Rutgers-the State Univ., New Brunswick, NJ (USA). Inst. Marine Coastal Sciences
CF: Conference
23. Benthic Ecology Meeting, New Brunswick, NJ (USA), 17-19 Mar 1995
ED: Editor
Grassle, JP; Kelsey, A; Oates, E; Snelgrove, PV (eds)
SO: Source
TWENTY-THIRD BENTHIC ECOLOGY MEETING., 1995, vp
NT: Notes
Abstract only.
AB: Abstract
Dispersal is a key component in metapopulation dynamics. The Caribbean spiny lobster (Panulirus argus) and Nassau grouper (Epinephelus striatus) differ dramatically in dispersal mode, but exhibit similar benthic life history patterns. We quantified spatial variation in abundance over scales of 200 km for the two species in Exuma Sound, Bahamas during cruises in 1993 and 1994. Despite different spawning and dispersal strategies, observed patterns of abundance were similar. Consequently, we infer that local processes controlling abundance (e.g. settlement habitat availability) are relatively more important than dispersal characteristics in determining local abundance.

TI: Title
Spiny lobster culture: an alternative to natural stock assessment
AU: Author
Tamm,G.R.
AF: Author Affiliation
Science Applications, Inc., Suite 209, 2760 29th St., Boulder, CO 80302, USA
SO: Source
Fisheries. 5(4), 59-62, (1980)
AB: Abstract
Routine culture of larvae has not yet been achieved, whereas it has for juveniles and adults. A long and complex larval life, inadequate knowlege of nutritional needs, and the maintenance of high water quality standards are major constraints in larval culture of Panulirus argus . Growth in older animals, although naturally slow, can be enhanced by environmental manipulation. Several species appear well suited for advanced culture efforts including polyculture. Coordinated programs of aquaculture and fisheries management appear feasible.

TI: Title
Enhancing coastal production.

AU: Author
Tangley, L
SO: Source
Bioscience, vol. 37, no. 5, pp. 309-312, 1987
IS: ISSN
0006-3568
AB: Abstract
Do artificial shelters help or hurt Mexico's valuable spiny lobster fishery? For more than a decade, lobster fishermen on the Caribbean coast of Mexico have augmented traditional local practices by sinking simple, wooden platforms beneath the water to attract their prey. By mimicking natural crevices in reefs and rocks, these structures, known as casitas, are also intended to increase the number of lobsters the area can support. If casitas increase harvests without boosting populations by a comparable amount, the Mexican's strategy will lead to overexploitation and a possible collapse of the fishery. Spiny lobsters (Panulirus argus) provide the mainstay of the state's economy, bringing in more than $1 million in export earnings annually.

TI: Title
Threshold determination for olfactory receptors of the spiny lobster
AU: Author
Thompson,H.; Ache,B.W.
AF: Author Affiliation
Dep. Zool. Physiol., Louisiana State Univ., Baton Rouge, LA 70803, USA
SO: Source
Mar. Behav. Physiol., 7(3), 249-260, (1980)
AB: Abstract
Studies on the sensitivity of antennular chemoreceptors of Panulirus argus to taurine revealed lower thresholds than previously reported for aquatic crustaceans. This high sensitivity is common to both lateral and medial filament receptors. Receptors are not homogeneous in their response to stimulus concentration.

TI: Title
Biochemistry of an olfactory purinergic system: Dephosphorylation of excitatory nucleotides and uptake of adenosine.
AU: Author
Trapido-Rosenthal, HG; Carr, WES; Gleeson, RA
AF: Author Affiliation
C.V. Whitney Lab., Route 1, Box 121, St. Augustine, FL 32086, USA
SO: Source
Journal of Neurochemistry [J. NEUROCHEM.], vol. 49, no. 4, pp. 1174-1182, 1987
IS: ISSN
0022-3042
AB: Abstract
The olfactory organ of the spiny lobster, Panulirus argus , is composed of chemosensory sensilla containing the dendrites of primary chemosensory neurons. Receptors on these dendrites are activated by the nucleotides AMP, ADP, and ATP but not by the nucleoside adenosine. It is shown here that the lobster chemosensory sensilla contain enzymes that dephosphorylate excitatory nucleotides and an uptake system that internalizes the

nonexcitatory dephosphorylated product adenosine. The uptake of (super(3)H)-adenosine is saturable with increasing concentration. The results indicate that the enzymes and the uptake system whereby chemosensory sensilla of the lobster inactivate excitatory nucleotides and clear adenosine from extracellular spaces are very similar to those present in the internal tissues of vertebrates, where nucleotides have many neuroactive effects.

TI: Title
The biochemistry of the olfactory purinergic system.
AU: Author
Trapido-Rosenthal, HG; Gleeson, RA; Carr, WES; Lambert, SM; Milstead, ML
AF: Author Affiliation
C.V. Whitney Lab. and Dep. Zool., Univ. Florida, St. Augustine, FL 32086, USA
CF: Conference
8. Meeting ISOT IX/AChemS, Snowmass, CO (USA), 20-24 Jul 1986
SO: Source
Chemical Senses [CHEM. SENSES.], vol. 11, no. 4, p. 673, 1986
IS: ISSN
0379-864X
NT: Notes
Poster session; abstract only.
AB: Abstract
The olfactory system of the spiny lobster has purinergic receptors that are excited by the purine nucleotide, adenosine 5'-monophosphate (AMP). Both biochemical and physiological studies are in progress to characterize the purinergic receptor cells and the factors affecting their activity. Radiolabeled substances have been used to discover that olfactory sensilla (aesthetasc sensilla) excised from the antennule of the lobster dephosporylate the olfactory stimulant AMP and internalize the dephosphorylated product, adenosine. These findings followed an earlier discovery that (super(3)H)AMP, or some tritiated product of (super(3)H)AMP, was rapidly internalized by a sensillar uptake system shown to be concentration dependent. Evidence that AMP is dephosphorylated prior to uptake was obtained with a double label experiment and by employing an inhibitor of 5'-nucleotidase.

TI: Title
A review of research by Florida Department of Natural Resources on species of Trans-Caribbean importance
AU: Author
Walber, F.A.; Beaumariage, D.S. (Florida Dep. Nat. Resour. Mar. Res. Lab., 100 Eighth Avenue S.E., St. Petersburg, FL 33701, USA);Stewart, H.B. Jr. (ed.)
CF: Conference
Presented at: Symp. on Progress in Marine Research in the Caribbean and Adjacent Regions, Caracas (Venexuela), 12 Jul 1976
SO: Source
In: Cooperative Investigations of the Caribbean and Adjacent Regions - 2. Symposium on Progress in Marine Research in the Caribbean and Adjacent Regions, Caracas, Venezuela, 12-16 July 1976. Papers on fisheries, aquaculture and marine biology., /Investigaciones

Cooperativas del Caribe y Regiones Adyacentes - 2. Simposio sobre Adelantos en las Investigaciones Marinas en el Caribe y Regiones Adyacentes, Caracas, Venezuela, 12-16 julio 1976. Contribuciones sobre pesquerias, acuicultura y biologia marina. ;FAO Fish. Rep., Publ.by: FAO, Rome (Italy)., Dec 1977., p.227-229, (no.200)

NT: Notes
En;en,es.

PB: Publisher
Publ.by: FAO, Rome (Italy).

IB: ISBN
ISBN 92-5-000533-4; FAO FIR/R200(E/Es).

ER: Environmental Regime
Marine

AB: Abstract
A comprehensive survey is made of the history, output and plans for Department research in the northern Caribbean and southern Gulf of Mexico. Emphasis is placed on studies of spiny lobsters (Panulirus argus), sea turtles and billfishes as resources between Florida and other Caribbean locales. Spiny lobster investigations are discussed in respect to recruitment of postlarvae and young juveniles, especially with regard to techniques for establishing rates and locations of postlarval settling. The results of many years of rearing and tag-release studies on laboratory husbandry and migrations of green turtles are presented. A report is made of the Laboratory's long-standing project on population dynamics of the Atlantic sailfish, with suggestions of how such work might be conducted elsewhere and the extent to which the Caribbean may contribute to population stabilities throughout the western Atlantic. The summary contains recommendations about research planning needs and opportunities for cooperative programmes to more thoroughly understand and manage these important animals.

TI: Title
Ectonucleotidase activities associated with the olfactory organ of the spiny lobster.

AU: Author
Trapido-Rosenthal, HG; Carr, WES; Gleeson, RA

AF: Author Affiliation
Whitney Lab., 9505 Ocean Shore Blvd., St. Augustine, FL 32086, USA

SO: Source
Journal of Neurochemistry [J. NEUROCHEM.], vol. 55, no. 1, pp. 88-96, 1990

IS: ISSN
0022-3042

AB: Abstract
The olfactory system of the Florida spiny lobster, Panulirus argus , has olfactory receptors that are excited by the purine nucleotides AMP, ADP, and ATP. These receptors reside on chemosensory neurons that are contained within aesthetase sensilla on the lateral filaments of the antennules. Studies of the 5'-ectonucleotidase, ecto-ADPase, and ecto-ATPase activities of this olfactory system showed that each activity was characterized by Michaelis-Menten kinetics. The effects can be either direct,

such as the conversion of an odorant to an inactive compound, or indirect, such as the conversion of an odorant to another compound that can activate or inhibit either receptors or enzymes associated with the system.

TI: Title
Effects of air exposure on desiccation rate, hemolymph chemistry, and escape behavior of the spiny lobster, Panulirus argus .
AU: Author
Vermeer, GK
AF: Author Affiliation
Florida Dep. Nat. Resour., Bur. Mar. Res., 100 Eighth Ave. S.E., St. Petersburg, FL 33701, USA
SO: Source
Fishery Bulletin [FISH. BULL.], vol. 85, no. 1, pp. 45-52, 1987
IS: ISSN
0090-0656
AB: Abstract
Desiccation rates and hemolymph pH, lactic acid and ammonia concentrations of spiny lobsters Panulirus arqus , exposed in air for up to 2 hours were measured. Results suggest that desiccation and hemolymph chemical changes, caused by exposure, do not directly cause mortality, but rather induce secondary physiological damage, manifested as aberrant defensive and escape behavior.

TI: Title
Management strategies for the spiny lobster resources in the western Central Atlantic: A cooperative approach.
AU: Author
Villegas, L; Jones, AC; Labisky, RF
AF: Author Affiliation
FAO/UNDP/WECAF Project, PO Box 6-4392, El Dorado, Panama, Republic of Panama
SO: Source
North American Journal of Fisheries Management [N. AM. J. FISH. MANAGE.], vol. 2, no. 3, pp. 216-223, 1982
IS: ISSN
0275-5947
AB: Abstract
Spiny lobsters, principally Panulirus argus and Panulirus laevicauda , constitute an important fishery resource for most countries in the western central Atlantic region. To address regional management strategic for this fishery, a 3-day meeting/workshop was sponsored in San Jose, Costa Rica, in November 1980 by the Gulf and Caribbean Fisheries Institute (GCFI), UNDP/FAO interregional Fisheries Development and Management Programme (WECAF Project), and the Intergovernmental Oceanographic Commission Association for the Caribbean and Adjacent Regions (IOCARIBE). Participants, who attended as individuals and not as official representatives of their governments, included fishery professional from 23 countries in the western central Atlantic. Workshop discussions centered on six major topics; management objectives and the planning process, biological research, economics, regulations, administration, and

cooperative programs.

TI: Title
Periaxonal ensheathment of lobster giant nerve fibres as revealed by freeze-fracture and lanthanum penetration.
AU: Author
Villegas, GM; Sanchez, F
AF: Author Affiliation
Cent. Biocienc., Inst. Int. Estud. Avanzados (IDEA), Apdo. 17606, Caracas 1015-A, Venezuela
SO: Source
Journal of Neurocytology [J. NEUROCYTOL.], vol. 20, no. 6, pp. 504-517, 1991
IS: ISSN
0300-4864
AB: Abstract
Sheath structure and permeability have been studied in the nerve fibres of lobster (Panulirus argus) walking limbs, in particular the individually ensheathed larger giant fibres, of which there are five or six in a peripheral bundle. They are easily distinguished and can be separated from neighbouring fibre bundles in which smaller giant axons and many axons of much smaller diameter are ensheathed together. Each of the larger giant axons is enveloped by a Schwann cell layer outside of which is a multilayered sheath consisting of one-cell thick belts of flattened cells and interleaved zones of collagen fibrils and extracellular matrix. The results indicate structural similarities but distinct permeability differences between the multilayered sheath surrounding the lobster giant axons and the vertebrate nerve perineurium. Other ultrastructural details provided by the freeze-fracture replicas concern the distribution of intramembrane particles in the exolemma and the Schwann and sheath cell membranes.

TI: Title
Antennal responses to hydrodynamic and tactile stimuli in the spiny lobster Panulirus argus
AU: Author
Wilkens, LA; Schmitz, B; Herrnkind, WF
AF: Author Affiliation
Dep. Biol., Univ. Missouri-St. Louis, 8001 Nat. Bridge Rd., St. Louis, MO 63121-4499, USA
SO: Source
Biological Bulletin, Marine Biological Laboratory, Woods Hole [BIOL. BULL. MAR. BIOL. LAB. WOODS HOLE], vol. 191, no. 2, pp. 187-198, Oct 1996
IS: ISSN
0006-3185
AB: Abstract
The responses of the long, spiny, antennal flagella of the spiny lobster Panulirus argus to hydrodynamic and tactile stimuli were investigated. Experiments were performed in the dark and included

videographic laboratory studies of small tethered lobsters (<20 mm carapace length) and nighttime field observations of larger, subadult, foraging animals. The antennae are held laterally in both tethered and free-ranging animals. Water jets trigger bilateral antennal responses in which both flagella are swept forward for rostrally directed stimuli, backward for caudal stimuli, and in an intermediate backward direction when stimulated laterally. Mean response angles are greater for caudal stimuli (17 degree -48 degree) than for rostral stimuli (10 degree -16 degree), and lobsters exhibit lateralized sensitivity when jets are directed from the caudal sector, as indicated by larger ipsilateral responses - up to twice the amplitude of contralateral responses in field experiments. Untethered lobsters frequently turn the body in the direction of the water jet and tailflip away or tailflip without first turning. Tactile stimuli to the lateral edges of the antenna, carapace, walking leg, abdomen, and tailfan also trigger primarily backward sweeps of the antennae. Only the antennule and medial antennal receptive fields yield forward movements, and these elicit smaller responses (mean response less than or equal to 5 degree) than in the backward direction (mean responses up to 15 degree). Threshold tactile stimuli trigger exclusively ipsilateral responses; thus, lateralization is absolute. These results demonstrate that spiny lobsters accurately localize mechanosensory stimuli and direct their antennal flagella in the perceived direction, a response consistent with a defensive function of the antennae in these nonchelate decapods. Overall sensitivity is greatest for hydrodynamic stimuli, a result interpreted as being important for the detection of and defense against large predatory fish whose nearby movements would generate broad, directional, water-current pulses.

TI: Title
Lobster fishery management under the Fishery Conservation and Management Act
AU: Author
Zuboy,J.R.; Jones,A.C.; Costello,T.J.
AF: Author Affiliation
Southeast Fish. Cent., NMFS, 75 Virginia Beach Drive, Miami, FL 33149, USA
SO: Source
Fisheries, 5(4), 50-52, (1980)
AB: Abstract
The Fishery Conservation and Management Act of 1976 (PL 94-265) created a new era in fishery management, featuring development of comprehensive fishery management plans by regional fishery management councils and management for 'optimum yield'. In this paper, the authors discuss the main features of the Act, consider the development of fishery management plans in general, and briefly describe management plans for lobsters (Panulirus argus).

TI: Title
The Delphi technique: A potential methodology for evaluating recreational fisheries.
AU: Author
Zuboy, JR
AF: Author Affiliation
NOAA, NMFS, Southeast Fisheries Cent., 75 Virginia Beach Drive, Miami, FL 33149, USA
CA: Corporate Author
FAO European Inland Fisheries Advisory Comm., Rome (Italy)
CF: Conference
Tech. Consult. on Allocation of Fishery Resources, Vichy (France), 20 Apr 1980
ED: Editor
Grover, JH (ed)
SO: Source
ALLOCATION OF FISHERY RESOURCES. PROCEEDINGS OF THE TECHNICAL CONSULTATION ON ALLOCATION OF FISHERY RESOURCES HELD IN VICHY, FRANCE, 20-23 APRIL 1980., (nd), pp. 510-529
AB: Abstract
The Delphi technique, a methodology for systematically developing expert opinion consensus, is suggested as an approach for generating recreational fishery data. This paper describes the Delphi technique, cites an example of how it has been applied in water resource management, and discusses the results of a Delphi experiment which was designed to provide an estimate of the recreational (diver) catch of spiny lobsters (Panulirus argus) from Florida waters.

Panulirus guttatus

TI: Title
Life history of the spotted spiny lobster, Panulirus guttatus, an obligate reef-dweller
AU: Author
Sharp, WC; Hunt, JH; Lyons, WG
AF: Author Affiliation
Department of Environmental Protection, Florida Marine Research Institute, 2796 Overseas Highway, Suite 119, Marathon, FL 33050, USA
CF: Conference
5. Int. Conf. and Workshop on Lobster Biology and Management, Queenstown (New Zealand), 10-14 Feb 1997
SO: Source
Marine & Freshwater Research, vol. 48, no. 8, pp. 687-698, 1997
IS: ISSN
1323-1650
PB: Publisher
C.S.I.R.O. Publishing
AB: Abstract
Population dynamics of the spotted spiny lobster, Panulirus

guttatus, were examined at Looe Key Reef, Florida, USA, from April 1987 to August 1989. The 347 lobsters captured (including recaptures), ranged from 9 mm (puerulus) to 75 mm carapace length (X super(-) = 54 mm CL). Pueruli settled all year round into small holes along the underside of the reef. All lobsters recaptured were found at the site of their initial capture; one was captured four times, all on the same reef spur, over 762 days. Adults sheltered within the reef during the day and foraged on top of the reef at night. Males and females were captured in equal proportions (1.2 M:1 F) from den entrances during the day; females were numerically dominant on foraging grounds at night (3 F:1 M). Reproduction occurred all year round but peaked between March and June; minimum size at maturity was 38 mm CL for females and 48 mm CL for males. The sheltering behaviour of P. guttatus, typically found on the ceiling of dens, contrasted markedly with that of the sympatric P. argus, typically found on the floor; both species used many of the same dens, but simultaneous co-occupancy was rare.

Panulirus laevicauda

TI: Title
Females sexual maturity of the spiny lobster Panulirus laevicauda (Latrielle) (Crustacea: Palinuridae) 1. Effect of the eyestalk ablation.
OT: Original Title
Maturacao de - Femeas da Lagosta Panulirus laevicauda (Latrielle) (Crustacea: Palinuridae) em Confinamento. 1. Influencia da ablacao do Pedunculo ocular
AU: Author
Gesteira, TCV; Silva, JRF; Schrader, E; Lima, AVP
AF: Author Affiliation
Lab. Cienc. Mar, Dep. Eng. Pesca, Univ. Fed. Ceara, Fortaleza Ceara, Brazil
SO: Source
Arquivos de ciencias do mar. Fortaleza [ARQ. CIENC. MAR], vol. 28, pp. 17-26, 1989
IS: ISSN
0374-5686
AB: Abstract
Two experiments were performed to determine the effects of the eyestalk ablation on ovary maturation of the spiny lobster Panulirus laevicauda. The first experiment was carried out from July to October, 1990 and the second one from October, 1990 to January, 1991. Each experiment was divided into two groups: Group 1- uncovered aquarium with lobster in three conditions: intacted (IN), partially ablated (PA) and totally ablated (TA). Group II-

aquarium with covered walls. The lobsters received the same treatment used in group 1. The eyestalk ablation gives higher gonadal index and stimuled more gonadal development than partial eyestalk ablation. Intact individuals showed inactive gonads.

Scyllarides nodifer

TI: Title
Reproductive status, sex ratios and morphometrics of the slipper lobster Scyllarides nodifer (Stimpson) (Decapoda: Scyllaridae) in the northeastern Gulf of Mexico.
AU: Author
Hardwick, CW Jr; Cline, GB
AF: Author Affiliation
Biol. Dep., Univ. Alabama, Birmingham, AL 35294, USA
SO: Source
NORTHEAST GULF SCI., vol. 11, no. 2, pp. 131-136, 1990
AB: Abstract
Morphometric data on the slipper lobster, Scyllarides nodifer , was determined by assessing the catch of a commercial vessel trawling in the northeast Gulf of Mexico on a 3-day cruise in April, 1985. Over 900 lobsters were captured during 17 trawls in two well-established areas. Reproductive status, male:female ratios and the relationship between carapace length and weight were determined. Forty-six percent of the lobsters captured were determined. Forty-six percent of the lobsters captured were female. A high percentage of these females were ovigerous, extending the previously reported reproductive season of this species. Mean weight of the lobsters was 430.5 g and the carapace length was 95 mm. No juvenile S. nodifer were captured. The first reported migratory behavior for S. nodifer is presumed from nightly catches in small well-defined trawl areas. In addition, the first description of a new habitat for this species in this area is included.

TI: Title
Preliminary studies of the mariculture potential of the slipper-lobster, Scyllarides nodifer .
AU: Author
Rudloe, A
AF: Author Affiliation
Panacea Inst. Mar. Sci., PO Drawer AB, Panacea, FL 32346, USA
SO: Source
Aquaculture, vol. 34, no. 1-2, pp. 165-169, 1983
IS: ISSN
0044-8486
AB: Abstract

The gregarious, non-aggressive slipper lobster, Scyllarides nodifer , which commonly reaches weights of 250-300 grams, was examined for its mariculture potential. Two groups of lobsters, one predominantly adult and one predominantly juvenile, were held between December 1980 and February 1981. Observations were made on food preference and consumption, growth increments and behavior. Size frequency data on field populations were also gathered. Live bivalves were the preferred food. Growth from post-larvae to a 300-g animal is hypothesized to require nine to ten molts and approximately 18 months. No problems of disease, malnutrition or water quality were encountered.

Appendix B. List of Contributions to SAFE as provided by NMFS SERO.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Regional Office
9721 Executive Center Drive N.
St. Petersburg, FL 33702
(727) 570-5335; FAX (727) 570-5300

March 24, 1999 F/SERX1:RCR:dcp

Mr. Robert Mahood, Executive Director
South Atlantic Fishery Management Council
1 Southpark Circle, Suite 306
Charlotte, SC 29407

Dear Bob,

Enclosed are lists of contributions to the SAFE reports for the FMPs under your Council's jurisdiction. The lists represents contributions sent directly to our office as of Friday, March 19, 1999, and also includes some items extracted from Council briefing books and other sources.

Dr. Kemmerer recently announced that the responsibility for SAFE reporting is being transferred from the Fisheries Economics Office to the Sustainable Fisheries Division (Dr. James Weaver). The March 19, 1999 cut-off date for this report has been established to avoid confusion during the transition period. The Fisheries Economics Office will temporarily maintain a file of new contributions received after March 19, 1999. These documents will be given to the Sustainable Fisheries Division at the time the transition is completed and they become responsible for maintaining the SAFE files.

Sincerely yours,

Richard C. Raulerson, Chief
Fisheries Economics Office

Attachment: Lists of SAFE Contributions

RECEIVED
MAR 2 9 1999

cc: F/SE - Andrew Kemmerer/Carol Ballew
F/SER2 - James Weaver/Mike Justen
F/SF - George Darcy/Richard Surdi
SEFSC - Brad Brown/Alex Chester
F/SEC7 - John Merriner
F/SEC5 - Tom McIlwayne

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Stock Assessment and Fisheries Evaluation Report Contributions
Gulf and South Atlantic Fishery Management Councils
Spiny Lobster

Title	Contributor	Date
Evaluation of effort reduction in the Florida Keys spiny lobster, *Panulirus argus*, fishery using an age-structured population analysis	Robert G. Muller, John H. Hunt, Thomas R. Matthews and William C. Sharp	1997
Status of the Spiny Lobster Fishery in Florida, 1997	Florida Department of Environmental Protection	1997
National Report - Spiny Lobster Fisheries of the United States of America	Douglas E. Harper and Robert G. Muller	Spiny Lobster Assessment Workshop, April 21-May 2, 1997 - Belize City, Belize
The Developing Live Spiny Lobster Industry - NMFS-SEFSC-395 Technical Memorandum	William O. Antozzi - NMFS - SERO - Fisheries Economics Office	December 1996
The 1995 Spiny Lobster update of Trends in Landings, CPUE, and Size of Harvested Lobster	Douglas E. Harper, SEFSC, NMFS, Miami, FL	September 1995
Florida's Spiny Lobster Fisheries, SERO-ECON-98-23	John Vondruska, NMFS-SERO- Fisheries Economics Office	September 3, 1998

Appendix C. Florida's Spiny Lobster Fisheries (SERO-ECON-98-23)

Florida's Spiny Lobster Fisheries

Prepared by:

John Vondruska
National Marine Fisheries Service
Fisheries Economics Office
9721 Executive Center Drive North
St. Petersburg, FL 33702

September 3, 1998

SERO-ECON-98-23

Florida's Spiny Lobster Fisheries

September 3, 1998

Introduction and Summary

Landings, inputs and management: Commercial landings of spiny lobster in Florida in 1997 were at the upper end of the range for 1976-97. Estimated recreational catch adds another one-fourth or more to the landings. Prior to 1976, fishing on the Bahama grounds accounted for the larger amounts that were landed commercially (Table 2). After a sharp decline in 1976 due to the loss of access to the Bahama grounds, growth in the inputs in the fisheries off the Florida coast resumed again until about 1991 (Tables 3-7). The growth in inputs, crowding on the fishing grounds and declines in average productivity (or CPUE) are among the problems indicated in the 1992 law that established Florida's trap certificate program, one of the first transferable license programs in the United States. The performance of this program is being assessed and a bioeconomic model of the fishery is being developed (Milon, Larkin, Quigley and Adams, draft 1998; Milon, Larkin and Ehrhardt, forthcoming).

Stock conditions and trap reduction: The number of traps is being reduced under Florida's trap certificate program and the rate of fishing mortality has fallen, but it is not clear whether this or natural fluctuations in stock abundance accounts for recently high landings (Muller, Hunt, Matthews and Sharp, 1997). Rates of fishing mortality exceed common benchmarks used in fishery management, meaning that excess traps remain in the fishery (Ibid.). Reportedly, the planned number of traps for the 2001/02 fishing season will be about half the number for 1991/92. Annual stocks assessments are planned, including one in October 1998.[1] Catch appears to occur mostly in the relatively shallow waters of the continental shelf and traps account for 97% of the commercial landings, with bully nets and divers accounting for the rest, but there are caveats about the potential for fishing in deeper water (in the EEZ):

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[1]Robert G. Muller, August 1998, personal communication, Florida Department of Environmental Protection, Florida Marine Research Institute, Division of Marine Resources, 100 Eighth Avenue, SE, St. Petersburg, FL 33701-5095.

(1) The landings [in the Florida Keys] should remain at levels similar to those obtained today unless fishers expand the fishery, not by adding traps, but by developing methods to fish the deeper reef faces. The deeper reefs and the areas with untrappable bottom, in effect, provide a refuge for the population (quoting, Muller and Harper, 1997, p. 10).

(2) While the trend in Florida west coast spiny lobster landings from the EEZ is somewhat complicated by the inexact boundary demarcation (the 3 to 12 nautical mile mixed category), it appears that the EEZ contribution to total west coast landings is increasing (0.7% in 1980 and 11.2% in 1992) (quoting Harper, 1995, p. 4).

Markets for live lobster: In recent years, it has been practicable to air ship live spiny lobster from Florida to Asia, Europe and Canada (Antozzi, 1996), but the markets in Asia have been affected by weakened general economic conditions in the past two years or so.

Landings

In 1997, landings of spiny lobster in Florida were 7.1 million pounds (round weight), lower than in 1996, but well above the 1976-97 average of 6.25 million pounds (Tables 1-2 and Figure 1). Fishing on the Bahama grounds had accounted for the larger amounts that were landed in Florida in about 1969-75, with a peak of 11.4 million pounds in 1972. However, many nations extended and enforced their exclusive jurisdiction over continental shelf areas and economic zones farther from shore. This apparently affected the landings of spiny lobster in southeastern states other than Florida as well, and their landings have been quite small since the early 1970s (Table 1). There are smaller fisheries for spiny lobster in California, Hawaii, Puerto Rico and the Virgin Islands. Imports (mostly of raw, frozen, shell-on tails) from fisheries in other countries have long accounted for much of the U.S. supply and use of spiny lobster (Table 8). However, the worldwide market has become more complex, U.S. imports of lobster tails have fallen, and U.S. exports of live spiny lobster account for a significant part of Florida's landings. The improved capability to deliver live animals to foreign markets in Asia, Europe and Canada affected the mix of the Florida fishery's products (Antozzi, 1996).

The 1997 exvessel value of spiny lobster landed in Florida totaled $29.6 million. Real prices (in 1990 dollars) have been notably higher in the 1990s, although they were off in 1996-97 from 1994-95 (Table 2 and Figure 2). The lower prices for Florida landings of spiny lobster in 1996 and 1997 likely trace to the effect of economic conditions on demand for live and frozen whole spiny lobster in Japan and other Asian importing countries and the effect of a stronger dollar. According to available information, the prices were so low in early August 1998, the first month of the 1998/99 commercial fishing season in Florida, that processors in the Florida Keys may not operate their live holding tanks during this season and instead prepare frozen tails for the U.S. market (Antozzi, 1998).

1997/98 fishing season: In the 1997/98 commercial fishing season (August 6, 1997 to March 31, 1998), landings on Florida's east coast were 0.595 million pounds, a bit below the long-term average, while the landings on the west coast, 6.7 million pounds, were above average (Tables 3-4).[2]

Recreational catch estimates: In the Florida Keys, where most of the commercial fishing for spiny lobster occurs, there is a significant recreational catch, and most of it is taken between the start of the Special Two-Day Sport season in late July and Labor Day. It has been estimated from mail surveys of recreational licence holders that the number of lobsters caught is about a fourth or more of the number for commercial landings in the Florida Keys (Muller, Hunt, Matthews and Sharp, 1997).

Inputs and Their Productivity

After sharp declines in 1976 due to the loss of access to the Bahama grounds, the numbers of fishermen, fishing craft and traps in the Florida fisheries for spiny lobster resumed growing again until about 1991 (Figures 3-8 and Tables 5-7). The number of traps, which had reached a half million in 1975, nearly doubled between 1975 and 1991, and then it was reduced under the 1992 Florida law that established a Trap Certificate Program, in the context of cooperative fishery management.[3]

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[2]Using data for the 1978/79 to 1997/98 fishing seasons in Tables 3 and 4, landings on Florida's east coast averaged 0.633 million pounds and landings on Florida's west coast averaged 5.560 million pounds.

[3]Management of the spiny lobster fisheries occurs under a cooperative arrangement among the Florida Marine Fisheries Commission, the Florida

After 1975, the overall number for fishing craft seemed to fluctuate about a flat trend line up to the mid-1980s, before turning upward to 845 in 1991, surpassing the previous high of 832 that had been reached in 1975 (Figures 3-4, Table 6). Moderate growth in the number of *vessels* had resumed in the late 1970s, and sharp growth in the number of *boats* occurred between 1985 and 1992 (Figure 5).[4] However, the total for gross registered tons for vessels remained below the 1974 peak of 9,579 tons, with the average declining from 27 tons per vessel in 1971-72 to about 16 tons in 1992-96. The increase in boats that began in the late 1980s was associated with full-time rather than part-time boat fishermen, in contrast to the situation for stone crab (Vondruska, 1998b).

The increases in use of inputs in fishing for spiny lobster since 1976 occurred largely on Florida's west coast, though there was some growth for the east coast in the 1990s, especially in the numbers of boats and traps (Figures 6-7 and Table 5). The sharp downturns in numbers for the east coast were not necessarily reflected in offsetting upturns in numbers for the west coast after 1976.

<u>Productivity</u>

The decline in average pounds per trap (CPUE), along with the growth in total numbers of traps, congestion and conflict on the water, and other problems were stated by Florida legislators in the 1992 law that established the trap certificate program. Based on NMFS data for numbers of fishermen, fishing craft and spiny lobster traps, indicators of average productivity are shown in Table 7 for 1950-94. The declines in average productivity are

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Department of Environmental Protection, the South Atlantic Fisheries Management Council, the Gulf Fisheries Management Council, and the National Marine Fisheries Service.

[4]A *vessel* is a commercial fishing craft having an internal cubic capacity of 5 net tons or more (1 net ton = 100 cubic feet). Vessels are enrolled or documented by the U.S. Coast Guard and have an official number assigned by that agency. A *motorboat* is a commercial fishing craft (usually with a capacity of less than 5 net tons) *that is not officially documented by the U.S. Coast Guard*. *Full-time* commercial fishermen are persons that receive more than 50% of their annual income from commercial fishing activities, including port activity, such as repair and re-rigging. *Part-time* commercial fishermen are persons who receive less than 50% of their annual income from commercial fishing activities.

more notable in pounds than in real value, because of the upward trend in real prices (Figures 2 and 8).

Prochaska and Cato (1980) compare the concepts of average productivity and marginal productivity graphically using results of an empirical model. Marginal productivity of traps represents the addition to landings associated with the addition a specific number of traps, assuming values for other variables are held constant in the model. Even without this assumption and the model, the concept of marginal productivity is intuitively and generally recognized. That is, if a specific number of traps were added in the Florida spiny lobster fisheries when they are operating at a high level of traps (say 700,000 traps), then one would expect very little if any addition to landings, but one would expect a significant addition to landings if the fisheries were operating at a low level of traps (say 25,000).

Given the increase in inputs over time, the proportion of landings that occurs in the first two months of the fishing year has increased to about 50%; close to 90% occurs by December (Figures 9-10).[5] Going from August to March during any one fishing season, both the number of commercial fishing trips and the landings per trip decline significantly. For example, the number of trips for spiny lobster in Florida declined from 7,173 in August 1994 to 1,344 in March 1995, and the mean landings of spiny lobster per trip declined from about 300 pounds to about 125 pounds (Harper and Muller, 1997, Figure 6).

<u>Caveats</u>: For purposes of stock assessment or fishery evaluation, available data on the spiny lobster fishery inputs has some caveats. The NMFS data on numbers of fishermen, fishing craft and gear represented the maximums for a calendar years, based on a general canvass of dealers in about January of the next year. For 1995 and later years, only the data for vessels is available from NMFS, not the data for boats which are a significant part of the fishery. Records from the Florida Trip Ticket System provide data on the number of trips for individual Saltwater Products Licences (SPLs). For empirical work, a "spiny lobster trip" has been defined as one where 75% or more of the

[5]The opening date has changed over time, varying from late July to early August, and it is not strictly correct to depict long-term trends using an "August-to-July fishing year," as in Figures 9-10 of this report, or to depict them using an "August-to-March fishing season."

landings is spiny lobster (Harper and Muller, 1997, p. 2). Use of trap gear, but not necessarily the type has been a mandatory entry for trip tickets since 1992.[6]

Fishing Activities

The fishing craft used to target spiny lobster have become smaller in size on average. Operators of many of them are likely to target other fish seasonally, and far more are likely to land lobster that is suitable for shipment to foreign markets as live animals than in the past, depending on such things as the availability of various species, prices and fishery regulations. Net income for such small commercial fishing boats (typically, individual businesses) in Florida is low, though not quite as low when spiny lobster is among the fish a boat targets.

Beginning in the 1950s, there was a shift to fishing craft of larger size, cost and sophistication. By the late 1960s, the modern fishing *vessel* used for spiny lobster was described as being 30-55 feet, with fiber glass hull and diesel engine, both larger in size than in the past, with hydraulic trap pullers (to allow the handling of more traps) and electronic equipment. All of this allowed operation farther from shore in more difficult weather on the Bahama grounds or off the Florida coast (Labisky, Gregory and Conti, 1980). Since the 1970s, the vessels have become smaller, as already noted. They averaged 27 gross registered tons in 1971-72 and about 16 tons in 1992-96 (Tables 5-7). The typical craft with federal fishing permits for spiny lobster in 1997 was 35 feet long and had a 290 horsepower engine (Vondruska, 1998a).

Live wells, one-day trips, and "TLC" are needed to maintain the viability of lobsters destined for shipment to foreign markets as live animals. This activity brings a higher exvessel price than fishing that involves longer trips, deeper water, and larger animals that are usually iced and seldom landed alive

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[6]Apparently, it has been mandatory to record gear on trip tickets since 1992 (Harper and Muller, 1997, p. 5), but not type of trap. That is, Norris (1996) notes that gear may be designated by writing in a gear code, which differentiates stone, spiny lobster, blue crab and fish traps, or gear may be designated by checking the box marked traps, and this does not indicate the type of trap used. Hunt, Bertelsen, Cox, Matthews and Sharp (n.d.) found the *number* of traps for the 1993/94 season in 7,403 out of 32,632 data records.

(Antozzi, 1996). Most shipments of live lobster to foreign markets occur in August-September, the beginning of the fishing season in Florida and also a two month window that precedes the opening of the lobster season in Australia, a major supplier of live spiny lobster (Ibid.). Use of live wells has another purpose. By the mid-1980s, some fishermen were using live wells for purposes of holding undersized live lobster which would be used as bait or decoys in traps (Hunt, Heatwole and Marx, 1986), and the use of live wells for such animals became mandatory under fishery management regulations starting with the 1987/88 fishing season (Harper, 1991).

Noetzel and Gaynor (1974) cross-classified fishing vessels operating in 1969 according to gear. In 1969, when fishing on the Bahama grounds was significant, 117 vessels used spiny lobster pot gear in the South Atlantic region (115 in Florida) and 102 of them used that gear exclusively. Fifteen used two kinds of gear, including runaround gill nets (7 vessels), handlines (5), shrimp trawls (2) and troll lines (1). In the Gulf region, there were 92 vessels (all in Florida) that used spiny lobster pot gear in 1969, and 49 of them used that gear exclusively. Twenty-eight used two kinds of gear and 15 used three kinds of gear, including among the additional gear, hand lines (13 vessels), stone crab pots (8), runaround gill nets (7), shrimp trawls (5) and troll lines (4).

Noetzel and Wojnowski (1975) reported vessel gross revenue of $19,900 from spiny lobster in their survey in Florida Keys for the 1972/73 and 1973/74 seasons, and $11,100 for boats, plus off-season revenue from finfish of $2,100 for vessels and $1,700 for boats. As for two other studies, they found variation in gross revenue, costs, net returns (losses), returns to factors of production, and importance of lobster by size of craft. Prochaska and Williams (1976) reported similar revenue for lobster of $13,848 from their Florida Keys survey for the 1973/74 season, but relatively larger total revenue of $21,952, after adding revenue from stone crab and fish. For their Florida Keys sample for the 1978/79 season, Prochaska and Landrum (1981) reported gross revenue of $40,912 per craft from spiny lobster. They found that gross revenue from spiny lobster rose from $20,862 for craft less than 27 feet long to $61,961 for craft greater than 42 feet, but return on investment declined.

Waters, Rhodes and Wiggers (1998, draft for review) designed and summarized an economic survey of reef fish boats that operated in 1993 in the Florida Keys. Given the emphasis on reef fish in the survey design, one might expect that boats that fished for other species would be less well represented. Yellowtail snapper was the most important species: an estimated 543 of the 653 boats in the sampled population targeted it, and operators of 435 of them ranked it as their most important species in terms of annual revenue (Ibid., p. 72). Spiny lobster was the second most frequently cited species in terms of annual revenue, fishing for it was the most profitable activity examined in the study, and lobsters were targeted in August-March, with the estimated number of boats targeting it declining as the season progressed (Ibid., p. 72). The report indicates the number of boats that targeted various species by month.[7] Eight of the sampled boats averaged nearly 42 trips and 66 days fished per year for spiny lobster (Ibid., pp. 63-64). Overall, net income was low for surveyed Florida Keys reef fish boats. It averaged about $6,600, it was zero or less for about 20% of the boats, and fishing for spiny lobster appeared to be one of the most profitable activities (Ibid., pp. 23-24, 29 and 63-64).

For Monroe County, Florida, Muller and Bert (1997, p. 9) report that 73% of the SPL holders with permits to fish for stone crab also have permits to fish for spiny lobster.

In a descriptive analysis of the boats with federal fishing permits and home ports on the Atlantic and Gulf coasts (Maine to Texas, but mostly in the southeast) in 1997, it was found that 936 boats reported that spiny lobster was among their top four fish in value of sales (Vondruska, 1998a).[8] For 719 with federal

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[7]For boats that otherwise fished for yellowtail snapper, estimates of the number of boats in the sampled population are given by month for the number that targeted other species (Table 32, p. 48). Spiny lobster was targeted by an estimated 96 boats in August, 83 in September, 76 in October, 64 in November, 57 in December-February and 51 in March. In August-October, spiny lobster was targeted by more of the boats than any other species, though stone crab was a close second in October (71 boats, as the stone crab season begins on October 15). Stone crab led in November with 78 boats, but not in December with 78 boats. King mackerel led in December with 135 boats and in January with 160 boats.

[8]Out of 6166 boats with federal fishing permits in 1997, applicants for 5345 boats selected from a list the fish that were among their top four in value of sales. Reef fish was specified for 66% of the boats, followed by king mackerel (64%), and more distantly by Spanish mackerel (40%), shark

permits for fishing for spiny lobster, regardless of home port location, the *geometric* means were as follows for boats with usable values: length, 35 feet; horsepower, 290; gross income from fishing, $21,606 (Monroe County, $28,096); expense from fishing, $16,808 (Monroe County, $21,085).[9] The median net income was $5,176. For all boats for which usable data was available, the *geometric* means were $18,215 (Monroe County, $14,636) for gross income, and $13,579 (Monroe County, $11,750) for fishing expense, while the median for net income was $3,929.

Markets

1998 update on live spiny lobster markets[10]

U.S. exports of live spiny lobster to foreign markets appear to have been depressed by the deteriorating economic conditions in Japan. Spiny lobster exports totaled 203 metric tons, valued at $2.7 million in 1997. This represents a drop of 14 percent in volume from the 1996 level, the first drop after three years of steady increases.[11]

In 1997, Taiwan was the leading destination for live spiny lobster, followed by Canada, Thailand, China and France (Table 9d). Japan which was the second leading destination in 1996, with imports from the United States of 28.4 metric tons, fell to

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(33%), swordfish and tuna (24%), spiny lobster (18%), shrimp (17%), stone crab (16%), and other fish (13%). Of the 939 boats that listed spiny lobster, 727 also listed reef fish, 594 also listed king mackerel, 456 also listed stone crab, 256 also listed Spanish mackerel, and so on. Apparently, less than a fourth (939 - 727 = 212) listed spiny lobster only.

[9]For the permits data, it was found that for three of five variables one would likely reject the assumption that the frequency distributions were close enough to being statistically normal ("bell shaped") for practical applications. Thus, geometric means and medians were used as measures of central tendency rather than arithmetic means. Among the three measures of central tendency, arithmetic means had much higher values, because of the skewed nature of the frequency distributions.

[10]This section replicates Antozzi (1998), an update to Antozzi (1996).

[11]Due to data problems (believed to be caused by the mis-coding of spiny lobster exports as American lobster) these figures are believed to be under reported by a factor of at least two.

thirteenth place in 1997, with imports of only 0.2 metric tons. Notably, exports of frozen spiny lobster to Japan were also down considerably.

The economic recession in Japan is believed to be the cause of the collapse of the Japanese market for live spiny lobster. Spiny lobster is an expensive item and as economic conditions worsen, Japanese consumers have cut back on the high-priced commodities. The falling purchasing power of the Japanese yen versus the dollar has exacerbated the situation by raising the price of spiny lobster to new highs. The economic downturn has spread to other Asian nations, some of which also have ben buying US live spiny lobster, such as Thailand, Taiwan and China. Results are expected to be additional falling markets in these countries.

The NMFS Fishery Reporting Specialist stationed in Key West, Ed Little, reports that ex-vessel prices have been low during the first month of the new open season in August. Current exvessel prices are around $3.50 to $3.75 per pound compared to prices last year which were mostly between $4.00 and $4.50 per pound.

Most dealers report that foreign demand for live spiny lobster is so weak that they have not "cranked up" their live lobster holding tanks. In other words, they may not engage at all in the live fishery/market this season because of the poor foreign market conditions. Instead, they will process lobster into frozen cooked tails for the domestic market.

In summary, the live spiny lobster sector appears to be in the doldrums, a victim of the poor economic conditions in Asia, Japan most importantly. The situation is not expected to change any time soon, but will most probably coincide with recovery of Asian economies, whenever that occurs.

U.S. market trends, 1950-97

Using the smaller of two indicators for apparent consumption (market disappearance), the U.S. market for spiny lobster increased from 50 million pounds (round weight) in the 1950 to a peak of 120 million pounds in 1970, and then declined to 70 million pounds by 1997 (Table 8 and Figure 11). The largest component, imports of raw, frozen, shell-on spiny lobster tails ("green tails") peaked at 37 million pounds (product weight) in 1969, and then exhibited a downward trend into the 1990s. Imports of tails were 22 million pounds in 1997. Imports of live spiny lobster represent a smaller component of the U.S. market supply, but one that has increased to 1-2 million pounds in 1994-97. Official descriptions for these two categories of foreign trade (both imports and exports) for 1989 onward designate species that are considered to be spiny (rock) lobster.[12] Because of the lack of comparable data for 1989 onward, the amount of imports of "other" products for spiny lobster poses a problem in analyzing trends.[13] Imports of these other products were as high as 15 million pounds a year during 1960-88 (Table 8). In Table 8, the total for U.S. exports includes shipments of both *domestic* and *foreign* products, as detailed for 1989-97 in Tables 9a and 9b.

Table 9c shows U.S. imports of frozen and live spiny lobster by country of origin in 1989-97. Table 9d shows U.S. exports to foreign markets of live and frozen spiny lobster for 1989-97 by country of destination for *domestic* products only.

Looking at U.S. imports of frozen spiny lobster tails by country of origin, it appears that much of the decrease between 1972 (34 million pounds) and 1997 (22 million pounds) relates

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[12]Under the new product classification scheme in effect since 1989, only *Palinurus, Panulirus and Jasus* species are indicated for "rock lobster and other sea crawfish," both the frozen and not-frozen categories in the 306 grouping. To the extent that exporters, U.S. importers and the U.S. Customs Service actually follow this classification requirement, these categories would exclude imports of *Scyllaridae* (slipper lobster), *Metanephrops andamanicus* (Andaman lobster) and *Nephrops norvegicus* (Norway lobster), and *Camaroncillos, langostinos*, etc. (Craylets and squat lobster), judging by the FAO (1997a) Tables B-43 and B-44 on landings by species and country.

[13]Imports of "other" chilled, fresh or frozen lobster are considered to be meat in the computation of supplies for both American and spiny lobster for 1988 and earlier years in the NMFS annual report *Fisheries of the United States*. The data is for item 114.4530, Tariff Schedule of the United States Annotated, 1987 (TSUSA). There is no equivalent product category for lobster under the internationally Harmonized Tariff Schedule of the United States Annotated (HTSUSA) for 1989 onward. Several countries shipped 0.5 million pounds or more in some years of the 1972-88 period: Mexico, Honduras, Bahamas, Chile, Brazil, Iceland, Thailand, Taiwan, Australia and New Zealand.

shipments from countries that supply cold-water lobster tails.[14] Imports from Australia, New Zealand, South Africa and Namibia were 18 million pounds in 1972 and 2.5 million pounds in 1997. Imports of warm-water tails continue to come mostly from Latin American and Caribbean countries (Table 9c).

Japan import trends, 1974-97

According to available data, imports of live spiny (rock) lobster by Japan increased from "nil" in 1974 to nearly 3.0 metric kilotons (kt) in 1994, and then declined to 2.4 kt in 1997 (Figure 12 and Table 10). Australia, New Zealand and, more recently, South Africa have been the leading suppliers, with smaller amounts coming from the United State,. Indonesia and other countries.

Compared with live rock lobster, Japan imports larger amounts of frozen, whole rock lobster from several countries, including the United States. There was an upward trend in the total from 2.7 kt in 1976 to about 12 kt in 1988-91, and what appears to have been a more volatile, but downward trend to 8.2 kt in 1997 (Figure 13 and Table 12). Comparing January-June 1998 and 1997, imports of frozen rock lobster fell to 4.3 kt from 5.5 kt (FAO, Infofish Trade News, issue 15/98, 17 August 1998).

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[14]In the U.S. market, the distinction between cold-water and warm-water spiny (rock) lobsters is partly one of perception, not just global latitude and other factors (weather, oceanic currents, water depth, etc.) that affect the water temperature of their habitat (Dore, 1989, pp. 150-155).

Biologists have grouped spiny lobster as tropical, semi-tropical and temperate (Williams, 1986). Spiny lobster (rock or non-clawed lobster, in the super family *Palinuroidea*) excludes squat lobsters or langostinos (family *Galatheidae*), clawed lobsters (family *Nephropoidea*, i.e., American lobster, European lobster, Southern longoustine, and Norway lobster), and flat (slipper) lobster (Scyllaridae).

According to Dore's discussion of trade practice, the higher-priced cold-water spiny (rock) lobster tails are said to be a "good, firm, tasty product," while warm-water tails are "cheaper and generally less tasty and consistent." Tropical lobsters are warm-water, and temperate zone lobsters are cold-water, but subtropical lobsters may be acceptably marketed as either. Unfortunately, Dore (1989, p. 154) reports that "some of the most blatant cheating in seafood applies to lobster tails." For example, one species may be repacked and/or sold as another, including warm-water for cold-water and glazing may be excessive.

Compared with live and frozen rock lobster, smaller amounts of live and frozen *Homarus* species lobster, mostly American lobster from Canada and the United States, are also imported (Tables 11 and 13).

Inferring from the average unit value of Japan's imports in yen per kilogram, market prices may be ordered roughly as follow (highest to lowest): live rock lobster, frozen rock lobster and *Homarus* species lobster (Tables 10-13). So far as demand is concerned, prices for shipments from Florida or other specific countries or fisheries depend in part of perceptions, tastes and preferences, respecting appearance, color, size, species, country of origin. There are traditions for special occasions (weddings, New Year holiday and other celebrations, banquets, etc.).

On the supply side, shortfalls in production or a shift in markets for major producer-exporters can affect price. For example, South Africa was a major supplier of cold-water lobster tails to the United States, with shipments in the range of 2.5 to 6.0 million pounds (tail weight) in 1972-86, but they virtually disappeared until the apartheid sanction was lifted in 1991. They reached a range of 0.2 to 0.7 million pounds in 1992-97 (Table 9d). South Africa's production in 1991-95, about 2.5 to 3.1 kt, amounted to half or less of what it was in 1983-88 (FAO, 1997c). Japan's imports from South Africa of what is assumed to be frozen whole rock lobster rose from the range of 0.3 to 0.6 kt (in 1978-86 to the range of 1.1 to 1.5 kt (2.4 to 3.3 million pounds) in 1987-95, after which they declined along with Japan's imports overall (Table 12).

Trends in global production and trade

World production of lobsters totaled 226.6 metric kilotons in 1995 (including squat lobster, *Galatheidae*)(FAO, 1997a). Two major categories, spiny (rock) lobster, 72.9 kt, and American lobster, 70.6 kt, accounted for about two-thirds of the world total, though the absolute and relative amounts for the two have varied over the years (FAO, 1997c). A book by Williams (1988), *Lobsters of the World--an Illustrated Guide*, is useful in trying to better understand possible effects of changes in major producing-exporting countries and major consuming-importing countries on demand for products of the Florida spiny lobster fishery and the exvessel prices paid to Florida fishermen.

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Table 1.--Landings of spiny lobster by state
(Quantity, thousands of pounds, round weight)
(Data for 1998 is incomplete, some areas to May)

Year	NC-GA	FLec	FLwc	AL-TX	Total
1962	32	672	2,435	.	3,139
1963	.	815	2,771	.	3,585
1964	.	786	2,845	.	3,631
1965	35	1,329	4,385	.	5,749
1966	.	1,686	3,664	.	5,350
1967	.	1,677	2,737	.	4,414
1968	1,004	2,234	3,921	.	7,159
1969	882	2,929	4,653	.	8,463
1970	33	3,018	6,852	213	10,115
1971	.	3,418	4,788	506	8,712
1972	.	6,268	5,149	230	11,647
1973	.	5,622	5,550	23	11,194
1974	.	4,147	6,735	1	10,883
1975	.	2,319	5,089	0	7,409
1976	.	987	4,358	.	5,346
1977	.	1,501	4,843	.	6,344
1978	.	891	4,711	.	5,602
1979	.	840	6,988	.	7,828
1980	1	999	5,696	.	6,696
1981	0	880	5,014	.	5,894
1982	0	857	5,640	.	6,497
1983	0	654	3,663	.	4,317
1984	.	205	6,047	.	6,252
1985	.	295	5,445	.	5,739
1986	0	621	4,408	.	5,029
1987	0	569	5,523	1	6,094
1988	0	514	5,796	3	6,312
1989	0	516	7,163	1	7,681
1990	0	563	5,424	1	5,987
1991	0	968	6,055	.	7,023
1992	0	482	4,005	0	4,487
1993	0	884	4,495	0	5,379
1994	0	810	6,295	.	7,104
1995	0	696	6,328	.	7,024
1996	0	671	7,196	.	7,867
1997	0	613	6,490	.	7,103
1998	.	58	812	.	870

Table 2a.--Landings of spiny lobster in Florida, by coast
(Quantity, thousands of pounds, round weight)
(Value, thousands of dollars)
(Price, dollars per pound, round weight)
(Real value, thousands of 1990 dollars)
(Real price, 1990 dollars per pound, round weight)

Florida, east coast

Year	Quantity	Value	Price	Real value	Real price
1962	672	260	0.39	952	1.42
1963	815	327	0.40	1,205	1.48
1964	786	351	0.45	1,290	1.64
1965	1,329	752	0.57	2,707	2.04
1966	1,686	810	0.48	2,828	1.68
1967	1,677	1,058	0.63	3,685	2.20
1968	2,234	1,580	0.71	5,374	2.41
1969	2,929	1,933	0.66	6,314	2.16
1970	3,018	1,830	0.61	5,768	1.91
1971	3,418	2,932	0.86	8,951	2.62
1972	6,268	6,254	1.00	18,275	2.92
1973	5,622	5,748	1.02	14,854	2.64
1974	4,147	5,068	1.22	11,016	2.66
1975	2,319	3,026	1.30	6,025	2.60
1976	987	1,734	1.76	3,300	3.34
1977	1,501	2,526	1.68	4,527	3.02
1978	891	1,691	1.90	2,814	3.16
1979	840	1,783	2.12	2,635	3.14
1980	999	2,238	2.24	2,898	2.90
1981	880	2,211	2.51	2,624	2.98
1982	857	2,209	2.58	2,569	3.00
1983	654	1,654	2.53	1,899	2.90
1984	205	540	2.63	605	2.95
1985	295	776	2.63	875	2.97
1986	621	1,716	2.76	1,991	3.20
1987	569	2,065	3.63	2,336	4.10
1988	514	1,646	3.20	1,791	3.48
1989	516	2,267	4.39	2,350	4.55
1990	563	2,017	3.58	2,017	3.58
1991	968	3,320	3.43	3,314	3.43
1992	482	1,779	3.70	1,766	3.67
1993	884	3,211	3.63	3,141	3.55
1994	810	3,488	4.31	3,366	4.16
1995	696	3,057	4.39	2,849	4.09
1996	671	2,639	3.93	2,403	3.58
1997	613	2,751	4.49	2,507	4.09

Table 2b.--Landings of spiny lobster in Florida, by coast
(Quantity, thousands of pounds, round weight)
(Value, thousands of dollars)
(Price, dollars per pound, round weight)
(Real value, thousands of 1990 dollars)
(Real price, 1990 dollars per pound, round weight)

Florida, west coast

Year	Quantity	Value	Price	Real value	Real price
1962	2,435	928	0.38	3,403	1.40
1963	2,771	1,081	0.39	3,977	1.44
1964	2,845	1,212	0.43	4,459	1.57
1965	4,385	2,467	0.56	8,884	2.03
1966	3,664	1,659	0.45	5,794	1.58
1967	2,737	1,675	0.61	5,831	2.13
1968	3,921	2,828	0.72	9,617	2.45
1969	4,653	3,325	0.71	10,861	2.33
1970	6,852	4,088	0.60	12,885	1.88
1971	4,788	4,124	0.86	12,589	2.63
1972	5,149	5,517	1.07	16,122	3.13
1973	5,550	5,914	1.07	15,283	2.75
1974	6,735	8,325	1.24	18,097	2.69
1975	5,089	6,837	1.34	13,616	2.68
1976	4,358	6,852	1.57	13,043	2.99
1977	4,843	7,899	1.63	14,156	2.92
1978	4,711	18,035	3.83	30,006	6.37
1979	6,988	13,409	1.92	19,816	2.84
1980	5,696	11,845	2.08	15,340	2.69
1981	5,014	12,319	2.46	14,619	2.92
1982	5,640	13,357	2.37	15,534	2.75
1983	3,663	9,093	2.48	10,439	2.85
1984	6,047	15,143	2.50	16,983	2.81
1985	5,445	13,127	2.41	14,793	2.72
1986	4,408	11,598	2.63	13,462	3.05
1987	5,523	19,923	3.61	22,540	4.08
1988	5,796	15,759	2.72	17,145	2.96
1989	7,163	20,266	2.83	21,007	2.93
1990	5,424	18,297	3.37	18,297	3.37
1991	6,055	24,227	4.00	24,185	3.99
1992	4,005	15,463	3.86	15,345	3.83
1993	4,495	14,807	3.29	14,483	3.22
1994	6,295	26,855	4.27	25,919	4.12
1995	6,328	28,250	4.46	26,326	4.16
1996	7,196	27,207	3.78	24,778	3.44
1997	6,490	26,803	4.13	24,430	3.76

Table 2c.--Florida spiny lobster landings, by coast
(Quantity in thousand pounds, round weight, Value in thousand dollars)

	East coast		West coast		Total		Real values in 1990 dollars		
Year	Q	V	Q	V	Q	V	Total value	Price $/lb	Deflator 1982=100
1930	108	12	180	14	288	27	209	0.72	14.9
1931	304	31	152	11	456	42	383	0.84	12.6
1932	347	26	98	6	446	32	333	0.75	11.2
1934	183	10	169	7	351	17	175	0.50	11.4
1936	211	14	116	6	327	20	181	0.55	12.9
1937	225	18	68	4	293	22	181	0.62	13.9
1938	265	20	63	3	328	23	182	0.56	14.9
1939	234	16	125	8	359	24	210	0.58	13.5
1940	256	19	208	12	464	32	275	0.59	13.3
1945	572	116	205	41	777	157	1,006	1.29	18.2
1949			1,482	189					26.3
1950	932	168	628	113	1,560	281	1,196	0.77	27.3
1951	2,020	384	1,077	205	3,097	589	2,251	0.73	30.4
1952	656	164	957	239	1,612	403	1,584	0.98	29.6
1953	1,121	224	874	175	1,995	399	1,590	0.80	29.2
1954	1,223	269	724	159	1,947	428	1,700	0.87	29.3
1955	1,079	248	1,216	280	2,295	528	2,096	0.91	29.3
1956	799	228	2,314	597	3,113	825	3,167	1.02	30.3
1957	651	200	3,389	923	4,040	1,124	4,188	1.04	31.2
1958	623	184	2,332	653	2,954	837	3,079	1.04	31.6
1959	543	176	2,637	778	3,180	954	3,501	1.10	31.7
1960	719	281	2,129	820	2,849	1,100	4,037	1.42	31.7
1961	702	249	2,101	721	2,803	969	3,567	1.27	31.6
1962	672	260	2,435	928	3,107	1,187	4,355	1.40	31.7
1963	815	327	2,771	1,081	3,585	1,408	5,182	1.45	31.6
1964	786	351	2,845	1,212	3,631	1,562	5,749	1.58	31.6
1965	1,329	752	4,385	2,467	5,714	3,219	11,591	2.03	32.3
1966	1,686	810	3,664	1,659	5,350	2,469	8,623	1.61	33.3
1967	1,677	1,058	2,737	1,675	4,414	2,733	9,516	2.16	33.4
1968	2,234	1,580	3,921	2,828	6,155	4,409	14,992	2.44	34.2
1969	2,929	1,933	4,653	3,325	7,581	5,258	17,176	2.27	35.6
1970	3,018	1,830	6,852	4,088	9,870	5,918	18,654	1.89	36.9
1971	3,418	2,932	4,788	4,124	8,206	7,057	21,540	2.62	38.1
1972	6,268	6,254	5,149	5,517	11,417	11,771	34,397	3.01	39.8
1973	5,622	5,748	5,550	5,914	11,172	11,661	30,138	2.70	45.0
1974	4,147	5,068	6,735	8,325	10,883	13,393	29,113	2.68	53.5
1975	2,319	3,026	5,089	6,837	7,408	9,863	19,642	2.65	58.4
1976	987	1,734	4,358	6,852	5,346	8,586	16,344	3.06	61.1
1977	1,501	2,526	4,843	7,899	6,344	10,425	18,682	2.94	64.9
1978	891	1,691	4,711	10,253	5,602	11,945	19,874	3.55	69.9
1979	840	1,783	6,988	13,409	7,828	15,192	22,451	2.87	78.7
1980	999	2,238	5,696	11,845	6,695	14,083	18,238	2.72	89.8
1981	880	2,211	5,014	12,319	5,894	14,530	17,243	2.93	98.0
1982	857	2,209	5,640	13,357	6,497	15,566	18,103	2.79	100.0
1983	654	1,654	3,663	9,093	4,317	10,747	12,338	2.86	101.3
1984	205	540	6,047	15,143	6,252	15,682	17,588	2.81	103.7
1985	295	776	5,445	13,127	5,739	13,903	15,668	2.73	103.2
1986	621	1,716	4,408	11,598	5,029	13,314	15,453	3.07	100.2
1987	569	2,065	5,523	19,923	6,092	21,988	24,875	4.08	102.8
1988	514	1,646	5,796	15,759	6,310	17,405	18,936	3.00	106.9
1989	516	2,267	7,163	20,266	7,680	22,533	23,357	3.04	112.2
1990	563	2,017	5,424	18,297	5,987	20,314	20,314	3.39	116.3
1991	968	3,320	6,055	24,227	7,023	27,547	27,499	3.92	116.5
1992	482	1,779	4,005	15,463	4,486	17,243	17,110	3.81	117.2
1993	884	3,211	4,495	14,807	5,379	18,019	17,625	3.28	118.9
1994	810	3,488	6,295	26,855	7,104	30,343	29,285	4.12	120.5
1995	696	3,057	6,328	28,250	7,024	31,307	29,175	4.15	124.8
1996	671	2,639	7,196	27,207	7,867	29,846	27,181	3.46	127.7
1997	613	2,751	6,490	26,803	7,103	29,554	26,937	3.79	127.6

Sources: NMFS (and predecessor agencies), Fishery industries of the United States, 1930-38, Fishery statistics of the United States, 1939-61 and umpublished data files for 1962 onward; Bureau of Labor Statistics, Producer Price Index for all commodities. West coast value for 1978 changed from $18,034.

