

Abstract—We documented depredation by bottlenose dolphins (*Tursiops truncatus*) in the Florida king mackerel (*Scomberomorus cavalla*) troll fishery. Between March and June 2003, we conducted 26 interviews of charter and commercial fishermen in Islamorada, Florida, and 23 along Florida's east coast from Fort Pierce south to Lake Worth Inlet. All fishermen indicated they had observed bottlenose dolphins depredating bait or catch—king mackerel being the species most often taken by dolphins. During on-board observations of depredation between March and June 2003, we found that dolphins took 6% of king mackerel caught by charter fishermen and 20% of fish caught by commercial fishermen. We concluded that depredation by bottlenose dolphin occurs commonly in this fishery and has the potential to incur a significant economic cost to king mackerel fishermen. To address this concern, we conducted preliminary tests of a gear modification designed to reduce depredation in the king mackerel fishery between December 2003 and January 2004. These tests demonstrated that a modification to the outrigger planer will successfully deter bottlenose dolphins from engaging in depredation, without causing a reduction in catch.

Depredation of catch by bottlenose dolphins (*Tursiops truncatus*) in the Florida king mackerel (*Scomberomorus cavalla*) troll fishery

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Depredation is the removal of or damage to captured fish or bait caused by marine predators. Evidence of depredation exists for several pinniped and cetacean species (Yano and Dahlheim, 1995; Reeves et al.¹; NRC, 2003). A recent increase in the number of reports of depredation by marine mammals may reflect changes in fishing effort, increased spatial overlap between these predators and fisheries, or behavioral learning among marine mammals (Donoghue et al.²). With a rapidly growing human population, fishing effort in coastal regions will likely continue to increase, causing even greater conflicts between fisheries and marine mammal populations throughout the world's oceans (Read, 2005).

Marine mammals engaging in depredation cause damage to fishing gear, decrease the value and quantity of catches, and reduce catch by dispersing fish (Reeves et al.¹). Depredation may benefit marine mammals by increasing foraging success, but the behavior, habitat, and distribution of mammals may change as they frequent areas of high fishing effort (Reeves et al.¹). Harmful consequences of depredation to marine mammals may include injury or mortality from entanglement with fishing gear or from the retaliatory measures of angry fishermen.

Our purpose in this study was to document the extent, nature, and cost of depredation by bottlenose dolphins (*Tursiops truncatus*) in the king mackerel (*Scomberomorus cavalla*) charter and commercial fisheries of Florida. There have been previous anecdotal reports of depredation by dolphins in this fishery (Odell, 1975), but no systematic study of these interactions has been conducted. We also worked with fishermen to identify potential tools that would deter dolphins from engaging in depredation. Other studies have employed this approach with considerable success. For example, Noke and Odell (2002) modified the design of crab pots, and thus prevented dolphins

¹ Reeves, R. R., A. J. Read, and G. Notarbartolo di Sciara (eds.). 2001. Report of the workshop on interactions between dolphins and fisheries in the Mediterranean: evaluation of mitigation alternatives, 44 p. Istituto Centrale per la Ricerca Applicata al Mare, Rome, Italy. Website: <http://www.cetaceanbycatch.org/Papers/Reeves.pdf> [accessed on 12 March 2004].

² Donoghue, M., R. R. Reeves, and G. Stone. 2003. Report on the workshop on interactions between cetaceans and longline fisheries held in Apia, Samoa, November 2002. New England Aquarium Aquatic Forum Series Report 03-1, 44 p. Website: <http://neaq2.securesites.net/scilearn/conservation/LonglineReport2002.pdf> [accessed on 17 January 2004].

from opening pot doors and taking bait fish. Melvin et al. (1999) demonstrated a reduction in seabird depredation of salmon gill nets by combining the use of acoustic devices and mesh panels strategically placed in the upper portion of the gillnet as a deterrent to seabirds.

