BEHAVIOR AND MOVEMENT OF SOUTHERN RIGHT WHALES:

EFFECTS OF BOATS AND SWIMMERS

A Thesis

by

DAVID JEFFREY LUNDQUIST

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2007

Major Subject: Wildlife and Fisheries Sciences

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Approved by:

Chair of Committee,	Bernd Würsig
Committee Members,	Randall Davis
	Douglas Biggs
Head of Department,	Thomas Lacher

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ABSTRACT

Behavior and Movement of Southern Right Whales: Effects of Boats and Swimmers.

(May 2007)

David Jeffrey Lundquist, B.S., The University of Iowa

Chair of Advisory Committee: Dr. Bernd Würsig

Guidelines for sustainable swim-with tourism for large whales are not well-developed, as researchers have focused on delphinids. Nations that signed the Convention on Biological Diversity at the Earth Summit in Rio de Janeiro in 1992 are obligated to consider sustainable use principles when allowing new ecotourism activities, yet the fast-growing worldwide swim-with-whales industry is lacking the research needed to create successful management guidelines that can be implemented by local communities. From September to November of 2005 and July to October of 2006, I collected movement and behavioral state data for southern right whales in proximity of swimmers at Península Valdés, Argentina. Whales were observed before, during, and after a series of directed interactions with swimmers. I quantified the behavioral and movement effects relative to group composition of whales (mother/calf pairs, juveniles or adult/mixed groups) and activity level of swimmers.

Group composition had a significant effect on the response of whales to swimmers. Swimmer activity level did not substantially affect the reaction of whales. Resting and socializing activities significantly decreased and traveling activities significantly increased when boats approached and when swimmers entered the water.

Resting and socializing bout length in the presence of swimmers decreased to less than a third of the length of bouts when swimmers were not present. Whales swam faster, reoriented more often, and followed a less linear path during interactions. Effects were greater for mother/calf pairs than juveniles, while mixed adult/juvenile groups showed no significant changes in behavior or movement. The initial reaction of whales to the approach of the boat and the entry of swimmers into the water was a good predictor of the magnitude of effects on the behavior and movement patterns of the whale. Increased levels of activity are a concern for the whales that are resting and not feeding in this area. To provide quality resource management guidelines for this activity, additional research is needed to determine long-term effects of boat and swimmer activities on the behavior of whales. It is also important to obtain energetic data for right whales to determine the magnitude of impacts.

DEDICATION

To my family and friends: you give me the love, support and encouragement I need to follow my dreams. You keep my feet on the ground even as you push me to achieve my lofty goals. You may not always understand what I’m doing or why, but you stand behind me anyway. I love you all!

ACKNOWLEDGMENTS

I would like to offer my thanks to my committee chair, Bernd Würsig, and committee members, Randall Davis and Douglas Biggs. Without their support, encouragement, and guidance, the end product of this research would have been much less. I owe Bernd a much greater debt than I can ever expect to repay. You took a chance on me as someone with no background in biology, and I hope I have made you proud. Along the line, you have become a great friend, inspiring mentor, and even the officiant for my marriage. Bernd, I hope you know I appreciate everything you've done for me almost as much as I appreciate your bad jokes!

I would also like to thank all of the wonderful people I had the opportunity to work with during my research in Argentina: Mariano, Juli, Marcos, Ale, the good folks at ICB, and all of the divers and operators who participated in our field research. As well, many thanks to all of the friends I made living in Pirámides: Lala, Chris, Gen, Mumo, Pinino, Sofi, Rafa and others. My time at the Península was an incredible experience for me and I will always remember fondly those who played such a large part in it. You were much more than co-workers and made my research a true life experience

There is a long list of people who graciously offered assistance with various aspects of this project. Mariano Sironi, Vicky Rowntree, Jane Packard and Olivia Lee reviewed my thesis at various stages and all provided significant feedback to help me learn, grow, and produce a cohesive piece of work. David Lusseau helped a great deal in understanding many of the fine details of the statistical techniques I used. Kike Crespo, Silvana Dans and Manolo Arias all provided scientific input and offered much-needed political support during the course of our second field season.

I would like to thank my wife, Lesley, as well. We met while taking Bernd's class and survived the first field season apart and the second field season together, all before getting married. You helped a great deal in the second field season, provided insightful comments on my thesis, helped with my defense presentation and listened to my endless droning on about whichever part of this project was causing me stress at the time – all without a single complaint! Your love and support is what has made all the good things in our life possible. Thank you for always being yourself and allowing me to do the same.

Last, but not least, this research would not have been possible without funding received from the Secretary of Tourism of the Province of Chubut, Argentina, The Erma Lee and Luke Mooney Travel Grant, and the Texas A&M – Galveston Marine Biology Department.

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CHAPTER I

INTRODUCTION

The southern right whale (*Eubalaena australis*) is a large baleen whale that resides throughout much of the Southern Ocean. There are three species in the genus *Eubalaena*, with southern right whales having the largest and most widespread distribution. North Atlantic right whales (*Eubalaena glacialis*) and North Pacific right whales (*Eubalaena japonica*) are two of the most critically endangered of all cetaceans, with estimates for each species in the low hundreds. Southern right whales have an estimated 7500 animals in several distinct populations (IWC 2001).

HUMAN INTERACTIONS WITH SOUTHERN RIGHT WHALES

Southern right whales were hunted extensively for two centuries, beginning with Basque whalers in the 1500s and continuing through illegal Soviet hunts in the 1960s. Historical populations are estimated to range from 60,000-100,000 animals, with around 110,000 animals killed during hunts (Baker and Clapham 2004). The species was nearly extirpated, with estimates of reproductive females reaching as few as 60 animals in 1920 (Baker and Clapham 2004). Fortunately, hunting bans brought a reprieve, and the populations in the southern hemisphere now have an annual growth rate near 7% (IWC

This thesis follows the style of Marine Mammal Science.