Table 3.--Florida east coast landings of spiny lobster, monthly
(Thousands of pounds, round weight)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals Jan-Dec	Totals Aug-Jul	Totals Aug-Mar
1952	132	74	0	3	0	0	49	216	199	219	219	45	1,156	1,431	1,311
1953	182	231	1	0	0	0	120	251	206	203	71	156	1,421	1,195	1,173
1954	61	79	145	22	0	0	0	234	122	166	188	207	1,223	1,314	1,271
1955	165	59	130	43	0	0	0	187	102	160	152	82	1,079	884	882
1956	51	72	77	2	0	0	0	201	203	71	55	67	799	820	820
1957	73	50	100	0	0	0	0	141	83	100	58	46	651	569	550
1958	22	56	44	19	0	0	0	126	109	132	71	44	623	581	581
1959	33	42	23	0	0	0	0	122	82	83	105	52	543	561	560
1960	36	44	36	0	0	0	0	175	121	142	108	57	719	723	723
1961	46	31	42	0	0	0	0	167	122	134	106	54	702	664	664
1962	39	21	21	0	0	0	0	218	113	86	97	77	672	668	668
1963	34	23	20	0	0	0	0	184	178	131	112	133	815	903	903
1964	84	41	40	0	0	0	0	129	139	172	96	84	786	963	963
1965	85	83	173	0	0	0	0	267	216	128	146	230	1,329	1,501	1,501
1966	133	182	198	0	0	0	0	316	254	172	236	195	1,686	1,603	1,603
1967	115	117	198	0	0	0	0	301	176	187	290	291	1,677	1,840	1,840
1968	121	177	296	0	0	0	0	346	227	270	456	342	2,234	2,481	2,481
1969	150	284	407	0	0	0	0	462	533	382	393	317	2,929	2,899	2,899
1970	179	234	398	0	0	0	0	416	441	375	503	472	3,018	3,080	3,080
1971	206	225	443	0	0	0	0	583	490	457	559	455	3,418	4,869	4,287
1972	378	564	800	41	124	121	297	747	862	836	753	746	6,267	7,151	5,753
1973	484	560	766	252	365	442	340	454	523	382	458	596	5,622	4,461	3,588
1974	267	251	657	186	171	246	270	524	385	440	355	387	4,139	3,418	2,689
1975	133	209	256	94	207	203	225	315	145	211	171	150	2,319	1,155	1,077
1976	17	17	50	13	8	8	49	203	161	191	155	115	987	1,463	1,107
1977	97	59	127	54	86	93	123	160	131	249	162	162	1,501	1,386	1,083
1978	41	86	94	28	74	112	89	146	57	36	68	60	891	651	595
1979	69	91	67	1	6	13	35	119	83	138	134	82	840	793	758
1980	66	51	84	5	2	5	23	227	122	161	172	80	999	1,000	970
1981	104	51	53	2	5	4	20	159	133	175	104	71	880	870	821
1982	41	50	89	13	0	0	36	180	102	166	97	84	857	812	782
1983	43	77	33	17	0	0	13	139	90	92	90	60	654	547	499
1984	7	10	11	36	0	0	11	37	29	24	21	19	205	181	154
1985	6	5	15	0	0	0	27	114	49	37	25	17	295	374	306
1986	36	16	11	13	1	3	51	148	79	136	74	53	621	625	574
1987	53	12	19	0	0	0	51	133	80	136	58	26	569	477	477
1988	14	18	10	0	0	0	0	192	105	81	50	44	514	528	528
1989	23	14	19	0	0	0	0	140	79	109	79	52	516	547	544
1990	33	16	35	1	1	1	1	159	86	108	80	42	563	577	574
1991	33	32	35	2	0	0	0	288	179	236	100	63	968	927	926
1992	23	19	18	0	0	0	0	78	119	115	54	54	482	523	522
1993	35	32	35	0	0	0	0	233	182	150	133	83	884	876	876
1994	34	33	27	0	0	0	0	242	176	158	100	39	810	767	767
1995	20	14	17	0	0	0	0	280	142	123	62	38	696	711	711
1996	28	22	17	0	0	0	0	216	111	133	109	35	671	681	681
1997	36	18	23	0	0	0	0	189	113	107	78	49	613		595
1998	35	7	16												

Annual totals differ from those in Table 2 for 1952, 1953 and 1974.

Table 4.--Florida west coast landings of spiny lobster, monthly
(Thousands of pounds, round weight)

													Totals		
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan-Dec	Aug-Jul	Aug-Mar
1952	36	31	29	0	0	0	26	62	40	54	108	72	457	535	513
1953	65	35	78	0	0	0	22	115	86	49	68	56	574	492	478
1954	39	31	34	14	0	0	0	84	102	78	183	159	724	975	942
1955	87	84	165	32	0	0	0	311	133	114	152	138	1,216	1,399	1,398
1956	133	126	291	1	0	0	0	569	202	315	310	367	2,314	2,629	2,629
1957	271	227	368	0	0	0	0	689	422	533	526	351	3,389	3,273	3,188
1958	246	169	250	86	0	0	0	422	322	303	286	248	2,332	2,313	2,312
1959	221	111	399	0	0	0	0	461	353	386	368	337	2,638	2,393	2,392
1960	175	177	135	0	0	0	0	412	280	404	316	230	2,129	2,098	2,098
1961	133	174	149	0	0	0	0	394	327	311	373	241	2,101	2,199	2,199
1962	190	118	245	0	0	0	0	438	329	300	420	395	2,435	2,424	2,424
1963	223	119	200	0	0	0	0	504	418	417	459	430	2,771	2,881	2,881
1964	247	215	191	0	0	0	0	534	414	453	508	283	2,845	2,984	2,984
1965	182	182	427	0	0	0	0	778	585	1,157	640	434	4,385	4,650	4,650
1966	222	389	446	0	0	0	0	648	367	591	719	284	3,664	3,122	3,122
1967	205	109	199	0	0	0	0	531	389	497	465	341	2,737	3,233	3,233
1968	343	287	380	0	0	0	0	708	489	642	732	339	3,921	3,600	3,600
1969	153	266	270	0	0	0	0	971	895	709	753	635	4,653	5,141	5,141
1970	451	304	423	0	0	0	0	1,153	1,038	1,385	1,139	960	6,852	6,546	6,546
1971	352	211	309	0	0	0	0	1,126	735	876	768	411	4,788	5,505	5,090
1972	454	460	259	162	162	49	41	691	670	934	737	529	5,149	4,711	4,434
1973	375	272	226	59	84	88	46	968	995	1,007	780	650	5,550	5,575	5,163
1974	259	184	320	114	133	117	49	1,707	864	1,493	506	991	6,736	6,527	6,280
1975	300	222	198	101	38	40	69	1,467	897	839	568	351	5,089	5,116	4,771
1976	264	134	250	209	13	2	121	1,044	588	819	594	320	4,358	3,962	3,886
1977	244	144	133	12	20	14	28	1,025	860	1,228	696	437	4,843	4,873	4,773
1978	308	122	96	9	7	21	63	841	756	1,175	794	519	4,711	5,160	5,033
1979	426	323	199	22	3	2	99	1,425	1,300	1,266	1,165	758	6,988	7,115	6,959
1980	498	331	217	30	1	3	122	1,500	839	893	855	409	5,696	5,269	5,138
1981	304	183	155	13	0	0	118	1,402	687	879	764	509	5,014	5,007	4,808
1982	253	167	148	0	0	0	199	1,421	1,120	1,090	826	416	5,640	5,436	5,383
1983	257	147	106	6	0	0	48	991	711	556	558	285	3,663	3,958	3,750
1984	288	156	206	0	0	1	206	1,527	1,126	1,092	977	468	6,047	6,084	5,907
1985	363	172	183	2	0	0	176	1,322	1,187	787	604	648	5,445	5,402	5,265
1986	345	218	153	9	6	0	122	949	623	882	512	589	4,408	4,753	4,611
1987	539	302	216	3	6	1	131	1,322	885	1,122	637	359	5,523	4,772	4,768
1988	172	162	109	1	0	2	1	1,658	1,580	981	627	503	5,796	6,039	6,036
1989	297	190	201	1	1	2	0	1,893	1,577	1,385	1,061	557	7,163	7,277	7,276
1990	307	186	311	0	0	0	0	1,489	1,134	1,012	685	300	5,424	5,417	5,415
1991	241	247	308	1	0	1	0	1,832	1,261	1,050	653	462	6,055	5,917	5,913
1992	271	182	203	2	1	0	0	529	975	996	500	347	4,005	3,990	3,987
1993	219	210	212	3	0	0	0	1,205	891	719	619	416	4,495	4,441	4,436
1994	261	136	189	4	1	0	0	1,838	1,336	1,302	741	487	6,295	6,445	6,444
1995	371	199	171	0	0	0	0	1,945	1,322	1,140	781	400	6,328	6,313	6,311
1996	375	217	131	2	0	0	0	2,102	1,567	1,467	823	513	7,196	7,064	7,047
1997	287	123	167	16	0	0	0	1,774	1,290	1,275	942	616	6,490		6,708
1998	498	88	225	0											

Annual totals differ from Table 2 for 1952, 1953 and 1959.

Table 5.--Inputs (operating units) of the Florida spiny lobster trap fishery, by coast

Year	Fishermen on vessels		Boat & shore fishermen				Number of vessels		Gross tonnage of vessels (1)		Boats		Number of traps	
			East coast		West coast									
	East	West	Full time	Part time	Full time	Part time	East	West	East	West	East	West	East	West
1950	2	4	68	0	90	0	1	2	10	12	38	69	5,795	5,715
1951	2	2	109	2	60	0	1	1	10	8	73	38	12,312	4,625
1952	0	0	95	0	71	0	0	0	0	0	48	54	10,350	4,500
1953	4	0	173	2	70	0	2	0	18	0	90	55	19,274	6,500
1954	0	4	142	15	83	28	0	2	0	13	84	71	18,755	11,690
1955	10	4	124	10	61	10	4	2	35	14	99	61	26,342	12,700
1956	10	28	57	0	80	18	4	14	33	104	53	57	16,150	16,775
1957	8	49	79	6	138	10	3	25	25	206	50	83	14,915	21,720
1958	11	33	87	3	106	8	4	17	31	142	78	88	11,095	23,221
1959	11	30	107	5	174	20	4	17	31	134	74	159	18,100	33,612
1960	11	29	89	2	192	18	4	16	38	171	49	152	18,990	54,640
1961	13	32	88	0	170	11	5	16	48	166	50	124	13,360	38,990
1962	13	40	88	9	192	7	5	20	56	212	72	151	16,140	58,250
1963	25	44	83	8	233	12	10	24	148	261	50	162	20,240	60,050
1964	41	68	143	14	238	104	13	34	204	358	80	214	40,100	73,553
1965	50	56	163	26	306	24	18	28	347	308	98	188	49,200	89,700
1966	128	104	233	24	300	12	54	58	800	824	166	210	76,420	74,550
1967	156	143	291	3	330	24	65	75	974	1,189	164	224	94,125	91,800
1968	367	323	74	11	214	12	128	137	2,675	3,433	52	135	69,890	98,500
1969	325	184	92	9	255	20	113	92	2,557	2,185	59	176	67,700	96,955
1970	311	287	110	3	331	17	103	123	2,396	3,534	52	214	69,050	150,050
1971	383	364	98	6	259	39	128	142	3,038	4,184	55	195	78,825	147,037
1972	552	350	46	4	333	37	169	155	4,751	4,006	37	238	98,005	174,490
1973	735	399	92	0	319	30	227	175	5,486	3,924	58	211	132,900	171,590
1974	595	446	145	8	404	50	181	197	5,228	4,351	62	250	144,050	227,250
1975	470	612	54	7	774	150	151	242	4,562	4,693	41	398	92,075	428,250
1976	120	665	45	11	338	28	37	258	1,206	4,306	34	220	31,500	314,500
1977	105	655	135	21	559	56	34	244	938	4,308	79	278	47,160	407,950
1978													43,000	529,000
1979	69	785	85	16	625	175	25	274	628	4,914	40	325	28,800	565,250
1980	53	861	51	9	250	50	19	298	458	5,298	28	232	43,600	523,525
1981	56	845	65	24	250	50	20	293	483	5,199	36	232	26,700	513,925
1982	64	831	58	14	214	200	22	289	553	5,132	31	273	27,300	580,950
1983	67	865	69	24	415	58	23	305	583	5,451	37	274	46,000	578,300
1984	69	865	66	26	234	45	24	305	586	5,446	36	283	19,625	662,100
1985	70	827	67	27	450	57	25	311	595	5,583	37	210	34,000	679,850
1986	72	833	68	28	403	41	26	324	610	5,755	38	229	21,750	706,500
1987	66	759	69	6	480	20	24	303	586	5,330	39	269	40,000	731,900
1988	71	791	84	2	385	60	26	325	612	5,787	43	276	45,000	737,880
1989	71	932	74	16	600	32	26	346	612	6,215	45	324	65,050	849,630
1990	48	928	95	45	621	10	20	345	391	7,086	72	357	81,735	851,500
1991	39	978	32	46	680	10	18	365	262	6,485	77	385	51,651	928,115
1992	51	826	46	71	639	41	24	300	290	4,904	103	386	54,578	774,350
1993	49	649	69	70	476	73	23	257	435	4,422	107	359	82,803	574,013
1994	71	731	71	39	437	77	33	258	352	4,315	86	319	87,719	558,284
1995	61	674					30	270	348	4,436			37,505	314,823
1996	64	667					30	270	354	4,579			28,364	282,278

(1) Net tons rather than gross tons prior to 1960. For 1957, west coast tonnage assumed to be 206 rather than 26 as published; east coast tonnage for 1992 assumed to be 290 rather than 29. Sources: NMFS (formerly BCF), Fishery statistics of the United States, annual issues for 1950-77, and unpublished data from the operating units file for 1979-96. Data for 1995-96 is for vessels only.

Table 6.--Inputs (operating units) of the Florida spiny lobster trap fishery

Year	Traps	Boats	Vessels	Craft	Vessel gross tons (1)	Fisher-men	Traps per craft	Traps per man	Fishermen per craft	Fishermen per boat	Fishermen per vessel
1950	11,510	107	3	110	27	164	105	70	1.49	1.48	2.00
1951	16,937	111	2	113	22	175	150	97	1.55	1.54	2.00
1952	14,850	102	0	102	0	166	146	89	1.63	1.63	
1953	25,774	145	2	147	22	249	175	104	1.69	1.69	2.00
1954	30,445	155	2	157	16	272	194	112	1.73	1.73	2.00
1955	39,042	160	6	166	60	219	235	178	1.32	1.28	2.33
1956	32,925	110	18	128	168	193	257	171	1.51	1.41	2.11
1957	36,635	133	28	161	283	290	228	126	1.80	1.75	2.04
1958	34,316	166	21	187	212	248	184	138	1.33	1.23	2.10
1959	51,712	233	21	254	202	347	204	149	1.37	1.31	1.95
1960	73,630	201	20	221	209	341	333	216	1.54	1.50	2.00
1961	52,350	174	21	195	214	314	268	167	1.61	1.55	2.14
1962	74,390	223	25	248	268	349	300	213	1.41	1.33	2.12
1963	80,290	212	34	246	409	405	326	198	1.65	1.58	2.03
1964	113,653	294	47	341	562	608	333	187	1.78	1.70	2.32
1965	138,900	286	46	332	655	625	418	222	1.88	1.81	2.30
1966	150,970	376	112	488	1,624	801	309	188	1.64	1.51	2.07
1967	185,925	388	140	528	2,163	947	352	196	1.79	1.67	2.14
1968	168,390	187	265	452	6,108	1,001	373	168	2.21	1.66	2.60
1969	164,655	235	205	440	4,742	885	374	186	2.01	1.60	2.48
1970	219,100	266	226	492	5,930	1,059	445	207	2.15	1.73	2.65
1971	225,862	250	270	520	7,222	1,149	434	197	2.21	1.61	2.77
1972	272,495	275	324	599	8,757	1,322	455	206	2.21	1.53	2.78
1973	304,490	269	402	671	9,410	1,575	454	193	2.35	1.64	2.82
1974	371,300	312	378	690	9,579	1,648	538	225	2.39	1.95	2.75
1975	520,325	439	393	832	9,255	2,067	625	252	2.48	2.24	2.75
1976	346,000	254	295	549	5,512	1,207	630	287	2.20	1.66	2.66
1977	455,110	357	278	635	5,246	1,531	717	297	2.41	2.16	2.73
1978	572,000			672			851				
1979	594,050	365	299	664	5,542	1,755	895	338	2.64	2.47	2.86
1980	567,125	260	317	577	5,756	1,274	983	445	2.21	1.38	2.88
1981	540,625	268	313	581	5,682	1,290	931	419	2.22	1.45	2.88
1982	608,250	304	311	615	5,685	1,381	989	440	2.25	1.60	2.88
1983	624,300	311	328	639	6,034	1,498	977	417	2.34	1.82	2.84
1984	681,725	319	329	648	6,032	1,305	1,052	522	2.01	1.16	2.84
1985	713,850	247	336	583	6,178	1,498	1,224	477	2.57	2.43	2.67
1986	728,250	267	350	617	6,365	1,445	1,180	504	2.34	2.02	2.59
1987	771,900	308	327	635	5,916	1,400	1,216	551	2.20	1.87	2.52
1988	782,880	319	351	670	6,399	1,393	1,168	562	2.08	1.66	2.46
1989	914,680	369	372	741	6,827	1,725	1,234	530	2.33	1.96	2.70
1990	933,235	429	365	794	7,477	1,747	1,175	534	2.20	1.80	2.67
1991	979,766	462	383	845	6,747	1,785	1,159	549	2.11	1.66	2.66
1992	828,928	489	324	813	5,194	1,674	1,020	495	2.06	1.63	2.71
1993	656,816	466	280	746	4,857	1,386	880	474	1.86	1.48	2.49
1994	646,003	405	291	696	4,667	1,426	928	453	2.05	1.54	2.76
1995	352,328		300		4,784						2.45
1996	310,642		300		4,933						2.44

(1) Net tons for 1950-59 converted to gross tons using ratio of east coast tons for 4 vessels for 1959-60, 38/31. Source: Table 5. Data for 1995-96 is for vessels only.

Table 7.--Productivity and other measures for the Florida spiny lobster fishery

Year	Landings in pounds per			Value of landings in 1990 dollars per			Landings in pounds/trap		Average gross tons per vessel (1)			Traps per craft	
	Trap	Craft	Man	Trap	Craft	Man	East	West	State	East	West	East	West
1950	136	14,179	9,510	104	10,872	7,293	161	110	9	12	7	149	80
1951	183	27,411	17,699	133	19,924	12,865	164	233	11	12	10	166	119
1952	109	15,808	9,713	107	15,529	9,542	63	213				216	83
1953	77	13,574	8,014	62	10,813	6,384	58	134	11	11		210	118
1954	64	12,403	7,159	56	10,831	6,252	65	62	8		8	223	160
1955	59	13,828	10,481	54	12,624	9,569	41	96	10	11	9	256	202
1956	95	24,320	16,130	96	24,741	16,408	49	138	9	10	9	283	236
1957	110	25,092	13,930	114	26,013	14,442	44	156	10	10	10	281	201
1958	86	15,798	11,913	90	16,464	12,415	56	100	10	10	10	135	221
1959	61	12,518	9,163	68	13,784	10,089	30	78	10	10	10	232	191
1960	39	12,889	8,353	55	18,265	11,838	38	39	10	10	11	358	325
1961	54	14,376	8,928	68	18,294	11,361	53	54	10	10	10	243	279
1962	42	12,528	8,903	59	17,562	12,479	42	42	11	11	11	210	341
1963	45	14,574	8,852	65	21,065	12,795	40	46	12	15	11	337	323
1964	32	10,648	5,972	51	16,860	9,456	20	39	12	16	11	431	297
1965	41	17,211	9,143	83	34,913	18,546	27	49	14	19	11	424	415
1966	35	10,964	6,679	57	17,670	10,765	22	49	15	15	14	347	278
1967	24	8,359	4,661	51	18,024	10,049	18	30	15	15	16	411	307
1968	37	13,617	6,149	89	33,168	14,977	32	40	23	21	25	388	362
1969	46	17,230	8,566	104	39,035	19,407	43	48	23	23	24	394	362
1970	45	20,060	9,320	85	37,914	17,614	44	46	26	23	29	445	445
1971	36	15,781	7,142	95	41,423	18,747	43	33	27	24	29	431	436
1972	42	19,060	8,636	126	57,425	26,019	64	30	27	28	26	476	444
1973	37	16,649	7,093	99	44,914	19,135	42	32	23	24	22	466	445
1974	29	15,772	6,604	78	42,193	17,666	29	30	25	29	22	593	508
1975	14	8,904	3,584	38	23,608	9,502	25	12	24	30	19	480	669
1976	15	9,737	4,429	47	29,770	13,541	31	14	19	33	17	444	658
1977	14	9,991	4,144	41	29,421	12,203	32	12	19	28	18	417	782
1978	10	8,336		35	29,574		21	9					
1979	13	11,790	4,461	38	33,811	12,792	29	12	19	25	18	443	944
1980	12	11,603	5,255	32	31,609	14,316	23	11	18	24	18	928	988
1981	11	10,145	4,569	32	29,679	13,367	33	10	18	24	18	477	979
1982	11	10,564	4,704	30	29,437	13,109	31	10	18	25	18	515	1034
1983	7	6,756	2,882	20	19,309	8,236	14	6	18	25	18	767	999
1984	9	9,648	4,791	26	27,142	13,477	10	9	18	24	18	327	1126
1985	8	9,845	3,831	22	26,874	10,459	9	8	18	24	18	548	1305
1986	7	8,151	3,480	21	25,045	10,694	29	6	18	23	18	340	1278
1987	8	9,594	4,351	32	39,174	17,768	14	8	18	24	18	635	1280
1988	8	9,418	4,530	24	28,262	13,593	11	8	18	24	18	652	1228
1989	8	10,364	4,452	26	31,520	13,540	8	8	18	24	18	916	1268
1990	6	7,540	3,427	22	25,584	11,628	7	6	20	20	21	888	1213
1991	7	8,311	3,934	28	32,544	15,406	19	7	18	15	18	544	1237
1992	5	5,518	2,680	21	21,046	10,221	9	5	16	12	16	430	1129
1993	8	7,210	3,881	27	23,625	12,716	11	8	17	19	17	637	932
1994	11	10,207	4,982	45	42,076	20,537	9	11	16	11	17	737	968
1995									16	12	16		
1996									16	12	17		

(1) Net tons for 1950-59 converted to gross tons using ratio of east coast tons for 4 vessels for 1959-60, 38/31. Source: Tables 2 and 5. Data for 1995-96 is for vessels only.

Table 8.--Estimated U.S. supply and use of spiny lobster
[1,000 pounds, round (whole) weight equivalent, or product weight, if noted (1)]

Year	Beginning stocks (1)	- Landings - Florida	- Landings - United States	Imports (1) Live, fresh or frozen Tails	Imports (1) Live, fresh or frozen Live	Imports (1) Live, fresh or frozen Other	Imports (1) Canned	Imports (1) Total	Total imports (round wt.)	Total supply	Ending stocks (1)	Exports (1)	Apparent consumption Total	Apparent consumption w/o other imports
1950	1,676	1,560	3,921	12,927			2,610	15,538	50,529	59,479	2,795		51,094	51,094
1951	2,795	3,097	2,420	14,758			1,966	16,724	53,122	63,927	2,580		56,188	56,188
1952	2,580	1,612	2,745	15,813			2,621	18,434	59,234	69,719	2,472		62,301	62,301
1953	2,472	1,995	2,849	19,041			2,978	22,019	70,525	80,791	2,854		72,230	72,230
1954	2,854	1,947	3,154	19,387			1,172	20,558	63,432	75,147	2,710		67,018	67,018
1955	2,710	2,295	3,849	22,479			1,661	24,141	74,914	86,892	3,632		75,996	75,996
1956	3,632	3,113	4,687	25,258			1,285	26,543	81,557	97,140	4,846		82,602	82,602
1957	4,846	4,040	3,588	28,181			1,067	29,248	89,344	107,470	6,303		88,561	88,561
1958	6,303	2,954	3,686	25,938			378	26,316	79,516	102,111	4,189		89,544	89,544
1959	4,189	3,180	3,199	28,092			2,105	30,197	93,747	109,513	3,733		98,314	98,314
1960	3,733	2,849	3,210	27,895	593	3,866	533	32,887	103,493	117,902	4,241		105,179	88,360
1961	4,241	2,803	3,235	27,648	692	4,321	56	32,718	102,688	118,646	5,123		103,277	84,480
1962	5,123	3,107	3,664	31,329	611	5,562	198	37,700	119,684	138,717	6,665		118,722	94,527
1963	6,665	3,585	4,180	28,752	735	4,561	281	34,329	108,094	132,269	5,071		117,056	97,216
1964	5,071	3,631	4,088	29,302	396	5,405	193	35,297	112,684	131,985	2,711		123,852	100,339
1965	2,711	5,714	6,237	30,923	591	6,300	129	37,943	121,344	135,714	5,483		119,265	91,861
1966	5,483	5,350	5,844	29,337	322	7,265	157	37,081	120,641	142,934	6,811		122,501	90,899
1967	6,811	4,414	4,868	27,300	301	7,738	149	35,489	116,533	141,834	3,760		130,554	96,893
1968	3,760	6,155	7,476	35,800	259	7,002	213	43,274	139,077	157,833	5,210		142,203	111,743
1969	5,210	7,581	8,781	37,337	309	7,346	301	45,293	145,631	170,042	7,544		147,410	115,454
1970	7,544	9,870	10,345	32,526	151	5,064	102	37,842	120,213	153,190	4,267		140,389	118,362
1971	4,267	8,206	8,941	34,572	348	6,876	105	41,901	134,448	156,190	4,109		143,863	113,952
1972	4,109	11,417	12,215	34,110	370	8,529	95	43,104	140,229	164,771	7,461		142,388	105,286
1973	7,461	11,172	11,432	30,756	373	7,029	134	38,293	123,823	157,638	5,044		142,506	111,928
1974	5,044	10,883	11,708	31,243	327	8,759	95	40,424	132,586	159,426	6,485		139,971	101,870
1975	6,485	7,408	7,613	30,343	265	11,721	112	42,441	142,783	169,851	2,719		161,694	110,709
1976	2,719	5,346	5,643	33,269	352	14,874	719	49,213	168,093	181,893	6,246		163,155	98,455
1977	6,246	6,344	6,660	33,863	297	10,867	337	45,364	150,673	176,071	4,968		161,167	113,897
1978	4,968	5,602	4,629	31,336	285	11,414	125	43,160	144,507	164,040	5,872		146,424	96,774
1979	5,872	7,828	6,301	31,067	241	13,110	134	44,552	151,074	174,991	5,668		157,987	100,959
1980	5,668	6,695	6,861	27,447	123	8,587	88	36,244	120,212	144,077	4,517		130,526	93,171
1981	4,517	5,894	6,619	28,128	294	9,548	217	38,187	127,188	147,358	3,864		135,766	94,234
1982	3,864	6,497	6,438	25,505	43	9,804	50	35,402	119,431	137,461	3,330		127,471	84,822
1983	3,330	4,317	5,218	26,412	99	11,900	131	38,542	131,691	146,899	2,913		138,160	86,394
1984	2,913	6,252	6,303	29,422	133	13,469	18	43,042	147,069	162,111	3,019		153,054	94,462
1985	3,019	5,739	5,311	29,603	275	13,618	56	43,552	148,577	162,945	3,187	797	152,587	93,347
1986	3,187	5,029	6,775	27,404	159	14,346	37	41,946	144,942	161,278	2,229	1,244	153,347	90,942
1987	2,229	6,092	5,755	26,723	351	14,835	136	42,046	145,667	158,109	3,197	2,093	146,425	81,892
1988	3,197	6,310	7,166	23,378	316	14,112	52	37,858	132,072	148,829	2,899	2,689	137,443	76,056
1989	2,899	7,680	8,127	26,992	725		164	27,881	82,439	99,263	1,643	1,697	92,637	92,637
1990	1,643	5,987	7,120	28,569	849		2	29,420	86,565	98,614	1,034	3,875	91,637	91,637
1991	1,034	7,023	7,096	26,906	246		2	27,154	80,973	91,171	2,343	3,381	80,761	80,761
1992	2,343	4,486	4,872	25,428	527		0	25,955	76,812	88,713	2,404	1,687	79,814	79,814
1993	2,404	5,379	6,076	23,097	268		1	23,366	69,565	82,853	3,061	1,213	72,457	72,457
1994	3,061	7,104	8,104	21,589	1,015		12	22,616	65,836	83,123	3,455	1,184	71,574	71,574
1995	3,455	7,024	7,123	27,047	1,739		5	28,790	82,901	100,389	3,237	1,748	88,930	88,930
1996	3,237	7,867	8,308	22,927	2,154		11	25,092	70,984	89,003	2,731	3,032	77,778	77,778
1997	2,731	7,103	7,600	22,114	2,560		12	24,685	68,953	84,746	4,295	2,286	69,575	69,575

Imports and exports converted to round weight using the following factors: 3, tails; 4.5, canned; 4.35, other (assumed to be mostly lobster meat). Imports other than canned for 1950-59 assumed to be lobster tails. Exports are assumed to be frozen whole or live lobster. Data for U.S. landings data for 1978 onward are preliminary; estimated for 1997. Florida landings from Table 2. Export data revised to exclude Sweden by the author for 1989. Total consumption incorporates imports of all products shown, the second consumption amount excludes "imports of other" lobster items. Sources: NMFS, Fishery Statistics of the United States, 1949-77; NMFS, Frozen Fishery Products, 1978 to date; NMFS, Fisheries of the United States, 1978 to date; NMFS, unpublished trade data base for 1972 to date.

Table 9a.--U.S. exports of domestic lobster, by product and year
(Thousand pounds, product weight)

	1989	1990	1991	1992	1993	1994
Rock lobster, frozen	1334.502	2255.739	1635.261	925.397	682.725	668.671
Rock lobster, not frozen (live, other)	234.523	345.508	368.844	451.718	195.416	246.816
All products	1569.026	2601.247	2004.106	1377.115	878.141	915.487

	1995	1996	1997
Rock lobster, frozen	1066.720	1911.571	930.670
Rock lobster, not frozen (live, other)	273.340	523.444	447.913
All products	1340.060	2435.015	1378.584

Table 9b.--U.S. exports of foreign lobster, by product and year
(Thousand pounds, product weight)

	1989	1990	1991	1992	1993	1994
Rock lobster, frozen	122.870	1258.094	1369.787	310.027	334.823	267.412
Rock lobster, not frozen (live, other)	5.016	15.834	7.169	.	.	0.917
All products	127.886	1273.928	1376.957	310.027	334.823	268.329

	1995	1996	1997
Rock lobster, frozen	391.944	434.591	263.457
Rock lobster, not frozen (live, other)	15.545	162.884	644.151
All products	407.489	597.475	907.608

Table 9c.--U.S. imports of rock lobster by product, year, and country
(Thousand pounds, product weight)

Rock lobster, frozen

	1989	1990	1991	1992	1993	1994	1995	1996	1997
Canada	5	62	70	96	46	51	38	51	8
Mexico	1176	1461	892	771	886	905	754	573	404
Guatemala	.	59	1	5	.	.	.	.	.
Belize	547	426	383	269	306	260	291	338	509
El Salvador	14	0	.	7	9	.	.	65	6
Honduras	2300	3951	4919	3557	2198	2256	2708	3076	2318
Nicaragua	.	235	990	1275	1269	1893	2904	3035	3686
Costa Rica	191	364	369	411	156	89	101	220	212
Panama	1324	257	691	668	133	93	160	109	170
Bermuda	.	.	.	2	.	.	.	.	.
Bahamas	3851	3420	2313	3522	4316	4096	2874	3034	3014
Jamaica	169	133	290	306	309	408	527	344	160
Turks & Caicos Is.	163	197	297	441	273	203	170	105	173
Cayman Is.	939	1603	1016	513	527	404	293	315	263
Haiti	204	314	184	0	30	18	177	51	195
Dominican Republic	62	250	235	316	133	205	144	5	123
British Virgin Is.	.	.	15	.	.	.	.	.	.
Antigua & Barbuda	.	1	.	.	.	.	1	1	.
St. Lucia	.	2	.	.	.	.	.	.	.
St. Vincent-Grenadine	.	64	163	.	.	0	1	.	.
Trinidad & Tobago	.	.	.	.	.	.	35	48	2
Netherlands Antilles	10	11	43	103	64	29	.	.	.
Aruba	.	.	.	101	25	9	.	.	0
Colombia	79	205	626	420	120	40	87	234	300
Venezuela	.	3	.	.	25	13	9	27	2
Suriname	.	.	.	.	.	.	.	55	.
Ecuador	64	94	95	38	11	25	129	134	157
Peru	2	.	13	72	.	36	1	.	.
Chile	61	308	431	261	485	481	1087	642	798
Brazil	4790	5112	5503	5140	5064	4253	4925	3457	3265
Uruguay	.	.	.	3	.	.	.	.	.
Iceland	196	117	17	249	48	1	28	.	130
Sweden	1	.	.	.	.	.	.	.	.
Norway	27	.	3	.	.	.	.	.	.
Faroe Islands	.	.	.	.	.	.	2	.	.
Denmark	20	86	1	.	.	.	.	0	.
United Kingdom	254	163	100	59	111	116	139	136	55
Netherlands	3	1	3	.	4	.	.	.	4
Belgium	.	59	.	.	.	.	.	.	.
France	.	2	.	.	.	.	.	.	.
Austria	.	.	.	3	.	.	.	.	.
Switzerland	14	.	.	.	.	.	.	.	.
Former USSR	.	73	13	.	.	.	.	.	.
Russia	.	.	.	26	.	10	.	.	.
Spain	.	1	5	.	.	.	0	0	.
Portugal	.	0	.	.	.	.	.	.	.
Italy	.	.	.	.	.	.	.	45	.
Bosnia-Hercegovina	.	.	.	.	.	7	.	.	7
Cyprus	75	.	19	.	.	.	.	.	.
Iraq-Saudi Arabia NZ	2	.	2	.	.	.	.	.	.
Saudi Arabia	35	.	1	35	.	.	.	.	.
United Arab Emirates	196	134	.	241	233	225	58	273	287
Yemen	.	114	.	.	66	238	.	.	.
Oman	737	572	26	118	302	237	69	340	470
Bahrain	.	.	.	8	.	.	55	31	.
Afghanistan	.	.	.	.	.	4	.	.	.
India	257	159	178	34	32	57	40	103	104
Pakistan	97	38	6	.	2	8	4	14	.
Bangladesh	.	.	3	.	.	.	.	.	.
Sri Lanka	37	18	5	4	12	6	5	5	2
Burma (Myanmar)	.	.	.	.	.	.	4	.	.
Thailand	515	628	725	495	363	343	200	248	505
Viet Nam	.	.	.	.	.	.	.	.	9
Malaysia	45	10	19	4	.	.	3	13	9
Singapore	187	190	162	322	95	64	69	84	1322
Indonesia	172	60	2	21	36	18	25	17	1
Philippines	58	63	99	48	12	26	8	.	0
Macao	5	36	18	.	0	.	.	.	10

Table 9c.--U.S. imports of rock lobster by product, year, and country
(Thousand pounds, product weight)

Rock lobster, frozen

	1989	1990	1991	1992	1993	1994	1995	1996	1997
China	93	120	63	18	458	1099	5122	3256	617
South Korea	4	.	.	.	.	.	.	1	.
Hong Kong	281	158	127	105	.	.	.	.	.
Taiwan	613	287	213	121	89	100	141	93	171
Japan	1	17	35	5	5	.	.	.	.
Australia	5596	5573	4290	4131	3616	2304	2564	1410	1755
Cocos Is.	.	3	.	.	.	.	.	.	.
Christmas Is.	.	.	.	.	.	.	.	2	.
Heard & Mcdonald Is.	12	.	.	.	.	.	.	.	.
Papua New Guinea	53	75	68	78	66	131	129	105	104
New Zealand	1385	1225	875	605	385	335	390	306	193
Solomon Is.	.	.	.	.	3	.	0	.	.
Pitcairn Is.	2	.	.	.	.	.	.	.	.
Kiribati	.	.	.	.	.	.	1	.	0
Tonga	.	.	.	.	.	2	.	.	.
Guinea	.	.	.	.	.	5	.	.	.
Ghana	.	.	0	0	.	1	0	.	.
Gambia	.	8	.	.	.	.	.	.	.
Somalia	12	12	270	241	.	.	.	.	.
Tanzania	.	1	.	3	.	.	.	.	2
Mozambique	12	8	.	.	.	.	.	.	.
Madagascar	35	.	.	.	.	.	.	.	.
South Africa	.	.	21	154	747	482	573	505	591
Namibia	6	18	.	.	29	.	.	19	.
Swaziland	.	10	.	.	.	.	.	.	.
All countries	26992	28569	26906	25428	23097	21589	27047	22927	22114

Table 9c.--U.S. imports of rock lobster by product, year, and country
(Thousand pounds, product weight)

Rock lobster, not frozen (live, other)

	1989	1990	1991	1992	1993	1994	1995	1996	1997
Canada	513	13	16	21	0	35	2	29	1
Mexico	0	106	33	159	180	847	1554	1922	1773
Belize	.	0	.	.	.	9	12	24	138
El Salvador	2	.	.	.	.	.	.	.	.
Honduras	.	79	22	183	0	.	0	.	294
Nicaragua	.	3	17	5	.	3	1	97	107
Costa Rica	28	48	18	6	3	4	6	10	25
Panama	7	470	7	20	34	41	15	3	4
Bahamas	38	37	37	28	26	6	70	27	145
Jamaica	2	2	21	13	.	.	8	0	7
Turks & Caicos Is.	2	.	1	.	.	6	23	8	12
Cayman Is.	33	.	0	.	.	.	.	.	.
Haiti	16	.	.	.	.	.	9	0	.
Dominican Republic	.	.	1	.	.	4	.	.	.
Anguilla	.	.	1	.	.	.	.	.	.
Grenada	.	.	.	.	.	1	0	.	.
Trinidad & Tobago	.	.	.	.	.	.	.	.	2
Netherlands Antilles	.	.	3	.	.	.	.	.	.
Colombia	.	54	22	0	.	.	.	.	34
Venezuela	.	.	.	.	.	1	.	4	1
Ecuador	.	4	5	.	.	.	.	3	1
Peru	.	.	.	.	.	.	.	.	1
Chile	.	.	4	.	3	.	.	3	.
Brazil	48	18	.	25	12	26	17	8	1
Iceland	1	3	.	.	1	1	1	1	.
United Kingdom	1	0	.	.	.	.	.	.	.
Netherlands	.	.	0	.	4	.	0	.	.
Portugal	4	.	.	.	.	.	.	.	.
Albania	.	.	.	.	.	.	1	.	.
Saudi Arabia	.	.	.	0	.	.	.	.	.
India	.	3	.	48	.	.	.	.	.
Pakistan	.	.	.	4	.	.	.	.	.
Thailand	2	.	.	.	0	.	.	.	.
Philippines	.	.	.	.	2	.	.	.	.
China	.	.	.	1	.	.	.	.	.
Japan	3	1	1	.	.	.	.	.	.
Australia	.	3	38	6	1	8	15	8	4
Christmas Is.	0	5	0	0	.	.	.	4	.
New Zealand	22	.	.	.	1	23	1	2	12
Kiribati	.	.	.	7	0	1	2	.	.
South Africa	.	.	.	0	.	.	.	.	.
All countries	725	849	246	527	268	1015	1739	2154	2560

Table 9d.--U.S. exports of rock lobster, by product, year, and country
(Metric tons, product weight, domestic product only)

Rock lobster, not frozen (live, other)

	1989	1990	1991	1992	1993	1994	1995	1996	1997
Canada	21	22	10	1	6	7	3	23	41
Mexico	1	1	.	1	.	.	.	.	1
Costa Rica	.	.	.	1	.	.	.	.	.
Bahamas	.	.	.	.	.	1	.	.	.
Chile	0	.	.	.	.	.	.	.	.
Sweden	.	.	.	2	1	.	11	.	11
Norway	5	2	7	6	.	.	.	.	.
Denmark	11	19	23	9	1	.	.	.	.
United Kingdom	3	9	27	7	12	0	.	.	1
Netherlands	1	6	2	1	4	1	5	8	.
Belgium	0	.	5	1	5	4	0	19	.
Luxembourg	0	.	.	.	.	.	.	.	.
France	1	30	11	6	7	14	4	24	12
Germany	33	4	.	10	3	23	.	.	.
Austria	0	.	.	.	.	.	.	.	.
Switzerland	.	.	0	.	.	.	.	1	0
Spain	2	28	67	11	1	4	.	2	.
Malta & Gozo	.	.	.	.	.	.	1	2	1
Italy	4	9	1	6	5	.	2	0	.
Greece	0	.	.	.	1	.	.	.	.
Saudi Arabia	.	1	.	.	.	.	.	.	.
Thailand	.	.	.	.	1	4	2	31	22
Singapore	.	.	.	.	8	2	.	.	1
China	.	.	.	14	.	.	.	0	16
South Korea	.	.	.	1	8	18	4	23	5
Hong Kong	2	.	6	28	6	0	2	9	3
Taiwan	14	8	.	92	11	16	45	67	90
Japan	6	18	7	7	8	17	45	28	0
French Polynesia	.	.	.	1	.	.	.	.	.
All countries	106	157	167	205	89	112	124	237	203

Table 9d.--U.S. exports of rock lobster, by product, year, and country
(Metric tons, product weight, domestic product only)

Rock lobster, frozen

	1989	1990	1991	1992	1993	1994	1995	1996	1997
Canada	13	287	169	40	26	18	17	3	38
Mexico	51	1	3	13	17	19	12	8	14
Guatemala	.	.	.	1	.	.	.	.	.
Belize	.	.	.	.	.	.	.	5	.
Honduras	.	5	.	.	.	.	7	6	.
Nicaragua	.	.	3	.	.	.	.	.	1
Panama	.	.	.	50	.	.	.	.	0
Bermuda	5	3	2	2	2	1	.	.	.
Bahamas	2	.	.	.	.	.	.	.	.
Jamaica	.	.	.	.	.	.	.	.	1
Cayman Is.	1	.	.	.	.	.	.	17	1
Haiti	.	2	.	.	.	.	.	.	.
Dominican Republic	.	.	5	.	.	.	.	.	.
British Virgin Is.	.	.	5	.	.	.	.	.	.
St. Kitts-Nevis	.	.	0	0	0	.	.	.	.
Antigua & Barbuda	.	.	.	.	1	.	.	.	.
St. Lucia	.	.	.	0	.	.	.	0	.
Netherlands Antilles	2	1	0	13	11	27	18	5	1
Aruba	.	0	8	6	5	14	5	5	3
Guadeloupe	.	1	.	.	.	.	2	.	.
Martinique	.	.	.	.	.	.	.	12	.
Colombia	1	.	.	.	.	.	.	.	7
Venezuela	.	.	.	0	.	.	.	1	.
Chile	.	.	.	2	.	0	.	.	.
Brazil	.	.	25	8	16	.	.	.	.
Norway	19	.	15	16	1	.	.	.	.
Finland	4	31	7	0	0	0	.	.	.
Denmark	.	16	16	9	.	.	.	.	.
United Kingdom	.	3	4	31	0	.	.	.	1
Ireland	.	.	.	1	.	.	.	.	.
Netherlands	13	2	2	29	5	.	24	42	10
Belgium	.	.	18	21	54	.	.	.	.
France	115	236	122	36	80	17	169	101	37
Germany	0	.	0	6	.	.	.	.	0
Austria	.	.	2	.	.	.	.	.	.
Hungary	17	.	.	.	.	.	.	.	.
Switzerland	.	1	.	.	.	.	.	.	.
Former USSR	0	.	1	.	.	.	.	.	.
Russia	.	.	.	1	0	.	.	.	.
Spain	2	20	45	43	.	.	1	1	0
Portugal	.	.	.	1	.	.	10	.	.
Italy	1	.	.	.	1	.	.	.	.
Greece	.	2	.	0	.	.	.	.	.
Turkey	53	57	.	.	.	.	.	.	0
Israel	.	.	.	.	.	.	.	0	.
Jordan	.	0	0	2	1	.	.	.	.
Kuwait	.	.	.	.	0	.	.	.	.
Saudi Arabia	.	25	2	2	.	.	.	.	.
United Arab Emirates	.	.	.	.	.	9	.	.	.
Bahrain	2	1	.	0	2	.	.	.	.
Thailand	.	.	.	.	.	0	.	.	.
Malaysia	.	.	3	.	.	.	.	.	.
Singapore	.	19	1	13	7	1	.	.	.
Indonesia	.	.	.	.	.	.	.	.	1
Philippines	.	.	.	.	.	.	.	1	.
South Korea	.	.	3	7	2	.	5	9	7
Hong Kong	1	14	1	.	2	.	5	10	1
Taiwan	260	168	26	1	12	20	12	42	51
Japan	42	107	228	57	31	116	170	591	231
Australia	.	15	27	.	.	60	26	4	14
New Zealand	.	7	.	6	33	.	.	.	.
French Polynesia	0	.	1	.	.	.	.	.	.
Egypt	.	.	.	.	.	.	.	.	3
South Africa	.	.	.	.	.	.	.	6	.
All countries	605	1023	742	420	310	303	484	867	422

Table 10.--Estimated Japan imports of live spiny (rock) lobster
(Q in metric tons, V in million yen, and P in yen per kilogram)

Year	Total			United States		Australia		New Zealand		South Africa		Indonesia		Other		Yen per dollar
	Q	V	P	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	
1974	0	0				0	0	0	0	0	0	0	0			
1975	0.1	0.3	2893			0.1	0.3	0	0	0	0	0	0			
1976	0.1	0.3	3000			0.1	0.3	0	0	0	0	0	0			296
1977	2.4	7.4	3083			2.4	7.4	0	0	0	0	0	0			267
1978	22	62	2857			22	62	0	0	0	0	0	0			210
1979	81	242	3002			79	239	2	3	0	0	0	0			219
1980	118	393	3332			99	344	19	49	0	0	0	0			226
1981	171	577	3377			136	477	34	99	0	0	0	0			220
1982	31	102	3321			0.2	0.7	31	102	0	0	0	0			250
1983	386	1270	3296			341	1137	45	134	0	0	0	0			237
1984	394	1418	3599			341	1244	53	174	0	0	0	0			234
1985	404	1702	4214			271	1166	133	536	0	0	0	0			240
1986	862	2796	3245			590	1952	272	844	0	0	0	0			169
1987	1292	4177	3232			882	2796	409	1376	1	4	0	0			146
1988	1908	6095	3195	14	37	1062	3316	759	2431	11	33	0	0	62	278	
1989	2342	7739	3305	17	51	1088	3475	1124	3811	66	194	1	2	46	206	
1990	2374	8849	3727	5	13	969	3690	1292	4751	79	273	8	23	23	99	
1991	2402	9550	3975	9	23	1168	4634	1189	4755	11	36	9	26	17	77	
1992	2439	8918	3657	5	11	1352	4810	1049	3961	5	15	11	37	17	84	
1993	2804	8961	3195	10	22	1531	4768	1178	3875	39	98	6	19	40	179	
1994	2998	10167	3392	29	74	1636	5528	1083	3860	210	527	8	22	32	157	
1995	2903	9233	3181	42	93	1530	4919	994	3365	271	675	23	56	44	125	
1996	2698	9619	3566	18	44	1459	5172	893	3376	292	878	13	39	22	110	
1997	2397	9093	3793	13	37	1458	5568	613	2461	278	859	13	43	22	125	

Data for 1992 onward is for rock lobster and other sea crawfish, live, fresh or chilled (0306.21-100). For 1988-1991, data is for live lobster (0306.21-110), and it excludes fresh or chilled (0306.21-190). Data for 1987 & earlier years is for shrimp, prawns and lobster, live (03.03-111; 031311 for 1974-75), wherein imports from the selected countries are assumed to represent all of Japan's imports of live spiny lobster in those years.

Table 11.--Estimated Japan imports of live Homarus species lobster (Q in metric tons, V in million yen, and P in yen per kilogram)

Year	Total			Canada		United States		Other		Yen per dollar
	Q	V	P	Q	V	Q	V	Q	V	
1974	3	13	4027	0.3	1	3	12			
1975	6	22	3675	0.1	1	6	21			
1976	3	9	2765	1	2	2	8			296
1977	4	12	2674	3	8	1	4			267
1978	4	10	2590	2	4	2	6			210
1979	24	67	2753	13	38	11	29			219
1980	24	76	3247	8	26	15	50			226
1981	30	106	3544	20	67	10	39			220
1982	38	136	3582	30	102	9	34			250
1983	97	303	3134	87	271	9	32			237
1984	143	455	3179	133	422	10	32			234
1985	189	585	3090	177	544	13	41			240
1986	424	1001	2362	374	887	50	114			169
1987	759	1695	2232	575	1301	184	394			146
1988	1143	2182	1909	494	956	639	1185	10	41	
1989	1318	2702	2049	647	1321	661	1349	10	32	
1990	1361	2779	2042	826	1681	524	1062	11	35	
1991	1905	3045	2023	1026	2073	455	879	25	92	
1992	1500	3181	2121	859	1804	602	1236	38	141	
1993	1466	2579	1760	877	1526	542	911	47	142	
1994	1629	2480	1523	878	1364	738	1077	13	39	
1995	1872	2731	1459	985	1442	870	1232	17	57	
1996	1988	3484	1752	1260	2234	712	1185	17	64	
1997	1753	3258	1859	1105	2073	640	1152	9	33	

Data for 1988 onward is for lobster (Homarus spp.), live, fresh or chilled (0306.22-100). Data for 1987 & earlier years is for shrimp, prawns and lobster, live (03.03-111; 031311 for 1974-75), wherein imports from Canada and the United States are assumed to represent all imports of live Homarus lobster for Japan in those years. Values in yen are based on dollar values in source that are converted to yen using the exchange rate in the last column for 1976, 1977, 1981 and 1983-87.

Table 12.--Estimated Japan imports of frozen spiny (rock) lobster
(Q in metric tons, V in million yen, and P in yen per kilogram)

Year	Total			India		Cuba		United States		Brazil		Namibia		South Africa		Australia		Other		Yen per dollar
	Q	V	P	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	
1976	2663	4381	1645																	296
1977	3502	6340	1810																	267
1978	5789	12762	2205	143	280	1135	2900			0	0	0	0	909	1972	681	1326	2921	6284	210
1979	5610	11997	2139	229	457	1342	2977			340	729	0	0	550	1270	1556	3312	1593	3252	219
1980	4621	8513	1842	101	149	2299	4073			9	30	508	1002	267	567	641	1359	796	1333	226
1981	5404	10566	1955	319	601	1289	1916			7	23	522	1048	503	1016	1788	4197	977	1764	220
1982	6246	14667	2348	329	817	1868	3637			26	113	831	2142	361	832	848	2247	1983	4879	250
1983	7206	16855	2339	386	918	2159	4639			2	67	1394	3840	454	1009	1489	3507	1321	2876	237
1984	7474	16810	2249	644	939	2368	4984			0	0	1540	4008	525	1092	1266	3346	1130	2441	234
1985	8707	20913	2402	1032	1796	3042	6926			0	0	1526	3766	547	1117	1155	4011	1406	3296	240
1986	9249	18337	1983	1133	1954	2630	5887			0	0	1777	3114	616	1027	1181	2751	1911	3604	169
1987	10737	20651	1923	1283	2162	2791	5049			15	52	1289	2387	1149	2128	2099	5024	2111	3850	146
1988	11991	22467	1874	1144	1799	3041	5105	290	398	83	215	1516	2827	1178	2124	2545	5872	2194	4126	128
1989	12224	24726	2023	1314	2062	2846	5471	418	653	195	421	987	2256	1255	2421	3291	7739	1919	3703	138
1990	11998	28006	2334	1387	2690	2239	4787	616	1142	561	1632	535	1452	1470	3332	2371	6927	2819	6043	145
1991	12378	33056	2671	1383	3154	1737	4265	683	1492	1034	3108	354	1111	1503	3809	2961	9298	2724	6819	135
1992	11129	27831	2501	803	1445	1884	4459	314	563	881	2097	137	502	1250	3401	3252	9425	2607	5939	126
1993	9231	17189	1862	983	1099	934	1711	290	430	573	1139	185	452	1135	2111	3407	7124	1723	3122	112
1994	10251	19615	1914	936	1233	1831	2559	501	763	605	1523	128	241	1394	2195	2913	7922	1941	3180	103
1995	11240	20836	1854	810	1122	1640	2152	888	1481	593	1432	200	373	1175	2352	2595	6792	3338	5132	
1996	8963	18583	2073	757	1038	1393	2418	921	1531	837	2042	213	386	830	1848	2144	6000	1868	3321	
1997	8209	18664	2274	852	1206	1833	3738	424	761	252	585	236	512	1041	2629	2195	6620	1376	2613	

Data for 1988 onward is for rock lobster & other sea crawfish, frozen (0306.11-000). Data for 1976-87 is for Ise-ebi (lobster), fresh, chilled or frozen (03.03-112), i.e., including some Homarus spp. lobster. Totals for countries for 1978-80 and 1982 are based on monthly data, with data for some months missing: 1978 includes Mar-Oct only; 1979 excludes Nov; 1982, excludes Apr and Dec. Values in yen are based on dollar values in source that are converted to yen using the exchange rate in the last column for 1976, 1977, 1981 and 1983-87. Available data for imports from the United States for 1978-87 included in Table 13.

Table 13.--Estimated Japan imports of frozen Homarus species lobster
(Q in metric tons, V in million yen, and P in yen per kilogram)

Year	Total Q	Total V	Total P	Canada Q	Canada V	United States Q	United States V	Other Q	Other V	Yen per dollar
1978	84	105	1250	na	na	84	105			210
1979	83	106	1277	na	na	83	106			219
1980	na	na	na	na	na	na	na			226
1981	62	73	1175	62	72	0	1			220
1982	na	na	na	na	na	na	na			250
1983	83	137	1656	83	137	0	0			237
1984	60	90	1506	53	73	7	18			234
1985	78	153	1959	32	51	46	102			240
1986	207	302	1454	106	124	101	177			169
1987	364	478	1314	339	432	25	46			146
1988	1742	2512	1442	1448	1921	85	157	209	434	
1989	1113	1784	1603	672	874	108	187	333	723	
1990	1331	1796	1350	1128	1326	34	70	169	401	
1991	2109	3572	1693	1527	2234	329	597	254	741	
1992	1873	3084	1646	1577	2455	149	262	148	367	
1993	1407	1810	1286	1013	1157	123	181	272	472	
1994	1271	1711	1346	1030	1212	81	143	160	357	
1995	1797	2541	1414	1624	2203	87	136	86	203	
1996	1465	2753	1879	1003	1638	70	159	392	957	
1997	1344	2919	2172	1031	2079	34	92	279	748	

Data for 1988 onward is for lobster (Homarus spp.), frozen (0306.12-000). Data for 1987 & earlier years is for Ise-ebi (lobster), fresh, chilled or frozen (03.03-112), wherein imports from Canada and the United States are assumed to represent all imports of frozen Homarus lobster for Japan in those years. U.S. totals for 1978 and 1979 are based on monthly data; 1978 includes Mar-Oct only; 1979 excludes Nov. Values in yen are based on dollar values in source that are converted to yen using the exchange rate in the last column for 1981 and 1983-87.

