Abstract—The U.S. East Coast pelagic longline fishery has a history of interactions with marine mammals, where animals are hooked and entangled in longline gear. Pilot whales (*Globicephala* spp.) and Risso's dolphin (*Grampus griseus*) are the primary species that interact with longline gear. Logistic regression was used to assess the environmental and gear characteristics that influence interaction rates. Pilot whale interactions were correlated with warm water temperatures, proximity to the shelf break, mainline lengths greater than 20 nautical miles, and damage to swordfish catch. Similarly, Risso's dolphin interactions were correlated with geographic location, proximity the shelf break, the length of the mainline, and bait type. The incidental bycatch of marine mammals is likely associated with depredation of the commercial catch and is increased by the overlap between marine mammal and target species habitats. Altering gear characteristics and fishery practices may mitigate incidental bycatch and reduce economic losses due to depredation.

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Interactions between marine mammals and pelagic longline fishing gear in the U.S. Atlantic Ocean between 1992 and 2004

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Marine mammal mortalities and injuries occur in gillnet fisheries (Perrin et al., 1994), trawl fisheries (Fertl and Leatherwood, 1997), and longline fisheries (e.g., Garrison, 2005; Kock et al., 2006). The U.S. East Coast pelagic longline fishery targeting swordfish, tunas, and sharks has long been the focus of bycatch reduction efforts for nontarget fish species (e.g., billfish; Goodyear, 1999) and for marine turtles (Watson et al., 2005). In addition, marine mammal bycatch in the pelagic longline fishery is common, particularly of pilot whales (*Globicephala* spp.) and Risso's dolphins (*Grampus griseus*). An estimated average of 132 (CV [coefficient of variation]=0.49) pilot whales and 45 (CV=0.38) Risso's dolphins either died or were seriously injured because of interactions with pelagic longline gear each year between 1999 and 2003 (Waring et al., 2006). These numbers account for 63% of the total commercial fishery-related mortality for pilot whales and 88% for Risso's dolphins along the U.S. East Coast. The total fishery mortality for pilot whales approaches the potential biological removal (PBR) benchmark (PBR=249 for pilot whales and 129 for Risso's dolphins), and it exceeds the requirement that mortality caused by commercial fishing approach insignificant levels as mandated by the U.S. Marine Mammal Protection Act (MMPA) (Waring et al., 2006).

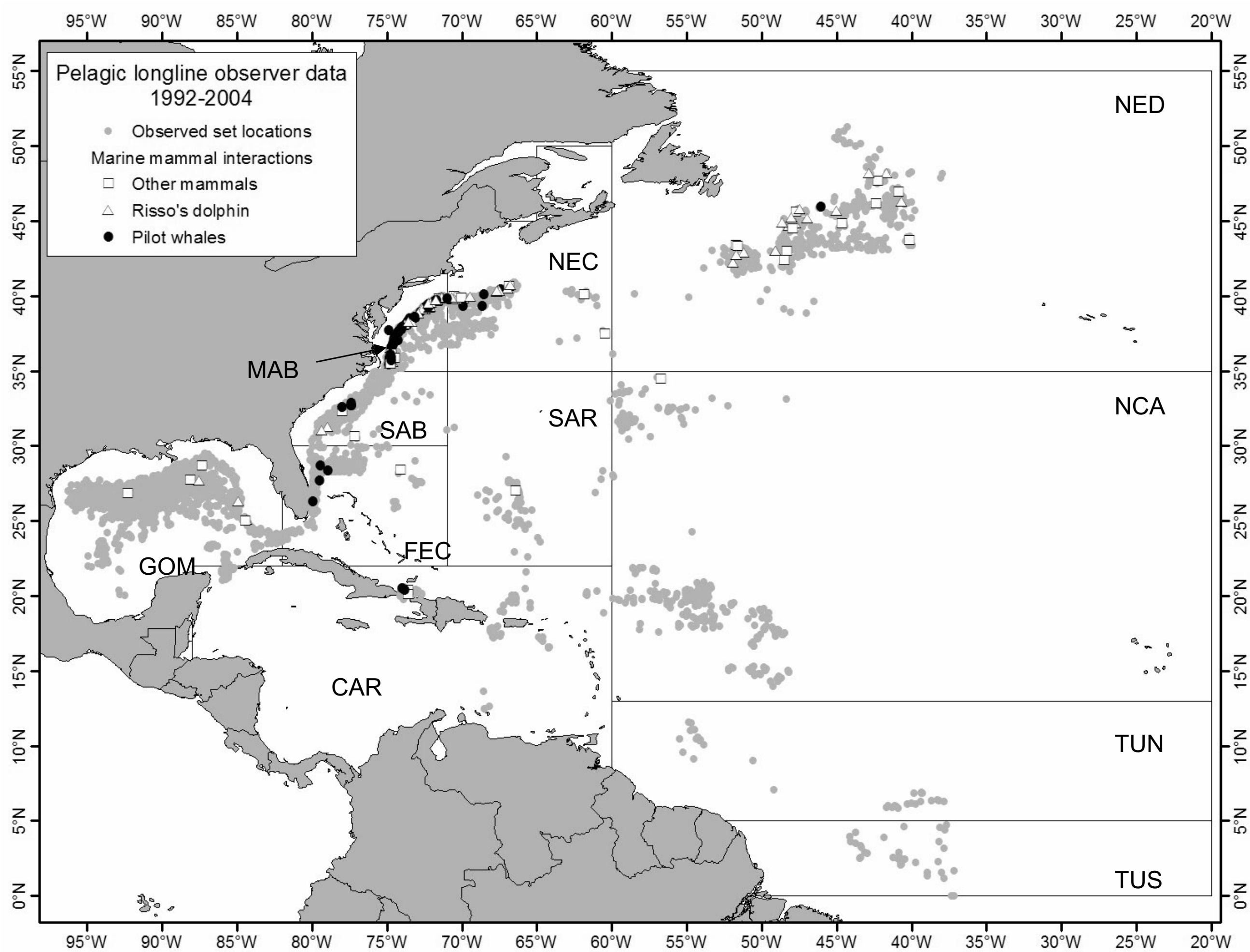
In addition to marine mammal conservation concerns, the occurrence of depredation, or marine mammals feeding on the catch or bait from commercial fishing gear, is an emerging global issue. Depredation has been observed on both bottom and pelagic longlines by killer whales (*Orcinus orca*; Secchi and Vaske, 1998; Kock et al., 2006), false killer whales (*Pseudorca crassidens*), pilot whales, and sperm whales (*Physeter macrocephalus*; Kock et al., 2006). Fishermen in the Atlantic longline fleet indicate that damage to commercial catch by pilot whales is common (Angliss and DeMaster, 1998). Depredation has a direct economic impact on commercial fishermen by removing commercially valuable catch.