2001).

Hunting bans, the subsequent growth of cetacean populations and strong public interest in seeing and interacting with the natural world around them has spawned a huge industry in nature-based tourism. Worldwide cetacean-watching activities have grown considerably in the last two decades (Hoyt 2001). Growth rates of 18.6% (in US$) and 12.1% (in participants) per year were observed in the period from 1991-1998 (Hoyt 2001). Revenues of greater than $1 billion US$ for 9 million participants were realized in 1998 (Hoyt 2001). The continued growth of this industry has generated much interest within the scientific community in determining the effects of tourism activities on cetaceans and whether the activity is sustainable.

Previous studies have demonstrated the potential for increased boat activity and human presence in the water to change animal behavior, and increase stress levels (Rose et al. 2003; IFAW et al. 1996). In particularly disruptive cases, such disturbances may have resulted in the displacement of a population of animals, such as gray whales abandoning San Diego Bay (Reeves 1977). Animals may also apparently habituate to human activities, as Watkins (1986) described for baleen whales in Cape Cod Bay. It is difficult, however, to determine whether animals have become *habituated* to the activity or just *tolerant* of it (see Bejder 2005 for a discussion of this topic). Animals that remain in an area with increasing disturbance may be incapable of moving elsewhere, or suitable options may not exist (Bejder et al. 2006).

The majority of cetacean-watching tourism is boat-based and does not involve swimmers entering the water (Hoyt 2001). However, swimming with cetaceans is increasing, as tour operators attempt to provide tourists with more "intimate" interactions with the animals (Bejder and Samuels 2004). At least 29 commercial operators are offering opportunities to swim with whales, and nine others may do so opportunistically (Rose et al. 2003). Swimming with large whales occurs in at least 20 locations globally, including several (Argentina and the Azores) where it is specifically prohibited (Rose et al. 2003). Despite the fact that swimming with whales in Argentina is prohibited by federal law, Rio Negro province legalized swim-with-whale tourism in early 2006, and at least one commercial operation began operating shortly thereafter. In Chubut province, Provincial Law #2381/84 (modified by Provincial Law #2618/85) "Forbids approach and/or harassment, sail, swim and diving with any marine mammal species and their calves, inshore and offshore, in provincial waters during the whole year."

Previous studies have documented several areas of concern for swim-with-dolphin operations. Demonstrated changes in behavior include increased avoidance of swimmers (Constantine et al. 2003), increased risk of injury or death due to food provisioning (Samuels and Bejder 2004) and increased communication and echolocation (Scarpaci et al. 2000). Not only is there a clear risk of harassment of the animals, there is also a risk of injury to the human participants (Samuels et al. 2000).

Valentine et al. (2004) noted there have been few swim-with studies focused on large whales, and much of the analysis is based on limited data – typically anecdotal or opportunistic interactions under uncontrolled conditions (Ritter and Brederlau 1999; Kiefner 2002; Magalhães et al. 2002). While data for other cetacean species may apply 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, with annual migrations spanning vast areas of the oceans. They typically only spend part of the year in the area where the tourism occurs. The Scientific Committee of the International Whaling Commission has 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).

OBJECTIVES AND HYPOTHESES

The goals of this study were to: 1) Establish normal, undisturbed behavior and movement patterns of southern right whales on their calving grounds at Península Valdés; 2) Evaluate whether these behavior and movement patterns are altered by swimmers entering the water in proximity to whales; 3) Evaluate the effect of the activity relative to composition of the group of whales being approached and activity level of the swimmers; and 4) Examine the possibility of using the initial reaction of the animals to the interaction as a predictor of the overall effects on their behavior. These goals were designed to help understand the biological implications of swim-with-whale programs and to guide the creation of regulations around the activity should it be legalized.

The null hypotheses of this study are that there is no difference in behavior or movement patterns of the whales 1) With or without human activity; 2) Relative to group composition; and 3) Relative to the activity level of the swimmers.

CHAPTER II

SHORT-TERM EFFECTS OF EXPERIMENTAL SWIMMER INTERACTIONS ON THE BEHAVIOR OF SOUTHERN RIGHT WHALES

INTRODUCTION

Population

This study was conducted on the population of southern right whales (*Eubalaena australis*) that spend each austral winter and spring mating, giving birth and raising their newborn calves off Península Valdés, Argentina (Payne 1986; Payne et al. 1991; Cooke et al. 2001). The high cliffs of Península Valdés provide a unique opportunity to observe the effects of swim-with-whale tourism on large 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 (Figure 1). The whales use the relatively protected waters of the gulfs to raise their calves during the first 3 months of their lives (Taber and Thomas 1982, Thomas and Taber 1984, Payne 1986).

The first animals arrive at the Península in April and the last leave in December, with peak numbers in September and October (Payne 1986). Females calve on a three- to seven-year cycle, and typically reach reproductive maturity at 9 years of age (Payne 1986; Payne et al. 1991; Cooke et al. 2001). They then leave for the feeding grounds, returning with their calf a year later (Payne 1986; Cooke et al. 2001). The calf is weaned early in the second year, and the mother spends a year or more feeding and re-gaining weight before her next pregnancy, typically giving birth at a three-year interval (Payne 1986; Cooke et al. 2001). The population is estimated to be growing at 6.9% per year (Cooke et al. 2001).