Figure 1.--Landings (1950-97)
Florida spiny lobster fisheries

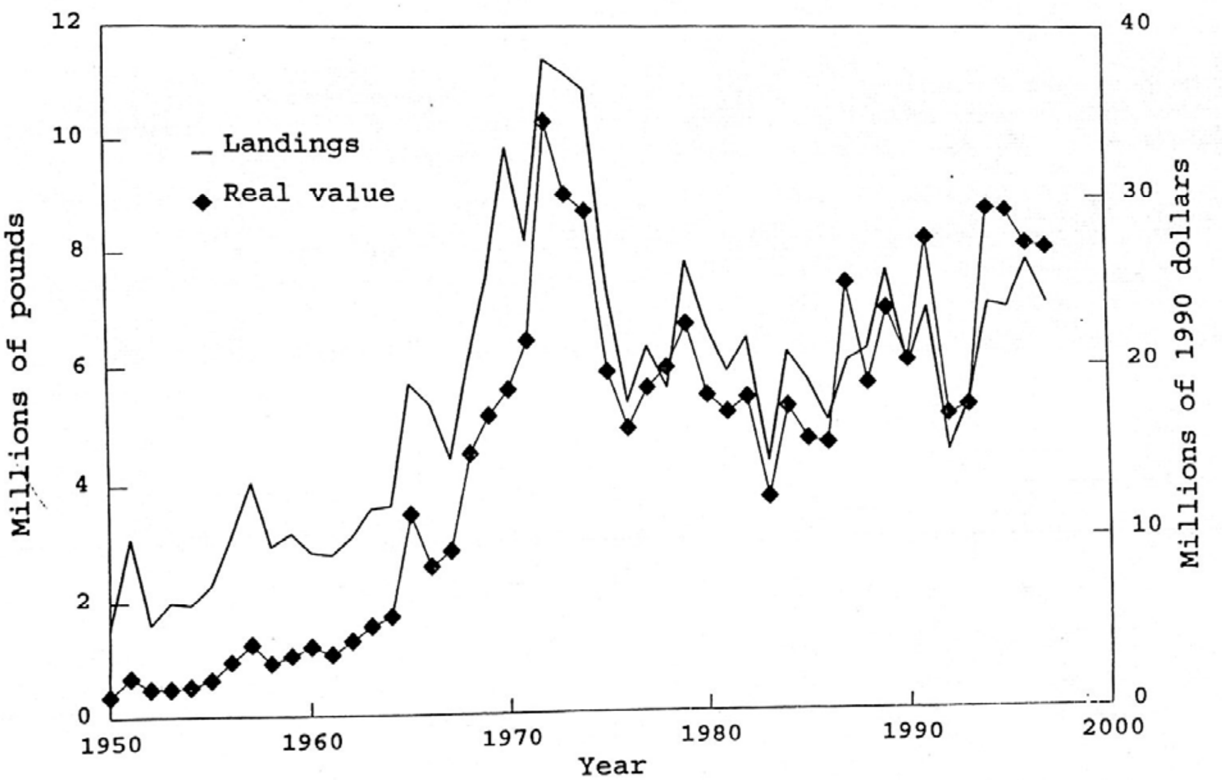


Figure 2.--Landings (1950-97)
Florida spiny lobster fisheries

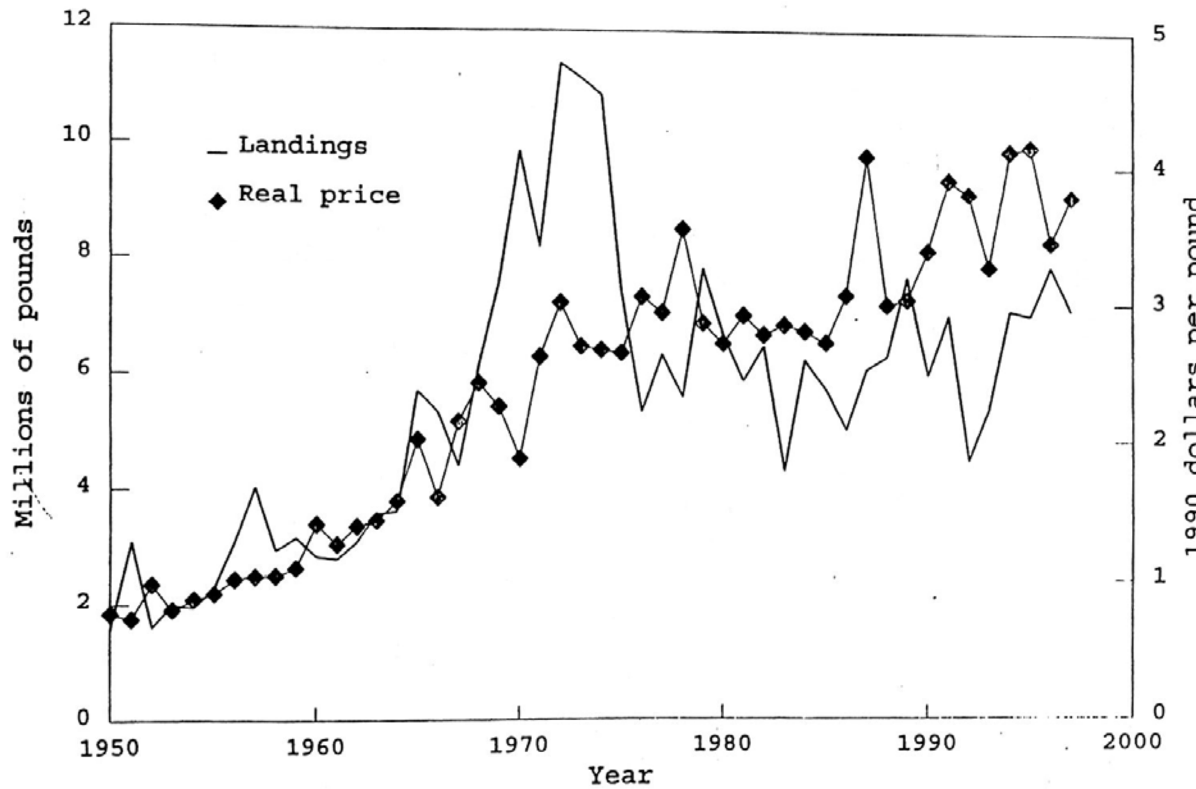


Figure 3a.--Operating units (1950-94), semi-log scale
Florida spiny lobster fisheries

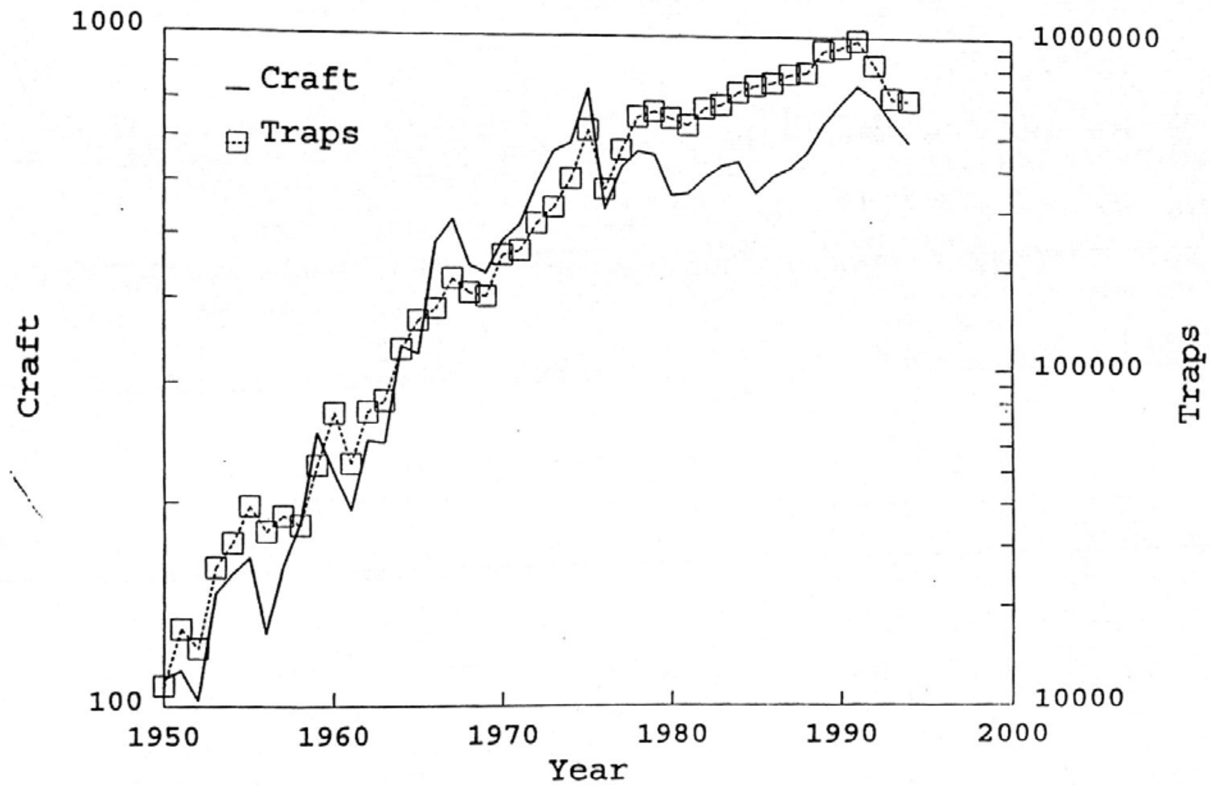


Figure 3b.--Operating units (1950-94)
Florida spiny lobster fisheries

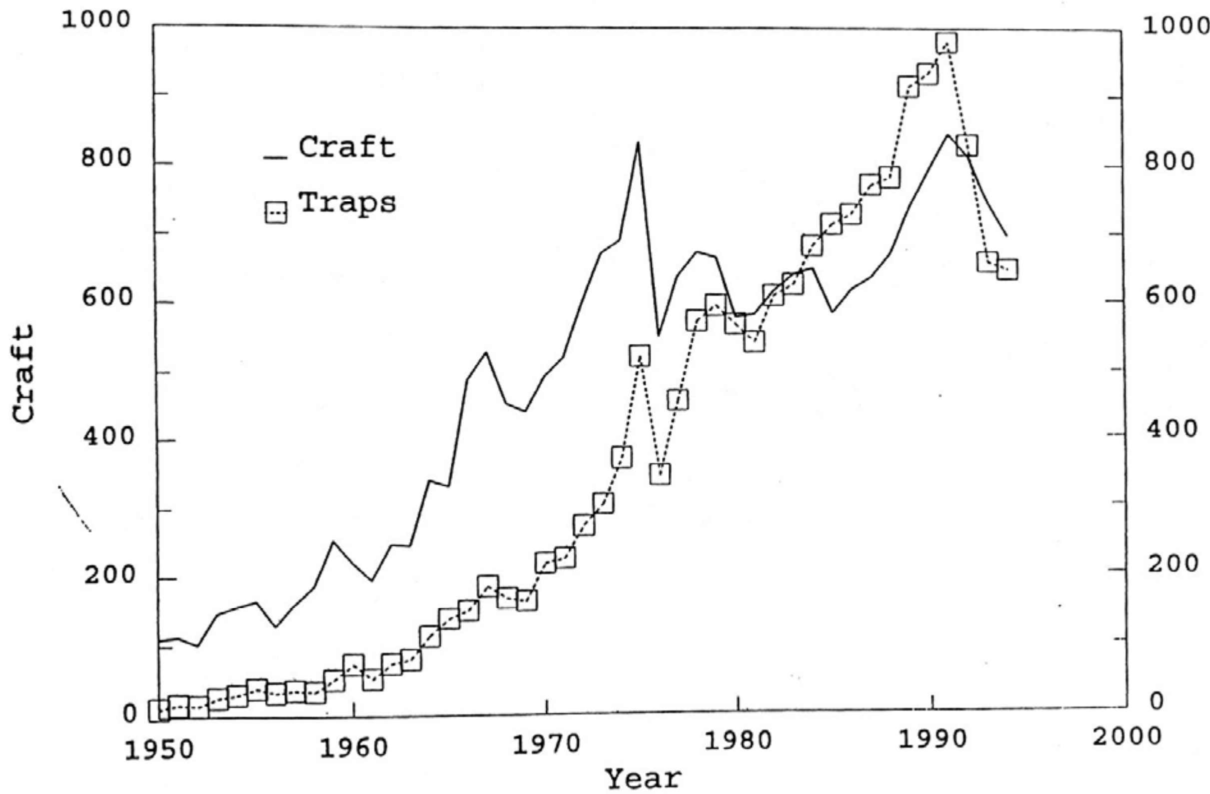


Figure 4.--Craft and fishermen (1950-94)
Florida spiny lobster fisheries

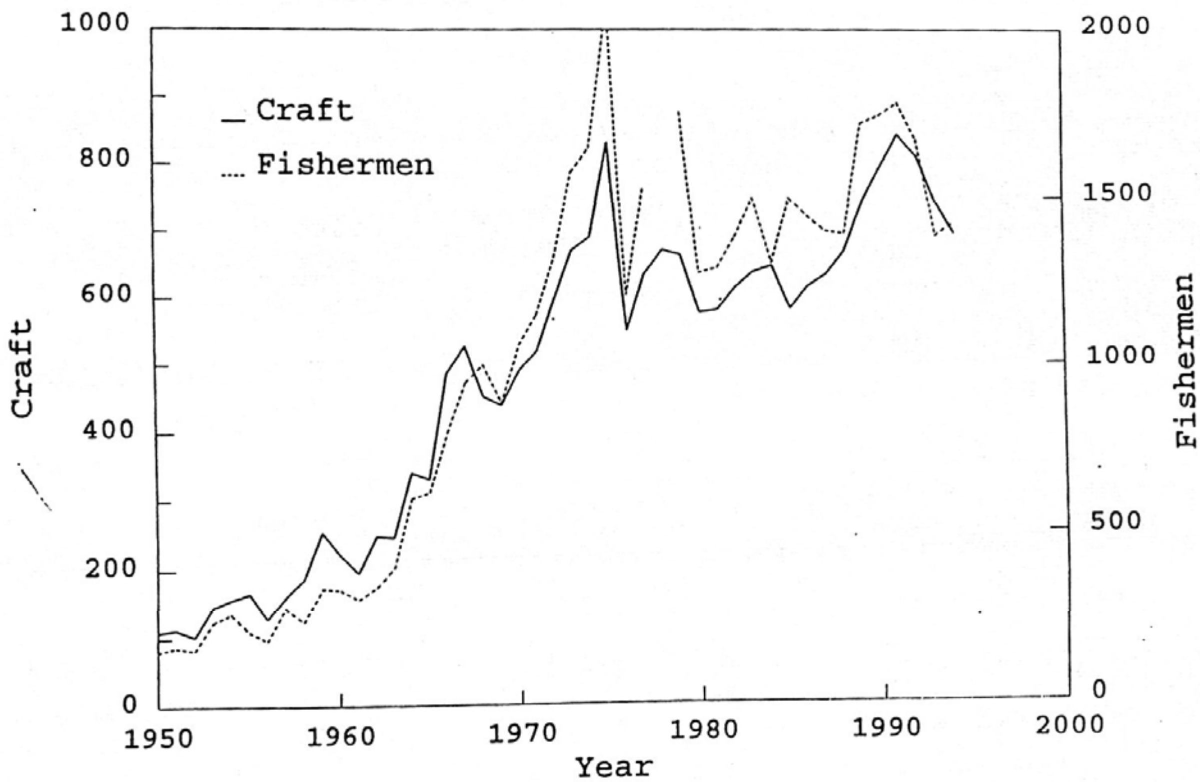


Figure 5.--Vessels (1950-96) and boats (1950-94)
Florida spiny lobster fisheries

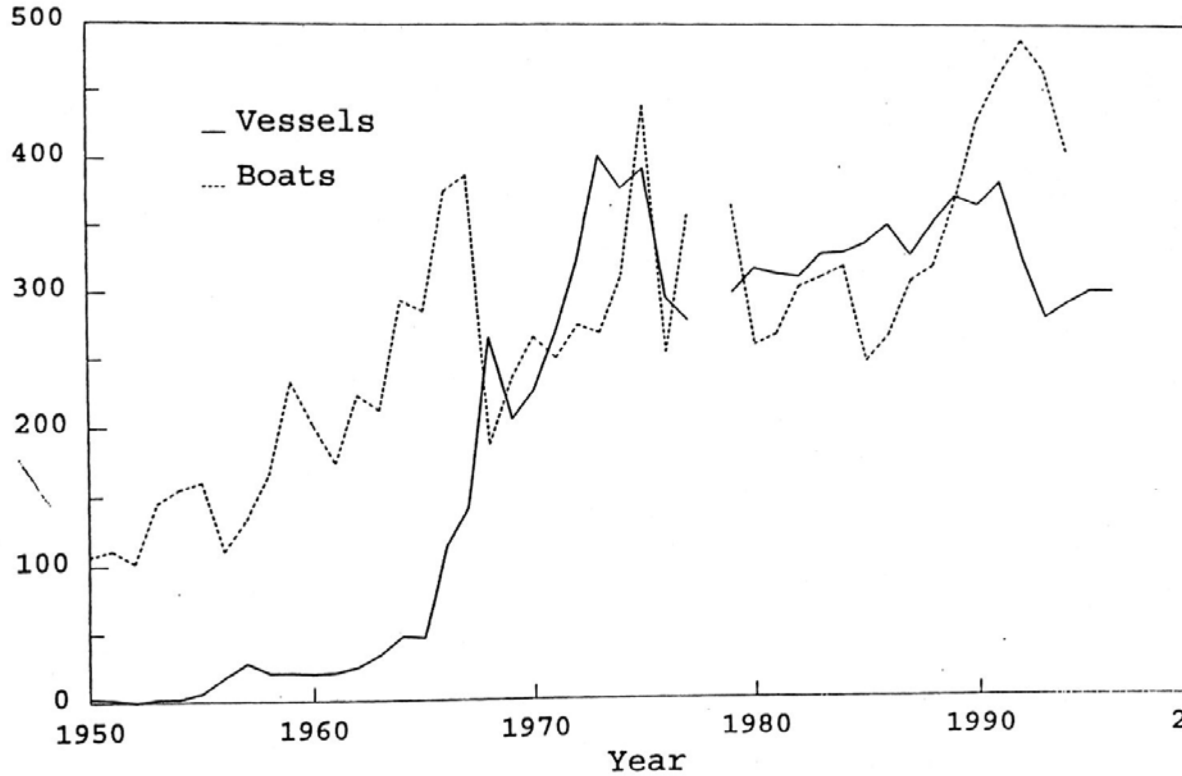


Figure 6.--Vessels, by coast (1950-96)
Florida spiny lobster fisheries

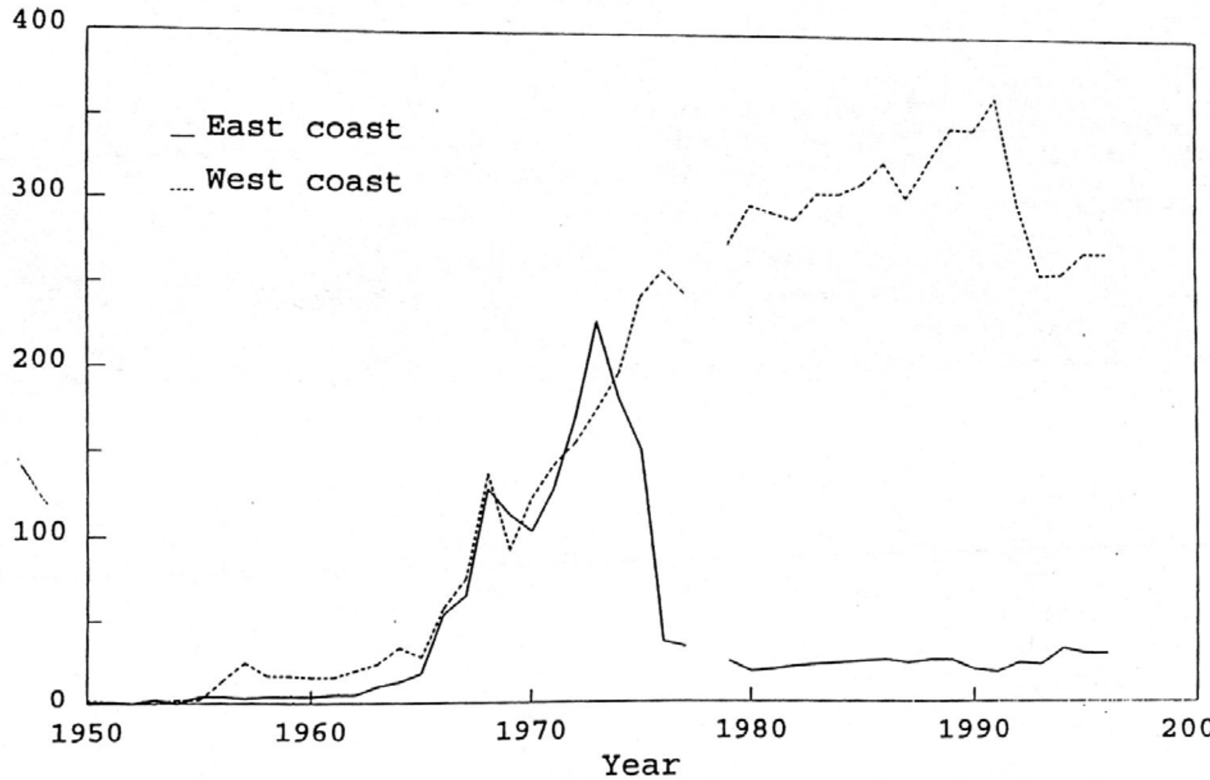


Figure 7.--Boats, by coast (1950-94)
Florida spiny lobster fisheries

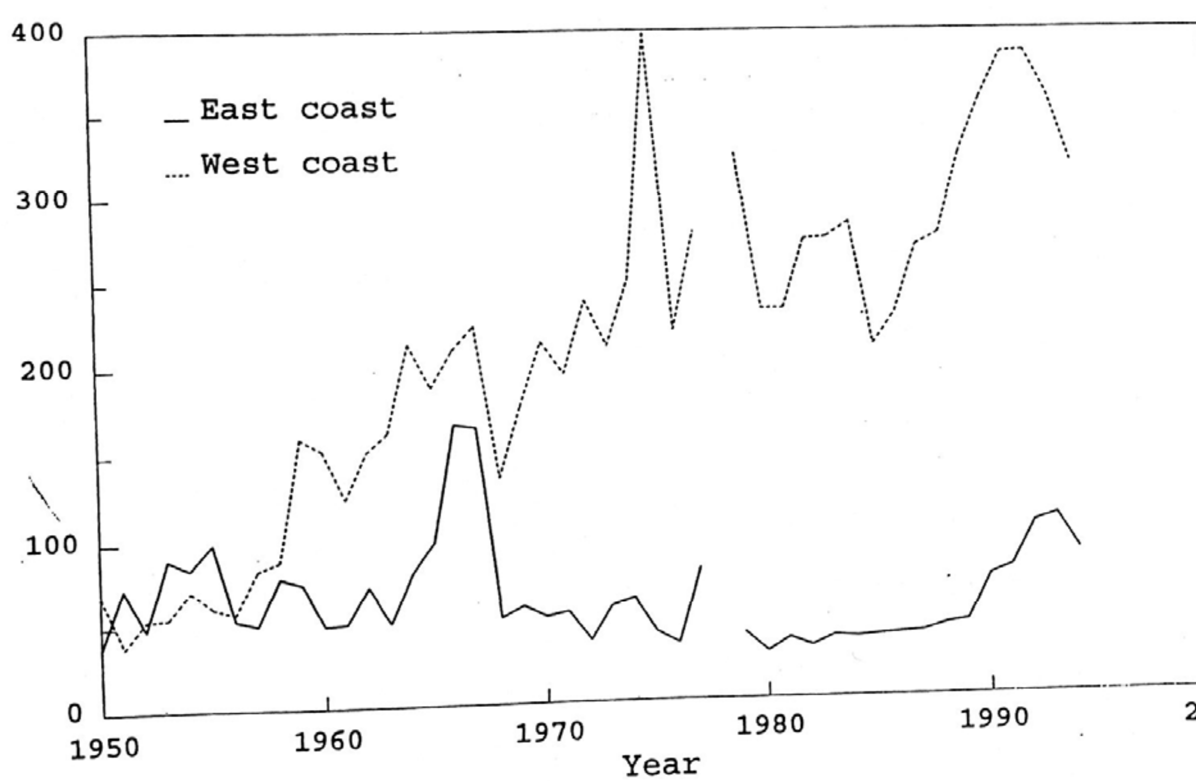


Figure 8.--Average trap productivity (1950-94)
Florida spiny lobster fisheries

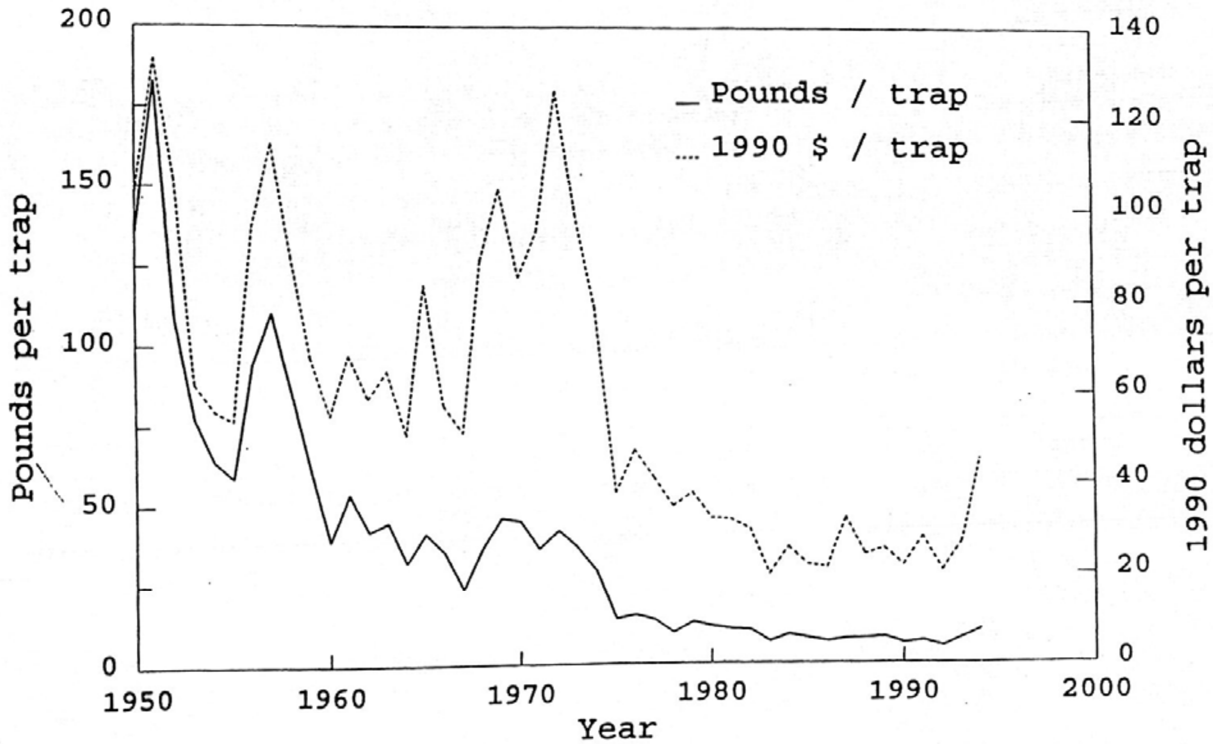


Figure 9.--Seasonal distribution of landings
Florida east coast spiny lobster fishery

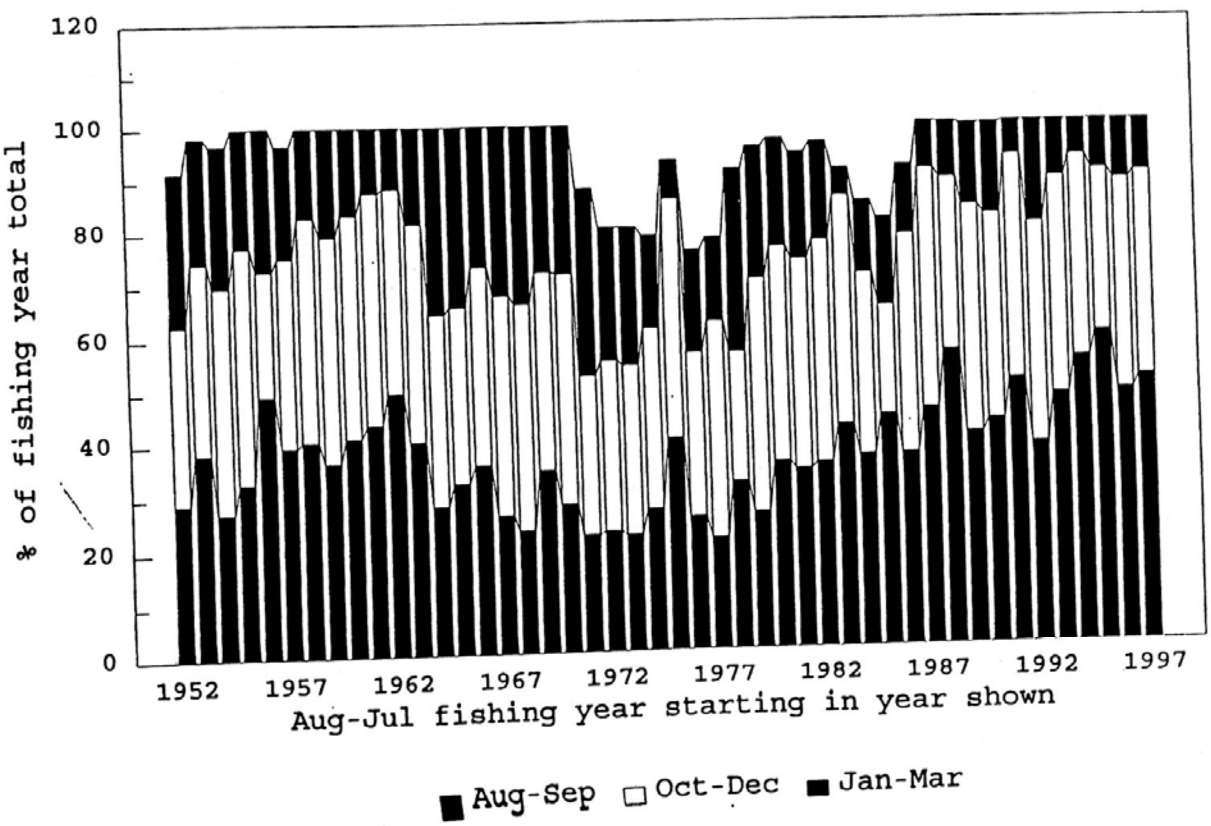


Figure 10.--Seasonal distribution of landings
Florida west coast spiny lobster fishery

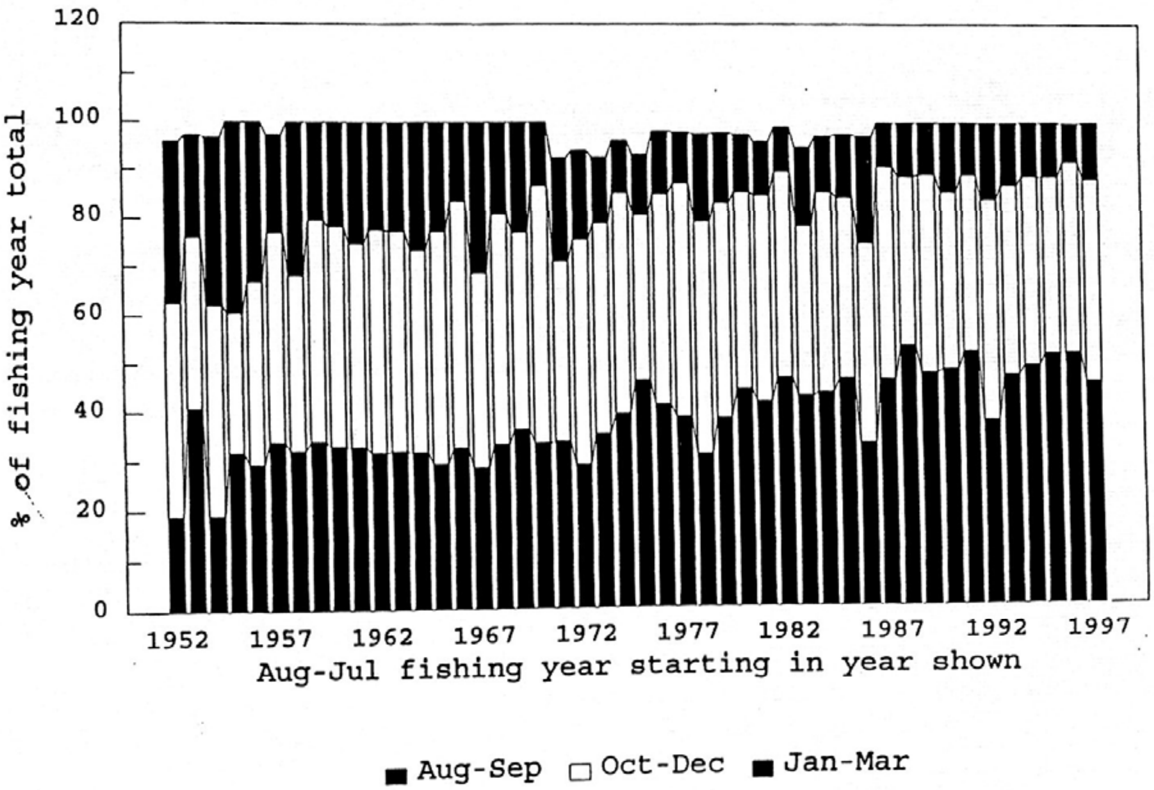


Figure 11.--Estimated U.S. consumption of spiny lobster (1950-97)

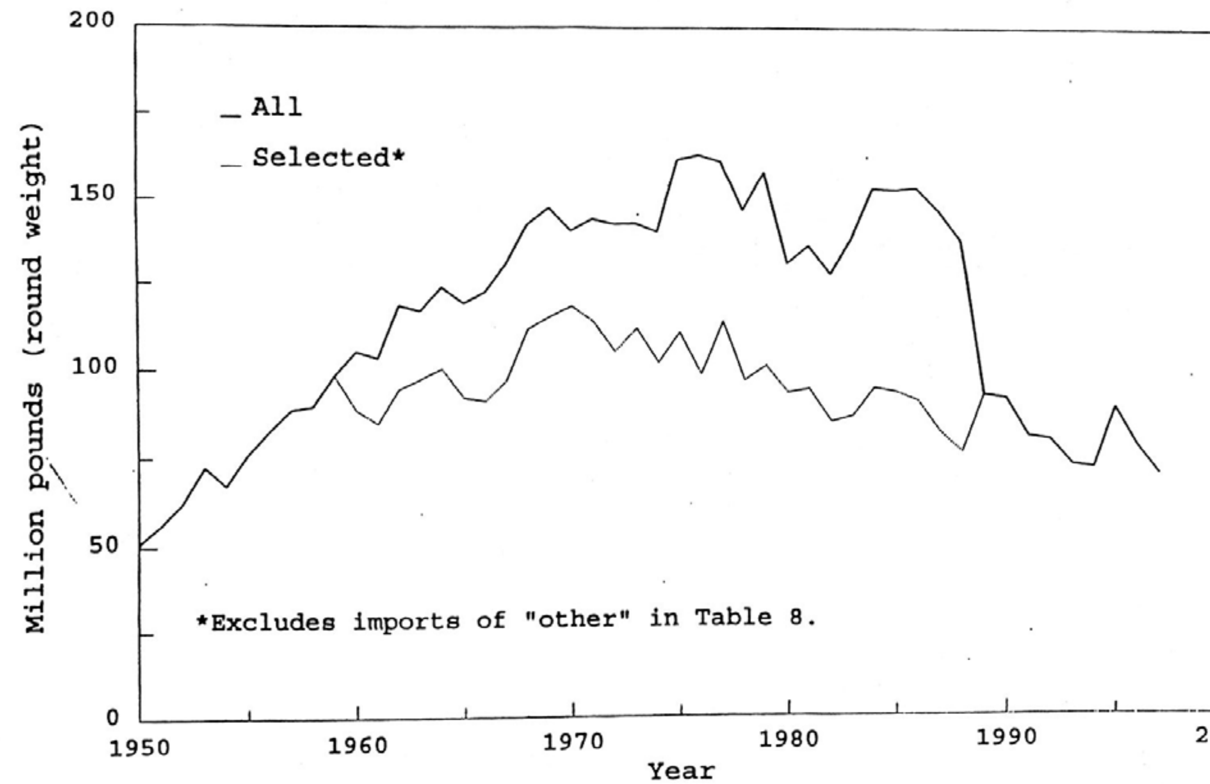


Figure 12.--Estimated Japan imports of live spiny lobster
Quantity and average unit value for 1974-97

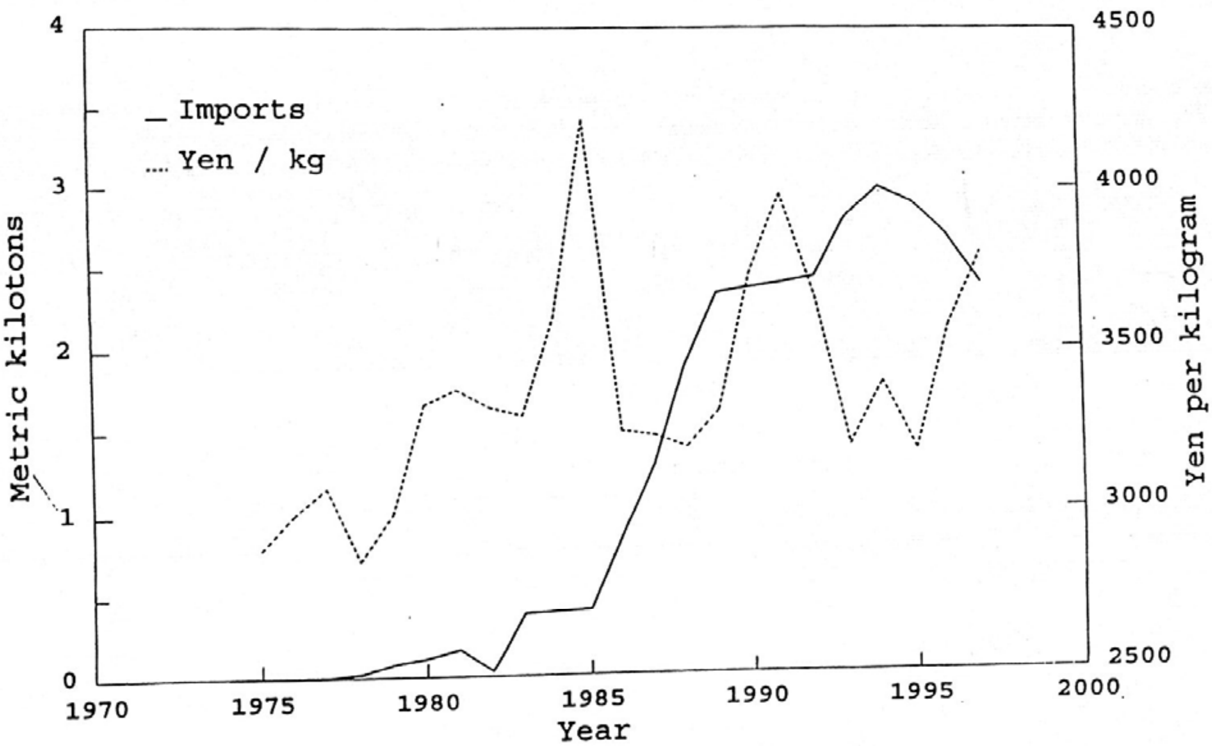
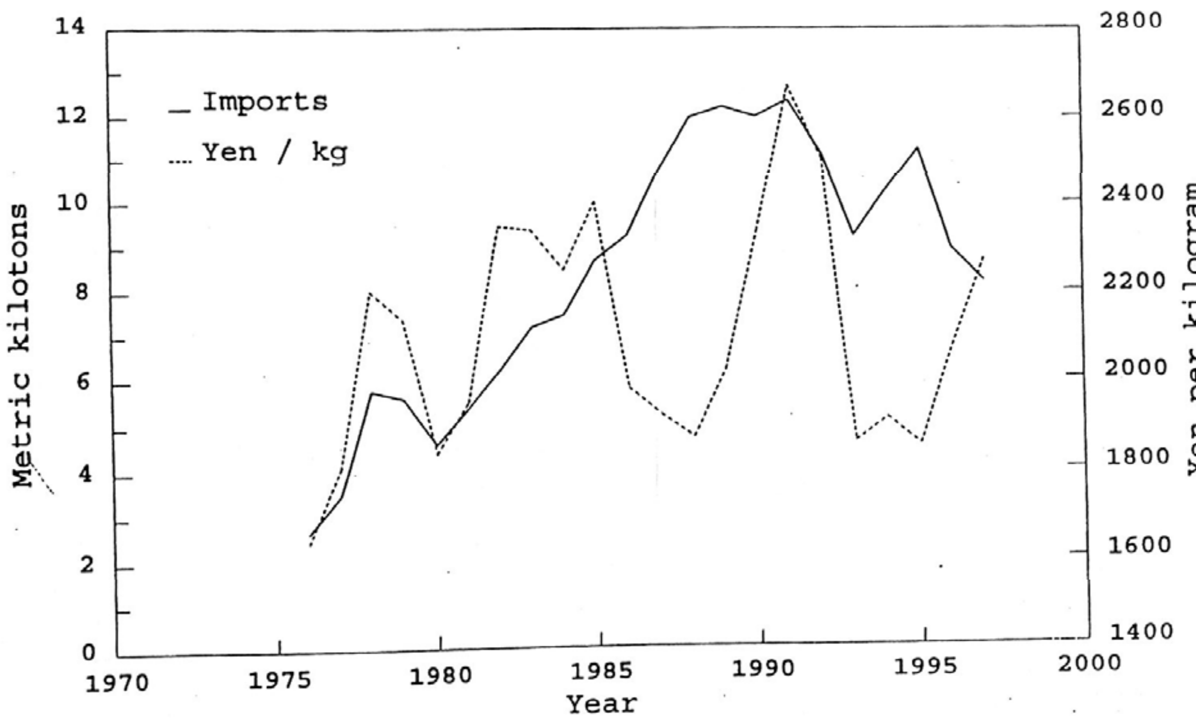


Figure 13.--Estimated Japan imports of frozen spiny lobster
Quantity and average unit value for 1976-97



Appendix D. The Developing Live Spiny Lobster Industry

NOAA Technical Memorandum NMFS-SEFC-395

THE DEVELOPING LIVE SPINY LOBSTER INDUSTRY

by:

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Notice

This report should be cited as follows:

William O. Antozzi, 1996. The Developing Live Spiny Lobster Industry. NOAA Technical Memorandum NMFS-SEFSC-395, 8 p.

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Acknowledgement

I would like to thank Richard C. Raulerson for his support of this project and my special thanks to Debbie Protomaster for her skills with desktop publishing. Also, thanks to the Florida seafood industry for their valuable assistance.

Introduction

A live spiny lobster industry has developed in the last few years and has become significant, with potential for future growth. This paper will describe this trend as well as provide some background information and implications for fisheries management consideration.

Fishing Industry

The Florida spiny lobster, Panulirus argus, is a decapod crustacean belonging to the family Palinuridae which contains almost 50 species that are principally tropical and subtropical in distribution. These palinurids support major fisheries worldwide, the five largest being found in Australia, South Africa, Brazil, Cuba, and the United States. In 1995, Florida accounted for 91 percent of U.S. spiny lobster production. California, Hawaii, Puerto Rico and the U.S. Virgin Islands accounted for the remainder.

The Florida spiny lobster fishery began around the turn of the century. However, significant production (consistently more than one million pounds annually) did not begin until 1941. Florida's heaviest annual catch of spiny lobsters was recorded in 1972 when fishermen landed 11.4 million pounds. That catch occurred when Florida boats were making substantial catches in Bahamian waters and landing them in Florida. Production has been averaging about six million pounds a year since 1980. In 1995, landings totaled 7.0 million pounds with a dockside (ex-vessel) value of 31.8 million dollars, a record. The current season opened in August with heavy landings and low dockside prices. This is not an uncommon occurrence at the beginning of the season, according to Ed Little, Fisheries Reporting Specialist for the National Marine Fisheries Service (NMFS) in Key West.

Management of spiny lobster occurs under a cooperative arrangement among the Florida Marine Fisheries Commission, the Florida Department of Environmental Protection, the South Atlantic Fisheries Management Council, the Gulf of Mexico Fisheries Management Council, and the NMFS.

The commercial fishing season extends from August 6 to March 31. Size limit regulations require that carapace length be greater than 3", and that lobsters be landed whole except under special permits. Over 2,000 spiny lobster fishing licences were issued for the 1995-1996 season. The spiny lobster fishery is now a restricted species fishery and it has become more difficult to enter the fishery.

Spiny lobster boats range in length from about 20 feet to 60 feet, but most boats in the fishery range from 35 feet to 40 feet. There are no freezer boats in the fishery. Most boats make one-day trips and the catch is kept in live wells or shaded boxes. Some boats, especially those fishing in deep waters further offshore, make three to five-day trips and keep lobsters on ice. Dockside (ex-vessel) prices vary according to form. For illustrative purposes, prices might be as follows:

1. Live ($3.75/pound) These lobsters are given "TLC" in a live well to maintain viability (for the live market).

2. Fresh ($3.50/pound) Lobsters which are kept cool in shaded boxes. Many are still alive when they are unloaded. They yield a high-quality processed product.

3. Fresh/iced ($3.25/pound) These lobsters are the result of multi-day trips, iced, seldom landed alive.

4. Fresh/iced/extra large ($3.00/pound) These lobsters are more than two pounds each, typically the result of deep water fishing, usually iced.

It is not uncommon for spiny lobster fishermen to engage in other fisheries, such as those for stone crab or golden crab, during the latter part of the spiny lobster open season when catch rates drop, as well as during the closed season.

Buoyed traps are the principal gear, made of wood, wire-reinforced wood, plastic, or wire, of dimensions 3 feet by 2 feet by 2 feet. Most of the spiny lobster fishery occurs on habitat associated with the Florida Keys and adjacent grounds, extending from the Dry Tortugas to Palm Beach.

During April 1996, a contentious situation surfaced that was induced by the proposed withdrawal by NMFS of the Spiny Lobster Fishery Management Plan (FMP) which covers federal waters (EEZ). Fishermen harvesting spiny lobster from the EEZ were concerned that their way of fishing would be jeopardized if the FMP withdrawal took place. The State of Florida does not authorize the use of wire traps as a lobster gear, while federal regulations allow their use. Without the FMP, management of spiny lobster would fall entirely to the State. Wire traps are favored by fishermen that fish the deeper federal waters because of their durability and ease of handling. Currently, NMFS has placed withdrawal of the spiny lobster FMP "on hold."

Processing and Marketing

Historically (pre-1980) the spiny lobster was rarely marketed alive although lobster frequently reached fish houses in the Florida Keys in live condition before being processed there or trucked to Miami for processing.

The main product forms of spiny lobster are:

1. Whole - raw ("whole green"): available fresh but usually frozen. Usually shipped in a 20-22 pound carton.

2. Whole - cooked: available fresh but usually frozen. Usually shipped in a 20-22 pound carton.

3. Tails - raw ("green tails"): frozen and usually deveined, shell-on. Deveining involves removal of the intestinal tract while leaving the meat and shell intact. Tails are usually shipped in 10 pound boxes, four boxes to a master carton.

4. Live: usually shipped in 10 kilo boxes.

Spiny lobster has become a gourmet item, frequently occupying the premier niche on restaurant menus and a favorite for special occasions and celebrations. In the United States, it is more expensive than American lobster (1995 whole weight average ex-vessel price for American lobster was $3.24 per pound versus $4.85 for spiny lobster). In most foreign markets, spiny lobsters command a price that is two or three times that of American lobster.

The domestic restaurant industry constitutes the major market for the whole raw, whole cooked, and raw tail market forms. Spiny lobster is also sold through supermarkets and retail fish markets, but this constitutes a much smaller volume according to Henry McAvoy, Development Representative, Florida Bureau of Seafood and Aquaculture. The live market is primarily an export market, and will be discussed in further detail.

Much of the U.S. demand for spiny lobster is being supplied by imports from Latin America (29 million pounds in 1995) comprised mostly of frozen raw tails (due to harvesting methods and lower freight costs per unit of value).

Export Data

Export data for spiny lobster was examined. Live spiny lobster exports for 1995 were reported as 123.9 metric tons (273,200 pounds). This data appears to be seriously flawed. Several wholesalers reported that individual companies had exported more than the official total.

The data, which is collected by U.S. Customs Service and collated by the Bureau of the Census, was examined on a transaction (individual shipment) basis by the author and Bob Ross, International Trade Specialist, NMFS, Northeast Region. It was determined that much of the spiny lobster export volume had been counted as exports of American lobster (New England lobster). This problem appears to have been caused by faulty data entry due to coding errors. Industry leaders have provided estimates on the volume of live spiny lobster exports industry-wide that range from 7% to 30% of total production (landings).

Live Spiny Lobster Industry

In order to describe this developing industry, the author conducted field and phone surveys of wholesalers, processors, fishermen, and exporters in Miami and the Florida Keys.

Until a few years ago, no one attempted to ship live spiny lobsters to distant markets because there was an unacceptable amount of mortality in transit. However, recent improvements in lobster handling, air routes, and packing technology have made it possible to ship live lobsters to markets where demand exists.

Around 1990, innovators in the live spiny lobster industry began to experiment with different packing methods, the goal being to produce a lightweight container that would maintain spiny lobster alive during air shipment. Early air freighting of live spiny lobster involved much experimentation and mortality rates varied. Successful techniques were eventually achieved and are still being perfected.

Basically, the methodology involves creation of a cool, moist environment with sufficient oxygen within the container. This environment must be stable throughout the shipment. The goal was achieved through the use of moist wood shavings, gel packs (blue ice) and Styrofoam-insulated containers. The cool environment apparently lowers the metabolism of the spiny lobster, putting them into a semi-dormant state during which oxygen requirements are reduced and stress is minimized. No water other than the moisture provided by the wood shavings is needed. Lobsters in transit remain viable for 48 hours with less than 5% mortality, according to some exporters.

Lobsters that have been maintained alive on-board are placed in live holding tanks as soon as possible after being brought to shore, usually at dealers' facilities. There are also some ancillary live holding facilities at strategic locations in the Florida Keys that are utilized by fishermen as drop-off points for live lobsters. Under arrangements with dealers, the lobsters are periodically collected and taken to the primary holding facilities. When orders are received, lobsters are removed from the holding tank and placed in the cool, moist, insulated boxes. Exporters commonly fill LD3's (large air freight containers) with boxed live lobsters (about 1000 pounds per LD3).

In order to ensure viability, product temperature must be maintained within certain parameters. This requires that exporters take into consideration the flight times and ambient temperatures throughout the shipment when initially adding the coolant to the containers.

Product destined for western Pacific countries is commonly air freighted to transhipment plants in Los Angeles first. There, the lobsters are unpacked and revitalized in salt water tanks. After a period of revitalization, the lobsters are repacked for the remaining flight to the Asian destination. Techniques have evolved to the point that this year, for the first time, live spiny lobsters are being flown directly, without revitalization, to Asian markets. Live product destined for Europe is flown directly from Miami International Airport.

Most of the major spiny lobster wholesalers are now involved in the live trade. Although some initially were very reluctant, the success and profits achieved by their competitors encouraged them to participate in the market. Currently there are about four large and five small concerns involved in exporting live spiny lobster.

At this time, Asian markets appear to be the strongest foreign markets for live U.S. spiny lobster, especially Taiwan and Japan. Asian markets put a high premium on quality and live product is considered to be paramount. Markets of lesser importance are found in France, the Netherlands, S. Korea, Italy, Canada, and Hong Kong, according to U.S. Census Bureau data.

Taiwan has experienced a 260% growth in spiny lobster imports (all market forms) during the last five years, with continued growth expected by industry insiders. This rapid growth is attributable to the considerable rise in consumer spending power and the propensity to spend on high value food items, especially when entertaining. Another important factor is the depletion of the indigenous spiny lobster stock due to overfishing. Taiwan is now 99% reliant on imports. The U.S. currently has 7% of the import market (Foreign Agricultural Service, 1996). Spiny lobster is held in very high regard by the Taiwanese, with local customs dictating that it be the main course at most wedding banquets. A temporary downturn in the Taiwanese market is evident at the time of this report, the result of slow economic conditions engendered by mainland China's recent threatening posture.

Japanese acceptance of Florida spiny lobster is very good, second only to South African rock lobster which has redder coloration, a trait desired by Japanese consumers. The appearance of the lobster is important to the Japanese (intact body with no legs or antenna broken). The average size of live spiny lobster from Florida is about 500 grams (1.1 pounds), with an average value of 3,000 yen per kilogram ($13.60 per pound), according to data collected at the Tsukiji Central Wholesale Market in Tokyo (provided by Tom Asakawa, Fisheries Specialist, U.S. Embassy in Tokyo). Restaurant prices in Japan reportedly run 3-4 times Japanese wholesale prices.

Most live spiny lobster exports occur during August and September. This is when Florida Keys production is at its highest and this period precedes open seasons for spiny lobsters in Australia, Mexico and California. This fortuitous combination of high Florida production and critical timing provides the two-month "window" that is driving the live export industry.

Legal Size and Market Size

State and Federal laws currently require harvested spiny lobster to have a carapace length greater than 3" in order to be legal. This size limit seems well suited to allow the production of live spiny lobster of the size in demand in foreign markets, i.e., it results in a significant production of spiny lobster that weigh between 1-1.25 pounds. Exporters report that this is an excellent size for the foreign live market. If the carapace size limit were changed to 3.5", for example, the result would be production of lobster weighing 1.5 pounds and above, too big for Asian markets, although somewhat acceptable for sectors of the European market. Of course a higher size limit would also affect the domestic market, which is principally a tail market. Processors would lose the ability to produce 5-8 ounce tails, a popular size (and more valuable on a per pound basis than larger sizes).

A majority of wholesalers and exporters of spiny lobsters favor maintaining the minimum size limit at the three-inch carapace length and opine that any change to a larger minimum size would seriously damage the burgeoning live spiny lobster industry, as well as curtail the ability to produce small tails. Some wholesalers would prefer a smaller size limit (i.e., two and seven-eighths inches).

Future Outlook

The future of the Florida live spiny lobster industry looks bright. Spiny lobster is a very popular seafood item in much of the world. Recent trade negotiations have produced results that are expected to reduce foreign trade barriers and increase the opportunities for live spiny lobster exports in countries where demand is high.

Taiwan is currently applying to enter the GATT/WTO (General Agreement on Tariffs and Trade, World Trade Organization) and, upon joining, will incrementally reduce the tariff on spiny lobster from 42.5% to 15% over a five-year period on all market forms including live. This should open up this lucrative market further to U.S. exports. At the moment, the People's Republic of China is reportedly causing problems by insisting that they should be accepted into GATT/WTO before Taiwan.

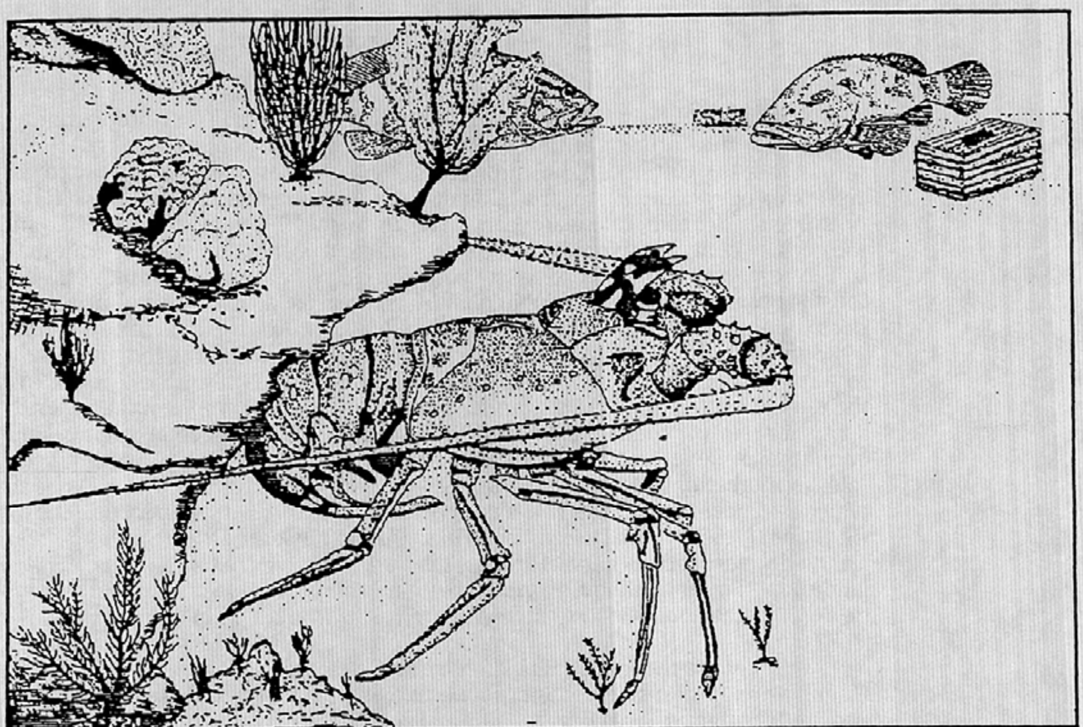
Japan is expected to continue as a leading market. In fact, Tom Asakawa, Fishery Specialist at the U.S. Embassy in Tokyo, has listed spiny lobster as one of the two top prospects for increased U.S. exports to Japan. The Japanese tariff on spiny lobster is low (2.6%).

