Acoustic devices help to reduce incidental mortality of the Franciscana dolphin *(Pontoporia blainvillei)* in coastal gillnets.

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ABSTRACT

A new double blind experiment in artisanal gillnet fishery at northern Buenos Aires in Argentina was conducted during two consecutive fishing seasons to determine the effectiveness of acoustic deterrents at reducing bycatch of the Franciscana dolphin (*Pontoporia blainvillei*). The fishery consisted of over 20 fishermen and it was featured by small inflatable and fiberglass vessels operating between 0.5 to 7 km from the coast. The experiment was done working in association with 7 artisanal fishermen. Each fishery vessel carried an independent observer who was rotated throughout the course of the experiment. The acoustic devices (Airmar 70kHz) were assigned randomly and placed on the nets by the on-board observers. Equivalent numbers of active and silent acoustic devices were attached at the nets. Neither fishermen nor observers were aware of which type of alarms was being placed on each net. The nets were then identified as active or inactive for the analysis. Information on the number of dolphins captured, geographic position, depth, configuration of fishing gear, soak time, biomass of fish caught and sea lion predation in a string/net producing any damage was recorded. A total of 43 dolphins were caught in the silent nets, and only 2 dolphins were caught in the active nets, demonstrating a highly significant reduction in bycatch. Although these acoustic devices showed promise as a management tool in this fishery, long term effectivenes must be investigated. Acoustic devices should be addressed as only a simply component of approach to a viable dolphin bycatch reduction plan and fishery management strategy in the study area.

KEYWORDS: BYCATCH, FRANCISCANA DOLPHIN, *Pontoporia blainvillei*, CONSERVATION

INTRODUCTION

The Franciscana dolphin, *Pontoporia blainvillei* is an estuarine/marine species inhabiting only the coastal areas of the Southwestern Atlantic Ocean from Espirito Santo State, Brazil (18°25'S) (Siciliano 1994) to Chubut Province, Argentina (41°09'S) (Crespo *et al.* 1998). Along its distribution, Franciscana dolphins have been subject to a significant level of bycatch in gillnets for several years, and incidental mortality probably represents the major threat to the species survival. Previous studies have shown that in Argentina, small fishing camps situated along coastal Buenos Aires pose more of a threat to the species than operations from large fishing harbors (Corcuera *et al.* 1998). This is primarily due to the fact that the artisanal fishing is carried out in shallow waters. A minimum annual catch of 500 dolphins was estimated from the fisheries of the Buenos Aires coastal area in Argentina (Corcuera *et al.* 1998). However, it has been suggested that this bycatch was underestimated in the last decade (Bordino *et al.* 2002). It is listed under the Convention on International Trade in Endangered Species on Apendix II, in Appendix I of the Convention on Migratory Species, and is also classified on the IUCN's Red List of Endangered Species as "data deficient", meaning that there is inadequate information to make an assessment of its current status. As gillnet fisheries will continue operating in the same areas inhabited by the Franciscana dolphin, methods to reduce entanglement are urgently needed. Cetacean bycatch problems have been addressed in other locations with the use of acoustic deterrents, demonstrating that alarms or pingers reduce both porpoise and whale bycatch without decreasing the normal harvest of fish (Lien *et al.* 1992, Kraus *et al.* 1997, Gearin *et al.* 2000,). It is not clear whether dolphins become entangled, but it seems that when they hear the sound produced by acoustic devices, dolphins activate their internal sonar in order to identify the source of sound, recognizing and avoiding nets. Busnel *et al.* (1974) recorded clicks of low, high, ultra high frequencies mainly with signals below 30 kHz on free range Franciscana dolphins. Von Fersen *et al.* (1997) recorded echolocation clicks around 130 kHz as the dominant frequencies in a captive individual; no whistle sounds and other lower frequency were recorded. In Argentina, efforts to reduce franciscana bycatch with 10kHz acoustic devices were successful, although this pinger had a "dinnerbell" effect in attracting predatory sea lions (Bordino *et al.* 2002). Local fishermen are concerned and consider sea lion predation as a restriction to fishing because the damage caused on fishing gear and loss of fish catch. For fishermen, sea lion interaction is more important than dolphin bycatch. All marine mammals in Argentina are currently protected from harvests, but incidental mortality is not considered in the laws. Because lack of enforcement, sea lions are also often killed by local fishermen.