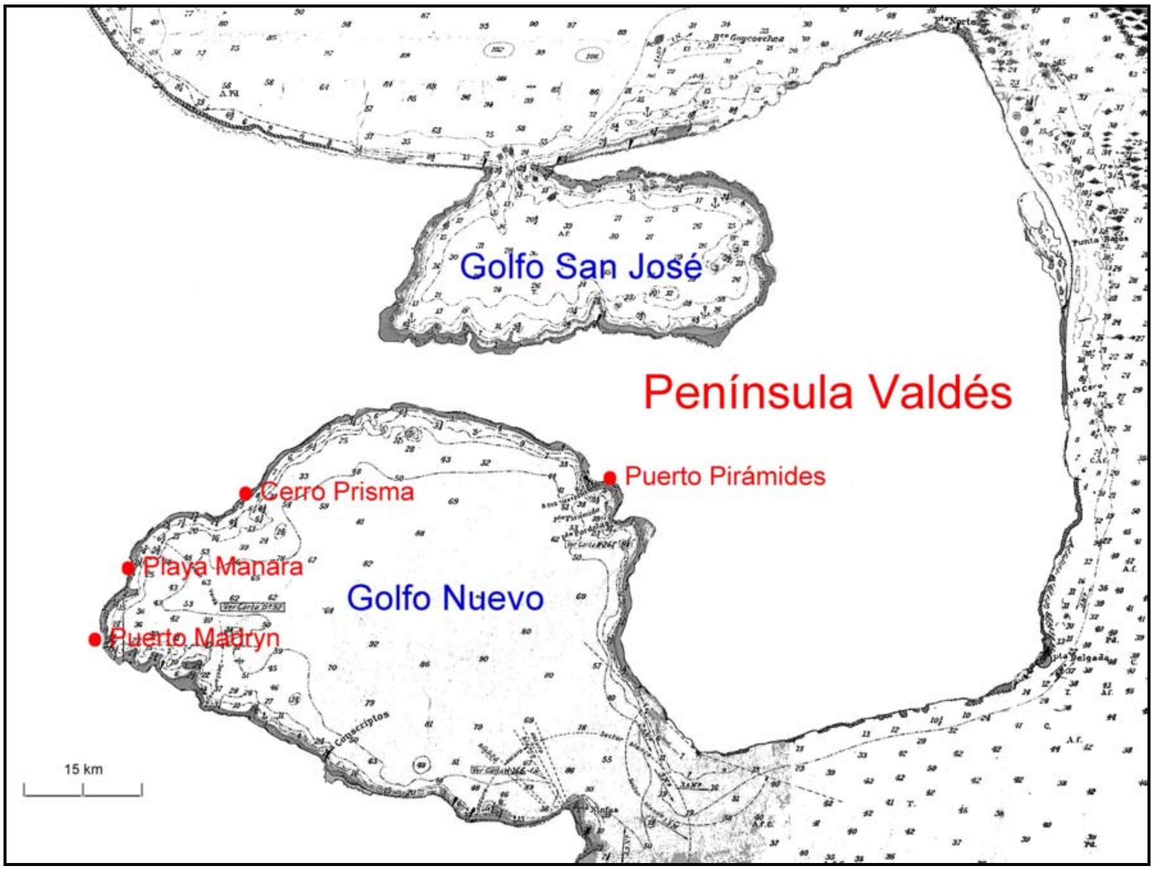

Figure 1. Map of Península Valdés with towns and study sites

Most of the whales are distributed close to shore in shallow waters (Payne 1986) and are easily reached by boat, which has driven a rapidly expanding local whale-watching industry (Rivarola et al. 2001; Sironi et al. 2005). Tourism is one of the main industries in the Valdés area, and whale-watching is one of the main tourist activities (Sironi et al. 2005). The town of Puerto Piramides is the departure location for the tours. The season runs from June to January, with the majority of visitors in October and November (Sironi et al. 2005). The number of passengers on whale-watch vessels has increased at an annual rate of 14% since 1991, and in 2004 nearly 100,000 passengers paid to go on whale-watching tours from Piramides (Sironi et al. 2005).

Previous studies at Península Valdés describe short-term changes in the behavior and swimming speeds of right whales in response to boat approaches (Garciarena 1988; Alvarez Colombo et al. 1990; Arias et al. 1992; Campagna et al. 1995; Rivarola et al. 2001). These studies focused on the responses to whale-watching vessels, and found that solitary animals and groups other than mother/calf pairs increased their speed in the presence of boats. Swim-with-whale tourism is quite different than whale watching, however, because boats must approach the whales very closely and swimmers enter the water. The boat approaches described in previous studies were not controlled by the observers and did not specifically compare the behavior and movement of the whales before, during and after the interaction.

SCUBA diving is also a seasonal tourist activity at Península Valdés, but involving many fewer participants than whale-watching. Divers are specifically prohibited from entering the water with the whales by Chubut provincial law #2381/84. In recent years, a proposal was submitted to the Secretary of Tourism of the Province of Chubut by the Puerto Madryn Diver's Association to remove the prohibition on swimming with whales and allow dive operators to offer swim-with-whales tours. In response to a request for proposals (RFP) by the Province to investigate the effects of swimming-with-whales, our research group submitted a proposal and was awarded funds. We conducted this study to quantify the effects of this activity on the whales' behavior and movement patterns, and provide recommendations to the Secretary of Tourism. The research was conducted as a collaborative effort involving representatives from the Diver's Association, local government, NGOs, and local and international researchers. Involving as many stakeholders as possible from early in the process was the best way to maximize the likelihood that the recommendations would be satisfactory to all parties. This idea is well established in the wildlife management literature as a key to successful regulation of certain activities, particularly when there are a large number of stakeholders with conflicting goals and viewpoints (Cortner 1996, McMullin 1996).

