Changes in the movement patterns of southern right whales in response to simulated swim-with-whale tourism at Península Valdés, Argentina

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ABSTRACT

Movement patterns of southern right whales (*Eubalaena australis*) in proximity of swimmers at Península Valdés, Argentina were recorded from September to November 2005 and July to October 2006. Whales were observed before, during, and after interactions with swimmers that approached the whales from a boat. Changes in movement patterns were quantified relative to group composition of whales (mother/calf pairs, juveniles or adult/mixed-age groups). The whales changed their reorientation rate significantly when the boat approached within 500 meters. Whales swam faster, reoriented more often, and followed a less linear path during interactions than when not exposed to the boat and swimmers. Responses were greater for mother/calf pairs than juveniles, while adult/mixed groups showed no significant changes in movement. The initial reaction of whales to the approach of the boat and swimmers was a good predictor of the magnitude of response. Increased levels of activity are a concern for whales on the nursery ground where they spend much of their time resting and rarely feed. Disruption of socialization among adults, juveniles and mother/calf pairs has unknown long-term consequences. Additional research is needed to determine the long-term effects of boat and swimmer activities on the movement patterns of whales.

KEY WORDS: SWIM-WITH, SOUTHERN RIGHT WHALE, *EUBALAENA AUSTRALIS*, TOURISM IMPACT, THEODOLITE, MOVEMENT RESPONSE

INTRODUCTION

Theodolite tracking has been used successfully by researchers to record the movement patterns of marine mammals and has become accepted as a practical way to study animals without disturbing their behavior (Würsig *et al.* 1991, Bejder 2005). A broad variety of marine mammal species have been studied using a theodolite, ranging from smaller animals such as dusky dolphins (*Lagenorhynchus obscurus)* (Yin 1999) and spinner dolphins (*Stenella longirostris*) (Würsig *et al.* 1991) to larger animals such as killer whales (*Orcinus orca)* (Williams *et al.* 2002) and gray whales (*Eschrichtius robustus*) (Gailey *et al.* 2004).

Theodolite tracking can also be used to evaluate potential disturbances of near-shore marine mammals (Würsig *et al.* 1991). Changes in movement patterns (speed, acceleration, path linearity, ranging indices, *etc.*), social characteristics (group cohesion, group dispersion), and habitat use (distribution) can all be recorded with a theodolite. The magnitude and significance of changes allow researchers to quantify the responses of cetaceans to a variety of human activities.

Recent studies using theodolites to measure the responses of cetaceans to swimmers have relied upon opportunistic observations of interactions between humans and cetaceans and include studies on: Hector's dolphins (*Cephalorhynchus hectori*) (Bejder *et al.* 1999), sperm whales (*Physeter macrocephalus*) (Richter *et al.* 2001), killer whales (*Orcinus orca*) (Bain *et al.* in press). Only a small number of studies have used controlled, experimental approaches to assess disturbance: bottlenose dolphins (*Tursiops truncatus*) (Nowacek *et al.* 2001) and killer whales (Williams *et al.* 2002).

This paper expands upon earlier descriptions of the movement patterns of southern right whales (*Eubalaena australis*) at Península Valdés in response to boats (Garciarena 1988; Campagna *et al.* 1995), and focuses on the whales' responses to boat approaches and interactions with swimmers. It presents baseline data that will be useful in assessing the long-term response of southern right whales to this or other forms of tourism and human activities.

METHODS

Data Collection

Positions of focal whales, boats and swimmers were recorded using a Sokkisha DT5A digital theodolite with ±5-sec precision and 30-power 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 over time provides information on speed and orientation of whales, as well as the whales' movements in relation to swimmers (see Würsig *et al.* 1991, Gailey 2001, Gailey and Ortega-Ortiz 2002, and Gailey *et al.* 2004, for further information). 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).

Data were collected with the theodolite operator tracking whales and verbally relaying behavior and fix information to the computer operator for input into *Pythagoras*. An attempt was made to fix the whale each time it was at the surface, or every 2 minutes if it remained at the surface for an extended period of time. To eliminate inter-observer variability, the first author was the theodolite operator for all days of the study. During analysis, focal follow data were split into segments before (BI), during (DI) and after (AI) the interaction. The DI period was determined by the approach distance defined below.

