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Fishery gear interactions from stranded bottlenose dolphins, Florida manatees and sea turtles in Florida, U.S.A

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ABSTRACT

Documenting the extent of fishery gear interactions is critical to wildlife conservation efforts, especially for reducing entanglements and ingestion. This study summarizes fishery gear interactions involving common bottlenose dolphins (*Tursiops truncatus truncatus*), Florida manatees (*Trichechus manatus latirostris*) and sea turtles: loggerhead (*Caretta caretta),* green turtle *(Chelonia mydas),* leatherback (*Dermochelys coriacea),* hawksbill (*Eretmochelys imbricata)*, Kemp's ridley (*Lepidochelys kempii),* and olive ridley (*Lepidochelys olivacea*) stranding in Florida waters during 1997–2009. Fishery gear interactions for all species combined were 75.3% hook and line, 18.2% trap pot gear, 4.8% fishing nets, and 1.7% in multiple gears. Total reported fishery gear cases increased over time for dolphins ($p < 0.05$), manatees ($p < 0.01$), loggerheads ($p < 0.05$) and green sea turtles ($p < 0.05$). The proportion of net interaction strandings relative to total strandings for loggerhead sea turtles increased ($p < 0.05$). Additionally, life stage and sex patterns were examined, fishery gear interaction hotspots were identified and generalized linear regression modeling was conducted.

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1. Introduction

Entanglement of non-targeted species in traps, snares, fishing gear, etc. is of growing concern for wildlife worldwide (Kirkwood et al., 1997; Reeves et al., 2003; Anderson et al., 2011; Dau et al., 2009; Becker et al., 2013). Fishery gear, most notably monofilament and micro-multifilament lines, trap pot lines, and nets, has been documented as the most significant source of entanglements for sea turtles, marine mammals, coastal and marine birds, fish and crabs (Laist, 1997). Read et al. (2006) suggests that entanglement in fishery gear poses the single greatest threat to many populations of marine mammals in the United States and elsewhere in the world, with global by-catch totaling in the hundreds of thousands. Large marine vertebrates can be particularly vulnerable to fishery gear impacts due to their slow growth rates and low fecundity (Musick, 1999; Read, 2000; Cox et al., 2003).

Wallace (1985) speculated that wildlife become entangled during: (1) accidental encounters in which the objects or gear are not perceived; (2) indiscriminate/opportunistic occasions in which the object cannot be distinguished from an appropriate natural object; or (3) deliberate situations resulting from curiosity, foraging or investigation of a novel object. Impacts from entanglement can include: death or injury including loss of normal swimming ability or mobility, strangulation, suffocation and reduced growth, fitness or fecundity (Laist, 1996, 1997; Knowlton and Kraus, 2001; Marine Mammal Commission, 2001; Wells et al., 2008; Benjamins et al., 2012). Ingested fishing gear can also affect feeding abilities, decrease feeding resulting in starvation, and obstruct normal passage of food through the digestive tract or introduce toxic chemicals into tissue (Barros et al., 1990; Laist, 1997; Clapham et al., 1999; Moore and Clarke, 2002; Moore, 2008; Cassoff et al., 2011; Stolen et al., 2013). Furthermore, gear can be carried for several years (Moore et al., 2006; Van der Hoop et al., 2013), with the associated drag resulting in chronic entanglement injuries

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(Feldkamp, 1985; Clapham et al., 1999), increased energy requirements and expenditures (Feldkamp, 1985; Kraus et al., 2001), and/or extensive injuries that eventually lead to embedment (Moore et al., 2004) or self-amputation (U.S. Fish and Wildlife Service, Manatee Rescue, Rehabilitation and Release Database, Unpublished data; Balazs, 1985; Heyning and Lewis, 1990).

The state of Florida, U.S.A., has been dubbed "The Recreational Fishing Capital of the World," and has one of the greatest populations of saltwater recreational anglers in the United States (U.S. Department of the Interior, 2011). Over 1 million recreational licenses are sold annually in Florida, with sales increasing by around 1% annually since fiscal year 2002 (Freitas, 2009; Hanson and Sauls, 2011). Commercial fishing in Florida is also extensive, encompassing a variety of target species, including some 218 species of finfish, 41 species of invertebrates and numerous gear types (Florida Fish and Wildlife Conservation Commission, http://myfwc.com/research/saltwater/fishstats/commercial-fisheries/faq/, accessed 30.06.13). Commercial fishing is Florida's second largest contributor to the state economy, generating $217 million USD in in-state sales and supporting 64,744 jobs (National Marine Fisheries Service, 2011).

A comprehensive assessment of fishery gear interactions (e.g., entanglement and ingestion) for wildlife species in Florida has not been published. Documenting interactions across coastal megafauna, including an in-depth understanding of prevalent gear types, is critical for future conservation efforts. The focus of this study was on protected species megafauna, including common bottlenose dolphins (*Tursiops truncatus truncatus*), Florida manatees (*Trichechus manatus latirostris*) and sea turtles (loggerhead (*Caretta caretta*), green turtle (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricata*), Kemp's ridley (*Lepidochelys kempii*), and olive ridley (*Lepidochelys olivacea*) stranding along the Florida coast from 1997 to 2009. The aims of this study were to: (1) summarize fishery interaction records involving hook and line gear, trap pot gear, and nets; (2) evaluate and identify geographic "hot spots" for fishery gear interactions and seasonal trends in coastal and inland waters; (3) analyze annual fishery gear interactions by gear type and animal life stage; and (4) recommend potential solutions to reduce fishery gear impacts on Florida marine wildlife.

2. Materials and methods

2.1. Stranding data

Stranding data for bottlenose dolphins, Florida manatees, and sea turtles were obtained from four databases: National Marine Fisheries Service (NMFS) Marine Mammal Health and Stranding Response Database, Florida Fish and Wildlife Conservation Commission (FWC) Manatee Mortality Database, U.S. Fish and Wildlife Service (USFWS) Manatee Rescue and Rehabilitation Database, and the Sea Turtle Stranding and Salvage Network (STSSN) Database. Data collection for each database has improved over the years due to increased reporting, public education and outreach, and expansion of program infrastructure. Specific information regarding data collection and management of each database is available from the respective agencies. Data records used in the present study were those associated with stranded[1] or rescued individuals (i.e., injured, sick or dead animals found floating or washed ashore). To maintain consistency between each database, cases where animals were caught in research gear and those where sea turtles were reported or caught directly in active fisheries or on hook and line and reported by fishermen were not included in this analysis. Strandings in Florida during 1997–2009 were sorted to only include cases that had fishery gear on or in their body at the time of the stranding or during necropsy. Records were examined by coast using −80.5° longitude as the dividing line between the Atlantic and Gulf of Mexico (used by NMFS for categorizing STSSN data).

Due to the limited cases of known sex for stranded sea turtles and the difficulties in determining life stage for many stranded sea turtles (there are large overlaps in sizes of immature and mature sea turtles), only dolphins and manatees were analyzed by sex and life stage. Approximate dolphin life stages were based on straight length measurements and defined as: calf: <200 cm; sub-adult: ⩾200 to <240 cm; and adult: ⩾240 cm, recognizing that there is much variability in body length relative to age (personal communication, Wells; Read et al., 1993). Manatee life stage was determined from straight length measurements and defined as: calf <235 cm; juvenile 235–264 cm; and adult >264 cm (Bonde et al., 2012).

For the purpose of this study we defined fishery gear interactions to include those strandings that involved entanglement or ingestion of fishery gear. Fishery gear was divided into four categories: (1) hook and line (HL) – entanglement in, or ingestion of, fishing line (monofilament or multifilament), fishing hooks, lures, weights, and/or jigs; (2) trap pot gear (TPG) – entanglement in any part of a trap pot, most typically the buoy line; (3) fishing net (FN) – entanglement in any type or size (whole or partial) of fishing net; and (4) multiple gear – any combination of the aforementioned gear categories. Non-fishery gear cases (i.e., unidentified rope, plastic straps, marine debris) and those cases where strandings occurred without attached gear and/or possessing marks/scars consistent with fishery gear interactions were excluded from this analysis. Cases of external entanglements were further divided into four categories indicating gear location on the animal: (1) body (any part of the head, neck, shell, torso, dorsal fin, peduncle, or tail); (2) flippers; (3) multiple locations (signifying the combination of entanglements on multiple parts of the animal); and (4) unknown locations (records where fishery gear location was not reported). Cases of gear being ingested were divided into two categories depending on whether or not they were externally detectable: (1) gear in mouth or protruding from mouth, anus, or cloaca (detectable without a necropsy); and (2) gear in GI tract but not in mouth or protruding from mouth, anus, or cloaca (detectable only during necropsy).

2.2. Statistical analysis

Generalized linear regression models (GLMs) (R Core Team, 2013) were used to examine temporal trends in fishery gear interaction strandings. Residual diagnostics, AIC (Akaike, 1974), and goodness-of-fit tests were used to select the appropriate functional fit to the data for each species. Because observation effort was unknown, the proportion of strandings with fishery gear interactions to total strandings was compared through time as a proxy for interaction rate. These comparisons were made across species, sexes, and life stages using beta regressions for proportional data in R (R Core Team, 2013); comparisons were also made for the Atlantic and Gulf coasts. To examine spatial trends in strandings, we performed kernel density analyses (cell size = 30, 11 natural breaks: Jenks classification; ArcMap 10.1) for HL and TPG interactions for each animal group. For manatees and dolphins, G-test analyses (PopTools 3.2: Build 5) were completed to determine if stranded animals with gear had similar life stage/sex ratios as compared to animals that stranded without evidence of gear interactions (non-interaction animals only). Animals in which a human-interaction could not be determined were excluded from the analyses. For these analyses, animals were also broken down by life stage (e.g., calf, juvenile, adult). To explore the seasonal dynamics of interaction observations, we applied GLM time-series modeling methods implemented in SAS v9.3. Generalized and high/low treatments season were evaluated for each species group. Generalized seasonal assignments were based on life history

[1] 16 U.S.C § 1421h(3) (2013).

patterns for dolphins (Season 1: December–January; Season 2: Feburary–March; ...; Season 6: October–November), manatees and all sea turtle species combined (Season 1: December–Feburary; Season 2: March–May; ...; Season 4: September–November). High/low seasonal models compared summer/fall entanglements to winter/spring for dolphins, manatees, and all sea turtle species. High/low seasonal assignments were also based on life history patterns for dolphins (High: May–September), manatees and sea turtles (High: April–October).

3. Results

During 1997–2009, a total of 25,138 strandings were reported in Florida for all three animal groups including 2413 dolphins, 4962 manatees, and 17,763 sea turtles (9950 loggerheads, 5347 green turtles, 1346 Kemp's ridleys, 362 hawksbills, 304 leatherbacks, 3 olive ridleys, and 451 unidentified sea turtles). Of these, 1582 (6.3%) cases were identified as fishery gear interactions, including: 132 dolphins, 380 manatees, and 1070 sea turtles (418 loggerheads, 481 green turtles, 69 Kemp's ridleys, 30 hawksbills, 43 leatherbacks, 1 olive ridley, and 28 unidentified sea turtles) (Table 1). Due to the low number of olive ridley strandings ($N = 3$), the proportion of cases for this species involving each gear type were not given. Fishery gear interactions for all species combined were 75.3% hook and line ($n = 1192$), 18.2% trap pot gear ($n = 288$), 4.8% fishing nets ($n = 75$), and 1.7% in multiple gears ($n = 27$).