Because right whales are distributed close to shore at Península Valdes, on-shore researchers can observe whales without affecting their behavior. The objective of this study was to describe behavior of different age classes of right whales and quantify any behavioral changes due to the presence of swimmers in the water. The primary focus was on mother/calf pairs and juveniles, as they are found nearest to shore, are the most abundant age classes, are more easily approached by boats, and are presumably at highest risk for disturbance. These categories of whales were also chosen because they are the individuals that are most likely to be encountered by operators of swim-with-whale programs. For instance, Rivarola et al. (2001) found that mother/calf pairs were the selected target for all whalewatching trips at the end of the season at Península

Valdés. The behavior of swimmers was also examined to determine if level of activity altered results.

Study Area

Data were collected between September-November 2005 and August-September 2006 from two different observation stations located on the cliffs on the southern coast of the Península in Golfo Nuevo. The first station was located near Cerro Prisma (42° 35' 42.42"S, 64° 48' 42.64"W) (Figure 2). This location was chosen as it provided easy access to high cliffs (25 m) relatively close to the shoreline (~100 m to where the whales approach) for observation and to a beach for loading and unloading personnel from the boat. This site was located on a rocky point with two shallow bays on either side, offering greater than 180 degrees of observation area. Boat traffic is forbidden in this area, so the observation boat was the only potential source of human disturbance within several km of the whales.

The second field site was Playa Manara (42' 40" 33.24˚ S, 64' 59" 25.02˚ W), which was located a very short distance from Puerto Madryn (Figure 3). It had lower cliffs (18 m) and was closer to the shoreline than Cerro Prisma. It offered almost 180 degrees of observation area. El Doradillo, which is a popular beach for shore-based whale-watching, is located on the eastern edge of the study site. The rest of the study site comprised slightly more exposed waters, though still characteristic of the shallow, calm conditions of Golfo Nuevo. Playa Manara was added as a second field site in 2006 to lessen the cost of bringing the boats from Puerto Madryn to Cerro Prisma each day during the month of August.

