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Response of southern right whales to simulated swim-with-whale tourism at Península Valdés, Argentina

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ABSTRACT

Guidelines for sustainable tourism involving swimming with large whales are not well-developed compared to those focused on programs of swimming with delphinids. From September to November 2005 and August to September 2006, we collected behavioral and movement data for southern right whales (*Eubalaena australis*) exposed to interactions with boats and swimmers at Península Valdés, Argentina. Whales were tracked from shore using a theodolite before, during, and after a series of directed interactions with swimmers and a boat. Resting, socializing, and surface active behavior decreased, traveling increased, and whales swam faster and reoriented more often during interactions. Responses were variable by age/sex class, with mother/calf pairs showing strongest responses. Increased levels of tourism activity are a concern, as reduction in resting time and disruption of socialization among adults, juveniles, and mother/calf pairs have unknown long-term consequences. Additional data should be collected for whale behavior in proposed tourism and nontourism areas to build a long-term database which can be used to determine if reactions of whales change over time. Our data suggest that swimming with whales in Chubut Province should not be legalized until further investigations are completed, especially in light of the recent southern right whale die-offs recorded in Península Valdés.

Key words: behavioral effects, *Eubalaena australis*, right whale, tourism impact, whale watching, disturbance, ecotourism, wildlife management.

Cetacean-watching activities have grown considerably in the past two decades, with most such tourism boat-based and not involving swimmers (Hoyt 2001, O'Connor *et al.* 2009). However, swimming with cetaceans is increasing, as tour

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operators attempt to provide tourists with more "intimate" interactions with animals (Bejder and Samuels 2004). At least 51 commercial operators offered opportunities to swim with whales in 2005, and others may do so opportunistically (Rose *et al.* 2005). Swimming with large whales occurs in over 20 locations globally, including several where the activity is prohibited by law (Rose *et al.* 2005).

A variety of behavioral changes have been documented for dolphins targeted by swim-with-dolphin operations. Demonstrated changes in behavior include increased avoidance of swimmers over several years, (*i.e.*, sensitization, Constantine *et al.* 2003), increased vocalizations and echolocation (Scarpaci *et al.* 2000), changes in group spacing (Bejder *et al.* 1999), and seasonal differences in receptivity (Martinez *et al.* 2011). Not only is there a clear risk of harassment for animals, there may also be a risk of injury for the human participants (Samuels *et al.* 2000). While observations for small cetacean species may be similar to large whales, there are enough behavioral differences between large and small cetaceans to warrant further investigation. Whereas small coastal delphinid species may spend much or all of their lives in a discrete area, large whales live long lives and make annual migrations spanning vast areas of the oceans, typically spending only part of the year in areas where tourism occurs.

Studies have demonstrated a variety of effects on the behavior of large whales in the presence of whale-watching vessels, including changes in speed and direction of travel, dive times, respiration rates, and surface activity (Watkins 1986, Corkeron 1995, Au and Green 2000, Scheidat *et al.* 2004, Richter *et al.* 2006). A number of studies have examined social science aspects of swimming with large whales (Orams 2001, Valentine *et al.* 2004, Kessler and Harcourt 2010), but relatively few quantitative studies have been performed. Valentine *et al.* (2004) noted that there have been few swim-with studies focused on large whales, and much of the analysis has been based on limited data and anecdotal or opportunistic interactions under uncontrolled conditions. A small industry focuses on swimming with dwarf minke whales (*Balaenoptera acutorostrata*) on the Great Barrier Reef in Australia (Birtles *et al.* 2002, Valentine *et al.* 2004). These whales voluntarily approach stationary vessels and remain nearby for hours, resulting in elevated risks to participants due to the close proximity of large animals, and to the focal whales due to boat strikes and/or entanglement with ropes used by swimmers (Mangott *et al.* 2011). These results bear similarities to the "boat-positive" behavior of gray whales (*Eschrichtius robustus*) in Mexico (Dalheim *et al.* 1981), but are starkly different from other descriptions of large whale reactions to vessel traffic. The Scientific Committee of the International Whaling Commission noted that the impact of tourism activity may vary by species or site, and each situation should be evaluated on its individual merits (IWC 2000).

Southern right whales (*Eubalaena australis*) use nursery grounds off Península Valdés, Chubut Province, Argentina in austral winter and spring to mate, give birth, and raise their newborn calves (Payne *et al.* 1991, Cooke *et al.* 2001, Valenzuela *et al.* 2009). The coastal habits of southern right whales and high cliffs of Península Valdés provide a unique opportunity to quantify the effects of swim-with-whale tourism on southern right whales in an experimental setting. The Península extends out as a cape and forms two gulfs: Golfo San José to the north and Golfo Nuevo to the south. Adult females use the relatively protected waters of the gulfs to raise their calves during their first 3 months of life (Taber and Thomas 1982, Thomas and Taber 1984), as is common among this species throughout the Southern Hemisphere (Best 1994, Burnell and Bryden 1997). Juveniles spend much of their time socializing and resting and adults engage in courtship and mating behavior (Payne 1986, Burnell and Bryden 1997, Sironi 2004).

Most whales in this area are distributed close to shore in shallow waters (Payne 1986) and are easily reached by boat, which has facilitated a rapidly expanding local whale watching industry (Rivarola *et al.* 2001, O'Connor *et al.* 2009). Tourism is one of the main industries in the Valdés area, a World Heritage site, and whale watching is a primary tourist attraction, regulated by Chubut Provincial Law 5714 enacted in 2008 (Sironi *et al.* 2005*a*, 2009*a*). The town of Puerto Pirámides is the only departure point for the whale watch tours. The whale watching season runs from June to December, with the majority of trips (53%) occurring in October and November (Sironi *et al.* 2009*a*). During the past two decades, the number of tourists participating in whale watch tours to see southern right whales on this nursery ground increased over five-fold, from 17,446 in 1991 to 113,148 in 2007 (Sironi *et al.* 2009*a*).

Previous studies at Península Valdés described short-term changes in behavior and swimming speeds of right whales in response to boat approaches (summarized by Rivarola *et al.* 2001). These studies focused on responses of whales to whale watching vessels, and found that solitary whales and groups other than mother/calf pairs increased swimming speeds in the presence of boats. Swim-with-whale tourism is different from whale watching tourism, because boats must motor very close to the whale before swimmers enter the water. Despite the fact that swimming with whales is prohibited by federal law in Argentina, Rio Negro Province (immediately to the north of the Valdés area) legalized swim-with-whale tourism in early 2006 and at least one commercial operation began offering the activity shortly thereafter. In Chubut Province, Provincial Law 5714 enacted by provincial decree 42/08 "forbids to approach, chase, sail, swim and/or dive with southern right whales in provincial waters during the calendar year without an official permit issued by the Enforcement Authority." Southern right whales are experiencing high levels of mortality at Península Valdés (IWC 2010), so there is concern about the effects of adding new commercial activities targeting this population, particularly on this nursing ground.