In response to the results obtained in previous research, we conducted a new experiment to test the effectiveness of a 70 kHz pinger in reducing bycatch of the Franciscana dolphin, and to evaluate the effect on sea lion predation behavior.

METHODS

We conducted a 2-year double blind experiment using acoustic alarms in the Cabo San Antonio gillnet fishery between December 2001- March 2002 and December 2002 - April 2003 (Fig. 1). These fisheries consisted of over 20 fishermen who fished from September to April, although some boats operated throughout the year. The fisheries were conducted by small inflatable, fiberglass and wood vessels 5-8m in length operating between 0.2 to 7 km from the coast. The fishery mainly targeted on Sea trout (*Cynoscion striatus)*, Whitemouth croacker (*Micropogonias furnieri)*, Parona leatherjack *(Parona signata),* and Patagonian smooth-hound (*Mustelus* sp.). The nets were composed of mono or polyfilament nylon and were set on the bottom anchored in position, placed in waters from 3 to 12 m. The nets were 50-75 m long and 2-2.5 m deep with a stretched mesh size between 10 to 12 cm, although fishermen sometimes used 2 to 5 nets together in a string. Working in association with seven artisanal fishermen, active and inactive (silent) pingers were attached to the upper rope of any net/string. Each net/string was identified as active or inactive net in the analysis. The active pinger Airmar 70kHz emitted a 300 ms broadband signal every 4 sec centered at 70kHz, with a source level of 132 dB (1 micropascal @ 1m). This pinger was choosen because the frequency is within the hearing known range for Franciscana dolphin, and because it was suspected that the frequency do not create a "dinnerbell" effect on sea lions. Because of water turbulence and boat traffic affecting the perception of sound in the water, background noise was previously recorded in the study area. The pinger specifications ensured a 100 m safety zone around each net/string with ambient noise level in the 10kHz at 45 dB. The experimental design was similar to that developed by Kraus *et al.* (1997), and previously used in the same study area by Bordino *et al.* (2000). Because fishing in the area is territorial, strings/nest were placed at least 300m apart, minimizing the potential for any confounding effects between silent and active gear. Each alarm was alphanumerically coded to track battery life, malfunctions and losses. The observers were randomly rotated from vessel to vessel throughout the course of the experiment. The number of dolphins captured, geographic position, depth, configuration of fishing gear, soak time, coded pinger in every set, and the biomass of fish caught was recorded. We also recorded if target fish species in a string/net had been damage by sea lion *(Otaria flavescens)*, if sea lion predation produced any damage to the net, as well as the presence of sea lions close to nets at the beginning and end of any daily fishing trip. The fishing gear was not observed permanently, and it was assumed that interaction was produced for solitary sea lion individuals instead a large group. Because partially damaged nets were used during the experiment, any new daily damage was marked and identified with plastic tags, and classified as produced by *sea lions*, *sharks,* or *unknown,* based on fishermen's experience. The intensity of sea lion attack was classified as *low* or *high* in relation to damage recorded on fish and net. Observers recorded estimated fish catch in every net/string. Fish catch by species was unfeasible, and total catch was weighted before processing for sale. Where possible, bycaught dolphins were collected for necropsy analysis. To prevent experimental bias, fishing trips no following any aspect of the used protocol were excluded. Due to several differences in nets and strings used by the fishermen, and the different soak times during the experiment, fishing effort was defined in m^2 X h. The capture per unit effort for dolphins (CPUE *dolphins*) and the capture per unit effort for fish (CPUE *fish*) was expressed as the number of dolphins caught and kg of fish caught per fishing effort respectively. Multiple entanglements of two dolphins in the same nets the same day were recorded only four times and assumed as rare events for the analysis. In order to compare bycatch rate with other areas, the CPUE *dolphins* values recorded were also recalculated as the number of dolphins captured per 1000 linear meters of gillnets per day. The 95% confidence intervals for CPUE *dolphins* were calculated based in a Poisson distribution of data. The CPUE *dolphins* were classified by sex in relation to depth of catch and analized with non parametric tests as Kruskal Whalis and Pairwise Multiple Comparison Dunn's test.