Fishery gear interactions for dolphins consisted of 73.5% hook and line, 20.5% trap pot gear, 3.0% fishing nets, and 3.0% multiple gear. Fishery gear interactions for manatees consisted of 76.3% hook and line, 21.9% trap pot gear, 1.3% fishing net, and 0.5% multiple gear, while interactions for sea turtles consisted of 75.2% hook and line, 16.6% trap pot gear, 6.2% fishing net, and 2.0% multiple gear. Dolphin gear interactions were comprised of 36.3% adults, 33.9% calves, 23.6% sub-adults, and 6.2% unreported life stage. Dolphin sex category composition included 53.0% males, 33.3% females and 13.6% unreported sex. Stranded manatees known to interact with fishing gear at all life stages and sex categories remained stable over time. The manatee life stage composition was 48.4% adults, 27.6% calves, 19.8% juveniles, and 4.2% unreported life stage, while the sex category composition included 56.0% females, 30.3% males, and 13.7% unreported sex. Records indicated that 14.2% of manatees stranded with fishery gear also showed evidence of previous gear interactions; these comparative data were not consistently reported for dolphins or sea turtles.

The number of reported fishery gear interaction cases for dolphins ($p < 0.05$), manatees ($p < 0.01$), loggerheads ($p < 0.05$), and green turtles ($p < 0.05$) increased over time; no significant trends were detected for the other species of sea turtles. Beta regression analyses were used to evaluate temporal trends in the proportions of gear interaction strandings for each gear type relative to total strandings, for each species. Proportions of fishery gear interactions relative to total strandings were also evaluated by life stage and sex category for dolphins and manatees. The proportion of fishery gear interaction strandings to total strandings significantly increased through time for dolphins ($p < 0.05$), primarily due to increases on the Gulf coast ($p < 0.01$). By contrast, the proportion of fishery gear interaction strandings to total strandings significantly decreased through time for leatherback sea turtles ($p < 0.05$). These proportions increased for adult dolphins ($p < 0.05$); when considered separately, the proportion for female dolphins also significantly increased ($p < 0.01$), but no significant trend was observed for males.

3.1. Hook and line

No significant trends were observed in HL gear interaction observations for dolphins, manatees, or sea turtles. Proportions of stranded animals found with HL gear by species were dolphin (4.0%), manatee (5.8%), green turtle (7.7%), hawksbill (6.1%), Kemp's ridley (4.2%), loggerhead (3.1%), and leatherback (1.6%). External HL entanglements were most commonly found on the body for dolphins (55.3%), and flippers for manatees (77.3%) and sea turtles (55.7%). In addition, 22 dolphin cases, 4 manatee cases, and 207 sea turtle cases exhibited HL gear in the mouth or protruding from the anus or cloaca. HL gear in the GI tract was reported for 215 out of 4,097 (5.2%) manatee carcasses, 118 out of 1687 (7.0%) sea turtles carcasses, and in 54 of 1404 (3.8%) dolphin carcasses.

G-tests indicated that adult male dolphins had significantly higher HL gear stranding interactions than would be expected if strandings were independent of sex, life stage, and fishery gear ($p < 0.01$, Fig. 1A). G-tests also indicated that adult manatees had significantly higher HL gear stranding interactions than would be expected if strandings were independent of life stage and fishery gear ($p < 0.01$, Fig. 1B). Additionally, the proportion of female manatees stranded with HL gear was greater than expected, and the proportion of males stranded with HL gear was less than expected if strandings with HL gear were independent of sex ($p < 0.01$).

Overall, HL interaction hotspots on the Atlantic coast occurred in the central east to southeast coastal, Intracoastal Waterway, and inland Florida waters, while hotspots on the Gulf coast were less evident. Dolphin (Fig. 2A) and manatee (Fig. 2C) hotspots were more centralized than those for sea turtles (Fig. 2E).

3.2. Trap pot gear

Beta regression analyses indicated a decreasing trend ($p < 0.05$) in the proportion of TPG interaction strandings relative to total strandings for Kemp's ridley sea turtles; however, only seven turtles were observed stranded in TPG and over-interpretation of this trend should be avoided. No significant trends in the proportions of TPG interaction strandings relative to total strandings were observed for other species. The overall percentages of stranded animals found with TPG gear by species were: dolphins (1.1%), manatees (1.7%), leatherback (11.8%), loggerhead (0.9%), green turtle (0.8%), hawksbill (0.8%) and Kemp's ridley (0.7%). External TPG entanglements most commonly occurred on the body (in particular the fluke/peduncle insertion) for dolphins (55.6%), and on flippers for manatees (37.3%) and sea turtles (39.6%). Additionally, two dolphin cases showed TPG (buoy line) in the mouth during external examination; upon further investigation from necropsy reports, an escape ring from TPG was identified in the GI tract of one of these dolphins. There were no cases of TPG ingestion in manatees or sea turtles.

No significant differences were found between life stage of female or male dolphins interacting with TPG when compared to life stage of dolphins not interacting with gear. When the ratio of manatee female and male TPG related-strandings were compared to the non-interaction female and male ratio, the proportion of females entangled in TPG was statistically greater than expected and males were statistically less than expected ($p = 0.002$). Furthermore, results showed that the ratio of stranded adult and juvenile female manatees that interacted with TPG gear were statistically greater when compared to the ratio of stranded non-interaction female manatees ($p < 0.01$). No significant differences were found between the life stage of stranded TPG and non-interaction male manatees.

TPG entanglement hotspots occurred in various locations throughout Florida depending on the animal group. TPG hotspots for dolphins (Fig. 2B) and manatees (Fig. 2D) were again found in discrete locations, while sea turtle hotspots (Fig. 2F) encompassed more counties throughout the state.

3.3. Fishing net

Beta regression analyses indicated the proportion of net interaction strandings relative to total strandings for loggerhead sea

Table 1
Total number of fishing gear interaction cases for each species.

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
Sea turtles (Chelonioidea spp.)														
Loggerhead (Caretta caretta)														
Hook and line	16	19	18	12	21	24	37	24	31	26	25	16	37	306
Trap pot gear	13	4	7	3	3	9	10	0	2	8	7	3	8	77
Fishing nets	0	0	1	1	0	0	3	6	2	5	1	4	3	26
Multiple gear	1	0	0	1	2	2	1	1	0	0	0	0	1	9
Total	30	23	26	17	26	35	51	31	35	39	33	23	49	418
Green (Chelonia mydas)														
Hook and line	32	30	28	24	21	27	46	24	32	33	32	31	50	410
Trap pot gear	2	4	2	2	3	6	0	1	1	3	5	4	7	40
Fishing nets	1	2	1	7	0	1	2	1	2	2	3	1	1	24
Multiple gear	0	0	1	0	0	0	0	0	0	1	1	0	4	7
Total	35	36	32	33	24	34	48	26	35	39	41	36	62	481
Leatherback (Dermochelys coriacea)														
Hook and line	2	0	0	0	2	0	1	0	0	0	0	0	0	5
Trap pot gear	2	3	2	3	2	5	6	1	1	3	3	3	1	35
Fishing nets	0	0	0	0	0	0	0	2	0	0	0	0	0	2
Multiple gear	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Total	4	3	2	3	4	5	7	4	1	3	3	3	1	43
Hawksbill (Eretmochelys imbricata)														
Hook and line	2	2	1	0	1	0	1	2	2	0	3	7	1	22
Trap pot gear	1	0	0	1	0	0	0	0	0	0	1	0	0	3
Fishing nets	0	2	0	0	0	0	0	2	0	1	0	0	0	5
Multiple gear	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	3	4	1	1	1	0	1	4	2	1	4	7	1	30
Kemp's ridley (Lepidochelys kempii)														
Hook and line	1	1	5	5	6	7	5	0	4	5	5	3	9	56
Trap pot gear	1	3	0	0	0	1	0	0	0	1	0	1	0	7
Fishing nets	0	1	0	0	0	0	0	0	0	1	0	2	0	4
Multiple gear	0	0	0	0	0	0	0	0	0	2	0	0	0	2
Total	2	5	5	5	6	8	5	0	4	9	5	6	9	69
Olive ridley (Lepidochelys olivacea)														
Hook and line	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trap pot gear	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fishing nets	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Multiple gear	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Unidentified sea turtle species														
Hook and line	1	0	1	1	1	0	0	0	1	0	0	0	1	6
Trap pot gear	4	1	1	0	0	0	1	1	0	3	3	1	1	16
Fishing nets	0	0	1	0	1	0	0	0	1	1	0	0	0	4
Multiple gear	0	0	1	0	0	0	0	0	0	1	0	0	0	2
Total	5	1	4	1	2	0	1	1	2	5	3	1	2	28
Florida manatees (Trichechus manatus latirostris)														
Hook and line	9	13	20	17	25	20	25	27	32	27	18	31	26	290
Trap pot gear	4	7	4	3	4	4	10	8	6	4	11	13	5	83
Fishing nets	1	1	0	1	0	0	0	0	0	1	0	0	1	5
Multiple gear	0	0	0	0	0	0	0	1	0	0	1	0	0	2
Total	14	21	24	21	29	24	35	36	38	32	30	44	32	380
Bottlenose dolphins (Tursiops truncatus truncatus)														
Hook and line	3	2	4	4	11	7	11	7	5	16	9	13	5	97
Trap pot gear	2	4	1	0	1	3	1	3	1	2	3	4	2	27
Fishing nets	0	0	1	1	0	1	0	1	0	0	0	0	0	4
Multiple gear	0	0	1	0	0	0	0	0	0	1	0	2	0	4
Total	5	6	7	5	12	11	12	11	6	19	12	19	7	132

turtles was increasing ($p < 0.05$); no significant trends were observed for other species. External FN entanglements were most commonly found on the body for dolphins (66.7%) and manatees (40.0%), and on the flippers for sea turtles (26.4%). Based on external examination, one stranded dolphin was found to have fishing net in the mouth. Upon further investigation from necropsy reports, 1 out of 4097 manatees and 1 of 1404 dolphins were observed with net in the GI tract. Although FN entanglements were found to occur throughout the state, only one hot spot region was documented on the central east coast, from Volusia to Martin counties, encompassing 47.7% of all FN strandings.

3.4. Multiple gear

No significant trends were observed for multiple gear entanglement observations on manatees, dolphins or sea turtles. External multiple gear entanglements for all species combined were on: flippers (45.8%), the body (20.8%), multiple locations (16.7%), or unreported locations (16.7%). Based on external examination, one sea turtle case reported multiple gear types in the mouth and from internal examination (at necropsy) one case was reported with multiple gears in the GI tract. There was no obvious hotspot for multiple gear entanglement strandings.

