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INTERACTIONS BETWEEN CETACEANS AND THE TUNA FISHERY IN THE AZORES

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ABSTRACT

We studied the operational and ecological interactions between cetaceans and the tuna–fishery in the Azores, based on reports of observers placed on board tuna fishing vessels from 1998 to 2000. Data were collected during 617 fishing trips (representing 43% of total fishing trips) and 6,554 fishing events. Cetaceans were present during <10% of the observed fishing events, with common dolphins (*Delphinus delphis*) accounting for 78% of the occurrences. The presence of cetaceans during fishing varied both spatially and temporally, depending on the distribution of fishing effort and on the pattern of occurrence of each cetacean species in the region. Overall, cetaceans interfered in 5% of the fishing events. This interference resulted in a higher proportion of events with no catches. In the three years, 49 dolphins were caught in the fishing lines but were released alive, although it is impossible to determine if they survived the interaction. Annual estimates of incidental capture of cetaceans by all the tuna fleet were calculated based on total tuna landings. An estimated 55 dolphins were captured in 1999, 38 in 1998, and 16 in 2000. Overall, our results suggest a low level of interaction between cetaceans and this fishery.

Key words: cetacean/fishery interactions, tuna fishery, tuna–dolphin association, Azores.

There is evidence of an extensive worldwide interaction between marine mammals and fisheries (Northridge 1991). Marine mammals are known to interact with fishing activities either directly (operational interactions) or indirectly (ecological interactions) (Harwood 1983). Operational interactions may result in damage to fishing gear and incidental capture of marine mammals.

Probably the best-studied case of interaction between marine mammals and fishing is from the Eastern Tropical Pacific (ETP) and involves the tuna purse-seine fishery. The high levels of cetacean incidental mortality recorded in this fishery (IATTC 2000) result from the fishing techniques and procedures developed by the purse-seine fishermen, who discovered a way to profit from the frequent association between yellowfin tuna (*Thunnus albacares*) and several dolphin species (Au and Pitman 1986).

In the Azores there are no reports of incidental mortality of cetaceans in the tuna fishing activity. This is not unexpected since the tuna fishery fleet uses exclusively pole-and-line gear with live bait, which has a low probability of catching dolphins. Moreover, the general belief amongst Azorean tuna fishermen is that dolphins frighten or compete with the tunas, thus reducing the catch. As a result, and contrary to what happens in the ETP, tuna fishing vessels in the Azores tend to avoid schools of dolphins. In spite of this, there were some rumors on the direct take of small cetaceans by the tuna fishermen in the Azores. According to these, fishermen were harpooning dolphins to stop them from interfering with the fishery or to use the dolphin meat to catch and feed the live bait.

Following these unconfirmed reports, in 1998 the Azorean Fisheries Observer Program (POPA) was initiated with the main objective of guaranteeing a "dolphin-safe" certificate to the Azorean tuna vessels and to the tuna caught. This was carried out by placing observers aboard tuna vessels aiming to ensure a minimum of 50% coverage of the fleet. This level of coverage was established by the Direction Board of the program for logistical and budgetary reasons. POPA also collected data on the distribution and relative abundance of cetaceans, marine turtles, and seabirds, and biological data on tuna and other pelagic fishes.

The aim of the present study is to assess the interaction between cetaceans and the tuna fishing activity in the Azores, by examining the spatial and temporal patterns of occurrence of cetaceans in the fishery and investigating its impact on the activity.

Methods

The Archipelago of the Azores (Portugal) is located between 37° and 41°N and 25° and 31°W, extending more than 480 km along a northwest–southeast trend and crossing the Mid-Atlantic Ridge. It is composed of nine volcanic islands divided into three groups—eastern, central, and western—separated by deep waters (*ca.* 2,000 m) with scattered seamounts (Santos *et al.* 1995). The Gulf Stream and the North Atlantic and Azores currents (and their branches) are responsible for the complex pattern of ocean circulation that characterizes the Azores Archipelago, and result in the high-salinity, high-temperature and low-nutrient regime waters (Johnson and Stevens 2000).

Data were collected by POPA observers within the Exclusive Economic Zone (EEZ) of the Azores between 1998 and 2000. Most of the vessels operating in this area are Azorean, although a few vessels from Madeira Archipelago also fish in the zone sporadically.