Tide data were estimated using WXTide32 (v4.6) tide estimation software. Tidal fluctuations at Península Valdés are some of the largest in the world, up to 8 meters in one day. Tide heights were estimated every 15 minutes using the software and the resulting values loaded into *Pythagoras* to ensure the accuracy of readings. Weather was assumed to be a non-factor in data collection, because the swimmers could only be deployed from the boat in low sea-states (Beaufort 4 or less) and there was thus little variability in weather conditions from one experimental day to the next.

The researchers were split into two groups: one researcher was on board the boat with the divers and 2-4 researchers were observing from the cliff-top observation site. The researcher on board the boat was responsible for taking digital images of the focal whales for identification purposes, recording the reaction of the whale to the boat and swimmers, relaying instructions to the boat captain and swimmers prior to an approach, and recording incidental observations about the whales or swimmers (such as physical contact between them). Hand-held VHF radios were used to coordinate activities between the cliff-top observers and the boat with the swimmers.

The cliff-top team consisted of at least two people. The first was a theodolite operator, who was responsible for continuously tracking the focal whale and the boat using a Sokkisha DT-5A theodolite (30-power magnification) and relaying behavioral information. To eliminate inter-observer variability, the theodolite operator was always the same person. The theodolite was connected to a laptop computer running *Pythagoras* software (Gailey and Ortega-Ortiz 2002). The laptop was operated by the second researcher who was responsible for entering all theodolite and behavior information into the computer in real-time, as well as assisting in tracking the whale using a tripod-mounted 20x wide-angle telescope or binoculars. The behavioral state of the focal whale was recorded with each theodolite fix of the whale's position. In 2005, a third researcher was occasionally present to assist in tracking whales. In 2006, a full-time assistant was added to help track the whales and assist in data collection.

Each follow began by choosing a focal whale close to the cliff-top station, but as far away from the boat as possible, to ensure that the whale's movement patterns were undisturbed. Regardless of the number of whales or the composition of a group, the focal whale was followed exclusively. In the case of mother/calf pairs, the mother was always the focal whale. The focal whale's position was recorded every two minutes, on average, although when the whale was underwater and not visible the intervals were longer. After a minimum of 20 minutes of movement data were recorded for the BI segment, the boat was directed to begin approaching the focal whale.

The boat then approached the whale, and if it succeeded in getting close enough (10-20 m), the swimmers entered the water. The whale, boat and swimmers were then tracked for a minimum of 10 minutes during the interaction. Interaction time varied, depending on the reaction of the whales. Interactions were stopped at a maximum of 20 minutes of interaction behavior, because the dive operators felt it was the most appropriate length of time for tourists to be in the water. After 20 minutes of interaction were recorded for the DI segment, the swimmers exited the water, the boat moved away, and the whales were tracked for another 20 minutes for the AI segment. If the whale moved more than 3 km from the cliff station or was lost for some other reason, the 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 one after another as quickly as possible to get 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. At the beginning of each interaction we recorded whether the whale approached the boat (orienting and moving in the direction of the vessel), was neutral to the boat (no movement towards or away from the vessel), or avoided the boat (orienting and moving away from the vessel). We recorded the same information with respect to the swimmers when they entered the water.

Approach Distance

Approach distance was defined as the greatest distance between the boat and whale at which a significant change in the whales' movement was observed. To determine this distance, we compared the whales' movements when the boat was at varying distances from the whale. Movement variables used to describe whale movement patterns included: leg speed, acceleration, reorientation rate and linearity. Leg speed is the distance between two successive points divided by the time interval. Acceleration is the difference between the leg speed of successive legs, and is used to determine if a whale is generally increasing or decreasing speed during the track. Reorientation rate is a measure of how much the whale is changing course during the track. It is calculated by adding up the absolute values of heading changes (defined as 0 to 180 degrees relative to the current bearing) and dividing the total degrees of change 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).

The BI segment was divided into subsets based on the distance between the whale and the boat. It was assumed that the behavior that occurred when the whale was more than 1 kilometer from the boat was natural, undisturbed behavior. Movement variables for this subset of data were compared with movement variables for the subset of data when the boat was less than 500 meters from the whale and the subset when the boat was between 500 and 1000 meters from the whale. Only those whales that had at least 5 minutes of movement data in each distance segment were considered in the analysis. This low threshold of 5 minutes was used to maximize the amount of data in each distance segment.

