Stock Assessment of Spiny Lobster, *Panulirus argus*, in the U.S. Caribbean

Final stock assessment and fishery evaluation (SAFE) report
for the workshop on spiny lobster resources in the U.S. Caribbean
San Juan, Puerto Rico, September 11-13, 1990

James Bohnsack
Southeast Fisheries Center
National Marine Fisheries Service
75 Virginia Beach Dr.
Miami, FL 33149

Stephen Meyers
Caribbean Fishery Management Council
Suite 1108 Banco de Ponce Building
Hato Rey, PR 00918

Richard Appeldoorn
Department of Marine Sciences
University of Puerto Rico
Mayagüez, Puerto Rico 00708

Jim Beets
Division of Fish and Wildlife
Department of Conservation and Cultural Affairs
101 Estate Nazareth
St. Thomas, VI 00802

Daniel Matos and Yvonne Sadovy
Fisheries Research Laboratory
Puerto Rico Department of Natural Resources
P.O. Box 3665, Marina Station
Mayagüez, Puerto Rico 00708

Miami Laboratory
Southeast Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce
75 Virginia Beach Dr.
Miami, Florida 33149

Miami Laboratory Contribution No. MIA-90/91-49

April, 1991

INTRODUCTION

The Caribbean Fishery Management Council's (CFMC) Fishery Management Plan (FMP) for spiny lobster in the U.S. Caribbean was implemented on January 1, 1985. It identified a number of activities that require the attention of the National Marine Fisheries Service (NMFS) and the Caribbean Fishery Management Council (CFMC), in cooperation with the Commonwealth of Puerto Rico, and the Territory of the U.S. Virgin Islands through their pertinent agencies: Department of Natural Resources (DNR) and the Fisheries Research Laboratory in Puerto Rico, and the Department of Planning And Natural Resources in the U.S. Virgin Islands. A central management measure for this FMP is a 3.5 inch (89 mm) carapace length as the minimum legal size limit. A spiny lobster stock assessment workshop was conducted at the CFMC offices in San Juan, Puerto Rico on September 11-13, 1990 to meet FMP requirements for continual monitoring and subsequent action as data becomes available. This report is the resulting Stock Assessment And Fishery Evaluation (SAFE) Report for the spiny lobster resource in the U.S. Caribbean.

METHODS

In preparation for the assessment, data sheets from approximately 950 trip interviews from St. Thomas, St John, and Puerto Rico from 1985 through 1989 were assembled by the CFMC staff and submitted to Miami Laboratory NMFS for data entry in the Trip Interview Program (TIP) format. Additional data sheets for three

years of sampling from 1987 through 1989 for St. Croix were entered by CFMC staff. Data sets, representing over 25,000 measured lobster, were combined for length-frequency analysis using SAS[1] software at the workshop. Participants examined data and conducted analyses where appropriate. The assessment team chose to use Puerto Rico, St. Croix, and the combined St. John and St. Thomas areas as appropriate units for analysis. St. Croix was separated from the other Virgin Islands because it is located on a separate geological platform.

RESULTS AND DISCUSSION

Data Collection, Entry, and Management

Available Data

Several problems were noted in data collection procedures, or in data base management, which limited the types of analyses that were possible. These problems are detailed to improve future efforts and to give other researchers examples of situations to avoid:

1. Sampling units and gear types were not recorded on many data sheets so confusion existed as to whether measurements were kilos or pounds, centimeters or inches, carapace length or total length, lobster traps or fish traps, SCUBA, etc.

---

[1] SAS is a registered trademark of the SAS Institute, Inc., Box 8000, Cary, North Carolina 27511-8000. The National Marine Fisheries Service and other organizations listed in this report do not endorse any particular commercial product.

2. Zero catches (i.e. trips that targeted lobster but with zero landings) were not recorded in the trip interview samples for Puerto Rico.

3. Numerous coding problems existed in the data base because data sheets and codes were not standardized between islands or between time periods within islands. Some area codes were either erroneous or were not documented. The uncertainty as to how to interpret the data sheets created confusion for data entry personnel in Miami, who were not familiar with the peculiarities of the data collection program, such as sampling methodologies, exact landing locations, species codes, etc.

4. Completely and partially sampled trips were not distinguished on data sheets for Puerto Rico, which made calculating catch-per-unit-effort impossible.

5. In some cases units were recorded to several decimal places implying false precision. Apparently some measurements were collected in pounds but converted by calculator to kilograms before entry on a data sheet.

6. Virgin Island carapace measurements were recorded to the nearest tenth of an inch while in Puerto Rico measurements were to the nearest mm.

Recommendations

As part of a solution to addressing these problems, the workshop recommends standardization of data collection and data base management. Some problems in the analysis of these data were caused by lack of standardization as to how data were collected or recorded. For example, the sample sizes and coverage of length-frequency samples from the Virgin Islands were of limited use because the measurement units (0.1 in) were too large. We recommend using 1 mm increments. Frequently in Puerto Rico, only weights were recorded which were less useful than if combined with length measurements. We recommend preference be given to length measurements with subsamples being weighed where possible, however, weights without lengths are preferable to no data.

Where possible, data entry should be done by the data collecting agency to avoid misinterpretation. Many of the problems encountered in interpreting data sheets could have been solved by having the organizations or individuals that collected information enter data, preferably as soon as possible after collecting information. Although all data now being collected in Puerto Rico are now being entered very soon after it is collected, much of the data used in this workshop were entered into a computer several years after collection. Most entry errors could be corrected by inspection of print-outs of records immediately after data entry. Many errors could be corrected by error checking programs that identify unusual or out-lying values.

A standardized storage format should allow basic data analysis for local governmental use as well as for more complex analysis. The recently renovated microcomputer TIP program, TIP Data Entry System Version 3.0, developed by the Southeast Fisheries Center is one possible standardization solution. This system must be successfully tested in the field and allow easy data retrieval for local uses. A Spanish language version for Puerto Rico may be helpful.

Fishery Trends

Total Landings

Total spiny lobster landings data were assembled for Puerto Rico and the Virgin Islands (Table 1). In Puerto Rico total annual landings averaged 317,451 lbs for 23 years of available data, but have fluctuated over time (Fig. 1). Total reported annual landings increased from 1972 to a high of 512,000 lbs in 1979, and declined from 1979 to a low of 143,761 lbs in 1988. Thus, 1988 and 1989 total landings were, respectively, only 28% and 36% of the maximum reported landings in 1979. Despite uncertainty about the accuracy of calculated values for some years (see Matos and Sadovy, 1990a), the review team concluded that the data probably reflected general landings trends.

Total landings averaged 36,534 lbs for St. Thomas and St. John and 7,284 for St. Croix between 1980 and 1988 (Fig. 2). Landings in the Virgin Islands appeared relatively stable during the time that landings data were available between 1980 and 1988. Total

annual landings were higher from St. Thomas/St. John than from St. Croix presumably because the island platform around St. Croix is much smaller and supports a smaller resident lobster population and fewer fishermen.

In Puerto Rico, divers have accounted for a greater proportion of lobster landings in recent years. Divers reportedly accounted for 47,000 lbs (13% of total trap landings) in 1977 and 48,000 lbs (12%) in 1978 (hand and speared lobster; Weiler and Suarez-Caabro, 1980). A decade later divers accounted for more lobster and a greater percentage relative to total trap landings: 65,222 lbs (83% of trap landings) in 1988 and 53,232 lbs (42%) in 1989 according to landings reported under "skin and SCUBA divers" in Matos and Sadovy (1990a, Tables 6 and 7). Note, however, that Hurricane Hugo may have affected 1989 landings and effort. More information is needed about divers, particularly where they fish and the size-frequency of their landings.

Total reported average annual landings from Puerto Rico and the Virgin Islands (Table 1) were 361,270 lbs or approximately half (44%) of the maximum sustained yield (MSY) estimated in the FMP (830,000 lbs per year). The reasons for the difference are unknown but are most likely due to any, or all, of the following: overly optimistic MSY projections in the FMP, incomplete reporting of actual landings, and loss of yield due to landings of undersized lobster. As discussed later, the last factor is very likely to be important although its exact impact could not be quantified.

Size-Frequency

Historical size-frequency data, where available, are shown for Puerto Rico (Table 2), St. Thomas/St. John (Table 3), and St. Croix (Table 4). Mean carapace length has remained fairly constant above 4 inches in the Virgin Islands but has declined in Puerto Rico from 4.4 inches in 1951 to 3.5 inches in 1989.

Length-frequency data based on carapace lengths of sampled lobster were examined by sex classification for St. Croix, St. Thomas/St. John, and Puerto Rico (Table 5). Sex classifications were male, female without tar spots (spermatophores) or eggs, females with tar spots, and females with eggs. A few lobster, labeled in the data set as unidentified females, were not included in a specific sex classification, but were retained in the total length-frequency distribution. Because taking females with eggs is illegal, this category should be under represented which will bias the results in term of the number of females. For comparative purposes these data were expressed in percent (Table 6) and cumulative percentages (Table 7). Puerto Rico lobster carapace lengths showed an approximately normal distribution around the minimum legal size of 3.5 in (89 mm) while both Virgin Islands locations showed a distinct absence of lobster below the minimum legal size (Tables 6 and 7).

Differences between coasts of Puerto Rico were examined using 1985 data for the south, west, and combined north and east coasts (Fig. 3). The latter were combined because of few existing data. Length-frequency patterns were generally consistent between coasts

although there was a trend for the largest lobster to come from the combined north and east coasts. The most likely explanation for these larger lobster is that some were probably caught further east closer to the Virgin Islands which tends to have larger lobster as discussed previously.

Size-frequency data were compared to those of a heavily fished spiny lobster fishery in Florida and unfished areas in the Dry Tortugas (Fig. 4) using data provided by Gregory et al., (1982) and Davis (1975). Lobster from all areas of the Virgin Islands and Puerto Rico tended to be larger than those observed from Florida. Lobster from St. Croix and Puerto Rico tended to be smaller than those from the unfished Dry Tortugas. St. Thomas/St. John had a higher frequency of large lobster than Puerto Rico.

Size-frequency distributions were examined as a function of distance from shore in Puerto Rico in order to test the hypothesis that smaller lobster tended to be found closer to shore in shallow water, as in Florida. Data on depth of capture were not available at the workshop. Distances examined were 0 - 3 nautical miles (n = 113 interviews), 3 - 6 nm (n = 87), and greater than 6 nm (n = 294). No apparent differences is size-frequencies were noted with distance from shore (Figure 5). However, distance from shore did not necessarily reflect depth because the narrow shelf along the north and south coasts of Puerto Rico provides deep water close to shore and the presence of offshore islands, especially to the east and west, provides shallow "nearshore" water far from fishing ports.

Minimum Size Compliance

Compliance with minimum size limits was much more likely in the Virgin Islands than in Puerto Rico based on size-frequency of landings. In the St. Croix data showed that undersized lobster represented 1.3% of the total lobster landed from 1987 through 1989. In St. Thomas and St. John, only 2.9% of the landed lobster were undersized between 1985 through 1989. In Puerto Rico, undersized lobster represented 40% of the total lobster landed between 1985 through 1989. There was no evidence of differences in local size preferences, or differences in fishing gears, methods, or depths to account for the observed absence of undersized spiny lobster in the Virgin Islands. The review team interpreted the absence of smaller lobster in Virgin Island catches as an indication of compliance with minimum legal size limits.

Growth overfishing thus appears to be a major problem in Puerto Rico, based on the large number of undersized lobster being landed and the recent declines in total landings. A yield-per-recruit analysis would help quantify this situation, however, the review team, after considerable effort, was unable to generate an acceptable model because of a lack of growth data specifically tuned to Puerto Rico and the Virgin Islands (discussed later). Lyons and Kennedy (1980) found that harvesting of large numbers of small lobster resulted in 68-83% loss to the fishery in Florida.