This study was requested by provincial authorities to determine the effects of swim-with-whale tourism and to provide scientific input to wildlife managers in Chubut Province regarding potential legalization of this activity. We used a theodolite to observe and track whales without affecting behavior (Würsig *et al.* 1991), which was possible because right whales are distributed close to shore at Península Valdés. The objective of this study was to describe the behavior and movement patterns of different age classes of right whales and quantify any changes that resulted from the approach of a boat and three swimmers, as well as to provide recommendations relative to potential legalization of swim-with-whale tourism.

Methods

Data were collected from September through November 2005 and August through September 2006, from two observation stations located on cliffs on the southern coast of the Península in Golfo Nuevo. Both sites are within the El Doradillo Municipal Protected Area, where boat traffic is forbidden, so the research boat was the only potential source of human disturbance within several kilometers of the whales. The first station was located near Cerro Prisma (42°35'42.42"S, 64°48'42.64"W) and the second was at Playa Manara (42°40'33.24"S, 64°59'25.02"W) (Fig. 1). Playa

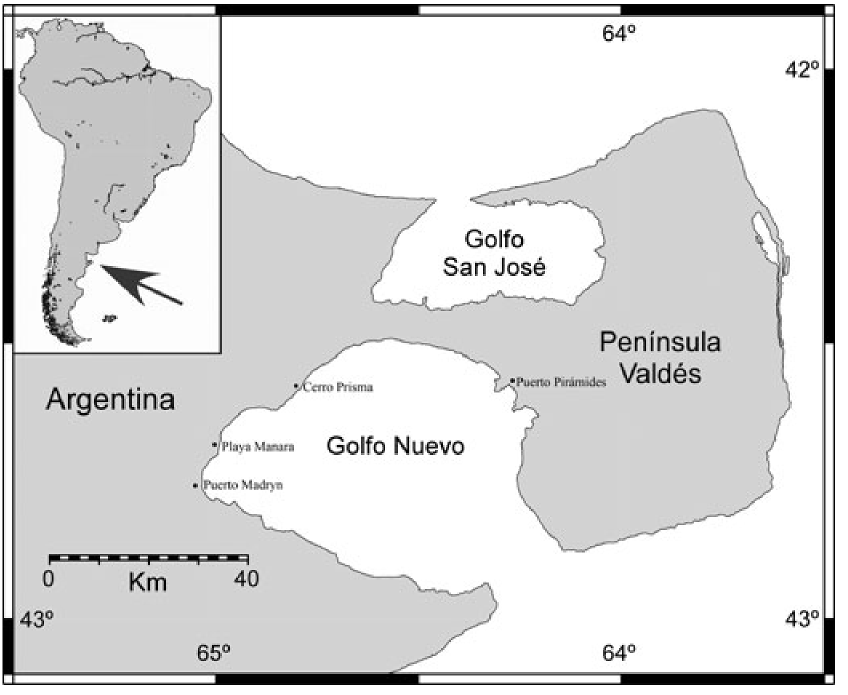


Figure 1. Map of study area with two port towns and two study sites.

Manara (18.17 m elevation) was generally used earlier in the season when whales were abundant throughout the gulf, and Cerro Prisma (25.08 m elevation) later in the season as whales began moving eastward toward the mouth of the gulf. A 10 cm error in height for a 20 m site would result in a position error of 5 m for a target 1 km away (Würsig *et al.* 1991), so elevation for each station was calculated precisely. The magnitude of error in position calculations associated with the difference in height of the two stations was deemed negligible, because height measurements were precise and the focal animal was generally within a few kilometers of the shore station. The two field seasons were offset temporally to ensure observations were made over a significant portion of the season when southern right whales are present at Península Valdés, but small sample sizes precluded analyzing the data for changes in reactions of whales to boats within a season. Taber and Thomas (1982) described changes in the behavior of mother/calf pairs during the course of the calving season in this area, so it is possible that additional research would show that reactions to boats change as calves grow and mature.

Study Design

The study was designed as a Before/During/After (BDA) comparison (Martin and Bateson 1993, Bejder and Samuels 2004), with behavior and movement of whales before an interaction with boat and swimmers serving as control data for behavior and movement during and after the interaction. Data were collected on the behavioral state of a whale before the boat approached, during the boat approach and while swimmers and boat were interacting with the whale, and after swimmers and boat left the area.

The Before segment (BI) was defined as all activity from the time we began tracking a whale from the cliffs to the time when the boat first approached within 500 m of the whale. The 500 m radius was determined by a preliminary analysis which indicated that whales reoriented significantly more when the boat approached within 500 m than when the boat was more than 1 km away (ANOVA, $F_{1,78} = 4.770$, $P = 0.03$). The During segment (DI) began when the boat was within 500 m of the whale, included the entire time swimmers were in the water, and ended when the boat traveled more than 500 m from the whale. The After segment (AI) was the period of time after the interaction when the boat traveled more than 500 m from the whale. In cases when whales swam more than 500 m away from the swimmers, the AI segment began immediately when the swimmers exited the water.

Boats used were owned and driven by local dive operators who were advised on best practices for approaching whales (slow approach, at a constant speed, from the rear and side) and asked to approach in a consistent, realistic fashion, but approaches were not strictly controlled. The boat motor was generally in neutral when swimmers were in the water, unless there was a safety reason to put it in gear and maneuver the boat. This ensured that the activity we were evaluating was comparable to what would happen if tourism were to be legalized, rather than an idealized version in which all boat operators approach in the most low-impact manner. We considered the activity as an entire unit (hereafter referred to as a "swim-with interaction") rather than trying to separate the effect of the boat from the effect of the swimmers, as the swimmers would never be present without the boat. The number of swimmers entering the water was fixed at three, because dive operators felt that one dive master and two tourists was the most likely group size if the activity were to be legalized. All swimmers participating in the study were professional and/or experienced divers.

Our observations were roughly evenly split between mother/calf pairs, juveniles (individual or in juvenile-only groups), and other whale groups (adults or mixed adult/juvenile). Mother/calf pairs and juveniles are generally distributed close to shore, are the most abundant age classes at this nursery ground, are more easily approached by boats, and are presumably the whales with the highest risk of being affected. For instance, Rivarola *et al.* (2001) found that mother/calf pairs were the selected target for all whale watching trips at the end of the season at Península Valdés. Juvenile whales are curious and often approach boats. A whale was determined to be a juvenile by observing head shape and body proportions (Sironi *et al.* 2005*b*), by comparing the subjects' body size to nearby adult females (identified as such by the presence of an accompanying calf) whose mean total length for this population is 13.66 m (Whitehead and Payne 1981), or by their evident small size.