Data Preparation and Filtering

While an attempt was made to collect fixes at 2-minute intervals during the course of a focal follow, this was not possible when the whales were underwater. Therefore, each "leg", or the period of time between two consecutive fixes, was of a different length of time. The DI segment had shorter leg times, because it was easier to spot the whales when the boat and swimmers were nearby. During the DI segment we tracked positions of the whale, swimmers and boat at about the same time. We rotated between the three as quickly as possible, resulting in a higher path resolution for the DI segment. To reduce this bias, we calculated the mean leg length for each segment and interpolated all movements based on this leg length. The interpolation assumed the focal whale traveled in a straight line at a constant speed between fixes.

The resulting whale tracks were filtered to include only those that had at least ten minutes of BI, DI and AI data. For each of these whales, 10 minutes of each segment were randomly selected for analysis and all other data were discarded. This ensured that equal amounts of time were being compared for all analyses. Means of leg speed, acceleration, reorientation rate and linearity were then calculated for each of the three 10-minute segments per whale.

Histograms were generated for the mean values of each of the movement characteristics in order to assess normality for statistical treatment. Acceleration was normally distributed, but leg speed, linearity and reorientation rate were all highly

non-normal in shape. Each of these characteristics was log-transformed using the equation:

$$Y_1 = \log_e(Y_0),$$

where Y_1 is the transformed value and Y_0 is the original value.

Statistical Analysis

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 $\alpha = 0.05$. For the "approach distance" analysis, tests were conducted with data from all whales combined, regardless of group type, interaction type or reaction of the whale to the boat or swimmers. Once approach distance was determined, lower-level analyses were performed with the data divided by group type (mother/calf pair, juvenile or other), reaction to the boat (approach, neutral or avoid) and reaction to the swimmers (approach, neutral or avoid). Post-hoc analyses were conducted to determine the significance of effects on each of these groups and sub-groups.

RESULTS

Calculation of Approach Distance

Due to small sample sizes, it was not possible to compare data for approach distance at a level more finite than 500-meter distances (e.g., in 100 meter increments). This is because the boat usually stayed more than one kilometer away from the whale until beginning an approach, and then approached the whale quickly and directly. Seventy-eight of the original 153 whale groups had at least 5 minutes of movement data in the distance segments under consideration.

No significant differences were found in leg speed, acceleration, reorientation rate or linearity when comparing data from the 500 to 1000 meter segment to the over-1000 meter segment (Table 1). Reorientation rate changed significantly ($P = 0.03$) between the under-500 meter and over-1000 meter segments (Table 1). Therefore, the 500-meter limit was used as the approach distance in all subsequent analyses of behavior and movement. Each focal follow was split into BI, DI, and AI segments based on the first time the boat approached the whale within 500 meters (the split between BI and DI) and the time when the boat last remained within 500 meters of the whale (the split between DI and AI).

Variable	0-500 m	500-1000 m	> 1000 m	Significance
Leg Speed (km/h)	2.02 ± 1.05	2.60 ± 2.42	2.00 ± 1.98	(1) NS
				(2) NS
Acceleration (km/h)	-.01 ± .18	.03 ± .09	.02 ± .11	(1) NS
				(2) NS
Reorientation rate (°/min)	**16.5 ± 17.8**	3.5 ± 3.3	**10.9 ± 14.0**	**(1) *P* = 0.03**
				(2) NS
Linearity Index	.88 ± .20	.99 ± .02	.95 ± .10	(1) NS
				(2) NS

Table 1. Movement characteristics of whales at different distances between boat and whale. Significance values are shown for comparison (1) 0-500m vs. >1000m and (2) 500-1000m vs. >1000m.

Response of Whales to Interaction with Swimmers

The linearity and reorientation rate of the whales were significantly affected by swim-with interactions when data were compared across segments for all whales (Table 2). Linearity decreased during (DI) the interaction and increased after (AI) it was over. Reorientation rate increased during (DI) the interaction and decreased after (AI) it was over. All movement variables were the same between BI and AI segments, although linearity remained slightly lower and reorientation slightly higher after the interaction. Leg speed and acceleration did not change significantly across experimental segments.

