CHANGES IN SURFACING PATTERNS OF BOTTLENOSE
DOLPHINS IN RESPONSE TO BOAT TRAFFIC

Recent growth in commercial whale and dolphin watching has raised the question of how cetaceans are affected by boat traffic. Many studies in this field looked at effects on baleen whales (review in Richardson et al. 1995), while only a few, e.g., Au and Perryman (1982), Kruse (1991) and Polacheck and Thorpe (1990) have studied influences on smaller odontocetes. The dominant behavioral reactions of cetaceans reported in these studies were an increase in swimming speed, spatial avoidance, and changes in diving behavior. All these are short-term reactions which may disrupt the ongoing activities of the animals. Such disruptions could cause longer-term changes in the behavior and status of a population through avoidance of certain areas or an increase in mortality (Thompson 1992, Richardson et al. 1995). Assessments of the potential impact of boat traffic therefore require a fuller understanding, first, of
the nature of any short-term changes in behavior and, second, of the longer-term consequences of any reactions.

The aim of this study was to quantify the behavioral reactions of bottlenose dolphins (*Tursiops truncatus*) to boat traffic in the Moray Firth, N.E. Scotland. Bottlenose dolphins have been recorded in the Moray Firth since at least the early 1970s (Evans 1980), and previous studies indicated that dolphins were often observed in the narrow channels which link the inner firths (Hammond and Thompson 1991). This study was carried out overlooking the Kessock channel, which connects the Moray and the Beauly Firths (Fig. 1). Water depth increases gradually from 6 to 38 m from east to west in the area. Because it is a relatively narrow channel tidal currents are strong. All observations have been made at rising tide. The area is exposed to frequent boat traffic because it connects the Caledonian Canal with the North Sea. Commercial dolphin watching trips also started operating in this area in 1994.

Between 8 August and 23 September 1994, boat-dolphin encounters were observed from a pier on the north side of the Kessock channel (Fig. 1). Observations were made only when sea state was 0 or 1 (Beaufort scale). A Sony 8 CCD-V88E camcorder was used to video-record the surfacing behavior of dolphin groups during a larger study of social and acoustic behavior. In this report we concentrate on the surfacing patterns of dolphins which occurred in response to boats which passed through the study area. During the study, dolphins usually moved into the channel for several hours each day. The es-
timated mean group size of dolphins was $3.92 \pm 2.48$ (SD, $n = 42$). The number of animals varied from 1 to 15. Forty-two boat-dolphin encounters were recorded on video. Additional comments on the audio track reported all surfacing dolphins which were outside the camera’s field of view. In seven cases the boat stopped at the last observed position of a dolphin. In all other cases the boat passed through without stopping. Recordings were later analyzed to compare the surfacing behavior of dolphins for one minute before and one minute after a boat had approached within 50 m ($\pm 5$ m) of the group. Because group size could only be estimated, we did not attempt to calculate individual surfacing rates but compared the total number of surfacings observed before and after a boat approached. In each one-minute period, we counted the number of dolphins which surfaced within 100 m of the first dolphin to surface within 50 m of the approaching boat. In 8 of 42 cases the boat had left the observation area again within the one-minute period after its approach. These cases were discarded from the analysis. As a control, we compared the number of surfacings during a one-minute period before and after 20 randomly chosen surfacings of a dolphin when no boats were present in the channel. Again, surfacing dolphins were counted in a circular area within 100 m around the chosen surfacing. The chosen surfacing itself was not counted. All results were tested with a Wilcoxon Signed Ranks Test (Siegel and Castellan 1988).

In 24 of the 34 observed boat-dolphin encounters we counted fewer surfacings after a boat approached a dolphin than in the minute before. In eight cases there were more surfacings after a boat arrived, and in two cases there was no change. The average number of surfacings before a boat arrived was $8.03 \pm 0.93$ (SE), and after a boat arrived it was $4.74 \pm 0.74$ (SE). The decrease in surfacings after a boat arrived was highly significant ($Z = -5.18$, two-tailed $P = 0.002$). In nine of the control cases there were more surfacings before the randomly chosen surfacing, in 10 cases there were more after the randomly chosen surfacing, and in one case there was no difference. There was no significant change in number of surfacings in the control condition ($Z = -0.36$, two-tailed $P = 0.717$).

