

Behavioural Responses of Chilean Dolphins (*Cephalorhynchus eutropia*) to Boats in Yaldad Bay, Southern Chile

Sandra Ribeiro,^{1,3} Francisco A. Viddi,^{2,3} and Thales R. O. Freitas^{1,4}

¹Programa de Pós-Graduação em Ecologia, Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves 9500, Caixa Postal 15007, CEP 91540-000, Porto Alegre (RS), Brazil

²Instituto de Ecología y Evolución, Universidad Austral de Chile, Valdivia, Chile

³Centro Ballena Azul (CBA/BWC), Santa Rosalía 111, Valdivia, Chile

⁴Laboratório de Genética Molecular, Departamento de Genética/UFRGS, RS, Brazil

Abstract

During the austral summer of 2002, theodolite tracking was used to evaluate Chilean dolphin (*Cephalorhynchus eutropia*) behavioural responses to boats in Yaldad Bay, southern Chile. This bay represents an important site for the occurrence of this species. Boat traffic has increased considerably since 1980 in this area due to aquaculture activities. Behavioural responses were analysed for each dolphin activity, and pre-, during, and post-boat encounters. When foraging and approached by a vessel, dolphins increased their reorientation rate, whereas swimming speed showed no significant change. When traveling, however, dolphins reacted to boats by increasing their directional swimming speed, while reorientation rate did not differ. After encounters, dolphins seemed to return quickly to previous behavioural patterns when traveling, whereas it took longer to establish normal patterns when foraging. Group dispersion analyses showed that when boats approached foraging dolphins, they became significantly more cohesively grouped. Consequently, dolphins reacted negatively to boat presence in Yaldad Bay, but these responses were conditional on dolphin behavioural activities prior to boat encounters. These findings emphasize the need to consider boat traffic disturbance on cetaceans in coastal management plans.

Key Words: Chilean dolphin, *Cephalorhynchus eutropia*, behavioural response, boat traffic, aquaculture, theodolite tracking, southern Chile

Introduction

Human impacts on marine ecosystems have increased considerably during the last decades, especially due to enhanced use of coastal areas (Roberts & Hawkins, 1999). The development in coastal areas has produced a substantial increase in vessel traffic, causing potential disturbance of

marine mammal behaviour (Richardson et al., 1995). The main short-term impacts are alterations of diving patterns, respiration rates, swimming speeds, reorientation rates, and variation in sound production (Au & Perryman, 1982; Bejder et al., 1999; Janik & Thompson, 1996; Kruse, 1991; Richardson et al., 1995; Van Parijs & Corkeron, 2001; Williams et al., 2002). All short-term reactions affect cetacean activities, potentially causing animals to leave important feeding or reproductive areas or causing long-term behavioural shifts (Wells & Scott, 1997), which might alter distribution patterns and affect individual energetic requirements (Allen & Read, 2000; Wells & Scott, 1997).

At present, due to the intense whale-watching industry worldwide (Anonymous, 1995), most research effort has focused on the impacts of tourist vessels on cetaceans (Bejder et al., 1999; Janik & Thompson, 1996; Kruse, 1991; Lusseau, 2003a; Williams et al., 2002; Yin, 1999). Nevertheless, it is still important to assess the impact of ship traffic in those areas where whale-watching is not represented, as is the case for Chile.

Southern Chile is a site with a rapid development of aquaculture, especially for salmon and mussels, which is quickly expanding in the fjords and channels (Bushmann et al., 1996; Sullivan-Sealey & Bustamante, 1999). This activity, besides producing severe pollution impacts, such as eutrophication and faunal shifts (Beveridge et al., 1994; Claude & Oporto, 2000), is responsible for increased boat traffic. Since aquaculture activities are restricted to coastal waters, there is a far-reaching overlap with the distribution of some cetacean species such as the Chilean dolphin (*Cephalorhynchus eutropia*) It is one of the smallest and most unknown dolphin species and is the only cetacean species endemic to Chile, with a distribution from Valparaíso (33° S) to Navarino Island, Cape Horn (55° S). It is a coastal species, inhabiting sheltered bays, channels, fjords, and exposed coast (Aguayo-Lobo et

al., 1998; Goodall, 1994; Goodall et al., 1988). Basic information about its biology and ecology are still very limited and there are no data available on abundance, population dynamics, home range size, and movement patterns (Goodall, 1994; Goodall et al., 1988), a consequence of which is that its current conservation status still corresponds to Data Deficient as listed by the IUCN (Hilton-Taylor, 2000). Anecdotal information suggests that between 1970 and 1990, the abundance of the Chilean dolphin was severely reduced due to extensive hunt for it for use as bait in the crab fishery in southern Chile (Lescrauwaet & Gibbons, 1994). Although a protective regulation has been implemented, Chilean dolphins still may be threatened by hunting both for use as bait in local fisheries, as well as for human consumption (Goodall, 1994). Furthermore, in addition to the mortality caused by entanglement and incidental catch produced by local coastal fisheries, Chilean dolphins may now be excluded from some sites (bays and fjords) and may be losing potentially critical areas by industrial activities such as aquaculture (Claude & Oporto, 2000; Goodall, 1994; Reeves et al., 2003).

According to the *2002-2010 Conservation Action Plan for the World's Cetaceans* (Reeves et al., 2003), work efforts on Chilean dolphins should focus on stock identity, abundance, and mortality estimate, as well as the effects on habitat loss on dolphin populations.

Occasional observations point out that the Chilean dolphin is shy in response to a boat approach and tends to avoid them (Crovetto & Medina, 1991), although no effort has been made so far to evaluate the influence of boat traffic on this species. Thus, the main objective of the present work was to assess and quantify dolphin behavioural responses to boat traffic caused mainly by aquaculture activities in Yaldad Bay, southern Chile.