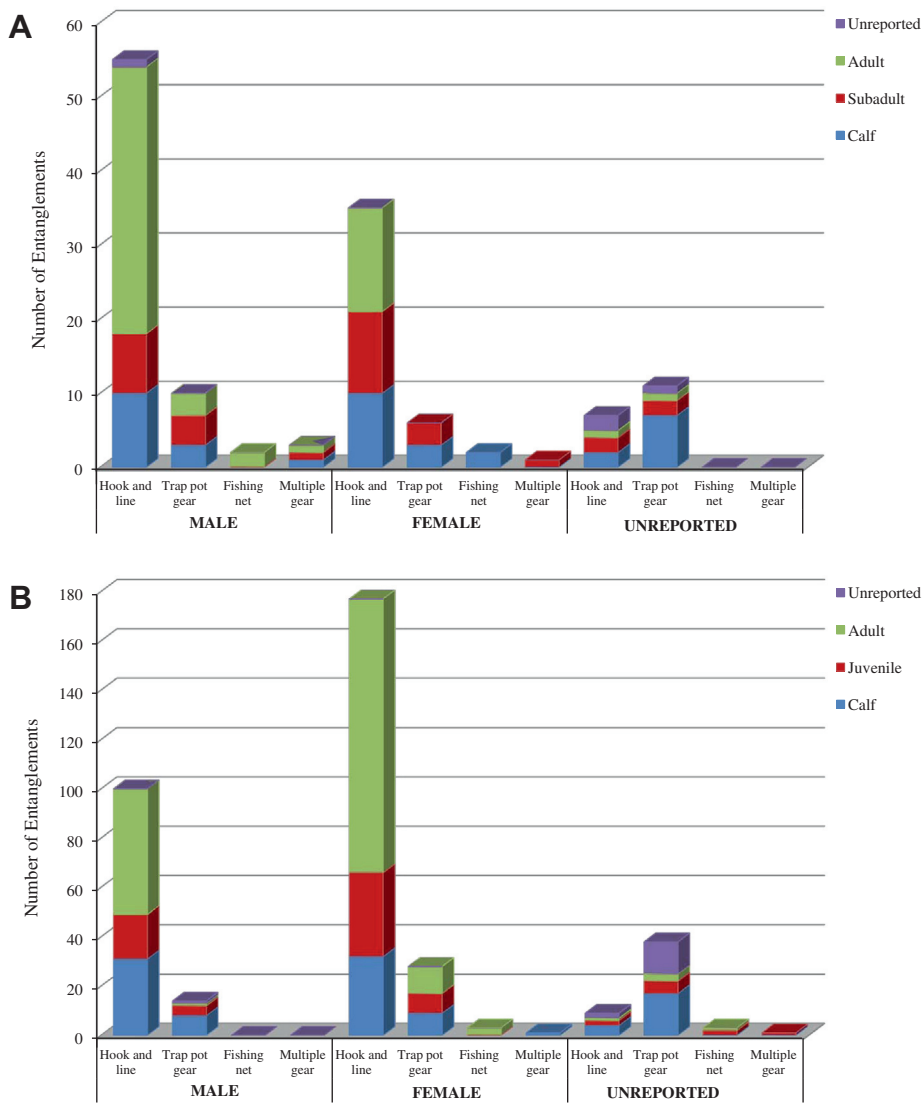

Fig. 1. Number of (A) bottlenose dolphin and (B) Florida manatee interactions in the state of Florida, USA throughout 1997–2009, categorized by gear type, life stage, and sex.

3.5. Seasonal analysis

Regression fits for generalized seasons were relatively poor. Regression modeling for the high/low seasons suggested more fishery gear interactions in summer/fall than in winter/spring for HL entangled dolphins (Fig. 3A, $R^2 = 0.34$), manatees (Fig. 3B, $R^2 = 0.38$), and sea turtles (Fig. 3C, $R^2 = 0.84$). In all cases, observed interactions were increasing across years (dolphins: $\beta_{year} = 0.0923$, $\chi^2 = 7.45$, $p < 0.01$; manatees: $\beta_{year} = 0.\ 0553$, $\chi^2 = 8.36$, $p < 0.01$; sea turtles: $\beta_{year} = 0.0285$, $\chi^2 = 4.85$, $p < 0.05$). Visual inspection of the residuals suggests that the rate of increase for dolphins and sea turtles may have been reduced since the early 2000s.

4. Discussion

The annual numbers of fishery gear interactions for dolphins, manatees, loggerheads, and green turtles have increased throughout the time series. This trend may be the result of several factors, including changes in: fishing activities both inside and outside of Florida, species behavior and habitat use, education and outreach, case reporting from the public, data collection and the overall effort in stranding response. However, there was no change over time in observed cases for hawksbills, Kemp's ridleys, and leatherbacks, which are less frequently encountered turtle species in Florida.

Fishery gear interactions are a result of either a passive or active interaction. Passive interaction is defined when an animal is free-swimming in the environment, not actively interacting with the gear and becomes entangled. These entanglements may occur simply by accident when an animal swims into line, while foraging near projections that snag and accumulate gear or accidental ingestion of free-swimming prey possessing hooks and/or line that broke from a fisher's rig. Active interaction is when an animal actively engages with the fishing gear, possibly to obtain food or investigating a novel object. These entanglements can occur during scavenging, begging, or depredating (i.e., taking baited hooks or taking catch on hooks) from fishers (Cannon et al., 1994; Rudloe and Rudloe, 2005; Zollett and Read, 2006; Powell and Wells, 2011).

For dolphins, manatees, and sea turtles, it appears that behavior plays a role in some portion of the cases of reported entanglement interaction (Laist, 1996). Natural foraging strategies (passive interaction) may predispose manatees and sea turtles to entanglements, while depredation (active interaction) is likely contributing to both dolphin and sea turtle entanglements. Furthermore, manatees are extremely tactile and the exploration of their surrounding

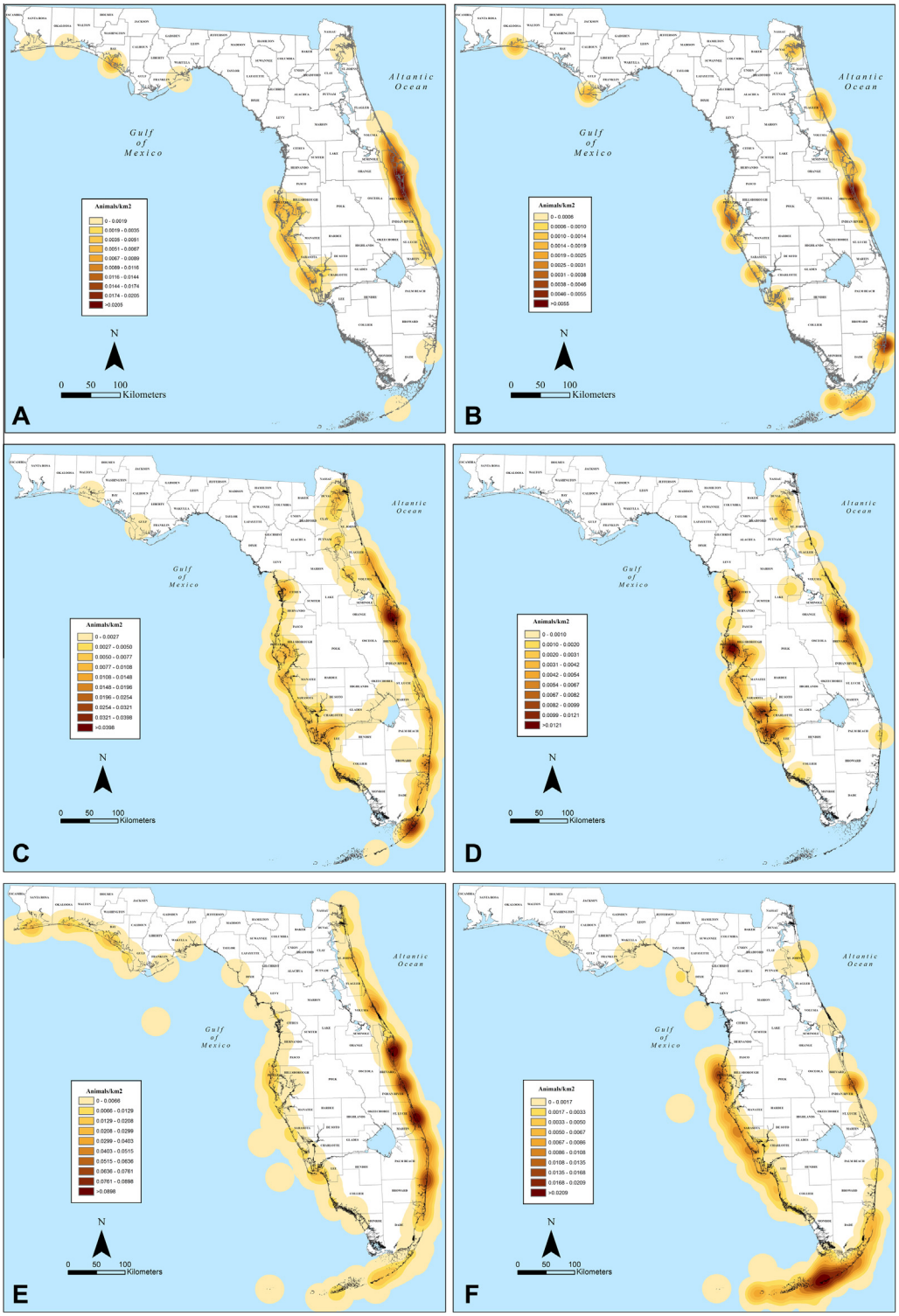

Fig. 2. Kernel density analysis on hook and line gear hot spots for (A) bottlenose dolphins, (C) Florida manatees, and (E) sea turtles. Kernel density analysis on trap pot gear hot spots for (B) bottlenose dolphins, (D) Florida manatees, and (F) sea turtles.

environment may also be a contributing factor in the likelihood of becoming entangled (Reep and Bonde, 2006).

4.1. Hook and line

The most commonly observed fishery gear found among all species in this study was hook and line. This is not surprising due to the high volume of hook and line based fisheries in the study area (U.S. Department of the Interior, 2011) and the implementation of the Florida Net Ban Amendment[2], which severely limited commercial net fishing is state waters (see Section 4.3).

The majority of external HL cases for all species combined were located around a flipper or on multiple locations on one animal;

[2] Art. X, § 16, FLA. CONST.

