Fine-scale behaviour of bottlenose dolphins around gillnets

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We studied the fine-scale behaviour of bottlenose dolphins *Tursiops truncatus* around gillnets in North Carolina, USA, during May and June 2002. We made observations from an overhead digital video camera, suspended from a helium-filled aerostat, tethered 70 m above a fishing vessel. We positioned the camera above a gillnet set for Spanish mackerel *Scomberomorus maculatus*. We observed frequent encounters ($n = 36$) and interactions ($n = 27$) between dolphins and the net, but no dolphins became entangled. Most dolphins diverted their course around the net, but on nine occasions we observed dolphins engaging in depredation. We conclude that interactions between dolphins and these gillnets are common, but that entanglement is rare.

Keywords: bottlenose dolphin; gillnet; entanglement; depredation; by-catch

1. INTRODUCTION

As human populations continue to grow, fishing effort increases in coastal areas, intensifying conflicts between fisheries and marine mammals. In some cases, marine mammals are killed accidentally in fishing gear, a process referred to as by-catch. By-catch threatens several populations and species of small cetaceans with extinction (Reeves *et al.* 2003). It is unclear why dolphins and porpoises become entangled in nets, as they possess a sophisticated echolocation system (Au 1993). Several authors have advanced explanations for how entanglement occurs (see reviews by Au 1994; Dawson 1994), but few of these hypotheses have been tested. Unfortunately, it is rarely possible to observe these interactions directly because they typically occur below the water's surface, where direct observation is not possible. At the conclusion of a workshop on cetacean by-catches held in 1990, Perrin *et al.* (1994, p. 52) concluded that there 'is almost no behavioural information on how and when entanglement of cetaceans occurs'. Despite considerable research in the intervening decade (see International Whaling Commission 2000, 2001), we still understand very little about the mechanisms of entanglement.

In the present paper, we address this shortcoming by describing the observations of interactions between

bottlenose dolphins and a gillnet fishery for Spanish mackerel *Scomberomorus maculatus* in North Carolina, USA. This fishery operates along the coast of North Carolina from May to October, taking approximately 14 bottlenose dolphins annually as by-catch (Palka & Rossman 2001) from a population of 7000 (L. P. Garrison, P. E. Rosel, A. Hohn, R. Baird and W. Hoggard, unpublished data). The fishery operates close to shore and thus offers an opportunity to observe the behaviour of dolphins around nets.

2. METHODS

We studied the behaviour of bottlenose dolphins around gillnets near Beaufort, North Carolina, from 31 May to 17 June 2002 (figure 1). We observed dolphins from an overhead digital video camera, suspended from a helium-filled aerostat. The aerostat was 9 m in length, with a maximum diameter of 3.4 m, and was tethered ca. 70 m above the FV *Endurance*, a 13 m commercial fishing vessel. We connected a JVC KY-F55BU digital video camera to a Sony HR1000 recorder aboard the *Endurance* with a combined electrical/mechanical tether (Nowacek *et al.* 2001). An operator aboard the vessel controlled the pan, tilt and zoom of the camera.

We set a commercial Spanish mackerel gillnet perpendicular to shore, with the inshore end of the net just outside the surf zone. We attempted to emulate typical commercial fishing practices (one of the authors is a full-time commercial gillnet fisherman) as much as possible. We positioned the camera directly over the cork line by anchoring the *Endurance* upwind of the net. We were able to observe the net at all times and were ready to respond if a dolphin became entangled.

The monofilament gillnet comprised two 90 m segments, tied together, and was 6 m deep, with a stretched mesh size of 80 mm. The net extended from the sea floor to the water's surface. Polystyrene floats were spaced along the cork line of the net at intervals of 115 cm, allowing us to estimate distance in the camera's field of view. We set the net in an area where other commercial vessels were fishing for Spanish mackerel and where we encountered dolphins on a regular basis. The location of each set (figure 1) was determined largely by viewing conditions (wind, sun angle and water clarity). We recorded the species and number of all fishes captured.