Materials and Methods

Study Area

Yaldad Bay ($43^{\circ} 08' S$, $73^{\circ} 44' W$) covers an area of approximately 22 km² and is located in southern Chiloe Island, Chile (Figure 1). The tidal cycle is semi-diurnal, ranging from 3 to 5 m (Anonymous, 1999). An extensive area of the bay is used to cultivate the mussel (*Mytilus edulis chilensis*), an activity that has expanded since the end of the 1980s (Bushmann et al., 1996; Clasing et al., 1998). Recently, an aquaculture farm for growing Atlantic salmon (*Salmo salar*) was established at the mouth of the bay (Figure 1). Due to aquaculture activities, boat traffic for transportation and maintenance is relatively intense in the bay.

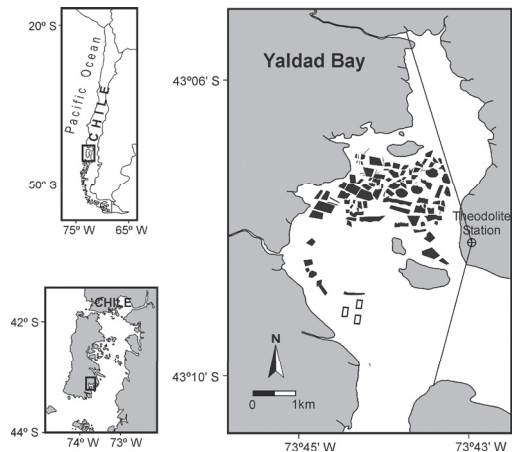


Figure 1. Study area in Yaldad Bay, southern Chile. Theodolite station (⊕), angle of sight (—), mussel farms (■) and salmon farms (□).

Data Collection

Data were collected between January and April 2002. Land-based observations were performed from a fixed vantage point (Figure 1) of 102.78 m above sea level. Dolphin and boat positions were determined using an electronic theodolite "Pentax ETH-10D" (precision $\pm 10''$ of arc and 30x magnification) (see Würsig et al., 1991, for details of the method). Two to three observers scanned the study area with binoculars (10 x 50) and spotting scope (60 x), to locate dolphin groups. When found, the group was tracked throughout the entire observation period until it was lost (group follow protocol, after Mann, 1999). A group of dolphins was defined as any aggregation of more than one dolphin (including all age classes) observed close to each other within 100 m (Mann, 1999).

Theodolite fixes were taken at the centre of the dolphin group approximately every 60 s. When boats were present, fixes were taken alternating between the boat and the focal dolphin group. Every dolphin's fix point included information on time (h, min, s) and activity pattern (focal group sampling, see Mann, 1999). If the group was out-of-sight for more than 5 min, a new group was searched.

Observation effort and tracking sessions varied and were limited to favourable environmental conditions. Observations were restricted to no rain and Beaufort Sea states ≤ 2 .

The activity patterns were defined in the following ways:

- **Feeding:** Cooperative hunting of fish schools. Dolphins could be seen chasing fish; making circles; having a parallel swimming formation, with fast, directional, and synchronised movements; fish leaping out of the water; and even dolphins with fish in their mouths. Dolphins

were frequently observed in association with marine birds, such as South American terns (*Sterna hirundinacea*).

- *Foraging*: Repeated unsynchronised dives in different directions in a determined location, probably representing scanning and searching for food or benthic feeding.
- *Resting*: Very slow movements or stationary on the surface.
- *Socialising*: Interindividual interactions within a group and frequent physical contact, with often vigorous movements and aerial behaviours such as leaping and breaching. Sexual and aggressive behaviours are included in this category.
- *Traveling*: Directional and persistent movement at constant speed.

Inter-individual dolphin proximity within the group was classified into three categories: (1) tight (dolphins spaced 0 to 5 body lengths apart), (2) spread (distance between individual dolphins more than 5 body lengths), or (3) mixed (some individuals spread and others grouped tightly).

Two types of boats were considered for analysis: (1) boats used in aquaculture activities made of wood or fibreglass (up to 10 m); or (2) a 3-m inflatable boat used for dolphin research). Both types of boats were powered by two cycle out-board engines (20-40 hp and 25 hp, respectively). Aquaculture boats always maintained a directional path at constant speed, whereas the research inflatable boat was used to approach the dolphins for photo-identification purposes, constantly altering the course and speed, although net velocity was always less than that of aquaculture boats.

Data Analysis

Only groups of dolphins tracked for a minimum of 15 min were included in the analysis. The software *Pythagoras*, Version 1.2^o (G. Gailey, Texas A&M University), was used to transform theodolite readings into geographical positions and to visualize the paths made by dolphins and boats, as well as to estimate the distance between them. An encounter between a boat and a group of dolphins began when the boat approached a group of dolphins within 500 m, which was defined as "interaction zone." The encounter finished when the boat moved away at a distance of 500 m. Two encounter types were established according to the minimum distance between boats and dolphins: (1) close encounters, when boats approached within a radius of 100 m or (2) distant encounters, when boats only approached an area of 100 to 500 m from dolphins.

To evaluate the dolphin behavioural post-encounter responses (up to 15 min after boats left the interaction zone), three time categories were established: (1) 0 to 5 min, (2) 5 to 10 min, and (3) 10 to 15 min.

Swimming speed and reorientation rate were the variables analysed in this study, also estimated using the *Pythagoras* software. Group swimming speed was calculated by dividing the distance covered between two consecutive theodolite readings by the time interval between these two readings (measured in km/h). Reorientation rate (Figure 2) represents the course change along the path of the dolphin group over time. It was calculated by summing the angles between observed dives and the straight-line paths predicted by the preceding reading (α), and then divided by the duration (t) of the whole path of the tracked focal group (measured in degrees/min).