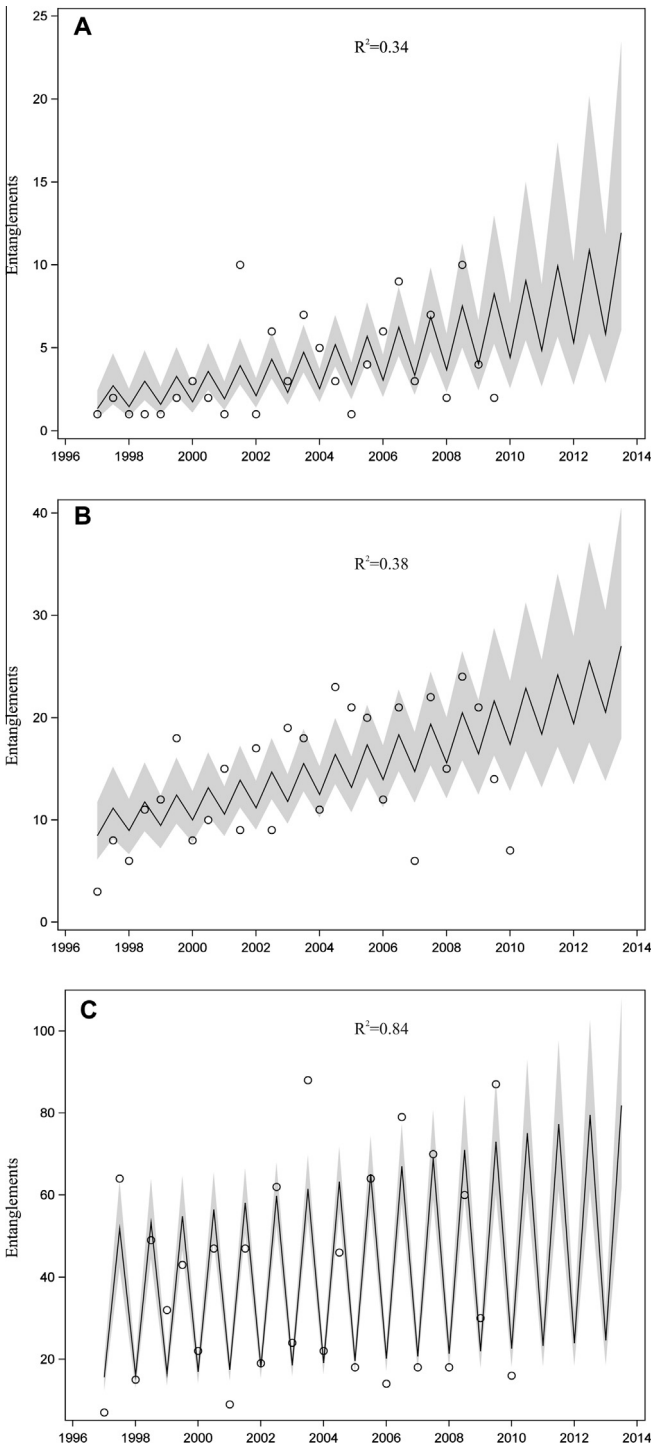

Fig. 3. Generalized linear regression model fit (black line) to (A) bottlenose dolphins, (B) Florida manatees, and (C) sea turtles hook and line, high-low season entanglement observation data (circles) with 95% confidence limits (gray bands).

however, differences in HL entanglement locations appeared when animal groups were assessed individually. Multiple entanglements on one animal may indicate individual propensities to elicit specific behaviors which promote entanglement. Previous entanglement scars are also susceptible to additional entanglements (USFWS Manatee Rescue, Rehabilitation and Release Database). For example, flipper entanglements were greatest in sea turtles and manatees, whereas dolphins had a greater incidence of entanglements on the peduncle or flukes, specifically at the fluke insertion. Entanglements for all species occurred on appendages which are used for navigation, propulsion, and/or maneuvering (i.e., are in motion relative to the animal).

4.1.1. Dolphins

The majority of fishery-related stranded dolphins in Florida were impacted by HL gear. Adult male dolphins had a greater number of HL interactions than expected. This finding is consistent with other literature, suggesting that males are more likely to engage in fisheries interactions such as depredation (Lopez et al., 2002; Kock et al., 2006; Brotons et al., 2007; Powell and Wells, 2011). Depredation is a foraging strategy that can be easily exploited by a single animal, thus lending itself to fit well with male life history patterns and behavior since adult males tend to travel by themselves or in pairs more often than females (Powell and Wells, 2011).

Dolphins may ingest gear during unnatural foraging behaviors, such as depredation or scavenging (Powell and Wells, 2011). Over 50 cases reported HL gear either ingested or entangled orally, suggesting dolphins may be actively interacting with fishing lines, resulting in gear ingestion/entanglement and oftentimes death (Gorzelany, 1998; Wells et al., 2008).

Popular recreational fishing spots can overlap with prime feeding habitat for dolphins, as both fishers and dolphins often hunt for the same fish species, resulting in spatial–temporal conflicts (Finn et al., 2008). Furthermore, despite the illegality of feeding wild dolphins in the U.S., some boaters, fishers, and the general public continue to engage in this behavior in many places around Florida and worldwide (Samuels and Bejder, 2004; Cunningham-Smith et al., 2006). Illegal feeding attracts dolphins to boats and over time, some individuals will learn to seek out fishers as a means of obtaining food (Powell and Wells, 2011). This behavior is further reinforced each time a fisher or boater intentionally feeds a dolphin, or unintentionally feeds an animal by releasing non-targeted or undersized fish near a dolphin. Since dolphins are social learners and can learn depredation and scavenging behaviors from other dolphins (especially calves from their mothers), these behaviors are likely to increase in heavily populated coastal areas (Nowacek, 2002; Mann and Sargeant, 2003; Wells, 2003).

4.1.2. Manatees

Entanglements are known to occur regularly for manatees (Forrester et al., 1975; O'Shea et al., 1985; Beck and Barros, 1991; USFWS Manatee Rescue, Rehabilitation and Release Database, Unpublished Data). Derelict gear, such as hooks and line, often snags and accumulates on natural and man-made objects in nearshore environments where manatees often reside, increasing their susceptibility to entanglement. In this study, manatees had a high incidence of ingestion cases likely due to their feeding behavior. We suggest manatees incidentally ingest fishery gear during indiscriminate foraging in shallow habitats (e.g., mangroves, seagrass, foliage debris patches, seagrass drift mats) where debris can accumulate and become entwined in the food resources (i.e., submerged, natant and emergent plants and algae) (Best, 1981). Ingestion of fishing gear can cause impaction, peritonitis, intussusception (Beck and Barros, 1991) and other indirect effects.

Active and passive tactile sensitivity, mediated by sinus hairs, provides manatees with a sensory system suited for murky habitats (Marshall et al., 2000; Reep et al., 2002; Marshall et al., 2003). Visual and chemical limitations (Marshall and Reep, 1995; Reep et al., 2002; Bauer et al., 2003; Reep et al., 2011) may require manatees to be in close proximity or physically touching an object in order to gain extensive information about the object. HL entanglement for most manatees is likely passive and accidental, due to transparency of thin lines and the poor visual acuity described for manatees (Bauer et al., 2003; Gaspard et al., 2012). Furthermore, manatees may have limited tactile ability necessary to detect finer

objects, such as monofilament, until it is actually wrapped around a flipper, leading to a greater chance of entanglement and constriction (Bauer et al., 2012).

Entanglement observations were less common among manatee calves, as compared to juvenile and adult manatees, which are generalist feeders known to consume approximately 60 different species of vegetation in marine, estuarine, and freshwater habitats (Hartman, 1979; Bengtson, 1983) and spend a significant portion of their day feeding. Entanglement of calves could be low due to nursing, thus reducing the chances of gear interactions during foraging. As suggested for other species, the high incidence of entangled juvenile manatees may be attributed to general inexperience (Dau et al., 2009), their inquisitive and curious disposition (Pemberton et al., 1992; Page et al., 2004), or unrefined motor skills (Fertl and Leatherwood, 1997; Wells et al., 1998).

4.1.3. Sea turtles

Overall, about 5% of the stranded sea turtles documented during the study period were observed with either fishing line or a fishing hook. This rate of occurrence was similar to that found in some studies (3–7%; Plotkin and Amos, 1988; Chaloupka et al., 2008), but much lower than that of other studies (about 20–50%; Oros et al., 2005; Casale et al., 2010). We suspect the turtles in the present study primarily interacted with HL gear from recreational fishing or commercial charter fishing, as was often evidenced by the lightweight nature of the gear that was found on the turtles. We believe that the stranded sea turtles found in Florida probably under-represented interactions with most commercial HL gear. Pelagic and bottom longline commercial fisheries are known to incidentally capture large numbers of sea turtles in the southeastern U.S. (Lewison et al., 2004; Finkbeiner et al., 2011), but these fisheries are prohibited in Florida state waters. Sea turtles that interact with these commercial HL fisheries beyond state waters would be less likely to strand along the coast of Florida than those turtles that interact with HL gear from the numerous inshore and nearshore recreational fishing in Florida (see Hanson and Sauls, 2011). The relatively low percentage of stranded leatherbacks in our study with HL gear (1.6%) may corroborate the presumption that we were not likely to document interactions with most commercial HL fisheries. Leatherbacks are regularly captured in longline fisheries (Lewison et al., 2004), but have not been known to be incidentally captured by recreational hook and line fishermen in Florida (FWC, Unpublished data).

Sea turtles are known to ingest baited hooks during feeding. Kemp's ridleys may be the most vulnerable to this interaction (Cannon et al., 1994; Rudloe and Rudloe, 2005). Nevertheless, stranded green turtles in the present study had a higher rate of HL interactions than stranded Kemp's ridleys (7.7% vs. 4.2%, respectively). In addition to ingesting baited hooks, green turtles were more commonly found to ingest and to entangle in fishing line. This may be in part because the green turtle is the only herbivorous species (Bjorndal, 1980), perhaps being particularly susceptible to interactions with fishing line while grazing on seagrass or algae.

4.2. Trap pot gear

While not as prevalent as hook and line entanglements, TPG is a common source of entanglement in Florida. Blue crab, lobster, and stone crab are the most abundant fisheries using trap pot gear in Florida (Florida Fish and Wildlife Conservation Commission, http://myfwc.com/research/saltwater/crustaceans-marine-arthropods/, accessed 23.07.13). For example, in 2009 approximately 16.4 million pounds of shellfish were harvested from commercial fisheries totaling over $45.5 USD million in value (FWC, 2011). The blue crab pot fishery is considered one of the largest commercial fisheries in the state, as crabs are harvested throughout the year and from a variety of nearshore habitats (Steele and Bert, 1998; Steele and Perry, 1990). The most recent estimates value statewide landings at over $10 million USD (Florida Fish and Wildlife Conservation Commission, http://myfwc.com/media/2515034/sumstate_12.pdf, accessed 23.07.12).

TPG is easier to observe on wild animals than HL gear. Many entangled manatees included in this study oftentimes had gear removed in situ versus needing to bring the animal into captivity for additional assistance. We suggest that interaction with TPG is both active and passive for the focal species in this study. TPG was most commonly found on the flippers for turtles and manatees, while it was found most commonly on the body of dolphins. Undocumented locations of gear on animals were also common, and likely due to incomplete reporting. TPG was not found to be ingested by manatees and sea turtles and only two cases for dolphins were reported. This is likely due to the size of the gear and the fact that unlike the transparent nature of monofilament, trap pot rope may be easier to detect in the aquatic environment.

4.2.1. Dolphins

Dolphins likely entangle in the trap pot line accidently, either through passive or active interaction with the trap-pot and line/buoy rig (McFee et al., 2007). Dolphins have been observed feeding around pots (Noke and Odell, 2002), and are believed to be attracted to fish that aggregate around the pot and line/buoy. In some instances dolphins have been observed pot-tipping in an attempt to get at the bait inside the trap (Noke and Odell, 2002; Haymans, 2005). Noke and Odell (2002) suggest that entanglements in TPG may correspond to seasonal pot fisheries and the density of pots in a given area. Noke and Odell (2002) also found that location of the traps played a significant role in the number of crab pot interactions that occurred. In some areas where traps are dense it is possible that dolphins do not detect a buoy line in murky water or waters with strong and/or variable currents. This could lead to an accidental encounter with the buoy line that may entangle on the body or flukes as they attempt an avoidance maneuver. Additionally, McFee et al. (2007) found that the type of buoy line used in the TPG can have implications to the rate of entanglement for dolphins. Unlike other focal species in this study, dolphins commonly entangle around the fluke/peduncle insertion (Burdett and McFee 2004). Once entangled in TPG dolphins may drown due to the weight of the gear, or drag the gear which is energetically costly, and often leads to death or serious injury if not assisted (Wells et al., 2008).