Identification of the fishing practices and environmental processes that drive interactions between marine mammals and longline fishing gear is important to understanding and reducing both incidental mortality and depredation. In this study, pelagic longline fishery observer data collected between 1992 and 2004 were analyzed to describe the number of interactions, seasonal and spatial patterns, and the types of interactions associated with serious injuries and mortalities of marine mammals. Logistic regression was used to examine factors affecting the probability of interactions with pilot whales and Risso's dolphins. The results of these analyses will help managers make informed decisions to reduce both marine mammal bycatch and economic losses due to depredation.

Materials and methods

Pelagic observer program

The U.S. East Coast pelagic longline fishery has been observed since 1992.



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Mexico, NEC=Northeast Coastal, NED=Northeast Distant, NCA=North Central Atlantic, MAB=Mid-Atlantic Bight, SAB=South Atlantic Bight, SAR=Sargasso Sea, TUN=Tuna North, and TUS=Tuna South.

Observer coverage was allocated randomly among fishing vessels by calendar quarter and fishing area. Achieved annual observer coverage typically ranged between 3–4% of longline sets between 1992–2001 and was near 7% during 2002–04. The observers collected detailed information on gear characteristics, set and haul locations, environmental data, and composition of the fish catch. Observers also documented incidental takes of marine mammals including estimated lengths and written descriptions of each animal and its interaction with the fishing gear (Beerkircher et al., 2004).

During 2001–04, the Northeast Distant (NED) fishing area (Fig. 1) was closed to the longline fishery because of concerns over marine turtle bycatch. An experimental program was initiated, in cooperation with the fishing industry, to explore potential gear and bait combinations to reduce interactions with marine turtles. During the study, fishermen used larger circle hooks rather than traditional, smaller, straight-shanked "J" hooks (Watson et al., 2005). There was 100% observer coverage of this experimental fishing. Because the fishing operations were prescribed by experimental design, and differed from standard commercial fishing operations, data from these experimental sets, including data on marine mammal interactions, were excluded from the current analysis.

Observed marine mammal interactions

When a marine mammal interacted with the longline gear (i.e., was hooked or entangled), the observers noted the condition of the captured animal and the type of fishing gear, documented efforts to remove the animal from the gear, and recorded the behavior of the animal after release. Observer comments were summarized to assess the most frequent types of interactions with longline gear. Two species of pilot whales inhabit the waters along the U.S. East Coast: the short-finned pilot whale (*G. macrorhynchus*) and long-finned pilot whale (*G. melas*). However, the two could not be reliably distinguished at sea by the observers and therefore were combined in this analysis.

Determination of serious injury to marine mammals

The MMPA requires that incidental mortality of and serious injury to marine mammals during commercial fishing operations be reduced below the PBR benchmark. Serious injury has been defined as an injury likely to result in mortality (Angliss and DeMaster, 1998). A workshop of National Marine Fisheries Service (NMFS) and nongovernmental experts was convened in 1997 to evaluate the types of injuries occurring in commercial fisheries and to develop guidelines to determine if a given marine mammal observed interacting with commercial fishing gear was seriously injured. For small cetaceans, including pilot whales and other delphinids, it was concluded that animals that ingested hooks, that were released with significant amounts of trailing fishing gear, that were swimming abnormally, or that suffered severe external trauma would be considered seriously injured (Angliss and Demaster, 1998). Serious injury determinations were made by NMFS staff on a case-by-case basis after reviewing the observations and comments of fishery observers.

Logistic regression analysis

Logistic regression was used to evaluate the effects of environmental conditions and fishing practices on the probability of interactions with pilot whales and Risso's dolphins. The vast majority (>85%) of interactions with marine mammals involved only one individual with a set. Therefore, the data were transformed to a binary response variable indicating whether or not a marine mammal interaction was observed.