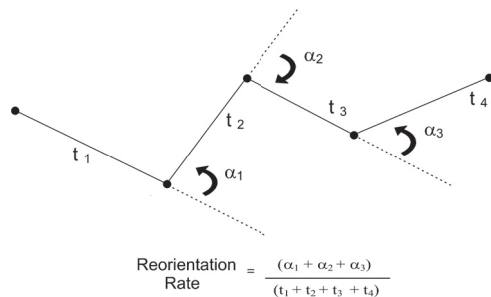


Figure 2. A sample swimming path with five theodolite readings (•) of focal Chilean dolphin groups, showing reorientation rate calculation; angles between observed dives (α), the straight-line paths predicted by preceding dives (---), and duration between readings (t) are shown.

A small value of the reorientation rate means a smoother straight-line path, whereas a high value implies a more erratic path. To avoid problems associated with nonlinear movements, all intervals of theodolite readings exceeding 120 s were excluded from analysis (Yin, 1999).

Since there is no information available on how dolphins' natural behaviour and activities correlate with their swimming speed and reorientation rate, pooling all data might cause potential bias in the interpretation of behavioural responses to boat traffic (Williams et al., 2002). Hence, data were separated for each dolphin activity for those tracks of dolphins without boats ("control" periods), and tested whether natural behavioural states had any effect on the variables considered. If any significant differences were detected, data analysis for dolphin-boat encounters would require considering dolphin activities separately.

For each focal dolphin group tracked, there was one estimated value of the reorientation rate, and an average value for swimming speed was calculated, derived from results obtained from every two consecutive theodolite readings. Values were calculated for each dolphin activity, in the

period without boats, during encounters, and post encounters. These new values constituted the sample units for later analysis.

A randomisation test (Edgington, 1995; Manly, 1991; Pillar & Orlóci, 1996) was applied to test the null hypothesis that there was no significant difference between the dependent variables (swimming speed and reorientation rate) and the following factors: dolphin activity patterns (feeding, foraging, resting, socialising, or traveling), boat condition (boat present, boat absent and post boat encounters), encounter type (close or distant encounter), and boat type (aquaculture or research vessel). Randomisation statistical analyses ($\alpha = 0.05$) were performed through the software *MULTIV, Version 2.0* (Pillar, 2000) (10,000 iterations from a dissimilarity matrix of Euclidian distance). To evaluate the existence of any significant association between interindividual dolphin proximity (tight, spread, and mixed) and boat conditions, a chi-square test with contingency table and adjusted residuals analysis were performed (Everitt, 1992) using the software *SPSS, Version 10*.

Results

Over the study period, 293.5 h of observation and searching effort were achieved. Although 192 groups of dolphins were sighted and 66 dolphin-boat encounters recorded, only 163 dolphin-group tracks and 27 encounters were considered for further analysis (which encompassed tracks of more than 15 min). Focal groups were tracked continuously for 63 h, with a total of 3,009 theodolite fixes. Encounters involving dolphins and aquaculture boats ($n = 17$) lasted on average 7.1 min, and the boats moved with an average speed of 9.34 km/h. Average time of the encounters involving the research boat ($n = 5$) was 22 min, with an average boat speed of 2.64 km/h. Group size average was 5.92 (median = 5, lower quartile = 4, and upper quartile = 7), and ranged between 1 and 25 animals.

Activity Patterns

In the absence of boats, swimming speed (ss) and reorientation rate (rr) varied significantly depending on dolphin activity patterns ($p(Qb_0 \geq Qb)_{ss} < 0.001$; $p(Qb_0 \geq Qb)_{rr} < 0.001$). Maximum average ss (5.8 km/h) was recorded when dolphins were traveling, whereas minimum average ss (2.8 km/h) occurred during resting periods (Figure 3). Average values for ss during foraging and socialising were similar to each other, remaining around 4 km/h (Figure 3). Average rr (Figure 3) was greater during socialising (98.2 degrees/min), followed by foraging (88.9 degrees/min). Traveling had the lowest average value for rr (48.8 degrees/min), whereas feeding and resting had

intermediate average values (76.1 and 71.7 degrees/min, respectively). Since ss and rr varied significantly in relation to dolphin activities pattern, data could not be pooled to evaluate the impacts of boat encounters. Thus, analysis was done separately for each behavioural state. Nevertheless, due to the small sample size of dolphin-boat encounters during feeding ($n = 1$), resting ($n = 2$), and socialising ($n = 2$), further analyses were only done for foraging ($n = 14$) and traveling ($n = 8$).

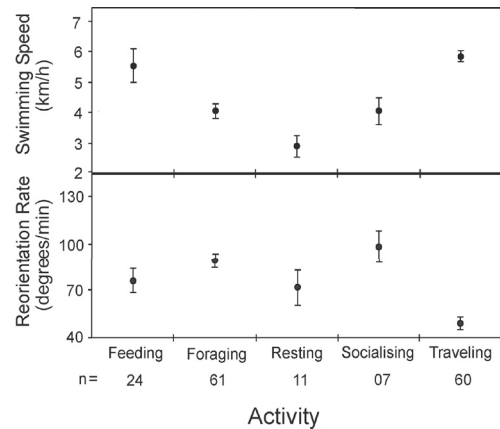


Figure 3. Swimming speed and reorientation rate (mean \pm SE) of Chilean dolphins (*C. eutropia*) in relation to activity patterns without boat(s) present (n = number of groups tracked)

Encounter Type

No significant difference (Figure 4) was detected in ss during close and distant encounters for both foraging ($p(Qb_0 \geq Qb)_{\text{foraging}} = 0.8$) and traveling ($p(Qb_0 \geq Qb)_{\text{traveling}} = 0.71$). The average rr in close encounters (196 degrees/min) was more than twice the average rate (94 degrees/min) in distant encounters during foraging (Figure 4); however, the difference in rr in relation to encounter type was not significant for both foraging ($p(Qb_0 \geq Qb) = 0.19$) and traveling ($p(Qb_0 \geq Qb) = 0.16$).