The tuna-fishing season usually starts at the beginning of May, extending until the end of October, and the trips last on average five to six days. In a fishing trip most of the time is spent searching for tuna schools, using seabirds and floating objects as sighting cues, or traveling to or from the harbor. All the tuna fishing vessels operating in the Azores use the pole-and-line fishing technique. Five different types of poles and one fishing hand line are employed, depending on the tuna size and species and on the distance or depth of the school. Four of these poles have a large steel hook without barbs in the extremity, whereas the hand line and the pole used to fish at greater depths ("espanhol") possess hooks with barbs. Five tuna species are caught in the Azores: bigeye (*Thunnus obesus*), skipjack (*Katsuwonus pelamis*), albacore (*T. alalunga*), yellowfin, and bluefin (*T. thynnus thynnus*). The former two species constitute the main basis of the fishery, accounting for 95% of total landings in weight, as well as in economic importance, being the most important Azorean fishery. However, their occurrence in the area is highly seasonal—bigeye is more abundant from May to July, and skipjack from July onwards (Pereira 1995).

Permanent contracted observers worked for the whole fishing season, and others participated as volunteers for short periods in the summer months. Both contracted observers and volunteers received intensive training on fishing gear and operations, identification of tunas, and cetacean, seabird, and turtle species. A single observer was assigned to each vessel for a 30-d period, during which all the trips were monitored. Observers rotated between all the vessels registered in the program and operating at that time.

When the boat was traveling or searching for tuna, observers maintained standardized watches and collected information on cetacean, seabird, and turtle sightings. Cetaceans were considered to be present during a fishing event if at least one individual was seen <50 m from the target tuna school. The cetacean species involved, number of individuals (in interval classes) and behavior, and type of association and its impact on the fishing activity were recorded. Observers also recorded if there was incidental or direct take of cetaceans, and whether any physical harassment to the animals or other type of interaction took place. During a fishing event, observers noted if cetaceans were already present when the fishing vessel arrived, or if they arrived after the vessel. Cetaceans were considered to interfere with the fishing activity when they were responsible for sinking the tuna school (the school sinks immediately after the arrival of the dolphins to the feeding frenzy), competed with tunas by feeding on the live bait, or both.

Fishing data were recorded as the number of fishing events per trip and per boat. The duration and number of lines (or poles) per fishing event were highly variable and poorly correlated to the total tuna caught. The catch per fishing event, defined as total tuna caught (in tons) per number of fishing events, was calculated per year of study and compared in the presence and absence of cetaceans in the fishing activity.

To represent the spatial distribution of fishing effort and the presence of cetaceans in the fishing activity, the map of the Azorean EEZ was divided into a 30-min latitude and longitude grid. The number of fishing events and number of events with cetaceans present were then calculated for each of these blocks.

The only statistics that are available for the entire tuna fleet in the Azores are total fish landed per fishing trip per boat, and no data on the number of fishing events exist in the official records. Therefore, we used total tuna landed per trip as a measure of the fishing effort of the whole fleet to estimate a capture rate of cetaceans. The capture rates were calculated by year as ratio estimates from the sum of the cetaceans caught divided by the sum of the observed tonnage of tuna landed per trip. The total number of cetaceans captured per year was then calculated as the observed capture rate multiplied by total tonnage of tuna landed by the fishery in that year. Standard error of the capture rate and confidence limits for the total estimated capture were calculated using the formulae given by Cochran (1977) for ratio estimators.

Results

Fishing and Observation Effort

Observations were carried out from May to October in 1998 and 2000, and from April to October in 1999. In 1998 the number of fishing trips per month for the whole tuna fleet varied between 29 and 129, in 1999 it ranged from 6–112, and in 2000 from 54–108. Observer coverage varied between years and months, ranging from 25% to 64% (Table 1). In the three years, 617 fishing trips were monitored, during which a total of 6,554 fishing events were recorded. Monthly variation of the fishing effort was similar in the three years, with the highest number of fishing events occurring in May and the lowest in October. The number of fishing events per day (3.1 ± 2.1 SD, $n = 617$) varied greatly depending on the tuna abundance and size of the school, ranging between 1 and 15.