4.2.2. Manatees

Trap pot gear, specifically from the blue crab fishery, is commonly found on manatees. In contrast to fishing line entanglements, which are likely accidental, we hypothesize that the inherent curiosity of manatees is a driving force in many TPG entanglements. Trap pot gear interactions may be the result of active investigation of a novel object that eventually leads to accidental entanglement (Bowles and Anderson, 2012). Captive and wild manatees are often observed exploring their environment in a tactile manner, including fishing gear such as trap pots, floats, nets and various types of line, via mouthing, playing, manipulating with flippers, and rubbing and resting against objects in water, (Bowles et al., 2001; Kikuchi et al., 2011; Williams et al., 2011). Flipper entanglements may also occur when the animal first "feels" the constriction and attempts to free itself. For example, when captive manatees detected trap pot line wrapped around the flipper or body, they spin in an effort to remove the gear, often exacerbating their entanglement (Bowles et al., 2001).

It has also been hypothesized that female manatees use trap line to rub irritated mammary glands (Beck and Barros, 1991), making them more susceptible to entanglements. Furthermore,

teat location could also increase the likelihood of a line getting trapped under the flipper. These suggestions may support why female manatees were found to have a higher rate of entanglement than males. This may also support why flipper entanglements were highest for TPG versus other locations observed on manatees. Juvenile females may entangle in TPG because they lack the force (i.e., size) required to dislodge gear and remain entangled, as hypothesized for some cetacean species (Lien, 1994; Cassoff et al., 2011)

Flipper injuries/scars are common for manatees. For example, current data of photo-documented manatees indicates that a minimum of 24.8% for the northwest region, 17.2% for Atlantic coast region, 15.6% for the Upper St. Johns River region, and 2.5% in the southwest region have flippers injured or missing due to a chronic entanglement incident (Manatee Individual Photo-identification System USGS, Sirenia Project; FWC, Fish and Wildlife Research Institute; Mote Marine Laboratory, Unpublished data). Scar healing properties on manatees may increase entanglement susceptibility over time, as scar tissue in the axilla region of the flipper is more likely to become re-entangled. Additionally, entanglement in fishery gear continues to be one of the major causes for manatee intervention in Florida; the success rate for in situ and captive care cases is high, however, partners expend numerous resources and expense every year to assist each entangled animal (USFWS Manatee Rescue, Rehabilitation and Release Program, Unpublished data). In those cases where intervention does not occur, animals may slowly "self-amputate" from chronic entanglements that cut through tissues and into the bone.

4.2.3. Sea turtles

The percentage of stranded leatherbacks entangled in TPG (always involving the buoy line) was 11.8%, yet was less than 1% for all other species. Entanglement of this particular species in TPG has also been observed in other studies (James et al., 2005; Laporta et al., 2006). Leatherbacks forage more commonly in the water column than the other sea turtle species (Bjorndal, 1997), and this activity likely increases the probability that they encounter the buoy lines of TPG. We expected that loggerheads would have a relatively high rate of TPG entanglement because they are known to directly interact with trap pots in an attempt to feed on the bait or catch inside (Avissar et al., 2009a,b); however, this was not the case. We also found no change in the annual percentage of stranded loggerheads entangled in TPG during our study period despite efforts that were initiated in the 1990s to reduce the numbers of trap pots set for spiny lobsters in Florida (Muller et al., 1997). Trap numbers peaked at 939,000 in 1991, but were reduced to about 500,000 by 2005 (Muller et al., 1997; FWC, Unpublished data).

4.3. Fishing nets

The incidence of reported fishing net interactions was minimal for all species and remained stable over the time series, except for loggerhead turtles which exhibited an increase. This is likely the result of the Florida Net Ban Amendment[3] implemented in Florida waters in 1995 which limited net fishing to bully, frame, dip, seine, and cast nets no larger than 500 square feet of mesh area and prohibited the use of all entangling nets in Florida waters. These net types are generally tended actively by the user, thus likely reducing the chance of entanglement. Furthermore, tended nets may also facilitate the immediate release of an animal by the fisher, and are likely not reported to authorities. When cases were observed and reported, fishing net entanglements were commonly found on the body and flippers.

[3] Art. X, § 16, FLA. CONST.

4.3.1. Dolphins

Dolphins had seven instances of reported net entanglements between 1997 and 2009 which occurred after the 1995 Florida net ban implementation. In states such as North Carolina, with active gill net fisheries, dolphin entanglements continue to be problematic and mitigation methods continue to be explored (Cox et al., 2003; Waples et al., 2013). Fortunately, as evidenced by the stranding record, the net ban in Florida has almost entirely eliminated the impacts of net entanglements for dolphins in near-shore waters. However, these data likely do not illuminate the impacts of federal net-based fisheries, which occur further offshore, as the probability of carcass detection in offshore waters is extremely low (Williams et al., 2011).

4.3.2. Manatees

Manatees had five reported instances of net entanglements after the 1995 Florida net ban. Manatee net entanglements likely still occur in low numbers due to the frequent use of cast nets in shallow, near-shore, coastal manatee habitats, including rivers, spring systems, and open-access lakes. We suggest manatee interaction with FN may be passive or active, depending on the individual and the circumstances. Although visual acuity is poor, some manatees may be able to see nets in the aquatic environment. For example, captive manatees presented with net-like obstacles have been documented swimming more often into these objects during the night, whereas a greater number of avoidance behaviors were recorded during the day (Kikuchi et al., 2011). Active interaction may also occur with FN, in which animals will explore them tactilely as they do with TPG. This activity is likely influenced by the ease at which manatees often travel successfully through surrounding mats of aquatic vegetation while feeding without becoming tangled. Nets may therefore be perceived by manatees as vegetation in the water.

4.3.3. Sea turtles

Only 66 (0.4%) of the stranded sea turtles in the present study were found entangled in fishing nets. There are commercial net fisheries operating in the southeastern U.S. that do incidentally capture sea turtles (Finkbeiner et al., 2011); however, most are prohibited in Florida state waters. We believe this is the most likely reason for the small number of FN interactions documented in the stranded sea turtles from Florida as compared to higher net entanglement rates (range 5–35%) reported in other regions (Plotkin and Amos, 1988; Oros et al., 2005; Chaloupka et al., 2008; Casale et al., 2010). We did note a statistical increase in the number of FN interactions documented among stranded loggerheads during our study period, however, this was minor (from an average of about one documented FN interaction per year to an average of about three FN interactions per year) and may have been a sampling artifact.

4.4. Hot spots

Fishing gear interactions for manatees, dolphins, and sea turtles were found throughout the inland, intracoastal, and coastal waterways of Florida, where these species reside and fishing occurs. The areas of HL fishery interactions occur in a broader range than any other gear type, essentially covering every coastal county. This may be due to the sheer number of fishers, accessibility of fishing grounds and broad habitat use of target species. Aggregate hot spots for fishery gear interactions for all species included: (1) Escambia, Santa Rosa and Bay counties, (2) Hillsborough and Pinellas counties south to Lee County, and (3) Volusia County south to Broward County. Many of these areas are known for their high commercial and recreational HL fishing activities (Florida Fish and Wildlife Conservation Commission, http://myfwc.com/research/saltwater/fishstats/, accessed 23.07.13). Hot spot counties such as St. Lucie, Palm Beach, Martin, Lee, Pinellas, Manatee and

Bay, corresponded with several top counties for commercial finfish landings using HL (Florida Fish and Wildlife Conservation Commission, http://myfwc.com/research/saltwater/fishstats/, accessed 23.07.13). Brevard, Broward, Volusia, Pinellas, Hillsborough, Lee and Palm Beach counties correlate with some of the highest counts of registered boaters in the State of Florida (Florida Department of Highway Safety and Motor Vehicles, http://www.flhsmv.gov/dmv/vslfacts.html, accessed 23.07.13). Brevard County was the only HL hot spot common for all animal groups in this study, which may be explained by the high commercial finfish license sales and landings, as well as registered boaters for this coastal county.

The southwest region may be a hot spot for dolphin fishery HL entanglements due to consistent harmful algal blooms, which have been known to increase levels of depredation due to reduced prey availability (McHugh et al., 2011; Powell and Wells, 2011). As temperatures rise, issues with climate change and global warming may also influence the incidence of this type of stress on the environment. The Florida Keys is a hot spot for manatee HL entanglements. High fishing pressure and extensive shallow environments support the accumulation of excessive amounts of fishery gear around piers, bridges, rocky shorelines, and reefs which may contribute to this location as a hot spot. Furthermore, finfish license sales and commercial landings in Monroe County are consistently among the highest in the state (Florida Fish and Wildlife Conservation Commission, http://myfwc.com/research/saltwater/fishstats/, accessed 23.07.13).

TPG entanglement hot spots were most common in areas with high commercial TPG license sales, such as Pinellas County (Florida Fish and Wildlife Conservation Commission, http://myfwc.com/research/saltwater/fishstats/, accessed 23.07.13). The highest density of blue crab landings for commercial fishers corresponds to several of our identified hot spot areas where landings have been highest including Lee, Charlotte, Brevard, and Monroe counties and to a lesser degree, Citrus and Pinellas counties, which have decreased in recent years (Florida Fish and Wildlife Conservation Commission, http://myfwc.com/research/saltwater/fishstats/, accessed 23.07.13). Brevard County was a hot spot for manatees and dolphins, and to a lesser degree, turtles. Monroe County was a hot spot for dolphins and turtles. This area is consistently among the leaders in commercial trap pot license sales and landings and is the most important area in the state for TPG invertebrate fisheries (Adams, 1992; Florida Fish and Wildlife Conservation Commission, http://myfwc.com/research/saltwater/fishstats/commercial-fisheries/landings-in-florida/, accessed 23.07.13). Citrus County was only a hot spot for manatees. Citrus County holds extensive spring systems where wintering manatees from the northwest region aggregate and has a local economy built around manatee tours, thus increasing opportunities for entanglements to be observed and reported. There were too few documented interactions with FN to identify hotspots with any confidence.

Hot spot information can assist the focus of management actions and prioritize stranding response in areas with high overlaps of fishery actions and where marine fishery debris is known to accumulate (Wallace, 1985; Williams et al., 2011). Data biases for hot spots may be present because stranding records may not accurately reflect where an animal actually became entangled with fishery gear, and regional data may be biased towards areas with high human population were observations and reporting are more common, versus more isolated coastal areas. Additionally, regions with high densities of human population have a greater degree of recreational fishing activity which may contribute to the prevalence of regional fishery interaction cases (Dau et al., 2009).

4.5. Seasonal entanglements

Higher reported interactions with HL gear were observed in the summer/fall season for dolphins, manatees, and sea turtles, which is not surprising, as favorable weather conditions and an influx of tourism leads to the highest commercial and recreational fishing pressure during this period (Farmer, Unpublished data). However, increased stranding observations during the summer/fall period may also be an artifact of reporting, as there are likely more recreational users of beaches and coastal waters who might notice a stranded animal during this time of year.

5. Conclusions and management recommendations

This is the first detailed, comprehensive analysis of fishery gear on/in stranded dolphins, manatees and sea turtles in Florida. Cases reported here are considered minimum estimates based on several natural and human factors including, but not limited to: (1) unreported/unobserved cases, (2) animal accessibility, (3) the mobility of live entanglements, (4) detectability in aquatic habitats, (5) inability to determine gut contents in live animals, (6) decayed necropsy evidence, (7) limited staff and resources, and (8) the reliability of initial public reports (Williams et al., 2011). These issues are further complicated by the inability to distinguish derelict fishing gear from active gear, and whether the incident was generated by commercial or recreational fishery activities.