A model in the Lobster FMP (CFMC, pg 38) predicted effects of minimum size regulations on total landings. The model was calibrated to begin in 1980 and predictions were consistent with

actually observed patterns assuming that 3.5" minimum carapace size regulations were observed in the Virgin Islands and that status quo (no size limits) were being observed in Puerto Rico. Note, that a 3.5" carapace length was in effect within the Virgin Islands during this time before the Federal FMP went into effect in 1985. Declining total landings were predicted under the status quo (no size limits) which appears to be the situation in Puerto Rico (Fig. 6a), although total landings declined at a somewhat faster rate than predicted. Total landings were expected to remain relatively stable and perhaps increase somewhat with a 3.5 in minimum carapace size regulation which is consistent with what was observed in the combined Virgin Islands' landings (Fig. 6b).

Catch-Per-Unit-Effort (CPUE)

A general consensus existed at the workshop that fishing effort has probably increased slowly in Puerto Rico and the Virgin islands over recent years. Although some data are available on the total number of fishermen (Table 1), effort data specifically targeting lobster were generally unavailable except for some data for St. Croix. One problem is that lobster are caught by a variety of techniques including fish traps (pots), lobster traps (pots), and divers among others (Matos and Sadovy, 1990a). In Puerto Rico, reported CPUE of lobsters landed (lbs/trap/yr) by fish traps, 34.3 (1977) and 29.2 (1978), was greater than that for lobster traps, 24.1 (1977) and 15.1 (1978) (calculated from figures in Weiler, Suarez-Caabro, 1980). The percentage of total lobster landed by

lobster traps relative to fish traps was small: 12% in 1977 and 9% in 1978 (Weiler, Suarez-Caabro, 1980), and 24% in 1988 and 14% in 1989 (Matos and Sadovy, 1990a).

Although a considerable amount of catch and effort data on a trip basis existed for Puerto Rico on the NMFS B6800 system in Miami, it was not considered useful for catch by trip analysis because there was no way to distinguish between completely and partially sampled trips. Although lobster are routinely caught by lobster and fish traps, it was not possible to distinguish from the data which trap type caught the lobster.

Analysis of catch-per-unit-effort (CPUE) for St. Croix from 1987 through 1989 based on monthly estimates of kilograms per trip and kilograms per pot (Fig. 7) show higher CPUE's in the winter and spring than in the summer and fall. Although Figure 7 also suggest that CPUE's may have declined over the 36 month sample period, not much confidence should be placed on a declining trend because data from only three months were available for 1987, these data came from winter months which tend to be high, and they are at one end of the regression series which gives them undue weight. Although the decline in kg/trip for 1988 and 1989 in Figure 7 seems to be clear, more data over a longer period are necessary to define trends in CPUE with greater confidence.

Recommendations

The assessment team concluded that the most obvious management action required to increase the productivity of the spiny lobster

fishery would be to enforce or increase compliance with minimum size restrictions in Puerto Rico. Spiny lobster growth studies are needed for Puerto Rico and the Virgin Islands to produce yield-per-recruit models. Studies should be directed at describing the expanding diver-based spiny lobster fishery, particularly in Puerto Rico. Better data are needed on effort directed at spiny lobster and comparisons should be made of catch rates of spiny lobster in fish traps versus lobster traps. These two trap types will very likely have quite different catch efficiencies. Additional raw data from St. Croix on length-frequencies and catch-per-unit-effort should be entered into the data base.

Biological Parameters

Growth

Determining growth is complex but essential for properly managing the fishery (Hunt and Lyons, 1986). The assessment team concluded that insufficient data existed to properly characterize spiny lobster growth for Puerto Rico and the Virgin Islands region. It was agreed that growth parameters used in the spiny lobster FMP were probably unreliable having been based on early studies from the Virgin Islands in which Olsen et al. (1975) had reported a growth coefficient (K) of 0.43 for males and 0.32 for females. Munro (1983) estimated K as 0.21 when L_∞ = 190 mm CL for Jamaica. Estimates of spiny lobster growth coefficients range from 0.10 per year to 0.44 per year (Gulf of Mexico Fishery Management Council, 1982). Davis and Dodrill (1979) reported mean annual growth rates

of 21.3 and 40.0 mm CL in Biscayne Bay and Florida Bay, respectively. Florida growth parameters, although well documented, were not considered appropriate because growth rates were likely to differ greatly due to different prevailing temperatures and stock conditions.

Considerable time was spent at the workshop attempting to estimate growth parameters for spiny lobster using the ELEFAN program (Pauly, 1985). The best available monthly length-frequency data to estimate growth were from St. Croix. Attempts to estimate growth parameters failed however for several reasons. First, carapace measurements were to the nearest one tenth inch which was too wide an interval to show distinct size-frequency peaks. Second, data were limited. Third, data were not available from individuals below the minimum size limit. Also, some assumptions of the ELEFAN program were violated because lobster grow in increments and lobster recruit throughout the year. CODREMAR had some growth data from very small tagged lobster but at too young an age to be useful.

After the workshop, a new study was found that examined spiny lobster growth in Jamaica. Haughton and Shaul (1989) gave a "first approximation" of spiny lobster growth for Jamaica at K = 0.48 per year and L_∞ = 193 mm CL for males and K = 0.48 per year and L_∞ = 193 mm CL for females. These estimates were considered inadequate to use for Puerto Rico and the Virgin Islands because of lack of precision in the estimates and possible differences in stocks between areas (Haughton and Shaul, 1989), as well as concerns about

the inappropriate application of the ELEFAN I program to lobster as discussed above. Without reliable growth parameters, yield-per-recruit models could not be generated.

Mortality

It was not possible to estimate natural mortality from available data. Annual mortality was assumed to be 34% (equivalent to M = 0.42/yr) in accordance with published literature from other locations (Waugh, 1981, Lyons and Hunt, 1987, Powers and Sutherland, 1989).

Fecundity

Potential annual egg production was examined for Puerto Rico (Fig. 8), St. Croix (Fig. 9), and St. Thomas/St. John (Fig. 10) based on female size. Potential egg production assumes that each female reproduces only once and all females breed. These assumptions are unrealistic because not all females necessarily breed, especially smaller individuals (Lyons, et al. 1981) and some size classes may breed more than once per year. Potential egg production as illustrated probably overestimates relative egg contributions of smaller size classes while underestimating contributions of larger size classes. Nevertheless these figures emphasize the importance of larger size classes to total egg production.

The Spawning Potential Ratio (SPR), the ratio of eggs produced between a fished and unfished population, was calculated from

fishery dependent data according to methods used by Gregory, et al. (1982, his Tables 4 and 5) with available data from the most recent year for Puerto Rico (Table 8), St. Croix (Table 9) and St. Thomas (Table 10). Spawning potential was based on total mean fecundity, defined as the total number of eggs potentially produced divided by the total number of females (see Table 5 in Gregory, et al., 1982). Number of eggs per female was calculated according to the formula:

$$\text{Number of eggs} = 4.8(0.98 + 0.2598\ \text{CL})^{3.53},$$

where CL is carapace length in mm. Breeding females were considered females with spermatophores (tar spots) or eggs. The estimated total numbers of breeding females may be low because of legal prohibitions against landing egg bearing females (berried females). Attempts to calculate an Index of Reproductive Potential (Lyons, et al., 1981, their Fig. 13) failed because the results could not be calibrated with earlier studies; the 76-85 mm size class, used to calibrate curves, did not exist in Virgin Islands data.

Spawning potential, based on mean total fecundity, was compared to an unfished population in the Dry Tortugas and a heavily fished Florida population. For comparative purposes, 10 mm carapace length categories were used in calculations. However, calculations based on the midpoint of the carapace length provide some bias because the number of eggs increases exponentially with

size. Therefore, calculations were also reported using 5 mm size categories and 1 mm size categories (see Tables 8 - 10).

Spawning potentials of 55.9% were calculated for Puerto Rico in comparison to an unfished population in the Dry Tortugas using 10 mm carapace length categories (see Gregory, et al., 1982). This spawning potential is much higher than the 18.2% calculated for the Florida Keys for 1976 (Table 5 in Gregory, et al., 1982) or the 6% estimated for 1988 (GMFMC, Lobster Plan, Draft Amendment 3).

Calculated spawning potentials for the Virgin Islands exceeded the unfished Dry Tortugas population: 142% for St. Croix and 197% for St. Thomas. Although fundamental biological differences may exist between spiny lobster populations in the Virgin Islands and the Dry Tortugas, most of the difference can be explained as an artifact of the methods and calculations. The Dry Tortugas estimate was based on actual catch from fishery independent sampling while the Virgin Islands estimates were based on commercial landings (fishery dependent) in which undersized individuals were excluded. Thus, very few females under 3.5" carapace length were included in Virgin Islands data which inflates mean total fecundity estimates because of the absence of numerous small, less fecund individuals in the calculations. Lyons et al. (1981) attempted to overcome this problem by standardizing data using a 76-85 mm carapace length as a basis for comparison. Unfortunately, this size category is missing from Virgin Islands landings. A fishery independent sampling program would be necessary to better sample smaller size classes.

Sex Ratios

Sex ratios (Males: Females) from available data since 1987 averaged 1.0 for Puerto Rico (Table 2), 1.6 for St. Thomas (Table 3), and 1.2 for St. Croix (Table 4). Sex ratios were skewed toward males in the Virgin Islands most likely because of larger lobster in the landings (since males tend to grow larger than females) and also because females with eggs were not landed which biases the ratio.

CONCLUSIONS

Status of Stocks

The spiny lobster fishery in the Virgin Islands appears healthy at present levels of fishing effort and under currently used fishing practices based on available data. Landings have remained consistent and the spawning potential appears high.

The spiny lobster assessment workshop panel viewed with particular alarm the nine-year decline in total landings and the large number of undersized lobster being landed in Puerto Rico. Growth overfishing[2] appears to be a significant problem in Puerto Rico based on these facts. Recruitment overfishing[3] does not appear to be a problem under present levels of fishing effort based on calculated levels of spawning potential. The most reasonable

[2] Growth overfishing occurs when fishes are caught too small, before they have had a chance to grow.

[3] Recruitment overfishing is a more serious problem that occurs when fishing reduces adult stocks such that lower egg production increases the chance of stock collapse through recruitment failure.

explanation for these observations is that shallow water areas are being heavily exploited and overfished while deeper waters are less effectively exploited and maintain a reasonable number of large spawning individuals, some of which enter the landings (NOTE, the fact that no difference is size-frequency distributions were found with distance from shore does not refute this hypothesis). Thus, spawning potential appears high even though total landings are down. This scenario should be interpreted as a need to reduce fishing mortality on smaller lobster and not as an excuse to increase fishing effort on larger lobster in deeper water. Also, changes in the fishery should be monitored in case the increased exploitation by divers noted in Puerto Rico increases access to deeper water.

The assessment team concluded that most obvious management action to increase the productivity of the spiny lobster fishery would be to increase compliance with minimum size restrictions in Puerto Rico. Compliance appeared acceptable in the Virgin Islands.

The workshop did not deal with other potential issues including slot-size regulations, mortality caused by using undersized lobster used as bait in traps, degradable escape panels, or trap escape gaps which have been treated elsewhere (e.g. Lyons and Hunt, 1987; Powers and Sutherland, 1989). Although the original FMP discussed differences in landings between territorial and Exclusive Economic Zone (EEZ) waters, these could not be examined at the workshop because data that distinguished catch by location within or outside of the EEZ were unavailable.

Data Collection, Entry, and Management

Results of this workshop emphasize the continued need for standardized data collection, entry, and storage. Some analyses were hampered or were impossible because data were unavailable or stored in different formats. Collection of effort data are especially needed for better analyses.