King mackerel are distributed along the east coast of the United States from Massachusetts to the Gulf of Mexico and Caribbean Sea (Gold et al., 2002). Two stocks of king mackerel occur in Florida, one that migrates along the Atlantic coast and the other that is found in the Gulf of Mexico (Schaefer and Fable, 1994; Gold et al., 2002).

King mackerel are captured primarily by trolling, in which a fishing vessel trails several fishing lines—either from fishing poles (on charter vessels) or from reels (on commercial boats). Both charter and commercial vessels use outriggers that help to prevent entanglement of multiple lines. Trolling is generally considered to be a “clean” fishery with little bycatch. By varying the size of hooks, lures, and choice of bait, fishermen effectively target particular species and limit the bycatch of undesired species (Alverson et al., 1994). Nontarget species are generally released and have a high probability of survival.

Commercial fishing operations in the United States yielded over 4.8 million pounds of king and cero mackerel (*Scomberomorus regalis*) during 2001. This commercial fishery was valued at almost seven million dollars, more than half of which was landed in Florida (O’Bannon, 2002). During 2001–02, commercial fishermen captured more than two million tons of Atlantic king mackerel, sixty percent of which was caught in Florida, whereas recreational fishermen reported catching about four million tons of fish from the same stock, and about fifty-eight percent of this catch was taken in Florida (NMFS³).

Materials and methods

Study sites

We selected two coastal regions of Florida: 1) Islamorada in the Florida Keys and 2) along the eastern coast, from Fort Pierce south to Lake Worth Inlet, for our study (Fig. 1). These regions represent areas in which commercial and charter fisheries for king mackerel exist during at

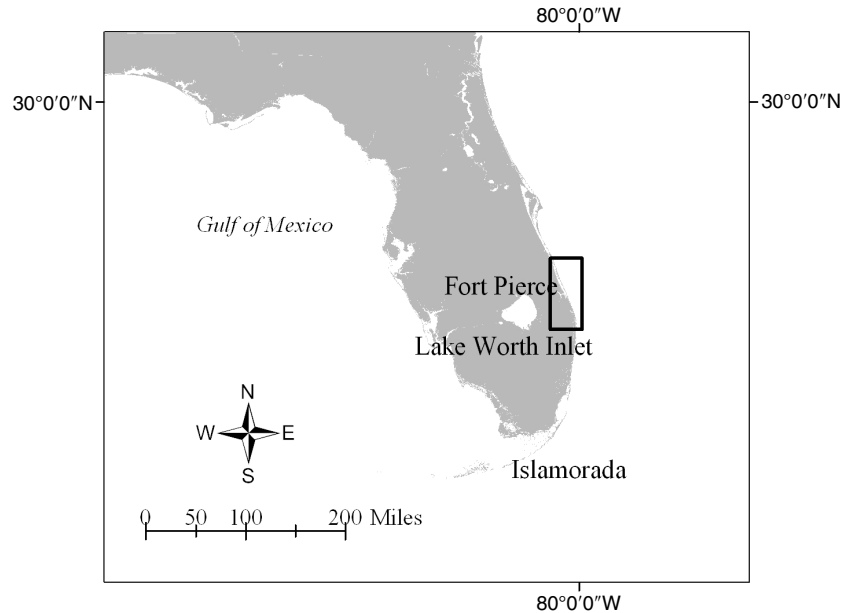


Figure 1

Survey area for bottlenose dolphin (*Tursiops truncatus*) depredation on the king mackerel (*Scomberomorus cavalla*) fishery in Florida. (Source of map: Florida Fish and Wildlife Conservation Commission; adapted by present authors.)

least part of the year. Islamorada draws thousands of tourists each year to its charter fleet; the east coast of Florida boasts a thriving commercial king mackerel fishery.

Interviews with fishermen

From March through June 2003, we interviewed fishermen, using the face-to-face method of Rea and Parker (1997). We selected captains of offshore fishing charter boats or commercial king mackerel fishermen in the study sites to participate in this study. Because of the multi-use nature of fishing vessels, we included commercial, charter, and recreational vessels as options of vessel type on the survey.