The European Union, as a result of the Uruguay Round of the GATT, has agreed to lower its tariff from 25% to 15.5%, incrementally over a five-year period, on all market forms of spiny lobster including live. This will greatly expand the potential for the development of live markets in Europe (primarily in Italy, France, and the Netherlands).

In summary, the development of live spiny lobster merchandising has provided increased viability and profitability for the Florida spiny lobster industry. Future growth will depend on the reduction of trade barriers and the prudent management of Florida's spiny lobster resource.

Appendix E. The 1995 Spiny Lobster Update of Trends in Landings, CPUE, and Size of Harvested Lobster (NMFS-SEFSC-395).

THE 1995 SPINY LOBSTER UPDATE OF TRENDS IN LANDINGS, CPUE, AND SIZE OF HARVESTED LOBSTER



by

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September 1995

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The 1995 Spiny Lobster Update of Trends in Landings, CPUE, and Size of Harvested Lobster

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Introduction

The Caribbean spiny lobster (Panulirus argus) is a valuable, highly exploited marine crustacean inhabiting shallow shelf waters off the southern United States, Bermuda, and throughout the Caribbean. In Florida, spiny lobster are principally caught by commercial trap fishers using wooden slat traps, although some commercial harvest by SCUBA divers and bully nets occurs. From calendar years 1986 through 1990 and during 1993 and 1994, the spiny lobster had consistently ranked as the second most economically important marine species landed in Florida being surpassed only by pink shrimp in commercial value. In 1991 and 1992 spiny lobster became the most valuable commercial marine species landed in Florida primarily due to decreased pink shrimp landings. Based on National Marine Fisheries Service (NMFS) data, the 1986 through 1994 spiny lobster ex-vessel value in Florida ranged from $13.2 million in 1986 to a record high $28.2 million in 1991 and averaged $20.8 million or approximately 10.8% of the total value for all Florida marine species harvested by commercial fishers. The Florida 1994 spiny lobster ex-vessel value of $26.9 million was the second highest annual spiny lobster commercial value recorded for the state. In Florida, the spiny lobster is also the target of an intense recreational fishery (Davis, 1987; Davis and Dodrill, 1980; Davis and Dodrill, 1989) which includes an annual two-day sport diving harvest that precedes the commercial season (Simmons, 1980). Bertelsen and Hunt (1991), using a mail survey, recently estimated the statewide recreational harvest during the 90-91 lobster season to equal 29% of the commercial landings. The magnitude of the recreational lobster harvest had been previously estimated to be 10% of the total lobster catch (Zuboy, 1980; Moe, 1991).

Spiny lobster in the Florida territorial sea are managed by the Florida Marine Fisheries Commission, while spiny lobster in the Exclusive Economic Zone (EEZ) off the Gulf of Mexico and south Atlantic coastal states are managed under the Fishery Management Plan of the Gulf of Mexico and South Atlantic (FMP) prepared by the Councils. On December 30, 1992, a rule to conform Florida and Federal regulations under Amendment 2 to the FMP became effective. This rule adopted Florida's spiny lobster trap certificate, trap reduction, and trap identification programs in the EEZ off Florida; reduced the number of undersized lobsters used as attractants in traps to 50 per vessel, or one per trap onboard, whichever is greater; specified diving and use of bully net, hoop net, and trap as the only authorized method/gear for the spiny lobster in a directed EEZ fishery; and established a catch limit of 5 percent, by weight, of all fish aboard for the incidental harvest of spiny lobster by trawls in the EEZ. Florida's spiny lobster trap certificate program became effective August 1993 and required that tags (1 certificate = 1 tag) issued by the Florida Department of Environmental Protection (FDEP) be attached to all spiny lobster traps. The total 1993 lobster season allocation of certificates was 700,000 plus an additional 125,000 certificates to be used during an appeals process to settle disputes raised by fishers concerning their initial certificate allocation (Hunt, 1994). Each fisher's allocation was based upon that inividual's reported landings during one of three benchmark fishing seasons (1988-89, 1989-90, or 1990-91). Other management regulations intended to provide for resource conservation are contained within Florida statues and the FMP. These regulations include but are not limited to the following: 1) setting a minimum size limit of 3 inches (76.2 mm) carapace length; 2) closing the fishing season April through July; 3) prohibiting the harvest of egg bearing females; 4) requiring that undersized lobster which will eventually be used as bait or decoys in traps be maintained in a continuously circulating live well while aboard the vessel. In addition to the management regulations described above, several large areas along the south Florida coast have been designated as lobster sanctuaries in which no harvest of spiny lobster is permitted. Due to concern caused by the intensive exploitation of the resource, the spiny lobster fishery and biological data have been periodically re-examined by the National Marine Fisheries Service (NMFS), Southeast Fisheries Science Center (Powers and Bannerot, 1984; Powers, 1985; Powers and Thompson, 1986; Thompson and Powers, 1987; Newlin, 1988; Powers and Sutherland, 1989; Harper, 1991; Harper, 1992; Harper, 1993; Harper, 1994). The objectives of this report are to examine: (1) trends in commercial landings and effort; (2) catch per unit of effort (CPUE); (3) size of lobster in commercial and recreational catches; and (4) recent research concerning spiny lobster life history and fishery aspects.

Data Sources and Methods

The data sources and methods of analysis are essentially identical to those reported in Harper (1992) with the addition of the 1994-95 season's data and some additional information which will be discussed below. The statistics reported in Harper (1994) and included in this report are: 1) Florida commercial lobster landings summarized by coastal area (east coast - Dade and other Atlantic coast counties; west coast - Monroe and other Gulf coast counties), 2) number of fishing craft and traps in the fishery based on data obtained during an annual canvas of seafood dealers and fishers by NMFS personnel, 3) seasonal catch per trap obtained by dividing total commercial landings by number of traps in the fishery, 4) monthly and seasonal catch per fishing trip based upon Florida Marine Trip Ticket System (FMTTS) data for those trips in which greater than 75% of total landings were spiny lobster, 5) mean size (carapace length) of lobster in commercial landings by area utilizing the Trip Interview Program (TIP) data collected by NMFS and FDEP personnel, 6) commercial lobster landings by gear type from U.S. southeastern states other than Florida, and 7) recreational lobster size data collected as part of the Biscayne National Park Creel Census. In addition to the above information, this report contains an estimate of the percentage of annual Florida spiny lobster landings caught at various distances from shore. The General Canvas Landings database, maintained by NMFS, is the source for these estimates and this information can be useful in partitioning spiny lobster landings into state territorial sea waters and EEZ waters.

The opening date for the spiny lobster fishing season has changed several times since 1960 but has usually begun during the last week in July or the first week in August. The season since 1960 has extended through the last day in March of the following year. Information contained within this report will be summarized by month or fishing season. Fishing season in the text will be referred to by the year beginning the season, hyphen, and then two digits to indicate an extension into the following calendar year (eg. 1980-81 season encompasses the period from the season opening date in 1980 and extending through March 31, 1981). Tables and figures within this report will also indicate fishing season as described above. It should be emphasized that the data for the 1994-95 season are preliminary and therefore probably incomplete and subject to revision.

Results and Discussion

COMMERCIAL FISHERY

Landings and Effort

Spiny lobster commercial landings in Florida increased from 2.8 million pounds in 1960-61 to a maximum of 11.9 million pounds in 1972-73. (Table 1, Fig. 1). Landings decreased from 1972-73 until 1975-76, with a dramatic decline of over 3.6 million pounds occurring in 1975-76 when compared to the previous season. Seasonal total Florida spiny lobster landings since 1975-76 have fluctuated, averaging about 6.1 million pounds through 1994-95 with a range of 4.3 to 7.9 million pounds. In recent seasons, an increase from 5.4 million pounds in 1986-87 to 7.9 million pounds in 1989-90 is noted. The preliminary estimated harvest for the 1994-95 season is 7.2 million pounds or about 1.9 million pounds more than the 5.3 million pounds landed during the 1993-94 season.

Florida west coast landings were greater that east coast landings for all seasons except 1972-73. Florida east coast landings increased steadily from 1960-61 (0.7 million pounds) through 1972-72 (7.2 million pounds) and then decreased rapidly to about 1.2 million pounds in 1975-76. Increases in Florida east coast landings from 1965-66 to 1975-76 were for the most part due to increased U.S. fishing effort in the Bahamas. An estimated 17% to 57% of total Florida spiny lobster landings from 1965 through 1975 were taken from "international waters", principally the Bahamas (Labisky, et. al., 1980). Florida east coast spiny lobster landings declined during the early 1970's when the Bahamian Government began enforcing fishery laws (Johnson, 1973). In 1975 all foreign commercial fishing was prohibited on the Bahamian continental shelf. The rapid decline in Florida east coast spiny lobster landings between 1972-73 (7.2 million pounds) and 1978-79 (0.7 million pounds) reflect the closure the Bahamian waters to U.S. spiny lobster fishers.

Pounds landed and landing percentages by month for the August- March periods from Florida's west coast during the 1960-1994 seasons are shown in Table 2. In the lobster seasons after 1979-80, an average of 78.8% of the total Florida west coast landings were harvested during the first four full months (August through November or approximately one half of the entire lobster season) suggesting that the effective fishing season is only about one half as long as the legal fishing season in Florida. During 1994-95, 81.0% of the total Florida west coast harvest was landed before December, a percentage slightly above the 1980-81 through 1994-95 seasonal average of 78.8%.

The number of reported craft in the spiny lobster fishery increased from 221 in 1960-61 to 823 in 1975-76 then decreased substantially to 549 in 1976-77, and fluctuated between 517 and 672 during the 1976-77 through 1985-86 seasons (Fig. 2, Table 1). Since 1985-86, number of craft has increased rapidly from 517 to a 813 in 1992-93 and then declined to the present estimate of 753 craft for 1994-95. The primary fishing gear for lobster in the commercial fishery is the wooden slat trap. The number of traps in the fishery has fluctuated, yet has maintained a steadily increasing trend from a low of 52,000 in 1961-2 to a maximum of 939,000 in 1991-2; and averaged 859,000 traps during 1987-8 through 1991-2 (Fig. 3; Table 1). Since 1991-92, the number of traps in the fishery has declined to the present 1994-95 estimate of 674,000 traps. This decline represents a 28.2% decrease over three seasons from the all-time high trap estimate recorded for 1991-92. The average number of traps per spiny lobster fishing craft increased from 1960-61 (325) through 1989-90 (1,236), with a sharp increase occurring from 455 traps/craft in 1973-74 to 1,105 traps/craft in 1981-82 (Fig. 4.). The mean number of traps per spiny lobster fishing craft was estimated at 895 for the 1994-95 season.

Commercial lobster landings by gear type from U.S. southeastern states other than Florida for 1980-1994 obtained from the NMFS Accumulated Landings database are shown in Table 3. During this time period, Alabama had reported landings of 5,831 pounds followed by South Carolina with 1,356 pounds. No landings were reported from North Carolina or Louisiana. Reported annual commercial spiny lobster landings from the southeastern U.S., excluding Florida, were highest during 1988 when a total of 2,644 pounds were recorded. Since 1988, reported landings declined with only 17 total pounds recorded during 1994. For the entire period 1980 through 1994 and all U.S. southeastern states except Florida, percent lobster landings by gear type were as follows: shrimp otter trawls (76.0%), hand lines (7.5%), diving/snorkeling (7.3%), fish otter trawls (5.2%), hand capture (2.7%), spears (1.0%), and unknown or unidentified (0.2%). Reported commercial spiny lobster landings from states other than Florida are quite small and therefore inconsequential.

In an effort to determine the relative contribution of total spiny lobster landings from Florida's territorial sea and the EEZ off Florida, the General Canvas Landings database was examined. The detailed files for this database include annual (calendar year) spiny lobster landings by Florida coast (east and west) with a distance caught from shore variable associated with these landings. The distance caught from shore categories include: 1.) from the shore up to a distance of 3 nautical miles from shore; 2.) from 3 nautical miles up to a distance of 12 nautical miles; and 3.) 12 nautical miles and/or greater distance from shore. For the east coast of Florida, category 1 indicates state territorial waters while categories 2 and 3 indicate the EEZ. For the west coast of Florida, category 1 would include state territorial waters, category 3 would include the EEZ, and category 2 could include a mixture of state and EEZ waters, since the state/EEZ boundary is located 9 nautical miles offshore Florida's west coast. Table 5 presents the 1980 through 1992 percentages of total domestic spiny lobster landings by state territorial sea/EEZ for the Florida east coast and the three distance from shore categories for the Florida west coast. On the Florida east coast, the relative contribution indicated for the EEZ is decreasing (73.4% in 1980 and 12.7% in 1992). While the trend in Florida west coast spiny lobster landings from the EEZ is somewhat complicated by inexact boundary demarkation (the 3 to 12 nautical mile mixed category), it appears that the EEZ contribution of total west coast landings is increasing (0.7% in 1980 and 11.2% in 1992.

Catch Per Effort

Seasonal catch per trap exceeded 25 pounds, from 1960-61 to 1974-75 (Fig. 4). A sharp decline in pounds harvested per trap from 43.6 pounds in 1972-73 to 12.1 pounds in 1975-76. Since 1976-77, seasonal catch per trap has tended to decline steadily with a record low 6.5 pounds per trap estimated for 1992-93. The inverse relationship between catch per trap and number of traps per fishing craft (Fig 4.) indicates that fishers increased the number of traps fished in the late 1970's after their landings per trap had greatly decreased, possibly in an attempt to compensate for the reduced income. Comparing the number of traps in the fishery to total Florida commercial landings (Fig. 5) indicates that increased number of traps did not result in yield per trap increases after 1976-77. Additional trap increases coincide with further declines trap yields after 1976-77. This suggests an excess of effort within the fishery when numbers of traps exceed a range delineated by the 1972-73 level (272,000) and the 1976-77 (347,000).

Seasonal (1984-85 through 1994-95) mean lobster catch per trip as reported by 324,212 spiny lobster trip tickets in the FMTTS is shown in Figure 6. The overall 1984-85 through 1994-95 mean catch per trip was 186.3 pounds although mean landings per trip have varied between years. Mean pounds landed per trip increased 25.5% from 140.6 pounds in 1984-85 to 176.6 pounds in 1985, although this increase may be overstated because of low numbers of trips reported during the early months (August, September, and October) of 1984 on the FMTTS. Another increase occurred in 1988-89 when mean pounds landed per trip increased to 215.7 pounds from 174.1 pounds in 1987-88 (a 24.0% increase) and then maintained this increase into the 1988-89 season with 215.9 pounds. Mean pounds landed per trip then decreased to 166.3 in 1990-91 and remained relatively stable through 1991-92 (164.8 pounds) and 1992-93 (164.7 pounds). The 243.7 pounds per trip calculated for 1994-95 represents an increase of 34.3% as compared to 1993-94 and is also a highest value for this statistic since inception of the FMTTS. As reported in (Harper, 1993) the number of spiny lobster trips completed during 1992-93 (31,316) was reduced due to the passage of Hurricane Andrew across southern Florida on August 24, 1992. This trend in reduced numbers of reported trips continued into 1993-94 (27,555 trips). During 1994-95, a slight reversal of this trend is noted with the number of reported trips increasing to 28,537, an increase of 882 trips or 3.5% over 1993-94 levels.

Monthly mean lobster catch per trip and number of trips reported by month for the FMTTS data is shown in Figure 7. Harper (1992) reported that FMTTS data, when analyzed for monthly number of trips and monthly catch per trip, exhibits a general trend with mean pounds landed per trip being higher during the first half of each season (August through November), followed by sharp decreases in both the number of trips and mean catch per trip in the second half of each season (December through March). This trend continued into 1994-95 (Fig. 7). Although mean catch per trip on a monthly basis for 1994-95 demonstrated comparable trends with previous seasons (Fig. 7), the monthly catch rates per trip were slightly elevated, more similar to the earlier seasons (1985-85 through 1989-90) than more recent seasons (1990-91 through 1993-94).

Size of Lobster in Commercial Landings

During Trip Interview Program (TIP) data collection, NMFS sampled 25,331 lobster from two areas (Table 4; Fig. 8) for 1985-86 through 1994-95 and FDEP sampled 30,222 lobster from eight areas (Table 4; Fig. 9) for 1987-88 through January 1995. Mean carapace lengths (mm) of lobster from TIP sampled commercial trips in the Florida Keys were examined (Table 4; Figs. 10 and 11). The trends in mean lobster size from sampled commercial catches, for the most part, are quite variable by area. Although, a slight bias toward increasing sizes in the 1987-88 through 1990-91 period with a trend toward decreasing mean lobster size after 1990-91 is noticeable in the graphic displays.

RECREATIONAL FISHERY

Size of Lobster in the Recreational Harvest

Mean sizes of measured lobster carapace lengths (mm) from recreational trips sampled during the intercept surveys conducted by National Park Service personnel from boat ramps within and adjacent to the Biscayne National Park, south Dade County, Florida from 1976 through 1994 were examined (Figure 12). Overall the mean carapace length was 84.3 mm (range = 65 to 168 mm; sd = 7.59) from a total of 26,238 lobster measurements recorded during this Biscayne National Park Creel Census. Most of these data were obtained during the special two-day sport lobster season which precedes the regular lobster season. For most lobster seasons in this dataset, the mean carapace length from sampled recreationally harvested lobster has been variable, yet has remained within the 83 to 85 mm mean size range. The large decrease in mean lobster carapace length recorded during 1984-84 may be the result of a major El Nino event which occurred during 1983.

OTHER RECENT RESEARCH

An additional concern to the health of the spiny lobster fishery in Florida has been the documentation of a catastrophic mortality of sponges and disappearance of seagrass habitat, along with a marked juvenile spiny lobster abundance decline in areas of Florida Bay (Anon. 1992). Sponges and seagrass provide critical habitat for juvenile spiny lobster during early development. The loss of seagrass habitat, recurring cyanobacerteria blooms, and subsequent mass mortality of sponges has resulted in juvenile lobster abundance decreases estimated at nearly 50% for formerly productive nursery areas in much of central Florida Bay (Butler, 1994). It is unclear whether this loss of juvenile lobster nursery habitat and subsequent decline in juvenile spiny lobster abundance will have lasting effects upon the Florida spiny lobster fishery.

Summary

Total Florida spiny lobster commercial landings have averaged around 6.1 million pounds since 1975-76. During 1994-95 commercial fishers harvested 7.2 million pounds of spiny lobster or approximately 1.9 million pounds more than during 1993-94. During 1994-95, the estimated number of traps (674,000) and number of craft (753) in the fishery declined, as the initiation of Florida's trap certificate/reduction program in August 1993 continues to impact fishery operating units and participants. Measures of 1994-95 spiny lobster CPUE; mean seasonal catch per trap (10.7 pounds), mean catch per trip (248.6 pounds), and mean catch per trip on a monthly basis (range = 122.5 to 291.5 pounds) showed increases when compared to 1993-94.

Acknowledgements

I thank the Florida Department of Environmental Protection and Martha Norris for providing spiny lobster Florida Trip Ticket System and trap certificate data; Rick Beaver, FDEP, Marathon, Florida for additional information about TIP samples; Richard Curry and Brian Lockwood of the National Park Service, Biscayne National Park, for providing recreational lobster length data; Jack Javech, NMFS Miami Laboratory, for creating the graphic image used on the cover page of this report; and Ed Little, Guy Davenport, Joshua Bennett, NMFS, for their assistance in preparing this report.

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Table 1. - Landings (whole weight), number of traps and number of craft in the Florida spiny lobster commercial fishery by fishin season, 1960-61 through 1994-95.

	FLORIDA EAST COAST			FLORIDA WEST COAST			FLORIDA TOTAL				
Fishing Season	Landings (1000's of lbs)	Trap No. (1000's)	Lbs per Trap	Landings (1000's of lbs)	Trap No. (1000's)	Lbs per Trap	Landings (1000's of lbs)	Trap No. (1000's)	Lbs per Trap	Total Craft	Traps per Craft
1960-61	723	19	38.1	2,098	55	38.1	2,821	74	38.1	221	335
1961-62	664	13	51.1	2,199	39	56.4	2,863	52	55.1	195	267
1962-62	668	16	41.8	2,424	58	41.8	3,092	74	41.8	248	298
1963-64	903	20	45.2	2,881	60	48.0	3,784	80	47.3	246	325
1964-65	963	40	24.1	2,984	74	40.3	3,947	114	34.6	341	334
1965-66	1,501	49	30.6	4,650	90	51.7	6,151	139	44.3	332	419
1966-67	1,603	76	21.1	3,122	75	41.6	4,725	151	31.3	488	309
1967-68	1,840	94	19.6	3,233	92	35.1	5,073	186	27.3	528	352
1968-69	2,481	70	35.4	3,600	99	36.4	6,081	169	36.0	452	374
1969-70	2,899	68	42.6	5,141	97	53.0	8,040	165	48.7	440	375
1970-71	3,080	69	44.6	6,546	150	43.6	9,626	219	44.0	492	445
1971-72	4,869	79	61.6	5,505	147	37.4	10,374	226	45.9	520	435
1972-73	7,151	98	73.0	4,711	174	27.1	11,862	272	43.6	599	454
1973-74	4,472	133	33.6	5,575	172	32.4	10,047	305	32.9	671	455
1974-75	3,417	144	23.7	6,527	227	28.8	9,944	371	26.8	690	538
1975-76	1,155	92	12.6	5,116	428	12.0	6,271	520	12.1	823	632
1976-77	1,463	32	45.7	3,962	315	12.6	5,425	347	15.6	549	632
1977-78	1,234	47	26.3	4,810	408	11.8	6,044	455	13.3	635	717
1978-79	685	43	15.9	5,119	529	9.7	5,804	572	10.1	672	851
1979-80	799	29	27.6	7,088	564	12.6	7,887	593	13.3	666	890
1980-81	995	35	28.4	5,273	570	9.3	6,268	605	10.4	595	1,017
1981-82	841	31	27.1	4,926	591	8.3	5,767	622	9.3	563	1,105
1982-83	848	40	21.2	5,588	502	11.1	6,436	542	11.9	539	1,006
1983-84	549	35	15.7	3,798	520	7.3	4,347	555	7.8	550	1,009
1984-85	165	20	8.3	6,115	655	9.3	6,280	675	9.3	610	1,107
1985-86	346	23	15.0	5,431	541	10.0	5,777	564	10.2	517	1,091
1986-87	625	40	15.6	4,734	536	8.8	5,359	576	9.3	549	1,049
1987-88	528	40	13.2	4,899	737	6.6	5,427	777	7.0	638	1,218
1988-89	528	45	11.7	6,032	742	8.1	6,560	787	8.3	672	1,172
1989-90	548	65	8.4	7,307	851	8.6	7,855	916	8.6	741	1,236
1990-91	579	68	8.5	5,466	807	6.8	6,045	876	6.9	745	1,175
1991-92	932	82	11.4	5,910	857	6.9	6,842	939	7.3	796	1,179
1992-93	637	55	11.6	4,730	776	6.1	5,367	831	6.5	813	1,022
1993-94	877	49	17.9	4,438	697	6.4	5,315	746	7.1	808	923
*1994-95	768	44	17.5	6,440	630	10.2	7,208	674	10.7	753	895

*Preliminary, incomplete data.

Table 2 - Reported spiny lobster commercial landings (lbs whole weight) and percentage by month (Au[illegible]arch) from the Florida west coast - 1960 through 1994 fishing seasons.

Season	Aug landings	Aug %	Sept landings	Sept %	Oct landings	Oct %	Nov landings	Nov %	Dec landings	Dec %	Jan landings	Jan %	Feb landings	Feb %
1960-61	411,804	19.6	279,797	13.3	404,489	19.3	316,389	15.1	229,668	10.9	132,836	6.3	173,584	8.3
1961-62	394,132	17.9	327,353	14.9	310,625	14.1	372,857	17.0	240,634	10.9	189,763	8.6	118,053	5.4
1962-62	438,487	18.1	329,181	13.6	299,664	12.4	419,675	17.3	394,713	16.3	223,351	9.2	118,885	4.9
1963-64	504,439	17.5	417,970	14.5	418,763	14.5	458,927	15.9	430,106	14.9	246,783	8.6	214,706	7.5
1964-65	534,350	17.9	413,994	13.9	452,829	15.2	508,299	17.0	283,257	9.5	182,436	6.1	181,693	6.1
1965-66	777,651	16.7	584,868	12.6	1,157,480	24.9	639,829	13.8	434,209	9.3	221,827	4.8	388,619	8.4
1966-67	647,991	20.8	366,745	11.7	590,559	18.9	719,041	23.0	283,679	9.1	205,385	6.6	109,322	3.5
1967-68	530,562	16.4	389,328	12.0	497,453	15.4	465,146	14.4	340,989	10.5	342,983	10.6	287,188	8.9
1968-69	708,159	19.7	489,229	13.6	642,067	17.8	732,060	20.3	339,454	9.4	152,840	4.2	266,326	7.4
1969-70	971,184	18.9	894,683	17.4	709,306	13.8	752,694	14.6	635,298	12.4	451,006	8.8	303,520	5.9
1970-71	1,152,538	17.6	1,038,109	15.9	1,385,101	21.2	1,138,968	17.4	959,608	14.7	351,651	5.4	210,785	3.2
1971-72	1,126,292	22.1	735,401	14.4	875,685	17.2	767,801	15.1	411,155	8.1	454,293	8.9	460,239	9.0
1972-73	691,349	15.6	670,160	15.1	933,803	21.1	736,621	16.6	528,908	11.9	374,854	8.5	272,058	6.1
1973-74	967,647	18.7	995,355	19.3	1,006,544	19.5	780,385	15.1	649,884	12.6	259,325	5.0	184,216	3.6
1974-75	1,706,642	27.2	864,153	13.8	1,492,501	23.8	505,822	8.1	991,034	15.8	300,347	4.8	221,756	3.5
1975-76	1,467,456	30.8	897,203	18.8	839,038	17.6	567,712	11.9	350,943	7.4	263,630	5.5	134,278	2.8
1976-77	1,043,551	26.9	588,312	15.1	819,081	21.1	593,926	15.3	320,180	8.2	244,056	6.3	144,158	3.7
1977-78	1,025,330	21.5	859,928	18.0	1,228,184	25.7	695,970	14.6	437,454	9.2	307,752	6.4	122,289	2.6
1978-79	840,862	16.7	755,954	15.0	1,175,205	23.3	794,408	15.8	519,159	10.3	425,751	8.5	322,995	6.4
1979-80	1,424,862	20.5	1,299,748	18.7	1,268,342	18.2	1,165,102	16.7	757,671	10.9	497,622	7.2	330,513	4.7
1980-81	1,499,828	29.2	838,512	16.3	893,424	17.4	854,746	16.6	408,854	8.0	304,361	5.9	183,493	3.6
1981-82	1,401,675	29.2	686,708	14.3	879,248	18.3	764,058	15.9	508,992	10.6	252,763	5.3	166,788	3.5
1982-83	1,420,952	26.4	1,120,090	20.8	1,090,177	20.3	826,038	15.3	415,921	7.7	256,777	4.8	147,330	2.7
1983-84	990,941	26.4	710,539	18.9	555,708	14.8	558,158	14.9	284,609	7.6	287,989	7.7	156,233	4.2
1984-85	1,526,607	25.8	1,126,283	19.1	1,091,619	18.5	976,727	16.5	467,660	7.9	363,478	6.2	171,558	2.9
1985-86	1,322,237	25.2	1,187,115	22.6	787,032	15.0	604,291	11.5	648,431	12.3	345,023	6.6	209,385	4.0
1986-87	949,269	20.6	623,192	13.5	881,565	19.1	511,559	11.1	589,121	12.8	538,692	11.7	302,070	6.6
1987-88	1,321,435	27.7	884,545	18.6	1,121,965	23.5	637,273	13.4	358,429	7.5	172,000	3.6	162,343	3.4
1988-89	1,656,945	27.5	1,580,181	26.2	980,470	16.3	626,959	10.4	502,795	8.3	296,469	4.9	189,519	3.1
1989-90	1,907,396	26.1	1,584,550	21.7	1,390,724	19.0	1,063,255	14.6	558,495	7.6	305,756	4.2	185,537	2.5
1990-91	1,529,239	28.0	1,131,518	20.7	1,013,256	18.5	679,089	12.4	315,879	5.8	240,926	4.4	247,364	4.5
1991-92	1,831,101	31.0	1,260,005	21.3	1,049,549	17.8	653,081	11.1	461,596	7.8	270,610	4.6	182,080	3.1
1992-93	1,236,146	26.2	993,777	21.0	995,345	21.1	499,406	10.6	356,918	7.6	222,447	4.7	209,863	4.4
1993-94	1,204,393	27.1	891,367	20.1	718,439	16.2	619,317	13.9	415,631	9.4	260,837	5.9	145,694	3.3
*1994-95	1,836,589	28.5	1,335,893	20.7	1,301,806	20.2	741,172	11.5	486,969	7.6	370,610	5.8	198,695	3.1
MEANS														
1960- -94	1,114,287	23.6	832,907	17.6	892,944	18.9	678,479	14.4	466,237	9.9	294,778	6.2	212,090	4.5
1980- -94	1,442,317	27.1	1,063,618	20.0	983,355	18.5	707,675	13.3	452,020	8.5	299,249	5.6	190,530	3.6

*Preliminary, incomplete data.

Table 3. - Commercial lobster landings (pounds) by gear type from U.S. southeastern states other than Florida 198

STATE Gear	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
ALABAMA													
Otter Trawls Bottom, Shrimp	--	--	--	--	--	--	--	1,141	2,514	1,406	336	--	255
GEORGIA													
Otter Trawls Bottom, Fish	156	44	--	--	--	--	--	--	--	--	--	--	--
Spears	--	--	--	--	--	--	--	--	30	45	--	--	--
Diving Outfits	--	--	--	--	--	--	62	11	79	--	--	18	42
Unknown	--	--	--	--	--	--	--	--	--	--	--	15	3
MISSISSIPPI													
Otter Trawls Bottom, Shrimp	--	--	--	--	--	--	--	--	--	15	--	--	--
SOUTH CAROLINA													
Otter Trawls Bottom, Fish	--	50	65	88	--	--	--	--	--	--	--	--	--
Lines, Hand	564	--	--	--	--	--	--	--	21	--	--	--	--
Diving Outfits	--	--	--	--	--	--	45	438	--	85	--	--	--
TEXAS													
Otter Trawls Bottom, Shrimp	--	--	--	--	--	--	--	67	--	--	171	--	--
TOTALS BY YEAR	**720**	**94**	**65**	**88**			**107**	**1,657**	**2,644**	**1,551**	**507**	**33**	**300**

Table 4. Lobster sizes (carapace length mm) sampled from commercial landings in the Florida Keys by area and fishing season. NMFS sampled landings for three areas from August 1985 through March 1995 and FDEP sampled landings for eight areas from July 1987 through January 1995.

NMFS DATA

SEASON	AREA*	NUMBER	CARAPACE LENGH (mm) MIN.	MAX.	MEAN	STD
1985-86	1.0	2,898	70	136	85.9	8.5
1986-87	1.0	2,516	71	164	86.2	9.2
1987-88	1.0	1,133	71	122	85.5	8.1
1988-89	1.0	1,080	72	116	85.4	7.4
1989-90	1.0	810	75	125	89.8	9.2
1990-91	1.0	141	75	110	84.4	8.0
1991-92	1.0	2,150	70	118	86.6	7.8
1992-93	1.0	2,060	70	200	82.3	10.5
1993-94	1.0	1,012	72	123	85.6	8.2
1994-95	1.0	1,545	72	127	85.9	8.1
1985-86	2.0	370	73	128	87.8	9.1
1986-87	2.0	749	69	155	87.7	9.7
1987-88	2.0	1,242	70	145	87.7	9.5
1988-89	2.0	194	75	109	87.1	8.1
1989-90	2.0	453	75	135	90.4	10.0
1990-91	2.0	229	81	161	104.9	16.3
1991-92	2.0	779	70	171	98.9	20.5
1992-93	2.0	4,111	70	185	105.7	21.0
1993-94	2.0	624	75	175	99.4	19.9
1994-95	2.0	1,235	58	185	91.3	13.3

NMFS
*AREA 1.0 = approx. Middle-Lower FL Keys : area bounded by 25 & 24 degrees N. Lat. and 81 & 82 degrees W. Long.
2.0 = approx. Key West to W. of Dry Tortugas : area bounded by 25 & 24 degrees N. Lat. and 82 & 84 degrees W. Long.

FDEP DATA

SEASON	AREA**	NUMBER	CARAPACE LENGH (mm) MIN.	MAX.	MEAN	STD
1987-88	1	1,182	73	151	83.1	6.7
1988-89	1	1,001	73	126	84.1	7.2
1989-90	1	962	74	129	85.7	7.5
1990-91	1	478	75	127	85.0	8.3
1991-92	1	320	76	114	85.0	7.4
1992-93	1	429	74	115	84.9	7.1
1993-94	1	269	75	105	84.2	6.0
1994-95	1	452	76	111	83.6	5.9
1987-88	2	556	75	112	84.2	6.5
1988-89	2	956	70	120	83.4	6.8
1989-90	2	421	75	111	85.4	6.6
1990-91	2	427	75	121	84.0	7.0
1991-92	2	503	75	122	84.9	7.0
1992-93	2	279	76	114	84.3	6.2
1993-94	2	378	76	105	83.4	5.7
1994-95	2	568	71	115	83.6	6.4
1987-88	3	1,659	70	119	83.4	6.8
1988-89	3	1,050	63	116	83.5	6.5
1989-90	3	1,178	74	197	86.2	8.5
1990-91	3	823	75	134	84.3	7.8
1991-92	3	422	72	115	84.5	8.0
1992-93	3	523	73	112	84.2	6.8
1993-94	3	966	72	123	83.1	6.0
1994-95	3	906	72	113	83.6	6.5
1987-88	4	1,045	72	126	84.6	7.6
1988-89	4	770	73	120	83.9	7.2
1989-90	4	669	74	110	84.2	6.7
1990-91	4	742	74	134	84.7	7.2
1991-92	4	543	75	123	85.1	7.2
1992-93	4	465	75	118	84.8	6.8
1993-94	4	572	75	121	85.1	6.5
1994-95	4	501	75	105	83.6	6.2
1987-88	5	348	74	110	83.7	6.4
1988-89	5	756	75	126	84.1	7.1
1989-90	5	609	72	116	84.9	7.4
1990-91	5	644	75	116	86.3	7.7
1991-92	5	198	74	116	83.6	6.8
1992-93	5	249	75	105	83.7	6.0
1993-94	5	237	76	113	84.6	6.7
1994-95	5	566	75	113	86.6	8.0
1987-88	6	531	75	119	84.2	7.5
1988-89	6	502	74	110	83.6	6.5
1989-90	6	461	74	112	84.4	7.0
1990-91	6	161	72	112	86.8	7.5
1991-92	6	77	74	101	82.6	6.5
1992-93	6	101	75	110	85.4	6.7
1993-94	6	176	75	112	85.6	6.9
1994-95	7	–	–	–	–	–
1987-88	7	477	70	134	85.8	9.0
1988-89	7	603	74	143	88.2	10.6
1989-90	7	585	70	151	90.7	12.1
1990-91	7	191	70	153	95.1	14.5
1991-92	7	91	76	105	82.7	6.3
1992-93	7	145	76	122	85.0	7.3
1993-94	7	86	75	106	83.3	6.2
1994-95	7	63	75	112	87.6	8.7
1990-91	8	116	78	139	104.7	15.7
1991-92	8	34	78	145	103.9	14.3

FDEP
**AREA 1 = Upper FL Keys - Bay Side : Key Largo to west of Long Key Bridge
2 = Upper FL Keys - Ocean Side : Key Largo to west of Long Key Bridge
3 = Middle FL Keys - Bay Side : West of Long Key Bridge to Big Pine Key
4 = Middle FL Keys - Ocean Side : West of Long Key Bridge to Big Pine Key
5 = Lower FL Keys - Bay Side : West of Big Pine Key to Key West
6 = Lower FL Keys - Ocean Side : West of Big Pine Key to Key West
7 = Key West to the Dry Tortugas
8 = West of the Dry Tortugas

Table 5. Percentage of Florida spiny lobster landings by calander year, coast, and distance from shore as determined from General Canvas Landings database. The state territorial sea extends from shore to 3 nautical miles on Florida's east coast and from the shoreline to a distance of 9 nautical miles along Florida's west coast.

	FLORIDA EAST COAST		FLORIDA WEST COAST		
YEAR	State waters (< 3 nm)	EEZ (> 3 nm)	State waters (< 3 nm)	Mixed (3 to 12 nm)	EEZ (> 12 nm)
1980	26.6%	73.4%	37.7%	61.6%	0.7%
1981	27.1%	72.9%	37.8%	61.5%	0.7%
1982	29.5%	70.5%	37.6%	61.7%	0.7%
1983	28.4%	71.6%	37.3%	61.3%	1.3%
1984	58.5%	41.5%	27.2%	49.7%	23.1%
1985	55.0%	45.0%	29.4%	65.4%	5.2%
1986	93.3%	6.7%	25.5%	51.2%	23.3%
1987	93.4%	6.6%	24.6%	49.9%	25.4%
1988	75.0%	25.0%	26.4%	56.2%	17.4%
1989	59.4%	40.6%	33.1%	53.4%	13.5%
1990	61.9%	38.1%	30.5%	56.2%	13.2%
1991	89.2%	10.8%	31.1%	55.7%	13.2%
1992	87.3%	12.7%	31.0%	57.8%	11.2%

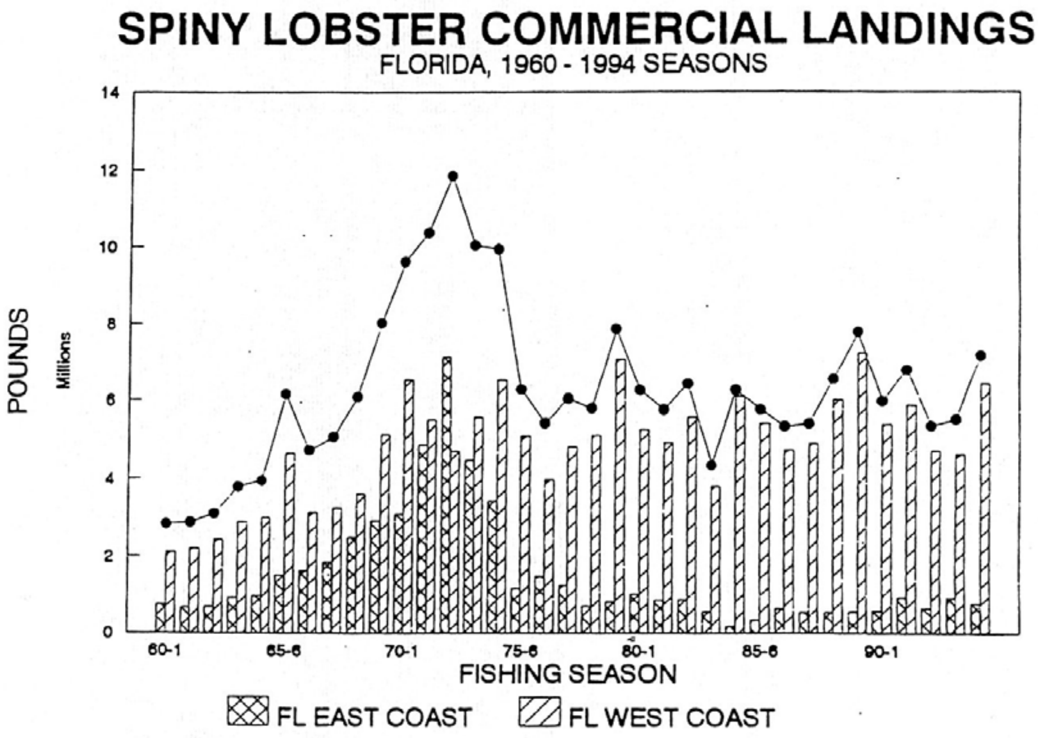


Figure 1. Spiny lobster commercial landings (whole weight) in Florida by fishing season, 1960-61 through 1994-95. The line represents the total Florida landings while bars indicate landings by coast (east or west).

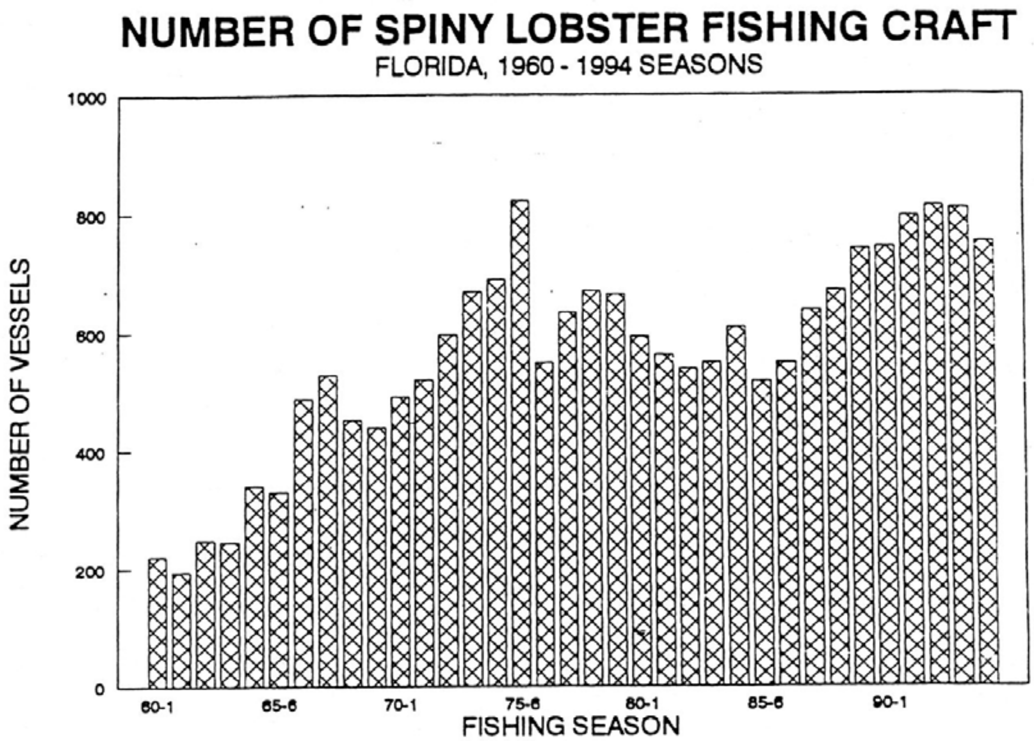


Figure 2. The number of commercial fishing craft by season (1960-61 through 1994-95) in the Florida spiny lobster fishery.

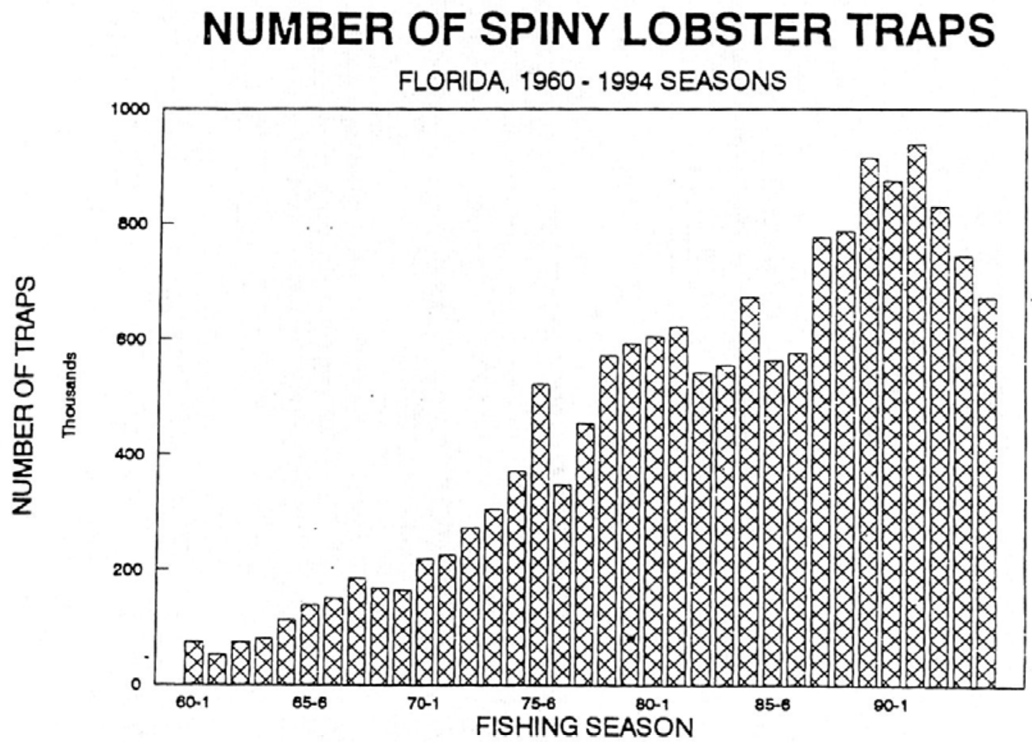


Figure 3. The number of traps by fishing season (1960-61 through 1994-95) in the Florida spiny lobster fishery.

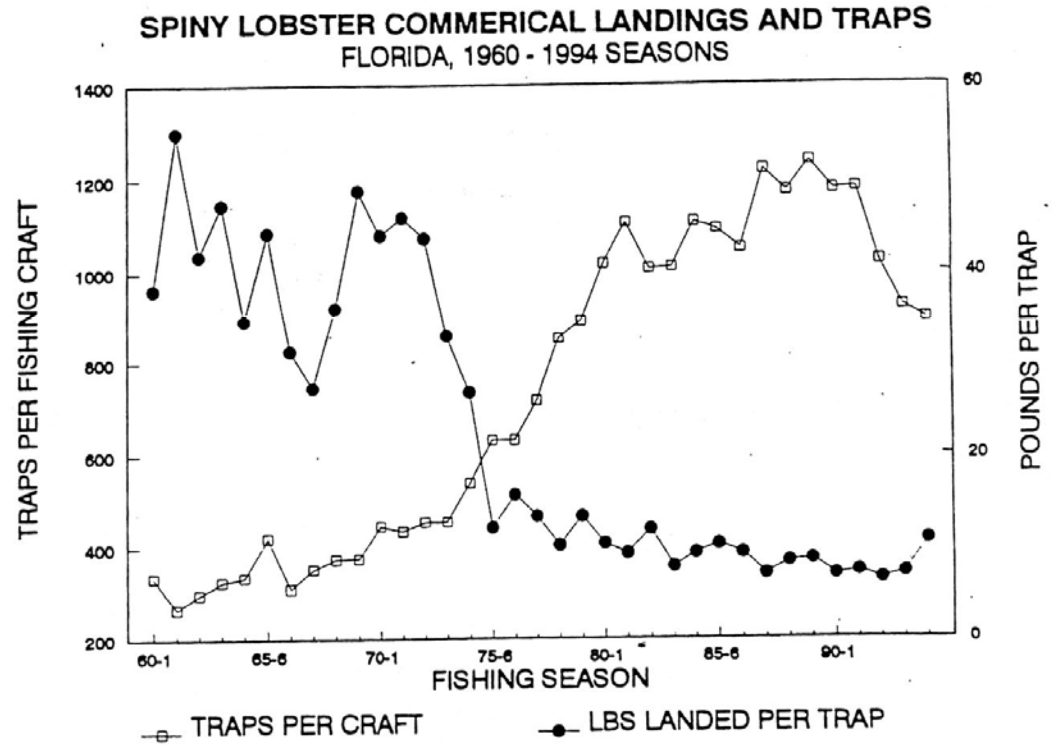


Figure 4. The number of spiny lobster traps per craft and the average landings (pounds) per trap by fishing season (1960-61 to 1994-95) in the Florida spiny lobster fishery.

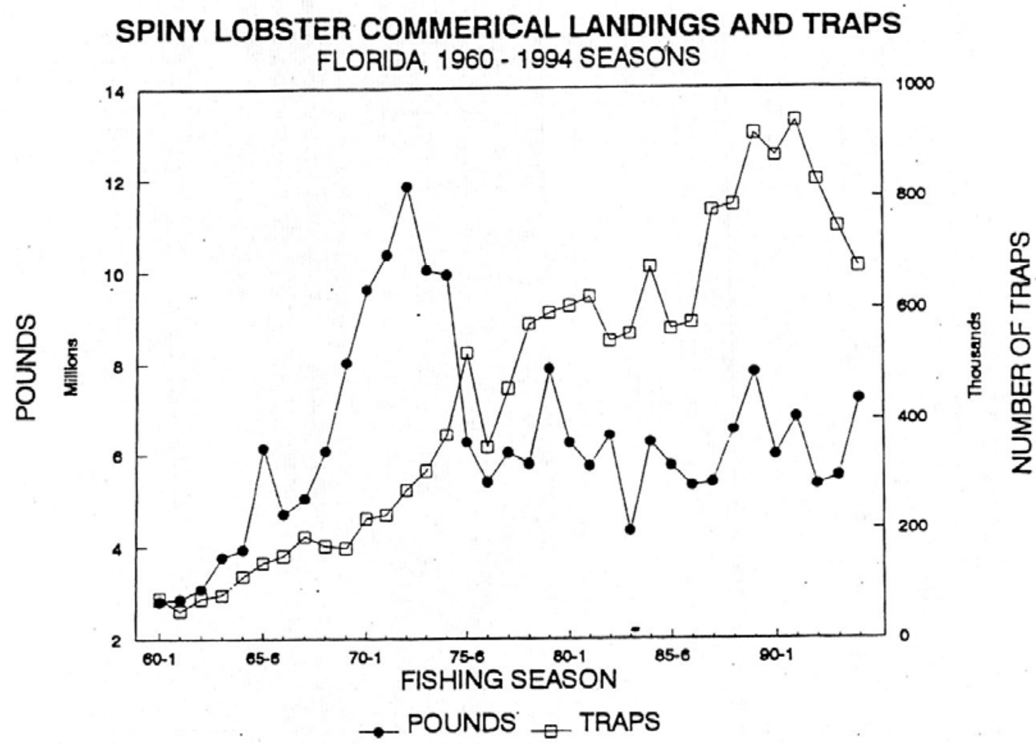


Figure 5. The Florida commercial spiny lobster landings and estimated number of traps in the fishery for the 1960-61 through 1994-95 fishing seasons.

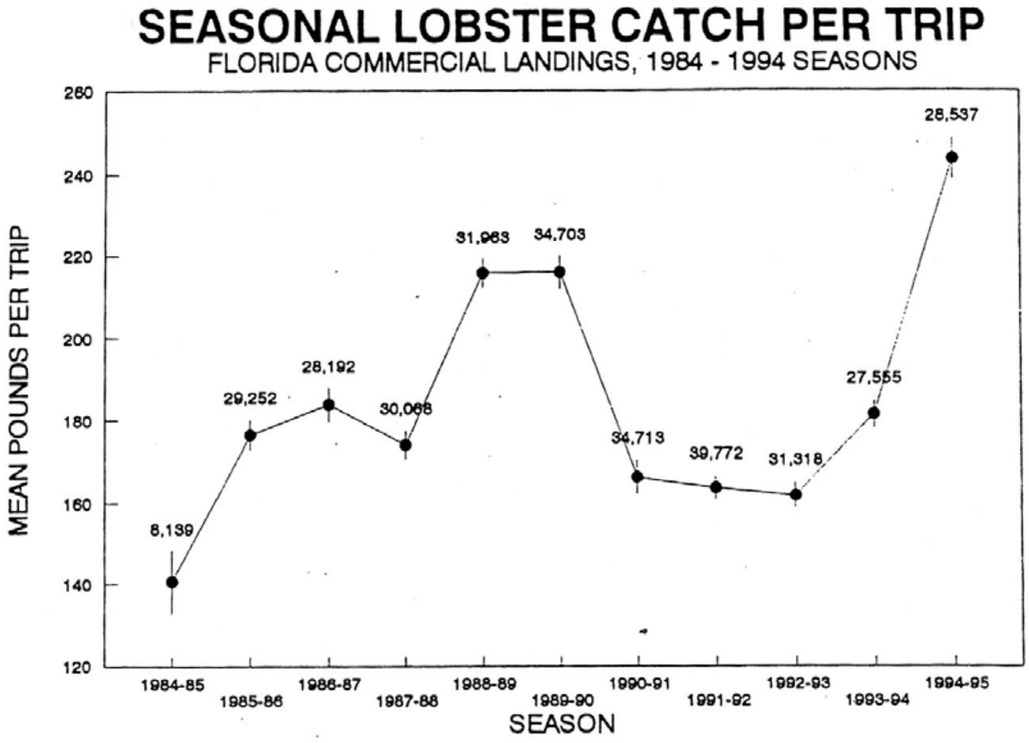
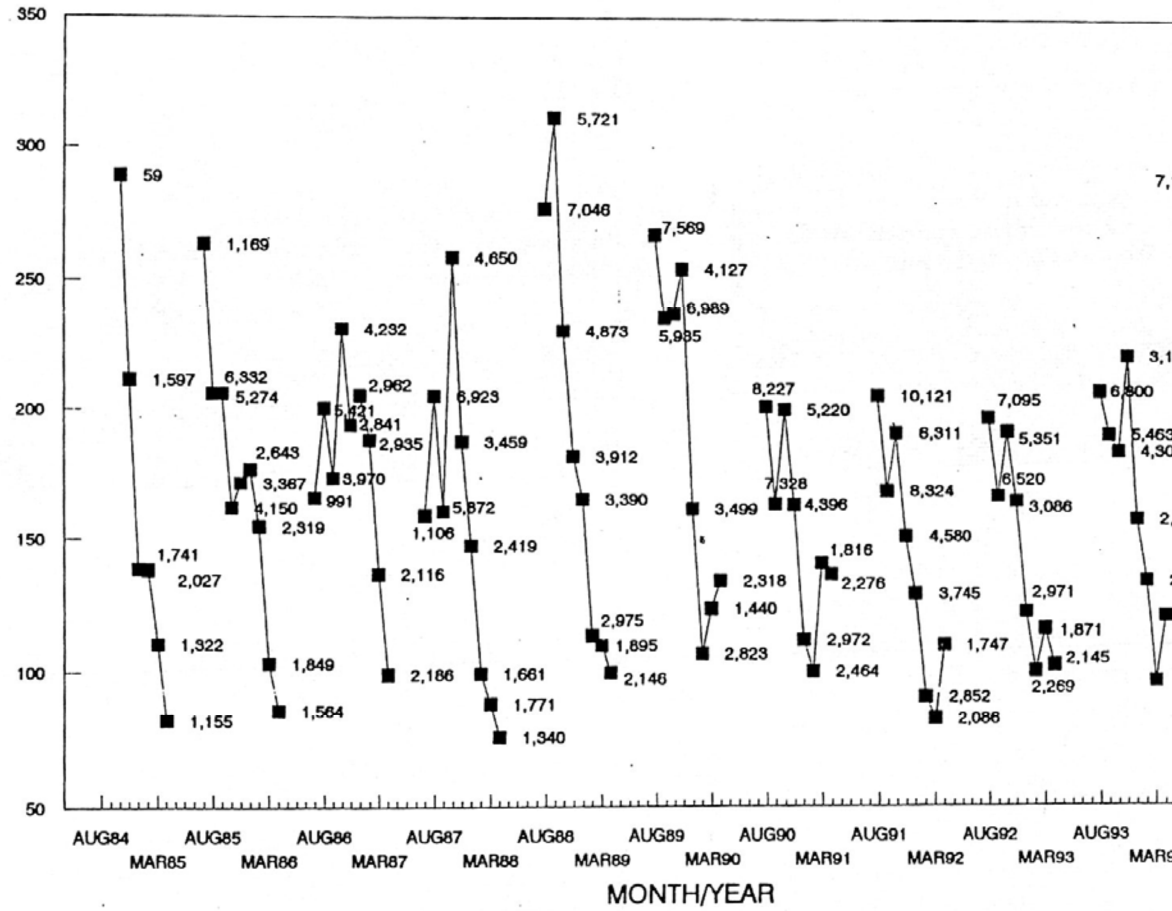


Figure 6. Mean catch (pounds landed) per trip by fishing season for 324,212 trips in the Florida spiny lobster fishery (1984-85 through 1994-95). Vertical lines for the 95% confidence interval and the number of trips is indicated for each seasonal .

MONTHLY LOBSTER CATCH PER TRIP

FLORIDA COMMERCIAL LANDINGS, AUGUST 1984 - MARCH 1995



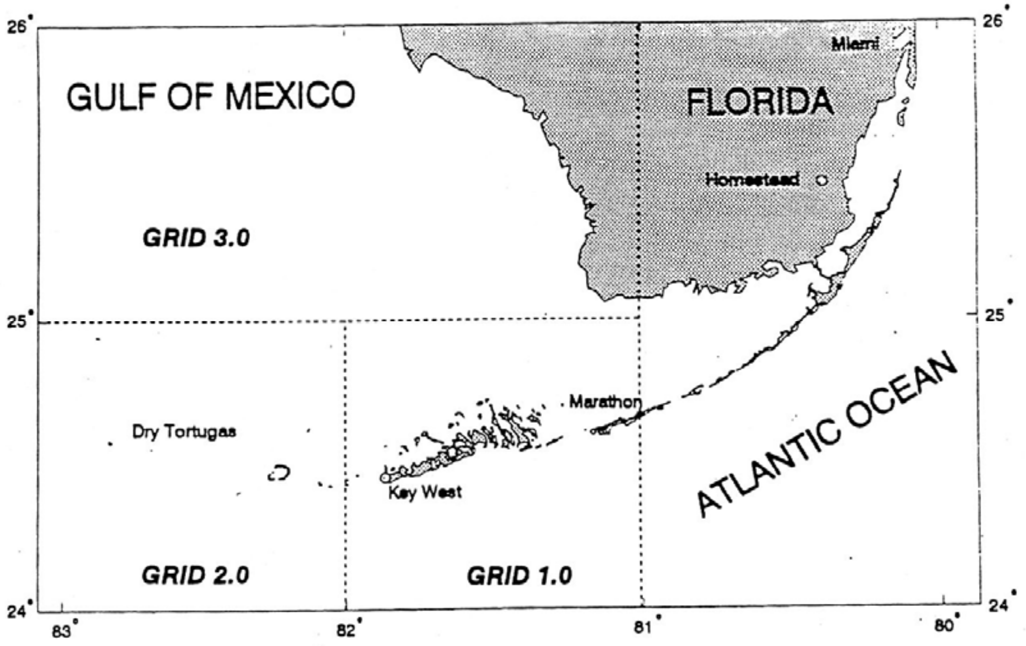


Figure 8. Approximate location of NMFS areas (grids) used to identify fishing areas for Trip Interview Program (TIP) samples in the Florida Keys.