Variable	Before	During	After	Significance
Leg Speed (km/h) (n = 93)	1.56 ± 0.77	1.85 ± 1.04	1.84 ± 1.20	(1) NS (2) NS (3) NS
Acceleration (km/h) (n = 88)	.00 ± .06	.01 ± .08	-.02 ± .08	(1) NS (2) NS (3) NS
Reorientation rate (°/min) (n = 88)	**13.1 ± 15.3**	**27.8 ± 20.0**	**16.4 ± 13.6**	**(1) *P* < 0.001** **(2) *P* < 0.001** (3) *P* = 0.11
Linearity Index (n = 93)	**.87 ± .20**	**.75 ± .24**	**.84 ± .20**	**(1) *P* < 0.001** **(2) *P* < 0.001** (3) *P* = 0.25

Table 2. Movement characteristics of whales before (BI), during (DI) and after (AI) swim-with interactions. Significance values are shown for comparison (1) BI vs. DI, (2) DI vs. AI, and (3) BI vs. AI.

Changes in the Movement Patterns of Mother/Calf Pairs in Response to Swimmers

Linearity and reorientation rate changed significantly between the BI and DI segments for mother/calf pairs (Table 3). Linearity decreased significantly during interactions (BI: mean=0.85 ± SD=0.22, DI: mean=0.71 ± SD=0.25, n = 38, P = 0.005; means and SD's shown for all data in the same manner from now on) and increased significantly once interactions were over (DI: 0.71 ± 0.25, AI: 0.87 ± 0.17, n = 38, P = 0.008). Reorientation rate increased during interactions (BI: 10.9 ± 10.2 °/min, DI: 29.7 ± 19.7 °/min, n = 38, P = 0.000) and decreased after they were over (DI: 29.7 ± 19.7 °/min, AI: 14.4 ± 13.3 °/min, n = 38, P = 0.002). These results indicate whales changed their direction of travel during interactions to either circle or avoid the boat and swimmers, but resumed a more linear path after interactions were over.

Mother/calf pairs that approached the boat showed a significant decrease in acceleration after the interaction (DI: 0.04 ± 0.04 km/h, AI: -0.04 ± 0.05 km/h, n = 7, P = 0.012) and a significant increase in reorientation rate during the interaction (BI: 6.1 ± 4.5 °/min, DI: 32.0 ± 13.9 °/min, n = 7, P = 0.003). Pairs that were initially neutral to the boat showed significantly decreased linearity during the interaction (BI: 0.88 ± 0.21, DI: 0.66 ± 0.24, n = 18, P = 0.000) and significantly increased linearity once the interaction was over (DI: 0.66 ± 0.24, AI: 0.89 ± 0.16, n = 18, P = 0.003). Their reorientation rate also increased during interactions (BI: 11.2 ± 11.7 °/min, DI: 31.7 ± 18.7 °/min, n = 18, P = 0.000) and decreased after they were over (DI: 31.7 ± 18.7 °/min, AI: 14.1 ± 12.4 °/min, n = 18, P = 0.013). This indicates that pairs that were initially neutral to interactions often circled the boat and swimmers during the interaction. Pairs that avoided the boat had a significant increase in leg speed during interactions (BI: 1.7 ± 1.0 km/h, DI: 3.1 ± 1.2 km/h, n = 11, P = 0.027) and their speed remained significantly high once interactions were over (BI: 1.7 ± 1.0 km/h, AI: 3.1 ± 1.5 km/h, n = 11, P = 0.041). Pairs that avoided the boat had the highest mean speeds observed for any group (mean = 3.1 ± 1.2 km/h).