Data Collection

Positions of focal whales, boats and swimmers were recorded with a Sokkisha DT5A digital theodolite with ±5 s precision and 30× magnification, connected to a laptop computer running the program *Pythagoras* (Gailey and Ortega-Ortiz 2002). *Pythagoras* calculates a real-time conversion of horizontal and vertical angles collected by the theodolite into geographic positions of latitude and longitude each time a determination of position (or "fix") is initiated. The simultaneous tracking of whales, boats, and swimmers at 2 min intervals provided information on speed

Table 1. Definitions of behavioral states of individual southern right whales

State	Definition
Resting	Whale is motionless and horizontal at surface of water; may also be drifting or slightly below water, surfacing only to breathe.
Traveling	Whale is moving from location to location, leaving visible surface swirls ("footprint") behind in its path.
Surface Active	Whale is causing whitewater at the surface by rolling, breaching, tail- or flipper-slapping.
Social	Whale is actively rubbing, touching, or circling around another whale.

and orientation of whales, as well as whale movements in relation to boat and swimmers (see Würsig *et al.* 1991 and Gailey and Ortega-Ortiz 2002). For each fix, the following information was stored in a Microsoft Access database for later analysis: group number, horizontal and vertical angles, latitude, longitude, date, time, and bearing referenced to true North (Gailey and Ortega-Ortiz 2002).

We used focal animal observations (Altmann 1974, Martin and Bateson 1993) to record instantaneous point samples of the behavioral state of the focal whale at approximately 2 min intervals BI, DI, and AI. The following mutually exclusive behavioral states were used to define whales' behavioral budget: (1) resting, (2) traveling, (3) surface active, and (4) social (Table 1). These behaviors were defined similarly to those used in the literature for juvenile (Sironi 2004) and mother-calf pair right whales (Thomas and Taber 1984).

The researchers were in two groups: one was on board the boat with the swimmers and 2–4 observed from the cliff-top observation site. The researcher on the boat was responsible for taking digital images of callosities or other markings on focal whales for identification purposes (Payne 1986), relaying instructions to the boat captain and swimmers prior to an approach, and recording incidental observations about whales or swimmers (such as physical contact between them). Swimmers were asked to behave as tourists might—taking pictures and swimming close to the whales—but not to initiate any physical contact. Hand-held marine band (VHF) radios were used to coordinate activities between the cliff-top observers and the boat with swimmers.

Data were collected with the theodolite operator tracking whales and verbally relaying behavior and fix information to the computer operator for input to *Pythagoras*. To preclude interobserver variability, the first author was the theodolite operator for all days of the study. Focal follow data were analyzed BI, DI, and AI.

Each follow began by randomly choosing a focal whale close to the cliff-top station, but as far away from the boat as possible (500 m or more), to ensure that whale behavior was undisturbed. Regardless of the number of whales or composition of a group, the focal whale was followed exclusively. In the case of mother/calf pairs, the mother was always the focal whale. Otherwise, the most easily identifiable individual (based on callosities or pigmentation) was chosen. The focal whale's behavioral state and position were recorded every 2 min, on average, although when the whale was underwater and not visible, intervals were longer and the position was fixed when the whale surfaced. After a minimum of 20 min of behavioral data was recorded for the BI segment, the boat was directed to begin approaching the focal whale.

The boat approached the whale, and if it succeeded in getting close enough (10–20 m), swimmers entered the water. The whale, boat, and swimmers were then tracked for a minimum of 10 min during the interaction. Interaction time varied, depending on the reaction of the whale. Interactions were stopped at a maximum of 20 min because the dive operators felt it was the most appropriate length of time for tourists to be in the water. Once swimmers exited the water and the boat moved away, the whale was tracked for another 20 min for the AI segment. If the whale moved more than 3 km from the cliff station or was lost visually for some other reason, observations ended and a new whale was selected.

When taking location fixes of multiple objects (whale, boat, or swimmers), we alternated between objects and recorded each in quick succession (generally within about 10 s) to obtain a better estimate of relative positions. The time of boat approach, swimmer entry, swimmer exit and boat departure were recorded in *Pythagoras* to allow splitting the focal follow into the appropriate BI, DI, and AI segments.

Data Preparation and Filtering

Since data were not collected at even intervals or for equal amounts of time in each case, there was a risk of over- or under-sampling if the values were used in raw form. A mean interval between observations was calculated, and both the behavior and movement data were interpolated using this mean interval. Behavior was assumed to remain constant between observations. That is, if a whale was observed traveling at time 0 and resting at time 1, any interpolated points that fell between the two had traveling as their behavior. Movement was assumed to be in a straight line at a constant speed between fixes.

Focal follows were filtered to include only those that had a minimum of 10 min of data in each of the BI, DI, and AI segments. Ten minutes of each segment were randomly selected for analysis of movement characteristics and all other data were disregarded in analyses described here. This ensured that movement characteristics were compared over an equal amount of time for each focal follow, reducing the risk of over- or under-sampling. Behavioral transitions were tallied using the full track, as the statistical technique used for analysis (described below) did not require independence of observations.

Means of leg speed, reorientation rate, and linearity were calculated for each of the three 10 min segments per whale. Leg speed is the distance between two successive points divided by the time interval. Reorientation rate is a measure of how much the animal is changing course during the track, and is calculated by adding up the absolute values of heading changes (defined as 0 to 180 degrees relative to the current bearing) and dividing by the duration of the track in minutes (Smultea and Würsig 1995). Linearity is an index ranging from 0 (no net movement) to 1 (straight line). It is calculated by dividing net distance from the first to last fix of a track by the sum of all the distances for each leg (Batschelet 1980). To assess normality for statistical treatment, histograms were generated for the mean values of each of the movement characteristics. Leg speed, linearity and reorientation rate were highly non-normal in shape and were log-transformed.

Statistical Analysis

Since consecutive behavioral observations were not likely to be statistically independent, they were analyzed as a series of time-discrete Markov chains. To quantify the dependence of each behavioral event on the preceding event in the behavioral

Table 2. Akaike Information Criteria values for each model.

Model	AIC	ΔAIC
Boat + Group	−60.5	0
Boat	−37.2	23.3
Boat × Group	−33.8	26.7
Group	−16.2	44.3
Null model	2.8	63.3

sequence, we used first-order Markov chain analysis. Following assumptions used by Lusseau (2003*a*), defining a set of mutually exclusive and wholly inclusive behaviors allowed us to analyze temporal variations in behavior of whales using Markov chains. The Markov chain was used to build a matrix of preceding behavior (at time 0) *vs.* succeeding behavior (at time 1) for each transition within the BI, DI, and AI chains.