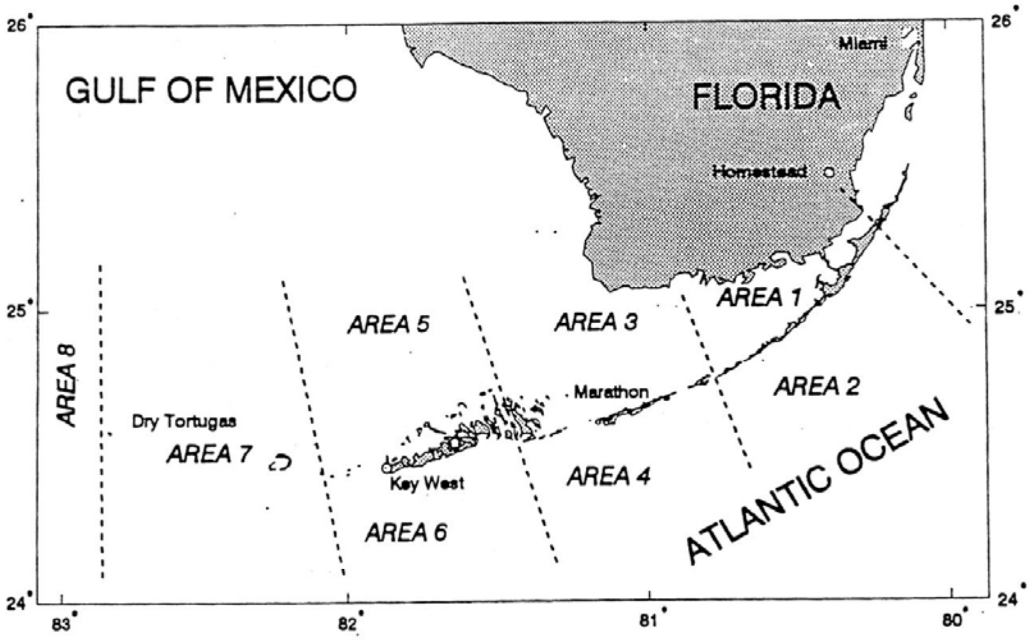
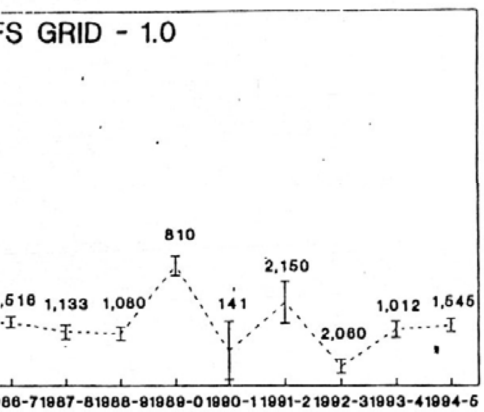
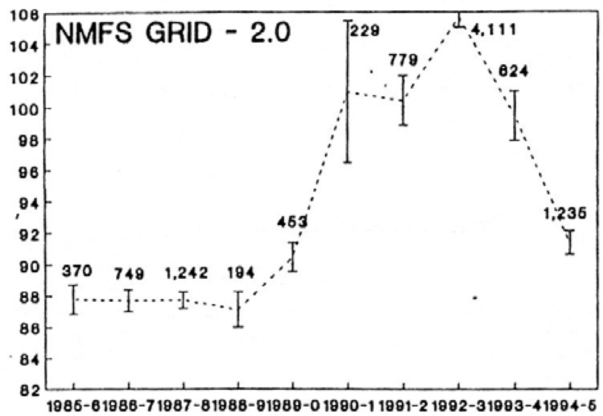
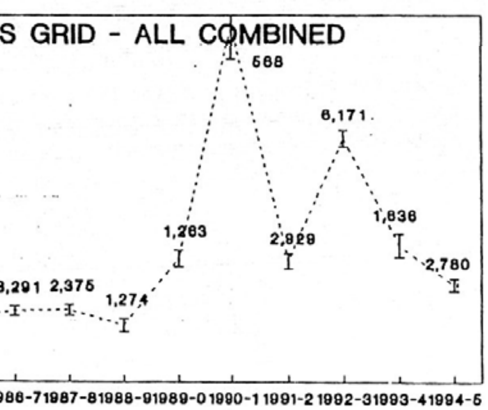


Figure 9. Approximate designation of spiny lobster biostatistical sampling areas used by the Florida Department of Environmental Protection in the Florida Keys.

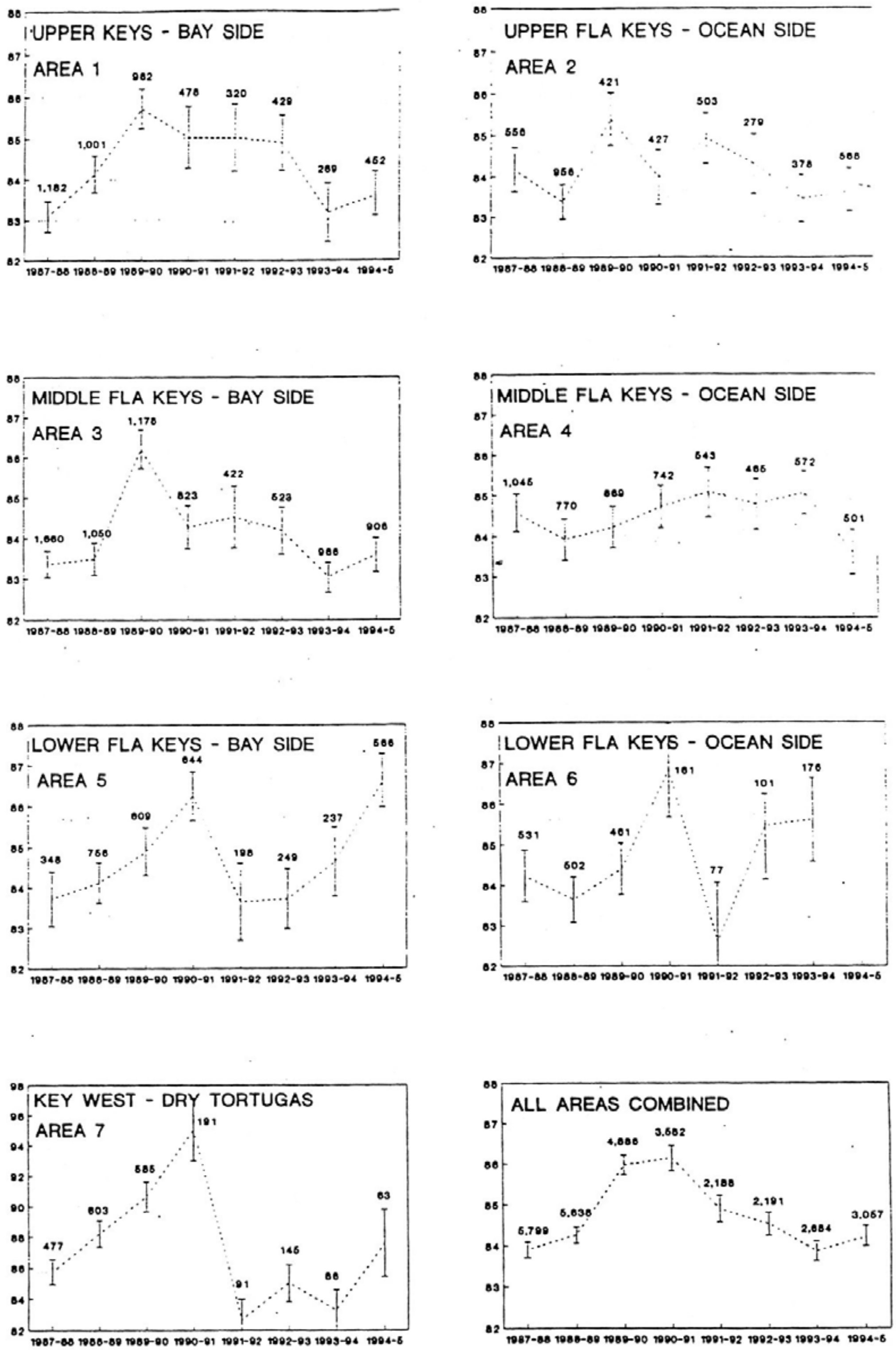






Mean lengths (carapace mm.) for spiny lobster sampled from commercial catches by NMFS personnel for seasons 1985-86 through 1994-95. The lobster were caught from two areas in the Florida Keys. The 95% confidence interval is indicated for each season.

Figure 11. Mean lengths (carapace in mm.) for lobster sampled from commercial catches by FDEP personnel for seasons 1987-88 through 1994-95. The lobster were caught from seven areas in the Florida Keys. The 95% confidence interval is indicated for each season.



BISCAYNE NATIONAL PARK
RECREATIONAL SURVEY - LOBSTER LENGTHS

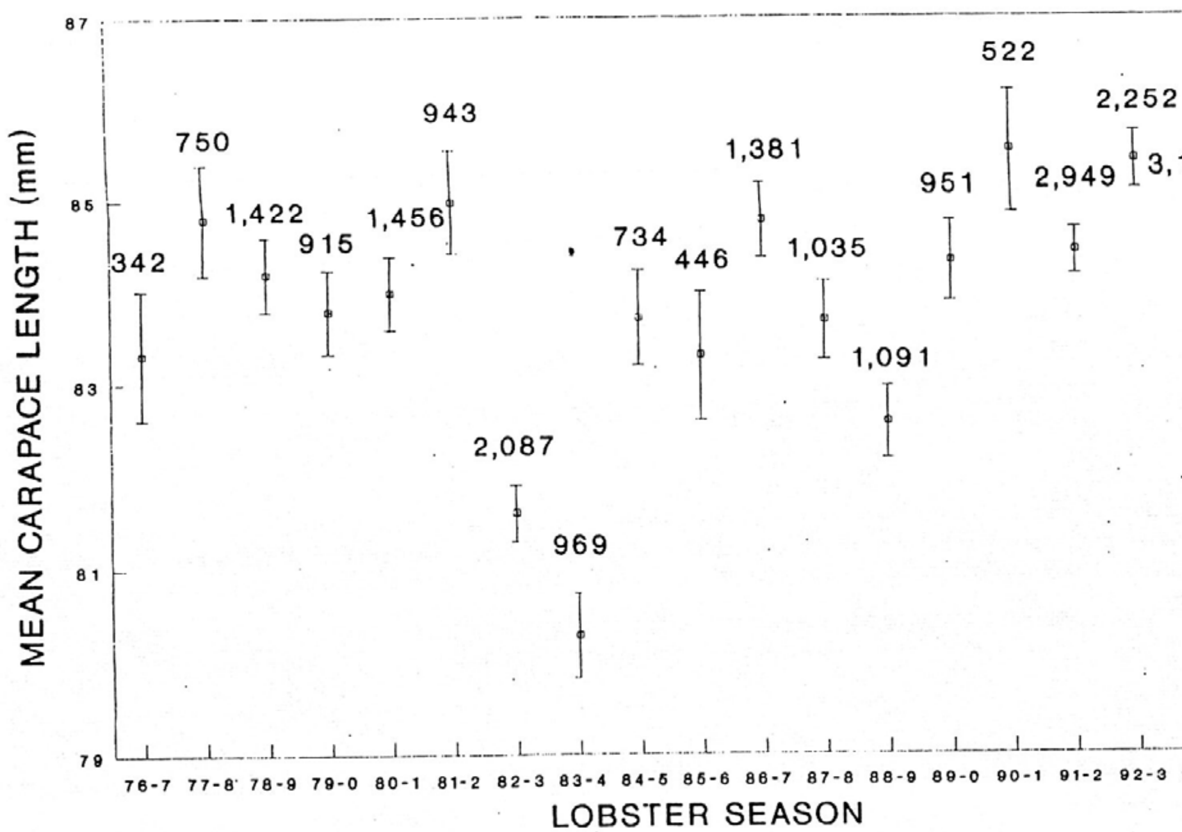


Figure 12. Mean lengths (carapace in mm.) for spiny lobster sampled from recrea
National Park Service personnel during fishing intercept surveys fro
1992-93. The surveys were conducted from boat launch sites within a
Biscayne National Park, south Dade County, Florida. The 95% confi
indicated.

Appendix F. National Report -Spiny Lobster Fisheries of the United States of America (1998

National Report of United States of America

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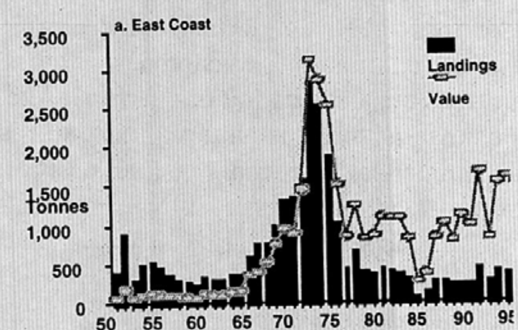
1. Biology

The biology of spiny lobsters in Florida has been studied extensively for more than 30 years (see last year's report for references). More recently, Cox et al. (1997) investigated the foraging behavior of spiny lobsters and prey densities in the Florida Keys and found that lobster gut contents contained a predominance of molluscs especially in rubble areas. Butler et al . (1997) used mesocosms and field observations to examine the spatial scales of "postalgal" juveniles.



They found that aggregated juveniles had higher mortality than non-aggregated ones. Butler and Herrnkind (In press) examined the efficacy of adding artificial shelters. Acosta et al. (1997) found that puerulus settlement increases during the first quarter of the moon phase, the highest settlement during the year centered on March, and they found a correlation between puerulus settlement and winds from the Northeast. Donahue et al. (1998) gave the equation for the numbers of eggs in a batch (E) as a function of carapace length (CL) as

$$E = 88.7\ CL^2 - 219\ 200.$$

An on-going study is looking at the growth of spiny lobsters in the wild from settlement at 6-7 mm using micro-coded wire tags. Based on the 59 lobsters that have been recaptured, the size of lobsters a year after settlement was 37-53 mm CL.

2. Description of fisheries

Florida's fishery for spiny lobsters began in Key West area of the Florida Keys in nineteenth century (Labisky et al. 1980) and developed until by the early 1960s the fishery was producing approximately 1 250 tonnes per year (Figure 1). When the minimum size of lobster was reduced to 76.2 mm (3.0 in) carapace length (CL) in 1968, the fishery expanded to the Middle and Upper Keys and the resulting harvest increased to an average of 2 500 tonnes. In addition, the smaller size allowed fishers on Florida's East Coast to land lobsters from Grand Bahamas Bank until the Bahamian government closed their waters to foreign fleets in 1977. Ninety percent of the landings in Florida come from the Florida Keys (Monroe county) and most of the following discussion will focus on that area. The commercial fishery primarily harvests spiny lobsters with traps. As the number of traps increased in the fishery, landings increased, but landings leveled off as the numbers of traps exceeded 250 000 traps. In 1993, Florida's Legislature instituted a Trap Reduction Program. The number of traps has been reduced from 939 000 traps to 582 000 traps with another reduction of 61 000 traps scheduled for July 1998. Spiny lobsters are also captured by diving and with bully nets. Increasingly, spiny lobsters are being landed and shipped live primarily to Taiwan and Japan with a few being shipped to Europe (Antozzi 1996).

3. Management regulations

Spiny lobsters are managed by the Florida Marine Fisheries Commission under Chapter 46-24, Florida Administrative Code. The regulations include an open season from August 6 through March 31, a Special Sport Season for recreational participants occurring the last Wednesday and Thursday of July; minimum size of 76.2 mm (3.0 in) carapace length; only diving, bully nets, or lobster traps are allowable gear; traps must have a minimum throat size of 88.9 mm x 152.4 mm (3 _ in x 6 in) and be fished such that the throat is on top of the trap; fishers using traps must have certificates for their traps; commercial traps cannot be pulled at night and recreational divers may not collect spiny lobsters at night; the recreational bag limit is 6 lobsters per day with a maximum possession limit of 12 lobsters in the Florida Keys and elsewhere in the state the

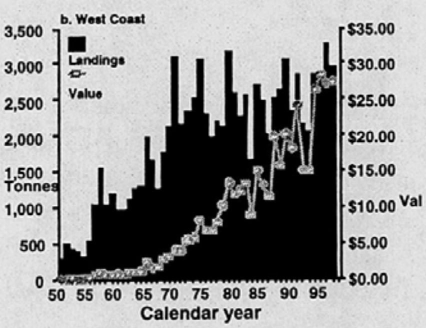


Figure 1. Annual landings and value of spiny lobster in the US by calendar year and coast.

daily bag limit is 12 lobsters with a maximum possession limit of 24 lobsters. Additional regulations require that fishers selling their catch have restricted species and crawfish endorsements on their Saltwater Products license (SPL).

4. Available data

4.1 Fishery dependent

Commercial effort and landings information is collected through trip tickets. Wholesale dealers provide the Department of Environmental Protection with copies of their landing receipts that includes the dealer number, Saltwater Product license number of the fisher, date of sale, county landed, area fished, water depth, time away from the dock, gear used on the trip, soak time for traps, number or traps, species landed, size category, and ex-vessel price paid. Catch rates from trip tickets are standardized with a general linear model and show a marked decline as the season progresses (Figure 2). Standardized catch rates from a general linear model are used as a tuning index in the stock assessment. In the past four seasons, there have been an average of 27 800 trips in the Florida Keys and those trips landed an average of 3 000 tonnes per fishing season. Data from the 1997-98 season are not complete but the landings reported to date are 3 056 tonnes from 28 205 trips with a value of $29 300 000.

Beginning in July 1991, the recreational harvest in numbers of spiny lobster for the Florida Keys and the rest of the state for the Sport have been estimated using a mail survey of persons possessing a crawfish stamp on their Saltwater Fishing license. In the past four seasons, recreational participants have caught an average of 1 100 000 lobsters in July and August. A survey estimated the landings for the entire 1994-95 season and showed that 95% of the recreational harvests occurs between the Sport Season in July and the first Monday in September.

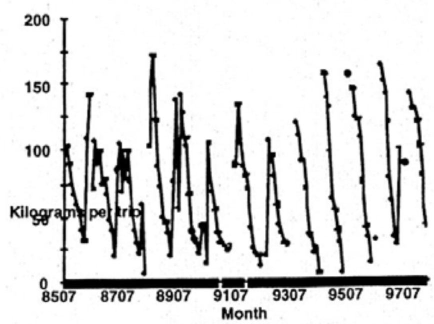


Figure 2. Monthly commercial catch per trip in the Florida Keys.

The final fishery dependent program is the on-board observer program that began in August 1993 and measures the total catch from between 100 and 150 traps per commercial trip. This

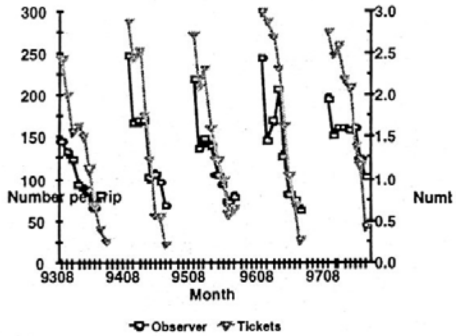


Figure 3. Comparison on commercial catch per trip from trip tickets with number of lobsters per trap from the observer program

program produces catch per trap and an independent measure of catch per trip. The catch per trap from the observer program is also used to as a check to ensure that the catch per trip from trip tickets reflects the dynamics in the fishery (Figure 3). Also, this program provides a recruitment index as the number of lobsters between 76 mm and 80 mm that will be incorporated into future stock assessments. Lastly, this program identifies the number of under-sized lobsters that are used as bait.

4.2 Fishery independent

Beginning in April 1987, puerulus collectors were established at two locations in the Florida Keys. In 1992, sampling frequency changed from weekly samples to monthly sampling during the first quarter of the lunar phase after analyzing the first five year's of data. The monthly number of recruits estimated from the onboard observer program was highly correlated with the number pueruli collected 21 and 32 months earlier. These times were similar to those Muller et al. (1997) estimated using probabilistic growth simulations of the time from settlement to recruitment as 23 months for males and 30 months for females. A new program is evaluating the efficacy of Special Protection Areas (SPA) that do not allow harvesting of any marine resources including spiny lobsters. Beginning in July 1997, divers have been collecting information to compare the density, sizes, and sex ratio of lobsters inside of the spas and outside. Those data are not available at this time but they have the potential for providing an independent tuning index for future stock assessments..

4.3 Socioeconomic

Prior to the Trap Reduction Program an average of 1 838 fishers (identified as unique SPL numbers) reported landings of spiny lobster and after the implementation of the Trap Reduction Program landings have been reported from about 1 100 fishers, but an average of 216 fishers produce 73% of the harvest. Similarly in the Florida Keys, in the past four seasons an average of 76 wholesale dealers have reported purchasing spiny lobsters but 20 dealers account for 84% of

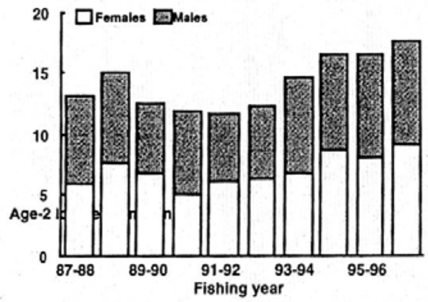


Figure 4. Recruitment expressed as number of age-2 lobsters as estimated by sex from the age-structured population analyses.

the landings. The ex-vessel price per kilogram reached a peak at \$9.88 per kg in the 1995-96 season and then declined to \$8.36 in the 1996-97 season and rebounded to \$9.33 in the 1997-98 season.

5. Status of the stock

An age-structured stock assessment was developed for spiny lobster in the Florida Keys in 1996 with a probabilistic growth model (Muller et al. 1997) and again in 1997 using the same procedures (Integrated Catch at Age, version 1.2, Patterson and Melvin 1996). Higher landings in recent seasons reflect larger population sizes rather than higher fishing mortality rates. Recruitment began increasing after the number of traps was reduced beginning in 1993 (Figure 4). A possible explanation lies with the use of under-sized lobsters as attractants in traps. With fewer traps in the fishery, fewer small lobsters were used for bait.

6. Important developments in the fishery over the previous year

There were no major developments in 1997-98 fishery. The commercial fishery was slower in August than in previous years but overall this season was the third highest season and the data are not complete at this time. The estimated recreational landings were higher with 1 270 000 lobsters collected in the Florida Keys. In July 1998, there will be an important development because the number of traps in the commercial fishery will be reduced by an additional 61 000 traps.

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Appendix G. Status of the Spiny Lobster Fishery in Florida, 1998 (FL DEP)

Status of the Spiny Lobster Fishery in Florida, 1998

Report to the Marine Fisheries Commission

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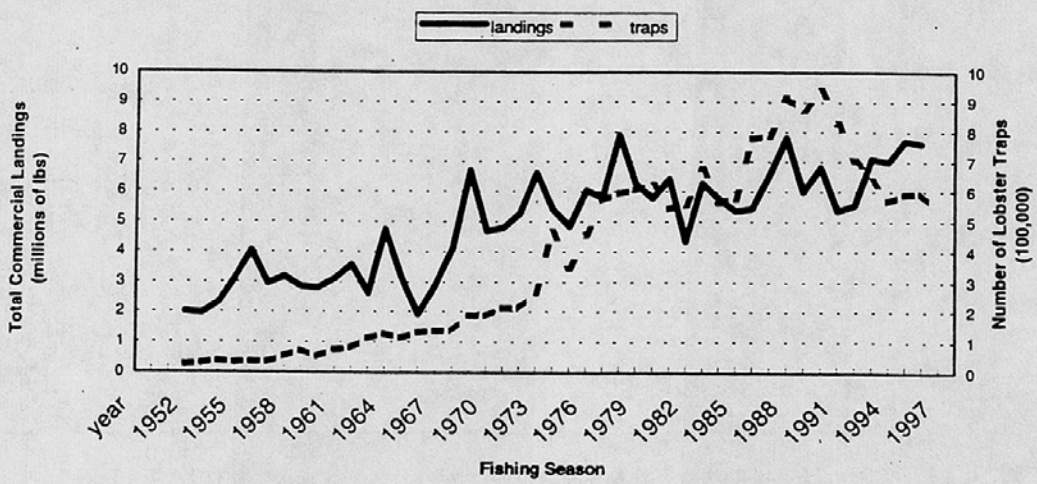
INTRODUCTION

The Caribbean spiny lobster, *Panulirus argus*, supports both an intensive commercial fishery and a popular recreational fishery throughout Florida. The Florida Department of Environmental Protection (FDEP) spiny lobster research program has established monitoring programs in both of these sectors to examine trends in harvest and other important fishery parameters. Herein, we present the results of our fishery monitoring efforts.

COMMERCIAL LOBSTER FISHERY MONITORING

Since the 1950's, the commercial lobster fishery in Florida has been dominated by the use of wooden slat traps. Landings increased throughout the 1960s and early 1970s as the number of traps in the fishery increased to approximately 250,000. Following the closure of Bahamian waters to U.S. fishers in 1975, the number of traps in Florida rapidly increased to approximately 500,000 (Figure 1); however, landings did not increase. The number of traps in the fishery continued to increase through the 1980s and reached a peak of approximately 939,000 in 1991, again with no commensurate increase in landings. Annual landings since the early 1970s have

Figure 1. Commercial spiny lobster landings from Florida and the number of traps in the fishery from the 1953/54 through the 1997/98 fishing season.



been cyclically stable, fluctuating from 4.3 to 7.9 million lbs. Landings have fluctuated on an approximate four to five-year cycle. In response to concerns expressed about excessive effort in the fishery, the Florida Legislature established the Spiny Lobster Trap Certificate Program (LTC). Implemented in 1993, the primary goal of this program was to reduce the number of traps in the fishery with the expectation that landings would remain cyclically stable (Hunt 1994). The LTC requires that all lobster traps display a numbered tag issued by the FDEP; traps without tags are illegal gear. Since 1993, we have used the number of tags issued each season as the estimate of the number of traps that were fished during that season. Before 1993, the number of traps in the fishery was estimated by the National Marine Fisheries Service General Canvass. As directed by the Florida Marine Fisheries Commission (FMFC), the number of tags issued was progressively reduced to approximately 568,000 by the 1995/96 season. The FMFC then suspended trap reductions in the two subsequent fishing seasons. However, the distribution of previously unissued trap tags via a lottery and the payment of overdue license fees during those two years increased the number of tags in the fishery, resulting in approximately 596,000 traps at the start of the 1997/98 fishing season. In 1996, the FMFC implemented a plan in which the number of traps in the fishery would be reduced every other fishing season. Accordingly, the number of tags issued for the 1998/99 fishing season was reduced to approximately 540,000.

In 1993, the FDEP established a program to evaluate the effectiveness of trap reduction as a management tool. This ongoing program integrates fishery data from three different sources to examine the dynamics of the spiny lobster fishery. Lobster landings and fishing effort data are obtained from the Marine Fisheries Information System (MFIS). Lobster length-frequency and sex-ratio data are collected by both the FDEP port sampler program and FDEP onboard observer program. The port sampler program measures lobster landed by the fishery at wholesale seafood dealers. The onboard observer program places researchers onboard commercial fishing vessels and is particularly valuable because, unlike lobsters measured by the port sampler program, onboard observers measure all lobsters captured in traps, including sublegal-sized lobsters, thus providing information on future recruitment to the fishery. This program also allows us to examine other potentially pertinent fishery information such as lobster reproductive dynamics and trap bycatch.

Since the initiation of the trap reduction process, landings have remained within the 20-year average, but the four most recently completed fishing seasons are among the highest on record (Figure 2). Although two consecutive seasons with high landings have commonly occurred, landings in excess of 7 million lbs. in each of four consecutive fishing seasons are unprecedented in this fishery. Additionally, catch per trap per season, as expressed by the relationship between the estimated total number of traps and the total harvest, has returned to levels comparable to those of the early 1980s (Figure 3). Our 1998 stock assessment of the south Florida lobster population using an age-structured analysis, Integrated Catch-at-Age (ICA)

Figure 2. The relationship between landings and the number of traps in the commercial spiny lobster fishery from the 1953/54 through the 1997/98 fishing season.

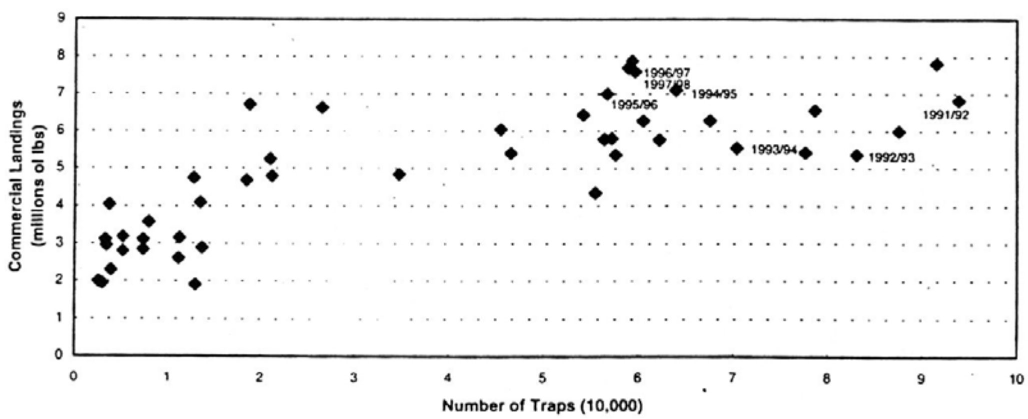


Figure 3. Catch-per-trap-per season (Total number of traps/Total landings) in the commercial spiny lobster fishery from the 1975/76 through the 1996/97 fishing season.

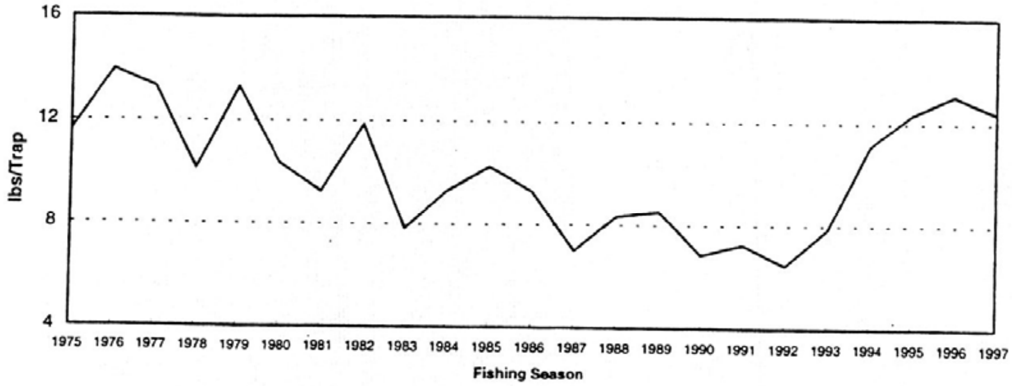
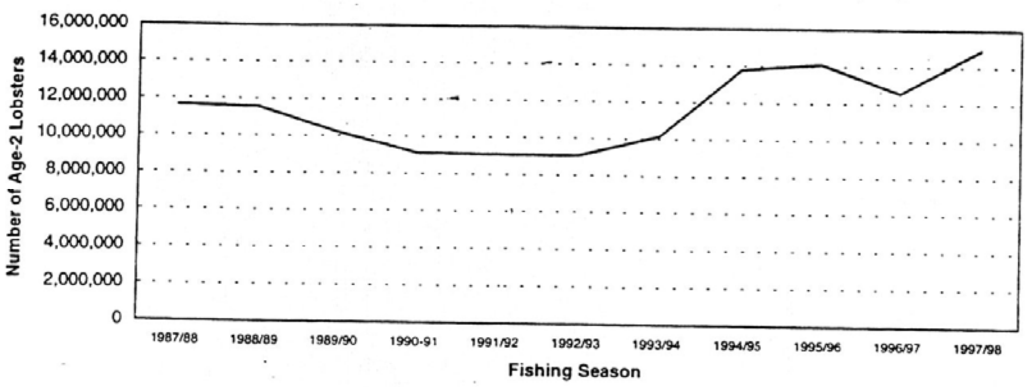
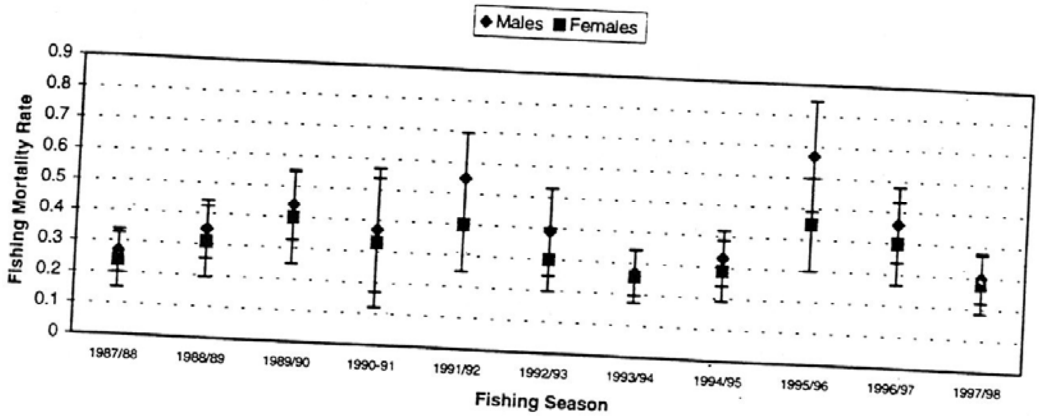


Figure 4. Results of the Integrated Catch-at-Age model predicting the abundance of age-2 lobsters in the spiny lobster fishery from the 1987/88 through the 1997/98 fishing season.



Version 1.2 (Patterson and Melvin, 1996), indicates that the number of lobsters that have recently attained legal size (age-2 lobsters) was 30% greater in 1994/95 than in the 1993/94 fishing season, and has remained high in the subsequent seasons (Figure 4; see Muller *et al.*, 1997 for detailed methods). Thus, the increased landings over the past four seasons are likely the result of high recruitment of age-2 lobsters to the fishery. However, the model also indicates that the trend in average fishing mortality during these four seasons remained similar to previous

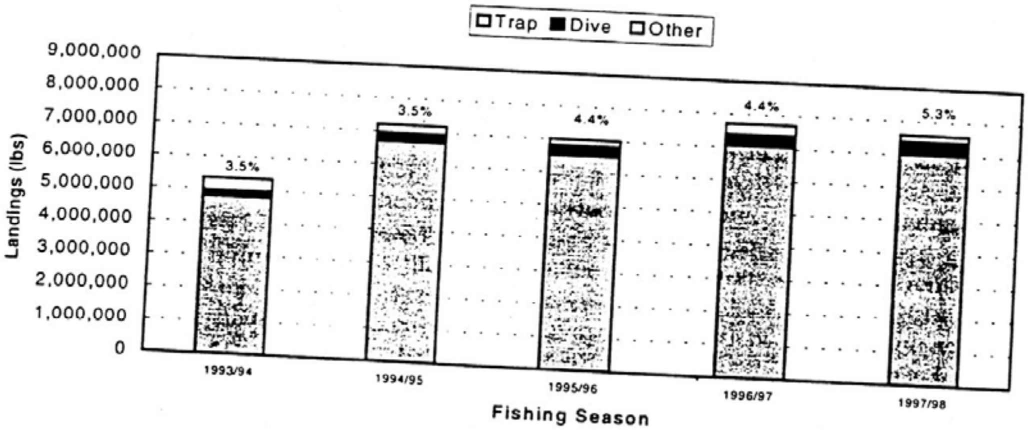
Figure 5. Average (± 1sd) fishing mortality in the commercial spiny lobster fishery estimated by the Integrated Catch-at-Age model for the 1987/88 through the 1997/98 fishing season.



seasons (Figure 5). These fishing mortality rates exceed F_{max} and $F_{0.1}$, two benchmarks commonly used to evaluate fisheries (see Muller *et al.* 1997 and references therein), suggesting that excessive traps remain in the fishery.

One concern expressed by the industry is that the reduction of traps may result in a substantial shift in the harvest allocation from trap fishermen to commercial divers. Commercial diver landings have increased from approximately 184,000 lbs. during the 1993/94 season to

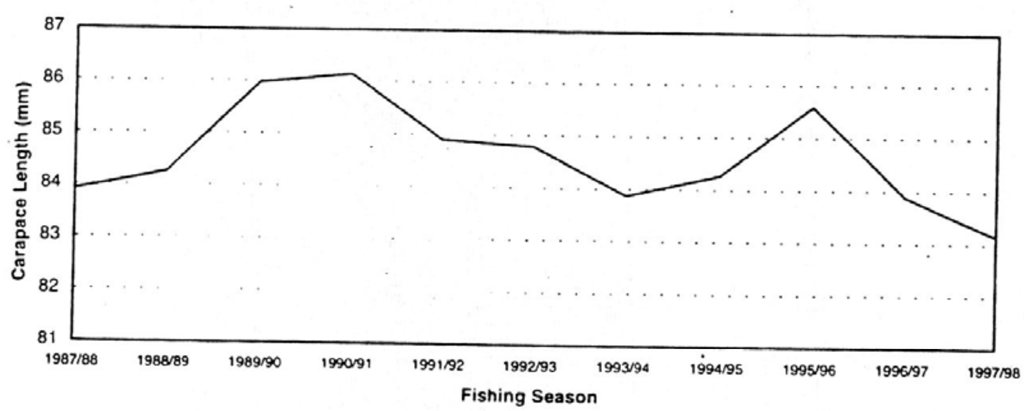
Figure 6. The proportion of commercial lobster landings by traps, divers and other gear from the 1993/94 through the 1997/98 fishing season obtained from the MFIS. Percentage indicates the proportion of diver landings.



approximately 400,000 lbs. during the 1997/98 season. This increase in landings represents a 2% shift in the total commercial landings towards the diving sector (Figure 6). Approximately 62% (251,000 lbs.) of diver landings in the 1997/98 fishing season were landed in August.

Another potential result of the trap reduction process is that the fishery may eventually shift from fishing predominantly on one or two-age classes to multiple age classes. This shift should be evidenced by an increase in the mean size of the lobsters landed. A multi-age class fishery is desirable because it would buffer the impacts of normally low abundance years as more lobsters from high abundance years remain in the fishery for more than one fishing season. In addition, small increases in the mean size of harvested lobsters would result in a considerably larger harvest by weight. For example, an increase in the carapace length of the average lobster landed from 85 mm (3.34 in) to 86 mm (3.38 in) would increase harvest by approximately 200,000 lbs., all other factors being equal. The mean size of lobsters measured at wholesale seafood dealers by FDEP port samplers did indeed increase from approximately 84 mm carapace length (CL) during the 1993/94 fishing season to approximately 86 mm CL during the 1995/96 season (Figure 7). We speculated after the 1995/96 season that the size increase indicated that a

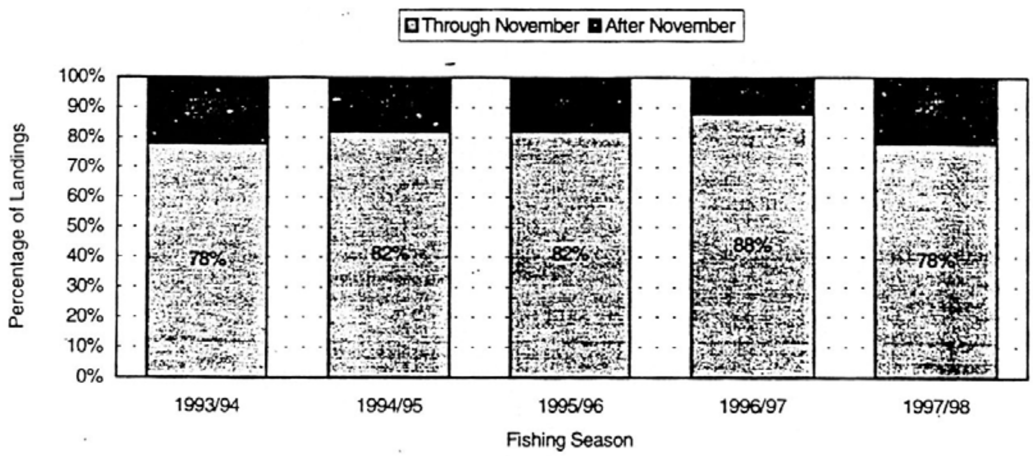
Figure 7. Mean carapace length (mm) of lobsters landed in the commercial spiny lobster fishery from the 1987/88 through the 1997/98 fishing season.



shift to a multi-year class fishery had begun. However, the mean size of lobsters measured by port samplers during the subsequent two seasons decreased to approximately 83 mm CL. This decrease in mean size, coupled with our model results indicating an increase in the abundance of newly recruited lobsters, indicate that this shift to a multi-age class fishery has not occurred. However, we will continue to monitor this trend closely.

Another potential effect of trap reduction could be to lengthen the effective fishing season. That is, a greater proportion of the harvest would occur later in the fishing season. We have not observed evidence that this has yet occurred. The proportion of lobsters harvested through November has remained approximately 80% from the 1994-95 through the 1997-1998 fishing season (Figure 8).

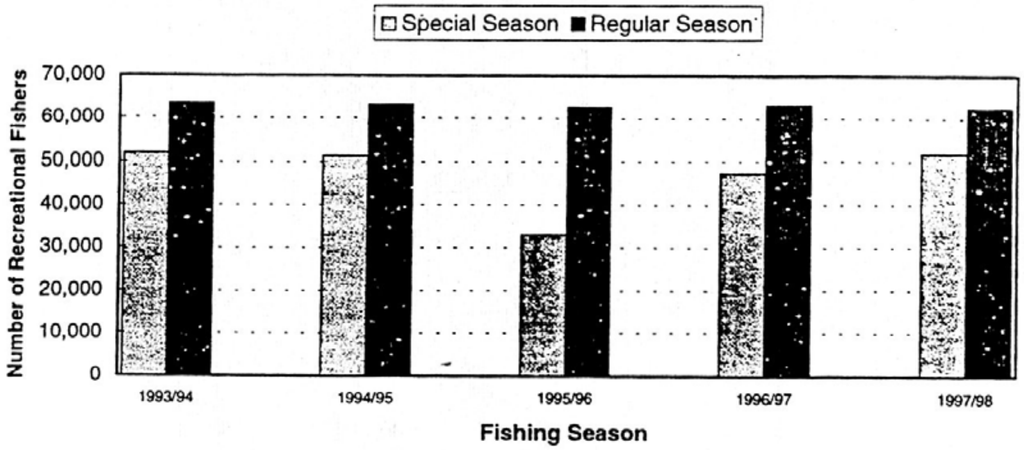
Figure 8. Percentage of landings made through November in the commercial spiny lobster fishery from the 1993/94 through the 1997/98 fishing season.



RECREATIONAL LOBSTER FISHERY MONITORING

Since 1991, the FDEP has conducted annual mail surveys of recreational lobster fishers for the Special Two-Day Sport Season and the first month of the regular season. Results from these surveys provide an estimate of recreational lobster harvest and fisher participation and permit analysis of long-term trends and the assessment of management regulations implemented within the fishery. In this section, we present a summary of lobster harvest and effort by the recreational fishing sector from the 1991-92 through the 1997-98 fishing season. Detailed

Figure 9. Estimated number of recreational spiny lobster fishers that participated in the Special Two-Day Sport Season and the first month of the regular season from the 1993/94 through the 1997/98 fishing season.



methodologies of our mail survey are presented in Sharp *et al.* (1994).

Since 1991, annual statewide recreational crawfish license sales have been stable at approximately 110,000. The number of participants has similarly remained generally stable Figure 9). Approximately 60,000 people participated at some time during the first month of the regular season and approximately 50,000 people participated in the Special Two-Day Sport Season, although a noticeable drop in participation occurred during the 1995 Special Two-Day Sport Season. We speculate that the drop in participation during that year was the result of inclement weather in the Florida Keys and in various other areas in the State. The recreational harvest has also remained stable (Figure 10). Since the 1991/92 season, the combined harvest of the Special Two-Day Sport Season and first month of the regular season has been approximately 1.7 million lobsters with the exception of the 1992/93 season. The lower harvest during that season was almost certainly the result of Hurricane Andrew, which effectively ended recreational lobster fishing in south Florida during the last two weeks of our regular season survey period. Most of the fishing effort (Figure 11) and harvest (Figure 12) occurred in the Florida Keys. Most of the remaining harvest and effort occurred along the southeast coast (Dade through Martin Counties) of Florida.

We also monitor the potential for temporal shifts in recreational fishing effort by using information provided to us by Special Recreational Crawfish License (RL) holders. These license holders are required to report their fishing activities and harvest for the entire season to the FDEP. Because these individuals are among the most dedicated recreational lobster fishers, we expect that they would be the first to increase their fishing activities beyond present levels should they perceive lobsters were more abundant in the latter part of the season. These license

Figure 11. Estimated participation of recreational fishers in the Florida Keys, the southeast coast of Florida, and the remainder of the state from the 1992/93 through the 1997/98 fishing season., A = Special Two-day Sport Season and B = regular season (first month).

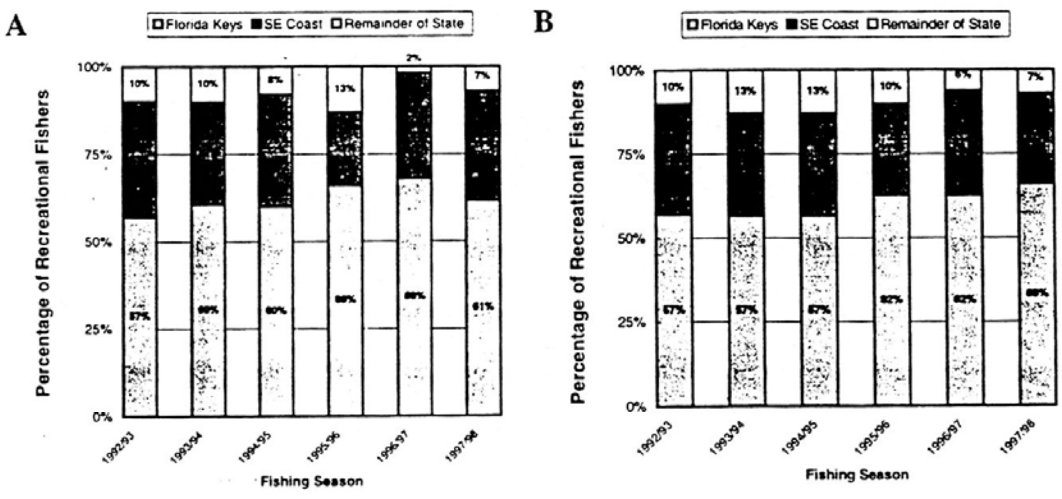
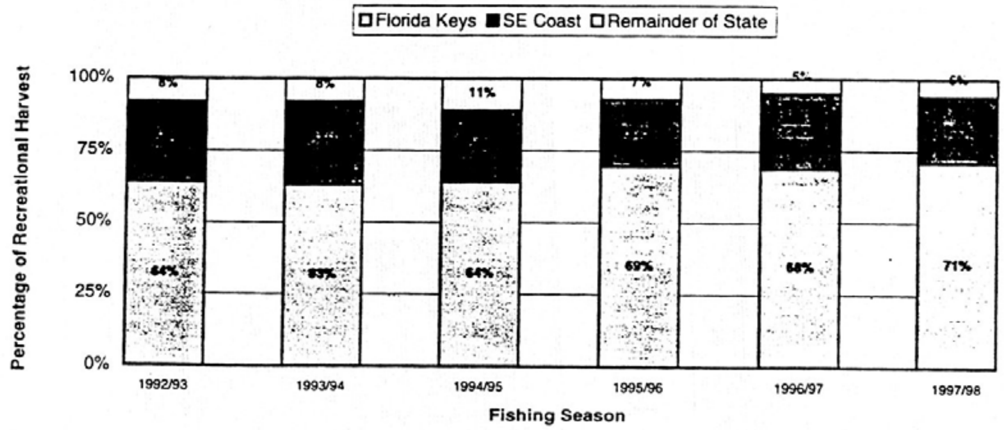


Figure 12. Combined percentage of recreational harvest in the Florida Keys, the southeast coast of Florida, and the remainder of the state from the 1992/93 through the 1997/98 fishing season during the Special Two-day Sport Season and the first month of the regular season .

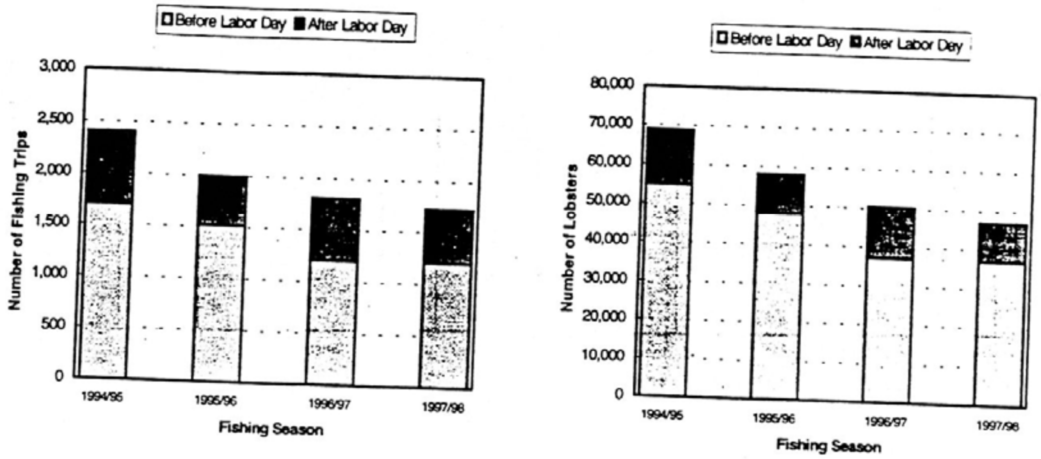


holders have submitted four years of fishing information and report that they conduct approximately 80% of their fishing effort and capture approximately 80% of their total harvest by Labor Day (the first Monday in September) (Figure 13). There has been no change in these proportions during the years.

THE 1998/99 COMMERCIAL SEASON AND HURRICANE GEORGES

For the past two seasons we have provided the FMFC with an estimate of the commercial lobster harvest for the season based on the August landings in each season. We predicted that total landings for the 1995/96 and 1996/97 fishing seasons to be 6.8 million lbs. and 7.5 million lbs., respectively (FDEP supplemental report to the FMFC, 1995,1996); actual landings during those two seasons were 7.0 and 7.7 million lbs., respectively. Hurricane Georges has almost certainly impacted this season's landings. However, we still provide a preliminary estimate of total landings based on landings during August. This estimate will be useful to evaluate the effects of the hurricane on the fishery once landings for the entire season are available. Unfortunately, the MFIS database for August 1998 is not yet complete. Therefore, we first had to estimate the total August landings based on the existing data. The MFIS data currently show that 1,185,024 lbs. of

Figure 13. The (A) number of lobster fishing trips and (B) harvest reported by Special Recreational Crawfish license holders from the 1994/95 through the 1997/98 fishing season.



lobster were landed during 5,466 commercial lobster fishing trips during August 1998. The average number of fishing trips reported during August from the 1985/86 through the 1997/98 fishing season is 7,700. Thus, we estimate that 71% of August fishing trips have been reported. Using this ratio, we estimate that the actual landings during August to be approximately 1,670,000 lbs. We then calculated a least squares linear regression equation using August landings from the 1985/86 through the 1997/98 fishing season as the independent variable and total landings over the same time period as the dependent variable. The analysis yielded the equation ($r^2 = .85$):

$$TL = 2.447\ (AL) + 2{,}074{,}075$$

From this equation, we estimate that the total landings (TL) for the 1998/99 fishing season would have been 6.2 million lbs. without the impacts from Hurricane Georges. Although this estimate is approximately 1 million lbs. less than those of the previous four seasons, it remains well within the range of landings of the past 20 seasons (see Figures 1 & 2). We will refine this estimate once all August landings are available in the MFIS database.

Hurricane Georges resulted in a considerable amount of lost and damaged fishing gear. Additional lost fishing effort resulted as many fishermen attended to personal issues in the aftermath of the storm. Although assessing the full impact of the storm on the fishery is impossible, we conducted an informal canvass of lobster fishermen after the storm to obtain a coarse estimate of the amount of gear lost. This survey indicated that as much as 50% to 80% of traps fishing ocean-side in the Keys were lost or damaged. An estimated 20% of traps fishing on the gulf-side of the Keys were lost or damaged. Given the extent of the gear loss, we expect that landings for this season will be below that of our predicted landings for this season. It is possible that many fishermen will not fish for lobster for the remainder of the season, while others that continue fishing for lobster during the remainder of the season may experience higher CPUE. Presently we can only speculate on these results but should be able to provide a more detailed evaluation of the effects of the storm on the lobster fishery at the end of the season.

We have been asked by the FMFC to assess the impact of the storm on sublegal attractants confined in traps. Although our assessment is purely speculative, we believe the impact of the storm on attractants to be minimal. Some attractants undoubtedly died in traps that were buried or destroyed; others probably escaped as traps broke apart. Presently it is impossible to estimate how many traps were lost or damaged. However, we believe the impact to attractant lobsters will have minimal effects on future recruitment to the fishery. Indeed, given the reduction in effort the fishery will now likely experience, the impact of fishing to sublegal lobsters may be less this season than in normal seasons and therefore may result in an increase in recruitment to the fishery next fishing season.

SUMMARY AND RECOMMENDATIONS

Our data and model results continue to show that there is room for further reduction of traps in the commercial spiny lobster fishery. The number of traps has been reduced from approximately 939,000 in 1991 to approximately 540,000 at the start of the 1998/99 fishing season. Commercial landings over the same period have remained similar to those of the past two decades. Further, a shift in the harvest allocation from the commercial to the recreational sector has not occurred (Figure 14). The optimal number of traps required to sustain landings within the range of landings of the past two decades is uncertain because there is minimal data on the fishery when it operated with 250,000 to 500,000 traps. Therefore, the plan developed by the FMFC in 1996 in which trap reductions occur every other year remains the prudent course of action for the next few fishing seasons.

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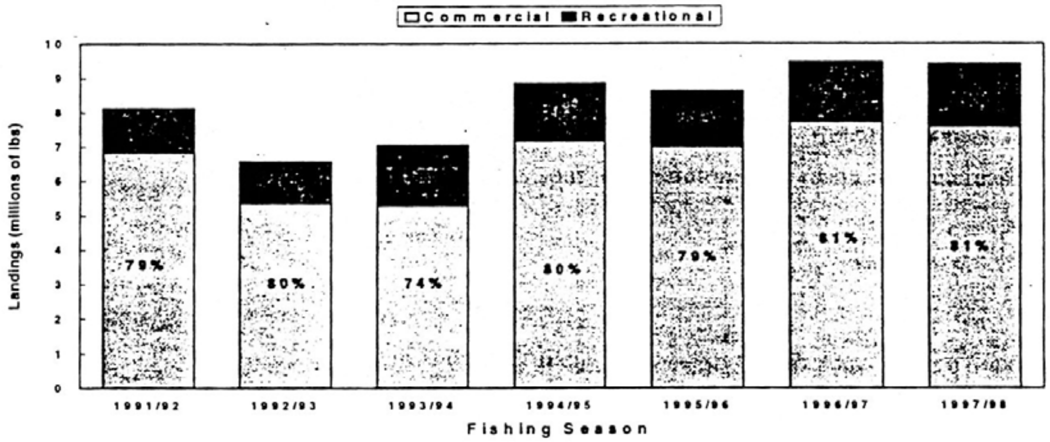
Figure 14. Combined spiny lobster harvest of the commercial and recreational fisheries (excluding RL landings) from the 1991/92 through the 1997/98 fishing season.



Fisheries Research Report **58.** 60p.

Sharp, W.C., R.D. Bertelsen, and J.H. Hunt. (*in press*) The 1994 Florida recreational spiny lobster fishing season: results of a mail survey. *Proceedings of the Gulf and Caribbean Fisheries Institute* **48.**

Appendix H. Evaluation of Effort Reduction in the Florida Keys Spiny Lobster, *Panulirus argus*, Fishery Using An Age-Structured Population Analysis (FL DEP).

Evaluation of effort reduction in the Florida Keys spiny lobster, *Panulirus argus*, fishery using an age-structured population analysis

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Abstract. A management programme implemented in Florida in 1993 was designed to reduce the number of traps in the spiny lobster fishery in order to reduce gear conflicts, environmental damage and effort without reducing harvest. Traps in the commercial fishery were reduced from 939 000 in 1991 to 568 000 in 1995. Landings by fishing season, zone (upper Florida Keys and lower Florida Keys), sex, and time period (summer *v.* winter) were pro-rated into numbers by length that were assigned ages by using growth simulations. From tag–recapture data, moult interval was estimated by using a logistic regression with terms for zone, sex, time period, carapace length, and time at large. For lobsters that moulted, the moult increment was modelled with a multiple regression including the same terms. Standardized catch-per-trip and total landings increased as traps were reduced. Age-structured analysis of the catches-at-age indicated that fishing mortality decreased by 16%, even as landings increased. It is not known whether the increase in landings was due to natural population fluctuations or to positive results of trap reduction. Fishing mortality rates still exceed common benchmarks used in fishery management, and excessive traps remain in the fishery.

Introduction

Caribbean spiny lobsters, *Panulirus argus*, have been harvested in Florida for over 100 years (Labisky *et al.* 1980) and are presently the State's second most valuable commercial fishery after pink shrimp, *Penaeus duorarum*, with an ex-vessel value that exceeded $US34 million in 1995 from landings of approximately 3000 t (Florida Department of Environmental Protection, Marine Fisheries Information System, unpublished data). The fishery is located principally in the Florida Keys, where approximately 90% of the State's harvest is landed. Spiny lobsters also support a large recreational fishery whose participants harvest approximately 1·5 million lobsters (750 t) annually (Sharp *et al.*, in press)

Since the 1950s, the commercial fishery has chiefly used wooden slat-traps. Landings in Florida increased throughout the 1960s and early 1970s as the number of traps increased to approximately 250 000. In 1975, the closure of Bahamian waters to USA fishers resulted in dramatically increased effort in the Florida Keys. The number of traps increased to approximately 500 000 (Labisky *et al.* 1980); however, landings did not increase. The number of traps continued to increase, reaching a peak of approximately 939 000 in 1991, again with no commensurate increase in landings (Table 1). Responding to the industry's concerns about excessive effort in the fishery, the State of Florida Legislature enacted a programme to reduce the number of traps in the fishery. The intended benefits of this programme, implemented in 1993, were to reduce effort while maintaining harvest at historic levels, minimize environmental damage, and reduce gear conflicts (Hunt 1994). By the onset of the 1995 fishing season, the number of traps had been reduced to approximately 568 000 and landings had not decreased. The number of commercial trips similarly peaked in the 1991–92 fishing season; trips decreased by approximately 28% between the 1991–92 and 1995–96 fishing seasons (Table 1). The combined harvest of the commercial and recreational fisheries fluctuated between 4·5 and 7·2 million lobsters.