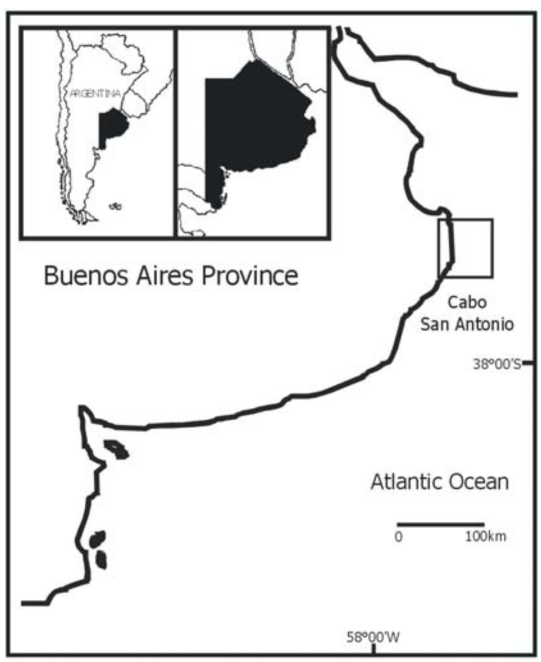

Fig.1. Location of the study area, Cabo San Antonio

Sea lion attack per unit effort (APUE) was expressed as the number of attacks per fishing effort. In order to investigate sea lion predation throughout the experiment, the APUE rate was calculated at the beginning and end of every 2-months periods each year. The APUE rate was defined as APUE active/APUE inactive. The dolphin bycatch and sea lion predation between active and inactive nets/strings were compared using Fisher's exact test with a 2X2 contingency table. The CPUE *dolphins* and APUE was tested for correlation with CPUE *fish* using Pearson analysis after a Kolmogorov- Smirnoff test for normality was passed. For additional analysis, the probability of catch at least one dolphin and the probability of at least to have one sea lion attack on inactive and pingered nets were calculated assuming Poisson and Binomial distribution respectively, and compared using likelihood and Chi-square tests. From previous records, a power analysis using Fisher's exact test indicated that approximately 2000 and 300 nets would be needed for detecting at least 50% decline in bycatch and sea lion predation rate respectively with 0.80 power. The experiment tested the hypothesis that dolphins and sea lions have the same bycatch and predation rate on active and on silent nets. We also assumed independence among fishing nets/strings and trips, and nets with constant catch per unit effort.

Twenty-seven dolphins were collected and necropsies were performed to determine diet and reproductive condition. Males and females were considered sexually mature based on Kasuya and Brownell (1979).

RESULTS

A total of 458 inactive (silent) and 380 active nets/strings were set in similar locations and similar mean soak times (Fig. 2). The annual fishing effort for both types of nets and dolphin bycatch per week are showed in Fig. 3.

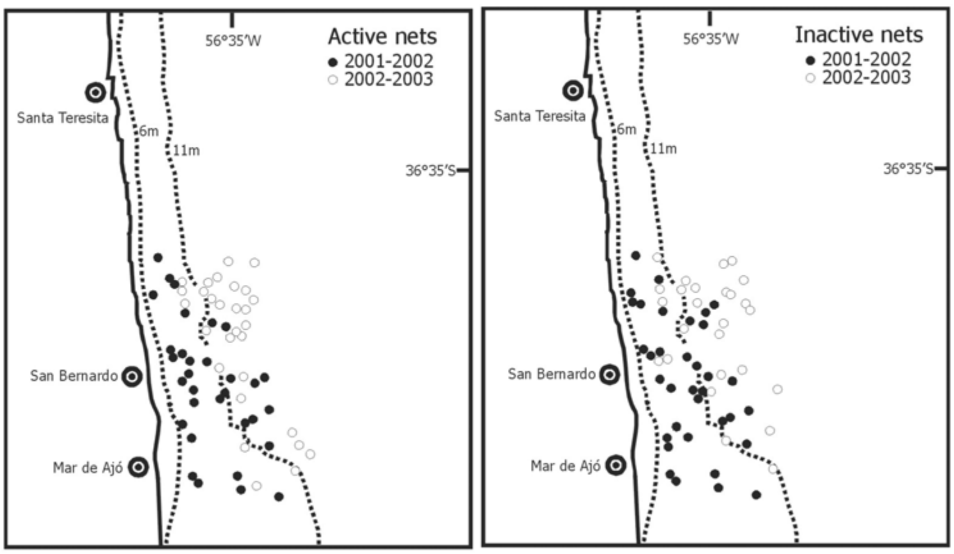

Fig. 2. Location and distribution of inactive and active nets/strings in Cabo San Antonio.