Reducing fishery gear impacts is a conservation priority for cetacean, manatee, and sea turtle managers in the United States. The Marine Mammal Protection Act prohibits take (i.e. serious injury or mortality) and the Endangered Species also prohibits take (e.g. harass or harm of a listed species) therefore requiring mitigation and reduction of commercial fisheries bycatch to insignificant levels. Also, the Inter-American Convention for the Protection and Conservation of Sea Turtles (USA is a signatory) has Article IV 2 h: The reduction, to the greatest extent practicable, of the incidental capture, retention, harm or mortality of sea turtles in the course of fishing activities, through the appropriate regulation of such activities, Furthermore, effective conservation and recovery strategies are necessary to assess threats based on robust data sets (Read et al., 2006; Runge et al., 2007b; USFWS, http://www.fws.gov/northflorida/, accessed 27.01.14; Hamann et al., 2010).

Although growing international concern about the effects of entanglements on marine mammal and sea turtle populations has led to research and management measures to mitigate entanglements (Johnson et al., 2005; Moore and Van der Hoop, 2012), impacts to wildlife continue to be a concern both locally and globally. We suggest exploring the possibility of a fishery fund to reduce the incidence of marine fishery gear interactions with wildlife. Funding could be generated from a nominal percentage collected from all fishing license fees sold to: (1) increase coordination with the fishing industry, (2) support research for gear modification, (3) assist with debris removal efforts, (4) increase education and outreach initiatives, and (5) enhance response, provide monitoring and standardize reporting. Funding could also support the creation of a full-time statewide entanglement coordinator to facilitate initiatives to reduce fishery gear hazard impacts on wildlife, organize fishery gear removal efforts from the environment, lead education and outreach efforts and increase collaboration on entanglement issues amongst conservation agencies. We encourage managers and conservation organizations to consider these initiatives to enhance future preservation of these protected and vulnerable species.

Between 1960 and 2008 Florida experienced a 261.6% increase in human population along the coastline, with over 75% of the population living within coastal counties (Wilson and Fishetti, 2010). Impacts on watersheds and coastal habitats will certainly continue into the foreseeable future, requiring a greater focus on solutions to protect Florida's natural resources and imperiled wildlife. Managers should encourage cost-effective and efficient gear modifications, pragmatic and incentive-based programs for the

identification, recovery and removal of discarded gear for recycling (Shomura and Yoshida 1985; Shomura and Godfrey 1990; Laist, 1996), increased disposal compliance (Laist, 1996) and incentives to use "wildlife friendly" or biodegradable products (Page et al., 2004). Greater coordination and collaboration with the fishing industry to investigate gear modifications may reduce fishery impacts and associated injury and mortality to wildlife species (Johnson et al., 2005, 2007; Benjamins et al., 2012). Line free trap pots (other than grappling which causes significant damage to the live substrate), stiffer trap pot lines, brighter lines for greater visibility detection and alternating color schemes (i.e., pattern on rope) in low light conditions have all been proposed as methods to reduce entanglements. Education and outreach might focus on retrieval and proper disposal of old gear, with incentive programs to increase awareness and encourage compliance (Shomura and Godfrey, 1990). Fishery debris removal efforts should be conducted on a regular basis and approached systematically to standardize data information and collection methods (Alaska Sea Grant, 1988). An increase in response, monitoring, and standardized entanglement reporting will assist in better understanding the prevalence and impacts of fishery gear and how to effectively manage these impacts on wildlife, while balancing the needs of fishing interests and human population growth (Shomura and Godfrey, 1990).

Fishery gear is a global problem impacting a vast number of species which are unintentionally captured or entangled (Perrin et al., 1994; Tasker et al., 2000; Baum et al., 2003; Ferraroli et al., 2004; Read et al., 2006; Benjamins et al., 2012). Although entanglement may not significantly reduce abundance of certain wildlife populations, some species, such as those in this study, may be more vulnerable to fishery gear entanglement (Volgenau et al., 1995; Song et al., 2010). The intention of this analysis was to provide conservation managers with information on the prevalence of fishing gear hazards in Florida and the location of "hot spots" posing the greatest threat of impact to wildlife. Future efforts should focus on solutions to reduce fishery gear interactions including those from derelict gear. These issues are expected to increase as the human population escalates along the coast, raising pressures on watershed resources and habitats. A multi-faceted management approach is necessary to reduce entanglement impacts to wildlife species and the environment, decrease human hazards, and minimize stranding network and rehabilitation costs for assisting injured and imperiled wildlife.

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References

Adams, C.M., 1992. Economic activities associated with the commercial fishing industry in Monroe County, Florida. Food and Resource Economics Dept., Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida, 21p.

Akaike, H., 1974. A new look at the statistical model identification. IEEE Trans. Automatic Control 19, 716–723. http://dx.doi.org/10.1109/tac.1974.11100705, mr0423716.

Alaska Sea Grant, 1988. Oceans of plastic: A workshop on fisheries generated marine debris and derelict fishing gear. Report to the National Marine Fisheries Service. Alaska Fisheries Science Center, 7600 Sand Point Way N.E., Seattle, WA 98115, 65 p.

Anderson, O.R., Small, C.J., Croxall, J.P., Dunn, E.K., Sullivan, B.J., Yates, O., Black, A., 2011. Global seabird bycatch in longline fisheries. Endangered Species Res. 14, 91–106.

Avissar, N., Hart, K.A., Crowder, L.B., Gannon, J., Marsh, J.C., 2009a. At loggerheads: gear damage in the blue crab fishery attributed to loggerhead sea turtles. N. Am. J. Fish. Manage. 29, 163–169.

Avissar, N., Hazen, E., Young, N., Crowder, L., 2009b. Will It Float? testing a new technique for reducing loggerhead sea turtle damage to crab pots. N. Am. J. Fish. Manage. 29, 170–175.

Balazs, G.H., 1985. Impact of ocean debris on marine turtles: entanglement and ingestion. In: Shomura, R.S., Yoshida, H.O. (Eds), Proceedings of the Workshop on the Fate and Impact of Marine Debris, NOAA TM: NOAA-TM-NMFS-SWFC-54, pp. 387–429.

Barros, N.B., Odell, D.K., Patton, G.W., 1990. Ingestion of plastic debris by stranded marine mammals from Florida, Abstract. In: Shomura, R.S., Godfrey, M.L. (Eds.), Proceedings of the Second International Conference on Marine Debris, Honolulu, Hawaii, 2–7 April 1989, NOAA TM: NMFSSWFSC-154, pp. 531–539.

Bauer, G.B., Colbert, D.E., Gaspard III, J.C., 2003. Underwater visual acuity of Florida manatees. Int. J. Comp. Psychol. 16, 130–142.

Bauer, G.B., Gaspard III, J.C., Colbert, D.E., Leach, J.B., Stamper, A., Reep, R., 2012. Tactile discrimination of textures by Florida manatees (*Trichechus manatus latirostris*). Mar. Mamm. Sci. 28, 456–471. http://dx.doi.org/10.1111/j.1748-7692.2012.00565.x.

Baum, J.K., Myers, R.A., Kehler, D.G., Worm, B., Harley, S.J., Doherty, P.A., 2003. Collapse and conservation of shark populations in the northwest Atlantic. Science 299, 389–392.

Beck, C.A., Barros, N.B., 1991. The impact of debris on the Florida manatee. Mar. Pollut. Bull. 22, 508–510.

Becker, M., McRobb, R., Watson, F., Droge, E., Kanyembo, B., Murdoch, J., Kakumbi, C., 2013. Evaluating wire-snare poaching trends and the impacts of by-catch on elephants and large carnivores. Biol. Conserv. 158, 26–36.

Bengtson, J.L., 1983. Estimating food consumption of free-ranging manatees in Florida. J. Wildl. Manage. 47, 1186–1192.

Benjamins, S., Ledwell, W., Huntington, J., Davidson, A.R., 2012. Assessing changes in numbers and distribution of large whale entanglements in Newfoundland and Labrador. Canada Mar. Mamm. Sci. 28, 579–601. http://dx.doi.org/10.1111/j.1748-7692.2011.00511.x.

Best, R.C., 1981. Foods and feeding habits of wild and captive Sirenia. Mamm. Rev. 11, 3–29.

Bjorndal, K.A., 1997. Foraging ecology and nutrition of sea turtles. In: Lutz, P.L., Musick, J.A. (Eds.), The biology of sea turtles. CRC Press, Boca Raton, FL, pp. 199–231.

Bjorndal, K.A., 1980. Nutrition and grazing behavior of the green turtle *Chelonia mydas*. Mar. Biol. 56, 147–154.

Bonde, R.K., Garrett, A., Berlanger, M., Askin, N., Tan, L., Wittnich, C., 2012. Biomedical health assessments of the Florida manatee in Crystal River – providing opportunities for training during the capture, handling, and processing of this unique aquatic mammal. J. Mar. Anim. Ecol. 5, 17–28.

Bowles, A.E., Alves, C.D., Anderson, R.C., 2001. Manatee behaviors in the presence of simulated fishing gear: response to novelty and the potential for reducing gear interactions. Report by Hubbs-Sea World Research Institute for the U.S. Fish and Wildlife Service on Permit MA010249-0. HSWRI Technical Report 2001-317, 21p.

Bowles, A.E., Anderson, R.C., 2012. Behavioral responses and habituation of pinnipeds and small cetaceans to novel objects and simulated fishing gear with and without a pinger. Aquat. Mamm. 38, 161–188.

Brotons, J.M., Grau, A.M., Rendell, L., 2007. Estimating the impact of interactions between bottlenose dolphins and artisanal fisheries around the Balearic Islands. Mar. Mamm. Sci. 24, 112–127.

Burdett, L.G., McFee, W.E., 2004. Bycatch of bottlenose dolphin South Carolina, USA, and an evaluation of the Atlantic blue crab fishery categorization. J. Cet. Res. Manage. 6, 231–240.

Cannon, A.C., Fontaine, C.T., Williams, T.D., Revera, D.B., Caillouet, C.W., Jr., 1994. Incidental catch of Kemp's ridley sea turtles (Lepidochelys kempii), by hook and line, along the Texas coast, 1980–1992. In: Schroeder, B.A., Witherington, B.E. (Comps.), Proceedings of the Thirteenth Annual Symposium on Sea Turtle Biology and Conservation, NOAA Tech. Memo., NMFS-SEFSC-341, pp. 40–42.

Casale, P., Affronte, M., Insacco, G., Freggi, D., Vallini, C., Pino d'Astore, P., Basso, R., Paolillo, G., Abbate, G., Argano, R., 2010. Sea turtle strandings reveal high anthropogenic mortality in Italian waters. Aquat. Conserv. 20, 611–620.

Cassoff, R.M., Moore, K.M., McLellan, W.A., Barco, S.G., Rotstein, D.S., Moore, M.J., 2011. Lethal entanglement in baleen whales. Dis. Aquat. Org. 96, 175–185.

Chaloupka, M., Work, T.M., Balazs, G.H., Murakawa, S.K.K., Morris, R., 2008. Cause-specific temporal and spatial trends in green sea turtle strandings in the Hawaiian Archipelago (1982–2003). Mar. Biol. 154, 887–898. http://dx.doi.org/10.1007/s00227-008-0981-4.

Clapham, P.J., Young, S.B., Brownell, R.L., 1999. Baleen whales: conservation issues and the status of the most endangered populations. Mamm. Rev. 29, 37–62. http://dx.doi.org/10.1046/j.1365-2907.1999.00035.x.