Most boats using the study area were either fishing boats or motor yachts of less than 10 m. However, the commercial 10-m dolphin-watching boat accounted for 22 of the 34 boat-dolphin encounters that we recorded. This watching boat differed from all other boats in its behavior. It always followed the dolphins and tried to stay in their vicinity. In a second step, we compared data involving this boat with those from all other boats. In 17 of the 22 observed cases involving the dolphin-watching boat we counted fewer surfacings after the boat arrived, in four cases there were more surfacings after the boat arrived, and in one case there was no change. In 7 cases of 12 involving other boats fewer surfacings were counted after the boat arrived, in four cases we counted more after the boat arrived, and in one case there was no change. Dolphins showed no significant change in behavior after encountering this other boat traffic ($Z = -1.95$, $P = 0.051$), but the number of surfacings decreased significantly after the dolphin-watching boat approached the animals.
Figure 2. Mean values and standard errors of the number of surfacings before (= black bars) and after (= white bars) a boat arrived. In the control condition the values are before and after a randomly chosen surfacing when no boats were present. The asterisk marks the only significant difference (Wilcoxon, $P = 0.002$). However, sample size for the other boats was relatively small ($n = 12$).

($Z = -2.576, P = 0.01$). Mean values and standard errors for all samples are shown in Figure 2. We used a Bonferroni procedure to avoid rejecting a null hypothesis due to double testing of the same data (Bakeman and Gottman 1986). This lowered the threshold for significance to $P < 0.025$. The significant results given above were clearly below that threshold. Besides normal surfacing no other surface behavior such as leaping or porpoising was observed in the one-minute periods before or after a boat approached.

Our study area has been exposed to frequent boat traffic for many years. Prior to 1982 a daily ferry connected the two sides of the channel, and the area remains important for passage to and from the Caledonian Canal and Inverness Harbour. In August and September 1994 a total of 281 boats entered or left the Caledonian Canal via this passage. Photoidentification studies in the area have also shown that the same individual dolphins have been sighted regularly in the study area over a 5-yr period (Wilson 1995). Thus, it seems likely that individual dolphins in this area must have been exposed to boat traffic for many years yet have still remained in the Firth. However, most boat traffic passed through the area in a predictable straight line and did not follow the dolphins. Our results showed that the decrease in surfacings after a boat arrived was only significant in cases which involved the dolphin watching boat. This boat accounted for over 50% of the traffic during this study. The behavior of the dolphin watching boat was different, in that it remained in the channel for longer periods and usually followed animals. However, the
sample size for all other boats was relatively small. Further studies are needed to assess the influence of boat behavior on the behavior of bottlenose dolphins in this area.

Although we could not observe single individuals, the decrease in the number of animals surfacing showed that at least some dolphins either dived for longer periods and/or moved away after the boat approached them. This could be either a direct reaction to avoid the boat itself or a secondary one, if the boat had an effect on prey movement. *Sardinella aurita*, for example, reacts with vertical avoidance to passing boats (Gerlotto and Fréon 1992). It is very important to consider such effects in the interpretation of scientific observations made from boats. Further work is required to determine whether certain individuals or age-classes are more sensitive to boats than others. We were also unable to determine whether dolphins reacted to a boat itself or to its enginenoise.

Our results showed that an approaching boat can alter the behavior of dolphins that have been exposed to boats for a long time. Other studies have also shown behavioral responses of dolphins to boat traffic (Au and Perryman 1982, Kruse 1991), but effects at the population level generally remain unclear. Jones and Swartz (1984), for example, could not observe any negative effects of a limited amount of boat traffic on a population of grey whales (*Eschrichtius robustus*). Behavioral studies need to be carried out alongside more detailed research on individual survival, reproductive rates and movements in order to assess whether boat traffic that follows the animals around has a significant impact at the population level. In investigating such effects it is important to recognize that not only avoidance but also seemingly positive reactions like approaches could have negative long-term effects if they influence the time spent feeding, for example. Whilst the bottlenose dolphin is not an endangered species, the Moray Firth population is the only resident one in the North Sea, with an estimated size of 130 individuals (Wilson 1995). The development of commercial cetacean watching and other increases in boat traffic should be managed carefully, and attempts made to understand its consequences on the animals.

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