Log-linear analysis (LLA) was performed using SPSS version 13.0.1 for Windows (SPSS Inc. 2004) to determine whether behavioral state transitions varied depending upon group composition. LLA allows the manipulation of the parameters (and the interactions between them) considered when fitting the model to the data. The analysis was conducted by including all possible combinations of parameters and interactions between parameters (Table 2). Maximum likelihood for the model is then approximated by G^2. Comparing results for a specific model to the fully-saturated model gave the effect due to whichever parameter was missing from that model. Difference in G^2 and degrees of freedom between the two models was used to determine whether the parameter was significant or not. Akaike Information Criteria (AIC) values were calculated to choose the best-fitting model (Table 2). AIC assists in selecting the most parsimonious model by rewarding a model for providing information, and penalizing it for using extra parameters to do so (Anderson *et al.* 2000, Caswell 2001). This technique is described in detail in Lusseau (2003*a*, 2004).

The transition probability for each behavioral state transition was calculated by dividing the number of times a transition from preceding behavior i to succeeding behavior j was observed by the total number of times i was seen as the preceding behavior. By comparing the calculated probabilities between control and treatment chains using a Z-test for proportions (Fleiss 1981), it was possible to test whether the swim-with interaction had a significant effect on the behavior of whales. This analysis was performed on the entire data set, regardless of group composition (mother/calf pair, juvenile, or other). Due to small sample sizes for some of the social and surface active behavioral state transitions, it was not possible to calculate transition probabilities for the different group types. Instead, the proportion of time whales were observed in each behavioral state was calculated before, during, and after the interaction, and a Z-test for proportions (Fleiss 1981) was used to determine if there were significant differences.

Analysis of variance (ANOVA) tests were conducted using SPSS version 13.0.1 for Windows (SPSS Inc. 2004) to determine effects of experimental approaches on movement characteristics of whales. Significance values were set at $\alpha = 0.05$. Analyses were performed with the data divided by group type (mother/calf pair, juvenile, or adult/mixed). *Post hoc* analyses were conducted to determine the significance of effects on each of these groups and sub-groups.

Results

Work Effort

Conditions were suitable for data collection on 36 of 108 days over two field seasons. Many work days were lost due to weather, as the boat could not safely operate and put swimmers into the water and retrieve them when winds were higher than about 13 kn. In total, we attempted to approach 184 groups of whales. In 31 instances (17%), whales avoided the boat to such a degree that the boat was not able to get close enough for swimmers to enter the water. Mother/calf pairs avoided the boat much more often than other group types: 27% of mother/calf pairs avoided the boat, whereas only 5% of juveniles and 7% of mixed groups did so.

A total of 153 approaches with swimmer interactions were conducted. After applying the filtering criteria described in the Methods, 93 interactions remained for analysis, comprised of 38 mother/calf pairs, 25 juvenile groups, and 30 mixed groups. Most groups were filtered out because the DI segment was shorter than 10 min. The only whale that had two interactions that were included in the analysis was a juvenile that was approached 3 weeks apart at two different locations. In the first interaction, the juvenile was alone, and in the second, it was part of an adult/mixed group. Focal follow data included 32 h of control data in the BI segment, 36 h in the DI segment, and 23 h in the AI segment. BI segments averaged 21 min (SD = 20 min, range = 10–56 min), DI segments averaged 11 min (SD = 19 min, range = 10–86 min), and AI segments averaged 23 min (SD = 22 min, range = 10–40 min).

The mean length of time between behavioral state observations was 2.67 min (SD = 2.28 min) in the BI segment, 1.85 min (SD = 1.95 min) in the DI segment, and 2.48 min (SD = 1.95 min) in the AI segment. These time differences indicate a slight observer bias during the DI period, which was probably due to the researchers attempting to track three objects (whale, boat, and swimmers) within a short time span. Additional data were collected during interactions in an attempt to obtain accurate distances between the objects. Two-minute intervals were chosen as the interpolation time period for subsequent analyses because all means were about 2 min long. After interpolation, a random 10 min bin of movement data was chosen from the BI, DI, and AI segment of each follow, resulting in 15.5 h of data for each segment. A total of 5,107 transitions were then tallied (BI = 1,731, DI = 1,472, AI = 1,904).

Log-linear Analysis of Behavioral Model

We performed a series of log-linear analyses to determine which variables affected the behavior of whales. The null model was that succeeding behavior (S) was dependent on preceding behavior (P), but independent of boat/swimmer presence (B) and group composition (G). This corresponds to a model of (PS, BGP) in SPSS (SPSS Inc. 2004). Models using every combination of these variables were tested using LLA (Table 2). Boat presence (BPS, BGP) and group composition (GPS, BGP) significantly affected the behavior of the whales. The best model took both boat presence and group composition (BPS, GPS, BGIP) into account (AIC = −60.5). The boat effect was stronger than the group composition effect, but using both explained more variance in the model (ΔAIC = 23.3).

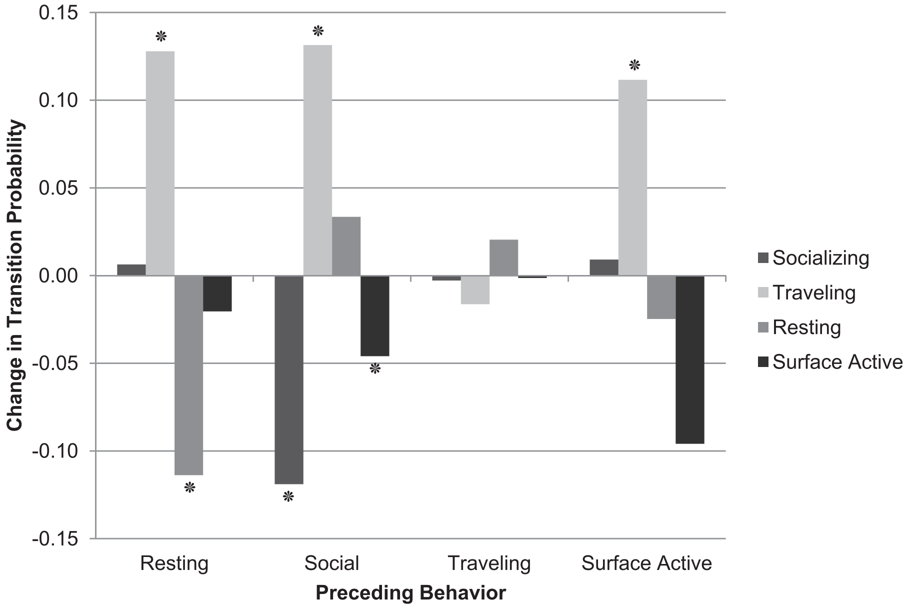


Figure 2. Difference in transition probability between behavioral states before (BI) and during (DI) swim-with interactions, $p_{ij\,(\text{during})} - p_{ij\,(\text{before})}$. Negative values mean the transition probability was greater before the interaction than during the interaction. Preceding behavior for each transition is indicated on the horizontal axis, with the color of the bar indicating the succeeding behavior. Transition probabilities that are significantly different ($P < 0.05$) are marked with an asterisk.