Boat Type

Average dolphin ss was higher in encounters with aquaculture boats than with research boats (100.4% higher during traveling and 38.5% higher during foraging). Average rr was higher for the period of encounters with the research boat than with aquaculture boats (44% higher during foraging and 5.4% higher during traveling); however, these differences were not significant (Figure 5) for any of the activities: foraging, $p(Qb_0 \geq Qb)_{ss} = 0.51$ and $p(Qb_0 \geq Qb)_{rr} = 0.63$; and traveling, $p(Qb_0 \geq Qb)_{ss} = 0.08$ and $p(Qb_0 \geq Qb)_{rr} = 0.96$. Considering the lack of significant differences for both encounter and boat type, data were pooled for

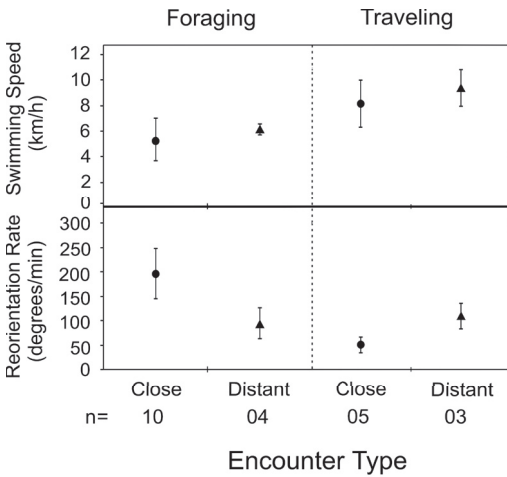


Figure 4. Behavioural responses (ss and rr) of Chilean dolphins (*C. eutropia*) (mean ± se) relative to encounter type (close: 0-100 m; distant: 100-500 m) during foraging and traveling

the evaluation of dolphin behavioural responses in relation to absence of boat, encounter, and post-encounter periods.

Behavioural Responses During Boat Approach

SS did not vary before, during, or after encounters ($p(Qb_0 \geq Qb) = 0.64$) when a vessel approached foraging dolphins (Figure 6); however, rr increased from 88.7 degrees/min in boat absence to 166.8 degrees/min during encounter, representing a significant increase of 88% ($p(Qb_0 \geq Qb) < 0.001$). RR decreased by 22.3% during post-encounters (129.5 degrees/min), but was significantly greater than the value observed during boat absence (post hoc analysis of multiple comparisons $p(Qb_0 \geq Qb)_{\text{boat absence/post-encounter}} = 0.03$). These results indicate that

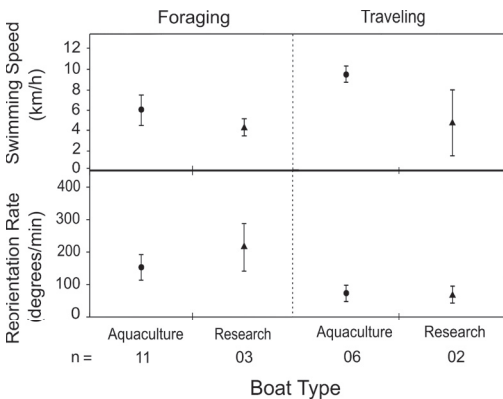


Figure 5. Behavioural responses (ss and rr) of Chilean dolphins (*C. eutropia*) (mean ± se) relative to boat type during foraging and traveling

dolphin behaviour did not return to normal rr pattern within 15 min when foraging.

When dolphins were traveling and approached by a boat, (Figure 6) rr did not vary significantly ($p(Qb_0 \geq Qb) = 0.21$). A significant increase in ss ($p(Qb_0 \geq Qb) = 0.002$) was observed from 5.8 km/h before the encounter to 8.2 km/h during the encounter. Post-encounter ss decreased to 5.4 km/h and reached normal values (post-hoc analysis of multiple comparisons $p(Qb_0 \geq Qb)_{\text{boat absence/post-encounter}} = 0.42$).

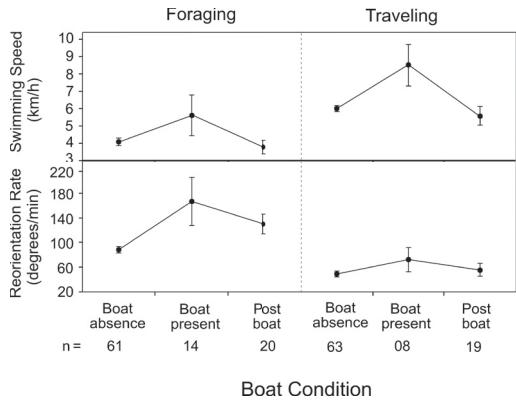


Figure 6. Behavioural responses (ss and rr) of Chilean dolphins (*C. eutropia*) (mean ± se) relative to boat condition during foraging and traveling

Analysis of ss during traveling and rr during foraging at 5 min, 10 min, and 15 min post-encounter (Figure 7) showed that when traveling, ss reached and remained close to normal values (as in boat absence). Even though there was a slight decline, 10 min post-encounter, the variation was not significant $p(Qb_0 \geq Qb)_{5/10/15\text{min}} = 0.26$). When comparing dolphin ss during boat absence and 5 min post-encounter, no significant difference was found between these two values ($p(Qb_0 \geq Qb)_{\text{boat absence/post-encounter 5 min}} = 0.57$), indicating a rapid recovery to normal ss (Figure 7).