Forty-three dolphins were caught in silent nets and only two in active nets. The 56% of entangled dolphins were females (*n*=43) and the 42% of these females were immature (*n*=24). Among males, the 37% were immature individuals (*n*=19). The bycatch rate was significantly lower on active than on inactive nets ($P<0.0001$, Fisher's exact test). The expected number of dolphins caught if alarms were not used would have been 84 (accounting 100% of nets as inactive nets, and determined by the CPUE *dolphins* recorded in inactive nets during this experiment), as opposed to the 45 takes observed. The mean CPUE *dolphins* recalculated per 1000 linear meters of gillnets per day was 0.43 (IC 95% 0.32-0.55). The mean depth of captures was significantly higher for male than for female and immature individuals (Kruskal Whalis test, *P*:0.020, H: 7.840, 2 *df*; Pairwise Multiple Comparison Dunn's test, $P<0.05$). The probability of one entanglement per fishing set during the experiment was 0.022 and 0.0017 on inactive and pingered nets respectively, and were significantly different ($P<0.001$, Log likelihood ratio test). No correlation was found between dolphin bycatch and CPUE *fish* on inactive nets in relation to depth (Pearson coefficient: -0.052, P = 0.886, Fig. 4).

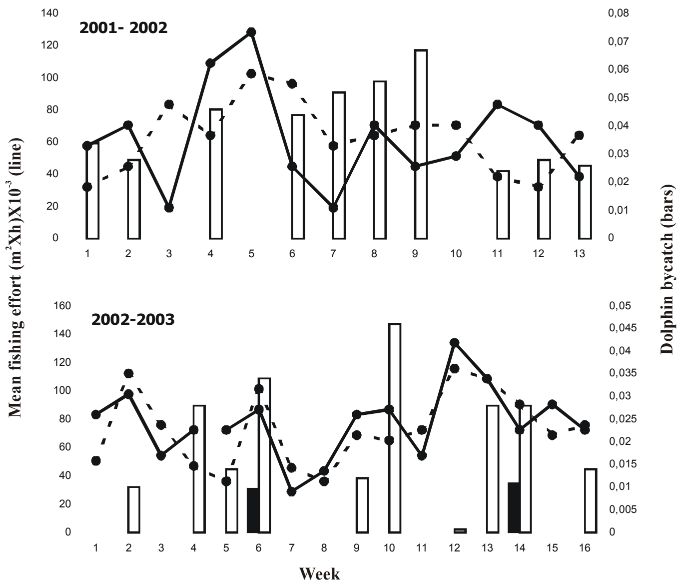

Fig. 3. Weekly summary of fishing effort in active (dashed line) and inactive (solid line) net/ string, and dolphin bycatch in active (black bars) and inactive (white bars) net/string.

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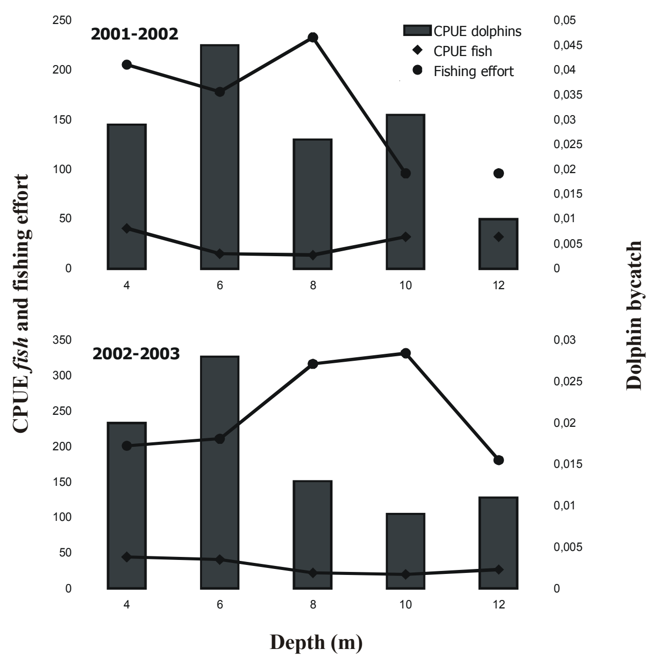

Fig. 4. Dolphin bycatch on inactive nets and CPUE fish in relation to depth range

Fishermen and observers retrieved 23 of the 45 dolphins entangled during the experiment and also some were examined on board. Additionally, two Burmeister's porpoises *Phocoena spinnipinnis* were caught in inactive nets.