In the laboratory, we reviewed video records to document the behaviour of dolphins. The overhead video records were supplemented by field notes and recordings made with a hand-held Sony DCR-TRV20 digital video camera from the deck of the *Endurance*.

In our analysis, we defined the following behaviours: *encounters*, in which dolphins approached within 500 m of the net; *interactions*, a subset of encounters, in which dolphins approached within one body length of the net, changed course to avoid it, or begged for fishes near the vessel; and *depredation*, in which dolphins removed fishes from the net. We noted the number and duration of discrete bouts in which groups of dolphins encountered or interacted with the net. In our analysis, we considered the behaviour of dolphin groups, rather than individuals, as it was difficult to identify individual dolphins in the overhead video. We estimated the closest observed approach for each group to the net, using the known distance between net floats.

3. RESULTS

We observed 30 sets of the net with the overhead video system. Mean soak time was 1.0 ± 0.27 h (mean $\pm$ s.d.). Mean depth at the inshore end of the net was 2.7 ± 0.7 m; mean depth at the offshore end was 4.4 ± 0.6 m. We caught 697 fishes, including Spanish mackerel (24% by number), various small sharks (24%), bluefish *Pomatomus saltatrix* (19%), Atlantic bonito *Sarda sarda* (18%) and harvestfish *Peprilus alepidotus* (10%).

We observed encounters and interactions between dolphins and the net in 24 and 19 sets, respectively. In several sets we recorded multiple encounters ($n = 36$) and interactions ($n = 27$). The most frequent type of interaction was avoidance (15 occasions), in which dolphins changed course to divert around the net. On nine occasions we observed dolphins within a body length of the net and, on three of these occasions, dolphins also begged for fishes. On three other occasions, dolphins were observed beg-

Figure 1. Locations of gillnet sets (grey circles) made near Beaufort, North Carolina, USA and observed with overhead video in May and June 2002. Scale bar is in kilometres.

ging, but did not interact directly with the net. We did not observe any entanglements of bottlenose dolphins.

Dolphins avoided the net by diverting offshore ($n = 10$) or inshore ($n = 5$) of the net. Dolphins typically swam parallel to the shoreline, changed course to avoid the net and then changed course again once past it, resuming their original path of travel along the shore. It was not possible to estimate the distance at which dolphins changed course from the video record, because this typically occurred outside the field of view of the overhead camera. On several occasions, however, we noted from the deck of the *Endurance* that dolphins changed course at considerable distances (100 m or more) from the net. The mean closest point of approach to the net was 17 ± 12 m, although this value is negatively biased, because it was not possible to estimate the closest approach for dolphins that diverted well away from the net.

During the nine bouts in which we observed dolphins within a body length of the net, the animals swam back and forth along the net, exhibiting a behaviour we described as *patrolling*, occasionally stopping to remove fishes from the net. On four occasions we observed dolphins partially under the cork line, with their bodies in direct physical contact with the net. Dolphins engaging in this type of behaviour often made *pinwheel turns* in which they rotated rapidly perpendicular to their long axis and approached the net with their ventral side towards the water's surface ($n = 7$). On three occasions, we observed dolphins exhale underwater, producing a bubble ring, as they removed fishes from the net. We frequently observed dolphins very close to the net (1.8 ± 2.5 m, $n = 40$ behavioural events), but they typically moved away from it (11.4 ± 7.1 m, $n = 139$) to surface.

Dolphins interacted with the net for prolonged bouts (27 ± 17 min, $n = 9$), but specific acts of depredation were

relatively brief (42 ± 10 s, $n = 8$). We confirmed depredation by dolphins from observations of partially consumed bluefish and Spanish mackerel in the net during four sets. On several other occasions, after observing dolphins engaging in depredation, we discovered holes in the net, but did not observe any partially consumed fishes. In two other sets we found partially consumed bluefish and bonito in the net, but did not observe any dolphins in the area, indicating that other predators also engage in depredation.