The geographical distribution of the observed fishing events was generally more concentrated around the islands, especially around the central and eastern groups of the Azorean Archipelago, and around seamounts (Fig. 1). However, there was a considerable variation between the years in the location of fishing events. Whereas in 1998 the fishing activity was more evenly distributed throughout the area, in 1999 more than 60% of the fishing events occurred around the eastern islands of the Archipelago in an area of approximately 8,000 nmi^2. In the following year there was a clear shift in the spatial pattern of fishing activity, and about 64% of the fishing events observed took place in a 3,500 nmi^2 area, located around the central group of islands.

Presence of Cetaceans in Fishing Events

Cetaceans were present in 649 fishing events, representing <10% of the 6,554 events observed. In 52% ($n = 334$) of the encounters the cetacean group arrived at the fishing site after the vessel. Mysticetes were present in five events during the whole period: fin whales (*Balaenoptera physalus*) were present on three occasions, and sei (*Balaenoptera borealis*) and minke (*Balaenoptera acutorostrata*) whales were recorded once. Common dolphins (*Delphinus delphis*) accounted for 78% of the occurrences recorded. Spotted (*Stenella frontalis*) and bottlenose (*Tursiops truncatus*) dolphins were seen on 14% and 5%, respectively, of total interactions recorded. The three dolphin species comprised almost 97% of all the

Table 1. Number of fishing trips, observer coverage (number of fishing trips with observers to total number of trips), and total tuna catch (tons) per month, from 1998 to 2000.

	1998			1999			2000		
Month	No. fishing trips	Percent observer coverage	Total catch (ton)	No. fishing trips	Percent observer coverage	Total catch (ton)	No. fishing trips	Percent observer coverage	Total catch (ton)
April	0	0	0	21	33	180.4	0	0	0
May	72	35	516.2	111	52	703.7	77	64	223.6
June	129	28	1921.2	112	27	516.5	108	60	414.4
July	128	33	1439.9	49	59	237.6	76	51	190.9
August	108	37	873	66	59	403.2	73	60	202.8
September	108	25	511.7	53	49	272.2	64	41	246.7
October	29	59	138.2	6	50	20	54	28	233.4

presences registered. Striped dolphins (*Stenella coeruleoalba*), Risso's dolphins (*Grampus griseus*), false killer whales (*Pseudorca crassidens*), and sperm whales (*Physeter macrocephalus*) accounted for the remaining cases of interaction (<2%). On 15 fishing events more than a single species was seen around the fishing vessel, the most common mixed groups being composed of common and spotted dolphins.

The location of encounters between operating fishing vessels and cetaceans was consistent with the distribution of fishing events in the three years (Fig. 1). The proportion of fishing events in which cetaceans were present was not independent of the year ($\chi^2 = 43.69$, df $= 2$, $P < 0.0001$). Cetaceans were present in more than 15% of the fishing events observed in 1998, 9.5% in 1999, and only 8% in 2000. Despite some interannual variability in the early months, the cetacean encounter rate decreased as fishing season progressed, with a similar pattern in all years ($\chi^2 = 202.58$, df $= 6$, $P < 0.0001$).

The monthly encounter rate was significantly correlated with the number of sightings per fishing trip for common and spotted dolphins (Pearson's correlation, common dolphin, $r = 0.84$, $n = 18$, $P < 0.0005$; spotted dolphin, $r = 0.85$, $n = 18$, $P < 0.0001$), but not in bottlenose dolphins $r = -0.29$, $n = 18$, $P > 0.1$).

Interference with Fishing Activities

In approximately 49% ($n = 319$) of the 649 fishing events in which cetaceans were present, interference with the fishing activity was noted. Tuna schools were observed to sink in the presence of cetaceans in 44% ($n = 140$) of the occasions. In 41% ($n = 130$) of the cases cetaceans were seen feeding on the live bait, thus competing with the tunas. On 41 occasions both situations occurred, and in the remaining cases the observer was unable to classify the type of interference. Common dolphins were responsible for most of the observed interferences (77%), followed by spotted dolphins (16%), bottlenose dolphins (5%), striped dolphins (1%), false killer whales (1%), and Risso's dolphin with just one case. Only the first three species were seen feeding on the live bait. There were no significant differences in the number of interferences in the fishing events by dolphin species