Observations of dolphins

We conducted observations from the flying bridge of the charter boats and from the stern of the commercial vessels from March to June 2003. We recorded positional coordinates every 30 minutes with a hand-held GPS unit. During each 30-minute interval, we recorded vessel activity (transit to and from fishing grounds, or active fishing) and further categorized the fishing activity, depending on the target species.

For each 30-minute period, we recorded the behavior and estimated the number of dolphins sighted during the interval. We defined the following behavioral categories:

- | | |
|-------------|---|
| Depredation | a dolphin was observed consuming bait or captured fish from the lines |
| Begging | a dolphin approached a vessel in order to obtain food |

³ NMFS (National Marine Fisheries Service). 2003. Stock assessment analyses on spanish and king mackerel stocks, 147 p. Prepared for the 2003 mackerel stock assessment panel meeting. Sustainable Fisheries Division Contribution SFD/2003-0008, NMFS, Southeast Fisheries Science Center, Sustainable Fisheries Division, 75 Virginia Beach Drive, Miami, FL 33149.

Eating discarded bait	a dolphin consumed bait thrown from a fishing vessel
Milling near the boat but not interacting with the boat	a dolphin was in the same area as the fishing vessel but did not seek food or become entangled in gear.
Following the boat	a dolphin was actively following or pursuing the boat
Passing the boat or being passed by the boat	a dolphin was observed traveling or was passed by the vessel, but the dolphin neither followed nor interacted with the vessel

Impact on the king mackerel fishery

To assess the extent and impact of depredation on the king mackerel fishery, we recorded the type of fishing gear, the number and species of fish caught, and the number and species of fish lost or damaged by depredation during each 30-minute fishing interval. We attributed lost fish to bottlenose dolphin depredation if we observed dolphins following the boat or chasing the fish. We recorded the species of the fish if a definitive part of the fish was retrieved or if we observed the fish before depredation occurred. We also recorded the fishermen's response to depredation. The categories of response included leaving fishing grounds, ignoring dolphin depredation, throwing objects or shooting, cutting fishing line, or increasing boat speed.

Testing a deterrence device

We also worked with fishermen to devise and test a deterrence device to be used on outriggers of commercial fishing vessels. The device was equipped with a planer that is used on outrigger lines. An outrigger release clip was secured to the back of the planer (Fig. 2). The bait line passed through the outrigger clip, which released when a fish bit on the bait. The clip also released a metal wire that was attached to the bait line. The wire traveled towards the fish and flapped around the fish at the end of the bait line, making it difficult for a dolphin to approach the fish.

We tested the device on commercial fishing vessels in Fort Pierce during December 2003 and January 2004. We randomly placed the device on one of two outriggers, noting on which of the two outriggers the device was placed and the time and GPS coordinates for each event. An event occurred when the fishing line was placed in or taken out of the water and when a fish was caught or depredated. We recorded the number and species of each fish that was caught, taken, or damaged.

Results

Interviews with fishermen

We conducted interviews with 26 king mackerel boat operators in Islamorada and 23 operators along Florida's

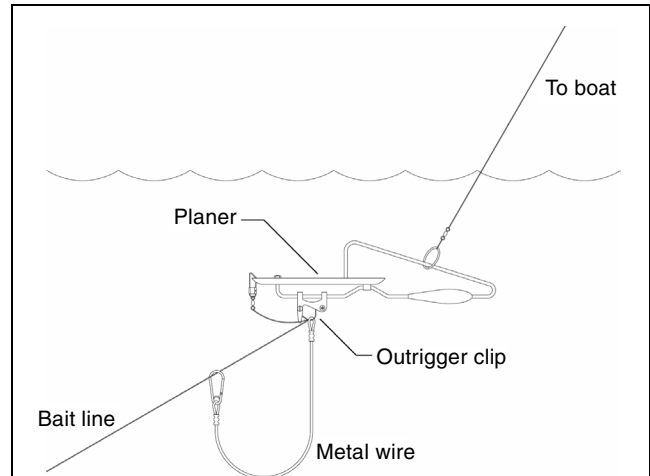


Figure 2

A device designed to reduce bottlenose dolphin (*Tursiops truncatus*) depredation in the commercial king mackerel (*Scomberomorus cavalla*) troll fishery. The device is created with an outrigger clip secured to the back of a planer. The wire, attached at one end to the outrigger clip and clipped at the other end to the bait line, is released from the outrigger clip when a fish bites the line, and it travels to the end of the bait line. At the end of the bait line, the metal wire flaps about and deters a dolphin from taking a captured fish. (Diagram by Eric Blankfield).