Definition of Overfishing

The assessment panel was asked to comment on a definition of overfishing. Compared to Florida, the Virgin Islands and Puerto Rico show good representation of larger individuals which was interpreted to indicate that lower fishing effort exists in both areas compared to the Florida spiny lobster fishery. The calculated spawning potential ratios were well above the 20% minimum level recommended for a definition of overfishing by the Science and Statistical Committee. The 20% minimum SPR was recommended based on theoretical grounds (i.e. Goodyear 1989) and not on empirically derived stock-recruitment relationships which are unavailable for lobster. The lobster assessment workshop endorses the 20% SPR definition of overfishing as a conservative measure. The 6% SPR recently proposed for Florida by the Gulf of Mexico Fishery Management Council Lobster Plan was based on a relatively long time period of empirical landings observations which are unavailable for the Caribbean region. The workshop participants considered it irresponsible to assume that the

Caribbean region will respond to fishing pressure in the same way as southern Florida.

A definition of overfishing based solely on spawning potential appears to be inadequate, particularly considering the fact that total landings in Puerto Rico have declined for 9 years and are only 28 to 36% of peak values. One alternative is to include in the definition of overfishing a defined level of spawning potential and total landings. Ideally, the amount of total landings should be a percentage of some long-term average. It is easier to define a level when landings have remained relatively stable such as in the Virgin Islands or in southern Florida (Powers and Sutherland, 1989). In Puerto Rico, however, no period of stable landings exist to use as a baseline. A possible definition submitted for Council consideration is:

> "A spiny lobster stock is considered overfished when any of the following are observed: the spawning potential ratio is less that 20%, when total landings have declined to a level below 75% of the 5-year running mean, or when total landings have declined for three consecutive years."

With this definition, the Puerto Rico fishery became overfished in 1983 when landings dropped below 318,000 lbs and remained overfished until 1989 when landings increased from 143,761 to 186,423 lbs (Figure 11). Unfortunately, the 1989 levels are still well below those in previous years (Table 1) although technically they are not overfished by this definition. One way to deal with this problem would be to include a definition stating that:

> "When overfished a stock will continue to be considered overfished until the SPR is above 20% and total landings are above the level at which the fishery first became overfished" (i.e. 380,000 lbs).

Obviously other levels of landings could be considered. Also, with additional information, other definitions of overfishing could be developed (R. Appeldoorn, pers. comm.) which are beyond the scope of this report but which could be considered in future workshops. The above definition assumes that the observed rise and fall of landings in Puerto Rico are primarily due to changes in fishing effort. It is possible, however, that long-term cycles of recruitment success exist due to physical processes. If this were the case, then the overfishing definition could be triggered due to natural variation in recruitment success. At present there is an insufficient time series of data to demonstrate that such long-term cycles exist. Also, stable landings trends in the Virgin Islands and Florida do not support the existence of long term recruitment trends that could explain the rise and fall of landings in Puerto Rico.

SUMMARY OF MAJOR RECOMMENDATIONS

1. Data collection, entry, and storage should be standardized as much as possible.
2. Where possible, data entry should be done by data collecting entities to avoid misinterpretation.
3. Raw data from St. Croix on length-frequencies and catch-per-unit-effort should be entered in the data base.
4. Compliance with minimum sizes and other regulations should be increased, particularly in the Puerto Rico fishery. This may require improved enforcement measures to be implemented.
5. Growth and mortality studies are needed for Puerto Rico and the Virgin Islands to produce yield-per-recruit models.
6. The diver-based spiny lobster fishery in Puerto Rico should be studied in terms of total effort, areas fished, and size composition of landings.
7. Better fishing effort data are needed.
8. Comparisons should be made of catch rates of spiny lobster in fish traps versus lobster traps.
9. Fishery independent sampling of lobster size-frequency distributions are needed to better estimate spawning potential.
10. A modified definition of overfishing is recommended that considers total landings as well as spawning potential.
11. More information is needed on frequency of female spawning by size class.

ACKNOWLEDGEMENTS

We thank John Hunt (Florida DNR, Marathon, FL) and Nancy Thompson (NMFS, Miami Laboratory) for critical comments on the draft report. Ausbon Brown Jr. coordinated data entry. Doug Harper and David McClellan (NMFS, SEFC, Miami) assisted with analyses.

LITERATURE CITED

CFMC. 1981. Environmental impact statement, fishery management plan and regulatory impact review for the spiny lobster fishery of Puerto Rico and the U.S. Virgin Islands. Caribbean Fishery Management Council. 66 p.

CFMC. 1982. Report on the spiny lobster size frequency survey 1980-81. Caribbean Fishery Management Council. 22 p.

Davis, G.E. 1975. Minimum size of mature spiny lobster, _Panulirus argus_ at Dry Tortugas, Florida. Trans. Am. Fish. Soc. 104: 675-676.

Davis, G.E. and J.W. Dodrill. 1980. Marine parks and sanctuaries for spiny lobster fisheries management. Proc. 32nd Gulf and Carib. Fish. Inst. 32: 194-207.

Feliciano, C. 1958. The lobster fishery of Puerto Rico. Proc. Gulf and Carib. Fish. Inst. 10: 147-156.

Goodyear, C.P. 1989. Spawning stock biomass per recruit: The biological basis for a fisheries management tool. ICCAT Working Document SCRS/89/82.

Gregory, D.R., Jr., R.F. Labisky, and C.L. Combs. 1982. Reproductive dynamics of the spiny lobster _Panulirus argus_ in South Florida. Transactions of the American Fisheries Society 111: 575-584.

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

Haughton, M. and W. Shaul. 1989. Estimation of growth parameters for the spiny lobster (Panulirus argus) in Jamaican Waters. Proc. Gulf and Carib. Fish. Inst. 39: 279-288.

Hunt, J.H. and W.G. Lyons. 1986. Factors affecting growth and maturation of spiny lobsters, Panulirus argus, in the Florida Keys. Can. J. Fish. Aquat. Sci. 43: 2243-2247.

Lyons, W.G., D.G. Barber, S.M. Foster, F.S. Kennedy, Jr., and G.R. Milano. 1981. The spiny lobster, Panulirus argus, in the Middle and Upper Florida Keys: Population structure, seasonal dynamics, and reproduction.

Lyons, W.G. and Hunt, J.H. 1987. Catch rates of spiny lobsters, Panulirus argus, in traps equipped with escape gaps, and potential benefits to the south Florida fishery. Proc. Gulf Carib. Fish. Inst. 39 (in press).

Lyons, W.G. and F.S. Kennedy, Jr. 1980. Effects of harvest techniques on sublegal spiny lobsters and on subsequent fishery yield. Proc. Gulf Carib. Fish. Inst. 33: 290-300.

Matos, D. and Y. Sadovy. 1990a. Overview of Puerto Rico's small-scale fisheries statistics (Perspectivas de las Estadisticas de la Pesca en Pequena Escala de Puerto Rico) 1988-1989. Technical Report CODREMAR 1(4): 1-17.

Matos, D. and Y. Sadovy. 1990b. CODREMAR/NMFS Cooperative Statistics Program for 1989-1990. Annual Report to the National Marine Fisheries Service. Project SF-33. June 1990. 44 p.

Mattox, N.T. 1952. A preliminary report on the biology and economics of the spiny lobster in Puerto Rico. Proc. Gulf Carib. Fish. Inst. 4: 69-70.

Munro, J.L. 1983. The biology, ecology and bionomics of spiny lobsters (Palinuridae), spider crabs (Majiidae) and other crustacean resources. Pages In: J.L. Munro (ed). Caribbean coral reef fishery resources. International Center for Living Aquatic Resources Management (ICLARM). Manila, Philippines.

Olsen, D.A., W.F. Herrnkind and R.A. Cooper. 1975. Population dynamics, ecology and behavior of spiny lobsters, Panulirus argus, of St. John, U.S.V.I.: I, Introduction and general population characteristics. In S.A. Earle and R.J. Lavenberg (ed.). Results of the Tektite program: Coral reef invertebrates and plants. Nat. Hist. Mus. Los Ang. Cty. Sci. Bull 20: 11-16.

Olsen, D.A. and I.G. Koblic. 1975. Population dynamics, ecology and behavior of spiny lobsters, Panulirus argus, of St. John, U.S.V.I.: II Growth and mortality. In S.A. Earle and R.J. Lavenberg (ed.). Results of the Tektite program: Coral reef invertebrates and plants. Nat. Hist. Mus. Los Ang. Cty. Sci. Bull 20: 17-21.

Pauly, D. 1985. The population dynamics of short-lived species, with emphasis on squids. NAFO Scientific Council Studies. No. 9: 143-154.

Powers, J.E. and D.L. Sutherland. 1989. Spiny lobster assessment, CPUE, size-frequency, yield per recruit, and escape gap analyses. Miami Laboratory, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, Coastal Resources Division Contribution Number CRD-88\89-24.

Waugh, G.T. 1981. Management of juvenile spiny lobster (Panulirus argus) based on estimated biological parameters from Grand Bahama Island, Bahamas. Proc. Gulf Carib. Fish Inst. 33: 271-289.

Weiler, D. and J. Suarez-Caabro. 1980. Overview of Puerto Rico's small-scale fisheries statistics (Perspectivas de las Estadisticas de la Pesca en Pequena Escala de Puerto Rico) 1972-1978. Informe Tecnico, CODREMAR 1(1): 1-17.

List of Tables

List of Figures

List of Participants

Dr. Richard Appeldoorn, Department of Marine Sciences, University of Puerto Rico, Mayagüez, Puerto Rico 00708.

Jim Beets, Division of Fish and Wildlife, Department of Conservation and Cultural Affairs, 101 Estate Nazareth, St. Thomas, VI 00802.

Dr. James A. Bohnsack, National Marine Fisheries Service, Southeast Fisheries Center, Miami Laboratory, 75 Virginia Beach Dr., Miami, Florida 33149.

Steve Meyers, Caribbean Fishery Management Council, Suite 1108 Banco de Ponce Bldg., Hato Rey, Puerto Rico 00918

Dr. Yvonne Sadovy, Fisheries Research Laboratory, Department of Natural Resources (previously of CODREMAR), P.O. Box 3665, Marina Station, Mayagüez, Puerto Rico 00709.

Table 1. Summary of total landings (lbs) and fishing effort.

Puerto Rico Year	Total Landings	Total Fishers	Total Vessels	St Thomas and St. Johns Year	Total Landings	Licensed Fishers	Total Vessels	St Croix Total Landings	Licensed Fishers	Total Vessels
1951	466760	223								
1964	150000									
1969	354000									
1970	417000									
1971	258000									
1972	237000	970								
1973	250000	930								
1974	244000	1120								
1975	311000	1230	865							
1976	384000	1230	901							
1977	421000	1368	1036							
1978	451000	1442	1073							
1979	512000	1442	1073							
1980	474000	1447	1087							
1981	481000			80-81	29418	258		7148	163	
1982	359000	1872	1449	81-82	47204	256		8280	322	
1983	294229	1415	1125	82-83	29460	259		2304	195	
1984	283262			83-84	39810	255		7419	182	
1985	246501	1766		84-85	41911	255		8328	182	
1986	219203	1135	865	85-86	39300	330		16031	206	
1987	158223	1731		86-87	23296	329		4322	200	
1988	143761			87-88	41875	306		4437	217	
1989	186423	1822	1107	88-89						
Mean	317451	1395	1058		36534	281		7284	208	

Table 2. Size-Frequency Surveys of Spiny Lobster for Puerto Rico.

Survey	Year	Number of Lobster Sampled	Mean Carapace Length (in)	Mean Carapace Length (mm)	Mean Weight (lbs)	Percent Below 3.5 in (Numbers)	Percent Below 3.5 in (lbs)	Females	Males	Sex Ratio M:F	Max. Carapac Length (mm)
Mattox, 1952	1951		4.4	113							
Feliciano, C. 1958	1956-5	1276	4.0	101.6	2.0	19.6	-				
CFMC, 1981	1968	223	3.8	95.3	1.7	25.0	-				
Olsen & Koblic 1975	1970		4.3	109.3		15.1					
CFMC, 1981	1978-7	9232	3.7	93.5	1.7	40.5	23.7				
CODREMAR*	1980	129	3.7	92.8		27.0		75	54	0.72	127
CFMC, 1982	1980-1	5574	3.8	95.3	1.8	34.7					
CODREMAR	1982										
CODREMAR	1983	211	3.7	94.4		28.0		106	105	0.990	152
CODREMAR	1984	2184				31.0		1093	1091	0.998	
CODREMAR (all)	1985					32.0					
" South Coast	"	554						297	257	0.865	
" N & E Coast	"	271						135	136	1.007	168
" West Coast	"	480						235	245	1.042	163
CODREMAR	1986	568	3.6	92.5		39.0		258	310	1.201	174
CODREMAR	1987	387	3.8	95.6		30.0		179	208	1.162	152
CODREMAR	1988	52						31	21	0.677	
CODREMAR	1989	392	3.5	90.1		41.0		235	276	1.174	
Matos & Sadovy, 1990b	1989	1037	3.5	90							

* Data collected by CODREMAR and available to the workshop on the NMFS TIP database.