Overall Responses of Whales to Swim-with Interactions

When all data were pooled and the BI and DI segments compared, swim-with interactions had a significant effect (Z-test for two proportions, $P < 0.05$) on six behavioral transition probabilities (Fig. 2). Transitions from resting to resting (−11%) and social to social (−12%) behavior (*i.e.*, remaining in a resting or socializing behavioral state) significantly decreased. Social to surface active transitions (−5%) also significantly decreased. Transitions from resting (13%), social (13%), and surface active (11%) to traveling each significantly increased. Linearity and reorientation rates of whales were significantly affected by swim-with interactions. Linearity decreased during interactions (BI: mean = 0.87 ± SD = 0.20, DI: mean = 0.75 ± SD = 0.24, $n = 93$, $P < 0.001$; means and SDs shown for all data in the same manner from now on) and increased after they were over (DI: 0.75 ± 0.24, $n = 93$, $P < 0.001$, AI: 0.84 ± 0.20, $n = 93$, $P < 0.001$). Reorientation rate increased during interactions (BI: 13.1 ± 15.3°/min, DI: 27.8 ± 20.0°/min, $n = 88$, $P < 0.001$) and decreased after they were over (DI: 27.8 ± 20.0°/min, AI: 16.4 ± 13.6°/min, $n = 88$, $P < 0.001$).

Three transitions were significantly altered when the BI segment was compared to the AI segment (Fig. 3). Social to surface active (−6%) and traveling to traveling (−5%) both showed significant decreases. Resting to social showed a significant increase of 2% (Fig. 3). All movement variables were the same between BI and AI

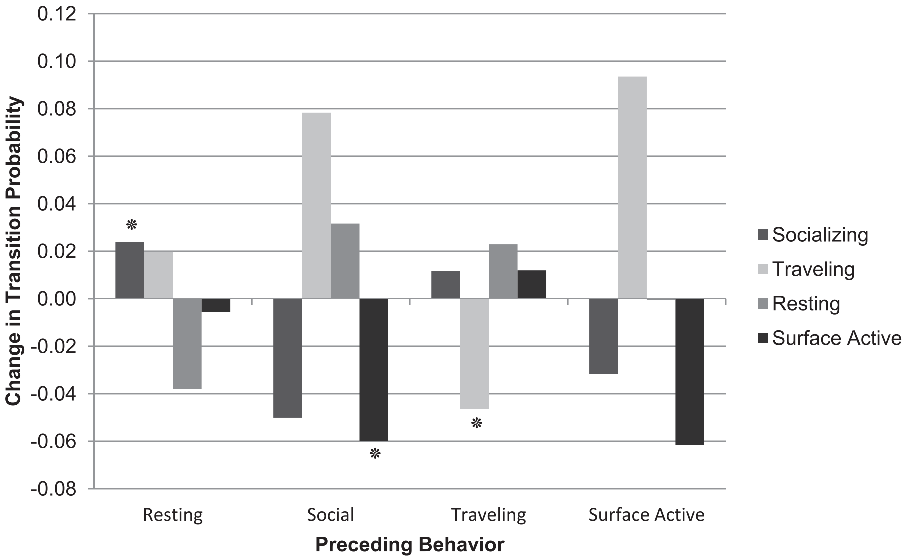


Figure 3. Difference in transition probability between behavioral states before (BI) and after (AI) swim-with interactions, $p_{ij\,(\text{after})} - p_{ij\,(\text{before})}$. Negative values mean the transition probability was greater before the interaction than after the interaction. Preceding behavior for each transition is indicated on the horizontal axis, with the color of the bar indicating the succeeding behavior. Transition probabilities that are significantly different ($P < 0.05$) are marked with an asterisk.

segments, although linearity remained slightly lower and reorientation rate slightly higher after interactions. Leg speed did not change significantly across experimental segments.

The proportion of time whales spent in each behavioral state changed during interactions. They spent significantly (Z-test for two proportions, $P < 0.05$) less time resting (−5%) and socializing (−3%), and significantly more time traveling (6%) in the DI segment compared to the BI segment (Fig. 4). The proportion of time whales spent traveling decreased (−8%) significantly from BI to AI (Fig. 4).

Responses of Different Age/sex Whales to Swim-with Interactions

The proportion of time mother/calf pairs spent resting (−5%) and socializing (−4%) decreased significantly during swim-with interactions compared to before interactions (Fig. 5a), while traveling increased (8%). After the interaction was over, socializing significantly increased (8%) and traveling decreased (−13%) relative to before the interaction (Fig. 5a). Linearity decreased significantly during interactions and increased significantly once interactions were over (Table 3). Reorientation rate increased during interactions and decreased after they were over (Table 3). These results indicate that mother/calf pairs changed their direction of travel during interactions to either circle (if attracted) or avoid (if evading) the boat and swimmers, and resumed a more linear path after interactions were over.

Juvenile whales spent a significantly smaller proportion of time socializing (−9%) and a significantly greater proportion of time traveling (11%) during swimmer