In relation to dolphin post-encounter rr during foraging, values remained higher than normal (Figure 7), showing no significant variation over time ($p(Qb_0 \geq Qb)_{5/10/15\text{min}} = 0.62$). These results showed that even 15 min after the dolphin-boat encounter has occurred, dolphins display an altered rr without signs of decline, suggesting that recovering time required post-encounter is greater when animals are foraging than when traveling.

Group Dispersion

Boat absence, encounter, and post-encounter periods (Figure 8) were significantly associated with inter-individual dolphin proximity for both foraging and traveling activities (foraging: $\chi^2 = 75.33$, DF = 4, $p <$

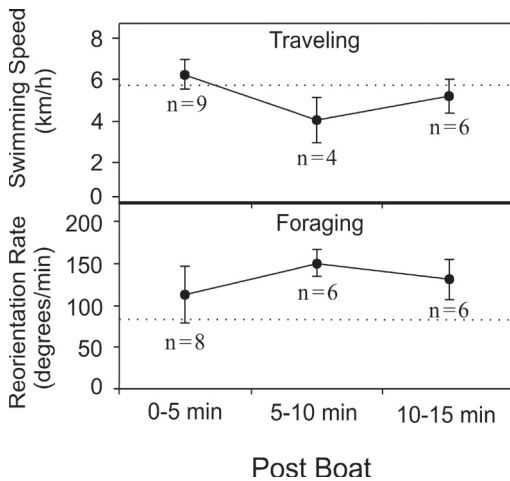


Figure 7. Behavioural responses (ss and rr) of Chilean dolphins (*C. eutropia*) (mean \pm se) in relation to post-encounters (post boat) between 0 to 5 min, 5 to 10 min, and 10 to 15 min during travelling and foraging; dotted line indicates average values for ss and rr

0.001; and traveling: $\chi^2 = 231.6$, DF = 4, $p < 0.001$). During foraging, dolphins were significantly tighter grouped throughout encounters than in periods of boat absence, and significantly more spread out during post-encounter periods. During traveling, dolphins remained significantly more tightly grouped in boat absence, and even though no significant difference was found for any of the categories of interindividual dolphin proximity during encounters, groups were never seen spread out. Nevertheless, dolphins remained significantly more spread out during post-encounter periods, as in the case of foraging.

Discussion

The findings reported here provide the first insights on how boat approaches and traffic affect short-term behaviour of Chilean dolphins. Boat encounters caused avoidance responses, during which dolphins showed changes in swimming speed and reorientation rate. Chilean dolphins did not appear to be attracted to boats as observed for other species of the genus *Cephalorhynchus* such as Hector's dolphins (*C. hectori*) in New Zealand (Bejder et al., 1999). Although Crovetto & Medina (1991) as well as S. Heinrich (pers. comm.) reported that Chilean dolphins sometimes performed bow riding in Yaldad Bay, this was never observed during this study.

Our findings on changes in ss and rr as behavioural responses towards approaching boats are consistent with reports for other cetaceans (Acevedo, 1991; Au & Perryman, 1982; Bejder

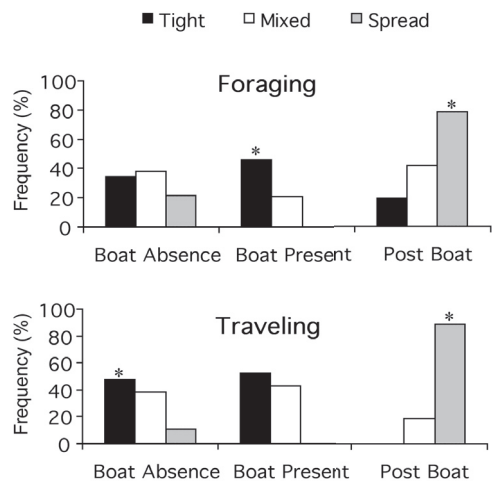


Figure 8. Frequency of occurrence for group dispersion (tight, mixed, and spread) of Chilean dolphins (*C. eutropia*) as a function of boat condition; (*) represents significant associations ($p < 0.05$) (adjusted residuals analysis).

et al., 1999; Irvine et al., 1981; Kruse, 1991; Nowacek et al., 2001; Richardson et al. 1995; Watkins, 1986; Williams et al., 2002).

Behavioural responses of Chilean dolphins differed, depending on the activity pattern the dolphins were engaged in prior to boat approaches. During foraging, dolphins avoided boats using frequent changes in rr and more erratic and unpredictable movement patterns. When traveling, dolphins moved away from the path of the boat by increasing their ss.

These differences in avoidance responses might reflect, in part, usual tactics to avoid predators, as pointed out for other species (Williams et al., 2002). According to the models described by Howland (1974) and Weihs & Webb (1984), optimal strategies for evading predators imply the ability to vary ss and course. Belugas (*Delphinapterus leucas*) and narwhals (*Monodon monoceros*) have been observed to react to vessel approach in the same way as they do to the presence of killer whales (*Orcinus orca*) (Finley et al., 1990). Due to cumulative effects of excessive boat encounters, dolphins might have learned, and passed on to consecutive generations, the best techniques to avoid boat approaches, just as they would learn the best tactics to evade predators.