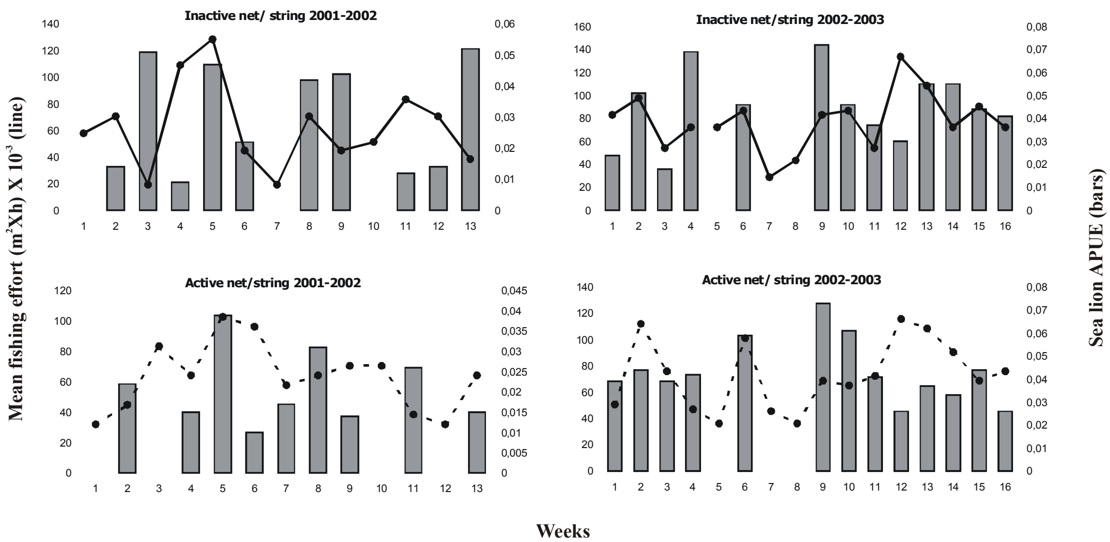

Fig. 5. Weekly summary of fishing effort in active (dashed line and inactive (solid line) net/ string and sea lion predation (bars).

Necropsies of 23 Franciscana dolphins revealed that entangled individuals were not eating the target species, and that 3 of 12 retrieved mature females were pregnant. In total, 15% of nets were attacked by sea lions (n=838); 44% of them presented high intensity of attack (n=127).

Sea lion predation was similar on active than on inactive nets (P=0.2042, Fisher's exact test, Fig. 5), but intensity of attack on active nets was significantly lower than expected (P = 0.0014, Fisher's exact test). The APUE rate was 0.66 (2001-2002) and 0.95 (2002-2003).

Similar CPUE *fish* was recorded for both types of nets/strings (P = 0.718, t test). A negative correlation was found between the APUE and CPUE *fish* on inactive nets in relation to depth (Pearson coefficient: -0.570, P = 0.009, Fig. 6).