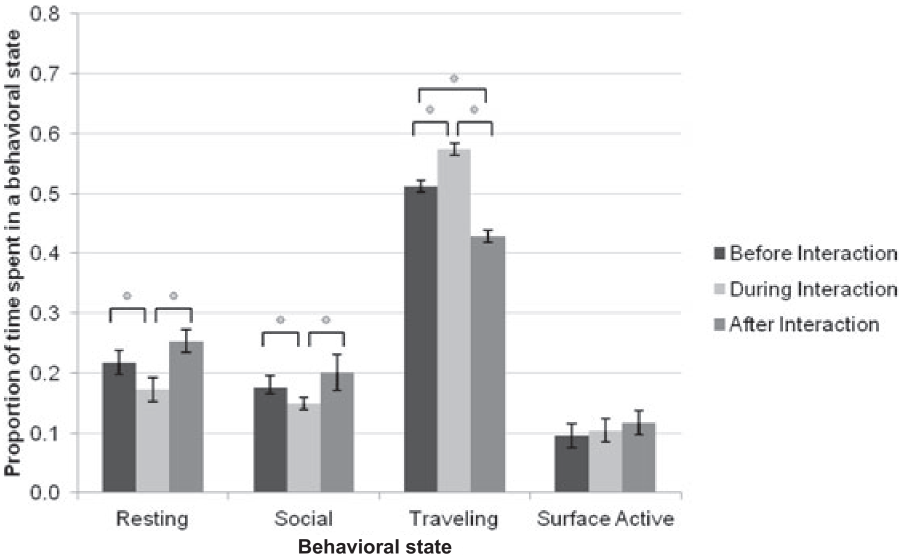


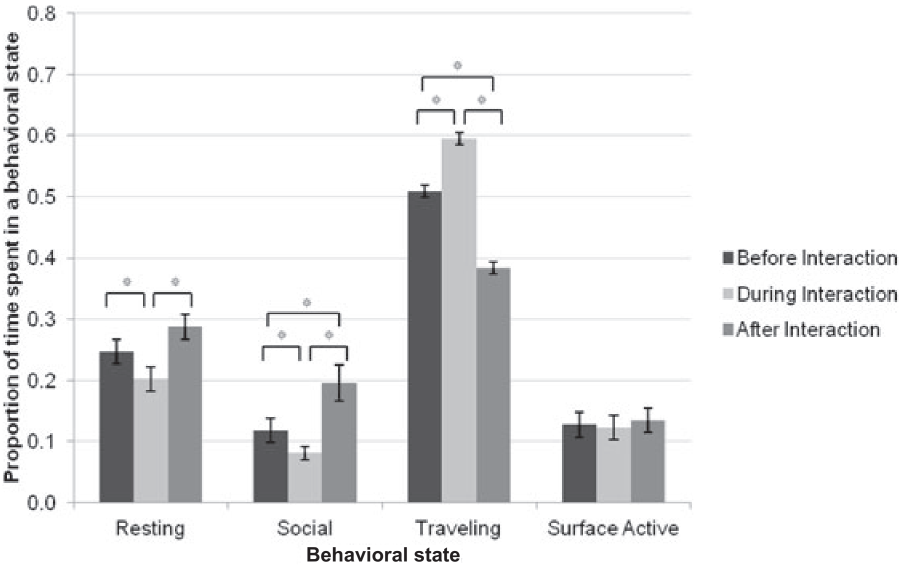
Figure 4. Proportion of time spent in each behavioral state before (BI), during (DI) and after (AI) interactions with swimmers. Error bars are 95% confidence intervals. Asterisks denote a significant difference (Z-test for two proportions, $P < 0.05$) in the proportion of time spent in a behavioral state was found between the two linked segments.

interactions than before interactions (Fig. 5b). After interactions were over, juveniles spent significantly more time resting (13%) and significantly less time traveling (−9%) than before interactions (Fig. 5b). Linearity decreased during interactions, while reorientation rates increased during interactions and decreased after they were over (Table 3).

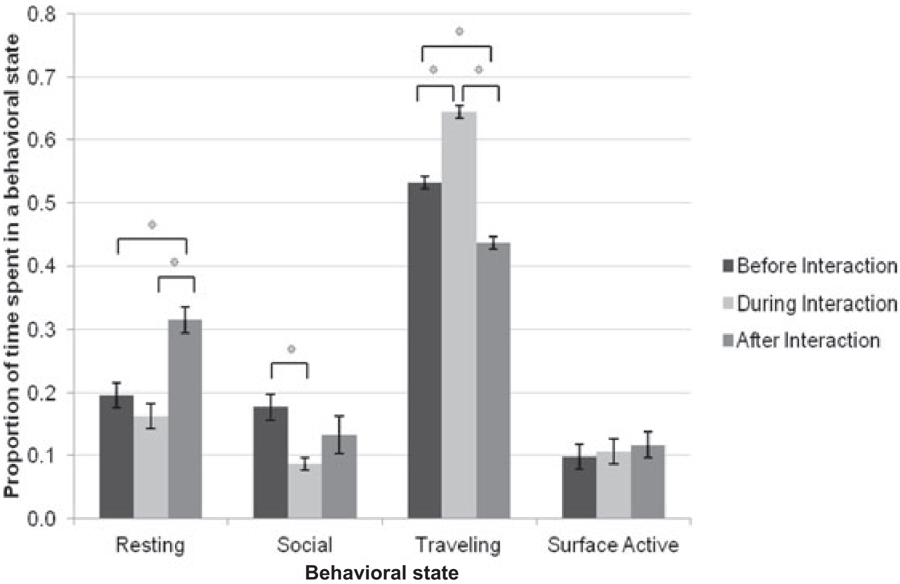
The only significant behavioral effect for other groups (adults or a mix of adults and juveniles) of whales was a significant decrease (−5%) in the proportion of time spent resting during interactions compared to before interactions (Fig. 5c). Movement patterns did not differ significantly between the BI and DI segments of the experiment (Table 3). No mating groups were observed to split up before the approach of the boat, but four of seven mating groups stopped courtship and the individuals separated upon approach of the boat and swimmers.

Underestimation of Effects

The magnitude of changes shown here may be underestimated, particularly for mother/calf pairs. For 31 of 184 groups we were unable to put swimmers in the water because whales avoided the approaching boat. The majority ($n = 26$) of these groups were mother/calf pairs, and they typically swam away quickly, reorienting and staying underwater for a long time (about 5–10 min), presumably to avoid the boat. Sixty groups were eliminated from analysis during data filtering, generally because the DI time period was too short to be of value. Of these 60 groups, 57% (34) were mother/calf pairs. Mother/calf pairs typically avoided the boat and swimmers, which reduced interactions to less than 10 min. In total, 49.5% of all groups (91 of 184)

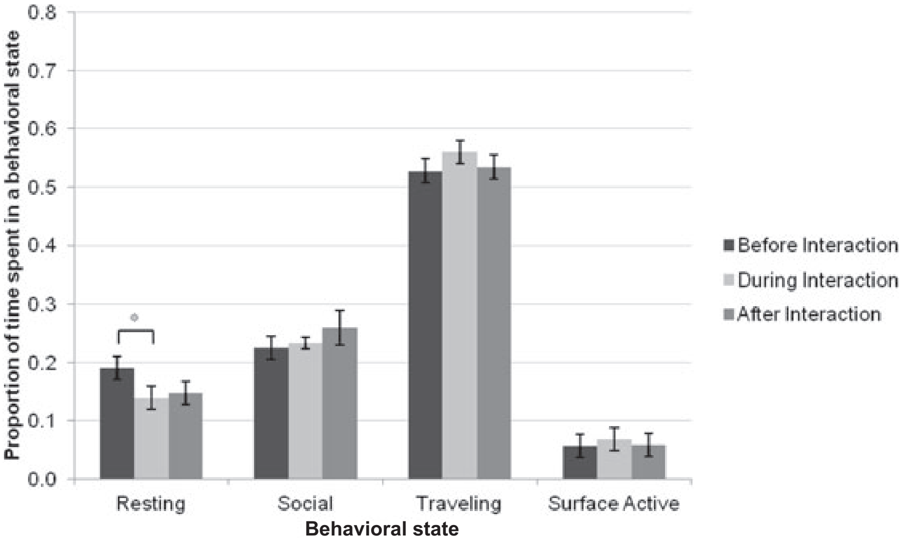


(A) Mother/calf pairs



(B) Juveniles

Figure 5. Proportion of time spent in each behavioral state before (BI), during (DI) and after (AI) interactions with swimmers for (A) Mother/calf pairs, (B) Juveniles, and (C) Adult and mixed groups. Error bars are 95% confidence intervals. Asterisks denote a significant difference (Z-test for two proportions, $P < 0.05$) in the proportion of time spent in a behavioral state was found between the two linked segments.