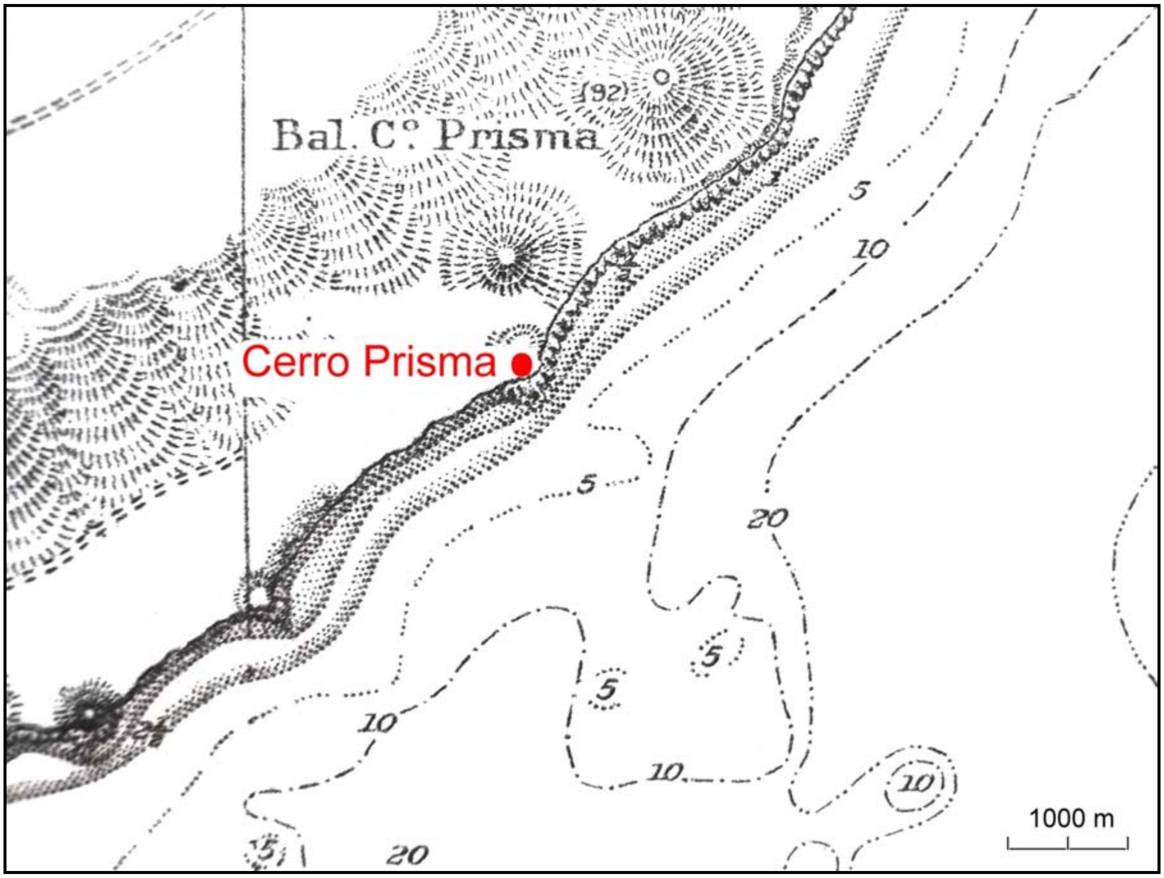

Figure 2. View of Cerro Prisma with depths in fathoms

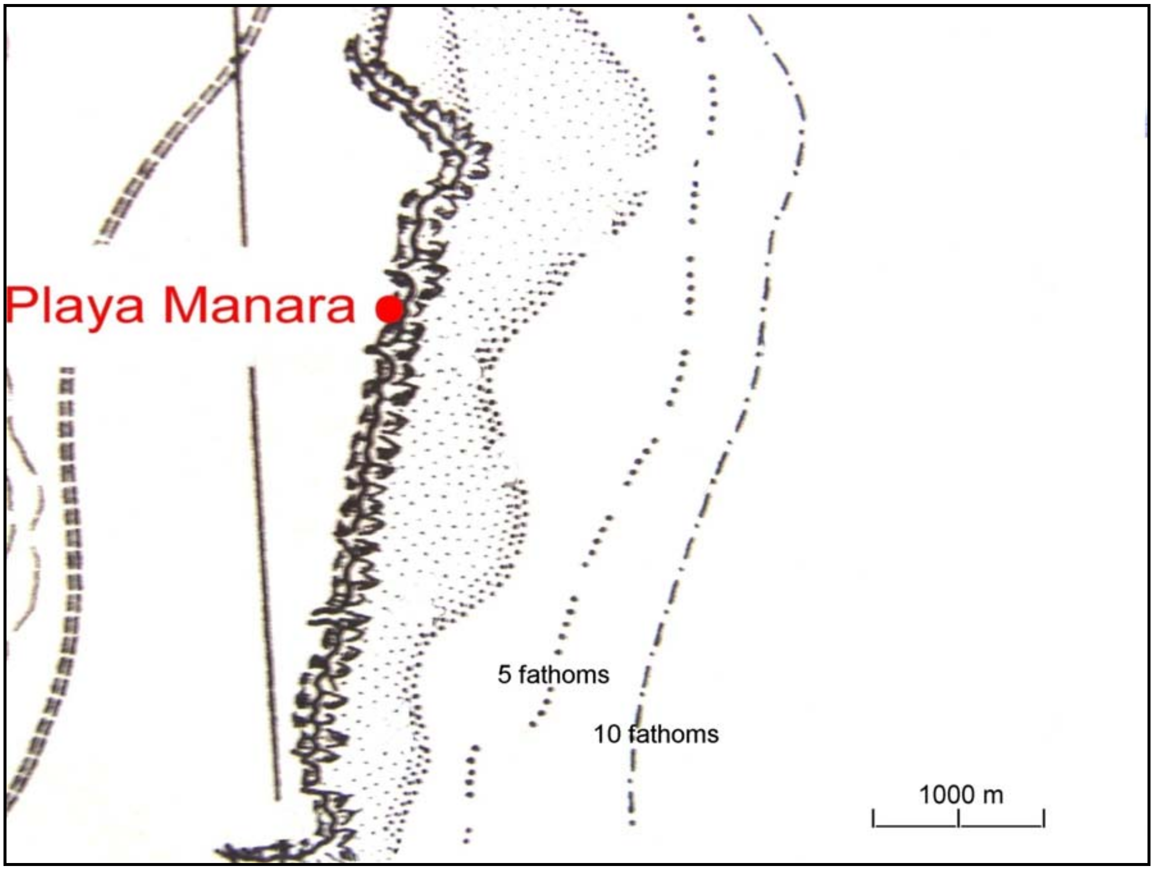

Figure 3. View of Playa Manara with depths in fathoms

METHODS

Study Design

This study was designed as a Before/During/After (BDA) comparison (Bejder and Samuels 2004), with the behavior of the animals before the interaction serving as the control data for the during and after time periods. Data were collected on the behavioral state of the animal before the boat approached, during the boat approach and while the swimmers were interacting with the animal, and after the swimmers and boat left the area.

The "Before" segment was defined as all activity from the moment we began tracking the animal to the moment when the boat first approached within ~500 m of the animal. The 500 m rule was determined based on the "approach distance" analysis performed for Chapter III of this thesis. The "During" segment was defined to begin when the boat approached within 500 m of the animal, encompass the entire time the swimmers were in the water, and end when the boat traveled more than 500 m from the animal. The period of time after the boat traveled more than 500 m from the animals was defined as the "After" segment. In some cases, the whale swam more than 500 m away from the swimmers, so the "After" segment began immediately when the swimmers exited the water.

The boats used in the study were provided and driven by members of the Diver's Association from Puerto Madryn, owners of dive operations from Puerto Pirámides, and the Fundación Vida Silvestre Argentina. Swimmers were experienced divers and most were also members of the Diver's Association. The number of swimmers entering the water was fixed at three, as this is the group size that the dive operators felt was most likely if the activity were legalized – one dive master and two tourists. Half of the interactions were designated as "Calm", with the swimmers entering the water smoothly and approaching the whales quietly. The other half were designated as "Noisy", with the swimmers splashing in the water, taking pictures of the animals, talking to one another and generally acting like excited tourists. As the study progressed, it became clear that the initial reaction of whales to the approach of the boat and the entry of swimmers into the water might be correlated to changes in behavior, so we began recording whether the whale approached, was neutral, or avoided the boat or swimmers.

We focused primarily on behavioral responses of mother/calf pairs and juvenile right whales. Mother/calf pairs are the group which may be most vulnerable to disturbance. They compose 2/3 of the whales in the study area and thus are the most frequently seen animals. Juvenile whales are curious and often seek encounters with boats. All other groups (adults or mixed adult/juvenile) were combined and analyzed separately.

Data Collection

We used focal animal observations (Altmann 1974; Martin and Bateson 1993) to record an instantaneous point sample of the behavioral state of the focal animal every ca. two minutes before the boat approached (control), during the boat approach and swimmer interaction (impact), and after the swimmers exited the water and the boat left the area (post-impact). Mutually exclusive behavioral states were used to define the entire behavioral budget of the whales as resting, traveling and surface active or social (Table 1). These definitions are similar to those used for the behavior of juvenile right whales by Sironi (2004) and Thomas and Taber (1984), but with Surface Active and Social behaviors combined into a single category.

The researchers were split into two groups: one member on board the research vessel and 2-4 cliff-top observers. The researcher on board the boat was responsible for taking digital images of the focal animals 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 any incidental notes about the animals or swimmers.