Only longline sets made along the U.S. Atlantic and Caribbean coasts, including the Florida East Coast (FEC), South Atlantic Bight (SAB), Mid-Atlantic Bight (MAB), Northeast Coastal (NEC), and Caribbean (CAR) fishing areas (Fig. 1), were included in this analysis because interaction rates in most other areas were extremely low or zero. Although Risso's dolphin interactions were observed during experimental fishing in the NED, the fishing characteristics of these sets were different from those of the normal commercial fishing operations. Therefore, sets observed in the NED (experimental and nonexperimental) were excluded from the analysis. This included two observed interactions with Risso's dolphins and none with pilot whales in nonexperimental fishing. The analysis focused on the Atlantic fishing areas with the highest overall interaction rates with pilot whales and Risso's dolphin and comprised 3187 observed longline sets.

Explanatory variables were drawn from a broad suite of data collected during each set by the fishery observer (Table 1), or they were derived from the date and location of the set (Table 1). Variables were categorized broadly as environmental conditions, space or time variables, gear characteristics, fishing effort level, and catch characteristics. However, each was considered independently in developing the best fitting, most parsimonious logistic regression model following strategies for model selection outlined in Hosmer and Lemeshow (1989). Briefly, each variable was examined individually to assess its explanatory power, and the subset of significant single terms was included in the initial model. Following this initial exploratory step, the single terms and all two-way interactions were examined by using stepwise selection. The explanatory power and significance of each potential model term was examined through chi-square tests and Akakie's information criterion (AIC; Hosmer and Lemeshow, 1989; McCullagh and Nelder, 1989). Terms were retained in the model if they were significant (at a P-value <0.10) based upon chi-square tests and if their addition resulted in a reduction in AIC. The resulting models were examined for overdispersion by using the ratio between the residual model chi-square and degrees of freedom (Burnham et al., 1987; McCullagh and Nelder, 1989). For both the pilot whale model and the Risso's dolphin model, this ratio was approximately equal to one, which indicated no significant problems with overdispersion and hence accurate estimates of variance for model parameters.

Results

Observed marine mammal interactions

Between 1992 and 2004, a total of 200 interactions between marine mammals and pelagic longline gear were observed. Of these, there were 10 observed mortalities and 94 observed serious injuries (Table 2). One hundred of the observed interactions were with pilot whales, 64 were with Risso's dolphin, and all other species had six or fewer observed interactions. Other marine mammal interactions of note occurred with a killer whale, unidentified beaked whales (family Ziphiidae), a pygmy or dwarf sperm whale (*Kogia* spp.), a northern bottlenose whale (*Hyperoodon ampullatus*), and two baleen whales (Table 2).

The majority of marine mammal interactions were observed near the shelf break along the U.S. Atlantic coast between North Carolina and Georges Bank (Fig. 1). Pilot whale interactions were concentrated in the MAB fishing area between North Carolina and New Jersey, whereas Risso's dolphin interactions primarily occurred in the NEC region (Fig. 1). Thirteen Risso's dolphins, one pilot whale, and eight additional animals of various species interacted with fishing gear during experimental fishing operations in the NED during 2001–03 (Fig. 1).

The observed interaction rates (number of sets with a marine mammal interaction/number of observed sets) fluctuated across the time series. The highest rates were observed during 1992–95 and in the most recent years from 2000 through 2004 (Fig. 2A). There were generally low interaction rates and very few pilot whale

Table 1

Environment, space or time, gear type, fishing effort, and catch variables examined in logistic regression analyses of the probability of marine mammal interactions in the U.S. pelagic longline fishery. The fishing areas included in the study were the following: Florida East Coast (FEC), Mid-Atlantic Bight (MAB), South Atlantic Bight (SAB), Northeast Coastal (NEC), and Carribbean (CAR) (see Fig. 1).