In this paper, the effect of the trap reduction in the spiny lobster fishery of the Florida Keys is evaluated. Fishery landings, length–frequency information and growth data obtained from tag–recapture studies were integrated to capture the dynamics of the fishery. We then applied an age-structured population analysis (Megrey 1989), specifically the Integrated Catch-at-Age Analysis (Patterson and Melvin 1996), to estimate fishing mortality rates and lobster population sizes. Model outputs were then used to determine whether recent increases in landings were the result of *(i)* increased lobster abundance related to cyclical fluctuations and positive effects of trap reduction, or *(ii)* increased efficiency of the commercial industry resulting in higher fishing mortality (Hunt 1994).

Table 1. Spiny lobster harvest and effort for the Florida Keys

Recreational harvest for the fishing seasons prior to 1991–92 were estimated from August commercial landings

Fishing season	Commercial Landings (t)	Traps	Trips	Commercial harvest No. lobsters	Recreational harvest No. lobsters	Combined harvest No. lobsters
87–88	2223	777.000	29.912	4.033.500	998.688	5.032.188
88–89	3010	787.000	32.202	5.621.467	1.345.871	6.967.338
89–90	3319	916.000	35.597	5.850.588	1.441.481	7.292.069
90–91	2461	876.000	35.349	4.109.189	1.125.678	5.234.867
91–92	2662	939.000	38.628	4.809.887	1.381.163	6.191.050
92–93	2119	831.000	30.441	3.885.551	928.312	4.813.863
93–94	2008	704.000	25.846	3.602.457	907.249	4.509.706
94–95	2923	639.000	27.116	5.250.992	1.382.204	6.633.196
95–96	2847	568.000	27.827	5.022.416	1.447.627	6.470.043

Methods

Data sources

Landings and effort data for the commercial lobster fishery from the 1987–88 through the 1995–96 fishing seasons were extracted from Florida's Marine Fisheries Information System. Beginning in 1984, all wholesale seafood dealers in Florida have been required to submit copies of their purchases of salt-water products ('trip tickets') to the Florida Department of Environmental Protection (DEP). Dealers are subject to random audits by the DEP to verify the accuracy of data reported on the trip tickets. Trip tickets show landings, fishing effort, gear, and the location and date of those landings for every fishing trip. The study was confined to the Florida Keys because most of the harvest occurs there. Accordingly, only lobsters landed in Monroe and Dade counties were incorporated because those lobsters were harvested primarily in Florida Keys waters. Estimates of the total number of traps in the fishery for the 1987–88 through 1992–93 fishing seasons were obtained from the National Marine Fisheries Service (NMFS) General Canvass. Trap numbers in subsequent fishing seasons were the number of trap certificates issued by the State of Florida (Hunt 1994). Numbers of commercial trips per season were the sum of individual trip tickets containing lobster landings.

Estimates of the recreational lobster harvest made for the 1991–92 through 1995–96 fishing seasons were obtained from mail surveys of recreational licence holders conducted by the DEP (Sharp *et al.*, in press). The recreational season in Florida comprises the Special Two-Day Sport season during late July and the regular season (concurrent with the commercial fishing season, 6 August through 31 March). Estimates encompassed only the Special Two-Day Sport Season and the period between 6 August and Labor Day (the first Monday of September). However, an additional mail survey (not used in production of the estimate) at the end of the 1994–95 season indicated that ~90% of the recreational harvest occurs by Labor Day (Sharp *et al.*, in press). We used the average ratio between commercial landings (converted to numbers of lobsters) and the recreational harvest from the 1991–92 through the 1995–96 fishing season to extrapolate recreational harvest for the 1987–90 fishing seasons.

Samplers from the DEP and the NMFS have measured the carapace length (CL, to the nearest 1 mm) and recorded the sex of spiny lobsters landed at dealers throughout the Florida Keys since August 1987. DEP observers on selected commercial lobster trips have recorded the same data directly from traps since 1993. Data collected directly from traps are crucial because traps capture lobsters smaller than the minimum legal size of 3 in (~76 mm) CL, and onboard observers measure the entire catch.

We developed growth models using tag–recapture information obtained from three studies. Growth was calculated for subadults and adults from data collected during 1975–76 in the lower Florida Keys (Warner *et al.* 1977) and during 1978–79 in the upper Florida Keys (Lyons *et al.* 1981). Growth of newly settled juveniles was calculated from data collected in an ongoing study in the upper Florida Keys.

Landings, length–frequency, and tag–recapture data were partitioned by zone (upper Keys and lower Keys), time period (summer and winter), and sex in order to capture within-fishing-season variability. We divided the Florida Keys into the two zones on the basis of two factors: differential access to fishing grounds and trip duration. The upper Keys zone extended from north Key Largo to Big Pine Key and the lower Keys zone extended from Big Pine Key to west of the Dry Tortugas (Fig. 1). Landings and the biological data measured at seafood dealers were assigned to a zone based on the location of the dealer; we assumed that lobsters landed at dealers located within a zone were harvested within that zone. Trap-based data collected by onboard observers was partitioned by zone on the basis of the location of each trap. Summer (May to October) and winter (November to April) were separated on the basis of differential growth rates related to water temperature (Hunt and Lyons 1986).

Catch-at-length

Catch-at-length for all lobsters harvested was extrapolated from the lengths measured in the length–frequency sampling by using the ratio of the sum of their estimated weights to the weight of commercial landings (Gulland 1969): the weights of measured lobsters were estimated from the appropriate sex-specific length–weight equation (Lyons *et al.* 1981). This process was repeated for each fishing season in each stratum (zone and time period). The recreational harvest was partitioned into lengths by using the length–frequency distribution developed from the commercial fishery. Finally, the commercial and recreational harvests were added together by stratum. Catch-at-length of the combined harvests then was pooled into 5-mm size-classes by sex.

Growth

We modelled growth by treating the two distinct components of lobster growth, moult interval and moult increment, separately (Hunt and Lyons 1986). For moult interval, we applied logistic regressions (Fogarty and Idoine 1988) to tag–recapture data to estimate the probability of an individual moulting in a given month. We included terms in the regression for time at large, and dummy variables for time period, zone and sex:

$$P_m = \frac{e^{a+bL+cT+dZ+et+gX}}{1+e^{a+bL+cT+dZ+et+gX}}, \qquad (1)$$

where P_m is the probability of moulting; a is a constant; b is the coefficient for carapace length, L; c is the coefficient for time at large in days, T ; d is the coefficient for zone, Z; e is the coefficient for time period, t; and g is the

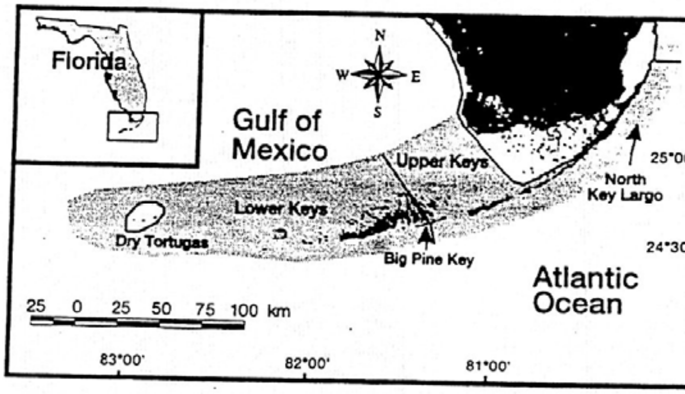

Fig. 1. Map of the Florida Keys showing the two lobster fishing zones: upper Florida Keys and lower Florida Keys. Grey, fished area; stippled, lobster sanctuaries.

coefficient for sex, X. We included only those lobsters that had been at large less than four months (n = 5848) in the regression analysis to reduce the chance that lobsters had moulted more than once.

We attempted to estimate moult increment by using the Fogarty and Idoine (1988) method of extracting mean length changes from overlapping distributions. However, after the recaptured lobsters that had moulted (n = 989) had been partitioned into strata, there were insufficient recaptures in some of the strata to use this method. Our alternative used the following multiple regression to estimate the moult increment as a function of initial length, time at large, and dummy variables for season, zone, and sex.

$$I = e^{a + bL + cT + dZ + et + gX} \qquad (2)$$

where I is the growth increment (mm).

We developed growth curves by zone and sex from growth trajectories of 250 lobsters per stratum produced by Monte Carlo simulations (Efron and Gong 1983; Manly 1991). We used an initial CL of 50 mm (CV = 10%), the approximate length of a lobster 12 months after settlement, to start each simulation. P_m was calculated monthly for 15 years (180 months) for each lobster. The lobster moulted when a number drawn from a uniform random variable between 0 and 1 was less than or equal to that lobster's calculated P_m. If the lobster moulted, the change in length was determined from Eqn 2. The resulting growth curves were plots of all the lengths within an age (for example, all lengths from 24 to 35 months post-settlement were assigned to age 2).

Catch-at-age

We combined catch-at-length and the growth curves by zone and sex to generate age–length keys. These keys retain the original variability of the lengths and their ages. Because numbers of lobsters by age for a given length are a function of total mortality, we used estimates of total mortality from Chapman–Robson catch curves (Ricker 1975; Murphy 1997) to create the initial age–length keys, then used those keys to convert the estimated numbers of lobsters by carapace length (catch-at-length) to numbers of lobsters by age (catch-at-age). We applied an age-structured model, described below, to the catch-at-age to solve for fishing mortality rates. The fishing mortality rates from the model, together with the natural mortality, were used to revise the age–length keys. This process was repeated with the revised catch-at-age until the fishing mortality rates no longer changed. In the data, some older ages occurred sporadically, so the oldest age that occurred in all fishing seasons was identified, then all lobsters older than that age were combined with that age, creating a plus group. For example, all the females older than 8 years in the upper Keys were combined into the 9+ group.

Estimation of mortality rates and population sizes

We used a derivative of Fournier and Archibald's (1982) age-structured assessment model that combines catch-at-age, an index of abundance, and natural mortality to estimate fishing mortality rates by season, the age-specific selectivity, the numbers of lobsters in the most recent fishing season, and the number of lobsters in the next-to-last-oldest age in each fishing season (ICA: Integrated Catch at Age, Version 1.2, Patterson and Melvin 1996). This method employs a non-linear minimization routine to identify values for the estimated parameters that minimize the differences between observed and predicted catch-at-age and between observed and predicted values for abundance index. Fishing mortality rates for any age and fishing season in this model are the product of the fishing mortality for fully recruited ages (age 3 for females and age 2 for males) and age-specific selectivity. The fishing mortality for each fishing season relates to fishing effort.

In addition to the catch-at-age information described previously, the ICA model requires one or more indices of abundance and an estimate of natural mortality. We used the standardized weight per commercial trip, partitioned by zone and fishing season, as the index of abundance. Weight per commercial trip was transformed by using the natural logarithm, then standardized with an analysis of covariance to reduce the confounding effects of month and trip duration. We used fishing season and month as classification variables and trip duration as the covariate. The catch rates were further partitioned into sex using the sex specific numbers of commercial lobsters harvested within each stratum. The indices were then normalized to their means in order to focus on the relative change of the catch rate and not the magnitude of the rate. We used a natural mortality rate of 0.3 per year which results in a maximum age of 15 years.

To facilitate fishery-wide comparisons, average fishing mortality rates were calculated from the Baranov catch equation (Ricker 1975) using the estimated population sizes produced by the ICA, the harvest in numbers, and the natural mortality rate:

$$C = NF\,(1 - e^{-Z}) / Z. \qquad (3)$$

where C is the number of lobsters harvested; N is the starting population size; F is the average fishing mortality rate; and Z is the total mortality rate (fishing mortality + natural mortality).

Catchability

Catchability refers to the amount of fishing mortality (F) by a unit of effort. A simple expression for catchability is

$$q = F / f, \qquad (4)$$

where q is the catchability coefficient, and f is the nominal effort. We calculated catchability from the number of traps in the fishery as the measure of effort and also from the number of commercial lobster trips per fishing season.

Spawning potential ratios

We used the mortality rates from the ICA to calculate transitional spawning potential ratios (SPR: Mace *et al.* 1996) based on biomass and egg production. We used a maximum age of 15 years in the calculations. The number of eggs produced per brood (E) by female lobsters in the Florida Keys as a function of body weight in grams (W) is given in Equation 5 (DEP, unpublished data):

$$E = 854.4W - 27480. \qquad (5)$$

Multiple spawning was incorporated by assuming that females between 71 mm and 80 mm CL had a single brood and larger lobsters had two broods per year (Lipcius 1985). As with the ICA, the natural mortality rate was 0·3 per year.

Results

Catch-at-length

Onboard observers measured and sexed 168 566 lobsters ranging from 6 to 190 mm CL from the 1993–94 through the 1995–96 fishing season (Fig. 2*a*). Median CLs ranged from 71 mm CL for upper Keys females to 74 mm CL for lower Keys males, i.e. smaller than the minimum legal size. Approximately 30% of the lobsters exceeded the minimum legal size.

Samplers from DEP and NMFS recorded the lengths and sexes of 73 228 lobsters landed by the commercial fishery in the Florida Keys (Fig. 2*b*). The median CLs ranged from 83 mm CL for upper Keys females to 86 mm CL for lower Keys males, i.e. larger than the minimum legal size. CLs from the lower Keys were more variable, as evidenced by wider 90% confidence intervals and interquartile ranges.

We coupled landings and length–frequency data to derive the catch-at-length tables for each fishing season by zone and sex (Table 2). Overall, fishers harvested more males than females. More large lobsters were harvested in the lower Keys than in the upper Keys.

Growth

Moult interval (the probability of moulting within a month) differed according to time period, sex, and carapace length in each zone (Figs 3*a*, 3*b*). In any given month, males were more likely to moult than females and smaller lobsters were more likely to moult than larger ones. The probability of moulting for all lobsters was higher during the summer than during the winter. Moult increments of males were larger than increments of females and were larger during summer than during winter (Figs 3*c*, 3*d*). Moult increment was inversely proportional to CL. The growth simulations indicated that females could attain minimum legal size in an average of 30 months after settlement whereas males could reach minimum legal size in an average of 23 months (Fig. 4).

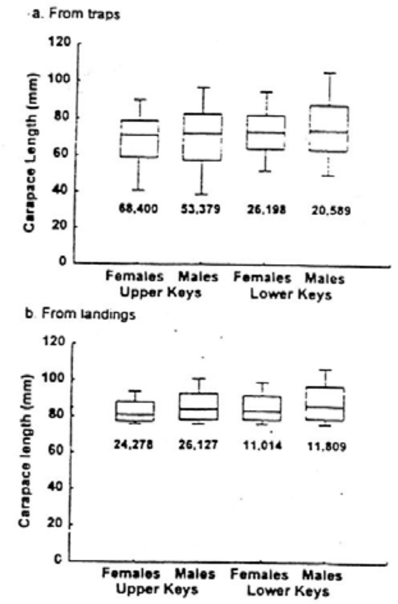

Fig. 2. Distribution of individual lobster carapace lengths by sex and zone in the Florida Keys: (*a*) lengths of lobsters captured in traps as measured by on-board observers; (*b*) lengths of lobsters landed and measured by samplers at seafood dealers. Horizontal line, median; vertical bar, 95% confidence interval; box contains the interquartile range; number represents number of lobsters measured.

Age-structured population analysis

The ICA analyses estimated the population size by fishing season and the fishing mortality rate for each age by fishing season (Table 3). The landings are composed primarily of lobsters that are from 2 to 7 years old. The ICA analyses were tuned with the standardized catch-per-trip adjusted for month and trip duration (Fig. 5). This index has increased in recent fishing seasons throughout the Florida Keys. The estimated abundance of age-1 and older lobsters in the Florida Keys prior to the 1993–94 fishing season averaged approximately 30 million individuals, but it has increased to an average of approximately 33 million lobsters in subsequent fishing seasons (Table 3). Recruitment, estimated by number of age-2 lobsters, varied from 7.8 million to 10.7 million lobsters (Fig. 6). Recruitment was more variable in the upper Keys than in the lower Keys.

Table 2. Catch-at-length of the combined commercial and recreational harvest of lobsters by zone, sex, and fishing season

Upper Florida Keys
Females

Carapace length (mm)	Fishing season								
	87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96
71 – 75	39,337	116,965	23,847	22,946	11,865	16,639	22,302	37,855	53,999
76 – 80	545,787	889,359	718,165	468,568	570,759	438,319	466,576	721,178	876,485
81 – 85	356,247	652,238	583,799	312,421	549,123	392,889	345,052	465,084	496,512
86 – 90	173,662	296,129	437,290	181,979	230,579	209,527	184,999	279,958	283,038
91 – 95	81,899	111,969	187,122	115,821	52,861	72,245	56,140	126,348	99,894
96 – 100	35,980	45,691	58,909	35,408	18,772	21,475	13,365	44,269	36,598
101 – 105	6,027	19,310	24,840	6,375	10,773	8,755	2,367	12,681	7,045
106 – 110	3,832	1,221	2,928	1,743			1,391	1,535	796
111 – 115	260			572		1,173		804	184
116 – 120			454					313	271
121 +								105	
Total	1,243,031	2,132,882	2,037,354	1,145,833	1,444,732	1,161,022	1,092,192	1,690,130	1,854,822

Upper Florida Keys
Males

Carapace length (mm)	Fishing season								
	87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96
71 – 75	21,214	60,655	14,452	12,853	4,047	7,185	6,548	19,709	20,838
76 – 80	461,199	647,276	503,109	384,128	334,249	386,091	450,361	530,844	551,975
81 – 85	403,080	731,514	537,118	324,128	460,718	373,659	446,623	445,248	475,045
86 – 90	252,420	433,460	459,344	240,014	429,406	291,167	303,850	346,567	361,936
91 – 95	144,779	303,079	359,238	168,608	214,172	178,757	181,700	239,022	233,564
96 – 100	65,492	144,733	179,587	71,236	88,201	91,028	78,790	137,190	120,979
101 – 105	20,772	23,325	83,261	39,434	66,486	41,905	25,346	63,933	49,505
106 – 110	9,716	31,779	32,058	18,934	22,390	14,037	5,987	25,634	20,774
111 – 115	5,059	10,185	7,231	11,027	13,232	9,928	2,928	8,488	6,467
116 – 120	4,243	5,554	6,191	727	759	1,173	0	3,321	2,106
121 – 125	260		1,566	1,898	1,339	777	1,384	1,131	584
126 – 130	447	305	454	572				566	156
131 – 135				1,144		777			78
136 – 140									78
141 +	743		1,566						78
Total	1,389,424	2,391,865	2,185,175	1,274,703	1,634,999	1,396,484	1,503,517	1,821,653	1,844,163

Lower Florida Keys
Females

Carapace length (mm)	Fishing season								
	87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96
71 – 75	58,299	18,392	35,723	16,420	23,336	101,407	3,318	25,825	22,826
76 – 80	466,090	376,281	501,911	315,760	491,209	380,432	291,071	502,840	359,780
81 – 85	316,399	367,497	383,917	355,987	409,030	324,330	240,288	353,606	290,308
86 – 90	206,171	218,454	285,799	282,514	251,757	182,869	152,032	291,458	252,704
91 – 95	78,140	96,367	134,931	193,021	145,742	73,201	90,854	178,593	223,937
96 – 100	46,355	66,573	97,027	90,979	82,628	27,963	63,090	97,670	114,868
101 – 105	17,919	24,821	35,136	39,648	25,432	7,989	17,397	47,552	47,131

Table 2. *continued*

Lower Florida Keys
Females

Carapace length (mm)	Fishing season 87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96
106 – 110	10,310	6,543	18,530	25,337	3,798	5,851	4,587	10,345	16,248
111 – 115	1,206	2,625	4,946	50,059	2,533	3,150	7,672	2,879	5,404
116 – 120	3,074		922	8,022	1,266	1,069	3,439	2,300	1,524
121 – 125				6,568		1,069	2,610		1,524
126– 130				6,568		2,138			762
131 – 135	1,206			9,852					
136 – 140			922	8,022					762
141 +									381
Total	1,205,169	1,177,553	1,499,764	1,408,757	1,436,731	1,111,468	876,358	1,513,068	1,338,159

Lower Florida Keys
Males

Carapace length (mm)	Fishing season 87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96
71 – 75	17,191	10,790	15,262	6,385	6,179	94,598	2,135	13,249	12,175
76 – 80	307,463	349,114	395,405	252,221	408,430	262,330	228,934	438,274	257,651
81 – 85	276,752	337,713	351,546	291,010	394,187	296,364	256,388	341,803	244,399
86 – 90	244,256	222,862	230,785	231,527	325,160	197,726	163,728	234,532	211,739
91 – 95	145,188	167,111	211,749	190,642	248,289	141,566	139,970	200,577	218,544
96 – 100	104,315	88,451	143,066	151,001	151,301	98,858	97,696	162,054	203,540
101 – 105	63,426	38,513	98,115	108,596	75,158	24,811	48,609	106,961	139,076
106 – 110	21,758	22,000	71,363	64,370	37,024	13,221	30,889	66,706	89,613
111 – 115	8,594	15,398	28,426	38,752	18,883	4,782	18,350	26,445	22,443
116 – 120	3,753	5,290	6,455	26,974	8,711	2,644	18,471	13,714	12,747
121 – 125	1,868		10,228	14,214		3,713	8,978	2,302	10,538
126 – 130		567	1,844	14,590		2,138	5,574	1,728	4,074
131 – 135		3,997	922	8,022		2,138	3,244		1,905
136 – 140			1,844	2,908			1,622		1,143
141 – 145		3,232	922	1,454	1,266		3,915		381
146 – 150			922	1,454			1,305		381
151 – 155			922	1,454					381
156 – 160							5,221		2,169
161 +							2,610		
Total	1,194,564	1,265,038	1,569,776	1,405,574	1,674,588	1,144,889	1,037,639	1,608,345	1,432,899

Fishing mortality rates on the fully recruited ages (age 3 in females and age 2 in males) varied more than two fold. In the upper Keys, this fishing mortality was highest during the 1989–90 fishing season and lowest during the 1993–94 season (Tables 3*a*, 3*b*). In the lower Keys, fishing mortality was highest among males during both the 1989–90 and 1990–91 seasons; highest mortality among females occurred during the 1990–91 season. The lowest fishing mortality on both sexes occurred during the 1993–94 fishing season.

Average fishing mortality rates estimated by the Baranov catch equation were variable but there were some clear patterns. Fishing mortality rates in the upper Keys (average $F = 0{\cdot}59$ per year) were higher than those in the lower Keys (average $F = 0{\cdot}33$ per year), and fishing mortality rates before 1993–94 fishing season (average $F = 0{\cdot}47$ per year) were higher than in subsequent seasons (average $F = 0{\cdot}39$ per year) for the entire Florida Keys. Selectivity (i.e. availability to the fishery) was inversely proportional to age.

Catchability calculated using the number of traps as the estimate of effort trap varied without trend (Fig. 7*a*) but was considerably higher during the 1995–96 fishing season than previous seasons. Catchability calculated using the number

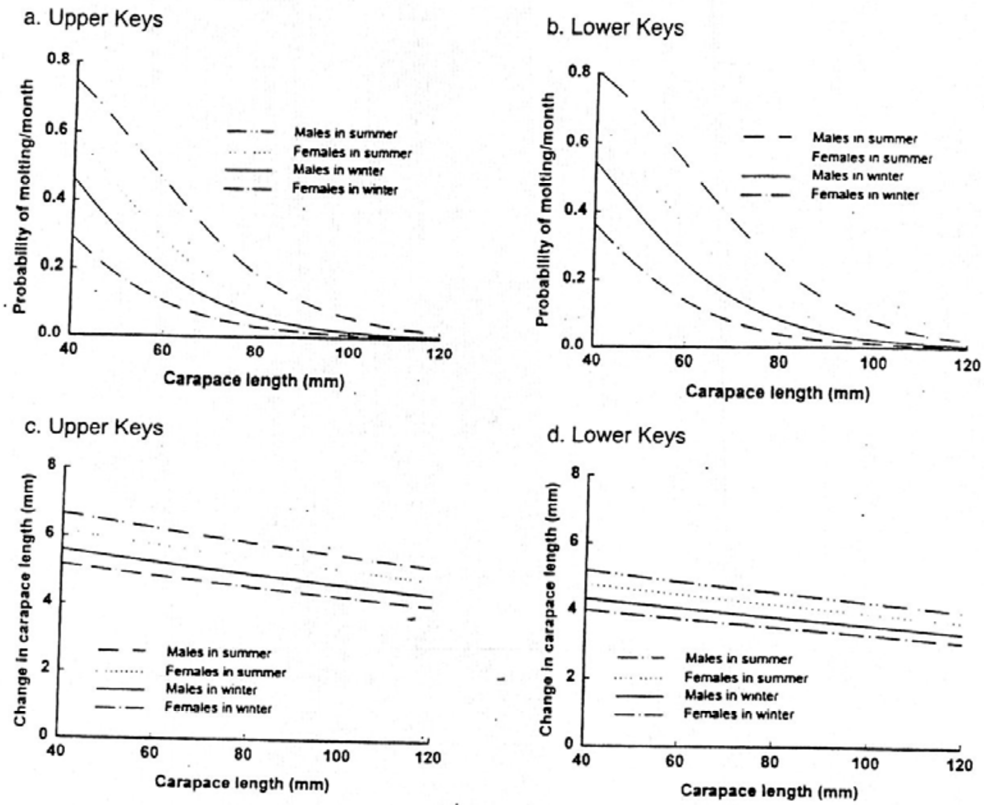

Fig. 3. Characterization of growth by sex, time period, and carapace length: *(a)* probability of moulting during a month in the upper Florida Keys; *(b)* probability of moulting during a month in the lower Florida Keys; *(c)* growth increment (mm) for lobsters that moulted in the upper Florida Keys; *(d)* growth increment (mm) for lobsters that moulted in the lower Florida Keys.

of commercial fishing trips similarly varied without trend but did not show the increase in 1995–96 shown by the trap catchabilities (Fig. 7*b*).

Transitional spawning potential ratios based upon biomass varied between 7% and 19% in the upper Keys during these years (Table 3*a*). The SPR values in the lower Keys were higher and varied between 20% and 31% (Table 3*c*). The SPRs were approximately 2%–4% higher when they were calculated from fecundity instead of biomass.

Discussion

Although length-based models are useful when the underlying information base is limited, they require assumptions regarding equilibrium conditions, especially that recruitment is constant and that the single mortality rate is constant across all ages in the fished stock (Shepherd *et al.* 1987; Hilborn and Walters 1992). Age-structured population models integrate life-history information with fisheries information and assume neither constant recruitment nor constant mortality across ages (Megrey 1989). Instead, these models solve for age-specific population size, fishing mortality rates by season, and age-specific selectivities. Consequently they more realistically model the dynamics of the fishery. Age-structured models require extensive background information and are data intensive. However, for those lobster fisheries where biological and fishery monitoring data are sufficient to develop growth curves from settlement and to assign ages to the catch, we recommend age-structured models because of the higher resolution that they provide.

Conclusions from age-structured analysis inherently depend upon the ages of the lobsters landed. Because we cannot directly age lobster individuals, growth is the key component of our analysis. We modelled the two distinct

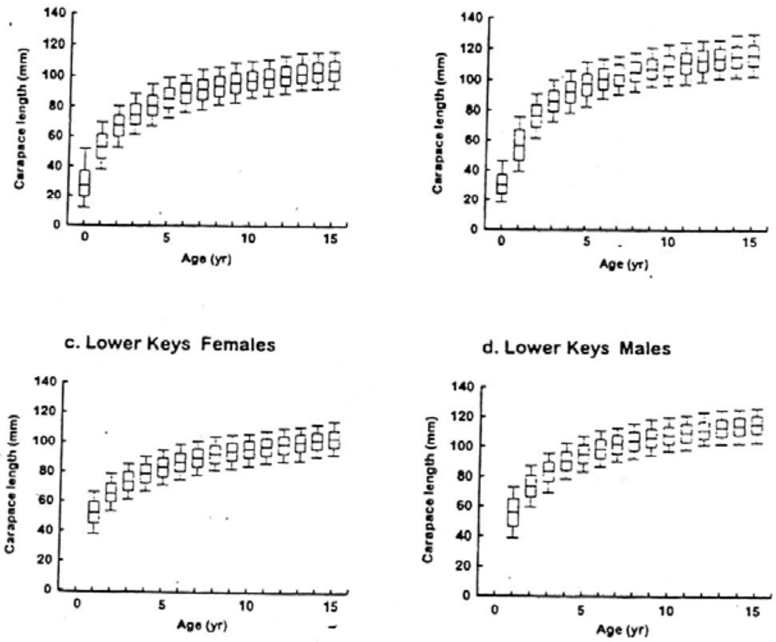

Fig. 4. Length–age distributions by zone and sex based on probabilities of moulting and the corresponding growth increments. Horizontal line, median; vertical bar, 95% confidence interval; box contains the interquartile range; number represents number of lobsters measured.

Table 3. Catch-at-age, estimated population size, fishing mortality rates, average fishing mortality rates for ages 2–7, and transitional spawning potential ratios by fishing season for *P. argus*

Fishing mortality rates in bold represent the rate for the fully recruited age-class (selectivity = 1·00). Natural mortality rate: 0·30 year^{-1}

(*a*) Upper Florida Keys Females

Number Harvested

Age (yr)	Fishing season 87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96
1	0	0	0	0	0	0	0	0	0
2	585.124	1.006.324	742.012	491.514	582.624	454.958	488.878	759.033	930.484
3	445.245	817.930	772.508	397.930	663.407	509.724	431.710	607.544	631.462
4	129.275	196.790	359.638	154.218	135.515	138.577	137.074	204.570	199.680
5	51.130	59.834	83.225	70.771	39.360	28.311	20.750	70.212	58.119
6	18.268	23.265	41.385	20.812	12.473	18.351	9.330	29.042	19.471
7	5.357	12.995	11.930	3.069	5.208	5.075	692	8.061	8.649
8	3.125	10.419	21.708	5.204	5.386	1.950	976	8.420	3.981
9+	5.507	5.325	4.948	2.315	759	4.076	2.782	3.248	2.976
Ages 2–7	1.234.399	2.117.138	2.010.698	1.138.314	1.438.587	1.154.996	1.088.434	1.678.462	1.847.865
Total	1.243.031	2.132.882	2.037.354	1.145.833	1.444.732	1.161.022	1.092.192	1.690.130	1.854.822

Table 3. *continued*

Population size

Age (yr)	87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96
	Fishing season								
1	4.844.306	3,591,667	3,003,250	2,937,536	2,581,710	3,252,713	3.820,053	4.164.219	3.301.833
2	2,780,013	3,588,750	2,660,772	2,224,862	2,176,180	1,912,578	2,409,669	2,829,965	3,084,929
3	1,070,898	1,611,619	1,844,506	1,099,428	1,120,238	1,129,754	1,064,361	1,544,808	1,526,971
4	372,346	466,057	540,188	385,091	352,435	383,738	449,965	576,210	575,384
5	170,552	169,082	166,435	124,790	131,991	128,402	160,607	249,779	226,739
6	122,269	89,137	74,460	53,732	53,371	58,961	63,318	96,859	117,874
7	49,831	67,703	42,785	27,583	25,169	25,924	31,102	39,509	49,253
8	14,848	31,109	38,860	21,088	15,606	14,548	15,729	20,829	23,460
9+	6,304	12,010	21,487	23,733	21,842	18,865	18,149	21,455	22,211
Ages 2–7	4,565,909	5,992,348	5,329,146	3,915,486	3,859,384	3,639,357	4,179,022	5,337,130	5,581,150
Total	9,431,367	9,627,134	8,392,743	6,897,843	6,478,542	6,925,483	8,032,953	9,543,633	8,928,654

Fishing mortality rates

Age (yr)	87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96	Selectivity
	Fishing season									
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.25	0.37	0.58	0.39	0.36	0.29	0.14	0.32	0.37	0.46
3	0.53	0.79	1.27	0.84	0.77	0.62	0.31	0.69	0.79	1.00
4	0.49	0.73	1.17	0.77	0.71	0.57	0.29	0.63	0.73	0.92
5	0.35	0.52	0.83	0.55	0.51	0.41	0.21	0.45	0.52	0.66
6	0.29	0.43	0.69	0.46	0.42	0.34	0.17	0.38	0.43	0.55
7	0.17	0.26	0.41	0.27	0.25	0.20	0.10	0.22	0.26	0.32
8	0.27	0.40	0.63	0.42	0.39	0.31	0.16	0.34	0.40	0.50
9+	0.27	0.40	0.63	0.42	0.39	0.31	0.16	0.34	0.40	0.50
Average Ages 2–7	0.35	0.52	0.82	0.55	0.50	0.40	0.20	0.45	0.52	

Transitional spawning potential ratios (SPR)

	87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96
	Fishing season								
Biomass	15%	12%	7%	8%	9%	12%	19%	16%	13%
Fecundity	18%	15%	9%	11%	12%	15%	23%	18%	15%

(*b*) Upper Florida Keys Males

Number Harvested

Age (yr)	87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96
	Fishing season								
1	281,594	427,178	282,347	235,697	194,498	231,358	263,009	355,483	372,927
2	885,939	1,503,944	1,311,805	772,208	1,104,082	871,220	988,409	1,047,333	1,089,175
3	165,025	371,727	430,807	181,374	220,749	211,256	205,464	291,267	280,165
4	32,824	38,155	96,673	45,426	62,796	49,709	34,384	80,307	63,773
5	9,529	28,808	30,888	13,574	32,407	17,558	4,880	27,040	22,256
6	4,208	6,009	17,141	13,682	7,996	4,282	4,035	8,547	8,272
7	4,092	9,502	4,698	5,957	8,854	7,201	1,952	5,883	4,087
8+	6,213	6,542	10,816	6,785	3,617	3,900	1,384	5,793	3,508
Ages 2–7	1,101,617	1,958,145	1,892,012	1,032,221	1,436,884	1,161,226	1,239,124	1,460,377	1,467,728
Total	1,389,424	2,391,865	2,185,175	1,274,703	1,634,999	1,396,484	1,503,517	1,821,653	1,844,163

Table 3 *continued*

(*b*) Upper Florida Keys Males
Population size

Age (yr)	87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96
	Fishing season								
1	3,577,928	3,817,765	2,101,228	2,915,715	2,519,570	2,585,993	3,476,854	3,144,816	4,216,661
2	1,659,635	2,446,622	2,503,993	1,308,891	1,916,460	1,627,137	1,711,394	2,401,976	2,050,051
3	451,771	632,133	659,016	439,462	358,894	453,890	472,219	709,725	614,958
4	159,384	185,636	191,093	136,303	134,961	96,805	146,583	209,227	205,110
5	40,602	84,015	81,959	67,765	60,729	55,790	44,402	80,703	90,006
6	33,137	23,035	41,481	34,078	33,698	28,476	28,382	26,065	39,043
7	16,392	19,692	12,204	19,069	18,162	17,108	15,464	17,348	13,579
8+	6,968	12,409	14,339	9,571	12,908	13,014	13,967	16,313	14,660
Ages 2–7	2,360,921	3,391,133	3,489,746	2,005,568	2,522,904	2,279,206	2,418,444	3,445,044	3,012,747
Total	5,945,817	7,221,307	5,605,313	4,930,854	5,055,382	4,878,213	5,909,265	6,606,173	7,244,068

Fishing Mortality Rates

Age (yr)	87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96	Selectivity
	Fishing season									
1	0.08	0.12	0.17	0.12	0.14	0.11	0.07	0.13	0.11	0.12
2	**0.67**	**1.01**	**1.44**	**0.99**	**1.14**	**0.94**	**0.58**	**1.06**	**0.89**	**1.00**
3	0.59	0.90	1.28	0.88	1.01	0.83	0.51	0.94	0.79	0.89
4	0.34	0.52	0.74	0.51	0.58	0.48	0.30	0.54	0.46	0.51
5	0.27	0.41	0.58	0.40	0.46	0.38	0.23	0.43	0.36	0.40
6	0.22	0.34	0.48	0.33	0.38	0.31	0.19	0.35	0.30	0.33
7	0.33	0.51	0.72	0.50	0.57	0.47	0.29	0.53	0.45	0.50
8+	0.33	0.51	0.72	0.50	0.57	0.47	0.29	0.53	0.45	0.50
Average Ages 2–7	0.40	0.61	0.87	0.60	0.69	0.57	0.35	0.64	0.54	

(*c*) Lower Florida Keys Females
Number Harvested

Age (yr)	87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96
	Fishing season								
1	0	0	0	0	0	0	0	0	0
2	524,389	394,673	537,634	332,180	514,545	481,839	294,389	528,665	382,606
3	394,624	459,768	496,710	479,023	521,393	412,896	300,527	466,947	399,772
4	171,127	169,323	225,167	242,738	200,105	115,403	134,391	257,966	239,542
5	48,701	62,886	111,870	129,186	99,003	64,198	60,478	122,903	155,016
6	32,613	56,914	67,927	71,554	68,656	15,866	50,868	73,511	87,487
7	10,548	15,770	11,991	20,976	12,551	4,276	6,247	31,448	21,379
8	6,165	3,997	13,585	15,388	11,768	2,644	9,015	13,806	15,405
9+	17,002	14,222	34,880	117,712	8,710	14,346	20,443	17,822	36,952
Ages 2–7	1,182,002	1,159,334	1,451,299	1,275,657	1,416,253	1,094,478	846,900	1,481,440	1,285,802
Total	1,205,169	1,177,553	1,499,764	1,408,757	1,436,731	1,111,468	876,358	1,513,068	1,338,159

Population size

Age (yr)	87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96
	Fishing season								
1	3,270,593	4,317,679	3,338,845	3,560,701	3,891,508	3,464,122	3,910,264	3,206,426	3,395,720
2	2,836,117	2,422,915	3,198,615	2,473,477	2,637,832	2,882,900	2,566,285	2,896,795	2,375,379
3	1,301,627	1,734,064	1,475,491	1,819,056	1,366,022	1,499,556	1,900,905	1,665,994	1,700,264
4	717,421	678,904	897,846	674,155	787,758	623,696	897,883	1,106,259	806,427

Table 3 *continued*

(*c*) Lower Florida Keys Females

Population size

Age (yr)	87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96
	Fishing season								
5	318,190	392,044	368,643	437,421	313,525	383,551	384,157	539,556	566,622
6	191,999	178,296	218,401	185,913	211,389	158,027	239,866	234,865	284,896
7	62,004	102,632	94,660	103,220	83,593	99,840	96,041	141,971	117,123
8	44,752	39,402	65,012	56,772	60,473	50,119	67,391	64,025	87,322
9+	16,581	38,125	48,015	65,758	69,402	75,533	83,686	99,198	97,743
Ages 2–7	5,427,358	5,508,855	6,253,656	5,693,242	5,400,119	5,647,570	6,085,137	6,585,440	5,850,711
Total	8,759,284	9,904,061	9,705,528	9,376,473	9,421,502	9,237,344	10,146,478	9,955,089	9,431,496

Fishing mortality rates

Age (yr)	87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96	Selectivity
	Fishing season									
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.19	0.20	0.26	0.29	0.26	0.12	0.13	0.23	0.23	0.55
3	**0.35**	**0.36**	**0.48**	**0.54**	**0.48**	**0.21**	**0.24**	**0.43**	**0.42**	**1.00**
4	0.30	0.31	0.42	0.47	0.42	0.18	0.21	0.37	0.37	0.87
5	0.28	0.29	0.38	0.43	0.39	0.17	0.19	0.34	0.34	0.80
6	0.33	0.33	0.45	0.50	0.45	0.20	0.22	0.40	0.39	0.93
7	0.15	0.16	0.21	0.23	0.21	0.09	0.11	0.19	0.19	0.44
8	0.18	0.18	0.24	0.27	0.24	0.11	0.12	0.21	0.21	0.50
9+	0.18	0.18	0.24	0.27	0.24	0.11	0.12	0.21	0.21	0.50
Average Ages 2–7	0.27	0.27	0.37	0.41	0.37	0.16	0.18	0.32	0.32	

Transitional Spawning Potential Ratios (SPR)

	87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96
	Fishing season								
Biomass	27%	27%	24%	21%	20%	27%	31%	27%	26%
Fecundity	30%	30%	26%	23%	23%	31%	34%	30%	28%

(*d*) Lower Florida Keys Males

Number Harvested

Age (yr)	87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96
	Fishing season								
1	182,780	225,320	262,317	136,555	235,388	249,002	120,936	264,604	171,420
2	688,990	721,724	753,239	673,500	948,493	624,129	561,017	801,236	602,239
3	199,563	216,145	306,093	285,659	321,681	210,434	199,580	299,356	333,695
4	79,224	45,214	103,901	111,687	85,984	28,975	49,401	111,562	156,193
5	23,644	19,099	77,821	57,620	40,364	10,071	28,791	70,724	86,947
6	9,766	20,532	23,479	46,871	24,143	8,438	15,150	28,172	39,935
7	4,976	2,625	17,023	19,328	1,266	2,138	8,542	11,498	3,997
8	1,206	5,251	5,533	18,952	13,471	3,713	9,491	10,350	9,700
9+	4,415	9,128	20,370	55,402	3,798	7,989	44,731	10,843	28,773
Ages 2 – 7	1,006,163	1,025,339	1,281,556	1,194,665	1,421,931	884,185	862,481	1,322,548	1,223,006
Total	1,194,564	1,265,038	1,569,776	1,405,574	1,674,588	1,144,889	1,037,639	1,608,345	1,432,899

Table 3 *continued* (*d*) **Lower Florida Keys Males**

Population size

Age (yr)	87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96
	Fishing season								
1	3,260,180	3,273,166	2,760,581	2,806,645	2,554,040	3,384,845	3,519,110	3,173,576	2,327,754
2	1,807,147	2,243,863	2,285,235	1,807,061	1,836,077	1,734,575	2,388,743	2,451,877	2,158,094
3	612,170	857,824	1,161,324	800,893	630,942	804,036	958,044	1,220,958	1,082,052
4	419,323	309,319	466,890	452,084	310,772	297,454	462,769	515,867	579,459
5	255,239	248,766	191,597	238,069	230,089	177,096	190,324	284,866	295,110
6	60,019	155,955	157,796	102,664	127,359	135,766	115,540	120,074	168,653
7	60,387	36,176	97,844	82,636	53,671	73,949	87,783	72,069	69,970
8	6,990	40,880	24,923	62,291	52,569	35,745	51,621	60,324	48,074
9+	4,620	6,885	29,576	27,769	45,804	56,030	58,706	67,889	73,310
Ages 2–7	3,214,285	3,851,903	4,360,686	3,483,407	3,188,910	3,222,876	4,203,203	4,665,711	4,353,338
Total	6,486,075	7,172,834	7,175,766	6,380,112	5,841,323	6,699,496	7,832,640	7,967,500	6,802,476

Fishing Mortality Rates

Age (yr)	87–88	88–89	89–90	90–91	91–92	92–93	93–94	94–95	95–96	Selectivity
	Fishing season									
1	0.07	0.06	0.12	0.12	0.09	0.05	0.06	0.09	0.09	0.17
2	**0.45**	**0.36**	**0.75**	**0.75**	**0.53**	**0.29**	**0.37**	**0.52**	**0.54**	**1.00**
3	0.38	0.31	0.64	0.65	0.45	0.25	0.32	0.45	0.46	0.86
4	0.22	0.18	0.37	0.38	0.26	0.15	0.19	0.26	0.27	0.50
5	0.19	0.16	0.32	0.33	0.23	0.13	0.16	0.22	0.23	0.43
6	0.21	0.17	0.35	0.35	0.24	0.14	0.17	0.24	0.25	0.46
7	0.09	0.07	0.15	0.15	0.11	0.06	0.08	0.10	0.11	0.20
8	0.22	0.18	0.37	0.38	0.26	0.15	0.19	0.26	0.27	0.50
9	0.22	0.18	0.37	0.38	0.26	0.15	0.19	0.26	0.27	0.50
Average Ages 2–7	0.26	0.21	0.43	0.43	0.30	0.17	0.21	0.30	0.31	

processes of lobster growth (moulting interval and moult increment) separately, and accounted for sex-specific and length-specific differences as well as seasonal and geographic differences. However, the range of carapace lengths recaptured (12–115 mm) does not fully encompass the range of lobsters in the fishery. Additionally, for larger lobsters, a particular carapace length may span several ages. We used a plus group to minimize that effect.

The results of ICA also depend on the tuning index. In these analyses, the only tuning index, standardized catch-per-trip, was obtained exclusively from the commercial fishery. During the seasons covered by these analyses, there were no changes to the minimum size regulation, the primary gear remained lobster traps, and the key technological changes in this fishery, such as trap pullers and LORAN–C, were already in place. The use of GPS has not further increased the effectiveness of this fishery. Hence, our index should be valid. When we update these analyses, we plan to incorporate additional tuning indices including an index from the recreational fishery, a pre-recruit index from the observer programme, and an index based on puerulus abundance that is presently being monitored on a long-term basis. The pre-recruit index and the puerulus index should provide finer resolution in recruitment. These indices may require additional years of data before they can be effectively used.

Only a few year classes make up the fishery. This is more pronounced in the upper Keys where fishers are more dependent on younger lobsters and consequently experience greater volatility in their landings. This may be explained by the fact that Florida Bay, the primary nursery for the fishery (Davis and Dodrill 1980; Field and Butler 1994), is adjacent to the upper Keys fishing grounds and lobsters in the Florida Keys migrate from Florida Bay toward the reef tract and toward the lower Keys (Gregory and Labisky 1986). Therefore the relative proportion of the estimated fishing mortality rates that reflects emigration from that area may be large. Conversely, the lower estimated fishing mortality rates in the lower Keys may include some immigration from the upper Keys. Finally, the scarcity of older lobsters in the

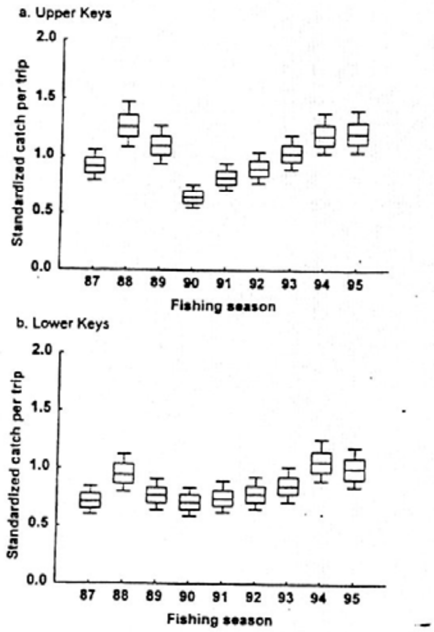

Fig. 5. Relative weight of lobsters per trip by zone after adjustment by analysis of covariance for month and trip duration: *(a)* upper Florida Keys; *(b)* lower Florida Keys.

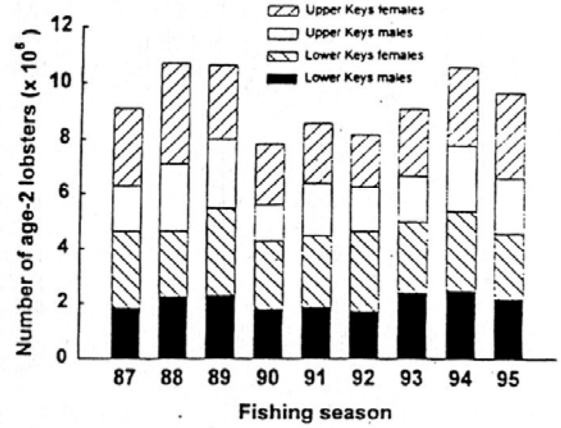

Fig. 6. Estimated recruitment (age-2 lobsters) by fishing season. Each fishing season is partitioned by zone and sex.

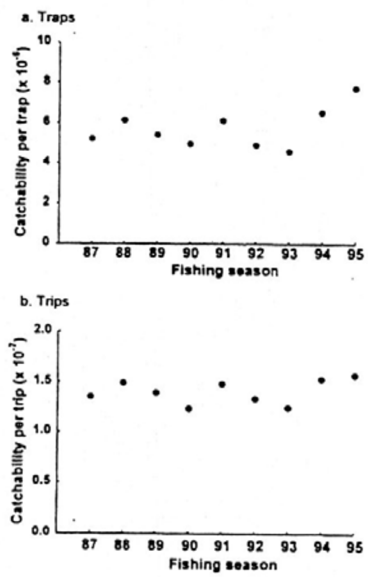

Fig. 7. Catchability by fishing season in the Florida Keys: *(a)* effort measured in commercial traps; *(b)* effort measured as the total number of trips.

landings may partly be a reflection of where fishers set their traps: the reef may have many natural sheltering sites for lobsters. The model represented the unavailability of older lobsters as reduced selectivity and not as higher mortality on younger ages.

The average fishing mortality rates produced by our ICA are lower than those of earlier stock assessments conducted on this fishery (Powers and Thompson 1986; Powers and Sutherland 1989). However, our fishing mortality rates are high compared with our calculated values of F_{max} and $F_{0.1}$, two fishing mortality benchmarks commonly used to evaluate fisheries (Sissenwine and Shepherd 1987). Our fishing mortality rates for the fully recruited year-class in the upper Keys for the 1995–96 fishing season (female $F = 0.79$ per year, male $F = 0{\cdot}89$ per year, Tables 3*a*, 3*b*) exceeded our F_{max} value ($F_{max} = 0{\cdot}71$ per year) and all of our fishing mortality rates exceeded $F_{0.1}$ ($F = 0{\cdot}28$ per year).

We explored the sensitivity of our analysis to growth by increasing the probability of moulting and repeating the analyses. The sensitivity analyses were run with a 50% faster moulting rate and a correspondingly higher natural mortality rate (0·42 per year, Powers and Sutherland 1989). With faster growth, fishing mortality rates were higher because the harvested lobsters were from fewer year classes, and the corresponding estimated population sizes were much smaller than those calculated from the slower growth model. However, the conclusions remained the same — that increased landings in recent years reflected increased lobster abundance in the Florida Keys rather than higher fishing mortality.

The application of age-structured analysis to the spiny lobster fishery has allowed us to look at some of the dynamics in the fishery. For example, although the time series is short, recruitment (abundance of age-2 lobsters) may be cyclic, with recent seasons representing the higher portion of the cycle (Fig. 6). Recent high recruitment was corroborated by on-board observers recording high numbers of pre-recruit lobsters in the past three fishing seasons. Furthermore, an increase in catchability after the implementation of trap reductions would be expected if inefficient fishers left the fishery. Catchability during the 1995–96 fishing season was substantially higher than in previous seasons. Finally, the analysis showed that fishing mortality rates remain higher than standard fishery management benchmarks. This means that although effort reduction has lowered the average fishing mortality rates, fishing mortality rates remain too high.

Acknowledgements

This assessment was made possible through the long-term dedication of those individuals, especially Richard Beaver (DEP) and Ed Little (NMFS), who have collected data on commercial lobster landings. Doug Gregory graciously supplied the tag-recapture data for the lower Keys from his Florida Sea Grant supported research. We thank the large number of commercial fishers who have permitted observers to gather data from their traps. Finally, we thank Kevin Sullivan, Nick Caputi, and Paul Breen for their cogent reviews of the manuscript. This research was supported by funds received by the DEP from commercial and recreational lobster licences and from the National Marine Fisheries Service.

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ERRATUM

MULLER, R. G., J. H. HUNT, T. R. MATTHEWS, and W. C. SHARP
1997. Evaluation of effort reduction in the Florida Keys spiny lobster, *Panulirus argus*, fishery using an age-structured population analysis. Marine and Freshwater Research 48: 1045–1058.

Page 1052, Figure 4—Legend for upper half of figure should read: a. Upper Keys Females, b. Upper Keys Males

Appendix I. By-Catch in Florida's Spiny Lobster Trap Fishery and the Impact of Wire Traps(FL DEP).

By-catch in Florida's Spiny Lobster Trap Fishery and the Impact of Wire Traps

A Report Submitted to:
South Atlantic Fisheries Management Council
Key West, Florida
June, 13, 1996

Submitted by

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Abstract

We examined the contents of 21,309 lobster traps while aboard commercial fishing vessels during the 1993-94 spiny lobster (*Panulirus argus*) fishing season and found 6,972 of these traps contained species other than spiny lobster. We observed 15,536 individuals comprising 172 species. Stone crabs, grunts, spider crabs, and sea urchins represented 65% of the by-catch. Four types of traps are used in the fishery: wood, wire-reinforced wood, wire, and plastic. Wire-reinforced and wire traps caught significantly more commercially important fish ($\propto < 0.05$) and often caught more aquarium and incidental species. Wire traps observed in 1993-94 were fished exclusively in deep water habitats, precluding direct comparisons with wood and wire-reinforced traps fished in shallow water habitats. Paired comparisons of wire and wood traps in 1995-96 confirmed that wire traps catch significantly more fish ($\propto < 0.05$), predominately grunts. Commercial quality snapper and grouper occurred in less than 0.5% of the traps we observed. By-catch mortality rates were 0.033% in 1993-94 and 0.21% in 1995-96. The types of traps observed and the habitats in which these traps were fished reflected current fishing methods. We expect by-catch rates to decrease further as the number of traps in the fishery is reduced.

Introduction

By-catch in spiny lobster traps is an important consideration for fishery managers and commercial fishers. Fishery managers are concerned that lobster traps catch significant quantities of by-catch, particularly species in the snapper/grouper complex and other reef fish as specified by the Gulf of Mexico Fishery Management Council-Reef Fish Fishery Management Plan (1989) (Harper *et al*, 1990). Commercial lobster fishers in Florida value the occasional snapper or grouper they harvest, but in general they do not target these species. Fishers consider some by-catch species competitors for space in lobster traps and even potential lobster predators. Competition for space in traps is common between American lobsters (*Homarus americanus*) and spider crabs (Richards and Cobb, 1987), and predation on rock lobster (*Panulirus cygnus*) confined in traps is well documented for octopus and several fish species (Joll, 1977).

Fishery managers lack data on which species of fish are captured in lobster traps, and they are also concerned that certain trap designs, particularly traps constructed with wire, capture a disproportionate number of fish. Fishery managers are also concerned that lobster traps can be modified to capture fish more effectively, and that these modified traps could be used to circumvent fish trap regulations. The traditional fishing gear for lobster is the wooden-slat trap, but lobster fishers use a variety of lobster trap designs to fish in a wide range of habitats. Large traps are used in areas containing large lobsters or in areas where lobsters are caught at infrequent intervals but usually in great abundance. Wire traps are used to facilitate trap retrieval from deep water or in areas subject to storm surges, and traps reinforced with wire are used to prevent damage from turtles attempting to foraging on lobster in traps (commercial lobster fishers, pers. comm.). Because these different trap types are used in discrete areas, it is difficult to evaluate the fishing efficiency of each trap type.

Our surveys were designed to evaluate current trap fishing practices and trap efficiency in the lobster fishery. Lobster and by-catch species in wood, wire, wire-reinforced wood, and plastic traps were counted. Trap induced mortality of lobster and by-catch species was also noted. We evaluated the potential by-catch captured in different trap types and made direct comparisons of by-catch capture efficiency between wood and wire-reinforced traps in one region of the fishery where both trap types were commonly used. A paired comparison examining by-catch in wood and wire traps was also completed. Breakage rates of wood and wire-reinforced wood traps were also examined to evaluate fishers contentions that wire-reinforced traps were more efficient than wood traps.

Methods

We attempted to observe a total of 400 traps from at least 3 different fishers in seven fishing regions (Figure 1) for each month of the fishing season in 1993-94. Fishers were chosen from a pool of volunteers obtained through mail survey correspondence. The mail survey was also used to ascertain how many wood, wire, wire-reinforced, and plastic traps existed. We attempted to sample 133 traps per trip. We accomplished this by altering our sampling frequency based on the number of traps the fisher retrieved. For example, if a fisher expected to pull 400 traps, every third trap was sampled. All lobsters and by-catch in sampled traps were placed in a plastic fish basket for examination. During a second study in 1995-96, we observed parallel lines of approximately 150 wood and wire traps each month of the fishing season. This second study was the basis for our direct comparison of by-catch capture rates between wood and wire traps.

Examination of each trap included recording trap type (wood, wire, wire-reinforced wood, or plastic), trap location (to the nearest latitude and longitude minute), trap status (fishing, broken, robbed or missing), soak duration (the number of days between successive trap pulls), type of bait, and use of attractants (*for attractant def. see* Hunt *et al*, 1986; Heatwole *et al*, 1988). Each lobster was also sexed, measured to the nearest 1 mm carapace length (CL), and the reproductive condition of females was noted (presence of fresh or eroded spermatophores and eggs). Lobsters measuring 76-76.5 mm CL were recorded to the nearest 0.1 mm to retain information relative to the legal size limit of 76.2 mm (3 in). Dead lobsters were sexed and measured when sufficient remains were present. By-catch species were identified and classified as either legal or sublegal when state fishery size regulations applied. By-catch observations in 1995-96 recorded standard length to the nearest cm. Sub-legal stone crab claws were recorded inconsistently, as either the number of claws or number of individuals with sub-legal claws. Encrusting and fouling organisms were not recorded as by-catch.

A comparison of by-catch capture rates between wood and wire-reinforced wood traps in 1993-94 was possible for a subset of the data that included both trap types from comparable areas. Different traps were considered in comparable areas if they were within 1 mile of each other. A Wilcoxon two-sample test was used to test the hypothesis that the wood and wire-reinforced traps contained equal numbers of lobster. The nonparametric test was chosen because of the negative-binomial distribution of lobster in traps. After the assumptions of comparable fishing areas for the traps and equal numbers of lobster in each trap design were met, a Wilcoxon two-sample test was used to test for differences between the number of reef fish in wood and wire-reinforced traps (α<0.05). We defined reef fish as all snapper, grouper, hogfish, triggerfish, porgies, grunts, and parrotfish; with the exception of parrotfish, this group was consistent with the Gulf of Mexico Fishery Management Council-Reef Fish Fishery Management Plan (1989). Parrotfish were included in the reef fish category because they were routinely harvested in the Miami region of the fishery. The number of snapper and grouper in wood and wire-reinforced traps was examined separately using the Wilcoxon two-sample test (α<0.05). We also reported the expected catch rates of reef fish and the snapper/grouper subset of that group separately for each trap design in the region tested. All analyses included both legal-size and sublegal-size lobster and fish. A G-test (using Williams correction) was used to determine if the number of broken wood and wire-reinforced wood traps observed in this region differed significantly. These same methods were also applied to the paired trap examinations in 1995-96.

Results

We accompanied 116 different commercial fishers on 192 fishing trips in 1993-94. We observed an average of 365 traps in seven fishing regions from at least three fishers each month. We were unable to complete sampling trips from the Dry Tortugas or the East Florida coast, and only eight trips were completed in the Miami fishing region (Figure 1).