Table 3. Size-Frequency Surveys of Spiny Lobster for St Thomas and StSt Thomas and St Johns, U.S. Virgin Islands

Survey	Year	Number of Lobster Sampled	Mean Carapace Length (in)	Mean Carapace Length (mm)	Mean Weight (lbs)	Percent Below 3.5 in (Numbers)	Percent Below 3.5 in (lbs)	Females	Males	Sex Ratio M:F	Max. Carapac Length (mm)	Mean Weight (g)
St. John												
DCCA USVI*	1985	1802	4.1	105				790	1012	1.281	152	
St. Thomas												
CFMC, 1981 +	1978	146	4.4	112	2.6	9.6	6.1					
CFMC, 1982	1979	89	4.4	113	2.8	7.9						
	1980											
CFMC, 1982	1981	89	4.5	114	2.8							
DCCA USVI*	1982	689	4.5	114		16.7 ‡						
DCCA USVI	1983	107	4.2	106								
DCCA USVI	1984	219	4.5	115	2.7	5.0		99	120	1.212	191	
DCCA USVI	1985	1060	4.6	116	2.6	0.7		481	564	1.172	203	
DCCA USVI	1986	1345	4.3	109	2.4	1.7		468	846	1.807	191	
DCCA USVI	1987	368	4.7	119	3.0	0.3		167	200	1.197	178	
DCCA USVI	1988	313	4.4	111	2.6	0.0		115	198	1.721	165	

* Data collected by Dept. of Conservation and Community Affairs and available to the workshop on the NMFS TIP database.

\+ June data only

Table 3. Size-Frequency Surveys of Spiny Lobster for St Thomas and StSt Thomas and St Johns, U.S. Virgin Islands

Survey	Year	Number of Lobster Sampled	Mean Carapace Length (in)	Mean Carapace Length (mm)	Mean Weight (lbs)	Percent Below 3.5 in (Numbers)	Percent Below 3.5 in (lbs)	Females	Males	Sex Ratio M:F	Max. Carapac Length (mm)	Mean Weight (g)
St. John												
DCCA USVI*	1985	1802	4.1	105				790	1012	1.281	152	
St. Thomas												
CFMC, 1981 +	1978	146	4.4	112	2.6	9.6	6.1					
CFMC, 1982	1979	89	4.4	113	2.8	7.9						
	1980											
CFMC, 1982	1981	89	4.5	114	2.8							
DCCA USVI*	1982	689	4.5	114		16.7 #						
DCCA USVI	1983	107	4.2	106								
DCCA USVI	1984	219	4.5	115	2.7	5.0		99	120	1.212	191	
DCCA USVI	1985	1060	4.6	116	2.6	0.7		481	564	1.172	203	
DCCA USVI	1986	1345	4.3	109	2.4	1.7		468	846	1.807	191	
DCCA USVI	1987	368	4.7	119	3.0	0.3		167	200	1.197	178	
DCCA USVI	1988	313	4.4	111	2.6	0.0		115	198	1.721	165	

* Data collected by Dept. of Conservation and Community Affairs and available to the workshop on the NMFS TIP database.

+ June data only

Table 4. Size-Frequency Surveys of Spiny Lobster for St Croix, U.S.V.I.

Survey	Year	Number of Lobster	Mean Carapace Length (in)	Mean Carapace Length (mm)	Mean Weight (lbs)	Percent Below 3.5 in (Numbers)	Percent Below 3.5 in (lbs)	Females	Males	Sex Ratio M:F	Max. Carapac Length (mm)	Mean Weight (g)
Olsen et al., 1975	1970-1	756	4.4	113								
CFMC, 1981	1976	996	4.1	103	2.0	1.0	-					
	1977											
CFMC, 1981 #	1978	233	4.6	117	2.6	0.4	2.7					
CFMC, 1982	1979	90	4.3	109		15.5 *						
	1980											
CFMC, 1982	1981	90	4.3	109	2.5							
DCCA USVI +	1981		3.9	99								
DCCA USVI	1982	482	4.1	105		25.9 *						
DCCA USVI	1983	41	3.8	96								
DCCA USVI	1984	383	4.1	104								
	1985											
	1986											
DCCA USVI	1987	637	4.1	105	2.2	2.7		297	340	1.144	150	989
DCCA USVI	1988	965	4.2	106	2.1	1.3		438	522	1.191	150	976
DCCA USVI	1989	578	4.2	106	2.2	1.4		245	333	1.359	152	983

* includes "legal" lobster 3.5 and 3.6" CL.
+ Available data collected by Dept. of Conservation and Community Affairs on the NMFS TIP database.
# July data only

Table 5: Length-frequencies for spiny lobsters (Panulirus argus) for St. Croix (1987-1989), St. Thomas and St. John (1985-1989), and Puerto Rico (1985-1989). Note, columns will not add up exactly because a few lobsters labeled in the data set as unidentified females, were not included in a specific column based on sex type, but were retained in the total columns.

	ST. CROIX					ST. THOMAS AND ST. JOHN					PUERTO RICO				
LGTH (IN)	ALL LOBSTER	MALE	FEMALE (TAR)	FEMALE (EGGS)	FEMALE (OTHER)	ALL LOBSTER	MALE	FEMALE (TAR)	FEMALE (EGGS)	FEMALE (OTHER)	ALL LOBSTER	MALE	FEMALE (TAR)	FEMALE (EGGS)	FEMALE (OTHER)
2.8						6				6	354	50	4		288
2.9						12				12	669	69	8		588
3						43	1			42	741	96	36	7	594
3.1	1	1				40		4		36	721	89	88	14	520
3.2	2	2				24	2	4		18	745	96	40	7	594
3.3	15	3	8		4	133	11	32		90	798	120	160	14	498
3.4	35	7	16		12	253	25	72		156	881	118	240	7	510
3.5	217	34	96	7	80	765	89	216	7	450	977	107	272	42	552
3.6	319	56	176		66	562	83	244	14	216	790	114	308	56	312
3.7	361	68	220	21	46	609	107	276	28	198	703	131	280	42	246
3.8	338	63	232	7	36	560	113	300	42	102	723	99	340	28	252
3.9	337	55	236		34	580	122	304	28	126	897	161	424	42	258
4	352	75	236	7	28	728	162	344	21	198	626	104	300	28	192
4.1	329	88	184	7	44	526	132	244	42	108	614	171	312	21	108
4.2	344	94	224		26	569	153	284	21	108	323	96	148	7	72
4.3	322	68	196	14	32	645	150	308	28	156	471	112	224	35	96
4.4	232	73	136	7	16	427	137	184	7	96	328	80	136	28	84
4.5	178	70	100		8	593	145	284	14	144	251	67	88	42	54
4.6	172	60	96		16	322	107	136	28	48	152	[illegible]	56	7	42
4.7	114	36	68		10	223	80	88	7	48	125	[illegible]	44	7	48
4.8	110	42	60		8	306	93	180		30	128	46	52		30
4.9	81	43	36		2	175	44	64	7	60	55	24	12	7	12
5	43	23	16		4	311	111	136	28	36	96	25	24	21	24
5.1	38	22	12		4	78	40	32		6	39	15	16		6
5.2	37	13	20		4	181	76	84		18	55	19	24		12
5.3	16	10	4		2	57	43	8		6	27	15	12		
TOTAL	3993	1006	2372	70	482	8728	2026	3828	322	2514	12289	2097	3648	462	5992

Table 6: Percent length-frequencies for spiny lobsters (*Panulirus argus*) for St. Croix (1987-1989), St. Thomas and St. John (1985-1989), and Puerto Rico (1985-1989).

LGTH	ST. CROIX					ST. THOMAS AND ST. JOHN					PUERTO RICO				
(IN)	ALL LOBSTER	MALE	FEMALE (TAR)	FEMALE (EGGS)	FEMALE (OTHER)	ALL LOBSTER	MALE	FEMALE (TAR)	FEMALE (EGGS)	FEMALE (OTHER)	ALL LOBSTER	MALE	FEMALE (TAR)	FEMALE (EGGS)	FEMALE (OTHER)
2.8						0.07%				0.07%	2.88%	0.41%	0.03%		2.36%
2.9						0.14%				0.14%	5.44%	0.57%	0.07%		4.82%
3						0.49%	0.01%			0.48%	6.03%	0.79%	0.30%	0.06%	4.87%
3.1	0.03%	0.03%				0.46%		0.05%		0.41%	5.87%	0.73%	0.72%	0.11%	4.26%
3.2	0.05%	0.05%				0.27%	0.02%	0.05%		0.21%	6.06%	0.79%	0.33%	0.06%	4.87%
3.3	0.38%	0.08%	0.20%		0.10%	1.52%	0.13%	0.37%		1.04%	6.49%	0.98%	1.31%	0.11%	4.08%
3.4	0.88%	0.18%	0.41%		0.31%	2.90%	0.29%	0.83%		1.80%	7.17%	0.97%	1.97%	0.06%	4.18%
3.5	5.43%	0.87%	2.44%	0.18%	2.04%	8.76%	1.02%	2.49%	0.08%	5.18%	7.95%	0.88%	2.23%	0.34%	4.52%
3.6	7.99%	1.42%	4.48%		1.68%	6.44%	0.96%	2.81%	0.16%	2.49%	6.43%	0.93%	2.52%	0.46%	2.56%
3.7	9.04%	1.73%	5.60%	0.53%	1.17%	6.98%	1.23%	3.18%	0.32%	2.28%	5.72%	1.07%	2.30%	0.34%	2.02%
3.8	8.46%	1.60%	5.90%	0.18%	0.92%	6.42%	1.30%	3.45%	0.48%	1.17%	5.88%	0.81%	2.79%	0.23%	2.07%
3.9	8.44%	1.40%	6.01%		0.87%	6.65%	1.40%	3.50%	0.32%	1.45%	7.30%	1.32%	3.48%	0.34%	2.11%
4	8.82%	1.91%	6.01%	0.18%	0.71%	8.34%	1.86%	3.96%	0.24%	2.28%	5.09%	0.85%	2.46%	0.23%	1.57%
4.1	8.24%	2.24%	4.68%	0.18%	1.12%	6.03%	1.52%	2.81%	0.48%	1.24%	5.00%	1.40%	2.56%	0.17%	0.89%
4.2	8.62%	2.39%	5.70%		0.66%	6.52%	1.76%	3.27%	0.24%	1.24%	2.63%	0.79%	1.21%	0.06%	0.59%
4.3	8.06%	1.73%	4.99%	0.36%	0.81%	7.39%	1.73%	3.54%	0.32%	1.80%	3.83%	0.92%	1.84%	0.29%	0.79%
4.4	5.81%	1.86%	3.46%	0.18%	0.41%	4.89%	1.58%	2.12%	0.08%	1.10%	2.67%	0.66%	1.11%	0.23%	0.69%
4.5	4.46%	1.78%	2.54%		0.20%	6.79%	1.67%	3.27%	0.16%	1.66%	2.04%	0.55%	0.72%	0.34%	0.44%
4.6	4.31%	1.53%	2.44%		0.41%	3.69%	1.23%	1.57%	0.32%	0.55%	1.24%	0.39%	0.46%	0.06%	0.34%
4.7	2.85%	0.92%	1.73%		0.25%	2.55%	0.92%	1.01%	0.08%	0.55%	1.02%	0.21%	0.36%	0.06%	0.39%
4.8	2.75%	1.07%	1.53%		0.20%	3.51%	1.07%	2.07%		0.35%	1.04%	0.38%	0.43%		0.25%
4.9	2.03%	1.09%	0.92%		0.05%	2.01%	0.51%	0.74%	0.08%	0.69%	0.45%	0.20%	0.10%	0.06%	0.10%
5	1.08%	0.59%	0.41%		0.10%	3.56%	1.28%	1.57%	0.32%	0.41%	0.78%	0.20%	0.20%	0.17%	0.20%
5.1	0.95%	0.56%	0.31%		0.10%	0.89%	0.46%	0.37%		0.07%	0.32%	0.12%	0.13%		0.05%
5.2	0.93%	0.33%	0.51%		0.10%	2.07%	0.87%	0.97%		0.21%	0.45%	0.16%	0.20%		0.10%
5.3	0.40%	0.25%	0.10%		0.05%	0.65%	0.49%	0.09%		0.07%	0.22%	0.12%	0.10%		
TOTAL	100.00%	25.60%	60.36%	1.78%	12.26%	100.00%	23.31%	44.05%	3.71%	28.93%	100.00%	17.19%	29.90%	3.79%	49.12%

Table 7: Cumulative percent length-frequencies for spiny lobsters (*Panulirus argus*) for St. Croix (1987-1989), St. Thomas and St. John (1985-1989), and Puerto Rico (1985-1989).