Type of variable	Variable name	Description
Environment	Average temperature	Average of sea surface temperature reported by observer at beginning and end of haul and set
Environment	Water depth	Water depth based on average location of set determined from a global bathymetry grid
Environment	Wave height	Recorded by observers at time of set
Environment	Wind speed	Recorded by observers at time of set
Environment	Weather conditions	Calm, cloudy, mild storm, stormy—recorded by observers at time of set
Space **or** time	Distance from 200-m isobath	Distance of the set (km) from the 200-m isobath
Space **or** time	Average location	Average of latitude and longitude for beginning set, end set, beginning haul, end haul
Space or time	Month	Calendar month of beginning set
Space or time	Quarter	Calendar quarter of beginning set
Space or time	Year	Calendar year of beginning set
Space **or** time	Fishing area	Fishing area of set: includes FEC, MAB, SAB, NEC, CAR
Space **or** time	Geographic area	Combined area categories MAB versus other areas
Space **or** time	Lunar phase	Lunar age since full moon
Gear type	Hook shape	Type(s) of hooks reported on the set. Categories include J-hook only, C-hook only, or both types
Gear type	Hook size	Size categories of hooks on the set were 7/0, 8/0, 9/0, 10/0, 12/0, 16/0, and 18/0
Gear type	Light sticks	Binary variable, whether or not light sticks were used on the set
Gear type	Bait type	Type(s) of bait recorded. Includes fish only, squid only, or both
Gear type	Live bait	Binary variable, whether or not live bait was used on the set
Gear type	Hook depth	Average of reported minimum and maximum hook depths (fathoms)
Gear type	Day set	Binary variable, whether or not set occurred during daylight
Gear type	Day soak	Binary variable, whether or not gear soaked during daylight
Gear type	Day haul	Binary variable, whether or not haulback occurred during daylight
Effort	Mainline length	Mainline length reported in miles
Effort	Number of hooks	Number of hooks set
Effort	Set duration	Number of hours to set the gear
Effort	Soak duration	Number of hours the gear soaked between the end of the set and the beginning of the haul
Effort	Haul duration	Number of hours spent hauling the gear
Effort	Total duration	Estimated number of hours the average hook was in the water (1/2 set duration + soak duration + 1/2 haul duration)
Effort	Hook density	Number of hooks/mainline length
Effort	Hook hours	Number of hooks×total duration
Catch	Bigeye tuna(*Thunnus obesus*)	Bigeye tuna catch (numbers)
Catch	Sharks	Shark catch (numbers)
Catch	Swordfish (*Xiphias gladius*)	Swordfish catch (numbers)
Catch	Other tunas	Other tuna catch (numbers)
Catch	Yellowfin tuna (*Thunnus albacares*)	Yellowfin tuna catch (numbers)
Catch	All tunas	Sum of yellowfin tuna, bigeye tuna, and other tunas
Catch	Damage	Binary variable, whether or not damage to the catch was observed
Catch	Swordfish damage	Binary variable, whether or not damage to swordfish catch was observed
Catch	Tuna damage	Binary variable, whether or not damage to tuna catch was observed

Table 2

Marine mammal interactions with pelagic longline fishing gear between 1992 and 2004. The totals include interactions observed during experimental fishing in the Northeast Distant Water (NED) fishing area. Determination of serious injury was based on observer descriptions and National Marine Fisheries Service criteria (Angliss and Demaster, 1998).

Species	Total captured	Total observed dead	Total seriously injured
Pilot whale (*Globicephala* spp.)	100	4	52
Risso's dolphin (*Grampus griseus*)	64	6	30
Common dolphin (*Delphinus delphi*)	6	0	0
Bottlenose dolphin (*Tursiops truncatus*)	6	0	2
Unidentified dolphin	4	0	2
Unidentified marine mammal	4	0	2
Unidentified beaked whales (*Mesoplodon* spp.)	3	0	1
Pantropical spotted dolphin (*Stenella attenuata*)	3	0	0
Atlantic spotted dolphin (*Stenella frontalis*)	2	0	2
Striped dolphin (*Stenella coeruleoalba*)	2	0	0
Unidentified whale	1	0	1
Northern bottlenose whale (*Hyperoodon ampullatus*)	1	0	1
Unidentified baleen whale	1	0	0
Killer whale (*Orcinus orca*)	1	0	0
Minke whale (*Balaenoptera acutorostratus*)	1	0	0
Pygmy or dwarf sperm whale (*Kogia* spp.)	1	0	1

Table 3

Types of serious injuries observed in marine mammals interacting with pelagic longline fishing gear between 1992 and 2004.

Species	Mouth hooked	Animal released with entangling gear	Mouth hooked and animal released with entangling gear	Total
Pilot whales (*Globicephala* spp.)	3	19	30	52
Risso's dolphin (*Grampus griseus*)	7	12	11	30
Other species	1	3	8	12
Totals	11	34	49	94

interactions were observed during 1996–98. Interaction rates for both pilot whales and Risso's dolphins peaked during the late summer and fall (Fig. 2B).

Types of serious injury

Of the 94 observed serious injuries, there were 60 cases where marine mammals were released with hooks remaining in the mouth. In 49 of these cases, monofilament line (typically 15–60 feet in length) remained with the animal (Table 3). In the remaining 11 cases, the animal was released with less than five feet of monofilament line and with the hook remaining in the mouth. In four of the 11 documented mortalities, the animal was hooked in the mouth.

There were 34 serious injuries in which the animal was released entangled with fishing gear that did not involve ingestion of a hook (Table 3). The majority of these cases were injuries to animals that became entangled in the mainline which typically consists of 700-lb test monofilament. In most of these cases, the animal was released with multiple wraps of mainline around its tail or body, and the gear remained with the animal after the line was cut. In five of the 10 documented mortalities, the animal was entangled in the mainline. Fishermen were typically able to cut the mainline away from entangled animals. Thus, the majority of animals entangled in the mainline were released without entangling gear, and these animals were not considered to be seriously injured.

Logistic regression results: Pilot whales

Geographic area (MAB vs. other areas; chi-square=31.24, df=1, $P<0.0001$), distance from the 200-m isobath (chi-square=11.31, df=1, $P=0.0008$), and observed damage to the swordfish catch (chi-square=7.26, df=1, $P=0.0071$) were significant factors correlated with the occurrence of pilot whale interactions with longline gear. A linear term for water temperature was also highly significant and, on inspection of initial regression results, there was a unimodal relationship between water temperature and interaction rate. Water temperature (chi-square=8.53, df=1, P=0.0035) and its second-order term (chi-square=7.87, df=1, P=0.0050) were included in the model and were statistically significant. There was also an apparent nonlinear relationship with mainline length, with a step increase in interaction rate for mainlines greater than 20 nautical miles in length. The continuous mainline length variable was replaced with a binary response (mainline ≥20 miles). This variable was highly significant (chi-square=13.24, df=1, P=0.0003) and provided greater explanatory power and a better model fit than the continuous variable. The final model was highly significant (total chi-square=146.67, df=6, P<0.0001), and both examination of residuals and goodness-of-fit tests indicated strong model fit.