Most previous studies dealing with cetacean-boat interactions have not taken into account the animals' behavioural states prior to the encounters (Bejder et al., 1999; Kruse, 1991; Yin, 1999). Potential effects of boat traffic could be masked if these states were not considered (William et al., 2002), especially if they influence the variables measured (ss and rr). Furthermore, although visual sex

determination on Chilean dolphins is difficult to assess in the wild, we would expect that males and females respond differently to interactions with boats due to different metabolic regime of sexes, as observed in bottlenose dolphins (*Tursiops* spp.) in New Zealand (Lusseau, 2003b).

Post-encounter recovery time varied depending on the dolphins' behaviour prior to the encounter. Dolphins took longer to recover when they were involved in foraging at the time of the encounter than when they were traveling. As SS increased, breathing and metabolic rate enhanced exponentially (Sumich, 1983). Thus, the rapid recovery of traveling dolphins post-encounter might be associated with energy conservation. The slow recovery of foraging dolphins might be linked to interindividual coordination in looking for food or hunting since boat presence might also disturb dolphins' prey (Allen & Read, 2000; Janik & Thompson, 1996). Furthermore, it is known that behavioural transitions are affected by boat interactions. As observed for bottlenose dolphins in New Zealand, animals were significantly more likely to be traveling after an interaction with a boat, and also were less likely to continue socialising or resting (Lusseau, 2003a).

Inter-individual dolphin proximity was altered by boat approaches as well. In the presence of boats, dolphins never dispersed (for either foraging or traveling); on the contrary, they were a significantly tighter group throughout encounters when foraging. Although no significant association was found during traveling, groups tended to remain cohesive during boat approaches. These results are also documented for other species (Au & Perryman, 1982; Bejder et al., 1999; Irvine et al., 1981). Generally, groups of dolphins remain cohesive in situations of surprise, threat, or danger (Johnson & Norris, 1986). This behaviour might favour greater individual protection (Bejder et al., 1999), and could facilitate interindividual communication (Erbe, 2002).

Although a limit of a 500-m (radius) was used to define the "interaction zone" in boat-dolphin encounters, it is probable that dolphins detect the presence of boats at greater distances as observed, for example, in Hector's dolphins (*C. hectori*), which can perceive boats at distance of at least 3 km (Bejder et al., 1999). Once boats entered the interaction zone, Chilean dolphins did not show any significant difference on how they reacted to boats at close or distant encounters.

Although Schevill (1968) suggested that cetacean behavioural responses generally are caused by boat noise, and that for some species, such as humpback dolphins (*Sousa chinensis*), their acoustic behaviour is affected by transiting boat traffic (Van Parijs & Corkeron, 2001), in this study, it is not known whether Chilean dolphins' reactions in

Yaldad Bay are due to boat presence, engine noise, or both. More sophisticated studies, such as acoustic modeling (Erbe, 2002), would be necessary to understand the cause of the reactions and determine the distance at which dolphins perceive boats.

Vessels with a more directional path may have less effect on animals' behaviour than vessels with more erratic and less predictable movements (Acevedo, 1991; Kruse, 1991; Richardson et al., 1995; Watkins, 1986; Yin, 1999). Acevedo (1991) observed that bottlenose dolphins (*Tursiops truncatus*) habituated to boats with directional paths and only reacted to them when the vessels started to follow the animals and approached to less than 5 m from the group. Chilean dolphins appeared to display behavioural alterations for both boats with directional (used in aquaculture) and erratic movements (research), although this might be arguable due to small sample size. The fact that Chilean dolphins alter their movement patterns in response to directional boats might be indicating that even after 20 years of traffic due to aquaculture activities in Yaldad Bay (Bushman et al., 1996), dolphins might not have adapted to boat presence. Hence, Chilean dolphins appear to be potentially more susceptible than other species such as *T. truncatus*. Gordon & Moscrop (1996) suggested that dolphins either become habituated to the sound and show less response, or show an increasing level of disturbance with exposure. The continued occurrence of *C. eutropia* in Yaldad Bay (Crovetto & Medina, 1991; Ribeiro, 2003), however, might be a sign of tolerance towards boats. As pointed out by Blane & Jaakson (1994), the apparent tolerance of marine mammals towards disturbance in some areas does not imply that negative impacts do not exist but, rather, that animals continue frequenting these sites for their critical importance in the development of the animal's biological and social activities. This might be the case for Chilean dolphins in Yaldad Bay, which is mainly used for feeding activities (Ribeiro, 2003).

Long-term effects of boat traffic on Chilean dolphins in Yaldad Bay are not known. Nonetheless, as behavioural and movement patterns are altered, several impacts might eventually be detected at the population level such as a decrease in reproductive success, an increase in mortality rate, or an alteration of habitat use patterns. For bottlenose dolphins, Allen & Read (2000) found that animals varied their habitat use patterns depending on the intensity of boat traffic. Bejder et al. (1999) suggested that the impact by boat traffic might be cumulative, rather than catastrophic. Dolphins may possibly remain in a constant state of alert, resulting in reduced biological fitness from increased energy consumption.

Although dolphin-watching tourism has not been developed in southern Chile, Chilean

dolphins might be considered a potential target species in this activity due to their coastal distribution. This type of tourism might help to promote cetacean conservation (Hoyt, 1995; IFAW, 1995). Evidence from this study, however, suggests that these dolphins could be affected by and become elusive towards boats. For this reason, before any dolphin-watching industry develops, more detailed studies will be necessary to achieve a better understanding of the potential impact of this activity on dolphin populations and to establish adequate policies and regulations. It should also be taken into account that in many areas, such as Yaldad Bay, dolphins have been affected by boat traffic as a consequence of the aquaculture industry.