Mother/calf pairs that initially approached the swimmers significantly decreased linearity during interactions (BI: 0.89 ± 0.15, DI: 0.59 ± 0.23, n = 9, P = 0.001) and significantly increased linearity once interactions were over (DI: 0.59 ± 0.23, AI: 0.91 ± 0.07, n = 9, P = 0.006). Their reorientation rate also increased during interactions (BI: 12.6 ± 14.8 °/min, DI: 40.9 ± 13.7 °/min, n = 9, P = 0.001) and decreased after they were over (DI: 40.9 ± 13.7 °/min, AI: 15.6 ± 12.7 °/min, n = 9, P = 0.029). Pairs that approached the swimmers had the highest reorientation rates observed for any group in the study (mean = 40.9 ± 13.7 °/min). Pairs that were neutral to the swimmers significantly increased reorientation rates during interactions (BI: 6.1 ± 4.0 °/min, DI: 28.1 ± 18.8 °/min, n = 5, P = 0.021). Pairs that avoided the swimmers significantly increased leg speeds during the interaction (BI: 1.7 ± 0.8 km/h, DI: 2.6 ± 1.3 km/h, n = 22, P = 0.041) and swam at higher speeds than those that were neutral to or approached swimmers.

Changes in the Movement Patterns of Juvenile Whales in Response to Interactions with Swimmers

Linearity and reorientation rates of juvenile whales changed significantly between the BI and DI segments (Table 3). Linearity decreased during interactions (BI: 0.90 ± 0.17, DI: 0.72 ± 0.26, *n* = 25, *P* = 0.001), while reorientation rates increased during interactions (BI: 14.6 ± 18.0 º/min, DI: 26.5 ± 20.2 º/min, *n* = 25, *P* = 0.000) and decreased after they were over (DI: 26.5 ± 20.2 º/min, AI: 17.8 ± 13.8 º/min, *n* = 25, *P* = 0.020). Juvenile whales that approached the boat significantly increased reorientation rates during interactions (BI: 15.6 ± 21.9 º/min, DI: 34.8 ± 28.8 º/min, *n* = 16, *P* = 0.023). Juveniles that were neutral to the boat significantly decreased linearity (BI: 0.93 ± 0.12, DI: 0.76 ± 0.24, *n* = 11, *P* = 0.029) and leg speeds (BI: 1.9 ± 0.7 km/h, DI: 1.3 ± 0.8 km/h, *n* = 11, *P* = 0.040) and increased reorientation rates (BI: 13.8 ± 14.3 º/min, DI: 22.8 ± 14.6 º/min, *n* = 11, *P* = 0.002) during interactions. Juveniles that approached the swimmers significantly decreased linearity (BI: 0.87 ± 0.19, DI: 0.69 ± 0.24, *n* = 17, *P* = 0.003) and increased reorientation rates (BI: 14.8 ± 19.0 º/min, DI: 34.2 ± 23.3 º/min, *n* = 17, *P* = 0.000) during interactions.

	Overall	Reaction to Boat			Reaction to Swimmers		
		Approach	Neutral	Avoid	Approach	Neutral	Avoid
Mother/Calf	SP ↑ (0.033)			SP ↑ (0.027)			SP ↑ (0.041)
	RR ↑ (<0.001)	RR ↑ (0.002)	RR ↑ (<0.001)		RR ↑ (0.001)	RR ↑ (0.021)	
	LN ↓ (0.005)		LN ↓ (<0.001)		LN ↓ (0.001)		
Juvenile			SP ↓ (0.040)	-		-	-
	RR ↑ (<0.001)	RR ↑ (0.023)	RR ↑ (0.002)		RR ↑ (<0.001)		
	LN ↓ (0.001)		LN ↓ (0.029)		LN ↓ (0.003)		
Adult/Mixed	-	-	-	-	-	-	-

Table 3. Significant changes in the leg speed (SP), reorientation rate (RR) and linearity (LN) of whale movements before (BI) versus during (DI) interactions, split by type of group and reaction to boat and swimmers. An increase or decrease is indicated by the direction of the arrow, with p-values listed in parentheses. Dashes indicate that no significant changes were observed.

Changes in the Movement Patterns of Adult and Mixed Age Groups in Response to Interactions with Swimmers

The movement patterns of adult and mixed-age groups did not change between the BI and DI segments of the experiment (Table 3). In general, the whales swam faster in a less linear direction and reoriented more during interactions with swimmers. Whales further increased their speed after interactions ended, reoriented less and swam in a more linear fashion. Whales that initially avoided the boat or swimmers swam faster than those that were neutral to or approached the boat or swimmers. The one exception to these trends was among whales that approached the boat. These whales decreased their acceleration, reoriented much less and swam in less linear paths. At least seven of the 30 adult/mixed-age groups were active courtship groups. Four of these groups split up upon the approach of the boat and swimmers.