Interactions with pilot whales were much more likely to occur in the MAB fishing area than in other regions. Both mainline length and damage to swordfish catch on the set also significantly increased the probability of observing a pilot whale interaction (Fig. 3). There was a strong decrease in the probability of a pilot whale interaction with increasing distance from the 200-m isobath (Fig. 4), and this trend was apparent in the MAB and other regions. No pilot whale interactions were observed in sets greater than 30 km away from the 200-m isobath. The correlation with water temperature was generally weaker than that for other factors; however, there was a peak in interaction rates in warm waters between 70 and 80°F in the MAB and between 75 and 85°F in the other geographic areas. This warm water peak was associated with late summer and fall in these regions.

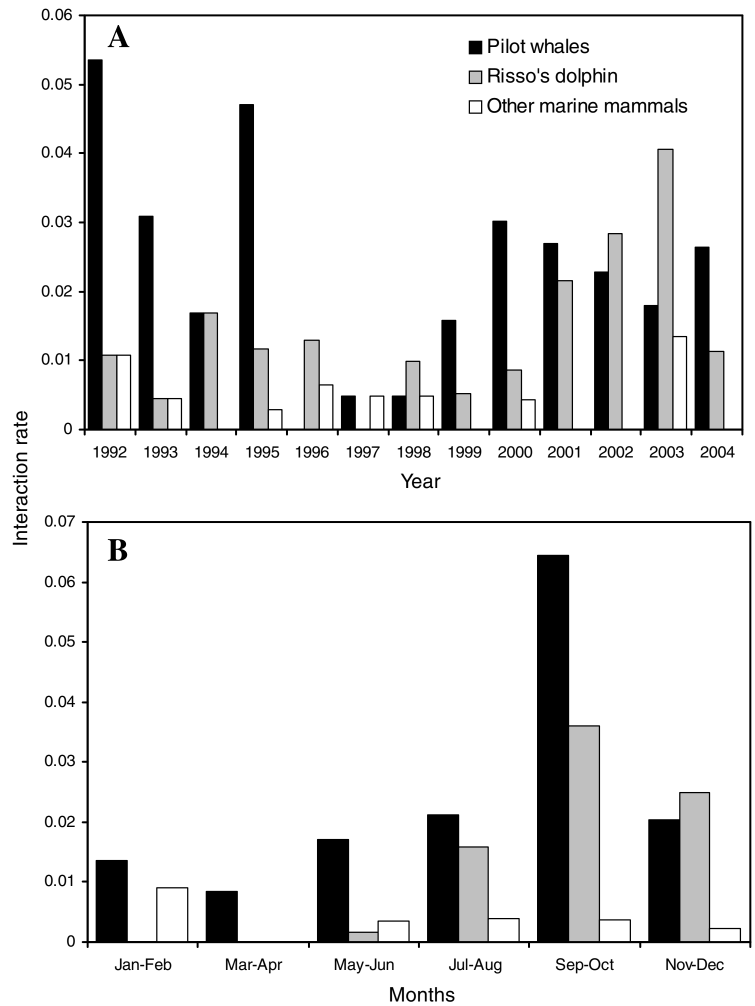

Figure 2

Annual (**A**) and seasonal (**B**) patterns in observed marine mammal interaction rates (number of positive sets/total number of observed sets) for pilot whales (*Globicephala* spp.), Risso's dolphins (*Grampus griseus*), and other marine mammal species.

Logistic regression results: Risso's dolphins

Risso's dolphin interaction rates were significantly higher in the MAB (chi-square=4.56, df=1, P=0.0328) and the NEC fishing areas (chi-square=13.03, df=1, P=0.0003) than in areas farther south. The highest interaction rates overall were observed in the NEC. As with pilot whales, distance from the 200-m isobath (chi-square=4.58, df=1, P=0.0306) and damage to swordfish catch (chi-square=4.68, df=1, P=0.0297) were important explanatory factors. However, overall, the strength of these effects was weaker than that for pilot whales. The mainline length effect, although improving the explanatory power of the model, was not a statistically significant factor (chi-square=3.284, df=1, P=0.07). The use of fish bait, either alone or in addition to squid bait, significantly decreased the probability of observing a Risso's dolphin interaction (chi-square=4.33, df=1, P=0.0375). The overall model was highly significant (chi-square=71.68, df=6, P<0.0001) and provided a good fit to the data.

The bait effect was apparent only in the observed data from the MAB region and the southern Atlantic areas and was not observed in the NEC region, but the positive correlation with damage to swordfish catch was observed across all regions (Fig. 5). The negative correlation with distance from the 200-m isobath for Risso's dolphins was somewhat weaker than that for pilot whales; however, no interactions were observed in waters greater than 30 km from the 200-m isobath, with the exception of one interaction observed in the south Atlantic areas (Fig. 6).