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

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

The cliff-top team consisted of at least two people at all times. The first was a theodolite operator, who was responsible for continuously tracking the focal animal using a Sokkisha DT-5A theodolite (30-power magnification) and relaying behavioral information. The theodolite operator was always the same person, to reduce inter-observer variability. The theodolite was connected to a laptop computer running *Pythagoras* software (Gailey and Ortega-Ortiz 2002), which was operated by the second researcher. This researcher was responsible for entering all theodolite and behavior information into the computer in real-time, as well as assisting in tracking the animal using a tripod-mounted 20x wide-angle telescope or binoculars. Behavior of the focal whale was collected in conjunction with theodolite fixes of the position of the whale. In 2005 a third researcher was occasionally present to assist in tracking animals. In 2006 a full-time assistant was added to help track the animals and record respiratory frequency.

Each follow began by choosing a focal animal close to the cliff-top station, but as far away from the location of the boat as possible, to ensure we recorded undisturbed behavior. Regardless of the number of animals or composition of a group, we followed the focal whale exclusively. In the case of mother/calf pairs, the mother was always the focal animal. We recorded the focal animal's behavioral state every two minutes on average, although at times the animal was underwater and not visible for longer periods of time. Once we had about 20 minutes of behavioral data for the Before segment, we directed the boat to begin approaching the focal whale. Hand-held VHF radios were used to coordinate activities between the cliff-top observers and the boat with the swimmers.

The boat then approached the whale, and if it succeeded in getting close enough, swimmers entered the water. We then tracked the whale, boat and swimmers for a minimum of 10 minutes during the interaction. The interaction was often longer or shorter, depending on the reaction of the whales. We recorded a maximum of 20 min of interaction behavior, as this was the amount of time that the dive operators felt was most appropriate for tourists to be in the water. After 20 minutes, the swimmers exited the water, and we continued tracking the whales for another 20 minutes. If the animal moved more than 3 km from the cliff station or was lost for some other reason, the observations ended and a new animal 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 good picture of relative positions. The time of boat approach, swimmer entry, swimmer exit and boat departure were recorded in Pythagoras to allow us to split the focal follow into the appropriate categories. 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.

Weather conditions were recorded at least at the start and end of each day. Because the dive boats could not operate safely putting swimmers in and out of the water during windy, rough conditions (>13 knots of wind), we did not work on these days. Therefore, there was very little variability in weather conditions over the course of the study, and weather was not considered as a variable during analysis.

Data Preparation and Filtering

Since the data were not collected at even intervals or for equal amounts of time in each case, there was some risk of over- or under-sampling if we used it in raw form. A mean interval between observations was calculated, and both the behavior and movement data were interpolated from this. Behavior was assumed to remain constant between observations. That is, if an animal was observed traveling at time 0 and resting at time 1, any interpolated points that fell between the two had traveling as their behavior.

Focal follows were also filtered to include only those that had a minimum of 10 minutes of data in each of the Before, During, and After segments. For each of these animals, 10 minutes of each segment were randomly selected for analysis and all other data were disregarded in analyses described here. This ensured that equal amounts of time were being compared for all analyses, reducing the risk of over- or under-sampling. Behavioral transitions were then tallied based on the three 10-minute segments per animal. Respiration intervals (time between blows measured in seconds) were calculated for each of the Before, During, and After segments for each animal. Because the whales were near shore in shallow water, we did not attempt to calculate any surface/dive characteristics, as the whales were not diving in any distinct way. Data were filtered to eliminate focal whales where blows were missed.

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 behavior event on the preceding event in the behavioral sequence, we used first-order Markov chain analysis. Following the assumptions used by Lusseau (2003), defining a set of mutually exclusive and wholly inclusive behaviors allowed us to analyze temporal variations in behavior of the whales using Markov chains.

The Markov chain could then be used to build a matrix of preceding behavior (at time 0) versus succeeding behavior (at time 1) for each transition within the Before (before the boat approached), During (while the boat was within 500 meters and/or the swimmers were in the water) and After (after the boat traveled more than 500 meters away) chains. The transition probability for each behavioral state transition could then be 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:

$$p_{ij} = \frac{t_{ij}}{\sum_k t_{ik}},$$

where t_{ij} is the number of times the transition from *i* to *j* was observed and $\sum_k t_{ik}$ is the number of times *i* was the preceding behavior. By comparing the calculated probabilities between control and impact chains using a Z-test for proportions (Fleiss 1981) it was possible to test whether the interaction with boat and swimmers had a significant effect on the behavior of the animals.

Bout length (t_{ii}) is the mean length of time the animal spends in a certain behavioral state before switching to another. This was calculated by the following equation using the assumptions set forth in Lusseau (2003):

$$t_{ii} = \frac{1}{1 - p_{ii}},$$

where p_{ii} is the probability of transitioning from behavior *i* back to behavior *i.* The standard error for bout length was calculated as:

$$SE = \sqrt{(p_{ii} * (1 - p_{ii})) / n_i} \quad ,$$

where n_i is the number of times where behavior *i* was observed as the preceding behavior.

The analysis described above was performed on the entire dataset, regardless of group composition (Mother/calf pair, juvenile or other) or interaction type (calm vs. noisy). Due to small sample sizes for each group type and interaction type, it was not possible to accurately compare transition probabilities. To examine the effects of these parameters on behavioral transitions, Log-linear analysis (LLA) was performed using SPSS version 13.0.1 for Windows (SPSS Inc. 2004).

LLA allows the manipulation of which parameters (and the interactions between them) are considered when fitting the model to the data. The analysis was conducted including all combinations of parameters and interactions. Maximum likelihood for the model is then approximated by G^2. Comparing the 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 tested to determine if the parameter was significant or not. Akaike Information Criteria (AIC) values were calculated to choose the best-fitting model. 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, 2004).