	ST. CROIX					ST. THOMAS AND ST. JOHN					PUERTO RICO				
LGTH (IN)	ALL LOBSTER	MALE	FEMALE (TAR)	FEMALE (EGGS)	FEMALE (OTHER)	ALL LOBSTER	MALE	FEMALE (TAR)	FEMALE (EGGS)	FEMALE (OTHER)	ALL LOBSTER	MALE	FEMALE (TAR)	FEMALE (EGGS)	FEMALE (OTHER)
2.8						0%				0%	3%	2%	0%		5%
2.9						0%				1%	8%	6%	0%		15%
3						1%	0%			2%	14%	10%	1%	2%	25%
3.1	0%	0%				1%	0%	0%		4%	20%	14%	4%	5%	33%
3.2	0%	0%				1%	0%	0%		5%	26%	19%	5%	6%	43%
3.3	0%	1%	0%		1%	3%	1%	1%		8%	33%	25%	9%	9%	51%
3.4	1%	1%	1%		3%	6%	2%	3%		14%	40%	30%	16%	11%	60%
3.5	7%	5%	5%	10%	20%	15%	6%	9%	2%	32%	48%	36%	23%	20%	69%
3.6	15%	10%	12%	10%	34%	21%	10%	15%	7%	41%	54%	41%	32%	32%	74%
3.7	24%	17%	22%	40%	43%	28%	16%	22%	15%	49%	60%	47%	39%	41%	78%
3.8	32%	23%	32%	50%	51%	34%	21%	30%	28%	53%	66%	52%	49%	47%	83%
3.9	41%	29%	41%	50%	58%	41%	27%	38%	37%	58%	73%	60%	60%	56%	87%
4	50%	36%	51%	60%	63%	49%	35%	47%	43%	66%	78%	65%	69%	62%	90%
4.1	58%	45%	59%	70%	73%	55%	42%	53%	57%	70%	83%	73%	77%	67%	92%
4.2	66%	54%	69%	70%	78%	62%	49%	61%	63%	74%	86%	77%	81%	68%	93%
4.3	74%	61%	77%	90%	85%	69%	57%	69%	72%	80%	90%	83%	87%	76%	95%
4.4	80%	68%	83%	100%	88%	74%	64%	74%	74%	84%	92%	86%	91%	82%	96%
4.5	85%	75%	87%		90%	81%	71%	81%	78%	90%	94%	90%	93%	91%	97%
4.6	89%	81%	91%		93%	85%	76%	85%	87%	92%	96%	92%	95%	92%	98%
4.7	92%	85%	94%		95%	87%	80%	87%	89%	94%	97%	93%	96%	94%	99%
4.8	95%	89%	96%		97%	91%	85%	92%	89%	95%	98%	95%	98%	94%	99%
4.9	97%	93%	98%		97%	93%	87%	93%	91%	97%	98%	96%	98%	95%	99%
5	98%	96%	98%		98%	96%	92%	97%	100%	99%	99%	98%	99%	100%	100%
5.1	99%	98%	99%		99%	97%	94%	98%		99%	99%	98%	99%		100%
5.2	100%	99%	100%		100%	99%	98%	100%		100%	100%	99%	100%		100%
5.3	100%	100%	100%		100%	100%	100%	100%		100%	100%	100%	100%		

Table 8. Fecundity Calculations for Puerto Rico (1989, West Coast).

Carapace Length (mm)	Percentage Contribution: Number of Females	Number of Breeding Females	Annual Egg Production	Estimated Number of Eggs[2] (x10^3)	Fecundity[1]: Puerto Rico 1989 (x10^3)	Florida Keys 1976 (x10^3)	Tortugas 1973-75 (x10^3)
<65	0	0	0	0.0	0.0	0.0	0.0
65-75	19	3	1	323.3	7.5	21.7	0.0
75-85	29	11	6	2025.6	31.6	68.8	63.3
85-95	23	34	26	9424.9	184.8	113.1	225.8
95-105	18	32	34	12399.7	302.4	380.6	394.0
105-115	8	15	22	8205.7	455.9	746.0	552.5
115-125	2	4	8	3013.0	753.2	0.0	761.9
125-135	1	1	4	1321.3	660.6	0.0	681.9
135-145	0	0	0	0.0	0.0	0.0	0.0
Total	100	100	100	36713.4	2396.2	1330.2	2679.4
Sample Size	223	73	73				
Total Mean Fecundity (uncorrected)				3	164.6	-	-
Total Mean Fecundity (corrected, n = 78 breeders)					175.9	57.2	314.7
Total Mean Fecundity (calculated with 5 mm classes)					177.9	-	-
Total Mean Fecundity (calculated with 1 mm classes)					182.5	-	-
Spawning Potential Ratio (10 mm classes)					55.89%	18.18%	

NOTES:

1 Fecundity = (number of eggs)/(number of females).

2 Number of Eggs = Number of breeding females x [4.8(0.98 + 0.2598CL)^3.53] where CL is the midpoint of the carapace-length class.

3 Corrected mean was calculated by multiplying the mean by 78/73 to account for 5 reproductive females without carapace measurements.

Table 9. Fecundity Calculations for St. Croix (1989).

Carapace Length (mm)	Percentage Contribution: Number of Females	Number of Breeding Females	Annual Egg Production	Estimated Number [2] of Eggs (x10^3)	Fecundity [1]: St. Croix 1989 (x10^3)	Florida Keys 1976 (x10^3)	Tortugas 1973-75 (x10^3)
<65	0.0	0.0	0.0	0.0	0.0	0.0	0.0
65-75	0.0	0.0	0.0	0.0	0.0	21.7	0.0
75-85	0.8	0.6	0.2	253.2	126.6	68.8	63.3
85-95	20.8	13.7	7.9	8670.9	170.0	113.1	225.8
95-105	41.2	43.5	36.0	39355.5	389.7	380.6	394.0
105-115	24.9	26.8	30.7	33568.9	550.3	746.0	552.5
115-125	9.8	13.1	20.2	22095.2	920.6	0.0	761.9
125-135	2.4	2.4	4.8	5285.0	880.8	0.0	681.9
135-145	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	100	100	100	109228.7	3038.059	1330.2	2679.4
n =	245	168	168				
Total Mean Fecundity (10 mm size classes)					445.8	57.2	314.7
Total Mean Fecundity (5 mm classes)					-	-	-
Total Mean Fecundity (0.1 in classes)					0.0	-	-
Spawning Potential Ratio					141.67%	18.18%	

NOTES:

1 Fecundity = (number of eggs)/(number of females).

2 Number of Eggs = Number of breeding females x [4.8(0.98 + 0.2598CL)^3.53]
where CL is the midpoint of the carapace-length class.

Table 10. Fecundity Calculations for St. Thomas (1988).

Carapace Length (mm)	Percentage Contribution: Number of Females	Number of Breeding Females	Annual Egg Productio	Estimated Number [2] of Eggs (x10^3)	Fecundity [1]: St. Croix 1989 (x10^3)	Florida Keys 1976 (x10^3)	Tortugas 1973-75 (x10^3)
<65	0.0	0.0	0.0	0.0	0.0	0.0	0.0
65-75	0.0	0.0	0.0	0.0	0.0	21.7	0.0
75-85	0.0	0.0	0.0	0.0	0.0	68.8	63.3
85-95	31.6	27.1	14.2	8670.9	279.7	113.1	225.8
95-105	19.4	20.0	15.1	9165.0	482.4	380.6	394.0
105-115	27.6	30.6	31.9	19395.3	718.3	746.0	552.5
115-125	10.2	10.6	14.9	9039.0	903.9	0.0	761.9
125-135	10.2	10.6	19.5	11891.3	1189.1	0.0	681.9
135-145	0.0	0.0	0.0	0.0	0.0	0.0	0.0
145-155	0.0	0.0	0.0	0.0	0.0	0.0	0.0
155-165	1.0	1.2	4.4	2698.9	2698.9	0.0	0.0
Total	100	100	100	60860.44	6272.337	1330.2	2679.4
n =	98	85	85				
Total Mean Fecundity (10 mm size classes)					621.0	57.2	314.7
Total Mean Fecundity (5 mm classes)					-	-	-
Total Mean Fecundity (0.1 in classes)					583.8	-	-
Spawning Potential Ratio					197.34%	18.18%	

NOTES:

1 Fecundity = (number of eggs)/(number of females).

2 Number of Eggs = Number of breeding females x [4.8(0.98 + 0.2598CL)^3.53] where CL is the midpoint of the carapace-length class.