Table 1

Vessel type and location of respondents in interview surveys of fishermen for a study of bottlenose dolphin depredation in the Florida king mackerel fishery. Nine individuals selected more than one vessel type.

	Commercial	Charter	Recreational
Islamorada	1	23	3
East Coast	17	12	2

east coast. Several individuals indicated that their boats served multiple purposes or that they operated different types of boats during different times of the year (Table 1).

All fishermen responded that they saw or interacted with bottlenose dolphins while fishing. Forty-seven fishermen provided useful responses to questions regarding depredation; all of these respondents indicated they had observed dolphins taking bait or catch. Other reported interactions included entanglement in fishing gear (10.6%), begging (4%), and eating discarded bait (10.6%). Ninety-seven percent of participating fishermen reported that king mackerel were taken by bottlenose dolphins. King mackerel was the species most often identified as being taken by bottlenose dolphins, but other fish reportedly taken included amberjack (*Seriola*

fasciata), blackfin tuna (*Thunnus atlanticus*), and Spanish mackerel (*Scomberomorus maculatus*) (Fig. 3).

More than half of the fishermen we interviewed indicated that the interactions with bottlenose dolphins occurred either daily or several times a week. In Islamorada, fishermen indicated that winter was the season with the highest number of interactions, and along the east coast of Florida, most interactions occurred during spring (Fig. 4). Most interviewees (76.6%) indicated they believed that bottlenose dolphin conflicts with fishing efforts had increased over the past several years. The vast majority (94%) of commercial fishermen indicated that bottlenose dolphin depredation was causing a significant economic loss, although a smaller number

of charter fishermen held this view (Fig. 5). A Mann Whitney test indicated a significantly higher perceived economic loss from depredation for commercial fishermen than for charter fishermen ($P < 0.001$).

Observations of dolphins

We made observations from five charter boats in Islamorada and from four charter and four commercial boats along the east coast. We spent 41 hours conducting field observations in Islamorada and 85 hours along the east coast. We observed dolphins taking or attempting to take catch, following the boat, feeding or milling near boat with no interactions, and passing by the boat (Fig. 6). All the observations of bottlenose dolphins following the vessel occurred when the vessel was fishing for king mackerel.

We observed 15 fish taken or damaged by bottlenose dolphins. Depredation by bottlenose dolphins was characterized by an abnormal jerk on the line after a fish was known to have taken the bait. For charter fishermen, 6% of the king mackerel catches were taken or damaged by bottlenose dolphins. Depredation events occurred more frequently on commercial fishing vessels, where bottlenose dolphins took almost 20% of the king mackerel. We observed thirteen depredation events on commercial vessels and single depredation events while aboard charter vessels on Florida's east coast and off Islamorada. All depredation events occurred during fishing operations for king mackerel. Only one event occurred in Florida's state waters (within three nautical miles from shore); all others occurred between three and twelve nautical miles offshore. In both study areas, the number of dolphins observed while depredation occurred ranged from one to three dolphins, although other dolphins were often in the same area, following or engaging in depredation with nearby fishing vessels.

It proved impossible to photograph bottlenose dolphin dorsal fins during acts of depredation, because of the nature of the interaction. Bottlenose dolphins typically remained too far from the vessel to allow useful photographs to be obtained. When a fish was caught, the dolphins would swim rapidly towards the boat with their dorsal fins directly below the surface in order to take the fish. After taking the fish, the dolphins would surface well away from the boat.