(C) Adult/mixed groups

Figure 5. Continued

Table 3. Movement characteristics of whales before (BI), during (DI), and after (AI) swim-with interactions. Asterisks indicate significant differences ($P < 0.05$) were found when comparing segments: (*) BI *vs.* DI and (**) DI *vs.* AI.

Variable	Before	During	After	Significance
Leg Speed (km/h)	1.56 ± 0.77	1.85 ± 1.04	1.84 ± 1.20	
Mother/Calf ($n = 38$)	1.54 ± 0.85	2.25 ± 1.21	2.11 ± 1.45	*
Juvenile ($n = 25$)	1.59 ± 0.73	1.34 ± 0.71	1.42 ± 0.60	
Adult/Mixed ($n = 30$)	1.57 ± 0.73	1.77 ± 0.86	1.47 ± 0.67	
Reorientation rate (°/min)	13.1 ± 15.3	27.8 ± 20.0	16.4 ± 13.6	*, **
Mother/Calf	10.9 ± 10.2	29.7 ± 19.7	14.4 ± 13.3	*, **
Juvenile	14.6 ± 18.0	26.5 ± 20.2	17.8 ± 13.8	*, **
Adult/Mixed	17.2 ± 17.9	19.0 ± 10.1	16.4 ± 14.5	
Linearity Index	0.87 ± 0.20	0.75 ± 0.24	0.84 ± 0.20	*, **
Mother/Calf	0.85 ± 0.22	0.71 ± 0.25	0.87 ± 0.17	*, **
Juvenile	0.90 ± 0.17	0.72 ± 0.26	0.85 ± 0.17	*
Adult/Mixed	0.85 ± 0.22	0.82 ± 0.21	0.81 ± 0.25	

and 61% of mother/calf pairs (60 of 98) that were approached avoided the boat or swimmers.

Whales that avoided interaction significantly changed swimming speeds during interactions (BI: 1.88 ± 0.28 km/h, DI: 2.91 ± 0.37 km/h, $n = 12$, $P = 0.040$). They also swam significantly faster when the boat approached within 500 m, while reorientation rate and linearity did not change significantly.

Discussion

Behavior and movement patterns of southern right whales at Península Valdés changed significantly when exposed to experimental swim-with interactions. Changes lasted throughout interactions and varied in magnitude with group composition. Whales were significantly more likely to cease resting, socializing, or engaging in surface active behaviors and begin traveling when interacting with the boat and swimmers. Some age/sex classes of whales also swam faster and in a less linear fashion and reoriented more often during interactions.

The results described here are similar to those reported for other cetacean species with respect to interactions with boats. Ollervides (2001) reported that gray whales at Bahía Magdalena, Mexico, also swam in a less linear path and reoriented more often, but swam at slower speeds when a boat was within 3,500 m. Au and Green (2000) described longer dive times, more frequent changes of course, and faster speeds among humpback whales (*Megaptera novaeangliae*) in the presence of whale watch boats in Hawaii. Corkeron (1995) described differences in surface behavior and dive characteristics of humpback whales approached by boats in Hervey Bay, Australia. Changes in respiration, surface intervals, vocalization, and swimming direction were described for sperm whales (*Physeter macrocephalus*) in Kaikoura, New Zealand by Richter *et al.* (2006). Lusseau (2003*a*) reported reduced resting and socializing among bottlenose dolphins (*Tursiops* spp.) in Doubtful Sound, New Zealand in the presence of tour boats, and Stockin *et al.* (2008) described reduced resting and foraging for common dolphins targeted by tourism operations in Hauraki Gulf, New Zealand. Nowacek *et al.* (2004) reported that North Atlantic right whales (*Eubalaena glacialis*) showed no response to playback of recorded noise from shipping vessels. Using close approaches with a small vessel rather than recordings of shipping traffic may have led to the difference in reported response.

The cumulative effect of stress from multiple sources of disturbance has been linked to reduced individual fitness (Baker and Herman 1989, Moberg 2000). Right whales at Península Valdés may be subjected to a growing set of anthropogenic and natural disturbance factors including tourism, parasitic attacks by kelp gulls (*Larus dominicanus*), shipping traffic and pollution, among others. Rivarola *et al*. (2001) summarized a series of unpublished reports describing reactions of southern right whales to whalewatching vessels in this area. Swimming speeds for whales other than mother/calf pairs were higher in Golfo Nuevo, the site of whalewatching, than in Golfo San José, where little boat traffic occurs (Rivarola *et al.* 2001). Reactions varied depending on the approach distance of the vessel, and "high impact" approaches (direct, encircling, chasing) caused whales to move away from boats (Rivarola *et al.* 2001). Rowntree *et al.* (1998) reported that attacks by kelp gulls parasitically feeding on the flesh of southern right whales reduced the proportion of time mother/calf right whale pairs spent in rest and slow travel by 39% and resulted in altered behavior for as long as 30–60 min after an attack. The proportion of whales with gull-induced lesions on their backs increased steadily from 1% of whales in 1974 to 37.8% in 1990, 67.6% in 2000, and 76.8% in 2008 (Sironi *et al.* 2009*b*). Most importantly, southern right whales are dying in unprecedented numbers at Península Valdés, with peaks in mortality levels in 2007–2009 (IWC 2010). Increasing the level of tourism activity could negatively affect the manner in which right whales use their habitat at Península Valdés and their socialization patterns on the nursery ground, as well as incrementally reduce individual fitness.

Mother/calf pairs are particularly vulnerable to disturbance, as the mothers are primarily fasting while nursing their calves and preparing them for the long journey to feeding grounds at the end of the season (Thomas and Taber 1984, Payne 1986). Right whale mother/calf pairs prefer shallow water areas during their time at the Península (Payne 1986, Rowntree *et al.* 2001), and when undisturbed, mothers spend 79% of their time resting and traveling slowly (Rowntree *et al.* 1998). During the 1980s, right whales shifted their distribution along the shoreline of Península Valdés and abandoned a preferred nursery area (Rowntree *et al*. 2001) for unknown reasons. This resulted in the greatest concentration of mother/calf pairs moving into the area adjacent to the center of whale watch activity in Puerto Pirámides (Rowntree *et al*. 2001). During our experiments, mother/calf pairs repeatedly changed their direction of travel, indicating that they may have been forced to move away from preferred water depths and areas along the shoreline in the study sites, a form of area avoidance which has been observed for bottlenose dolphins in Milford Sound, New Zealand (Lusseau 2005). If whales become displaced to suboptimal habitat, they may be exposed to greater risks from predators such as killer whales (Corkeron and Connor 1999), storm events (Evans *et al.* 2005), or other threats. Repeated changes in direction may also alter the relative spacing of the mother and calf, an important component in social learning and preparation for migration of the calf (Taber and Thomas 1982, Thomas and Taber 1984). Increased levels of social behavior after the interaction may reflect the need for the mother and calf to reestablish bonds after a disturbance.