The six observations of begging lasted for 18 ± 4 min. Begging dolphins typically arrived shortly after we started to retrieve the net (4 ± 4 min). These dolphins fed on discarded Spanish mackerel, bluefish, bonito and harvestfish. The dolphins surfaced repeatedly in the same position near the vessel, waiting for fishes to be discarded.

4. DISCUSSION

We conclude that bottlenose dolphins interact frequently with, but seldom become entangled in, Spanish mackerel gillnets. We observed dolphins in physical contact with the net on several occasions, but none became entangled during our study. This conclusion is supported by the observations of federal biologists working aboard fishing vessels (Palka & Rossman 2001) and also interviews with fishermen, who have reported frequent interactions, but few entanglements, in this fishery (Hagedorn 2002).

We believe that dolphins become entangled when they are unaware of the net, or are distracted by other stimuli in its vicinity (see Perrin *et al.* 1994). Under this scenario, entanglement is the result of navigational errors, much as road traffic accidents occur as a result of inattention or mistakes made by human drivers. If this hypothesis is correct, then making the net more detectable to a dolphin

might reduce the incidence of entanglements. As noted by many other researchers (see Perrin *et al.* 1994), there are at least two options to make a gillnet more detectable to a dolphin: placing sound makers, such as acoustic alarms, on the net, or making the net material more detectable to an echolocating animal.

Acoustic alarms have been shown to reduce the by-catches of various small cetaceans in other gillnet fisheries (Kraus *et al.* 1997; International Whaling Commission 2000; Bordino *et al.* 2002; Barlow & Cameron 2003). In a previous field study in North Carolina, we examined the response of bottlenose dolphins to acoustic alarms (Cox *et al.* 2003). We demonstrated that acoustic alarms displaced bottlenose dolphins in a subtle manner and concluded that these devices might be effective at reducing the by-catch of dolphins in gillnet fisheries. We cautioned, however, that dolphins could habituate to the presence of pingers, reducing their effectiveness over time (Dawson *et al.* 1998; Cox *et al.* 2001). Furthermore, based on our present work, it seems probable that dolphins engaging in depredation would learn to associate the sound of an alarm with the presence of a gillnet and that rates of depredation might increase markedly. Thus, acoustic alarms might help to reduce by-catch, but at a cost of increased depredation.

Acoustically modified nets hold the promise of increasing detectability to an echolocating dolphin, but without widely advertising their presence by broadcasting sound. Thus, these nets could conceivably reduce by-catch without increasing depredation. Recent field tests of acoustically modified nets in the Bay of Fundy, Canada, and in the North Sea have demonstrated a significant decrease in by-catches of harbour porpoises *Phocoena phocoena* (Larsen *et al.* 2002; Trippel *et al.* 2003). It is unclear, however, whether the acoustical reflectivity of these nets, or their mechanical properties and particularly their increased stiffness, were responsible for the decreased by-catches of porpoises (Larsen *et al.* 2002).

We believe that changing the physical properties of gillnets, such as their stiffness or breaking strength, holds significant promise to reduce by-catches of dolphins and porpoises, regardless of the cause of these interactions. Such changes could provide an inexpensive and simple alternative to the manufacture of acoustically modified nets or the use of acoustic alarms. Controlled field tests of such modifications are required to test their efficacy.

Finally, we would like to emphasize the utility of making direct observations of interactions between marine mammals and commercial fisheries. As noted earlier, conflicts between marine mammals and fisheries are likely to intensify as fishing effort increases throughout the world's oceans. Our understanding of the nature, extent and effects of these conflicts is still rudimentary. We need to make more direct observations of such interactions and to disseminate these findings throughout the fishing, management and conservation communities. Our study is one of the first to make detailed, fine-scale observations of the behaviour of marine mammals around active fishing gear. The overhead video system was somewhat cumbersome to employ and it was sometimes difficult to follow dolphins

around the gillnet. Nevertheless, our behavioural observations have provided a unique window into interactions between bottlenose dolphins and gillnets and it is unlikely that we would have drawn these insights without the benefit of such direct observation.