Figure 1 Puerto Rico Total Lobster Landings

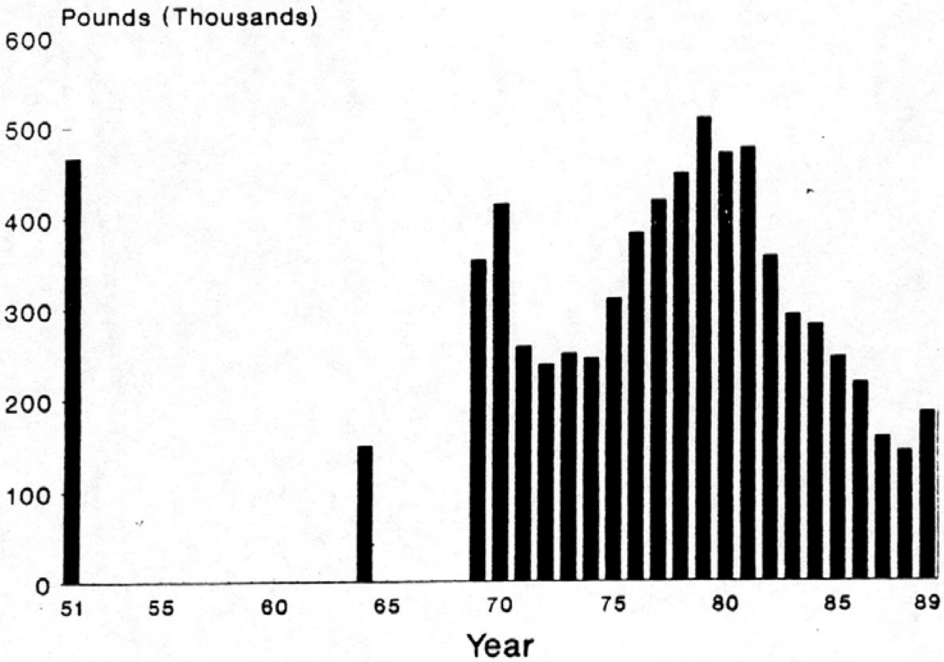


Figure 2 Virgin Islands Total Lobster Landings

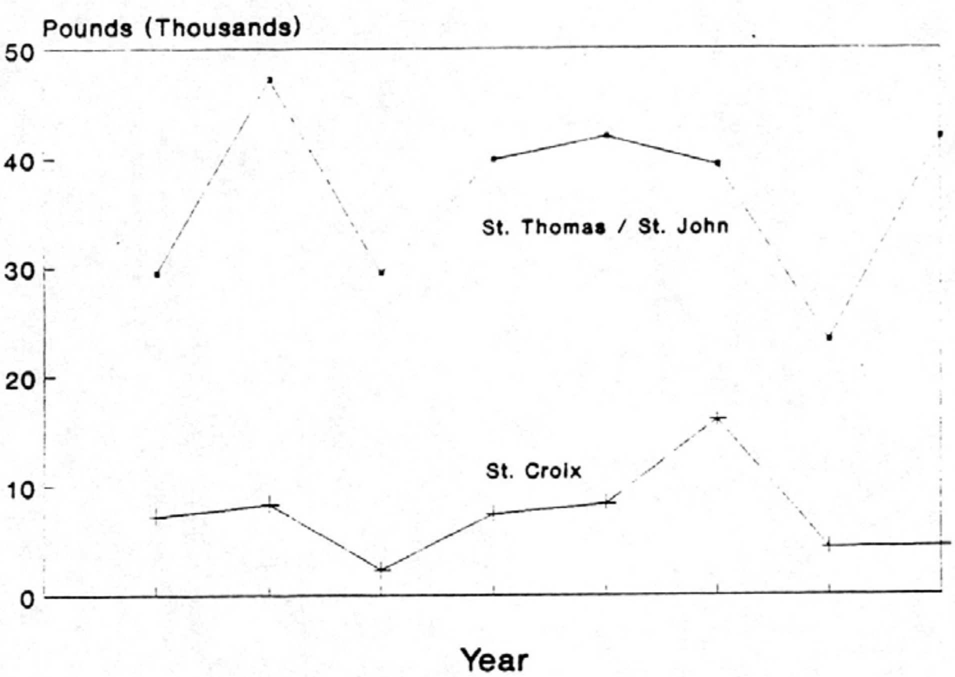
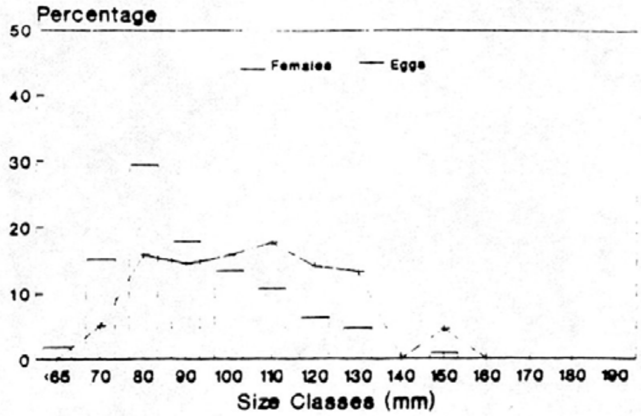
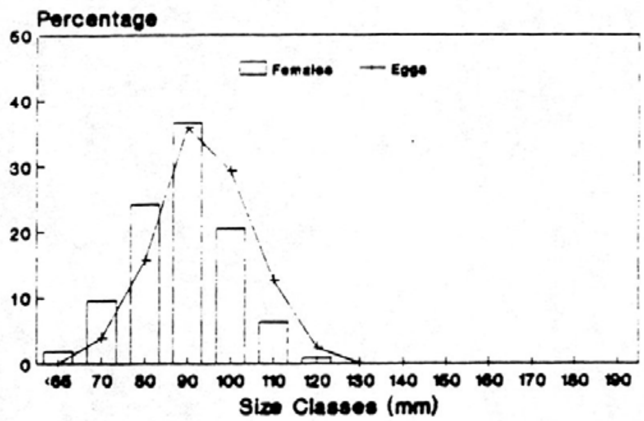


Figure 3

Puerto Rico, 1984 North & East Coast
(n = 112)



Puerto Rico, 1985 South Coast
(n = 219)



Puerto Rico, 1985 West Coast
(n = 214)

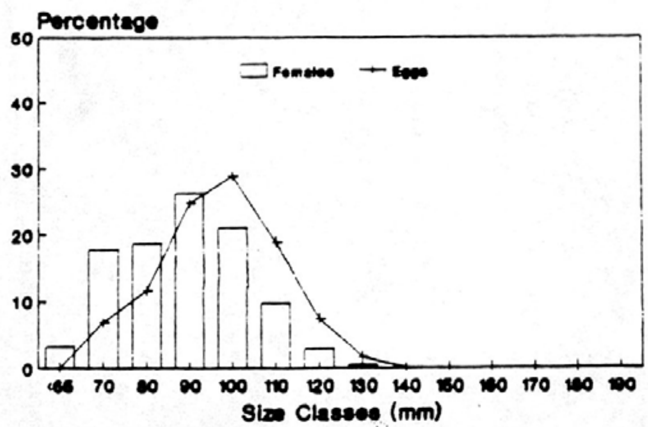
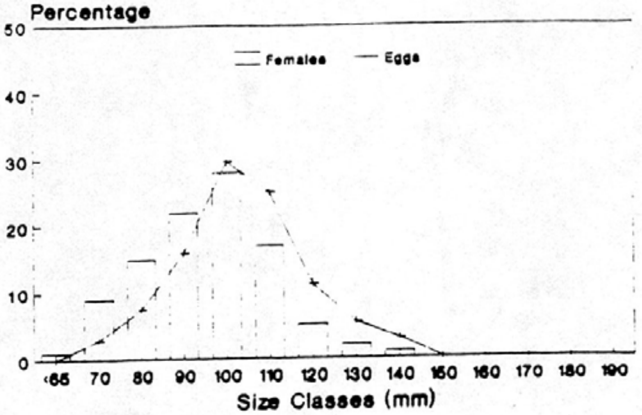
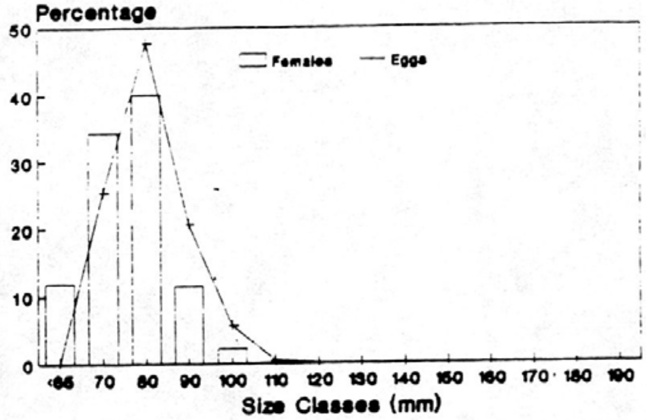


Figure-4

Dry Tortugas, 1973-75
(n = 1594)



Florida Keys, 1976
(n = 782)



Florida Keys, 1978-79
(n = 1594)

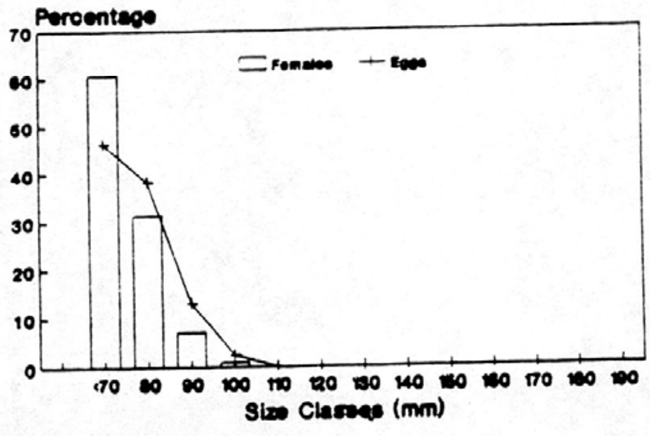


Figure 5

LOBSTER LENGTH FREQUENCY FROM PUERTO RICO

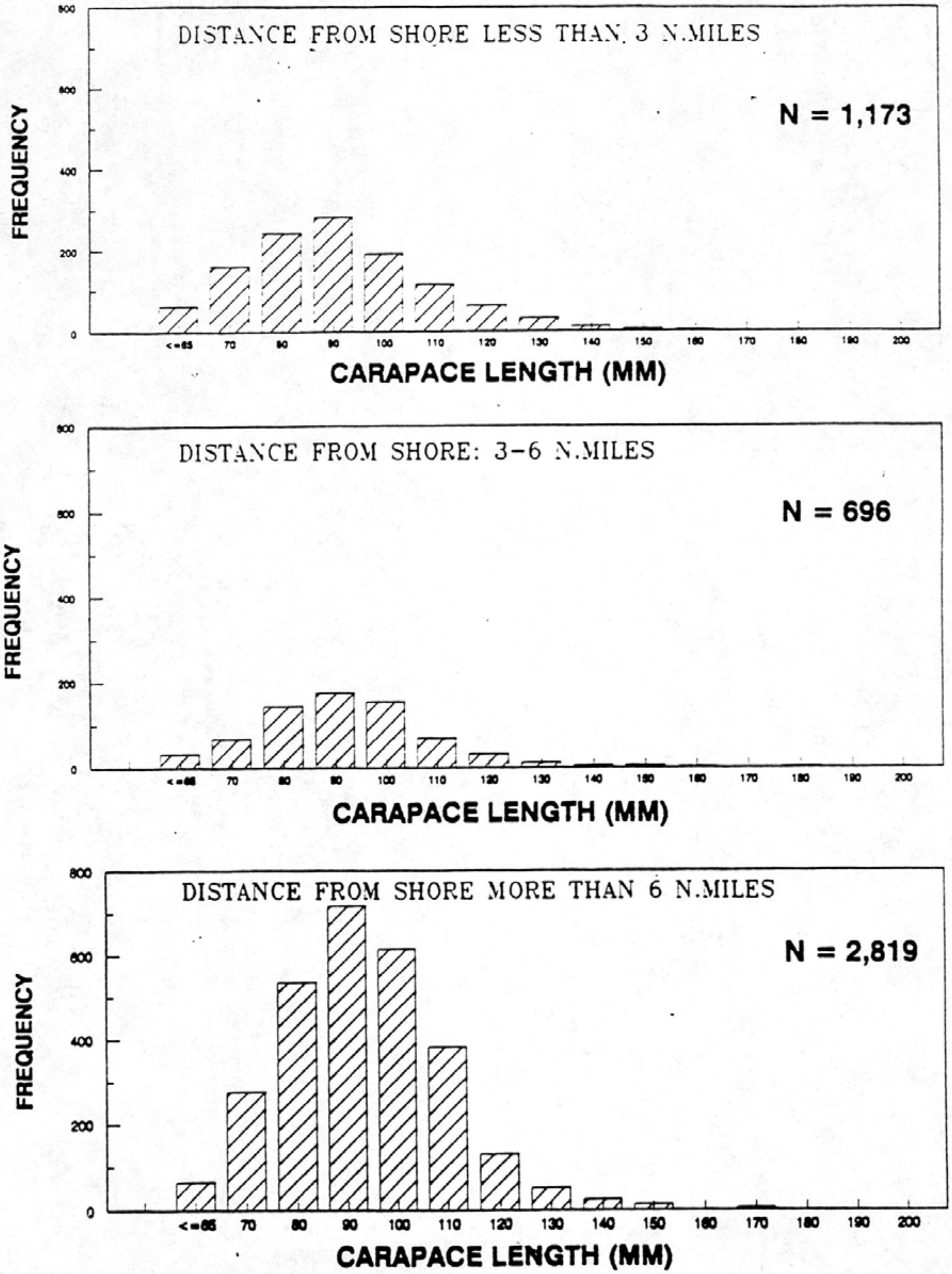
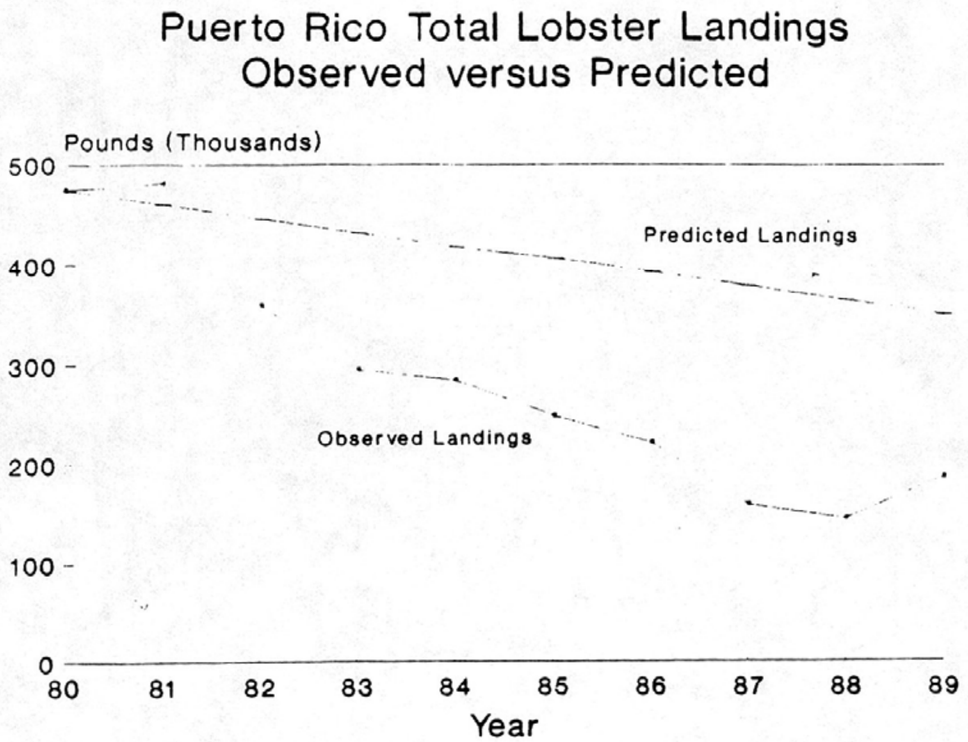