Mail survey returns from 351 fishers representing 319,066 of the 704,234 traps in the fishery, indicated that 90% of traps in the fishery were all wood, 8% were wire-reinforced wood, 1% were wire with wood tops, and 1% were plastic . Direct counts of trap types while aboard commercial fishing vessels corresponded with those estimated by the mail survey: 88% wood, 9%, wire-reinforced wood, 2% wire with wood tops, and <1% plastic. Wood traps were fished in all areas and depths; wire and wire-reinforced wood traps were observed exclusively in the Atlantic in a variety of depths and wire traps were observed only in deep water (greater than 20 m). Mail survey respondents indicated that some wire traps were used in deep water in the Gulf of Mexico, but none were observed during our monitoring trips. Most of the plastic traps were observed on one sampling trip.

Many species of fish and invertebrates were routinely observed in lobster traps during onboard monitoring. Table 1 presents 43 taxa which, on average, occurred in more than 0.1% of traps. An additional 46 taxa occurred less often. Stone crabs (*Menippe mercenaria*) were the most abundant and valuable by-catch species. Excluding those captured prior to the opening of the stone crab season (October 15), we observed 1,024 medium, 913 large, and 481 jumbo or extra-large claws valued at approximately $4,645 (dollar values were calculated from ex-vessel prices in Marathon, Florida in March, 1993). Grunts (predominately white grunt, *Haemulon plumieri*) were the second most abundant group. Large grunts (> 12 inches) were rarely observed, except in the Marquesas. Legal-size grouper (*Epinephelus morio* and *Mycteroperca bonaci*), hogfish (*Lachnolaimus maximus*), and snapper (*Lutjanus* spp. and *Ocyurus chrysurus*) were usually retained for sale or personal use. Spider crabs (*Mithrax spinosissimus*) were common and the claws were harvested occasionally. Some by-catch species were harvested for the aquarium trade. These included urchins (predominately *Lytechinus variegatus*), angelfish (*Holocanthus* spp. and *Pomacanthus* spp.), and nurse sharks (*Ginglymostoma cirratum*).

Cowfish (*Lactophrys quadricornis*), puffers (*Diodon* spp. and *Chilomycterus* spp.), and trunkfish (*Lactophrys bicaudalis*), were occasionally retained for use as stone crab bait. Octopus (*Octopus* spp.) and triggerfish (*Balistes capriscus*) were often killed and discarded because they were suspected lobster predators. Five of the observed by-catch species are protected by the Florida Department of Environmental Protection. There were 30 long-spined sea urchins (*Diadema antillarum*), 5 jewfish (*Epinephelus itajara*), 3 Nassau grouper (*Epinephlus striatus*), 5 Bahama starfish (*Oreaster reticulatus*), and a loggerhead sea turtle (*Caretta caretta*). The loggerhead turtle was tangled in the buoy-rope. All protected species were released alive and apparently unharmed. Twenty dead crabs, 8 dead fish, and 5 dead cormorants (*Phalacrocorax sp.*) were observed in traps. A small number of animals are also crushed on the deck or die of exposure during trap relocation and removal. Thirteen dead individuals were observed during the 1995-96 experiment (Table 5).

The by-catch species captured in different types of lobster traps were dependent on where the trap was fished and the abundance of lobster in the trap. The by-catch reported in specific trap types (Table 2) did not consider trap location or lobster abundance; therefore, the by-catch reported for specific trap types was indicative of how the traps were used in the 1993-94 fishing season and can not be used for comparative purposes. A comparison of by-catch rates was possible between the 1276 wood traps and the 1467 wire-reinforced wood traps in the Upper Keys-Atlantic. Traps of both designs were dispersed through the entire region but always within adjacent 1-minute square latitude/longitude areas. The number of lobster observed in each trap design (3.94 and 3.93 lobster/trap for wood and wire-reinforced traps respectively) did not differ significantly (Wilcoxon two-sample test, $\propto = .6343$). Wire-reinforced traps caught significantly more snapper/grouper and significantly more reef fish than wood traps (Wilcoxon two-sample test, $\propto = 0.0002$ and 0.0001 respectively). Although the catch rates of snapper/grouper and reef fish were significantly different between trap types, on average only 1 wood and 3.2 wire-reinforced traps per 100 trap pulls contained snapper/grouper, and only 4.5 wood and 11 wire-reinforced traps per 100 trap pulls contained reef fish. Further, only 34% of the snapper/grouper were above the minimum legal size.

The most abundant by-catch species were not evenly distributed among all traps. These taxa tended be more abundant in certain areas and aggregate in specific traps. For example, the average 0.875 grunts/wire trap (Table 2) is more realistically reported as 3.39 grunts in 1 out of 4 traps. The location of these wire traps in the deep water potentially influenced fish capture rates. Less common species, like grouper and large snapper were usually solitary.

Wood traps were damaged significantly more often than wire-reinforced traps ($\propto < 0.001$). Approximately 6.8% (87/1363) of the wood traps and 2.7% (40/1507) wire-reinforced wood traps were damaged per fishing trip.

The number of legal and sublegal sized lobster in traps that contain by-catch was consistently less than that observed in traps containing only lobster. Lobster mortality in traps containing by-catch was generally higher than that observed in traps with no by-catch (Table 3). On average, 0.021 dead lobster (slightly over 2 dead per 100 trap pulls) were observed in traps that contained no by-catch. Lobster mortality in traps containing triggerfish and octopus could that contained no by-catch. Lobster mortality in traps containing triggerfish and octopus could be directly attributed to these animals because of the presence of bite marks on the eyes, legs, and carapace of the lobster. Lobster mortality associated with catfish, trunkfish, and tulip snails was not directly attributable to any source because overt signs of predation were seldom visible. The relationships between lobster mortality in traps containing other notorious lobster predators: nurse sharks, grouper, and mutton snapper were unclear because lobster mortality rates did not consistently increase in the presence of these predators (Table 3).

The paired comparison of wood and wire traps in 1995-96 indicated that wire traps caught significantly more snapper/grouper and significantly more reef fish than wood traps (Wilcoxon two-sample test, $\propto > 0.001$). Although the catch rates of snapper/grouper and reef fish were significantly different between trap types, on average only 2.7 wood and 4.1 wire traps per 100 trap pulls contained snapper/grouper (Table 4). Size frequency histograms for abundant species indicate that most by-catch is less than 30cm (Figure 2). By-catch mortality was lower in the paired comparison than in 1993-94 (Figure 5).

Tagging experiments indicate that small tomtates (<15cm) escape wood and wire traps in less than 24 hours. Ninty percent of grey snapper (>25cm) escape in less than 24 hours and all escape in less than 48 hours. Disappearance is inferred to equal escape based on decay rate experiments which suggest that 25cm grey snapper decay completely in between 24 and 72 hours.

Discussion

Fishery managers are concerned about fish by-catch because of the potential misuse of lobster traps as fish traps and trap induced mortality of fish. In this study, we were able to observe the by-catch in wood, wire-reinforced wood traps, wire traps with wood tops, and a limited number of plastic traps. Wood lobster traps rarely captured commercial quality fish. Traps with wire of any type caught more fish, particularly grunts and porgies, but the capture of commercial quality reef fish was low. The by-catch of stone crabs was a significant addition to the value of the catch in some areas. Additional studies are required to compare the by-catch in other trap types. Our by-catch capture rates in 1993-94 were indicative of those species each trap type caught, but we could not make direct comparisons between the by-catch capture rates in different trap types because each trap type was used in particular areas and depths. Different areas potentially supported different fish populations, and we could not separate differential catch efficiencies of traps from regional differences in fish abundance. The comparative examination of by-catch in 1995-96 clearly indicated that wire traps catch more fish. The number of commercially important fish captured in all traps remained low.

Lobster traps containing by-catch of any species usually contain fewer lobster. We could not determine from our observations if by-catch exclude lobster from traps or if by-catch preferentially entered traps with fewer lobster. Similarly, we could not determine whether by-catch species entered the traps to kill lobster or entered the traps to scavenge dead lobster. We are limited to reporting the observation that by-catch were often associated with dead lobster, but we could not separate confinement induced mortality (Kennedy, 1982) from predator induced mortality. The apparent antagonistic relationship between lobster and most by-catch species also complicated our attempts to compare by-catch capture rates between different trap types. If lobster abundance varied between trap types, the abundance of by-catch may have varied in response to the covariate, lobster abundance, instead of trap type.

The direct comparison of by-catch capture rates in wood and wire-reinforced wood traps in the Upper Keys-Atlantic was possible because all traps were in adjacent areas and lobster capture rates were similar in both trap types. Documentation that wire-reinforced wood traps catch more snapper/grouper than wood traps indicates that wire-reinforced lobster traps could circumvent current fish trapping regulations. However, legitimate use of wire-reinforced lobster traps during 1993-94 resulted in an average of 1.1 legal size snapper/grouper captured per 100 traps (Table 2).

Mortality of by-catch occurs when fishers keep certain species as food or retain them as bait, and when a very limited number of other animals die in traps. Table 1 and Table 5 indicate that the number of fish suitable for harvest or dead in traps was small. The largest source of mortality was among the unregulated species that were retained as bait. This source of fish mortality was the result of a choice by the fisher to keep certain species as bait and was not an unavoidable source of by-catch mortality associated with the fishery.

Fishers contentions that wire-reinforced wood traps were required to fish effectively were substantiated for some areas. Trap breakage rates and the severity of the damage was significantly higher for wood traps than for wire-reinforced wood traps. Lobster capture rates were not significantly different between these two trap designs, but the decreased fishing effort associated with a 6.8% damage rate per fishing trip for wood traps would reduce the total lobster harvest per trip. Fishers also contended that wire traps maintain their position in strong currents and during storms better than wood traps. This study was not capable of addressing other factors influencing fishing effectiveness.

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Table 1. By-catch observed in 21,309 lobster traps during the 1993-1994 lobster season. Species are listed in order of abundance. For those species regulated by size restrictions, the number of legal and sub-legal sized individuals are presented separately.

SPECIES	TOTAL	SIZE		DEAD
		LEGAL	SUBLEGAL	
STONE CRAB[1]	4,898	3,368[2]	1,514	16
GRUNT	2,177	*	*	1
SPIDER CRAB	1,776	*	*	4
URCHINS	1,338	*	*	1
COWFISH	726	*	*	0
HERMIT CRAB[3]	538	*	*	0
PORGY	351	*	*	2
TRIGGERFISH	289	*	*	0
PUFFERS	262	*	*	0
PARROTFISH	263	*	*	1
ANGELFISH	233	131	101	1
TRUNKFISH	217	*	*	0
ARROW CRABS	161	*	*	0
SLIPPER LOBSTER	155	*	*	0
OCTOPUS	146	*	*	0
FILEFISH	110	*	*	0
TULIP	96	*	*	0
BLUE CRAB	94	*	*	0
GROUPER[4]	87	7	79	1
MUTTON SNAPPER	81	45	36	0
HOGFISH	77	*	*	0
NURSE SHARK	76	*	*	0
SCORPIONFISH	73	*	*	0
CUBBYU	69	*	*	0
SEACUCUMBER	64	*	*	0
SURGEONFISH	59	*	*	0
OTHER CRABS	56	*	*	0
LANE SNAPPER	56	13	43	0
BIGEYE	48	*	*	0
HORSE CONCH	46	*	*	0
SAND PERCH	45	*	*	0
COWRIE	41	*	*	0
GREY SNAPPER	38	13	25	0
PEPPERMINT SHRIMP	36	*	*	0
CATFISH	35	*	*	0
JACKKNIFE FISH	32	*	*	0
JACK	32	*	*	0
SNAILS, OTHER	29	*	*	0
TOAD FISH	27	*	*	0
HIGH-HAT	27	*	*	0
BASKET STAR	25	*	*	0
YELLOWTAIL SNAPPER	25	19	5	1
MORAY	23	*	*	0
CARDINALFISH	20	*	*	0

These species occur less than once per 1,000 traps:

WHELK	GOATFISH	PORKFISH	ROCKSEABASS	VERMILLION SNAPPER
PERMIT	ANENOME	DOG SNAPPER	NASSAUGROUPER	SCHOOLMASTER SNAPPER
BLENNY	CUSK EEL	AMBERJACK	ELECTRICRAY	BANDED CORAL SHRIMP
JEWFISH	PINFISH	SPADEFISH	BUTTERFLYFISH	LOGGERHEAD TURTLE[5]
WRASSE	FROGFISH	LIZARDFISH	SAND DOLLAR	CORMORANT(dead)
SEAHARE	SEAHORSE	NEON GOBY	CORALSPIDERCRAB	SQUIRRELFISH
HINDS	FLOUNDER	STARFISH[4]	TRUMPETFISH	BAHAMA STARFISH
HAMLETS	STINGRAY	SHEEPSHEAD	SAND TILEFISH	GOLDEN TILEFISH
MARGATE	SOAPFISH	DAMSELFISE	CALAPPA CRAB	SPOTTEDLOBSTER

[1]Legal claws [2]Approximate number [3]Underestimation [4]Excludes protected species

Table 2. Catch per trap of all observed species during the 1993-94 lobster season. Thesedifferent trap designs were typically fished in unlike habitats: therefor catch rates are not necessarily indicative of relative catch efficiency of each trap type (n = number of traps).

SPECIES	WOOD n=18773	WIRE REINFORCED n=1943	WIRE* n=496	PLASTIC n=100
SPINY LOBSTER*[1]	3.2525	3.7699	0.8750	1.66
STONE CRAB CLAWS*[2]	0.1664	0.1163	0.0040	0.16
STONE CRABS (small)*[3]	0.0690	0.1153	0.0	0.15
GRUNT	0.0936	0.1951	0.8750	0.15
SPIDER CRAB	0.0719	0.0139	0.0040	0.0
URCHINS	0.0674	0.0350	0.0040	0.02
COWFISH	0.0166	0.0396	0.6734	0.03
HERMIT CRAB*[4]	0.0135	0.0324	0.4375	0.04
PORGY	0.0038	0.0196	0.4859	0.01
TRIGGERFISH	0.0102	0.0206	0.1087	0.03
PUFFERS	0.0035	0.0041	0.3790	0.0
PARROTFISH	0.0058	0.0443	0.1371	0.0
ANGELFISH	0.0096	0.0170	0.0363	0.0
TRUNKFISH	0.0094	0.0170	0.0161	0.0
ARROW CRABS	0.0021	0.0082	0.2137	0.0
SLIPPER LOBSTER	0.0070	0.0056	0.0242	0.0
OCTOPUS	0.0075	0.0015	0.0061	0.0
FILEFISH	0.0028	0.0066	0.0867	0.01
TULIP	0.0045	0.0046	0.0040	0.0
BLUE CRAB	0.0030	0.0190	0.0	0.0
GROUPER*[5]	0.0035	0.0036	0.0262	0.01
MUTTON SNAPPER	0.0029	0.0118	0.0081	0.0
HOGFISH	0.0017	0.0237	0.0	0.0
NURSE SHARK	0.0033	0.0077	0.0	0.0
SCORPIONFISH	0.0015	0.0057	0.0686	0.0
CUBBYU	0.0036	0.0	0.0040	0.0
SEACUCUMBER	0.0034	0.0005	0.0	0.0
SURGEONFISH	0.0018	0.0124	0.0020	0.01
OTHER CRABS	0.0021	0.0051	0.0121	0.0
LANE SNAPPER	0.0021	0.0057	0.0081	0.01
BIGEYE	0.0015	0.0	0.0383	0.0
HORSE CONCH	0.0022	0.0021	0.0020	0.0
SAND PERCH	0.0013	0.0005	0.0403	0.0
COWRIE	0.0019	0.0026	0.0	0.0
GREY SNAPPER	0.0015	0.0041	0.002	0.0
PEPPERMINT SHRIMP	0.0003	0.0154	0.0	0.0
CATFISH	0.0018	0.0010	0.0	0.0
JACKKNIFE-FISH	0.0011	0.0010	0.0161	0.01
JACK	0.0015	0.0021	0.0	0.0
SNAILS, VARIOUS	0.0013	0.0026	0.0	0.0
TOAD FISH	0.0013	0.0010	0.0	0.0
HIGH-HAT	0.0007	0.0026	0.0161	0.0
BASKET STARFISH	0.0013	0.0	0.0	0.0
MORAY	0.0006	0.0062	0.0	0.0
CARDINALFISH	0.0	0.0015	0.0343	0.0
YELLOWTAIL SNAPPER	0.0004	0.0082	0.0020	0.0
BANDED CORAL SHRIMP	0.0002	0.0015	0.0242	0.0
GOATFISH	0.0001	0.0010	0.0100	0.01
BUTTERFLYFISH	0.0003	0.0001	0.0061	0.0
FROGFISH	0.0009	0.0	0.0061	0.0
REMAINING SPECIES	0.0081	0.0268	0.0383	0.0

*Wire traps have a wooden top [1]Includes all lobster [2]Legal claws [3]Approximate number [4]Underestimation [5]Excludes protected species

Table 3. Mean lobster catch in 21309 lobster traps that also captured other species during the 1993-94 lobster season. A trap with multiple by-catch species is listed repeatedly for each by-catch category. Lobster catch rates are not adjusted for soak.

BYCATCH	NUMBER OF traps	LEGAL LOBSTERS per trap	SUBLEGAL LOBSTERS per trap	DEAD LOBSTERS per trap
NO BYCATCH	14453	0.87	2.72	0.021
STONE CRAB	3114	0.44	1.81	0.018
GRUNT	755	0.60	1.76	0.024
SPIDER CRAB	1216	0.48	3.24	0.039
URCHINS	659	0.35	1.48	0.016
COWFISH	493	0.22	0.67	0.023
HERMIT CRAB	344	0.54	1.46	0.012
PORGY	172	0.23	1.27	0.006
TRIGGERFISH	262	0.45	1.89	0.102
PUFFERS	188	0.16	0.65	0.027
PARROT	158	0.31	0.80	0.006
ANGELFISH	217	0.62	2.19	0.032
TRUNKFISH	172	0.35	0.62	0.058
ARROW CRABS	104	0.67	1.83	0.010
SLIPPER LOBSTER	146	0.78	2.69	0.021
OCTOPUS	147	0.24	1.15	0.063
FILEFISH	104	0.33	1.12	0.010
TULIP	88	0.37	1.63	0.080
BLUE CRAB	78	0.55	1.00	0.013
GROUPER[1]	86	0.35	1.91	0.059
MUTTON SNAPPER	75	0.28	1.20	0.013
HOGFISH	66	0.30	1.38	0.030
NURSE SHARK	75	0.56	1.48	0.027
SCORPIONFISH	60	0.44	1.08	0.034
SEACUCUMBER	62	0.53	2.47	0.000
SURGEONFISH	58	0.39	1.64	0.036
GREY SNAPPER	33	0.33	1.52	0.030
CATFISH	33	0.0	0.84	0.091
MORAY	23	0.30	1.26	0.044

[1]Excludes protected species

Table 4. Number of individuals of each species observed in wood (n=1480) and wire (n=1411) lobster traps in the Atlantic (August 1995 - March 1996). Stone Crabs are reported as number of claws J=Jumbo, L=Large, and M=Medium where noted.

SPECIES	WOOD	WIRE	SPECIES	WOOD	WIRE	SPECIES	WOOD	WIRE
Tomtate	102	559	Banded Coral Shrimp		9	Sharpnose Puffer	1	1
White Grunt	127	221	Doctorfish	2	9	Unicorn Filefish	1	1
Other Crabs	8	136	Other Parrotfish	2	8	Blue Angelfish		2
Mithrax	78	58	Box Crab		10	Reef Butterflyfish	1	1
Stone Crab Claws (L)	62	44	Basket Star	7	2	Sea Cucumber	2	
Stone Crab Claws (M)	58	26	Yellowtail Snapper		7	Spadefish	2	
Stone Crab Claws (J)	39	29	Sand Perch	1	6	Florida Horse Conch	2	
Stone Crab/sublegal	39	19	Beaugregory	2	5	Jackknife-fish	1	2
Hermit Crab	14	42	Slippery Dick	2	4	Reef Octopus		2
Lane Snapper	24	25	Emerald Parrotfish		6	Butter Hamlet	1	
Arrow Crab	7	38	Nurse Shark	4	2	Porcupinefish		1
Porgy	2	41	Octopus	1	6	Other Scorpionfish		1
Grey Triggerfish	21	21	Trumpetfish	2	3	Ocean Surgeon		1
Cowfish	8	33	Margate	1	4	Queen Triggerfish		1
Redtail Parrotfish	3	36	Sergeant Major	1	3	Stingray		1
High-hat	9	24	Fringed Filefish	3	2	Bronze Cardinalfish		1
Hogfish	4	28	Other Cardinalfish	1	3	Sea Biscuit	1	
Peppermint Shrimp	14	17	Blue Tang	2	2	Other Urchin	1	
Planehead Filefish	1	26	Blue Striped Grunt		4	Toadfish	1	
Mutton Snapper	5	20	Redband Parrotfish		4	Reef Scorpionfish		1
Moray, Spotted	17	7	Bigeye		4	Murex Snail	1	
Blue Crab	5	18	Two-Spot Cardinalfish		4	Other Puffer		1
Sailor's Choice	2	21	Calico Crab	2	2	Remora	1	
Trunkfish	5	14	Golden Shrimp		4	Gray Snapper	1	
Cottonwick		18	Red Fin Parrotfish		5	Soapfish	1	
Pincushion Urchin	17		Goatfish		3	Lizardfish	1	
Spotted Goatfish		17	Bluehead Wrasse		3	Honeycomb Cowfish		1
Grey Angelfish	7	9	Spotted Trunkfish	2	1	Schoolmaster		1
Slipper Lobster	8	7	French Angelfish	1	2	Black Grouper		1
Red Grouper	10	1	Pinfish		3	Moray, Green	1	
Puddingwife	2	8	Greater Amberjack		3	Scad, Round	1	
Tulip Snail	3	7	Porkfish		3	Redfin Parrotfish		4

Table 5. Number of dead individuals of each species observed in wood (n=1480) and wire (n=1411) lobster traps in the Atlantic (August 1995 - March 1996).

SPECIES	WOOD	WIRE
Other Crab	1	2
Cowfish	1	1
Pincushion Urchin	2	
Tomtate		1

SPECIES	WOOD	WIRE
Blue Crab		1
Unknown Parrotfish		1
Lane Snapper		1

SPECIES	WOOD	WIRE
White Grunt		1
Queen Trigger		1

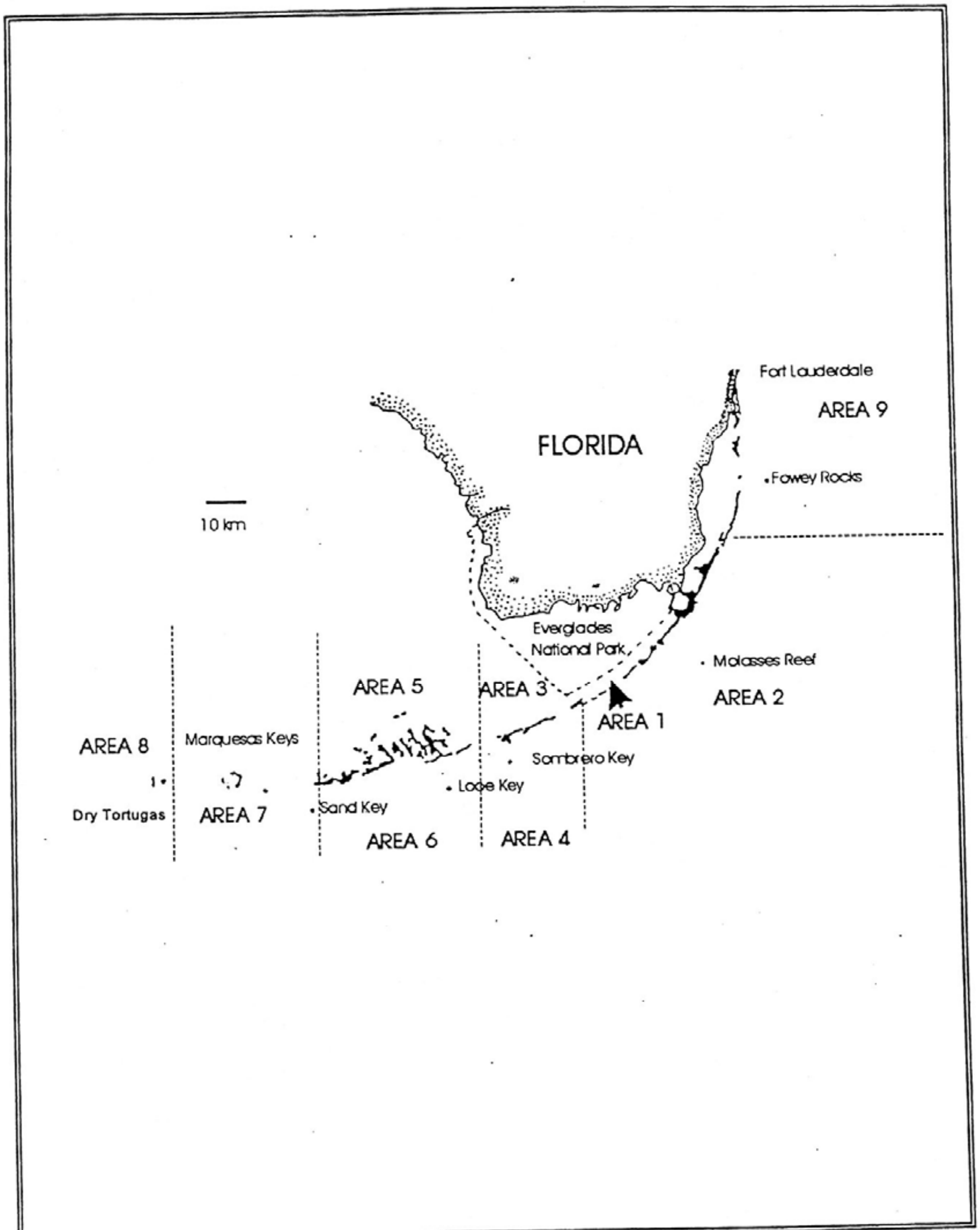
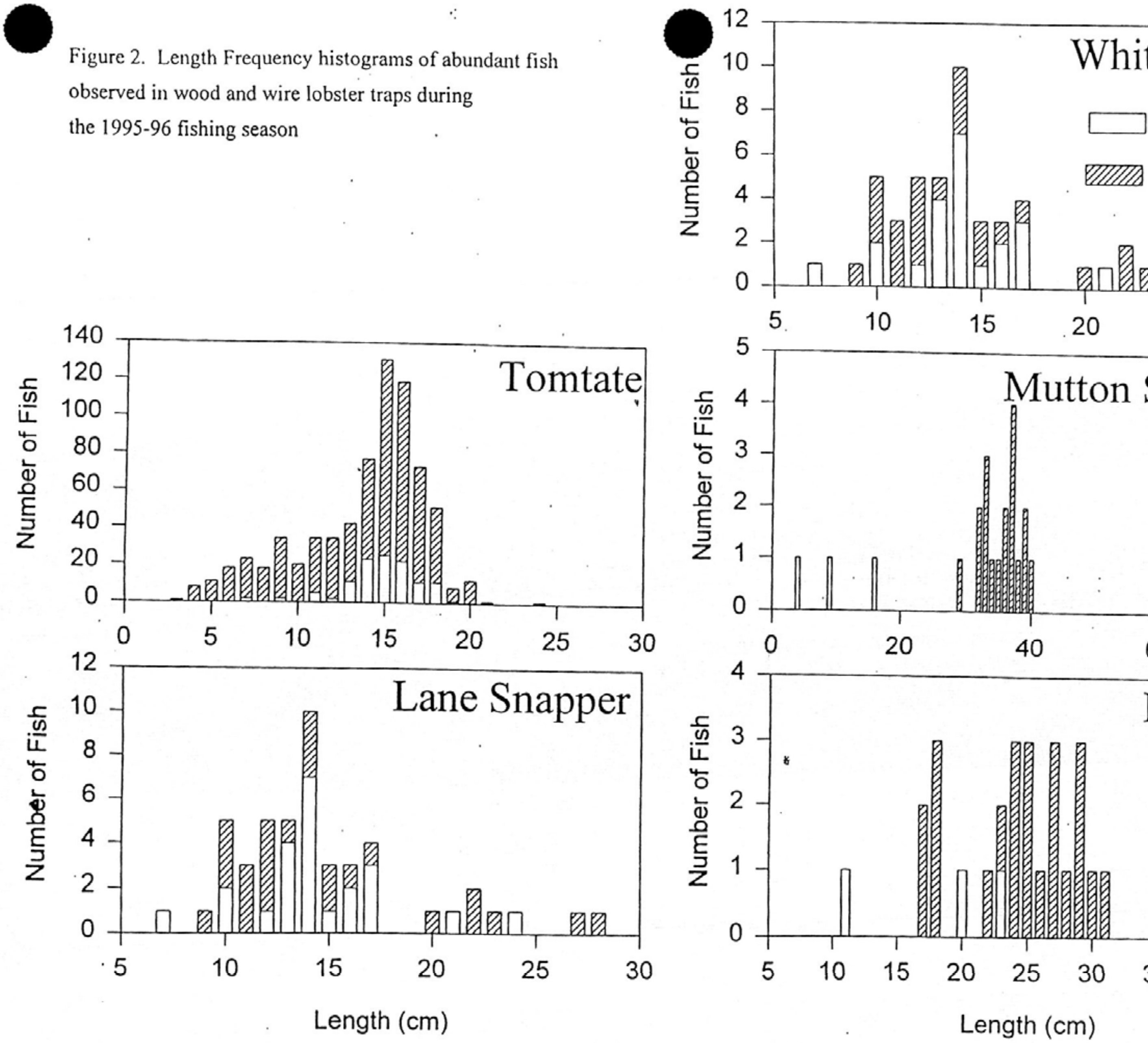


Figure 1. Approximate sampling areas for Commercial Lobster Fishery Monitoring. Areas have been modified from those of Beaver (1989). Areas are referred to as follows: Area 1, Upper Keys-Bay; Area 2, Upper Keys-Ocean; Area 3, Middle Keys-Bay; Area 4, Middle Keys-Ocean; Area 5, Lower Keys-Bay; Area 6, Lower Keys-Ocean; Area 7, Marquesas; Area 8, Dry Tortugas; Area 9, Miami.

Figure 2. Length Frequency histograms of abundant fish observed in wood and wire lobster traps during the 1995-96 fishing season



Appendix J. Nocturnal Foraging of the Carribean Spiny Lobster, *Panulirus argus*, At Offshore Reefs of Florida, USA (FL DEP).

Nocturnal foraging of the Caribbean spiny lobster (*Panulirus argus*) on offshore reefs of Florida, USA

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Abstract. During night dives along randomly selected transects across sand, seagrass, and rubble on the reef flat of Looe Key, a spur-and-groove coral reef, spiny lobsters (*Panulirus argus*) from dens on the forereef were observed foraging on the reef flat, particularly on the extensive rubble ridge and also relatively frequently in *Thalassia*. Subsequent sampling of the rubble revealed hundreds of taxa of appropriate prey items, many at high densities; the density of *Cerithium litteratum*, a favoured food item, was as high as 180 individuals m^{-2}. Arthropods, especially spider crabs (*Pitho* spp.), were common in seagrass. Gut contents of 75 intermoult lobsters caught on offshore reefs at Biscayne National Park and Dry Tortugas National Park included a myriad of prey items, predominantly molluscs—especially gastropods (49%), chitons (15%), and bivalves (11%)—and arthropods (12%); many of the species in lobster guts were rubble dwellers, but some guts contained multiple prey peculiar to seagrass and sand. It is concluded that *Panulirus argus* can forage successfully wherever suitable prey items, especially molluscs, are abundant. However, where a wide range of substrata, including rubble, is available, rubble is preferred because of its abundant, accessible prey.

Extra keywords: food, feeding, marine reserves

Introduction

The Caribbean spiny lobster (*Panulirus argus*) is one of the most successful shallow-water marine invertebrates of the tropical and warm-temperate western Atlantic Ocean. The species ranges from Bermuda to central Brazil, including shelf waters of the Gulf of Mexico and the south-eastern United States, and it occurs in abundances sufficient to support major commercial fisheries throughout much of its range (Aiken 1993; Briones and Lozano 1994; Ehrhardt 1994; Fonteles-Filho 1994; Hunt 1994; Cruz *et al.* 1995). Moreover, *P. argus* is a long-lived species that is able to utilize a variety of environments. Individual lobsters change habitats several times during their ontogenetic progression from inshore nursery areas to adult habitats on offshore reefs (Herrnkind 1980; Andree 1981; Lyons *et al.* 1981; Butler and Herrnkind 1991). Any species that occupies such a wide range of environments must be capable of utilizing different food sources available throughout many foraging habitats.

Individuals of *P. argus* seek daytime shelter in the crevices and caverns of offshore reefs and in undercuts along nearby seagrass 'blowouts' (erosional features within seagrass beds; Patriquin 1975), but they leave their dens at night to forage in surrounding areas. Herrnkind *et al.* (1975) determined that adult reef-dwelling lobsters foraged opportunistically throughout their home range, feeding in rocky areas, grass, and algal flats. Reef-dwelling juveniles of *P. cygnus* forage in seagrass beds located in front of their home reef or nearby reefs (Jernakoff 1987). Movement out of dens peaks several hours after sunset, and most lobsters return to their dens several hours before dawn (Herrnkind *et al.* 1975).

Little is known regarding the foraging behaviour of any life stage of *P. argus*. Other palinurids commonly eat live molluscs and crustaceans, which they locate by contact and chemoreception (Winget 1968; Engle 1979; Joll and Phillips 1984), and a similar diet seems to be favoured by *P. argus*. Herrnkind *et al.* (1975) found that gastropods were the favoured prey of *P. argus* juveniles at St John, US Virgin Islands, whereas crustaceans were more frequently eaten by reef-dwelling adult lobsters. However, Espinosa *et al.* (1991) found that molluscs, principally gastropods, constituted most of the diet of larger *P. argus* individuals captured in seagrass and on reefs off south-western Cuba. Andree (1981) identified small gastropods and crustaceans in faecal pellets of small *P. argus* individuals at Biscayne National Park, Florida.

Herein, we describe foraging activities by reef-dwelling lobsters in the Florida Keys, based upon nocturnal surveys at Looe Key National Marine Sanctuary. We evaluate the adaptability of *P. argus* to different food availability, in

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terms of prey abundance and diversity, based upon examinations of gut contents of lobsters from other Florida reefs and surveys of benthic fauna on various substrata at Looe Key. We theorize that the relative availability of prey and its accessibility influences the nocturnal foraging patterns of *P. argus* in that lobsters tend to forage where prey is most available.

Methods

Study site

Looe Key National Marine Sanctuary (LKNMS), located 9 km south of Big Pine Key in the Florida Keys, encompasses 18·2 km^2 and includes a spur-and-groove reef (forereef) on the seaward side (Wheaton and Jaap 1988). The sanctuary is divided into seven management units that correspond to physiographic zones (Anon. 1983). The study was conducted in two of these zones: the forereef and the reef flat (Fig. 1). A 50-ha 'core area' encompassing the entire forereef and most of the reef flat is closed to commercial lobster harvesting. Recreational lobster harvesting there is discouraged by rigorous enforcement of regulations that prohibit the touching of coral.

The reef flat, located landward of the forereef, encompasses a complex mosaic of seagrass, sand, and the surrounding rubble ridge (Fig. 1). Some of the rubble ridge (about 25%) is outside the core area, so lobsters there are not protected from harvesting. The reef flat was partitioned into Region 1 and Region 2, based on proximity to the forereef (Fig. 1). The boundary between the regions is an imaginary line drawn parallel to the reef crest from the point where the northern core-area boundary crosses the western rubble ridge. Region 1 is the area between the forereef and the boundary; it contains isolated coral heads, seagrass, and sand. Region 2, landward of Region 1 and extending to the apex of the reef flat, contains sand, seagrass, and ephemeral seagrass blowouts.

Nocturnal sampling of foraging habitat

Lobsters were sampled on the reef flat at night during five periods from June 1988 to January 1989. The reef flat comprises a mosaic of potential foraging habitats for *P. argus*, but this patchiness of substrata precluded direct comparisons of lobster abundance in equivalent replicated plots. Instead, we used randomly located belt transects that crossed over all substrata in proportion to their widely disparate distributions to acquire representative samples of lobsters as they foraged.

During daylight, a 200-m tape was placed on the sea bottom at a random location on the reef flat. This tape was subdivided into five equal (40-m) lengths, and a 100-m-long belt transect (belt width: 8 m) was established perpendicular to the 200-m tape at a random location within each 40-m length. The point on the belt transect (0 m to 100 m) at which the transect crossed the 200-m tape was also randomly determined.

Belt transects were sampled between 2300 and 0100 hours for two or three consecutive nights, depending upon weather conditions. Divers recorded by substratum type each lobster they encountered on the belt transects, and they attempted to catch all lobsters observed. Lobsters residing within dens were counted and captured but were not used in foraging analyses. Each captured lobster was marked with a uniquely numbered sphyrion tag inserted into the dorsolateral extensor muscle between the cephalothorax and abdomen (Herrnkind *et al.* 1975). Size (measured as carapace length to the nearest millimetre), sex, reproductive condition of females, and tag number were recorded, and lobsters were returned to the belt transect from which they had been captured.

Divers returned during daytime after the completion of each census and documented the composition and distribution of substrata along each transect. Substratum was initially categorized as one of three seagrass types (*Thalassia testudinum*, *Syringodium filiforme*, or a mixture of the two, termed 'mixed seagrass'), sand, edge (defined as the area within 1 m on either side of a blowout cliff face), coral heads, or rubble. During the last sampling period, a mixture of small compacted rubble and short *Thalassia testudinum* was encountered and categorized as *Thalassia*–rubble. The

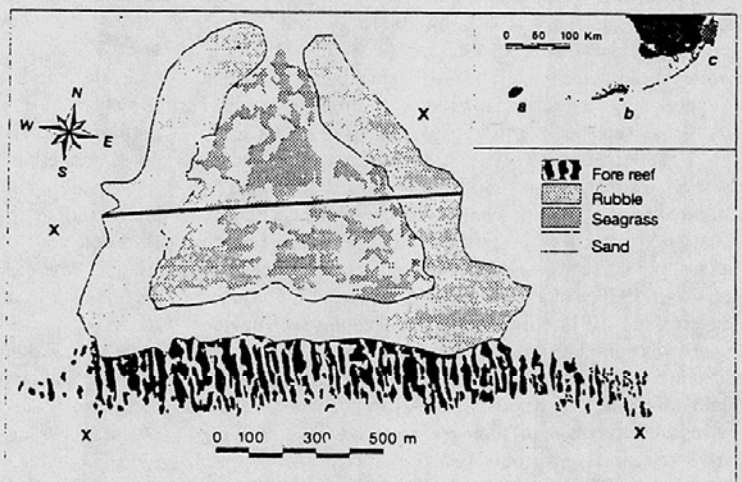

Fig. 1. Location of *(a)* Dry Tortugas National Park, *(b)* Looe Key National Marine Sanctuary (LKNMS), and *(c)* Biscayne National Park, and the forereef–reef flat complex at LKNMS. Xs denote boundary buoys of the core area of LKNMS. The line represents the boundary between Region 1 (bottom) and Region 2 (top) of the reef flat. Small patches of rubble are interspersed throughout the sand and seagrass of the reef flat.

percentage of each substratum type along the transects was calculated for every sampling period.

To determine whether lobsters were distributed proportionately among substratum types, a preference index was calculated for each substratum in every sampling period as follows: [preference index] = [percentage of lobsters on a substratum] – [percentage of that substratum available]. A positive index indicated that more lobsters were observed on a substratum than would be expected if lobsters were distributed randomly among substrata. A negative index indicated fewer lobsters than expected. Preference indices were tested for differences among substrata by analysis of variance (ANOVA).

Not all potential foraging substrata were included in preference analyses. *Thalassia*–rubble was not encountered until the last sampling period, so data for that category were insufficient for evaluation. Only 3% of the area sampled consisted of coral heads and the only lobsters found in association with them at night were denning beneath them, not foraging upon them, so the coral heads were excluded from analyses. Additionally, early in the sampling programme we observed many lobsters walking along blowout edges, prompting us to unobtrusively observe their behaviour. None of the many lobsters observed near edges was ever seen to actively forage there, so we also excluded 'edge' (3% of the area sampled) from preference analyses.

Because each preference index could be heavily influenced by wide variability in substratum patch size, we evaluated the foraging data by an additional analysis that provided a mechanism to examine each substratum across its range of patch sizes. We predicted that there would be more lobsters on transects with higher percentages of preferred foraging substratum. For each substratum, we regressed the number of lobsters on a transect by the amount of that substratum on the transect.

A one-time nocturnal survey of the entire reef flat, including the rubble ridge, was conducted on 19 July 1989. Four sets of three 100-m-long belt transects were placed throughout the reef flat. The first transect of each set was placed on the rubble ridge, the second transect was placed adjacent to the first, primarily in seagrass or *Thalassia*–rubble, and the third transect was placed perpendicular to the others, crossing many substrata. Two sets of transects were located in Region 1; the other two sets were in Region 2. Shortly after dusk (2130 hours), all four sites were sampled simultaneously by separate teams of divers who recorded each lobster they encountered by substratum type but did not capture the lobsters. The transects were sampled again at 2300 hours, and lobsters were captured. Lobsters were measured and substratum percentages were determined as previously described.

Population dynamics and tag recapture

As part of a larger study of trends in abundance and population dynamics of spiny lobsters at LKNMS, permanent sampling sites were established on the forereef and the reef flat in 1987. Sites on the reef flat included isolated coral heads in Region 1 and seagrass blowouts (Patriquin 1975) in Region 2. Each site was sampled during daytime for two years to determine the size structure, sex ratio, and movement patterns of lobsters living in different areas of the forereef–reef flat complex. Individuals of *P. argus* were also captured at two additional sites on the forereef that were sampled regularly at night for other purposes. All lobsters were measured, sexed, tagged as previously described, and returned to their capture locations.

Gut contents and prey abundance

To elucidate the types of prey consumed by reef-dwelling lobsters in Florida, we analysed a data-set containing counts and identifications of material in *P. argus* guts collected in 1978. Lobsters were collected one to two hours before dawn from dens in shallow-water reefs at Dry Tortugas National Park and Biscayne National Park (Fig. 1). Size, sex, and moult stage were recorded for each lobster. Only intermoult lobsters were included in gut-content analyses because little, if any, foraging occurs among lobsters in late premoult through middle postmoult stages (Lipcius and Herrnkind 1982). Lobsters were sacrificed quickly to obtain relatively undigested gut contents, which were identified to the lowest feasible taxon. Identifications to species level were sometimes possible for molluscs on the basis of chitinous remains (opercula or radulae). Empty gastropod shells were assumed to have contained snails and not hermit crabs. We are confident about this assumption because of the low incidence of hermit crab parts (chelae, dactyls, etc.) in guts relative to other arthropod parts and because of the high incidence of gastropod opercula.

Prey items were enumerated and categorized as follows: molluscs (gastropods, bivalves, chitons, scaphopods), arthropods, echinoderms, plants, and 'other' (foraminiferans, sponges, polychaetes, sipunculans, amorphous tissues, spicules, etc.). Data were analysed for differences by ANOVA or, when the assumptions of ANOVA were not met, by Kruskal–Wallis test. Multiple comparisons were made with the aid of Tamhane's T2 test, which does not assume homogeneity of variance (Anon. 1996*a*).

Potential prey residing in rubble, sand, and seagrass at Looe Key was quantified to test the hypothesis that prey was more abundant in rubble than in other substrata. A suction dredge was used to sample fauna from sand and seagrass on the reef flat by removing sediments from 0·25-m^2 quadrats at seven locations selected haphazardly within each substratum type; three replicate samples were collected at each location (2 substrata × 7 locations × 3 quadrats = 42 samples). Sediments were washed through 5-mm-mesh bags (maximum stretched diameter: 6 mm), and animals retained in the bag were identified. Rubble and *Thalassia*–rubble were sampled more extensively than were sand and seagrass. To sample rubble dwellers, divers collected animals by hand from 0·25-m^2 quadrats. We sampled two haphazardly selected sites at each of four locations on the rubble ridge and at a fifth location on *Thalassia*–rubble. Nine quadrats were sampled at each site (5 locations × 2 sites × 9 quadrats = 90 samples).

Molluscs, arthropods, and echinoderms from each sample were identified to the lowest feasible taxon; arthropods were identified by D. K. Camp (Florida Department of Environmental Protection, Florida Marine Research Institute).

To facilitate comparisons across all substrata, we collapsed the prey numbers in individual rubble subsamples into an overall mean prey abundance at each site. Data were then analysed for differences among substratum types by a Kruskal–Wallis test. Multiple comparisons were made with the aid of Tamhane's T2 test. Abundance was converted to density by dividing the number of individuals for each group by the area of substratum sampled.

Results

Nocturnal sampling of foraging habitat

A total of 45 896 m^2 (4·6 ha) was sampled by the use of random transects on the reef flat. Of the 158 lobsters (22–114 mm carapace length, or CL) observed, 123 were outside their dens. Overall density of lobsters for each substratum ranged from 5·4 lobsters ha^{-1} for *Syringodium* to 94·1 lobsters ha^{-1} for edge (Table 1). As expected, densities of lobsters in a given substratum were quite variable among transects, partly because of the variable size of substratum patches. Because of the high variance, lobster density was not significantly different among substrata.

Preference indices were calculated for rubble, sand, *Thalassia*, *Syringodium*, and mixed seagrass. Despite high variance among samples, preference indices were significantly different among substrata at an α level of 0·1 (ANOVA: $F = 2{\cdot}37$, d.f. = 4, $P < 0{\cdot}1$). The preference index for rubble was positive, whereas the preference index for

Table 1. Densities of spiny lobsters in different substrata on the reef flat in Looe Key National Marine Sanctuary at night

Densities are grand means for each substratum over the entire random-transect study. *Thalassia*–rubble was sampled only during the last census

Substratum	Total area (m^2)	Total lobsters	Density (lobsters ha^{-1})
Edge	1488	14	94·1
Rubble	8848	48	54·3
Thalassia	5184	20	38·6
Thalassia–rubble	2840	8	28·2
Mixed seagrass	11592	21	18·1
Sand	6624	7	10·6
Syringodium	9320	5	5·4

sand was negative (Fig. 2). Preference indices calculated for the three seagrass categories revealed disparities among those substrata: the preference index was positive for *Thalassia*, negative for *Syringodium*, and nearly zero for mixed seagrass.

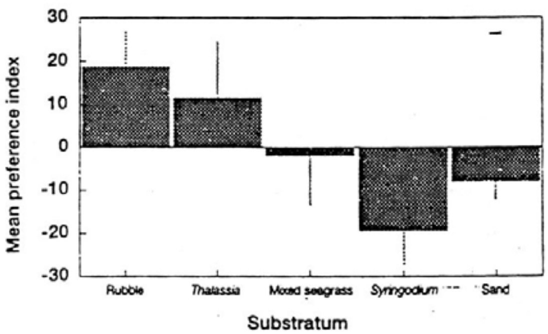

Fig. 2. Substratum preference indices for lobsters on the reef flat at night. Bars represent means from five sampling periods; vertical lines indicate ±1 s.e. of the mean.

The slope of the regression of the total number of lobsters on a transect and the percentage of rubble on that transect was significantly positive ($r^2 = 0·59$, d.f. = 1, $F = 30·65$, $P < 0·001$). In general, there were more lobsters on transects with higher percentages of rubble. In contrast, similar regressions revealed no such pattern for any other substratum; increasing percentages of other substrata did not result in correspondingly higher lobster counts. In all cases, values of r^2 were less than 0·16 and slopes were near zero.

During the single-night survey of the entire reef flat, we observed 58 lobsters on the first set of dives and 59 lobsters on the second set of dives (Table 2). Lobsters ranged in size from 59 to 107 mm CL. Contrary to our expectations, more of those lobsters were observed outside dens during the early-evening dives than later. The proportion of lobsters found in each rubble type (rubble ridge, other rubble, and *Thalassia*–rubble) was greater than the proportion of that substratum sampled in all but one instance (Dive 1: rubble ridge). The proportions of lobsters observed in other substrata were less than the proportions of those substrata sampled in all but one instance (Dive 1: *Thalassia*). Usually, however, higher proportions of lobsters were found foraging in rubble during the second dives than during the first dives, and the proportions of foraging lobsters found on sand and other substrata decreased accordingly.

Population dynamics and tag recapture

The success rate for capturing lobsters along the reef-flat transects at night was 88%. Daytime capture success rate was 94% on the reef flat and 84% on the forereef. Thus, captured lobsters are probably a representative subsample of the population.

The lobster population on the reef flat at night generally displayed characteristics intermediate between those observed on the forereef and on the reef flat during the day (Table 3). During the reproductive season, daytime sex ratios on the reef flat were nearly 1:1, whereas the sex ratio on the forereef was highly skewed toward females. At night, the sex ratio in Region 1 was intermediate between sex ratios on the forereef and in Region 1 during the day. The percentage of ovigerous lobsters on the reef flat (both Region 1 and Region 2) at night also was intermediate between percentages observed on the forereef and on the reef flat during daytime. Males were generally smaller in Region 1 at night than either on the reef flat or on the forereef during the day. Size and sex ratios during the non-reproductive season appear to follow trends similar to those observed during the reproductive season, but the number of lobsters observed was much smaller.

Lobsters found in dens on the reef flat during the day were often found foraging on the reef flat at night. We observed 20 lobsters during both day and night dives at the reef flat. Of these, 13 were observed at night in the same region (Region 1: $n = 11$; Region 2: $n = 2$) where their daytime dens were located, and seven were observed at night in the opposite region from that of their daytime shelters. An additional 10 lobsters first captured at night were recaptured only at night; five of these recaptures occurred on subsequent nights during the same census, and the other five occurred during subsequent sampling periods up to six months later.

Tagged lobsters also moved between the forereef and the reef flat. Seven female lobsters initially tagged on the reef flat at night were recaptured in shelters on the forereef during the day. Four lobsters (three females and one male) tagged on the forereef during the day were recaptured on the reef flat at night. Extensive surveys of dens on the forereef and reef flat revealed another 33 tagged lobsters (25 females

Table 2. Areas and proportions of substratum types covered by transects during simultaneous surveys throughout the reef flat, and numbers and proportions of lobsters observed on each substratum type
n, number of lobsters; 'Rubble ridge', high-relief mound of rubble bounding the reef flat; 'Other rubble', rubble observed on transects other than rubble-ridge transects

Substratum	Area		Dive 1		Dive 2	
	m^2	%	*n*	%	*n*	%
Rubble ridge	3160	33·0	15	25·9	23	39·0
Other rubble	496	5·2	5	8·6	6	10·2
Thalassia–rubble	568	5·9	17	29·3	14	23·7
Thalassia	640	6·7	4	6·9	1	1·7
Mixed seagrass	2960	30·9	7	12·1	3	5·1
Syringodium	424	4·4	2	3·4	1	1·7
Sand	1152	12·0	3	5·2	1	1·7
Edge	184	1·9	0	0	1	1·7
In den	—	—	5	8·6	9	15·3
Overall	9584	100	58	100	59	100

and 8 males) that moved between the forereef and the reef flat. Six lobsters originally tagged on either the forereef or the reef flat were recaptured from the rubble ridge just outside the core area by commercial and recreational fishers.

To assess the impacts of commercial and recreational fishing on the population of lobsters that resides within the core area, demographic parameters of abundance, sex ratio, and size were compiled for the two-month periods preceding and following the opening of the harvest season. Although mean sizes generally remained similar, lobster abundance throughout the core area declined rapidly after the season opened, and the sex ratios of lobsters on the forereef and in Region 2 shifted dramatically, indicating that more males than females were leaving the core area (Table 4).

Gut contents and prey abundance

We examined the gut contents of 55 lobsters (37 males, 18 females; size range: 49–135 mm CL) from Dry Tortugas National Park (DTNP) and of 35 lobsters (17 males, 18 females; size range: 27–104 mm CL) from Biscayne National Park (BNP). Of the 75 intermoult-stage lobsters, guts of 29 DTNP lobsters and 30 BNP lobsters each contained at least one prey item; the guts of the remaining 16 lobsters (21%) were empty. The guts contained a total of 623 prey items.

Panulirus argus at the two reef sites ate a wide variety of prey; 115 taxa (species or higher) of animals and plants were recorded among the gut contents (Table 5). The number of

Table 3. Proportion ovigerous, mean size (mm CL), and sex ratio (SR; female:male) of lobsters on the forereef and in Regions 1 and 2 in day and night samples taken during the reproductive and non-reproductive seasons
Reproductive season is March–September. *n*, number of lobsters

Zone	Time	Reproductive season				Non-reproductive season		
		Ovigerous (%)	Size		SR	Size		SR
			Female (*n*)	Male (*n*)	(*n*)	Female (*n*)	Male (*n*)	(*n*)
Forereef	Day	66·3	80·5 (368)	89·9 (92)	4·0:1 (460)	77·5 (80)	85·0 (21)	3·8:1 (101)
	Night	67·5	77·4 (36)[A]	88·9 (7)	5·3:1 (44)	81·5 (10)	89·0 (3)	3·3:1 (13)
Region 1	Day	30·9	78·6 (175)	86·0 (130)[A]	1·3:1 (306)	77·1 (44)	79·1 (18)	2·4:1 (62)
	Night	37·1	78·7 (54)	80·8 (21)	2·4:1 (75)	80·5 (45)	79·2 (18)	2·5:1 (63)
Region 2	Day	14·1	75·3 (149)	78·2 (120)	1·2:1 (269)	71·6 (39)	65·4 (33)	1·2:1 (72)
	Night	37·9	79·4 (29)	83·7 (30)	1·0:1 (59)	71·8 (10)	55·0 (2)	5·0:1 (12)

[A]One lobster was not measured.

Table 4. Abundance, mean size (mm CL), and sex ratio (SR; female:male) of lobsters during the last two months of the closed season (June and July) and the first two months of the open (harvest) season (August and September)

n, number of lobsters

Zone	Closed season *n*	Closed season Size Female	Closed season Size Male	SR	Open season *n*	Open season Size Female	Open season Size Male	SR
Forereef	211	79·7	90·3	4·0:1	50	81·9	96·7	4·6:1
Region 1	226	78·7	87·1	1·7:1	61	80·7	78·7	1·7:1
Region 2	166	76·6	80·3	0·8:1	47	77·1	78·0	2·6:1

prey consumed by individual lobsters ranged from 1 to 39 items ($\bar{X} = 10{\cdot}9$), and as many as 20 prey taxa ($\bar{X} = 8{\cdot}4$) were found in individual guts. There was no difference between sites in the number of prey items consumed (ANOVA: $F = 0{\cdot}743$, d.f. = 1, $P = 0{\cdot}392$). Nearly 75% of prey items were molluscs. Gastropods (49%)—especially moon snails (Naticidae: *Natica*, *Naticarius*, and *Polinices* spp.), top snails (Trochidae: *Calliostoma* and *Tegula* spp.), ceriths (Cerithiidae: *Cerithium* spp.), and dove snails (Columbellidae: principally *Columbella mercatoria*)—constituted a significantly larger percentage of lobster diet than did any other group (ANOVA : $F = 24{\cdot}726$, d.f. = 7, $P < 0{\cdot}001$; Tamhane: $P < 0{\cdot}001$). Chitons (especially *Acanthochitona* spp. and *Stenoplax* spp.), bivalves, and arthropods (principally spider crabs, *Pitho* spp.) were found in similar abundances, about 11% to 15% (Tamhane: $P = 1{\cdot}000$). Echinoderms constituted less than 4% of the items in lobster guts, but echinoderm parts (e.g. sea-urchin spines, brittle-star arms) were found in guts of 30% of the lobsters.

At Looe Key, many more potential prey items were found in rubble than in seagrass, *Thalassia*–rubble, or sand (Kruskal–Wallis: $\chi^2 = 28{\cdot}638$, d.f. = 3, $P < 0{\cdot}001$; Tamhane: $P < 0{\cdot}05$) (Fig. 3). Average density of potential prey in rubble was more than three times greater than that in seagrass and an order of magnitude greater than those in other substrata. Seagrass contained significantly more potential prey than did *Thalassia*–rubble or sand (Tamhane: $P < 0{\cdot}05$), between which abundances of potential prey did not differ (Tamhane: $P = 1{\cdot}0$).

Table 5. Major prey categories and principal food items in guts of 59 individuals of *Panulirus argus* from reefs at Biscayne National Park (30 lobsters) and Dry Tortugas National Park (29 lobsters)

N taxa, number of species-level and higher groups; *n*, number of individuals in each prey category; *F*, number of lobster guts containing each prey category. The principal gastropod families comprise 204 of the 304 gastropods in lobster guts

Prey	*N* taxa	Items *n*	Items %	Lobsters *F*	Lobsters %
Molluscs	88	465	74.6	48	81.4
Gastropods	53	304	48.9	43	72.3
Principal families:					
Naticidae		80	12·8	25	42·4
Trochidae		66	10·6	27	45·8
Columbellidae		30	4·8	23	39·0
Cerithiidae		28	4·5	23	39·0
Bivalves	28	66	10·6	31	52·5
Chitons	6	92	14·8	29	49·2
Scaphopods	1	3	0·5	3	5·1
Arthropods	8	73	11·7	38	64·4
Echinoderms	6	23	3·7	18	30·5
Plants	3	21	3·4	19	32·2
Other	10	41	6·6	26	44·1
Total	115	623	100		100

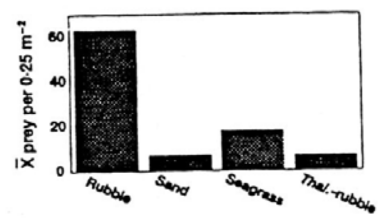

Fig. 3. Average densities of potential prey items in rubble, sand, seagrass, and *Thalassia*–rubble on the reef flat.

Gastropods were far more abundant in rubble than elsewhere (Kruskal–Wallis: $\chi^2 = 21{\cdot}574$, d.f. = 3, $P < 0{\cdot}001$; Tamhane: $P = 0{\cdot}001$) (Table 6) and constituted a high proportion (85%) of all molluscs there. Most of the gastropods were *Cerithium litteratum*, which occurred at densities of up to 180 individuals m^{-2}. Significantly more chitons were found in rubble than in seagrass (Tamhane: $P = 0{\cdot}019$), and significantly more bivalves were found in seagrass than in *Thalassia*–rubble (Tamhane: $P = 0{\cdot}009$). Among molluscs in the prey survey, 20 of 61 rubble-dwelling species (33%), 18 of 50 seagrass-dwelling species

Table 6. Average densities (m^{-2}) of potential prey in substrata sampled on the reef flat

	Rubble	Seagrass	*Thalassia*–rubble	Sand
Area sampled (m^2)	18	5·25	4·5	5·25
Molluscs	171·6	26·9	20·2	19·2
Principle classes:				
Gastropods	145·6	9·7	4·4	2·9
Bivalves	7·8	13·7	3·8	9·3
Chitons	18·2	3·0	12·0	6·1
Arthropods	65·7	40·0	4·4	6·1
Echinoderms	12·0	10·1	0·7	0·2
All taxa	249·3	77·0	25·3	25·5

(36%), 10 of 17 *Thalassia*–rubble species (59%), and 6 of 22 sand-dwelling species (27%) also occurred in lobster guts.