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- Au, W. W. L. 1993 *The sonar of dolphins*. New York: Springer.
- Au, W. W. L. 1994 Sonar detection of gillnets by dolphins: theoretical predictions. *Rep. Int. Whal. Commis.* **15**, 565–571.
- Barlow, J. & Cameron, G. A. 2003 Field experiments show that acoustic pingers reduce marine mammal by-catch in the California drift gillnet fishery. *Mar. Mamm. Sci.* **19**, 265–283.
- Bordino, P., Kraus, S., Albareda, D., Fazio, A., Palmerio, A., Mendez, M. & Botta, S. 2002 Reducing incidental mortality of Franciscana dolphin *Pontoporia blainvillei* with acoustic warning devices attached to fishing nets. *Mar. Mamm. Sci.* **18**, 833–842.
- Cox, T. M., Read, A. J., Solow, A. & Tregenza, N. 2001 Will harbour porpoises (*Phocoena phocoena*) habituate to pingers? *J. Cetacean Res. Mgmt* **3**, 81–86.
- Cox, T. M., Read, A. J., Swanner, D., Urian, K. W. & Waples, D. M. 2003 Behavioural responses of bottlenose dolphins *Tursiops truncatus* to gillnets and acoustic alarms. *Biol. Conserv.* (In the press.)
- Dawson, S. M. 1994 The potential for reducing entanglement of dolphins and porpoises with acoustic modifications to gillnets. *Rep. Int. Whal. Commis.* **15**, 573–578.
- Dawson, S. M., Read, A. & Slooten, E. 1998 Pingers, porpoises and power: uncertainties with using pingers to reduce bycatch of small cetaceans. *Biol. Conserv.* **84**, 141–146.
- Hagedorn, S. C. 2002 Depredation by bottlenose dolphins on gillnets in Dare County, North Carolina. Master's project, Duke University, Durham, NC, USA.
- International Whaling Commission 2000 Report of the sub-committee on small cetaceans. *J. Cetacean Res. Mgmt* **2**, 235–263.
- International Whaling Commission 2001 Report of the workshop on bycatch mitigation measures in static fisheries. *J. Cetacean Res. Mgmt* **3**, 292–296.
- Kraus, S. D., Read, A. J., Solow, A., Baldwin, K., Spradlin, T., Anderson, E. & Williamson, J. 1997 Acoustic alarms reduce porpoise mortality. *Nature* **388**, 525.
- Larsen, F., Eigaard, O. R. & Tougaard, J. 2002 Reduction of harbour porpoise by-catch in the North Sea by high density gillnets. Paper SC/54/SM30 submitted to the International Whaling Commission Scientific Committee.
- Nowacek, D. P., Tyack, P. L. & Wells, R. S. 2001 A platform for continuous behavioural and acoustic observation of free-ranging marine mammals: overhead video combined with underwater audio. *Mar. Mamm. Sci.* **17**, 191–199.
- Palka, D. L. & Rossman, M. C. 2001 Bycatch estimates of coastal bottlenose dolphin (*Tursiops truncatus*) in U.S. mid-Atlantic gillnet fisheries for 1996 to 2000. Northeast Fisheries Science Center reference document 01-15. Woods Hole, MA: Northeast Fisheries Science Center, NOAA.
- Perrin, W. F., Donovan, G. P. & Barlow, J. (eds) 1994 Gillnets and cetaceans. Report of the International Whaling Commission, Special Issue 15. Cambridge: International Whaling Commission.
- Reeves, R. R., Smith, B. D., Crespo, E., Notarbartolo di Sciara, G. & The Cetacean Specialist Group 2003 *Dolphins, whales, and porpoises: 2003–2010 conservation action plan for the world's cetaceans*. Gland, Switzerland: Species Survival Commission, IUCN.
- Trippel, E. A., Holy, N. L., Palka, D. L., Shepherd, T. D., Melvin, G. D. & Terhune, J. M. 2003 Nylon barium sulphate gillnet reduces porpoise and seabird mortality. *Mar. Mamm. Sci.* **19**, 240–243.