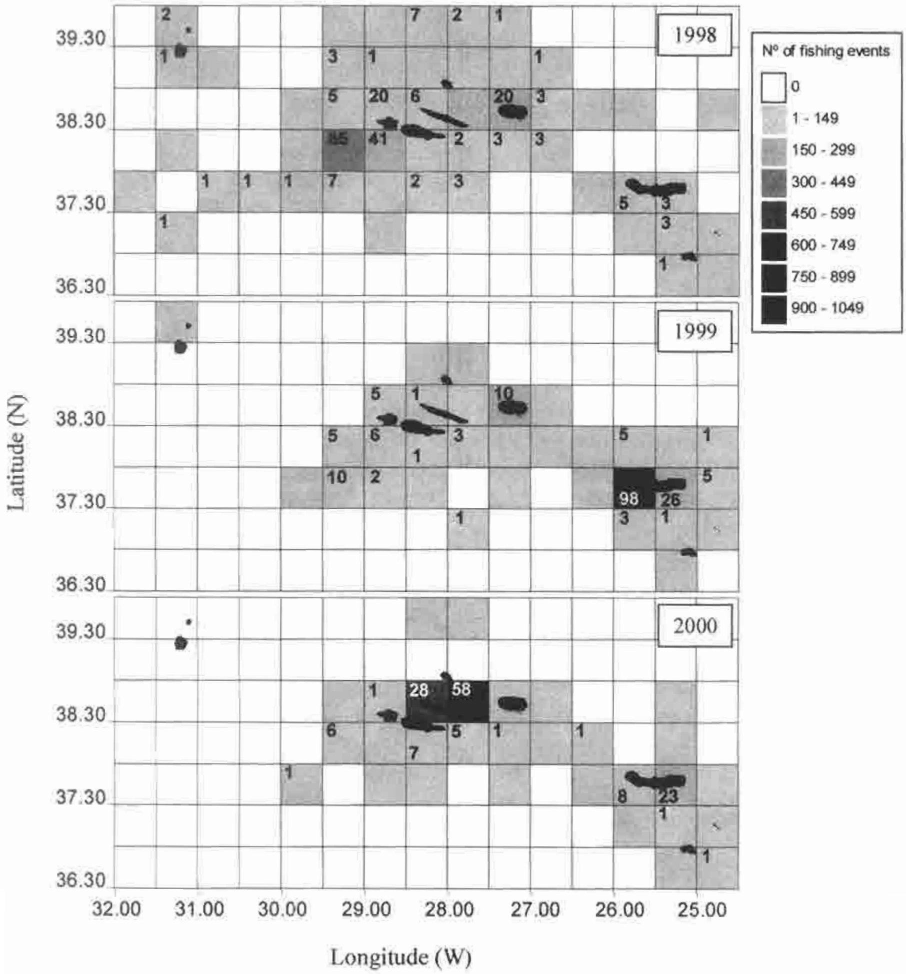

Figure 1. Geographic distribution of fishing events and of encounters with cetaceans during fishing activities by 0.5° × 0.5° blocks per year. Number of encounters with cetaceans presented in each block (559 encounters represented).

attendance ($\chi^2 = 2.04$, df $= 2$, $P = 0.37$). However, the type of interference observed was not independent of the species involved ($\chi^2 = 7.47$, df $= 2$, $P = 0.025$). Common dolphins were seen eating the bait on 52% of the situations where some kind of interference was detected. For spotted and bottlenose dolphins the most frequent interference was tuna school sinking, observed on 68% and 75% of the occasions, respectively.

Cetaceans can also interfere with the fishing activity in less obvious ways that are not so easily detectable or quantifiable by the observers aboard. There was a significantly higher proportion of fishing events with zero catches when cetaceans were seen interfering with the gear or bait ($\chi^2 = 8.85$, df $= 1$, $P < 0.005$). In about 8% ($n = 26$) of the fishing events carried out with interference of cetaceans there was no catch, whereas when they were present but did not interfere $<3\%$ ($n = 10$) of the events were unsuccessful. The mean weight of tuna caught per fishing event while cetaceans were interfering in the fishery (539.2 kg, SD = 789.2) was not significantly lower than when cetaceans were present but not interfering (633.2 kg, SD = 878.7) (Mann-Whitney, $U = 35735$, $P = 0.078$). However, a highly significant difference was found when mean weight of tuna caught per fishing event was compared in the presence (mean = 633.2 kg, SD = 878.7, $n = 302$) and absence (mean = 486.7 kg, SD = 852.4, $n = 5{,}151$) of cetaceans (excluding the events where interference was observed) (Mann-Whitney, $U = 689283$, $P = 0.00086$).