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Impact on the king mackerel fishery

During the fifteen depredation events, we observed lost and damaged fish and loss of gear, including line, lures, hooks, and occasionally planers. Fishermen typically responded to depredation by leaving the area or by ignoring the bottlenose dolphins. In one instance, we observed a charter boat captain shooting a gun into the water to protect his catch and fishing gear. We also observed the use of bird bangers, sound-creating devices similar to a

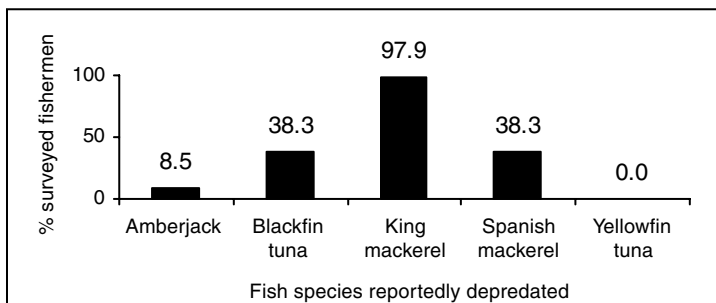


Figure 3

Percent of surveyed fishermen identifying fish species that are depredated by bottlenose dolphins (*Tursiops truncatus*) in the Florida king mackerel (*Scomberomorus cavalla*) fishery. No individuals reported depredation of yellowfin tuna (*Thunnus albacares*), and all of the fishermen reported depredation of at least one of the listed fish species.

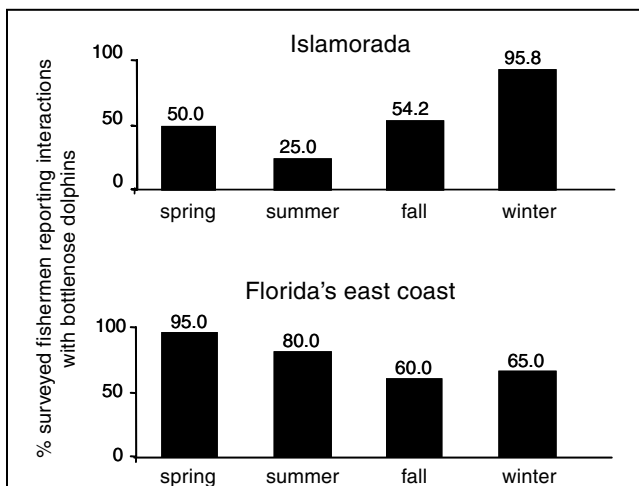


Figure 4

Percent of surveyed fishermen reporting interactions with bottlenose dolphins (*Tursiops truncatus*) during each season in the king mackerel (*Scomberomorus cavalla*) troll fishery along Florida's east coast and off Islamorada, Florida.

gun shooting blanks, in response to depredation. Anecdotal accounts of the use of seal bombs, guns, and bird bangers were also reported by commercial and charter fishermen.

Experimental testing of deterrence device

In three cases when the device was in use, bottlenose dolphins approached a king mackerel on the fishing line, but left the fish apparently after they detected the device. The number of fish caught per hour for each outrigger was 1.48. A *t*-test demonstrated no significant difference exists between the rate of fish caught by each outrigger when the device was not used ($P=0.99$). We also found no difference in the number of fish caught per hour by outriggers equipped with the device (1.40) with those without the device. The device did not cause a reduction in catch of targeted species ($P=0.83$).

Discussion

We documented frequent depredation in both the king mackerel charter and commercial troll fisheries in southeastern Florida. All commercial and charter fishermen indicated that they experienced bottlenose dolphins taking their bait or catch. During our observations, approximately one in every five fish caught by commercial fishermen was lost to bottlenose dolphins, but only 6% of catch was lost by charter fishermen. This difference in depredation rates may be attributed to seasonal variation in the distribution of king mackerel or differences in the gear used by the two fishery sectors. Fishermen in Islamorada reported that most conflicts with dolphins occur in the winter. Because of the highly migratory nature of king mackerel and the mixing of the South Atlantic and Gulf stocks in the winter in the Florida Keys, we anticipated that a higher depredation rate would be experienced by the charter fishery in winter (Gold et al., 2002). We observed commercial fishing operations along Florida's east coast during the season with the most reported conflicts. Depredation rates along the east coast, however, may be even higher in the spring than at the end of spring and summer when our observations were made.