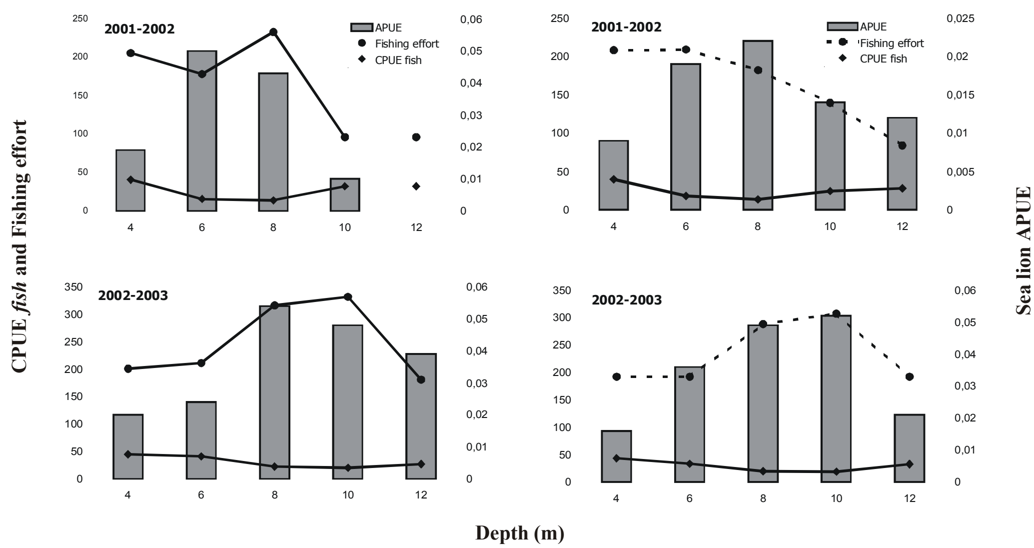

Fig. 6. Sea lion predation and CPUE fish in relation to depth range. Fishing effort in active (dashed line) and inactive (solid line) net strings.

DISCUSSION

The CPUE dolphins was over ten times lower on active than on inactive nets, showing that pingers were highly effective at reducing the bycatch of Franciscana dolphin in the study area. The effectiveness of the 70kHz pinger was higher than previously recorded with a 10 kHz pinger (Bordino *et al.* 2002). One of the most important critiques to the use of acoustic devices has been its long term effectiveness. This study showed that pingers reduce by-catch of Franciscana dolphins in gillnets at least over two consecutive fishery seasons. Although the potential for habituation needs to be addressed to determine long-term viability, there is no evidence to habituation from this experiment. Potential habituation effects, if exist, could be reduced with different signals waveforms produced in random order (Kastelein *et al.* 2000). Acoustic devices with higher frequencies must certainly be carefully considered because the possibility for disruption of dolphin communication. The dolphin bycatch by sex in relation to depth of catch showed prevalence of females and juveniles in shallow waters. It supports the idea that females are closer to the coast during spring and summer (Bordino *et al.* 1999). The high proportion of entangled immature animals could be explained in terms of lack of experience of the young dolphins (Perrin *et al*. 1994), higher proportion of young individuals in the population as expected for mammals (Caughley 1977), and/or by differential use of the habitat. The bycatch of younger individuals was also reported for other fisheries along the species' distribution (Kasuya and Brownell 1979, Perez Macri and Crespo 1989, Corcuera *et al.* 1994). The mean CPUE *dolphins* recorded during the pinger's experiment between 2001 and 2003 was similar to those previously reported in the same fishery (Corcuera *et al.* 1998). It was previously indicated that annual incidental mortality in northern Buenos Aires is about 200-260 individuals (Corcuera *et al.* 1998). It is interesting indicate that between 2001-2003 the fishing effort was similar to previous years, but fishermen used a higher proportion of drifnets instead gillnets, Thus, the CPUE reported not necessarially indicates a reliable value for gillnets because entanglement in drifnets seem to be rare events, basically because the reduced soak time. The Franciscana dolphin bycatch in Argentina has been underestimated in the last decade because previous information about dolphin bycatch in the area was only recorded through interviews with fishermen (Bordino *et al.* 2002), or because the number of fishermen and total fishing effort was not well evaluated (Bordino *et al.* 2004). The dolphin bycatch showed no correlation with CPUE *fish*, and necropsies revealed that caught individuals did not prey on target species from the nets. The mechanism involved in entanglement is unclear. The full stomachs of the entangled individuals indicates that capture occurred during or just after feeding activities, and it has been suggested that feeding behavior of Franciscana dolphin may be a contributing primary factor that makes them susceptible to entanglement (Bordino *et al*. 2000). Dolphins echolocate and communicate emitting different sounds. It is expected that dolphins have their internal sonar activated during foraging activities. Some studies showed that dolphins and porpoises are able to detect gillnets (Au and Jones 1991, Au 1994, Kastelein *et al.* 2000). However, it is still unclear if they are able to detect the nets at distances to avoid them, and also the ambient water noise must be an important variable. The echoes from gillnets could be also of little significance to a dolphin during feeding activities (Goodson and Datta 1992, Goodson *et al.* 1994). If the Franciscana dolphin is able to detect fishing nets, it does not necessarily mean that will avoid the entanglement. In a state of awareness produced by the pinger's sound, the Franciscana dolphin must be able to detect the net with enough distance and time to perform avoidance behavior in response to an "unknown" source of sound. While traveling between feeding areas, their echolocation rate could change or even their internal sonar could be turned off having a greater chance of being caught in gillnets. There is evidence that dolphins do not constantly need to use its sonar to investigate the environment (Woods and Evans 1980). Dawson (1991), noticed that free ranging Hector's dolphins *(Cephalorynvhus hectori)* were not always producing sounds. However, Stone *et al*. (2000) recorded that the same species use its sonar constantly, and no change in echolocation rate was recorded as result of pinger sound, indicating that the avoidance mechanism is not related to the echolocation habits but rather to their choice of where to echolocate. Behavioral responses to pingers including sonar behavior capabilities in relation to the mechanism involved in entanglement of Franciscana dolphin needs to be evaluated.