Discussion

Interactions of marine mammals with pelagic longlines are concentrated primarily in the MAB and NEC fishing areas along the shelf break. Interaction rates were consistent across the time series, with the exception of the period between 1996–99. There was relatively low observer coverage in the MAB fishing area during these years, and the low observed interaction rates may be a sampling artifact. Pilot whales and Risso's dolphins are the primary species interacting with the longline fishery, and mortality and serious injury of these species are a significant conservation concern. Assessing the impact of fishery-induced mortality on the two pilot whale species (longfin and shortfin pilot whales) is difficult because the species cannot be distinguished in either assessment surveys or when caught on fishing gear. Thus, although the total fishery mortality is below the PBR limit for the combined species, it is possible that the longline fishery disproportionately impacts one species. The shortfin pilot whale (*G. macrorhyncus*) generally has a more southern distribution than the longfin pilot whale (*G. melas*), and therefore the impact of the longline fishery may be more severe than current stock assessments indicate. Research is currently underway to determine the spatial distributions of the two species in order to assess their status more accurately.

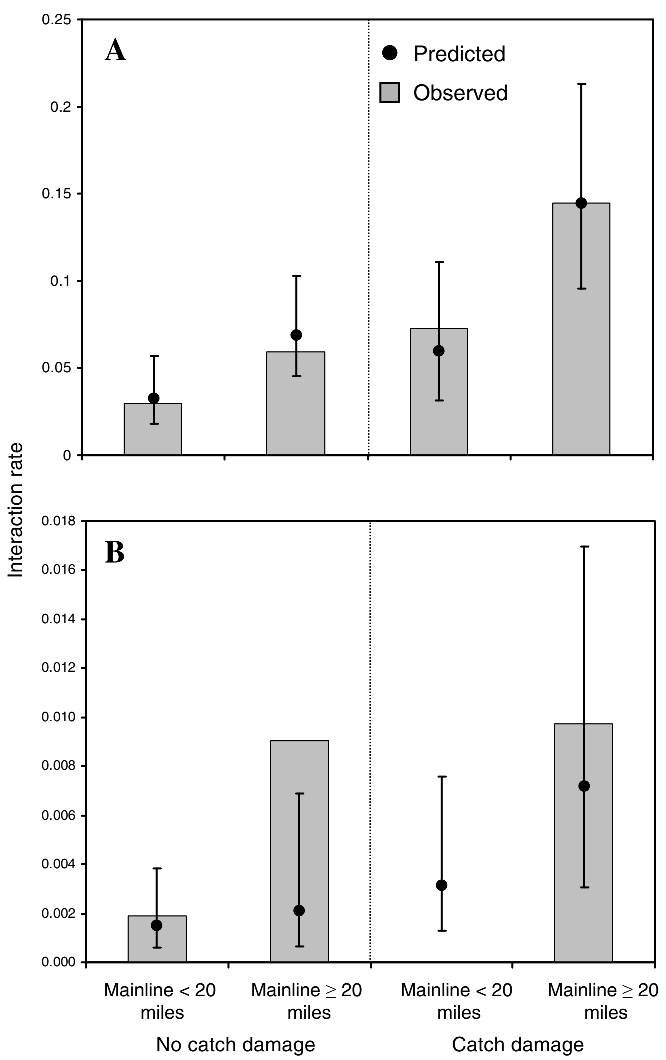

Figure 3

Predicted (black dots) and observed (bars) interaction rates with pilot whales (*Globicephala* spp.) by mainline-length category and observed catch damage for the Mid-Atlantic Bight fishing area (A) and other fishing areas (B). Error bars indicate 95% confidence intervals of predicted values. Note the difference in *y*-axis scale.

Approximately equal proportions of interactions involve hookings versus entanglement in the mainline for both species. Hooking almost exclusively involves the animal being hooked in the mouth. In most cases, the animal is released after the gangion line is either cut or broken; however the animal either trails or is entangled in a significant amount of monofilament line upon release. These animals are considered seriously injured and likely to die, and hence they are of greatest concern for conservation and management agencies. Marine turtle interactions with longlines also generally involve the animal swallowing the hook or being hooked externally. Therefore, developing and implementing guidelines for the removal of hooks and careful release of turtles is a major focus of management efforts (Watson et al., 2005). The challenges for release of marine mammals are more severe because larger animals can break gangion lines before these animals can be brought close to the boat, and there can be considerable risk of injury to the vessel crew. However, the development of equipment and protocols to more effectively remove ingested hooks from marine mammals would be an important step to reduce the severity of injuries.

The shape of the hook had no effect on marine mammal interaction rates in these analyses. This factor was examined closely because of recent changes in longline fishery gear—changes mandated to reduce the catch and mortality of endangered sea turtles. As of August 2004, all U.S. East Coast pelagic longline fishermen were required to use larger circle hooks rather than "J" hooks. In the data examined in the present study, there were relatively few circle hooks observed in the fishery and thus there was limited power to test this potential gear effect. Marine mammal interactions with the fishery will continue to be closely monitored to verify that actions to reduce turtle interactions do not inadvertently increase marine mammal interactions.