In addition, commercial fishermen target king mackerel, whereas charter boats use fishing gear that targets a variety of fish species, including amberjack, barracuda (*Sphyraena obtusata*), and bonito (*Sarda sarda*). The higher depredation rates encountered by commercial fishermen may result from the regular capture of king mackerel compared to the various species caught by charter boats during a fishing trip. In addition to

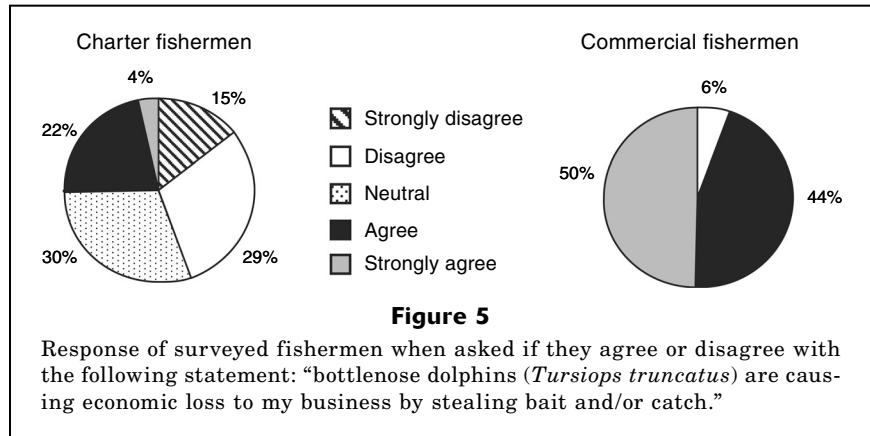


Figure 5
Response of surveyed fishermen when asked if they agree or disagree with the following statement: "bottlenose dolphins (*Tursiops truncatus*) are causing economic loss to my business by stealing bait and/or catch."

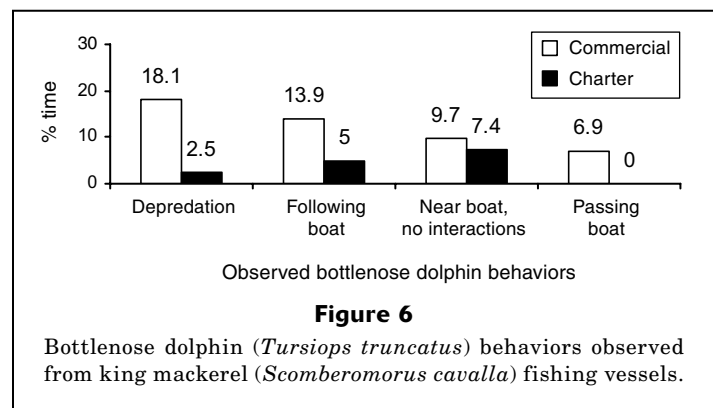


Figure 6
Bottlenose dolphin (*Tursiops truncatus*) behaviors observed from king mackerel (*Scomberomorus cavalla*) fishing vessels.

king mackerel, species that were reported taken by both commercial and charter boat fishermen included Spanish mackerel, amberjack, and blackfin tuna. We did not observe depredation of these species, most likely because they were rarely caught during our study. However, depredation of these species has been reported from Spanish mackerel fisheries elsewhere (Read et al., 2003).