Cox, T.M., Read, A.J., Swanner, D., Urian, K., Waples, D., 2003. Behavioral responses of bottlenose dolphins, Tursiops truncatus, to gillnets and acoustic alarms. Biol. Conserv. 115, 203–212.

Cunningham-Smith, P., Colbert, D.E., Wells, R.S., Speakman, T., 2006. Evaluation of human interactions with a provisioned wild bottlenose dolphin (*Tursiops truncatus*) near Sarasota Bay, Florida, and efforts to curtail the interactions. Aquat. Mamm. 32, 346–356.

Dau, B.K., Gilardi, K.V.K., Gulland, F.M., Higgins, A., Holcomb, J.B., St. Leger, J., Ziccardi, M.H., 2009. Fishing gear-related injury in California wildlife. J. Wildl. Dis. 45, 355–362.

Feldkamp, S., 1985. The effects of net entanglement on the drag and power output of a Californian sea lion, *Zalophus californianus*. Fish. Bull. 83, 692–695.

Ferraroli, S., Georges, J.Y., Gaspar, P., Maho, Y.L., 2004. Where leatherback turtles meet fisheries. Nature 429, 521–522.

Fertl, D., Leatherwood, S., 1997. Cetacean interactions with trawls: a preliminary review. J. Northwest Atl. Fish. Soc. 22, 219–248.

Finkbeiner, E.M., Wallace, B.P., Moore, J.E., Lewison, R.L., Crowder, L.B., Read, A.J., 2011. Cumulative estimates of sea turtle bycatch and mortality in USA fisheries between 1990 and 2007. Biol. Conserv. 144, 2719–2727.

Finn, H., Donaldson, R., Calver, M., 2008. Feeding flipper: a case study of a human-dolphin interaction. Pac. Conservation Biol. 14, 215–225.

Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, 2011. Florida's Inshore and Nearshore Species: 2010 Status and Trends Report. St. Petersburg, Florida, 19p.

Florida Fish and Wildlife Conservation Commission, <http://myfwc.com/research/saltwater/fishstats/commercial-fisheries/faq/> (accessed 30.06.13).

Florida Fish and Wildlife Conservation Commission, <http://myfwc.com/research/saltwater/fishstats/commercial-fisheries/landings-in-florida/> (accessed 23.07.13).

Florida Department of Highway Safety and Motor Vehicles, <http://www.flhsmv.gov/dmv/vslfacts.html> (accessed 23.07.13).

Florida Fish and Wildlife Conservation Commission, <http://myfwc.com/media/2515034/sumstate_12.pdf> (accessed 23.07.13).

Florida Fish and Wildlife Conservation Commission, <http://myfwc.com/research/saltwater/fishstats> (accessed 23.07.12).

Florida Fish and Wildlife Conservation Commission, <http://myfwc.com/research/saltwater/crustaceans-marine-arthropods/> (accessed 23.07.13).

Forrester, D.J., White, F.H., Woodward, J.C., Thompson, N.P., 1975. Intussusception in a Florida manatee. J. Wildl. Dis. 1, 566–568.

Freitas, T.L., 2009. Licenses and fees for Alabama, Florida, Louisiana, Mississippi, and Texas in their marine waters for the year 2008. Gulf States Marine Fisheries Commission. Ocean Springs, MS. 168, 20p.

Gaspard III, J.C., Bauer, G.B., Reep, R.L., Dziuk, K., Cardwell, A., Read, L.T., Mann, D.A., 2012. Audiogram and auditory critical ratios of two Florida manatees (*Trichechus manatus latirostris*). J. Exp. Biol. 215, 1442–1447. http://dx.doi.org/10.1242/jeb.065649.

Gorzelany, J.F., 1998. Unusual deaths of two free-ranging Atlantic bottlenose dolphins (*Tursiops truncatus*) related to ingestion of recreational fishing gear. Mar. Mamm. Sci. 14, 614–617. http://dx.doi.org/10.1111/j.1748-7692.1998. tb00748.x.

Hamann, M., Godfrey, M.H., Seminoff, J.A., Arthur, K., Barata, P.C.R., Bjorndal, K.A., Bolten, A.B., Broderick, A.C., Campbell, L.M., Carreras, C., Casale, P., Chaloupka, M., Chan, S.K.F., Coyne, M.S., Crowder, L.B., Diez, C.E., Dutton, P.H., Epperly, S.P., FitzSimmons, N.N., Formia, A., Girondot, M., Hays, G.C., Cheng, I.J., Kaska, Y., Lewison, R., Mortimer, J.A., Nichols, W.J., Reina, R.D., Shanker, K., Spotila, J.R., Tomás, J., Wallace, B.P., Work, T.M., Zbinden, J., Godley, B.J., 2010. Global research priorities for sea turtles: informing management and conservation in the 21st century. Endanger. Species Res. 11, 245–269. http://dx.doi.org/10.3354/esr00279.

Hanson, C.W., Sauls, B., 2011. Status of recreational saltwater fishing in Florida: characterization of license sales, participation, and fishing effort. Am. Fish. S.S. 75, 355–365.

Hartman, D.S., 1979. Ecology and behavior of the manatee (Trichechus manatus) in Florida. A.S.M. Special Publication No. 5, 174p.

Haymans, D., 2005. An investigation of bottlenose dolphin interactions with blue crab traps with three bait well designs. Report to National Marine Fisheries Service, Southeast Regional Office, St. Petersburg, Florida. No. GG133F04SE1321, 8p.

Heyning, J.E., Lewis, T.D., 1990. Entanglements of baleen whales in fishing gear off southern California. Rep. Int. Whal. Comm. 40, 427–431.

James, M.C., Ottensmeyer, C.A., Myers, R.A., 2005. Identification of high-use habitat and threats to leatherback sea turtles in northern waters: new directions for conservation. Ecol. Lett. 8, 195–201. http://dx.doi.org/10.1111/j.1461-0248.2004.00710.x.

Johnson, A., Salvador, G., Kenney, J., Robbins, J., Kraus, S., Landry, S., Clapham, P., 2005. Fishing gear involved in entanglements of right and humpback whales. Mar. Mamm. Sci. 21, 635–645.

Johnson, A.J., Kraus, S.D., Kenney, J.F., Mayo, C.A., 2007. The entangled lives of right whales and fishermen: can they coexist? In: Kraus, S.D., Rolland, R.M. (Eds.), The Urban Whale. Harvard University Press, Cambridge, MA, pp. 380–408.

Kikuchi, M., Suzuki, M., Ueda, K., Miyahara, H., Uchida, S., 2011. The differences in behavioral responses to a net obstacle between day and night in captive manatees; does entanglement happen at night? Fish. Sci. 77, 795–798. http://dx.doi.org/10.1007/s12562-011-0388-x.

Kirkwood, J.K., Bennett, P.M., Jepson, P.D., Kuiken, T., Simpson, V.R., Baker, J.R., 1997. Entanglement in fishing gear and other causes of death in cetaceans stranded on the coasts of England and Wales. Vet. Rec. 141, 94–98.

Knowlton, A.R., Kraus, S.D., 2001. Mortality and serious injury of northern right whales (*Eubalaena glacialis*) in the western North Atlantic Ocean. J. Cet. Res. Manage. 2, 193–208.

Kock, K.H., Purves, M.G., Duhamel, G., 2006. Interactions between cetacean and fisheries in the Southern Ocean. Polar Biol. 29 (5), 379–388.

Kraus, S.D., Hamilton, P.K., Kenney, R.D., Knowlton, A.R., Slay, C.K., 2001. Reproductive parameters of the North Atlantic right whale. J. Cetacean Res. Manage. 2, 231–236.

Laist, D.W., 1996. Marine debris entanglement and ghost fishing: a cryptic and significant type of bycatch. In: Alaska Sea Grant College Program Report 96-03, Solving Bycatch: Considerations for Today and Tomorrow, University of Alaska, Fairbanks, AK. pp. 33-39.

Laist, D.W., 1997. Impacts of marine debris: entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. In: Coe, J.M. (Ed.), Marine Debris: Sources, Impacts, and Solutions, Springer Series on Environmental Management, pp. 99–139.

Laporta, M., Miller, P., Horta, S., Riestra, G., 2006. First report of leatherback turtle entanglement in trap lines in the uruguayan continental shelf. Mar. Turtle Newsl. 112, 9–11.

Lewison, R.L., Freeman, S.A., Crowder, L.B., 2004. Quantifying the effects of fisheries on threatened species: the impact of pelagic longlines on loggerhead and leatherback sea turtles. Ecol. Lett. 7, 221–231.

Lien, J., 1994. Entrapments of large cetaceans in passive inshore fishing gear in Newfoundland and Labrador (1979–1990). In: Perrin, W.F., Donovan, G.P., Barlow, J. (Eds.), Gillnets and Cetaceans, Rep. Int. Whal. Comm. Spec Issue 15, pp. 149–157.

Lopez, A., Santos, M.B., Pierce, G.J., Gonzales, A.F., Valeiras, X., Guerra, A., 2002. Trends in strandings and by-catch of marine mammals in north-west Spain during the 1990s. J. Mar. Biol. 82, 513–521.

Mann, J., Sargeant, B., 2003. Like mother, like calf: the ontogeny of foraging traditions in wild Indian Ocean bottlenose dolphins (*Tursiops* sp.). In: Franganszy, D.M., Perry, E. (Eds.), The Biology of Traditions: Models and Evidence. Cambridge University Press, Cambridge, UK, pp. 236–266.

Marine Mammal Commission, 2001. Commission Annual Report to Congress. Bethesda, Maryland, USA, 260p.

Marshall, C.D., Reep, R.L., 1995. Manatee cerebral cortex: cytoarchitecture of the caudal region in Trichechus manatus latirostris. Brain Behav. Evol. 45, l–18.

Marshall, C.D., Kubilis, P.S., Huth, G.D., Edmonds, V.M., Halin, D.L., Reep, R.L., 2000. Food-handling ability and feeding-cycle length of manatees feeding on several species of aquatic plants. J. Mamm. 81, 649–658.

Marshall, C.D., Maeda, H., Iwata, M., Furuta, M., Asano, S., Rosas, F., Reep, R.L., 2003. Orofacial morphology and feeding behaviour of the dugong, Amazonian, West African and Antillean manatees (Mammalia: Sirenia): functional morphology of the muscular–vibrissal complex. J. Zool. 259, 245–260. http://dx.doi.org/10.1017/S0952836902003205.

McFee, W.E., Pennington, P.L., Burdett, L.G., Powell, J.W.B., Schwacke, J.H., Dockery, F.E., 2007. Assessing movements of three buoy line types using DSTmilli loggers: implications for entanglements of bottlenose dolphins in the crab pot fishery. NOAA Technical Memorandum NOS NCCOS 67, 58p.

McHugh, K.A., Allen, J.B., Barleycorn, A.A., Wells, R.S., 2011. Severe *Karenia brevis* red tides influence juvenile bottlenose dolphin (*Tursiops truncatus*) behavior in Sarasota Bay. Florida. Mar. Mamm. Sci. 27, 622–643. http://dx.doi.org/10.1111/j.1748-7692.2010.00428.x.

Moore, C.J., 2008. Synthetic polymers in the marine environment: a rapidly increasing, long-term threat. Environ. Res. 108, 131–139.

Moore, M.J., Bogomolni, A., Bowman, R., Hamilton, P.K., 2006. Fatally entangled right whales can die extremely slowly. Proceedings of the Oceans'06, MTS/IEEE, Boston, Mass, USA, September 2006.