Whales that Avoided Interactions with Swimmers

Whales that avoided interaction significantly changed swimming speeds between the BI and DI segments ("No Swimmer Interaction") (Table 4). They also swam significantly faster when the boat approached within 500 m. Their acceleration, reorientation rate and linearity did not change, though they tended to accelerate faster, reorient more often and swim in a less linear path.

Variable	Before	During	Significance
Leg Speed (km/h) (n = 12)	**1.88 ± 0.28**	**2.91 ± 0.37**	***P* = 0.04**
Acceleration (km/h) (n = 12)	.02 ± .06	.03 ± .09	NS
Reorientation rate (°/min) (n = 12)	7.0 ± 2.5	13.4 ± 3.3	NS
Linearity Index (n = 12)	.94 ± .03	.84 ± .06	NS

Table 4. Movement characteristics of whales that *avoided interactions* before (BI) and during (DI) swim-with interactions.

DISCUSSION

The movement patterns of southern right whales changed significantly when they were exposed to experimental interactions with swimmers. The changes lasted throughout the interaction and varied in intensity with group composition. Group composition was the most important predictor of the response of the whales to interactions. The initial reaction of whales to the boat and swimmers was also an important predictor of the whales' responses. Whales altered their movement patterns at an approach distance of 500 meters.

While a 500 m approach distance may seem conservative, other studies have shown that some cetaceans may respond to acoustic stimuli at distances greater than 10 kilometers (Au and Perryman 1982; Richardson *et al.* 1985; Baker and Herman 1989). Richardson *et al.* (1985) estimated source levels (1 m) of noise for small vessels such as those used in this study to be between 150 – 155 dB (re 1 µPa-m). Received noise levels 50 m away were estimated to be about 34 dB lower. At 500 m, the noise levels would still be loud enough to be easily detected by the whales and especially noticeable in an area that is normally closed to boat traffic. Other studies of cetaceans indicate that animals may be more tolerant of boats that move in a steady, predictable fashion than they are of boats that approach them directly or move irregularly (Blane and Jaakson, 1994).

Overall Changes in Whale Movements in Response to Experimental Interactions with Swimmers

Interactions with the dive boat and swimmers significantly affected the movement characteristics of whales. Whales swam faster and in a less linear fashion and reoriented more often during interactions than before the boat and swimmers approached. Whales that avoided the boat or swimmers swam faster and in a more linear fashion than those that approached the boat or swimmers.

The results described here are similar to those reported for other cetacean species with respect to approaching boats. Ollervides (2001) reported that gray whales (*Eschrichtius robustus*) 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 3500 m. Fin whales (*Balaenoptera physalus*) in the Mediterranean Sea significantly increased their swimming speeds when approached by a small craft used for biopsy sampling (Jahoda *et al*. 2003). Killer whales at Johnstone Strait, British Columbia, responded differently to experimental approaches depending on their sex. Females swam faster during the approach, while males maintained their previous speed but traveled in a less linear path (Williams *et al*. 2002).

Each of these responses could increase the whales' energy expenditure, regardless of whether they react "positively" or "negatively" (from the tourist's point of view) to the interaction. Changes in reorientation and linearity due to interactions with swimmers may not involve direct increases in energy expenditure, but they are indicative of changes in movement patterns of whales compared to those of undisturbed whales. These changes could negatively affect the way right whales use their habitat at Península Valdés and their socialization patterns on the nursery ground. Whales that were swimming toward their preferred locations in the bays and/or toward other whales modified their direction of travel, either because they avoided the boat and swimmers or because they were attracted to them. In either case, patterns of habitat use were modified, socialization time was reduced and interactions among whales were interrupted as a result of swim-with interactions.

Reduction in socializing time can negatively affect the social behavior of juvenile right whales. Undisturbed juveniles spend almost half of their time at Península Valdés socializing with other whales and learning behaviors that are relevant to their adult lives (Sironi 2004). Also, solitary juvenile and adult right whales are attracted to surface-active groups where courtship and mating occurs (Payne 1986; Kraus and Hatch 2001; Sironi 2004). The interruption of normal direction of travel of solitary whales by the presence of boats and swimmers may reduce the time whales spend in surface-active groups, where an essential part of their life cycle takes place. Multiple mating groups broke-up when the boat with swimmers approached them during the study.