The logistic regression results demonstrate that longline fishery interactions with both pilot whales and Risso's dolphins are largely driven by environmental factors and spatial overlap of marine mammals and fishery operations. Pilot whales are concentrated along the shelf break between the 200- and 1000-m isobaths, and the highest densities are found between Cape Hatteras, NC, and New Jersey and along the southern flank of Georges Bank (Payne and Heinemann, 1993; Mullin and Fulling, 2003; Waring et al., 2006). Risso's dolphins are similarly concentrated along the shelf break, but they have a more northern distribution from New Jersey to southern New England (Waring et al., 2006). Both species are found along the southeast Atlantic U.S. coast from North Carolina to Florida; however, they have much lower densities and are not as strongly associated with the shelf break (Mullin and Fulling, 2003; Waring et al., 2006) as in the former region. The fishery effort is similarly concentrated along the shelf break in both the MAB and NEC (Fig. 1; Abercrombie et al., 2005). Fishery effort is generally concentrated just north of Cape Hatteras, NC, during the winter months from January through April. The fishery then expands northward and overall effort increases through the MAB and NEC fishing areas, reaching peak effort levels during September and October and remaining high through December.

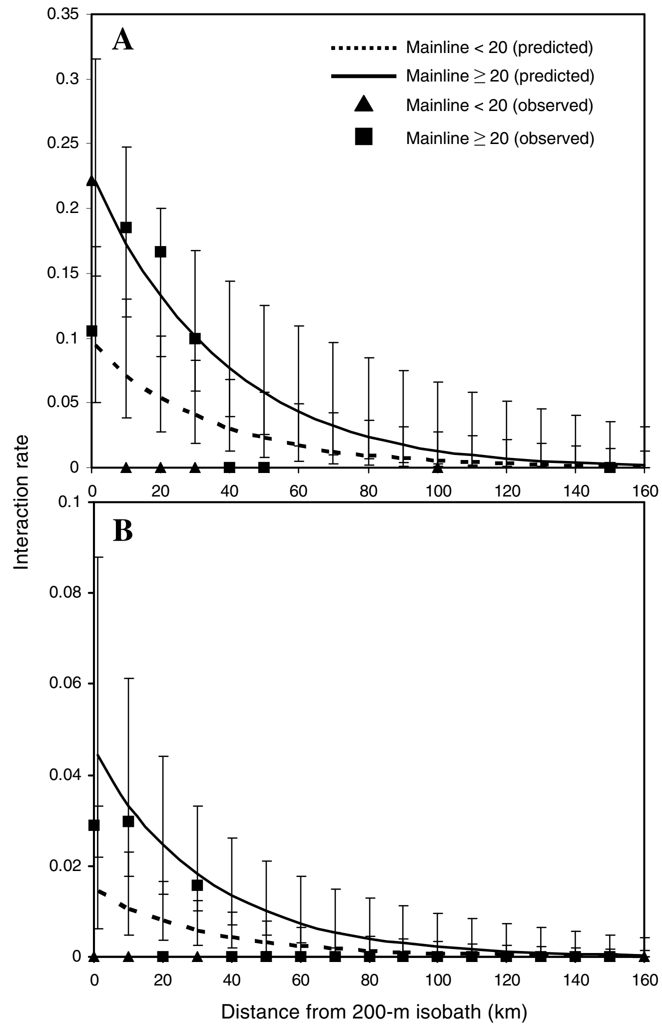

Figure 4

Predicted (lines) and observed (symbols) interaction rates (number of positive sets/total number of observed sets) for pilot whale (*Globicephala* spp.) in the Mid-Atlantic Bight fishing area (A) and other areas (B), with increasing distance from the 200-m isobath and by mainline-length category. Error bars indicate 95% confidence intervals of predicted values. Note the difference in the y-axis scale.

The strong overlap between fishery effort and high marine mammal presence is related to prey distribution. The pelagic longline fishery targets tunas and swordfishes that feed on small fish and squids. Both pilot whales and Risso's dolphins are also pelagic predators, and squids are a major component of their diets (Overholtz and Waring, 1991; Gannon et al., 1997; Kruse et al., 1999). Both longfin (*Loligo pealei*) and shortfin (*Illex illecebrosus*) squids are primary prey items, and both concentrate near the convergence zone of shelf-slope waters during summer and autumn (Brodziak and Hendrickson, 1999). The high interaction rate in the MAB area during summer and fall, and in warmer water temperatures, is therefore likely a function of environmental features driving availability of squid and small pelagic fishes that are prey for both the target fish species and marine mammals.

For both pilot whales and Risso's dolphins, there was a correlation between observed damage to swordfish catch and the likelihood of an interaction with a marine mammal. It should be noted that damage to catch may also be related to feeding by sharks, as well as by marine mammals. The strong correlation with damage to catch indicates that marine mammals are likely feeding upon the catch or bait. Similarly, the negative correlation between fish bait and Risso's dolphin interactions indicates that the animals were attracted to gear with squid bait as a ready food source.