Most arthropods in the prey survey were hermit crabs and spider crabs. Hermit crabs, principally *Clibanarius tricolor*, were most abundant in rubble, but their abundance was highly variable. Abundance at one site ranged from 0 to 134 specimens of *C. tricolor* per 0·25-m^2 quadrat. Arthropods were more abundant than molluscs in seagrass (Table 6), and several arthropods, including spider crabs (*Pitho* spp.), that were common there were rare or absent elsewhere. Significantly more arthropods were found in seagrass than in sand or *Thalassia*–rubble (Tamhane: $P < 0{\cdot}001$). Like arthropods, echinoderms were more abundant in rubble and seagrass, and significantly fewer echinoderms were found in sand and *Thalassia*–rubble (Tamhane: $P < 0{\cdot}01$).

The distributions of prominent prey taxa on the reef flat at Looe Key were examined to ascertain the relative availabilities of those taxa among the substratum types (Table 7). Among the seven categories of prominent prey, reasonable correspondence occurred between incidence in

Table 7. Prominent prey taxa in gut contents of reef-dwelling lobsters from Dry Tortugas National Park and Biscayne National Park, and average densities of those taxa in different substrata at Looe Key

Prey	Gut contents (%)	Density (m^{-2}) in substratum			
		Rubble	Seagrass	*Thalassia*–rubble	Sand
Gastropods					
Cerithium spp.	4·5	137·2	—	2·2	—
Columbella mercatoria	2·9	1·9	2·3	—	—
Trochidae	10·6	0·2	0·6	0·2	—
Polinices spp.	11·7	—	0·6	0·2	0·2
Chitons					
Acanthochitona spp.	3·7	0·2	1·3	0·2	0·4
Stenoplax spp.	2·7	3·1	0·2	0·9	—
Arthropods					
Pitho spp.	5·0	0·1	8·8	0·2	0·2

lobster guts and incidence in *(1)* rubble for *Cerithium* spp. and *Stenoplax* spp., *(2)* seagrass for *Pitho* spp., and *(3)* both rubble and seagrass for *Columbella mercatoria*. Although *Acanthochitona* spp. constituted 3·7% of all prey in guts, these chitons were found at low density in all substrata. Trochidae and *Polinices* spp., the two groups most abundant in lobster guts, were not abundant at Looe Key.

Discussion

Lobsters that foraged on the reef flat at Looe Key were more abundant in rubble than in other substrata. The rubble there also supported many more potential prey items, in terms of both abundance and diversity, than did sand or seagrass, and many of the species found in rubble, especially gastropods and arthropods, were also abundant in the guts of lobsters from other locations along the Florida reef tract.

Foraging lobsters were also relatively abundant in *Thalassia*. Likewise, guts contained substantial numbers of seagrass-dwelling prey. Lobsters were much more likely to find spider crabs in seagrass than in rubble; *Pitho* spp., which constituted 5% of lobster diets, also constituted 13% of the potential prey found in seagrass but were scarce in rubble (Table 7). Other prey, especially large snails (e.g. *Tegula fasciata*), graze on epibiota on the wide, flat blades of *Thalassia*, where they may be readily accessible to foraging lobsters. These large grazers are seldom found on *Syringodium* because its narrow, cylindrical blades provide little surface area for the snails to graze. This may explain why the substratum preference index for *Thalassia* was positive whereas the index for *Syringodium* was negative (Fig. 2). Feeding on such grazers may also explain the occasional occurrence of *Thalassia* fragments in lobster guts: the grass may be ingested incidently as grazers are consumed.

The gut contents reported here are very similar to those reported by Espinosa *et al.* (1991). Molluscs constituted 75% of the prey items found in the present study and 73% and 75% of the prey at two sites off south-western Cuba (Espinosa *et al.* 1991). Further, gastropods (primarily *Polinices lacteus*, *Tegula fasciata*, *Columbella mercatoria*, and *Cerithium litteratum*) were 57% and 66% of all molluscan prey at the two Cuban sites. In the present study, similar gastropods (Naticidae, Trochidae, Columbellidae, and *Cerithium* spp.) constituted 44% of all molluscs consumed (Table 5). Chitons (especially *Acanthochitona* spp. and *Stenoplax* spp.) constituted 12% of prey in Cuba and 15% of prey in Florida. Bivalves contributed 6% of the prey at each Cuban site, compared with 11% at the Florida sites. Similarities between gut contents from Florida and Cuba have led us to conclude that *Panulirus argus* employs similar foraging strategies and preys upon similar organisms in shallow-water reef environments throughout its biogeographic range.

Most prey items move through lobster guts within several hours of consumption (Herrnkind *et al.* 1975; Joll 1982). Even chitinous gastropod opercula (the most plentiful item we found in lobster guts) probably were ingested the night that the lobsters were captured. Joll (1982) found 135 opercula of *Littorina unifasciata* in the stomach of one individual of *Panulirus cygnus* that had been allowed to feed for only two hours after being starved. Most opercula were absent from guts within four hours of feeding. Similarly, we surmise that the many chiton radulae found were consumed the night that the lobsters were captured. Hence, the gut contents reported here probably represent prey that each lobster captured during a single night. Lobsters whose guts contained prey peculiar to a single substratum probably fed only in that substratum, whereas lobsters that consumed prey items peculiar to different substrata must have fed in several substrata in a single night. For example, the full gut of one lobster contained only five *Pitho* crabs, whereas the gut of another contained the remains of *Cerithium litteratum*, *Columbella mercatoria*, *Tegula fasciata*, and 13 *Polinices* opercula. As indicated by the substratum preferences of these prey (Table 7), the first lobster fed in seagrass but the other lobster probably fed in several substrata, including rubble and sand.

Although rubble supported more potential prey and attracted more foraging lobsters than did other substrata at Looe Key, the relative incidences of molluscs in rubble, seagrass and sand were similar (27–36%) in the guts of lobsters from the other Florida reefs (BNP and DTNP), probably reflecting environmental differences between the Looe Key reef flat and the isolated reefs where lobsters in the diet study were captured. *Cerithium* spp. and *Stenoplax* spp., which were numerically dominant in rubble at Looe Key, were also frequent in lobster guts at BNP and DTNP, but lobsters at these last two sites also consumed *Columbella mercatoria* and *Pitho* spp., which were more common in seagrass, as well as trochid and *Polinices* snails, two prey categories that were relatively uncommon in the Looe Key samples (Table 7). At the reefs where this diet study was conducted, lobsters had to cross large expanses of sand (reef halos) when they moved to and from seagrass and rubble zones during foraging, and the many *Polinices* individuals in their diet were probably taken from that sand.

These results demonstrate how adaptability has enabled *Panulirus argus* to be successful. Where a wide suite of foraging substrata is available, lobsters clearly prefer rubble, and to a lesser extent *Thalassia testudinum*, over other substrata within their foraging range. However, after considering the evidence from all aspects of this study, we conclude that spiny lobsters can successfully forage in nearly any substratum they encounter. Thus, we would expect *P. argus* to forage wherever suitable prey items, especially molluscs, are most available within the foraging range of the lobsters.

Movements of lobsters to and from foraging grounds are never random (Herrnkind *et al.* 1975; Jernakoff 1987). In addition to broad orientational cues such as geomagnetic fields and water movements (Creaser and Travis 1950; Herrnkind and McLean 1971; Lohmann 1985), structural cues in the environment may be used by lobsters to find their way to and from foraging grounds. We suspect that blowout edges may serve in that capacity because lobster density was highest along edges but no lobsters were observed to feed there.

Foraging areas may be sites of important behavioural interactions among lobsters. Lobsters of different sizes, sexes, and stages of maturity that do not normally associate during daytime in the reproductive season forage in proximity to each other at night, as evidenced by our observations of the increased percentage of ovigerous lobsters (Table 3) and tagged forereef lobsters on the reef-flat foraging grounds at night. Some large males on offshore reefs guard dens containing 'harems' of mature females (Herrnkind and Lipcius 1989). The distribution and size structure of lobsters on the Looe Key forereef during the reproductive season is consistent with the hypothesis that polygynous males establish and defend mating territories. However, Herrnkind *et al.* (1975) reported that foraging males do not display the aggressive behaviour they show while near their dens. At night, when the lobsters leave the protection of dens to forage, the large males probably cannot defend their harems from the courtship advances of others. Small males already residing on the reef flat (Table 3) may thus gain access to reproductively receptive females when the latter arrive to forage. Although copulation characteristically occurs near dens during the day, nocturnal copulation has been documented in laboratory pools and ponds for *P. argus* (Lipcius *et al.* 1983; Lipcius and Herrnkind 1985), *P. homarus* (Berry 1970), and *Jasus edwardsii* (McKoy 1979). Nocturnal courting by *J. edwardsii* has been observed in the field (A. B. MacDiarmid, personal communication). Additional field studies on foraging and mating behaviours will be required to determine the success of harem maintenance as a reproductive strategy for spiny lobsters.

Lobsters that reside in the core area at LKNMS are afforded some protection because commercial harvesting is prohibited there, but many of those lobsters lose that protection by foraging in rubble areas outside the core-area boundary. In fact, several lobster trappers reported harvesting tagged core-area lobsters from the rubble. The impact of harvesting is evident in the swift reduction in core-area lobster abundance that occurs concurrent with the season opening. If lobsters in marine reserves are to be maintained at population levels higher than those where fisheries operate, then the reserves must protect lobster foraging grounds as well as their denning sites. The newly established (1 July 1997) Looe Key Special Protection Area has increased the protected area to about 115 ha, including the entire reef-flat seagrass community and most of the rubble ridge (Anon. 1996*b*). However, the new area still does not fully encompass the rubble foraging grounds, nor does it provide a buffer around those grounds, so some Looe Key lobsters will remain vulnerable to harvesting during their diel activity cycle.

Acknowledgments

We thank the following people for the many hours they spent in the field: Lonny Anderson, Scott Andree, Barbara Blonder, Billy Causey, Jon Dodrill, David Forcucci, Dennis Gauld, Bill Green, Ken Hartsing, Doug Heatwole, Brenda Hedin, Lauri MacLaughlin, Tom Matthews, Cynthia Sandusky, and Carolyn Schultz. We are indebted to Rodney Bertelsen, Mark Butler, and Mark Luckenbach for their assistance with portions of the data analysis. Dan Marelli and Clarita Lund collected suction samples and helped identify bivalves from them. David L. Pawson, US National Museum of Natural History, examined vouchers of 'problem'echinoderms. Part of this work was conducted under Contract No. 50-DGNC-6-00093 from the US Department of Commerce, National Oceanographic and Atmospheric Administration, National Marine Sanctuary Program.

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Appendix J. Nocturnal Foraging of the Carribean Spiny Lobster, *Panulirus argus*, At Offshore reefs of f Florida, USA.

ERRATUM

COX, C., J. H. HUNT, W. G. LYONS, and G. E. DAVIS
1997. Nocturnal foraging of the Caribbean spiny lobster (*Panulirus argus*) on offshore reefs of Florida, USA. Marine and Freshwater Research 48: 671–679.

Page 675, Table 3, Column 6, Line 7—*Reads* 2·4:1. *Should read* 2·6:1.

Appendix K. Life History of the Spotted Spiny Lobster, *Panulirus guttatus*, an Obligate Reef-Dweller: Settlement, Population Structure, Reproduction, and Interactions With Other Lobsters (FL DEP).

 Mar. Freshwater Res., 1997, 48, 687–698

Life history of the spotted spiny lobster, *Panulirus guttatus*, an obligate reef-dweller

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Abstract. Population dynamics of the spotted spiny lobster, *Panulirus guttatus*, were examined at Looe Key Reef, Florida, USA, from April 1987 to August 1989. The 347 lobsters captured (including recaptures), ranged from 9 mm (puerulus) to 75 mm carapace length ($\bar{X}$ = 54 mm CL). Pueruli settled all year round into small holes along the underside of the reef. All lobsters recaptured were found at the site of their initial capture; one was captured four times, all on the same reef spur, over 762 days. Adults sheltered within the reef during the day and foraged on top of the reef at night. Males and females were captured in equal proportions (1.2 M:1 F) from den entrances during the day; females were numerically dominant on foraging grounds at night (3 F:1 M). Reproduction occurred all year round but peaked between March and June; minimum size at maturity was 38 mm CL for females and 48 mm CL for males. The sheltering behaviour of *P. guttatus*, typically found on the ceiling of dens, contrasted markedly with that of the sympatric *P. argus*, typically found on the floor; both species used many of the same dens, but simultaneous co-occupancy was rare.

Extra keywords: Looe Key, Florida Keys, *Panulirus argus*, population dynamics

Introduction

The spotted spiny lobster, *Panulirus guttatus*, occurs from Bermuda to Suriname, with populations in south-eastern Florida, in the Bahamas, and throughout the Caribbean Sea (Holthuis 1991). Unlike the sympatric *Panulirus argus*, *P. guttatus* is of limited commercial interest throughout most of its range. The only directed fisheries for this species are at Bermuda and Martinique (Sutcliffe 1953; Marfin 1978; Evans and Lockwood 1994), although limited fisheries probably exist elsewhere. Consequently, the relatively few published studies of *P. guttatus* have been largely confined to those two localities and were based on individuals caught in traps or nets (Sutcliffe 1953; Farrugio 1975, 1976; Marfin 1978; Evans and Lockwood 1994; Evans *et al.* 1995*a*, 1995*b*, 1996). Most of these studies focused on reproductive dynamics and stock assessment to provide information for fisheries management. The only studies of *P. guttatus* in Florida (Caillouet *et al.* 1971; Chitty 1973) reported the sex ratio, size distribution, and reproductive seasonality of a population living at man-made jetties near Miami Beach.

We conducted a two-year study of the lobster populations within Looe Key National Marine Sanctuary, Florida, USA. Although the principal objective was to describe the trends in abundance and population structure of *P. argus*, we also frequently encountered *P. guttatus*. This paper reports on the life history of *P. guttatus* and presents information on settlement habitat, juvenile and adult abundance, population structure, and reproductive dynamics. It also describes interactions related to resource allocation between *P. guttatus* and other lobsters.

Materials and methods

Looe Key National Marine Sanctuary, located approximately 9 km south of Big Pine Key, Florida, encompasses approximately 18.2 km^2 of spur-and-groove coral bank reef and associated habitats. The sanctuary is divided into seven management units that correspond to physiographic zones (Anon. 1983). Our study was conducted in the Intermediate Reef, Fore Reef, Reef Flat, and Patch Reef physiographic zones at the sanctuary (Fig. 1). The Intermediate Reef (IR) zone, ranging in water depth from 10 to 20 m, is typified by low-relief, partially drowned spur-and-groove formations. The Fore Reef (FR) zone, ranging in water depth from 2 to 9 m, is characterized by high-relief spur-and-groove formations with coral spurs that extend upward as much as 7 m above the surrounding bottom. The Reef Flat (RF) zone, ranging in water depth from 1 to 3 m, is comprised of coral rubble, isolated coral heads, and seagrass beds (*Thalassia testudinum* and *Syringodium filiforme*) containing numerous blowouts formed by erosion in the seagrasses (Patriquin 1975). The perimeters of these blowouts are often undercut by wave action and serve as dens for spiny lobsters. The Patch Reef (PR) zone, ranging in water depth from 5 to 8 m, consists of low-relief areas of hard bottom (exposed carbonate bedrock characterized by solution holes, sponges, and small corals) and high-relief (to 3 m), dome-shaped coral heads.

Six sites were established in each of the FR and PR zones, eight sites were established in the RF zone, and three sites were established in the IR zone. The locations of these sites were determined by a stratified random method. Each zone was divided into two geographic strata, and sites within each stratum were established randomly. Because suitable lobster habitat differed among zones, site configurations varied in each zone. Each IR site consisted of a 100-m-long belt transect; a 5-m strip on each side of the transect was sampled, producing a sampling area of 1000 m^2. Each FR site consisted of one vertical side and the horizontal top of each of two spurs on either side of a sand channel. Areas of the FR sites varied with the size and shape of each spur and ranged from 909 to 1863 m^2. Three RF sites consisted of isolated mounds of elkhorn coral (*Acropora palmata*), another RF site was a 551-m^2 area dominated by star corals (*Montastraea* spp.), and the remaining four RF sites were located in blowouts. Three PR sites were coral mounds that ranged in size from 344 m^2 to 662 m^2; each mound was

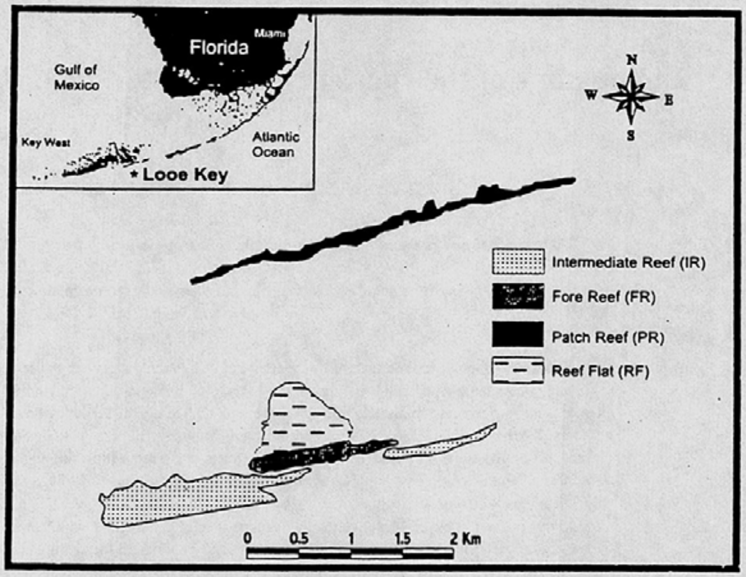

Fig. 1. Looe Key National Marine Sanctuary, Florida, USA. Zones sampled: Intermediate Reef, Fore Reef, Reef Flat, and Patch Reef.

of varying structural complexity and was surrounded by sand. The other three PR sites (areas 1014 m^2 to 1243 m^2) were located in a large expanse of hard bottom that contained many corals and other structures suitable for lobster shelter.

We searched for *Panulirus guttatus* and *P. argus* at all 23 sites during daylight hours with the aid of SCUBA. Searches were conducted from April 1987 through August 1989; sites were sampled biweekly until April 1988 and once every four weeks for the remainder of the study. When a lobster was found in a den, the location of the den was permanently marked by affixing a numbered tag adjacent to the den entrance. Once marked, dens were revisited during every subsequent sampling period. The number of lobsters in each den and the location of each lobster within a den (i.e. floor, wall, ceiling) were recorded; other kinds of information (e.g. size, sex, reproductive condition) were also recorded when obtainable. In addition to gathering these data, we attempted to capture all of the lobsters observed at nine of the 23 sites. Captured lobsters were brought back to the research vessel, where they were examined and tagged with a numbered sphyrion anchor tag (Floy Tag & Manufacturing, Inc., Seattle, WA) inserted into the dorsolateral extensor muscle between the cephalothorax and the abdomen. Data recorded for captured lobsters included the following: zone, site, date, den number, carapace length (CL) to the nearest millimetre, sex, presence and condition of spermatophores and eggs, condition of ovaries, moult stage, and length of second walking leg of males. Previously tagged lobsters were coded as recaptures. All lobsters were then returned to the dens from which they had been removed

Shortly after the study was initiated, it became clear that the daytime search protocol did not adequately sample *P. guttatus*; occasional daytime searches with battery torches revealed previously undetected *P. guttatus* individuals deep within the reef. Consequently, two additional FR sites were established that were sampled only at night, when foraging *P. guttatus* individuals could be captured in the open. Each site comprised a single spur, and each was sampled nine times between June 1987 and July 1989. One site (TR1) encompassed an area of 1070 m^2. TR1 was well demarcated by wide sand channels that isolated the site from adjacent spurs except for one expanse (6 × 3 m) of low-relief hard bottom that connected the site to adjacent spurs near the reef crest. The other site (TR2) encompassed an area of 935 m^2 but was less isolated from adjacent spurs than was TR1; a corridor (6 × 11 m) of rock and coral connected TR2 to an adjacent spur, and an expanse of low-relief hard bottom, similar to that of TR1, connected the site to adjacent spurs near the reef crest.

Both night-time sites were thoroughly searched by two teams of divers for 1 h each, and attempts were made to capture all *P. guttatus* and *P. argus* individuals observed during that hour. Captured lobsters were brought back to the research vessel, treated according to the onboard protocol described above, and returned to the site.

Because of the areal disparity between sites, abundance values were converted to density estimates to allow equitable comparisons. Estimates of density at daytime sites were calculated by summing the number of lobsters observed at a site and dividing that sum by the area of the site. All densities are expressed as number of lobsters per hectare. Our previous experience suggested that handling lobsters when they were in dens increased the likelihood that they would move. We therefore used data from daytime observation sites but excluded data from daytime capture sites to estimate density. Although lobsters were captured at the two night-time sites, densities were estimated at these sites in the manner described above. Further, estimates of population abundance, immigration, and survival were determined from the night-time sites with the aid of a Jolly–Seber model (Type A) (Jolly 1965) and a computer program adapted from that model (J. E. Lines, US Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel, MD). These abundance values were similarly converted to density estimates. Spatial patterns of den occupation were compared between *P. guttatus* and *P. argus* by three-way log-linear analysis (Sokal and Rohlf 1981).

The onset of functional reproductive maturity among males was estimated by determining the onset of allometric growth of the second pair of walking legs (George and Morgan 1979); data from males in the present study were augmented by data taken from individuals that we captured at other localities in the Florida Keys. The onset of allometric growth was determined by defining the point of discontinuity between carapace length and second-leg length according to the method suggested by Somerton (1980) and Lovett and Felder (1989) for defining the onset of differential growth of crustacean body parts. In this method, data were partitioned into two subsets, and separate Model II geometric-mean regression equations (Ricker 1973) were applied to each subset. This process was repeated iteratively along the entire range of the independent variable (carapace length) in 1-mm increments until the two regression lines best fit the combined data set; best fit was defined as that which yielded the lowest combined sum of squared residuals from the separate regression equations. Analysis of covariance (ANCOVA) was then applied to determine whether the slopes of the two regression lines were significantly different (Sokal and Rohlf 1981). The intersection of the two regression lines was interpreted as the transition point representing the onset of allometric growth of the second leg.

Results

In all, 2070 observations of *Panulirus guttatus* were recorded at the 23 daytime sampling sites. Of these observations, 1839 (89%) occurred at FR sites, 222 (11%) occurred at PR sites, and 9 (<1%) occurred within coral heads at RF sites; no *P. guttatus* individuals were observed at RF seagrass-bed blowout sites or at IR sites. Of the observations at PR sites, 115 (52%) occurred at a single site.

In all, 347 *P. guttatus* individuals were captured (including recaptures) during the study. However, capturing *P. guttatus* during the daytime proved exceedingly difficult. Many dens extended far back into the reef, and those lobsters that evaded the initial capture attempt usually disappeared into their dens. Consequently, the lobsters nearest the den entrance were often the only ones captured. We caught 112 (22%) of the 500 lobsters observed at the daytime sites where the sampling protocol dictated capture; 105 (94%) of these lobsters were caught at FR sites, 6 were captured at RF sites, and the remaining one was captured at a PR site. At the end of the study, we attempted to capture all lobsters found at non-capture sites, and we obtained 9 more *P. guttatus* individuals in this manner. Two additional *P. guttatus* individuals were captured in the reef-flat rubble zone during night-time sampling conducted to examine the foraging behaviour of *P. argus* (Cox *et al.* 1997), and one additional tagged *P. guttatus* individual was collected on the FR by recreational divers and returned to us. The remaining 223 *P. guttatus* individuals were captured at the two night-time FR sites. Although we did not record the total number of lobsters observed during these night dives and cannot quantify the capture rate, we perceive that capture success was approximately 90%.

Settlement

Pueruli (9 mm CL) and early benthic-stage juveniles (individuals estimated to be approximately 12 mm CL or smaller) were observed all year round (Fig. 2), but the number of these observations was insufficient to allow seasonal trends in settlement to be examined. Nevertheless, because virtually nothing has been published about

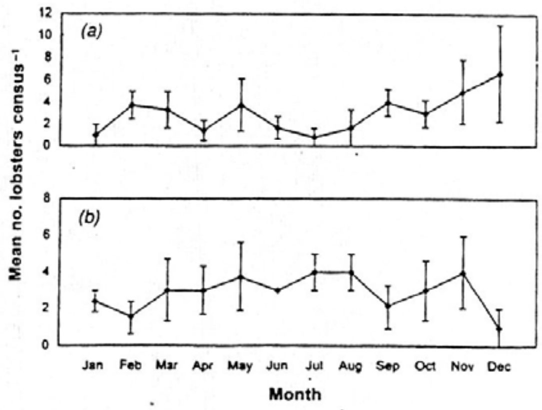

Fig. 2. Mean monthly abundance (± 1 s.e.) of *Panulirus guttatus* (*a*) pueruli and (*b*) early benthic-stage juveniles (approximately ≤12 mm CL).

settlement habitat or recruitment periodicity for *P. guttatus*, we present the following observations.

Pueruli were found in the FR and PR zones only. One cave at the PR contained one to five *P. guttatus* pueruli or early benthic juveniles ($\bar{X}$ = 1·15 ± 0·21) in 22 of 33 censuses; larger juveniles were also observed in that cave during 17 of those 33 censuses. Both pueruli and early benthic juveniles were typically encountered in holes that served as dens located along the underside of coral ledges and on the ceiling of undercut corals and caves, where their presence was discerned only because portions of their antennae were exposed. We never observed more than one lobster per hole. Typically, these holes were approximately 2 cm in diameter at the entrance, and in the few instances where individuals were successfully removed, depths of the holes ranged from 9 to 11 cm. In one instance, an entire puerulus den and surrounding substratum was removed from the reef. From the size and shape of the cavity and the texture of its interior walls, we suspect that it was created by the reef-boring mollusc *Lithophaga antillarum*. We speculate that many of the initial dens selected by *P. guttatus* settlers are cavities created by reef-borers.

Population structure

Size structure (*n* = 345) and sex ratio (*n* = 342) of the population were ascertained from the 347 lobsters (including recaptures) that were collected. These lobsters ranged in size from 9 mm CL to 75 mm CL (mean ± 1 s.e.: 53·6 ± 0·49 mm CL) (Fig. 3). Of these, 221 were females ($\bar{X}$ = 51·9 ± 0·42 mm CL; range: 21–63 mm CL) and 119 were males ($\bar{X}$ = 58·4 ± 0·75 mm CL; range: 18–75 mm CL); two other females were not measured. Four pueruli (9 mm CL) and one early benthic-stage juvenile (11 mm CL) of undetermined sex were also collected. The overall sex ratio (M:F) was 1:1·9. The daytime sex ratio was 1.2:1, but the

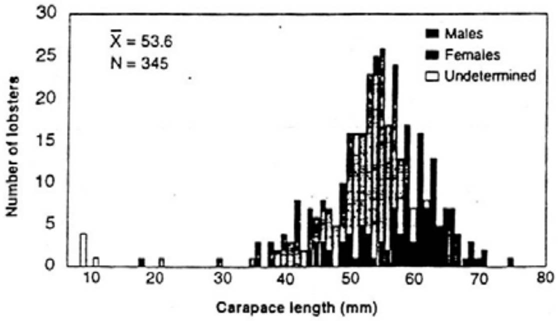

Fig. 3. Size–frequency histogram of *Panulirus guttatus* males, females, and juveniles (sex undetermined) by 1-mm-CL size classes.

ratio of night-time captures was strongly skewed (1:3) toward females.

In all, 238 *P. guttatus* individuals were tagged during the course of the study; tagged individuals ranged in size from 35 mm CL to 75 mm CL (mean ± 1 s.e.: 54.4 ± 0.49 mm CL). Ninety-one lobsters were tagged and 15 were recaptured during daytime sampling; 147 lobsters were tagged and 40 were recaptured during night-time sampling. Recaptures of previously tagged lobsters accounted for 33% of the total number of lobsters collected during night-time; the proportion of recaptures among all captured lobsters was noticeably higher at TR1 (44%) than at TR2 (26%). All daytime and night-time recaptures occurred at the site of initial capture; only one daytime FR lobster (male, 63 mm CL) was recaptured on the spur across the sand channel from its initial capture location. Repetitive recaptures were common (Table 1); of the 55 recaptured individuals, 20 were recaptured more than once, and one lobster was recaptured five times. Moreover, 12 lobsters were recaptured several times during more than one year after their initial capture, and one lobster was recaptured four times over the course of 762 days. Four lobsters (two males and two females) were each recaptured once in the same dens where they had previously been captured.

Extended periods of higher and lower densities of lobsters were evident at both the FR and the PR (Fig. 4), but no consistent pattern was observed across zones. Although single-sample densities as high as 163·4 lobsters ha^{-1} were observed during daytime at the FR, monthly averages produced estimates of 48·4 to 76·6 lobsters ha^{-1} (mean ± 1

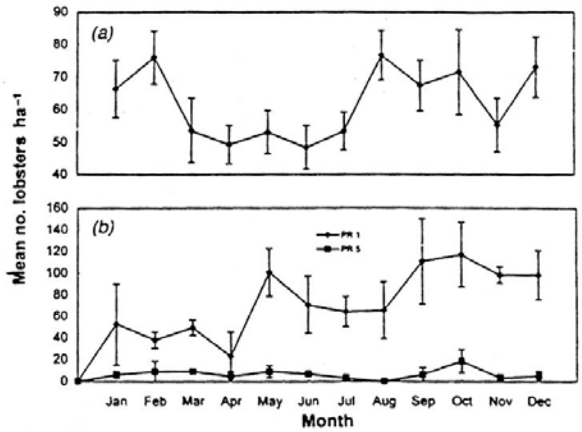

Fig. 4. Mean monthly density (± 1 s.e.) of *Panulirus guttatus* at *(a)* the fore reef and *(b)* two patch-reef sites (PR1 and PR5). Estimated densities are the mean of all observations during each month pooled across both years.

Table 1. Number of tagged *Panulirus guttatus* individuals recaptured during daytime and night-time sampling, April 1987 to August 1989

'Months at large' represents the time from initial capture to final recapture. 'Maximum number of recaptures' represents the greatest number of times an individual of a group was recaptured. Unless otherwise noted, all lobsters were recaptured on the same spur where they were initially captured

Months at large	Daytime			Night-time	
	Number of lobsters recaptured	Maximum number of recaptures	Recaptures in same den	Number of lobsters recaptured	Maximum number of recaptures
<1	5	1	1	4	1
1–3	5[A]	1	2	8	2
3–6	4	2	1	3	2
6–12	0	0	0	14	4
12–18	0	0	0	7	3
18–24	0	0	0	4	5
>24	1	4	0	0	0
Total	15			40	

[A]One lobster (male, 63 mm CL) was recaptured on an adjacent reef spur across the sand channel. Another lobster (female, 61 mm CL) was found dead and was returned to us by a recreational diver; recapture location is unknown.

s.e.: 62·0 ± 8·10 lobsters ha^{-1}). Average densities were 51·4 ± 3·00 lobsters ha^{-1} from March through July and 69·9 ± 3·50 lobsters ha^{-1} from August through February. *Panulirus guttatus* was observed at only two of the PR sites. One of those sites (PR1) was a high-relief coral mound of considerable structural complexity; of the six PR sites, this site most resembled the FR habitat. Average monthly density of *P. guttatus* at PR1 ranged from 22·7 to 117·1 lobsters ha^{-1} (mean ± 1 s.e.: 74·0 ± 22·0 lobsters ha^{-1}); average densities were 36·7 ± 18·8 lobsters ha^{-1} from January through April and 90·6 ± 23·6 lobsters ha^{-1} from May to December. Although estimating the size of these lobsters proved difficult, conservative estimates indicate that approximately 38% of the individuals observed at PR1 were either pueruli or early benthic-stage juveniles. The other site (PR5) where *P. guttatus* was observed consisted of low-relief hard bottom with scattered coral heads of various sizes. Average monthly density estimates there ranged from 0 to 18·4 lobsters ha^{-1} (mean ± 1 s.e.: 6·7 ± 4·3 lobsters ha^{-1}).

Mean density estimates based on night-time captures at TR1 and TR2 were 118·3 ± 10·9 lobsters ha^{-1} and 115·3 ± 12·2 lobsters ha^{-1}, respectively. In contrast, Jolly–Seber model population estimates based on tag–recapture data from these sites yielded appreciably higher average density values. The average densities at TR1 and TR2 estimated from the Jolly–Seber model were 363·2 lobsters ha^{-1} and 691·9 lobsters ha^{-1}, respectively (Table 2). Immigration (*B*) was considerably higher at TR2 than at the more isolated TR1. On a few occasions, the estimate of ø (representing emigration and survival) exceeded 1·00 at both sites (survival cannot exceed 100%). Bishop and Sheppard (1973) determined that the Jolly–Seber model typically overestimates survival and stated that the model should not be used to estimate this parameter. Alternatively, Cormack (1973) suggested that estimates of ø that exceed 1·00 should simply be interpreted as 1·00. When ø is recalculated with this approach, the mean estimates of ø from the two sites become similar; the mean of TR1 is reduced from 0·84 to 0·68 and the mean of TR2 is reduced from 0·64 to 0·60.

Reproduction

The smallest egg-bearing female encountered was 38 mm CL. The low number of observations of females ≥38 mm CL ($n = 213$), especially those in smaller size classes (38–43 mm CL, $n = 21$), limits the ability to provide a robust estimate of the size at which the female population reaches maturity (i.e. the size at which at least 50% of females are observed with eggs). However, when observations of all females captured

Table 2. Mark–recapture statistics, Jolly–Seber population estimates, and density estimates for *Panulirus guttatus* populations at the two FR night-time sampling sites, June 1987 to July 1989

Population estimates are: population size (*N*), population addition (*B*; the number of individuals immigrating into the population between sampling periods), and probability of survival (ø; the number of individuals surviving or emigrating from the population between sampling periods). When ø values of >1·00 are reduced to 1·00, mean ø values become 0·68 at TR1 and 0·60 at TR2

Site and date	Unmarked lobsters	Marked lobsters	Jolly–Seber estimates (± 1 s.e.) Pop. size (*N*)	Pop. addition (*B*)	Prob. survival (ø)	Density (lobsters ha^{-1})
TR1						
3.xii.87	14	—	—	—	—	—
23.vi.88	17	3	22·24 (4·61)	12·07 (15·50)	0·30 (0·13)	207·8
21.vii.88	3	5	39·90 (16·19)	12·15 (13·30)	1·25 (0·40)	372·9
23.viii.88	5	6	44·57 (17·46)	–4·33 (5·67)	0·81 (0·36)	416·5
4.x.88	1	11	17·55 (4·03)	52·06 (39·24)	0·49 (0·16)	164·0
18.i.89	9	5	87·50 (53·90)	–4·11 (10·19)	2·02 (1·03)	818·8
7.ii.89	4	8	22·82 (9·01)	21·20 (17·84)	0·31 (0·18)	213·3
3.v.89	9	5	37·50 (26·92)	—	0·71 (0·53)	350·5
12.vii.89	5	4	—	—	—	—
Mean			38·87 (9·59)	14·84 (6·49)	0·84 (0·15)	363·2
TR2						
17.vi.87	12	—	—	—	—	—
16.vii.87	17	2	102·22 (107·89)	16·17 (23·29)	1·28 (0·13)	1093·3
10.ix.87	12	2	35·00 (23·76)	85·43 (129·83)	0·18 (0·40)	374·3
7.x.87	9	1	126·50 (142·38)	–19·07 (72·07)	0·17 (0·36)	1353·9
5.v.88	4	2	53·67 (57·17)	46·28 (64·97)	0·58 (0·16)	574·0
23.v.88	6	1	68·00 (71·65)	18·12 (36·82)	0·40 (1·03)	727·3
7.ii.89	11	3	51·43 (28·68)	–6·040 (11·94)	0·49 (0·18)	550·1
27.iv.89	5	11	16·00 (—)	—	0·43 (0·53)	171·1
12.vii.89	6	3	—	—	—	—
Mean			64·69 (—)	23·48 (14·59)	0·64 (0·18)	691·9

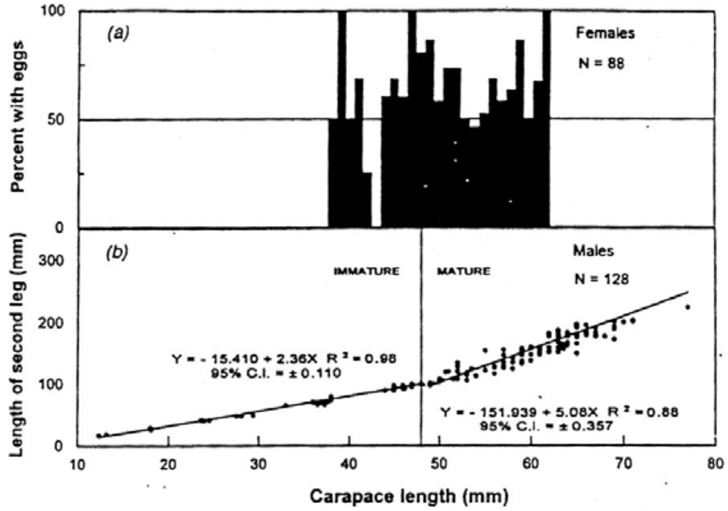

Fig. 5. *(a)* Percentage of mature (≥38 mm CL) *Panulirus guttatus* females carrying eggs, partitioned by 1-mm-CL size increments. *(b)* Separate Model II geometric-mean regressions of second-leg length on carapace length for *P. guttatus* males, subdivided at the transition point of approximately 48 mm CL.

throughout the year were partitioned by 1-mm size increments (38–63 mm CL), only in four size increments did fewer than 50% of the females carry eggs (Fig. 5*a*). The eight observations of 42-mm-CL lobsters were of four individuals, two of which were observed carrying eggs. The two 43-mm-CL lobsters and the one 63-mm-CL lobster were observed in September, November, and December; in two of those three observations, the female carried an eroded spermatophore, suggesting reproductive activity. Together, these observations indicate that virtually all females ≥38 mm CL are reproductively mature.

Population-wide functional maturity (Hunt and Lyons 1986) among males occurs at approximately 48 mm CL, as determined by the onset of allometric growth of the second walking legs (Fig. 5*b*). ANCOVA revealed that the slopes of the two regression lines were significantly different ($F = 116{\cdot}09$, d.f. = 124, $P < 0{\cdot}05$).

Evidence of reproductive activity was observed throughout the year (Fig. 6*a*). Between March and June, approximately 90% of mature females ≥38 mm CL showed evidence of reproductive activity. Lobsters bearing either eggs and ripe ovaries or egg remnants and ripe ovaries, both states being evidence of repetitive spawning without moulting, were frequently observed. Approximately 26% of mature females during March through June had ripe ovaries and were carrying either external eggs or egg remnants, indicating that spawning was imminent or that they had recently spawned. A few of these females also carried a fresh spermatophore deposited atop an eroded spermatophore. Although our observations of small mature females (≤45 mm CL) are limited (29 observations, 19 individuals), spawning among this size class was generally confined to March through June; no evidence of reproductive activity was observed among these lobsters from November through February (Fig. 6*b*).

Evidence of repetitive spawning was observed in only one of the smaller (≤45 mm CL) lobsters. The reproductive history of this female was followed for more than one year.

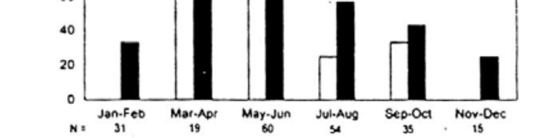

Fig. 6. *(a)* Percentage of mature (≥38 mm CL) *Panulirus guttatus* females observed with ripe ovaries, eggs, both eggs and ripe ovaries, or ripe ovaries and egg remnants, by two-month increments. *(b)* Percentage of small mature females (38–45 mm CL) and large mature females (>45 mm CL) that carried external eggs, by two-month increments.

When initially captured and tagged in December 1987, this lobster measured 38 mm CL and showed no evidence of reproductive activity. However, subsequent recaptures indicate that she spawned at least twice and possibly four times during the next year. When recaptured in June 1988, she measured 42 mm CL and had both external eggs and ripe ovaries. The lobster was recaptured once more in August and again in October 1988 but had neither eggs nor ripe ovaries on either occasion. Recaptured again in February 1989, she then measured 46 mm CL and possessed an eroded spermatophore. When recaptured for the last time in May 1989, she again carried external eggs.

Foraging

At night, all *P. guttatus* individuals were observed outside of dens, foraging on the tops and sides of spurs; all potential dens were searched to ensure that no lobsters remained inside. All lobsters observed on the tops and sides of spurs were adults; one juvenile (11 mm CL) was captured while it was walking on the ceiling of the underside of a large coral head. In contrast, the *P. argus* individuals that were encountered on spurs at night were primarily in dens.

Den dynamics and cohabitation with other lobsters

In all, 265 dens occupied by *P. guttatus* were identified during the course of the study. Of these dens, 222 were located at the FR, 40 were located at the PR, and three were located at the RF. These dens were searched a total of 6896 times, and one or more *P. guttatus* individuals were observed in them on 1576 (23%) occasions. The maximum number of *P. guttatus* individuals observed in a den was 7, and the average number of *P. guttatus* individuals found in occupied dens was 1·31 (s.e.: ± 0·02).

Coral heads at the reef flat did not serve as primary habitat for *P. guttatus*; accordingly, all RF observations are omitted from the following account. Of the 262 individual dens (FR and PR) that were occupied by *P. guttatus* at some time during the study, only 45 were occupied exclusively by *P. guttatus*; 214 of these dens were also occupied at some time by *P. argus*, and three were occupied at some time by scyllarid lobsters (Table 3). In addition, 499 dens were identified that were occupied exclusively by *P. argus*, seven that were occupied exclusively by scyllarids, and 20 that were shared by *P. argus* and scyllarids. Although 30% of the identified dens housed more than one species of lobster during the course of the study, there appeared to be little interaction between the species. The multispecies dens were found occupied on 3187 occasions, but only on 130 (4%) of those occasions were two taxa observed residing simultaneously within them. Moreover, *P. guttatus* and *P. argus* typically occupied different positions within the dens (Table 4); *P. argus* showed a strong affinity for the den floor, whereas *P. guttatus* was typically observed on the ceiling. This pattern was observed in dens that contained only conspecifics and in dens occupied simultaneously by both species. Similarly, on those few occasions when a scyllarid was observed residing with either *P. guttatus* or *P. argus*, the two taxa occupied positions opposite each other within the den.

Table 3. Den resource allocation and cohabitation among *Panulirus guttatus*, *P. argus*, and scyllarid lobsters (*Scyllarides nodifer*, *S. aequinoctialis*, and *Parribacus antarcticus*) at FR and PR sites
'Dens' represents the total of number of marked dens. 'Den observations' represents the total number of observations of dens by each taxonomic category. For the multi-group taxonomic categories, 'Alone' represents the number of times that either taxon was observed alone at different times in the same den and 'Simultaneously' represents the number of times that taxa were observed together in the same den at the same time

Taxa	Dens	Den observations	Number of times occupied: Alone	Simultaneously
P. argus	499	9846	1175	—
P. guttatus	45	766	111	—
Scyllarids	7	109	15	—
P. argus and *P. guttatus*	214	5941	2919	124
P. argus and scyllarids	20	552	122	5
P. guttatus and scyllarids	3	71	16	1
Overall	788	17285	4358	130

Table 4. Log-linear comparison of spatial patterns between *Panulirus guttatus* and *P. argus* within dens
Values represent the number of individuals observed occupying one of three positions in dens that contained only conspecifics or single lobsters ('Not shared') and dens that contained both species simultaneously ('Shared'). The three-way interaction (species × lobster position × shared *v.* not shared) was not significant ($G = 3{\cdot}78$, d.f. = 3, $P = 0{\cdot}287$).

Species	Not shared: Ceiling	Not shared: Floor	Not shared: Wall	Shared: Ceiling	Shared: Floor	Shared: Wall	G-test: shared *v.* not shared × lobster position
P. guttatus	1137	343	433	119	33	31	$G = 5{\cdot}929$, $P = 0{\cdot}0516$
P. argus	67	3568	118	5	284	4	
G-test: species × lobster position	$G = 4189{\cdot}516$, $P < 0{\cdot}0001$						

Discussion

Panulirus guttatus dwells solely on reefs and most often on the fore reef. No *P. guttatus* individuals were observed in the sand channels within the fore reef or at the reef-flat seagrass-bed blowout sites. *Panulirus guttatus* individuals were rarely observed in coral heads at the reef flat, even though these coral heads were adjacent to the reef crest and were connected to the fore reef by coral rubble. The average density of *P. guttatus* at one PR site equalled those at the FR, but this site was unique among the PR sites in that its relief and habitat complexity rivalled those of FR sites. No *P. guttatus* individuals were observed at any IR site. The present observations are similar to those of Sutcliffe (1953), Chitty and Waugh (1978), and Evans *et al.* (1995*a*), who reported that *P. guttatus* in Bermuda occurs principally in the shallow waters of outer reef margins and in lower numbers at lagoonal patch reefs. Chitty and Waugh (1978) further reported that *P. guttatus* rarely ventures from the reef. Their few night dives revealed that *P. guttatus* occurred almost exclusively on the reef; only two lobsters were observed on sand, and those were within approximately 0·6 m of the reef. Similarly, we observed no *P. guttatus* individuals on the sand at night; all lobsters were observed on the reef. Chitty and Waugh (1978) did note, however, that traps targeting *P. guttatus* at Bermuda are set not only on reefs but also in small sand patches within the reef, but they concluded that individuals captured in these traps were likely enticed from the reef habitat by bait in the traps. *Panulirus guttatus* is rarely captured in commercial lobster traps that are set for *P. argus* in the Florida Keys; such captures occur only when the traps are set directly on reef habitat (unpublished data, on-board vessel monitoring, Florida Marine Research Institute). Further, our FR and PR sites were typically surrounded by such traps, but no tagged *P. guttatus* individuals were returned. Clearly, *P. guttatus* is an obligate reef-dweller, rarely leaving the confines of the reef. Although we observed *P. guttatus* on patch reefs located approximately 2 km from the fore reef (Fig. 1), we conclude that these lobsters are effectively isolated from the main population on the fore reef.

The maximum range of any one *P. guttatus* individual is apparently the reef structure on which it settles. Although it is possible that *P. guttatus* individuals range over the entire length of the spur-and-groove habitat at Looe Key, we never observed a tagged *P. guttatus* individual on a site other than the one of its initial capture, and several lobsters were recaptured repeatedly for more than a year, always on the same spur. These observations, coupled with the fact that we observed all age classes, including pueruli and newly settled benthic juveniles, all using different structures and regions of a reef spur for shelter and foraging, cause us to conclude that an individual lobster spends its entire benthic life on a small portion of the fore reef, perhaps even on a single spur.

Panulirus guttatus adults forage on the reef at night. All adults observed on our night-time sites were in the open. Further, in 13 nights of sampling on the *P. argus* foraging grounds at the adjacent reef flat, only two *P. guttatus* individuals were observed (Cox *et al.* 1997). Only one *P. guttatus* juvenile was observed at night; this individual was foraging on the underside of a coral head that was a known shelter for *P. guttatus* adults.

The sex ratio of adults was strongly skewed toward females at night. We believe that the night-time sex ratio best approximates the true sex ratio of the *P. guttatus* population on the fore reef because *(i)* *P. guttatus* individuals were considerably easier to observe while they were foraging at night, *(ii)* we were successful at capturing most of those observed at night, and *(iii)* no adult lobsters were found to have lingered in dens at night. Skewed sex ratios have been reported in many other populations of adult palinurids (e.g. Chittleborough 1974; Cooper *et al.* 1975; Davis 1977; Pollock 1982; Hunt *et al.* 1991), but these have resulted from selective male or female movements (Kanciruk 1980). Yet, because *P. guttatus* is highly resident on reef spurs, it does not seem likely that the skewed sex ratio is due to selective movement (i.e. males or females moving to a different environment). The sex ratio of trap-caught *P. guttatus* has been reported to be heavily skewed towards males (Sutcliffe 1953; Evans and Lockwood 1994). Thus, we speculate that sex-specific differences in behaviour may result in differential mortality. Such sex-specific behaviour may be simply the result of higher natural activity rates among males, as has been reported for *Panulirus gracilis* and *P. inflatus* (Briones-Fourzán and Lozano-Alvarez 1992), or it may be the result of intraspecific competition related to reproduction (Hunt *et al.* 1991).

In contrast to the sex ratio of night-time captures, males and females were captured in approximately equal proportions during the day. Most of these captures were made at the entrances of dens that extended deep into the reef. Thus, it appears that adult males are more likely to occupy den entrances. We suspect that these males may be guarding den entrances to protect harems of females from other males. This behaviour has been observed in *P. argus* both in the laboratory (Lipcius and Herrnkind 1985) and in the field (Lipcius *et al.* 1983; Herrnkind and Lipcius 1989).

The smallest egg-bearing female we observed was 38 mm CL, slightly larger than the smallest egg-bearing female *P. guttatus* (36 mm CL) reported in each of two previous studies (Caillouet *et al.* 1971; Farrugio 1976). Chitty (1973) did not observe any egg-bearers smaller than 39 mm CL during his study but noted that egg-bearing females smaller than 36 mm CL had been previously observed at his study location by G. L. Beardsley. Finally, egg-bearing females as small as 32 mm CL have been found recently at patch reefs in Florida (D. Robertson, Old Dominion University, Norfolk, VA, personal communication). However, none of these studies reported an estimate of size at population-wide reproductive maturity (*sensu* Hunt and Lyons 1986). Evans *et al.* (1995*a*) estimated that the size at population-wide maturity for *P. guttatus* females at Bermuda ranged between 52·5 mm CL and 57·5 mm CL, based on sizes at which 50% of their lobsters possessed external eggs, egg remnants, or an eroded spermatophore. However, they concluded that their sample size was insufficient to accurately estimate size at maturity. Although our observations of mature females were limited, examination of all size classes ≥38 mm CL revealed that 50% or more of the females in nearly every size class carried eggs. We therefore conclude that population-wide maturity for *P. guttatus* females occurs at approximately 38 mm CL in southern Florida.

Panulirus guttatus males become functionally mature at a larger size than do females. This characteristic is common among palinurids; males apparently must be at least as large as their potential mates for copulation to be successful (Berry 1970; Lipcius *et al.* 1983). The size at maturity of 48 mm CL reported here for *P. guttatus* males is considerably smaller than the 69·3 mm CL reported by Evans *et al.* (1995*a*), who used similar criteria to obtain their estimate. However, inspection of their scatterplot of second-leg length against carapace length reveals that they examined no lobsters smaller than approximately 50 mm CL, and their plot shows no characteristic marked increase in leg length relative to carapace length similar to that observed here or in other palinurids (e.g. George and Morgan 1979; Grey 1979; Juinio 1987). We therefore conclude that their estimate, derived from trap-catch data, included exclusively mature individuals, causing them to overestimate size at functional maturity.

Panulirus guttatus spawns all year round throughout most of its range, and repetitive spawning without moulting is common. Egg-bearing females were observed at Looe Key throughout the year, with the peak in activity occurring from March through June. More than 80% of the mature (≥38 mm CL) females spawned during these months, and many of those lobsters had both ripe ovaries and either eggs or remnants of eggs, suggesting repetitive spawning. Similarly, egg-bearing *P. guttatus* females were observed on a man-made jetty at Miami all year round, except for a one-month interval during September and October, and the peak reproductive period was again from March through June (Chitty 1973). Repetitive spawning without moulting, evidenced by lobsters with both ripe ovaries and external eggs or egg remnants, was also noted there. Egg-bearing *P. guttatus* females were observed in Martinique in all months except September during a study conducted between January and October (Marfin 1978). In contrast, Evans and Lockwood (1994) reported that reproduction of *P. guttatus* in Bermuda is distinctly seasonal; they observed no egg-bearing lobsters during winter or spring. This truncated reproductive season probably reflects environmental influences, primarily cooler temperatures and a shorter photoperiod (Kanciruk 1980). Similar variations in the reproductive season have been reported for *P. argus*. Munro (1974) and Aiken (1977) found that *P. argus* spawns all year round in Jamaica, whereas observations in more northern portions of its range, including Florida, suggest more seasonal reproductive activity (Lyons *et al.* 1981 and references therein).

Reproductive activity among smaller mature females (≤45 mm CL) at Looe Key was confined largely to the peak reproductive period (March–June), and no reproductive activity among smaller females was evident from November through February. These smaller females apparently produce only a single brood per season; we observed only one female <45 mm CL that possessed both ripe ovaries and eggs. Similar findings have been reported for *P. argus* (Smith 1948; Lipcius 1985) and *P. gracilis* (Briones-Fourzán and Lozano-Alvarez 1992). Lipcius (1985) developed a general model for size-dependent reproduction in long-lived decapods wherein smaller, newly mature individuals spawn only once during the reproductive season whereas larger females spawn several times. Such size-dependent moulting and reproduction likely enhances reproductive success because larger females are more fecund. *Panulirus guttatus*, like other species (Smith 1948; Briones-Fourzán and Lozano-Alvarez 1992), shows size-dependent reproduction consistent with this aspect of the model. However, the model also indicates that smaller females moult early and spawn later in the reproductive season. Moulting and spawning in *P. argus* are consistent with this aspect of the model (Smith 1948). In contrast, small *P. guttatus* individuals spawn early during the peak reproductive period and probably moult soon thereafter.

Standard density values (i.e. values calculated directly from the number of lobsters observed) and those from the Jolly–Seber model yielded widely disparate estimates. Average overall density on the FR, estimated from daytime sampling, was 62 lobsters ha^{-1}. When adjusted for the population-wide adult sex ratio (i.e. night-time sex ratio), that estimate increased to 90 lobsters ha^{-1}. Standard estimates of density at sites sampled at night (TR1 and TR2) were 118 and 115 lobsters ha^{-1}, respectively, whereas Jolly–Seber estimates at those sites were 363 and 692 lobsters ha^{-1}, respectively. Given the difficulty in finding *P. guttatus* during the day and the uncertainty regarding our ability to sample night-time sites to exclusion, we conclude that standard density underestimates the abundance of *P. guttatus* at the Looe Key fore reef. In contrast, densities derived from the Jolly–Seber model are probably overestimates. A basic assumption of any tag–recapture study is that the mark used to identify an individual is permanent. Tag loss will result in overestimates, and tag loss did occur. Yet, we feel that our estimate of density at TR1 closely approximates the actual abundance of *P. guttatus* because TR1 was more isolated from other spurs than was TR2, thus leading to less immigration of lobsters at TR1. Consequently, we estimate that the density of *P. guttatus* on the Looe Key fore reef is between 118 and 363 lobsters ha^{-1}. This density range represents only the adult population; juveniles were rarely observed during the study, and the few that were observed were not tagged. Thus, the overall abundance of the *P. guttatus* population is undoubtedly higher.

These density estimates are the first for *P. guttatus* derived directly from observations by divers. The only previous attempt to estimate abundance of *P. guttatus* was reported by Evans and Lockwood (1994) at Bermuda. Using data obtained from traps placed adjacent to the reef crest during summer and autumn, they estimated the mean density of *P. guttatus* to be 29 lobsters ha^{-1}. Although traps can provide a good relative index of abundance (Miller 1989), other factors independent of population density can affect catch rates in traps (Kanciruk and Herrnkind 1976; Heatwole *et al.* 1988). Consequently, traps seldom provide accurate estimates of density.

Estimates of density among other palinurids with life histories similar to that of *P. guttatus* are rare. Ebert and Ford (1986) estimated the density of *Panulirus penicillatus*, another reef-dweller, at Enewetak atoll. They reported that two two-person teams collected between 2 and 4 lobsters per man-hour. Although our density estimates are not directly comparable, our sampling protocol was similar to theirs in that our night-time sites were also sampled by two two-person teams for 1-h periods. If our catch rate is then calculated on a per-man-hour basis, the relative density of *P. guttatus* ranges between 4 and 10 lobsters per man-hour.

Although *P. guttatus* and *P. argus* are abundant on the fore reef at Looe Key, direct competition for shelter and food appears minimal. There is considerable overlap in den usage on the fore reef, but interactions related to den resources are limited. The two species were only rarely observed residing simultaneously within dens. When that did occur, they usually occupied positions opposite each other within the den. The two species also use different areas of the reef complex to forage: *P. guttatus* forages exclusively on reef spurs, whereas *P. argus* uses the fore reef primarily as shelter and forages on the adjacent reef flat (Cox *et al.* 1997).

The sheltering requirements of *P. guttatus* appear to be more specific than those of *P. argus*. *Panulirus argus* was observed in 733 dens on the fore reef and patch reefs, of which only 214 were also used by *P. guttatus*. In contrast, *P. guttatus* had few dens that were not also used by *P. argus*. *Panulirus argus* was observed in dens ranging from small holes that concealed only the abdomen to large caverns and the undersides of coral heads that contained multiple entrances, whereas *P. guttatus* was typically observed in large, dark caverns and the undersides of coral heads that permitted individuals to fully retreat into the reef. Apparently, the characteristics of potential shelters attractive to *P. argus* overlap extensively with shelter traits required for *P. guttatus*.

The life history of *P. guttatus* differs markedly from that of *P. argus*. *Panulirus argus* is highly migratory. At various stages in its life cycle, it temporarily exploits a wide range of environments that are widely separated in space (Herrnkind 1980; Kanciruk 1980; Childress and Herrnkind 1994; Butler and Herrnkind 1997). At Looe Key, *P. argus* uses different environments as shelter and foraging grounds: it shelters on the fore reef and forages on the reef flat (Cox *et al.* 1997). In contrast, *P. guttatus* is an obligate reef-dweller. At Looe Key, *P. guttatus* is confined primarily to the shallow fore reef; the pueruli settle directly on the underside of the reef and, once there, spend the remainder of their lives on a small portion of the reef. Additionally, the sheltering requirements of *P. guttatus* appear to be much more specific than those of *P. argus*. This restriction of acceptable shelter characteristics for *P. guttatus* may be the primary factor controlling the abundance of this obligate reef-dweller.

Acknowledgments

We thank the following people for their invaluable assistance in the field: Barbara Blonder, Mark Butler IV, David Forcucci, William Herrnkind, Lauri MacLaughlin, Clarita Lund, Dan Marelli, Tom Matthews, Lonny Anderson, Dennis Gauld, Billy Causey, Ken Hartsing, Bill Green, Cynthia Sandusky, Brenda Hedin, Doug Heatwole, and Carolyn Schultz. We also thank Rodney Bertelsen for his assistance with the figures and Julie Overing for translating foreign-language literature. We thank Mark Butler IV and two anonymous reviewers for their comments. Part of this work was conducted under Contract No. 50-DGNC-6-00093 from the US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Sanctuary Program.

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