The APUE of sea lion attacks were similar on active and inactive nets/strings, although the intensity of attack was significantly lower on active nets. The APUE must be influenced by the number of sea lions around the nets, motivational state of sea lions, presence of entangled fish, net position, environmental conditions, and even the presence of sea lion predators as sharks or killer whales. No "dinnerbell" effect was recorded throughout this new experiment maybe as a direct consequence that sea lions do not hear the frequency produced by the tested pinger. The range of maximum sensitivity in pinnipeds is about 12 to 17 kHz, and threshold of pain is about 200db at 1 micropascal @ 1m (Greenlaw *et al.* 1986). There is no explanation for the lower intensity of sea lion predation on active nets. Sea lions have not displayed specialized adaptation for hearing high frequencies, but it may help them to avoid a potential predator as Killer whale *(Orcinus orca*), which can typically produce and hear high-frequency sounds up to 100-150 kHz (Au *et al* 1999). To consider reduction in sea lion predation intensity as successful is relative because such level of predation is not perceived by fishermen. The sea lion predation was mainly recorded at depth range with higher fishing effort, and there was a negative correlation between APUE and CPUE *fish*. It seems that sea lions in this area look for net locations instead fish school, probably because have learnt that catching fish is relatively easy once fish is entangled. Sea lions may have developed audible capacity to identify and recognize fishing boats or the noise of its motor as a source of food, and the boat or the net by themselves could also produces a "dinnerbell" effect. Local fishermen use small buoys instead flags to identify gillnet ends, because they believe that sea lions associate flags with net locations. Behavioral conditioning in association with pingers producing a negative reinforcement should help to effectively reduce sea lion predation on nets in this fishery. Sea lion predation in Cabo San Antonio artisanal fishery was reported to produce a lost of about 9% of total fish catch (Fazio *et al*. 2000), and damage to gear is currently the main concern for local fishermen. The closest South American sea lion colony is located at about 200km from the study area and this interaction seems to be produced for a reduced number of individuals (Bordino *et al.* 2002).

Artisanal fishing operations in coastal Buenos Aires are highly dependent on weather conditions, and as a consequence, fishing effort changes daily. Annual differences recorded in the CPUE *fish* in relation to depth must be consequence of environmental changes which also must play an important role in marine mammal-fishery interaction.

The activity, although relatively regular, presents reduced economy because operational and social factors. Also, because of political and economical reasons the fishery was atypical in 2001-2002, and changes in the fishing effort included to use a higher proportion of driftnets instead gillnets, and to operate mainly in shallow waters. Although it is a subsistence fishery, most of fishermen operating in the area were interested in adding alarms to their nets and to face the cost if the alarms could be made to minimize sea lion attacks. The presence of illegal trawlers operating in coastal waters in the area has produced the loss of fishing gear including many pingers. As a consequence, currently only a reduced number of nets are using pingers in the area.

It is expected that conflicts between marine mammals and fisheries in coastal areas will increase. Our study suggests that the use of the acoustic devices in small fisheries under appropriate controls should be considered as a tool in developing a strategy for conservation of the Franciscana dolphin in coastal Buenos Aires. The long term effectiveness of pingers should be investigated, as well as the mechanism of deterrence. The use of pingers in small fisheries should be addressed as only a simply component of approach to a viable fishery management strategy in the study area.

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