RESULTS

Work Effort

Over the course of two field seasons, we had 36 days of field work out of 108 total days. Many 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 13 knots. In total, we attempted to approach 184 groups of whales (Figure 4). Groups listed as "No Swimmer Interaction" are those where the boat approached, but the whale evaded it to such a degree that it was not able to get close enough for swimmers to enter the water. A much higher percentage of mother/calf pairs evaded the boat than other group types - 26.5% for M/C pairs, 7.1% for Juveniles and 4.5% for mixed groups.

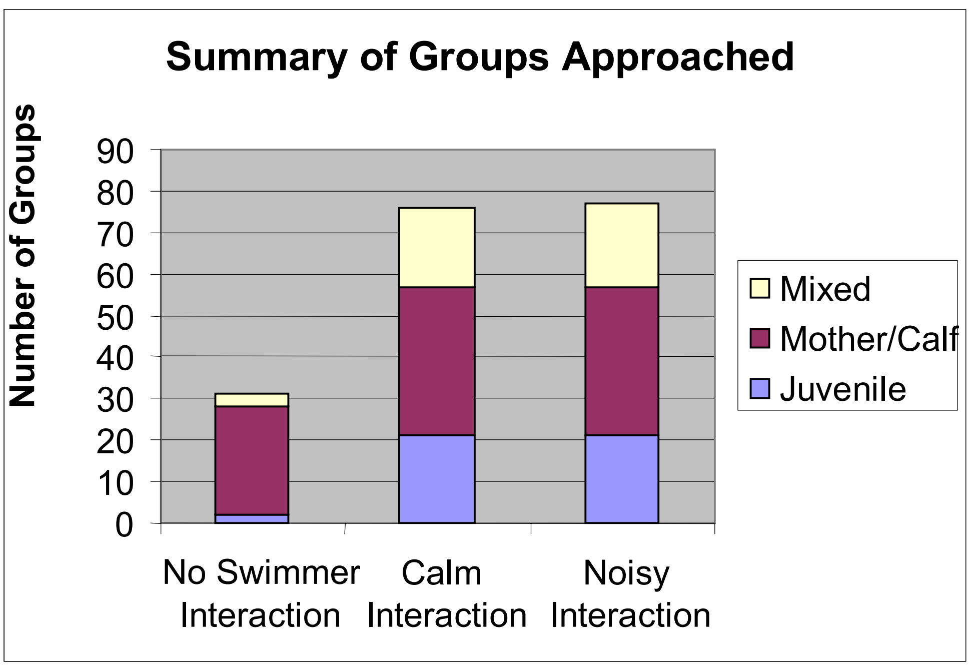

Figure 4. Number of groups approached by interaction type and group composition. Percentage of each interaction type is shown for each group type.

A total of 153 approaches with swimmer interactions were conducted. After applying the filtering criteria described in the Methods, 93 interactions remained for analysis – 38 Mother/calf pairs, 25 Juvenile groups, and 30 Mixed groups. We had two instances where we interacted with the same mother/calf pair twice in a single day. In both cases, the second interaction was filtered out of the analysis because it did not meet the criteria described in the Methods. In two cases, we attempted to interact with the same mother/calf pair on different days. With one of the pairs, we approached the animals three times in 5 days but never got close enough for the swimmers to enter the water. In the other pair, swimmers entered the water both times with the whales, but the interactions were filtered out because they did not meet the criteria described in the Methods. The only animal that we interacted with twice where both the interactions were included in the analysis was a juvenile that we 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.

We recorded 32 hours of control focal follow data in the Before segment, 36 hours in the During segment, and 23 hours in the After segment. Before segments averaged 21 minutes (SD = 20 min, Range = 10-56 min), During segments averaged 11 minutes (SD = 19 min, Range = 10-86 min), and After segments averaged 23 minutes (SD = 22 min, Range = 10-40 min).

The mean length between behavioral state observations in the Before segment was 2.67 minutes (SD = 2.28 min.), while the During segment was 1.85 min. (SD = 1.95 min.), and the After segment was 2.48 min. (SD = 1.95 min.). This indicates a slight observer bias in the During period, which is likely explained by the researchers trying to track three objects (whale, boat and swimmers) at once. Additional samples were taken to try to get accurate distances between the objects. Because all means are near 2 minutes, this was chosen as the interpolation time period for subsequent analysis. After interpolation, a random 10-minute bin was chosen from each BDA segment of each follow (as described above), resulting in 15.5 hours of data for each segment. A total of 465 transitions were then tallied for each segment.

Sixty-four interactions also had respiration data which met the filtering criteria. These 64 whales consisted of 18 mothers, 14 calves, 21 juveniles, and 11 adult (non-mother) whales.

Log-linear Analysis of Behavioral Model

I performed a series of log-linear analyses to determine which variables affected the behavior of the whales. Due to sample size considerations, it was necessary to consolidate all active behaviors (Traveling, Surface Active/Social) and compare them against Resting behavior. The null model was that succeeding behavior (S) was dependent on preceding behavior (P), but independent of boat presence (B), group composition (G) and interaction type (I). This corresponds to a model of (PS, BGIP) in SPSS (SPSS Inc. 2004). Models using every combination of these variables were tested using LLA. Boat presence (BPS, BGIP) and group composition (GPS, BGIP) 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, Table 2).

The boat effect was stronger than the group composition effect, but using both explained more variance in the model (ΔAIC = 23.3).

The model which took into account boat presence, group composition and interaction type but not interactions between the variables (BPS, GPS, IPS, BGIP) was also found to be plausible (AIC = -58.1, ΔAIC = 2.4, Table 2). The interaction type term never had a significant effect when it was added to the model (Figure 5), and therefore it did not provide additional information regarding changes in behavior.

Table 2. Akaike Information Criteria values for each model.