Undisturbed juveniles spend almost one-half of their time at Península Valdés socializing with other whales and learning behaviors relevant to their adult lives (Sironi 2004), and solitary juvenile and adult right whales are attracted to surface-active groups where courtship and mating occurs (Payne 1986, Kraus and Hatch 2001). From a tour operator's perspective, juvenile whales are often the "best" animals for swim-with activities, as they are most likely to approach the swimmers and engage in lengthy up-close encounters. Similarly, juvenile bottlenose dolphins in New Zealand are more likely to interact with swimmers than adults (Constantine 2001). Tourist activity, however, may interrupt or delay the behavioral development juvenile whales normally undergo in this area. Whales swimming toward their preferred locations in bays and/or toward other whales often modified their direction of travel, either because they avoided the boat and swimmers or because they were attracted to them. If the activity occurs with high frequency, there is a possibility that this could negatively affect development of the whales in a critical phase of life (Sironi 2004). Juvenile whales were also more likely to approach swimmers close enough to make physical contact and create an increased risk of injury to the swimmers. Physical contact (brushing of swimmer's flippers against whale or placing hands on whale) between divers and whales occurred on at least four occasions, three of which involved juveniles that reacted by arching their back and moving fast, putting swimmers in close proximity at risk.

During the course of the study, we attempted to interact with several large, solitary adults that were likely pregnant females. Each time we approached the whales, they actively avoided the boat by diving for an extended period of time and swimming rapidly away. Similar vertical avoidance has been described for female bottlenose dolphins when tour boat interactions became intrusive (Lusseau 2003*b*). Most calves are born in August (Payne 1986), and disturbing lone adults early in the calving season, when many females in the area have yet to give birth, has the potential to cause long-term effects. Exposing unborn calves to maternal stress hormones during prenatal development may result in permanent changes to behavior and physiology of the calf, as has been suggested for other vertebrates (reviewed by Reeder and Kramer 2005).

Four of the seven mating groups with boat and swimmer interactions stopped courtship and individuals separated upon approach of the boat and swimmers. It is possible that these groups would have ceased mating and split up irrespective of the approach of the boat, but the absence of any mating group splitting up before the approach of the boat suggests that the two events may be linked. Such effects, if numerous or sustained over the season, may potentially affect the likelihood of conception with preferred mates. Additionally, it is dangerous for swimmers to enter the water with whales that are extremely active and move unpredictably (Kraus and Hatch 2001).

Comparison Between Swim-with and Whale Watch Tourism

Previous studies of movements of right whales (summarized by Rivarola *et al.* 2001) at Península Valdés did not find a significant difference in swimming speeds of mother/calf pairs between Golfo San José, where little boat traffic occurs, and Golfo Nuevo, where whale watching activity occurs (Golfo San José = 2.322 km/h, Golfo Nuevo = 2.287 km/h). It was suggested that pairs were either unaffected by the activity, or their speed may have been limited by the swimming ability of the calf. It is not clear whether more boats were actually present in Golfo Nuevo or not, as the authors did not specifically indicate the number or type of vessels present in each location. Swimming speeds of mother/calf pairs before interactions in the current study were lower than previously reported, but during the interaction, swimming speeds were comparable to the previous study. The significant difference between values in the current study was attributable to mother/calf pairs that avoided the boat and swimmers.

We found no difference in swimming speed for juveniles or adult/mixed groups before and during interactions, but the study summarized by Rivarola *et al.* (2001) reported significantly higher speeds in Golfo Nuevo (3.053 km/h) compared to Golfo San José (1.784 km/h) for whales other than mother/calf pairs. The speed previously reported for Golfo San José is comparable to those in the current study, but the speed in Golfo Nuevo is roughly double what was observed most recently. It is unclear why different swimming speeds were observed in the two studies, though it may be related to a difference in data collection methodology, natural differences between sites, or some other unknown factor.

Many avoidance behaviors observed during this study were in response to the approach of the boat. Avoidance behavior may be triggered by boat maneuvers which are high impact (Williams *et al.* 2002, Lusseau 2006) and may carry energetic costs for the targeted animal (Williams *et al.* 2006). Current whale watch regulations in Chubut Province (the "Patagonian Technique for Whale Watching" described in Provincial Law 5714 enacted by provincial decree 42/08) establish different minimum approach distances to right whales depending on the behavior of the animals (*e.g.*, 30 m from the focal whale in a mating group, 50 m from a breaching or resting whale) (Sironi *et al.* 2009*a*). These distances are on the low end of similar regulations worldwide (Garrod and Fennell 2004), and closer than those within which responses were observed in the current study. Perhaps more importantly, enforcement of these regulations is not constant throughout the whale watching season, so operators may approach more closely at times.

Swim-with boats must be maneuvered close enough to whales to allow swimmers to enter the water within visual distance for tourists to consider the activity "successful." Approach speeds for swim-with boats are generally higher in order to approach whales closely. It is possible that swim-with tourism would have a greater impact on whales than whale watch tourism because of higher speeds and closer approaches. This does not rule out, however, that whale watch boats are affecting whales in a similar manner from distances much greater than current regulations permit. Behavioral responses have been described for a number of other cetacean species at distances greater than the current regulations (Corkeron 1995, Noren *et al.* 2009, Williams *et al.* 2009). Results presented here strongly indicate that a quantitative study is needed to determine appropriate approach distances for whale watching in this area.

Recommendations

Higham *et al.* (2008) offer a detailed framework for management of cetacean tourism, analyzing aspects such as the potential area of operation, control sites, long-term monitoring, age/sex of targeted animals, number of boats operating, and other factors. Their recommendations are based on information gained from long-term studies that demonstrated population-level effects on resident bottlenose dolphins exposed to tourism vessels (Lusseau 2004, Bejder *et al.* 2006, Lusseau *et al.* 2006). Factors such as the frequency and type of interactions with vessels (Lusseau 2004, Lusseau 2006) and the number of operators permitted to interact with the target species (Bejder *et al.* 2006) were identified as critical explanatory variables. Behavioral changes were observed with a single boat in the current study, so the potential for long-term effects exists even at low levels of tourism. It is unknown whether a comparatively large population of seasonally targeted baleen whales such as the southern right whale in Argentina would be affected by tourism in the same way as resident delphinid populations. Given the current state of knowledge, the precautionary principle should preclude legalizing this activity unless it can be clearly demonstrated that swim-with-whale programs will not cause long-term population-level impacts to the southern right whales at Península Valdés.

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