Figure 6


Puerto Rico Total Lobster Landings
Observed versus Predicted
Pounds (Thousands)
500
400
300
200
100
0
Predicted Landings
Observed Landings
80
81
82
83
84
85
86
87
88
89
Year

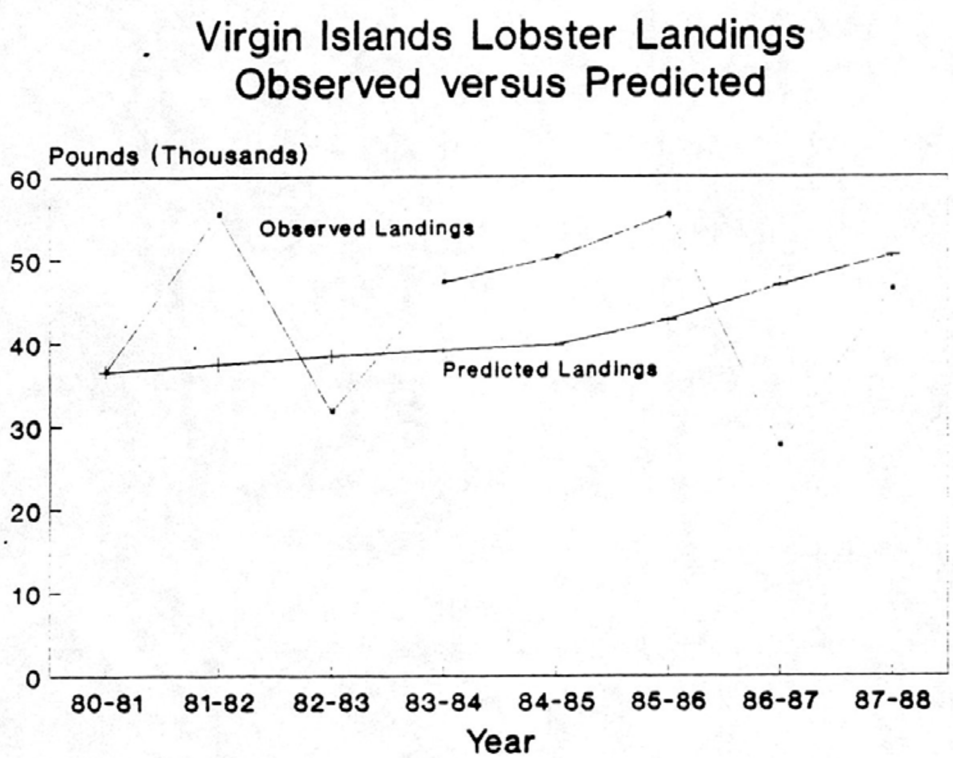
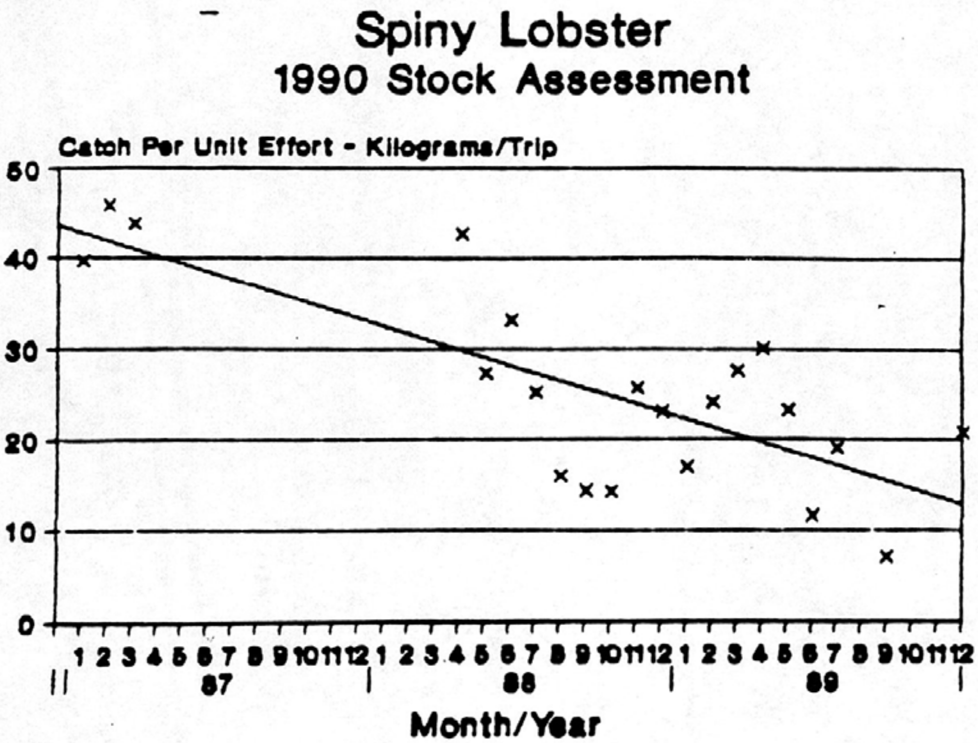

Virgin Islands Lobster Landings
Observed versus Predicted
Pounds (Thousands)
60
50
40
30
20
10
0
Observed Landings
Predicted Landings
80-81
81-82
82-83
83-84
84-85
85-86
86-87
87-88
Year

Figure 7


Spiny Lobster
1990 Stock Assessment
Catch Per Unit Effort - Kilograms/Trip
0
10
20
30
40
50
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
87
88
89
Month/Year

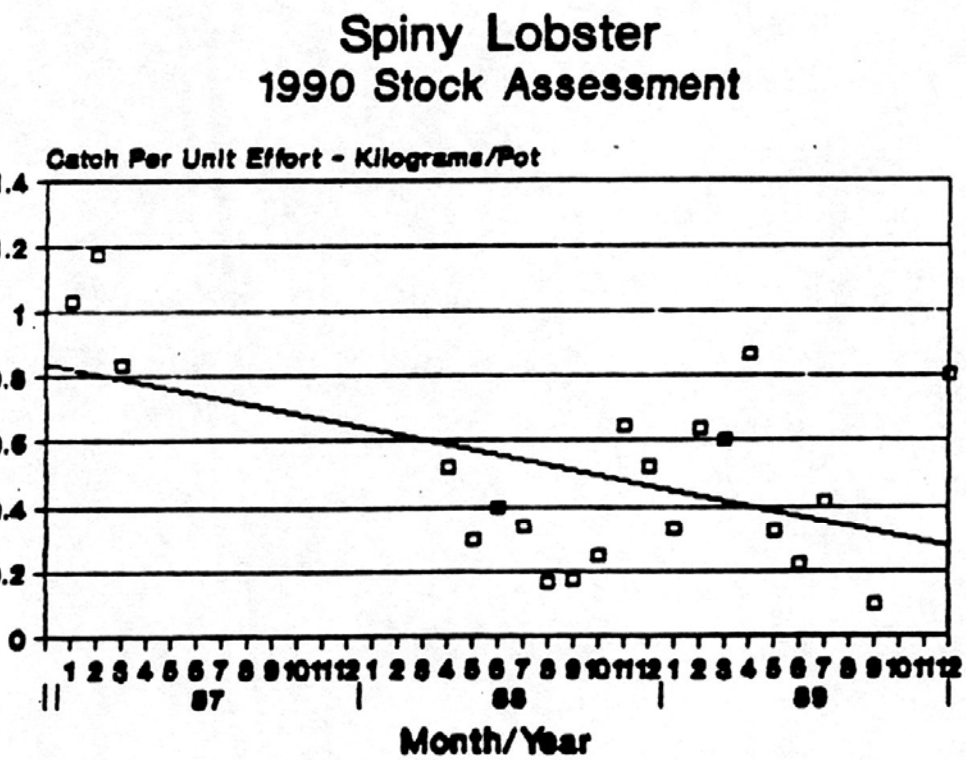

Spiny Lobster
1990 Stock Assessment
Catch Per Unit Effort - Kilograms/Pot
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
87
88
89
Month/Year