Moore, S.E., Clarke, J.T., 2002. Potential impact of offshore human activities on gray whales (*Eschrichtius robustus*). J. Cetacean Res. Manage. 4, 19–25.

Moore, M.J., Knowlton, A.R., Kraus, S.D., McLellan, W.A., Bonde, R.K., 2004. Morphometry, gross morphology, and available histopathology in Northwest Atlantic right whale (*Eubalaena glacialis*) mortalities (1970–2002). J. Cet. Res. Manage. 6, 199–214.

Moore, M.J., van der Hoop, J.M., 2012. The painful side of trap and fixed net fisheries: chronic entanglement of large whales. J. Mar. Biol., 4. http://dx.doi.org/10.1155/2012/230653.

Muller, R.G., Hunt, J.H., Matthews, T.R., Sharp, W.C., 1997. Evaluation of effort reduction in the Florida Keys spiny lobster, *Panulirus argus*, fishery using an age-structured population analysis. Mar. Freshwater Res. 48, 1045–1058. http://dx.doi.org/10.1071/MF 97217.

Musick, J.A., 1999. Life in the slow lane: ecology and conservation of long-lived marine animals. Proceedings of the symposium conservation of long-lived animals held at Monterey, California, USA 24 August 1997, Am. Fish. Soc. Symp. 23, Bethesda, MD, 265p.

National Marine Fisheries Service, 2011. Fisheries of the United States, 2011. U.S. Dept. Commerce, Current Fishery, Statistics No. 2011, 125 p.

Noke, W.D., Odell, D.K., 2002. Interactions between the Indian River Lagoon blue crab fishery and the bottlenose dolphin, *Tursiops truncates*. Mar. Mamm. Sci. 18, 819–832.

Nowacek, D.P., 2002. Sequential foraging behaviour of bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay. Florida. Behaviour. 139, 1125–1145.
Oros, J., Torrent, A., Calabuig, P., Deniz, S., 2005. Diseases and causes of mortality among sea turtles stranded in the Canary Islands, Spain (1998–2001). Dis. Aquat. Organ. 63, 13–24.
O'Shea, T.J., Beck, C.A., Bonde, R.K., Kochman, H.I., Odell, D.K., 1985. An analysis of manatee mortality patterns in Florida, 1976–81. J. Wildl. Manage. 49, 1–11.
Page, B., McKenzie, J., McIntosh, R., Baylis, A., Morrissey, A., Calvert, N., Haase, T., Berris, M., Dowie, D., Shaughnessy, P.D., Goldsworthy, S.D., 2004. Entanglement of Australian sea lions and New Zealand fur seals in lost fishing gear and other marine debris before and after Government and industry attempts to reduce the problem. Mar. Pollut. Bull. 4, 33–42.
Pemberton, D., Brothers, N.P., Kirkwood, R., 1992. Entanglement of Australian fur seals in man-made debris in Tasmanian waters. Wildlife Res. 19, 151–159. http://dx.doi.org/10.1071/WR9920151.
Perrin, W.F., Donovan, G.P., Barlow, J., 1994. Rep. Int. Whal. Comm. (Special Issue 15). In: Perrin, W.F., Donovan, G.P., Barlow, J. (Eds.), 629 p.
Plotkin, P., Amos, A.F., 1988. Entanglement in and ingestion of marine debris by sea turtles stranded along the South Texas Coast. In: Schroeder, B.A. (Comp.), Proceedings of the Eighth Annual Workshop on Sea Turtle Conservation and Biology, NOAA Tech. Memo., NMFS-SEFC-214, pp. 79–82.
Powell, J.R., Wells, R.S., 2011. Recreational fishing depredation and associated behaviors involving common bottlenose dolphins (*Tursiops truncatus*) in Sarasota Bay, Florida. Mar. Mamm. Sci. 27, 111–129.
R Core Team, 2013. R: A language and environment for statistical computing, reference index version 2.15.3. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, (<http://www.R-project.org>).
Read, A.J., 2000. Potential Mitigation Measures for Reducing the By-catches of Small Cetaceans in ASCOBANS Waters, Report to ASCOBANS. Duke University, Beaufort, NC, 22p.
Read, A.J., Drinker, P., Northridge, mS., 2006. Bycatch of marine mammals in U.S. and global fisheries. Conserv. Biol. 20, 63–169. http://dx.doi.org/10.1111/j.1523-1739.2006.00338x.
Read, A.J., Wells, R.S., Hohn, A.A., Scott, M.D., 1993. Patterns of growth in wild bottlenose dolphins, *Tursiops truncatus*. J. Zool. 231, 107–123. http://dx.doi.org/10.1111/j.1469-7998.1993.tb05356x.
Reep, R.L., Bonde, R.K., 2006. The Florida Manatee: Biology and Conservation. University Press of Florida, Gainesville, FL.
Reep, R.L., Marshall, C.D., Stoll, M.L., 2002. Tactile hairs on the postcranial body in Florida manatees: a mammalian lateral line? Brain Behav. Evol. 59, 141–154.
Reep, R.L., Gaspard III, J.C., Sarko, D., Rice, F.L., Mann, D.A., Bauer, G.B., 2011. Manatee vibrissae: evidence for a "lateral line" function. Annals of the New York Academy of Sciences Issue: New Perspectives on Neurobehavioral Evol. 1225, 101–109.
Reeves, R.R., Smith, B.D., Crespo, E.A., Notarbartolo di Sciara, G., 2003. Dolphins, whales and porpoises: 2002–2010 conservation action plan for the world's cetaceans. Gland, Switzerland; Cambridge, UK:IUCN/SSC Cetacean Specialist, Group, 147p.
Rudloe, A., Rudloe, J., 2005. Site specificity and the impact of recreational fishing activity on subadult endangered Kemp's ridley sea turtles in estuarine foraging habitats in the northeastern Gulf of Mexico. Gulf Mex. Sci. 23 (2), 186–191.
Runge, M.C., Sanders-Reed, C.A., Langtimm, C.A., Fonnesbeck, C.J., 2007b. A quantitative threats analysis for the Florida manatee (Trichechus manatus latirostris). Final report to U.S. Fish and Wildlife Service, Jacksonville, FL. Intergovernmental Contract No. 40181-5-N012. U.S. Geological Survey Open-File, Report 2007–1086, 34 p.
Samuels, A., Bejder, L., 2004. Chronic interaction between humans and free-ranging bottlenose dolphins near Panama City Beach, Florida, USA. J. Cet. Res. Manage. 6 (1), 69–77.
Shomura, R.S., Yoshida, H.O. (Eds.), 1985. Conclusions and Recommendations from the Workshop on the Fate and Impact of Marine Debris. Proceedings of the Workshop on the Fate and Impact of Marine Debris, 1984. U.S. Department of Commerce. NOAA-TM-NMFS-SWFSC-54, 594p.
Shomura, R.S., Godfrey, M.L. (Eds.), 1990. Recommendations from the Second International Conference on Marine Debris. Proceedings of the Second International Conference on Marine Debris, April 1989, Honolulu, Hawaii. Volume I and II. NOAA-TM-NMFS-SWFSC-154, 1304p.
Song, K.J., Kim, Z.G., Zhang, C.I., Kim, Y.H., 2010. Fishing gears involved in entanglements of minke whales (*Balaenoptera acutorostrata*) in the East Sea of Korea. Mar. Mamm. Sci. 26, 282–295.
Steele, P., Bert, T.M., 1998. The Florida blue crab fishery: history, status, and management. J. Shellfish Res. 17 (2), 441–449.
Steele, P., Perry, H.M., 1990. The blue crab fishery of the Gulf of Mexico, United States: a regional management plan. Gulf States Mar. Fish. Commission. Publ. 21, 172.
Stolen, M., Noke-Durden, W., Mazza, T., Barros, N., St. Leger, J., 2013. Effects of fishing gear on bottlenose dolphins (*Tursiops truncatus*) in the Indian River Lagoon system, Florida. Mar. Mamm. Sci. 29 (2), 356–364. http://dx.doi.org/10.1111/j.1748-7692.2012.00575.x.
Tasker, M.L., Camphuysen, C.J., Cooper, J., Garthe, S., Montevecchi, W.A., Blaber, S.J.M., 2000. The impacts of fishing on marine birds. ICES J. Mar. Sci. 57, 531–547.
U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau, 2011. National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, 143p.
U.S. Fish and Wildlife Service, <http://www.fws.gov/northflorida/> (accessed 27.01.14).
Van der Hoop, J.M., Moore, M.J., Barco, S.G., Cole, T.V.N., Daoust, P.-Y., Henry, A.G., McAlpine, D.F., McLellan, W.A., Wimmer, T., Solow, A.R., 2013. Assessment of management to mitigate anthropogenic effects on large whales. Conserv. Biol. 27 (1), 121–133. http://dx.doi.org/10.1111/j.1523-1739.2012.01934.x.
Volgenau, L., Kraus, S.D., Lien, J., 1995. The impact of entanglements on two substocks of the western North Atlantic humpback whale, *Megaptera novaeangliae*. Can. J. Zool. 73 (9), 1689–1698.
Wallace, N., 1985. Debris entanglement in the marine environment: a review. In: Shomura, R.S., Yoshida, O.H. (Eds.), Proceedings of the workshop on the fate and impact of marine debris, 27-29 November, 1984, NOAA TM: NMFS-SWFS-54. NOAA, Silver Spring, Maryland, pp. 259–277.
Waples, D.M., Thorne, L.H., Hodge, L.E.W., Burke, E.K., Urian, K.W., Read, A.J., 2013. A field test of acoustic deterrent devices used to reduce interactions between bottlenose dolphins and a coastal gillnet fishery. Biol. Conserv. 157, 163–171.
Wells, R.S., Hofmann, S., Moors, T.L., 1998. Entanglement and mortality of bottlenose dolphins, *Tursiops truncatus*, in recreational fishing gear in Florida. Fish. Bull. 96, 647–650.
Wells, R.S., 2003. Dolphin social complexity: lessons from long-term study and life history. In: de Waal, F.B.M., Tyack, P.L. (Eds.), Animal Social Complexity: Intelligence, Culture, and Individualized Societies. Harvard University Press, Cambridge, MA, pp. 32–56.
Wells, R.S., Allen, J.B., Hofmann, S., Bassos-Hull, K., Fauquier, D.A., Barros, N.B., DeLynn, R.E., Sutton, G., Socha, V., Scott, M.D., 2008. Consequences of injuries on survival and reproduction of common bottlenose dolphins (*Tursiops truncatus)* along the west coast of Florida. Mar. Mamm. Sci. 24 (4), 774–794.
Williams, R., Ashe, E., O'Hara, P.D., 2011. Marine mammals and debris in coastal waters of British Columbia, Canada. Mar. Pollut. Bull. 62 (6), 1303–1316.
Wilson, S.G. and Fishetti T.R., 2010. Coastline population trends in the United States: 1960-2008: Population estimates and projections. Current Population Reports: P25-1139. U.S. Department of Commerce, Economics and Statistics Administration, U.S. Census Bureau, Washington, D.C. Issued May 2010. 28.p
Zollett, E.A., Read, A.J., 2006. Depredation of catch by bottlenose dolphins (*Tursiops truncatus*) in the Florida king mackerel (*Scomberomorus cavalla*) troll fishery. Fish. Bull. 104, 343–349.