Changes in the Movement Patterns of Different Whale Groups in Response to Swimmer Interactions

Mother/Calf Pairs

The potential increase in energy expenditure in mother/calf pairs is particularly worrisome because Península Valdés is a nursery ground. Calves are born, rest, and gain weight and strength at the Península in preparation for the long ocean migration to the feeding grounds at the end of the calving season (Payne 1986, Payne *et al.* 1991). Whales rarely feed on the nursery ground, and mothers rely upon their fat reserves to keep themselves and their calves alive. Activities which cause mother/calf pairs to expend more energy have could affect calf mortality by slowing their growth rates (see Perry 1998 for a review of possible energetic implications).

Right whale mother/calf pairs prefer shallow water areas in particular bays during their time at the Península (Payne 1986; Rowntree *et al.* 2001). However, 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 and areas along the shoreline in the study sites. If the whales become displaced to sub-optimal habitat, they may be exposed to greater risks from predators such as killer whales (Sironi 2004), storm events, and other threats (Bejder 2005). 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).

Previous studies of the movements of right whales (summarized by Campagna *et al.* 1995) at the Península 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 whalewatching activity occurs). It was suggested that either the pairs were unaffected by the activity, or perhaps their speed was limited by the swimming ability of the calf. We found, however, a significant difference in the swimming speeds of mother/calf pairs during an interaction. This difference was attributable to the mother/calf pairs that avoided the boat and swimmers. The fact that the research boat approached the whales within a few meters to put the swimmers in the water may be the reason why we observed significantly higher speeds.

The effects shown here are underestimated, particularly for mother/calf pairs. Our experiments involved 31 unsuccessful attempts to approach and swim with groups, because the whales evaded 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 to avoid the boat. We were able to analyze movement characteristics for 12 of the evasive groups (10 of which were mother/calf pairs), and they increased their speed significantly when the boat approached. This is further evidence that mother/calf pairs are particularly disturbed by boat approaches.

Juveniles

Juvenile whales spend a large proportion of their time at the Península engaged in solitary and social play (Sironi 2004). This play may function as the catalyst for important behavioral development which allows juveniles to establish relationships with other whales and practice adult behaviors (Sironi 2004). 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. For instance, 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 which juvenile whales normally undergo in this area. In several instances, we observed juvenile whales that had been socializing for a period of time split up upon the arrival of the boat and swimmers. If the activity occurs with high frequency, there is a possibility that this could negatively affect the development of the whales in a critical phase of life (Sironi 2004). The curiosity of juvenile whales made them more likely to approach swimmers close enough to make physical contact and created an increased risk of injury to the swimmers.

Adult/Mixed-Age Groups

Lack of clear trends and statistically significant effects should not be taken as proof that interactions with swimmers have no effect on the movement patterns of adult or mixed-age groups. Different sub-types within our designation of "Other" may have clear and significant reactions to swim-with interactions, but we did not identify them or have a large enough sample size to know whether they were unique or significant. Two such sub-types are solitary adults and mating groups. 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 whale, it actively avoided the boat by diving for an extended period of time and swimming rapidly away. Most calves are born in August (Payne 1986). Disturbing lone adults early in the season, when many females in the area have yet to give birth, is a serious issue to be considered (Payne 1986).

Mating groups are also a concern for swim-with tourism. Approaching with a boat and attempting to put swimmers in the water near mating groups generally resulted in the group splitting up and the whales swimming in different directions. If this occurs many times over the course of the mating season, there is the potential for a negative impact on the ability of the whales to mate and conceive. Beyond that, mating groups are dangerous for swimmers. These groups are extremely active and move unpredictably (Kraus and Hatch 2001), greatly increasing the potential for swimmers to be injured.

Initial Reaction of Whales to the Boat or Swimmers as a Predictor

Our results show that the initial reaction of a whale to the approach of a boat or the entry of swimmers into the water can predict the movement patterns of the whale. Whales that initially avoided the interaction swam faster and in a straighter path than those that did not avoid the interaction. Whales that approached the boat or swimmers slowed down and traveled in a more circuitous path.