Figure 8

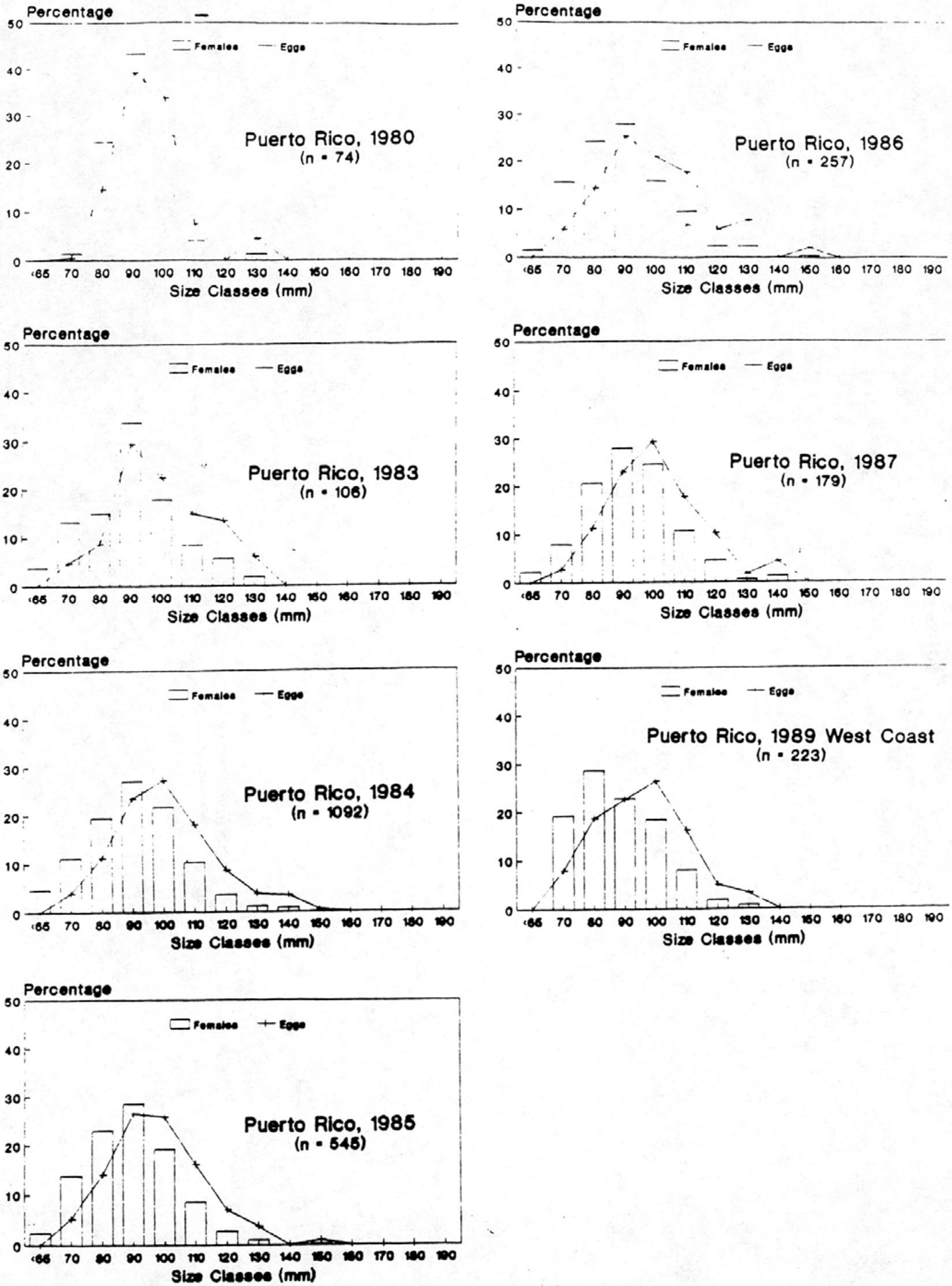

Percentage
Females
Eggs
Puerto Rico, 1980
(n = 74)
Size Classes (mm)
Percentage
Females
Eggs
Puerto Rico, 1986
(n = 257)
Size Classes (mm)
Percentage
Females
Eggs
Puerto Rico, 1983
(n = 106)
Size Classes (mm)
Percentage
Females
Eggs
Puerto Rico, 1987
(n = 179)
Size Classes (mm)
Percentage
Females
Eggs
Puerto Rico, 1984
(n = 1092)
Size Classes (mm)
Percentage
Females
Eggs
Puerto Rico, 1989 West Coast
(n = 223)
Size Classes (mm)
Percentage
Females
Eggs
Puerto Rico, 1985
(n = 545)
Size Classes (mm)
<65 70 80 90 100 110 120 130 140 150 160 170 180 190

Figure 9

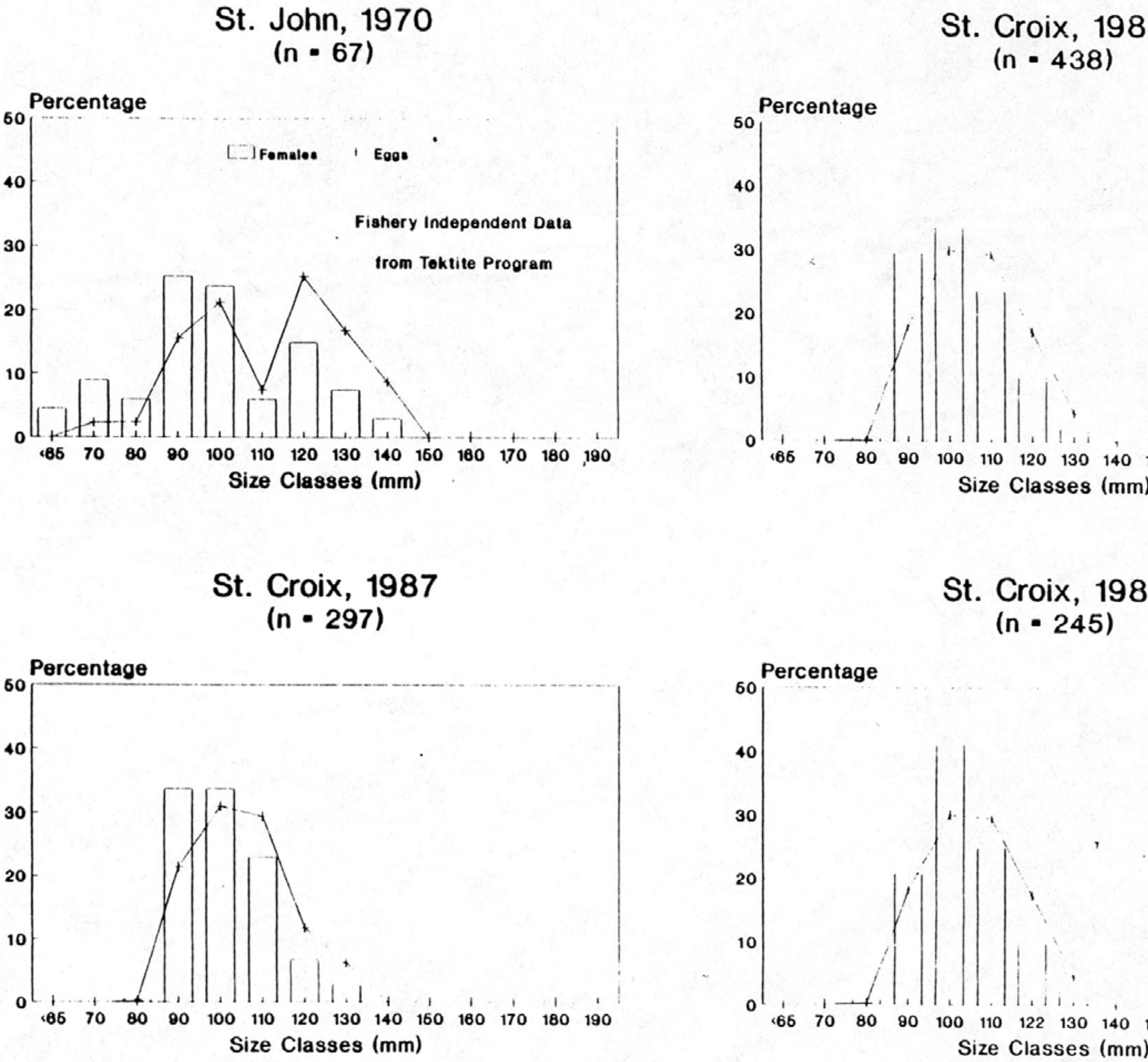
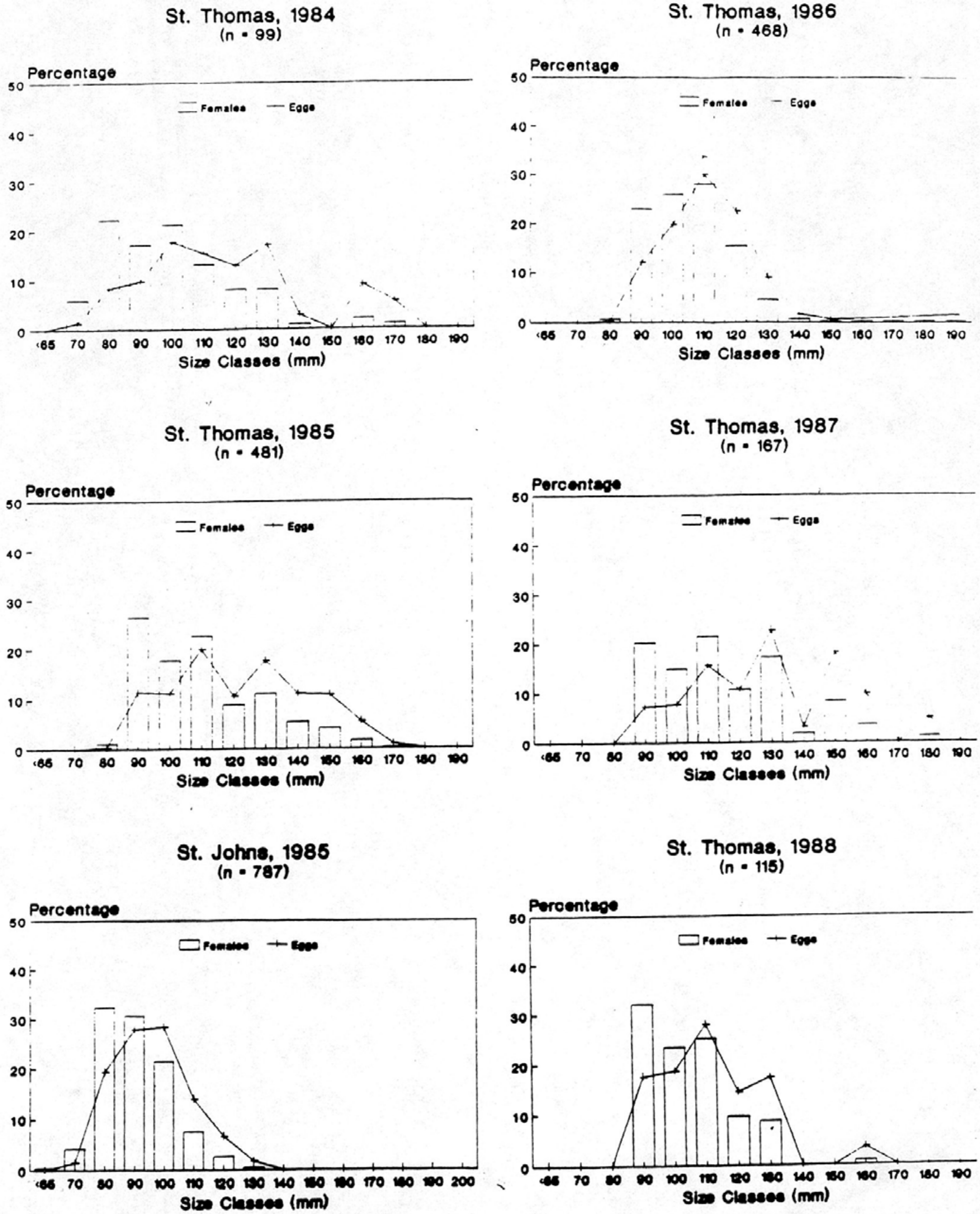

St. John, 1970
(n = 67)
Percentage
Females
Eggs
Fishery Independent Data
from Tektite Program
50
40
30
20
10
0
<65 70 80 90 100 110 120 130 140 150 160 170 180 190
Size Classes (mm)
St. Croix, 198
(n = 438)
Percentage
<65 70 80 90 100 110 120 130 140
Size Classes (mm
St. Croix, 1987
(n = 297)
Percentage
<65 70 80 90 100 110 120 130 140 150 160 170 180 190
Size Classes (mm)
St. Croix, 198
(n = 245)
Percentage
<65 70 80 90 100 110 122 130 140
Size Classes (mm)

Figure 10



St. Thomas, 1984
(n = 99)
Percentage
Females
Eggs
Size Classes (mm)
St. Thomas, 1986
(n = 468)
Percentage
Females
Eggs
Size Classes (mm)
St. Thomas, 1985
(n = 481)
Percentage
Females
Eggs
Size Classes (mm)
St. Thomas, 1987
(n = 167)
Percentage
Females
Eggs
Size Classes (mm)
St. Johns, 1985
(n = 787)
Percentage
Females
Eggs
Size Classes (mm)
St. Thomas, 1988
(n = 115)
Percentage
Females
Eggs
Size Classes (mm)