Further effects of aquaculture, such as restriction of space available to dolphins (Ribeiro, 2003) and organic and chemical pollution (Claude & Oporto, 2000), might contribute additional impacts on the local dolphin population. It seems that boat disturbance deserves more attention and needs to be taken into consideration when developing management plans and policies for coastal conservation, especially in areas like southern Chile, where widespread industrial activities such as aquaculture already take place.

Acknowledgments

We extend our sincere gratitude to Stefan Bräeager and Sonja Heinrich for their essential support, suggestions, and comments throughout this study and in earlier versions of this manuscript. Universidad Austral de Chile provided accommodation throughout our study. We are grateful to Danielle Krebs, Jeanette Thomas, and Sofie M. Van Parijs who provided helpful comments and improved greatly earlier versions of this manuscript. We are also thankful to all of the volunteers who helped in data collection: Alejandra Henny, Carla Christie, Carlos Lara, Gonzalo Burgos, Juan Harries, Nicolás Sanchez, Robert Ronconi, Ruth Ipa, Sarah Wong, and Victor Castillo. SR was supported by the postgraduate programme in Ecology of the Universidade Federal do Rio Grande do Sul and CNPq scholarship. This is contribution number 5 of the Blue Whale Center (CBA/BWC, Chile).

Literature Cited

- Acevedo, A. (1991). Interactions between boats and bottlenose dolphins, *Tursiops truncatus*, in the entrance to Enseada de La Paz, Mexico. *Aquatic Mammals*, 17, 120-124.
- Aguayo-Lobo, A., Torres, D. N., & Acevedo, J. R. (1998). Los mamíferos marinos de Chile: I. Cetacea. *Serie Científica INACH*, 48, 19-159.
- Allen, M. C., & Read, A. J. (2000). Habitat selection of foraging bottlenose dolphins in relation to boat density near Clearwater, Florida. *Marine Mammal Science*, 16, 815-824.
- Anonymous. (1995). *Report of the workshop on the scientific aspect of managing whale-watching*. East Sussex: IFAW, Tethys Research Institute and Europe Conservation. 40 pp.
- Anonymous. (1999). *Tablas de marea de la costa de Chile y puertos de la costa Sudamericana* (Publicación 3009). Valparaíso: Servicio Hidrográfico y Oceanográfico de la Armada de Chile (SHOA).
- Au, D., & Perryman, W. (1982). Movement and speed of dolphin schools responding to an approaching ship. *Fishery Bulletin*, 80, 371-379.
- Bejder, L., Dawson, S. M., & Harraway, J. A. (1999). Responses by Hector's dolphins to boats and swimmers in Porpoise Bay, New Zealand. *Marine Mammal Science*, 15, 738-750.
- Beveridge, M. C. M., Ross, L. G., & Kelly, L. A. (1994). Aquaculture and biodiversity. *Ambio*, 23, 497-502.
- Blane, J. M., & Jaakson, R. (1994). The impacts of the ecotourism boats on the St. Lawrence beluga whale (*Delphinapterus leucas*). *Environmental Conservation*, 21, 267-269.
- Bushmann, A. H., López, D. A., & Medina, A. (1996). A review of the environmental effects and alternative production strategies of marine aquaculture in Chile. *Aquacultural Engineering*, 15, 397-421.
- Clasing, H., Oñate, A., & Arriagada, H. (1998). *Cultivo de choritos en Chile*. Valdivia: Imprenta Universitaria. 36 pp.
- Claude, M., & Oporto, J. A. (2000). *La ineficiencia de la salmonicultura en Chile: Aspectos sociales, económicos y ambientales*. Santiago: Terram Publicaciones. 65 pp.
- Crovetto, A., & Medina, G. (1991). Comportement du dauphin chilien (*Cephalorhynchus eutropia* Gray, 1846) dans les eaux du sud du Chili. *Mammalia*, 55, 329-338.
- Edgington, E. S. (1995). *Randomization tests* (3rd ed.). New York: Marcel Dekker. 409 pp.
- Erbe, C. (2002). Underwater noise of whale watching boats and potential effects on killer whales (*Orcinus orca*), based on an acoustic impact model. *Marine Mammal Science*, 18, 394-418.
- Everitt, B. S. (1992). *The analysis of contingency tables* (2nd ed.). London: Chapman & Hall. 164 pp.
- Finley, K. J., Miller, G. W., Davis, R. A., & Greene, C. R. (1990). Reactions of belugas, *Delphinapterus leucas*, and narwhals, *Monodon monoceros*, to ice-breaking ships in the Canadian high Arctic. *Canadian Bulletin of Fishery and Aquatic Science*, 224, 97-117.
- Goodall, R. N. P. (1994). Chilean dolphins *Cephalorhynchus eutropia* (Gray, 1846). In S. H. Ridgway & S. R. Harrison (Eds.), *Handbook of marine mammals, Volume 5* (pp. 269-287). San Diego: Academic Press.
- Goodall, R. N. P., Norris, K. W., Galeazzi, A. R., Oporto, J. A., & Cameron, I. S. (1988). On the Chilean dolphin, *Cephalorhynchus eutropia* (Gray 1846).