The energetic requirements of the two different responses are unknown, so we do not know whether whales that avoid interactions are expending more energy or experiencing stress associated with the encounter. Stress is a biological response to a perceived threat that may result in changes in the behavior, endocrine response, immunological response and/or nervous system response of an individual (Moberg 2000). There are many factors that may determine whether "stress" becomes "distress" including: the length of time an individual is exposed to the stressor, the intensity of the stressor, the cumulative effects from multiple sources of stress, the fitness of the individual, and others (see Bejder and Samuels 2004 for a discussion). It is difficult to determine whether elevated levels of stress result in consequences of biological significance (lowered reproductive success, disease, increased mortality, *etc.*), particularly for long-lived species such as cetaceans. However, stress has been linked to these consequences in captive cetaceans (Waples and Gales 2002) and terrestrial animals (Sapolsky 1987, Mullner *et al.* 2004, Shively *et al.* 2005). Long-term, population-based studies of behavior, distribution, mortality and other factors remain the best option for identifying potential stressors for cetaceans.

Regulating For Sustainable Swim-With Tourism

If swimming with whales is legalized in the Province of Chubut, there are several issues that must be addressed to ensure that it does not have a negative impact on southern right whales. The results of this study may be useful for establishing preliminary regulations that protect the whales while allowing the activity. Fortunately, in the case of Península Valdés, the opportunity exists to establish guidelines at the beginning of the commercial tourism process, rather than retroactively. Other locations may not have this benefit, but the results presented here may be useful elsewhere and for comparison. Other species may react differently, so caution should be exercised when interpreting these results in other locations and with other cetacean species.

Mother/calf pairs are the most vulnerable of all age classes, and show the greatest changes in movement patterns in response to interactions with boats and swimmers. Juveniles are more likely to initiate interactions with swimmers, but may interrupt normal social development to do so. Adult and mixed-age groups were least affected by swim-with interactions. However, mating groups pose a greater danger for divers and lone adults early in the season may be females in the last stages of pregnancy. The different responses by age class described here are similar to the generalized cetacean disturbance findings described by other researchers (Würsig and Evans 2001). This may be useful in establishing guidelines that allow swim-with tourism with certain age classes but not others.

We have described short-term changes in movement patterns of southern right whales in response to interactions with swimmers interactions, but do not yet know the long-term biological impact, if any, of these changes. There are a number of areas of research that could assist in quantifying the impact of short and long term disturbances. Many of the issues presented here will take broad-based, long-term studies to understand properly. Whale energetics must be understood in order to quantify the effects of impacts. Combining knowledge of increased energetic requirements during interactions with the duration, frequency and distribution of encounters would give a better idea of the true impact of swim-with tourism. If energetic requirements on the nursery ground are low relative to the lifestyle of the whale (e.g., long migrations which use considerable energy, long periods of little or no feeding), the impact of this activity may be negligible in the long-term. Certain age classes may have different requirements, particularly mothers and calves versus juveniles and adults. It is also important to understand the impact of human activities on whale social behavior. Mating groups, juvenile social groups and mother/calf pairs may all be affected by swimmer interactions in ways that are not immediately apparent. While these effects may be short-term for a single encounter, if the activity becomes high-volume or geographically dense, the short-term effects may accumulate (Moberg 2000). This sort of density-dependent effect could result in avoidance of certain areas, as has been speculated for bottlenose dolphins (*Tursiops* sp.) relative to tourism activities at Milford Sound, New Zealand (Lusseau 2004).

If swimming with whales is legalized in Chubut Province, it will be critical to begin a long-term monitoring program to document the behavior and movement of the whales in areas where it occurs. Results of monitoring can be used to evaluate whether whales are habituating, tolerating or becoming sensitized to the activity (Bejder 2005). To assist in the evaluation, records should be kept of the number of trips per day, number of interactions per trip, group composition of the whales being approached, and other statistics related to the activity. GPS tracks of each boat trip could be used to determine the areas most highly affected. The tracks could then be compared with survey data to evaluate the impact of swim-with tourism on the distribution of the whales and to identify any changes in distribution of the entire population or a sub-group within the population.

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