The consistent effect of mainline length may also be related to depredation of catch on the longline gear. Longer mainlines represent a larger, more attractive food source or may be more easily detectable. Marine mammals therefore likely spend a longer time around the gear, creating greater opportunities for hooking

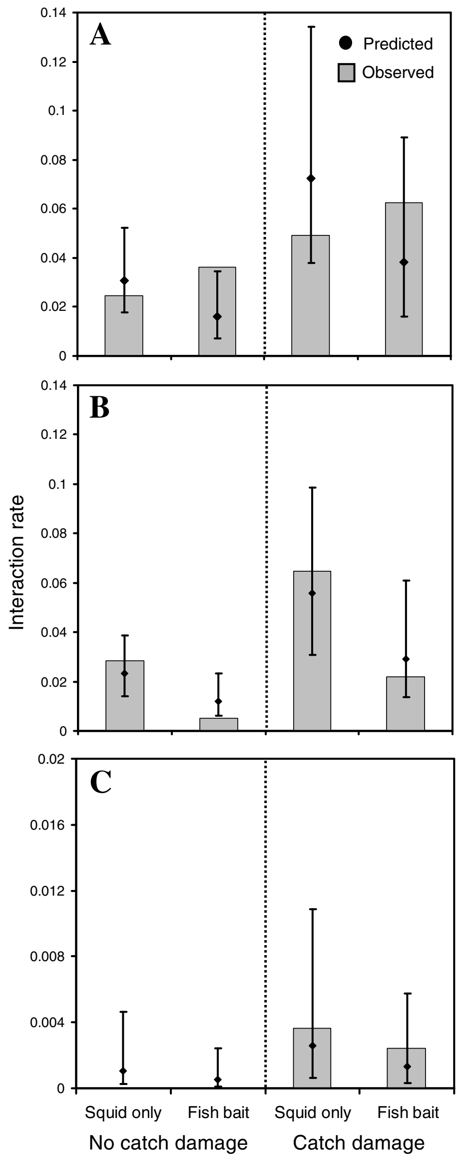

Figure 5

Predicted (symbols) and observed (bars) interaction rates (number of positive sets/total number of observed sets) for Risso's dolphins (*Grampus griseus*) in the Northeast Coastal fishing area (**A**), the Mid-Atlantic Bight fishing area (**B**), and other areas (**C**) as a function of bait type and observed catch damage. Error bars indicate 95% confidence intervals of predicted values. Note the difference in the y-axis scales.

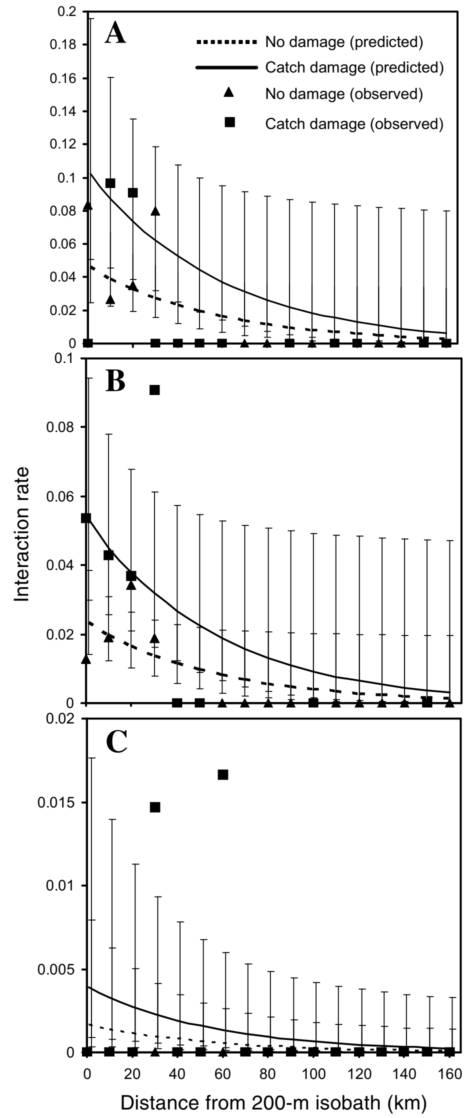

Figure 6

Predicted (lines) and observed (symbols) interaction rates of gear (number of positive sets/total number of observed sets) with Risso's dolphins (*Grampus griseus*) in the Northeast Coastal fishing area (**A**), the Mid-Atlantic Bight fishing area (**B**), and other areas (**C**) with increasing distance from the 200-m isobath and observed catch damage. Error bars indicate 95% confidence intervals of predicted values. Note the difference in the y-axis scales.

or entanglement. In other regions, sperm whales and killer whales are thought to respond to the sound of the vessel engines and winches when bottom longlines are hauled back on board (Kock et al., 2006). Longer haulback times associated with longer mainlines may thus further increase the opportunity for marine mammals to detect fishing gear. Improving the understanding of how and why marine mammals are attracted to longline gear will help both to reduce the economic losses due to depredation of catches and the impacts of commercial fishing activities on marine mammal populations.

Marine mammal bycatch in longline gear is driven to a large extent by the overlap of marine mammal and pelagic fish habitat with the area of longline fishery operations. In addition, this analysis demonstrates that longer mainlines had a significantly higher bycatch rate than shorter mainlines. Reducing mainline lengths below 20 nautical miles, particularly within the seasons and areas where interactions occur, has the potential to reduce the rate of interactions and the impact of the longline fishery on pilot whale and Risso's dolphin populations. This management option, along with a suite of other measures, is currently being considered by NMFS within the framework of the Pelagic Longline Take Reduction plan.

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