We observed bottlenose dolphins engaging in depredation only while the vessels were fishing for king mackerel. Bottlenose dolphins do not generally prey on king mackerel; Barros (1993) did not find king mackerel in the stomach contents of any stranded dolphins in Florida. Exploitation of fisheries by marine mammals may introduce a new food resource that was either not previously available or used, as seen in the case of pilot whales (*Globicephala spp.*) that feed on Atlantic mackerel (*Scomber scombrus*) in trawl fisheries off the north-eastern United States (Waring et al., 1990; Gannon et al., 1997) and in the case of killer whales (*Orcinus orca*) that prey on swordfish (*Xiphias gladius*) hooked on longlines in southern Brazil (Secchi and Vaske, 1998). It is likely that fishing affects not only the diet but also the behavior and spatial distribution of bottlenose dolphins (Leatherwood, 1975; Chilvers et al., 2003). The bottlenose dolphins in this study may spend less time foraging, but as indicated by the observed depredation

of king mackerel, the diet and possibly the distribution of these animals is impacted by their interaction with the fishery.

In this study, fishermen reported observing female bottlenose dolphins "teaching" their calves how to engage in depredation, indicating a behavioral transmission of knowledge. Depredation of king mackerel by bottlenose dolphins may have resulted from a learned behavior that results in a low-cost foraging specialization.

Over three quarters of interviewed fishermen reported increasing conflicts with bottlenose dolphins. The frequency of these interactions most likely result from a combination of factors, including behavioral learning, increasing fishing effort, and spatial overlap and resource competition between cetaceans and fisheries (Donoghue et al.²). In addition, an upsurge in depredation may be correlated with a rise in troll fishing effort that resulted from the July 1995 statewide ban of gill nets in Florida (Wells et al., 1998). The increase in depredation places bottlenose dolphins in close proximity to fishing vessels and gear, increasing the risk of injury or death to the dolphins. It is unknown if the dolphins in this study were injured by hooks. Although we did not observe entanglement in this study, entanglement in and ingestion of fishing gear by bottlenose dolphins could result from depredation. Hucke-Gaete et al. (2004) observed a fatal entanglement of a sperm whale (*Physeter macrocephalus*), likely engaging in depredation, in a longline fishery off southern Chile. Monofilament fishing line does not degrade rapidly, and injury or death can result from the entanglement in or ingestion of fishing gear (Mann et al., 1995). Previous research has documented the deaths of bottlenose dolphins from entanglement (Wells et al., 1998) and from ingestion of monofilament line (Gorzalany, 1998).

As a result of lost or damaged gear and catch, fishermen experience economic loss from these interactions. Commercial fishermen reported significantly higher economic losses than charter boat fishermen. Our observations confirm the potential for high economic loss by commercial fishermen due to lost fishing gear and depredation. Because of the cost to commercial fishermen and risk to marine mammal safety, we investigated gear modification as a potential solution to reduce these conflicts (FR, 1996). Gear modification has proven successful in decreasing depredation and bottlenose dolphin mortality caused by entanglement in the blue crab fishery in Florida, in reducing seabird bycatch in coastal gillnet fisheries, and in reducing sea turtle entanglement in shrimp trawlers (Crowder et al., 1994; Melvin et al., 1999; Noke and Odell, 2002;). Our preliminary tests demonstrated that a modification to the outrigger planer will successfully deter bottlenose dolphins from engaging in depredation, without causing a reduction in catch. The deterrence device is made of fishing gear already owned by most fishermen and therefore the cost of the gear modification is minimal.

The deterrence device could prove beneficial in reducing fishery-related injury or mortality of bottlenose dolphins in the king mackerel troll fishery, including harm

that may result from retaliatory measures of some fishermen. The 1994 amendments to the Marine Mammal Protection Act of 1972 allow the operator of a fishing vessel to deter a marine mammal from damaging his gear or catch. However, potentially harmful methods, such as guns and seal bombs observed and reported in the Florida king mackerel fishery, are strictly prohibited (FR, 1995). The deterrence device offers an alternative to such illegal measures and their associated harmful consequences. We recommend that the deterrence device be fully tested and, if successful, employed as a strategy to reduce depredation and its adverse effects on both fishermen and bottlenose dolphins.

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