Capture of Cetaceans

From 1998 to 2000, 49 dolphins on 44 observed fishing events (0.7%) were accidentally hooked on the fishing line. All the animals were released alive (by cutting the fishing line), although it is impossible to know if they survived the interaction or if the injuries caused death later on. Common dolphins were involved in 36 such events, striped dolphins in eight, and bottlenose dolphins in one. The two fishing techniques responsible for most of the catches ($n = 37$) are generally used to fish at greater depths and at a greater distance from the vessel. There were no reports on the direct take of cetaceans during the three years of study.

There is a small "capture" of dolphins associated with this fishery. Estimates of total incidental capture of cetaceans in the Azorean tuna fishery from 1998 to 2000 were calculated based on total tuna landings (Table 2). Capture rate reached the highest value in 1999 (0.0173, SE = 0.0067) and the lowest in 1998 (0.0070, SE = 0.0024). A total estimate of 55 dolphins may have been incidentally hooked by the tuna fishery during 1999, 38 in 1998, and 16 in 2000.

Discussion

Cetaceans occurred in $<10\%$ of the fishing events monitored during the present study. Half of the times when both were found together, cetaceans arrived at the fishing site after the vessel.

Ten different cetacean species were observed in the proximity of actively fishing vessels. For most of the species, however, encounters with fishing vessels were rare and seemed only casual. In general, the frequency of occurrence of each cetacean species during fishing activity is roughly consistent with its known relative abundance in the region. Common, spotted, and bottlenose dolphins comprised the largest number of occurrences in the fishery and are reported to be the most frequent and abundant cetaceans in the Azores (Clarke 1981, Martin 1988, Reiner 1988). Although fishermen sometimes took advantage of the presence of mysticetes—as these often behave as "floating objects" that attract tunas—these events were only casual and no real interaction existed.

The low number of interference cases observed does not support the notion that cetaceans, particularly small dolphins, are harmful to the tuna fishery activity in the Azores. The presence of cetaceans was reported to negatively affect the activity in only $<5\%$ of all the observed fishing events. Cetacean interference did result in a higher proportion of fishing events with no catches.

Table 2. Estimated capture of cetaceans by tuna fishery fleet in the Azores from 1998 to 2000. CR = capture rate (ratio of cetaceans caught per observed tonnage of tuna landed). SE = standard error of capture rate. L_1 = lower 95% confidence limit. L_2 = upper 95% confidence limit.

	Observed captured cetaceans			Estimates of captured cetaceans		
Year	Number	CR	SE	Number	L_1	L_2
1998	15	0.0070	0.0024	38.0	16.91	59.06
1999	25	0.0173	0.0067	54.6	19.55	89.55
2000	9	0.0105	0.0017	16.0	11.74	20.19

On the other hand, fishing events carried out in the presence of cetaceans (but without interference) yielded higher average tuna catches. Furthermore, the catch per unit effort was higher in the presence of cetaceans in the three years of study, suggesting the existence of an association between areas of tuna attendance and these dolphin species. Association between tunas and pelagic dolphins involving various species of both groups has been reported for several geographic areas (Allen 1985, Au and Pitman 1986, Hassani *et al.* 1997). There have been arguments favoring both the food-based and the antipredation theories (see Scott and Cattanach 1998). Edwards (1992) suggests that the tuna/dolphin association may result from the combination of several factors, including oceanographic features of the habitat, hydrodynamics, foraging energetics, and life-history characteristics of both groups. She proposes that tunas are more likely to follow dolphins than the reverse, and that the association is expected to be more prevalent in oceanic environments, where prey usually occurs in clumped distributions.

An estimated 55 dolphins were seized in the fishing lines in 1999, with lower numbers in the other two years. Thus, the tuna fishery in the Azores has very low cetacean capture rates and no incidental mortality was observed during the three years of the monitoring program. Therefore, this fishery seems to be unusual in that it does not involve significant mortality of cetaceans.

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