- Reports of the International Whaling Commission*, (Special Issue 9), 197-257.
- Gordon, J., & Moscrop, A. (1996). Underwater noise pollution and its significance for whales and dolphins. In M. P. Simmonds & J. D. Hutchinson (Eds.), *The conservation of whales and dolphins* (pp. 281-319). Greenwich, UK: John Wiley & Sons Ltd.
- Hilton-Taylor, C. (2000). *2000 IUCN red list of threatened species*. Gland, Switzerland: IUCN. 61 pp.
- Howland, H. C. (1974). Optimal strategies for predator avoidance: The relative importance of speed and manoeuvrability. *Journal of Theoretical Biology*, 47, 333-350.
- Hoyt, E. (1995). *The worldwide value and extent of whale watching: 1995*. Bath: Whale and Dolphin Conservation Society. 36 pp.
- Irvine, A. B., Scott, M. D., Wells, R. S., & Kaufmann, J. H. (1981). Movements and activities of the Atlantic bottlenose dolphin, *Tursiops truncatus*, near Sarasota, Florida. *Fishery Bulletin*, 79, 671-688.
- Janik, V. M., & Thompson, P. M. (1996). Changes in surfacing patterns of bottlenose dolphins in response to boat traffic. *Marine Mammal Science*, 12, 597-602.
- Johnson, M. C., & Norris, K. S. (1986). Delphinid social organization and social behavior. In R. J. Schusterman, J. A. Thomas, & F. G. Wood (Eds.), *Dolphin cognition and behavior: A comparative approach* (pp. 335-346). Mahwah, NJ: Lawrence Erlbaum Associates.
- Kruse, S. (1991). The interaction between killer whales and boats in Johnstone Strait, B.C. In K. Pryor & K. Norris (Eds.), *Dolphin societies: Discoveries and puzzles* (pp. 149-159). Los Angeles: University of California Press.
- Lescrauwaet, A. K., & Gibbons, J. (1994). Mortality of small cetaceans and the crab bait fishery in the Magallanes area of Chile since 1980. *Reports of the International Whaling Commission*, (Special Issue 15), 485-494.
- Lusseau, D. (2003a). Effects of tour boats on the behavior of bottlenose dolphins: Using Markov chains to model anthropogenic impacts. *Conservation Biology*, 17, 1785-1793.
- Lusseau, D. (2003b). Male and female bottlenose dolphins *Tursiops* spp. have different strategies to avoid interactions with tour boats in Doubtful Sound, New Zealand. *Marine Ecology Progress-Series*, 257, 267-274.
- Manly, B. F. J. (1991). *Randomization and Monte Carlo methods in biology*. London: Chapman & Hall. 281 pp.
- Mann, J. (1999). Behavioral sampling methods for cetacean: A review and critique. *Marine Mammal Science*, 15, 102-122.
- Nowacek, S. M., Wells, R. S., & Sollow A. R. (2001). Short-term effect of boat traffic on bottlenose dolphins, *Tursiops truncatus*, in Sarasota Bay, Florida. *Marine Mammal Science*, 17, 673-688.
- Pillar, V. D. P. (2000). *MULTIV User's guide version 2.0: Multivariate exploratory analysis, randomization testing and bootstrap resampling*. Porto Alegre: UFRGS. 38 pp.
- Pillar, V. D. P., & Orlóci, L. (1996). On randomization testing in vegetation science: Multifactor comparisons of relevé groups. *Journal of Vegetation Science*, Uppsala, 7, 585-592.
- Reeves, R., Smith, B., Crespo, E., & Notarbartolo di Sciarra, G. (2003). *Dolphins, whales and porpoises: 2002-2010 conservation action plan for the world's cetaceans*. Gland, Switzerland: The World Conservation Union, IUCN/SSC Cetacean Specialist Group. 139 pp.
- Ribeiro, S. (2003). *Ecologia comportamental do golfinho chileno Cephalorhynchus eutropia (Gray 1846): Seleção de habitat e interações com atividades antrópicas*. M. Sc. thesis, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brasil. 133 pp.
- Richardson, W. J., Greene, C. R., Jr., Malme, C. I., & Thompson, D. H. (1995). *Marine mammals and noise*. New York: Academic Press. 576 pp.
- Roberts, C. M., & Hawkins, J. P. (1999). Extinction risk at the sea. *Tree*, 14, 242-246.
- Schevill, W. E. (1968). Quiet power whaleboats. *Journal of the Acoustical Society of America*, 44, 1157-1158.
- Sullivan-Sealey, K., & Bustamante, G. (1999). *Setting geographic priorities for marine conservation in Latin America and the Caribbean*. Arlington, VA: The Nature Conservancy. 125 pp.
- Sumich, J. L. (1983). Swimming velocities, breathing patterns, and estimated costs of locomotion in migrating gray whales, *Eschrichtius robustus*. *Canadian Journal of Zoology*, 61, 647-652.
- Van Parijs, S. M., & Corkeron, P. J. (2001). Boat traffic effects the acoustic behaviour of Pacific humpback dolphins, *Sousa chinensis*. *Journal of the Marine Biological Association*, 81, 533-538.
- Watkins, W. A. (1986). Whale reactions to human activities in Cape Cod waters. *Marine Mammal Science*, 2, 251-262.
- Weih, D., & Webb, P. W. (1984). Optimal avoidance and evasion tactics in predator-prey interactions. *Journal of Theoretical Biology*, 106, 189-206.
- Wells, R. S., & Scott, M. D. (1997). Seasonal incidence of boat strikes on bottlenose dolphins near Sarasota, Florida. *Marine Mammal Science*, 13, 475-480.
- Williams, R., Trites, A. W., & Bain, D. E. (2002). Behavioural responses of killer whales (*Orcinus orca*) to whale-watching boats: Opportunistic observations and experimental approaches. *Journal of Zoology*, 256, 255-270.
- Würsig, B., Cipriano, F., & Würsig, M. (1991). Dolphins movement and patterns: Information from radio and theodolite tracking studies. In K. Pryor & K. Norris (Eds.), *Dolphin societies: Discoveries and puzzles* (pp. 79-112). Los Angeles: University of California Press.
- Yin, S. (1999). *Movements patterns, behaviors and whistle sounds of dolphins groups off Kaikoura, New Zealand*. M. Sc. thesis, Texas A & M University, College Station, TX. 106 pp.