Model	AIC	ΔAIC
Boat + Group	-60.5	0
Boat + Group + Interaction type	-58.1	2.4
Boat + (Group x Interaction type)	-51.9	8.6
Group + (Boat x Interaction type)	-47.3	13.2
Boat	-37.2	23.3
Boat + Interaction type	-35.3	25.2
Boat x Group	-33.8	26.7
Interaction type + (Boat x Group)	-31.8	28.7
Boat x Interaction type	-24.2	36.3
Group	-16.2	44.3
Interaction type + Group	-13.3	47.2
Interaction type x Group	-7.7	52.8
Null model	2.8	63.3
Interaction type	4.7	65.2

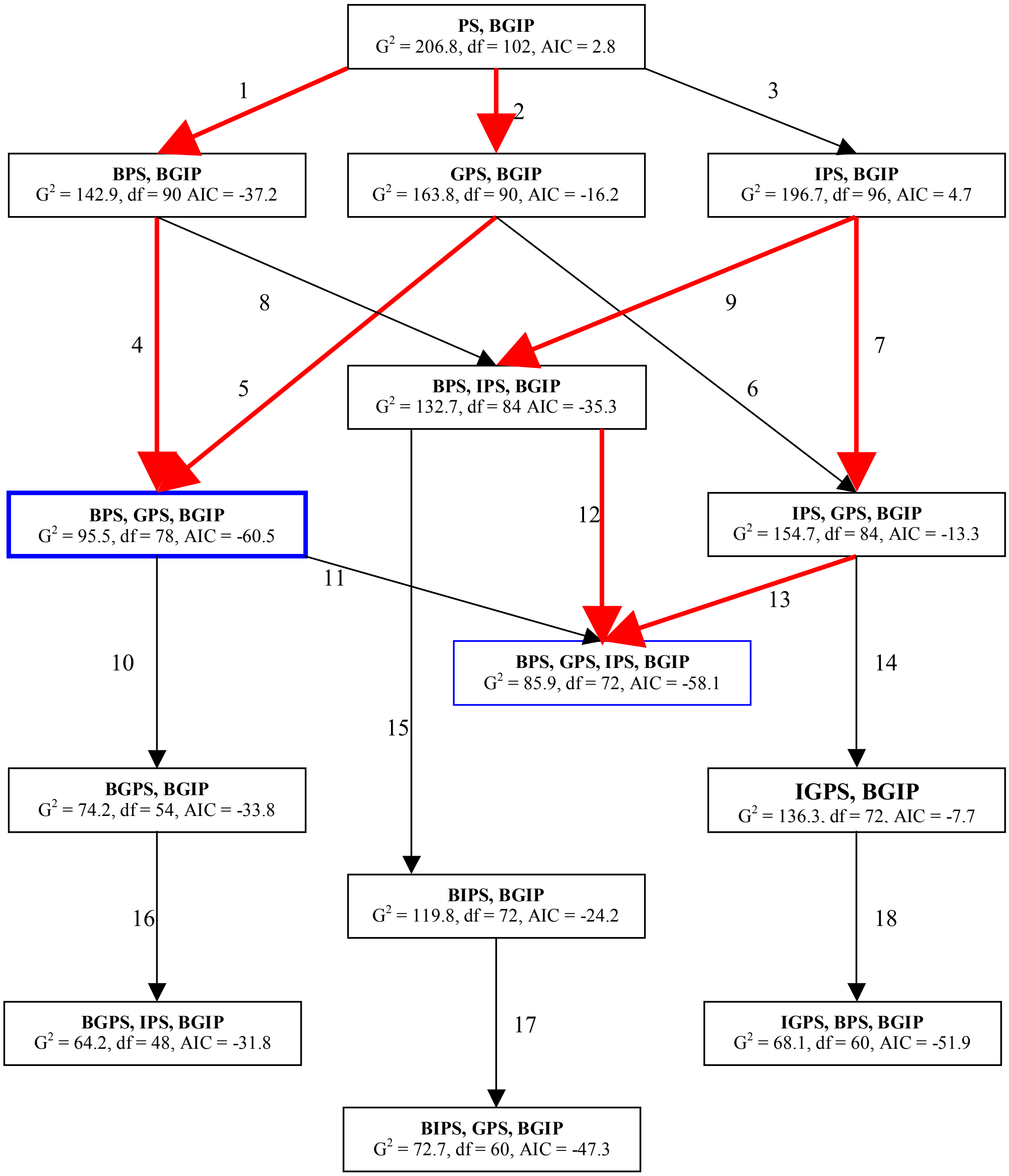

Figure 5. Effects of boat presence (B), group composition (G), and interaction type (I) on transitions between preceding (P) and succeeding (S) behavior. Boxes represent the model which was tested, while terms added and significance are given in Table 3 using the reference number listed next to the arrow (adapted from Lusseau 2004). Arrows in red indicate significant terms added. Boxes in blue indicate the best (bold) and second best (not bold) fitting models.

Table 3. Terms added and significance of effect between models.

Reference number	Terms added	ΔG^2	Δdf	Significance
1	BS, BPS	$\Delta G^2 = 64.0$	$\Delta df = 12$	$p < 0.001$
2	GS, GPS	$\Delta G^2 = 43.0$	$\Delta df = 12$	$p < 0.001$
3	IS, IPS	$\Delta G^2 = 10.1$	$\Delta df = 6$	not significant
4	GS, GPS	$\Delta G^2 = 47.3$	$\Delta df = 12$	$p < 0.001$
5	BS, BPS	$\Delta G^2 = 68.3$	$\Delta df = 12$	$p < 0.001$
6	IS, IPS	$\Delta G^2 = 9.1$	$\Delta df = 6$	not significant
7	GS, GPS	$\Delta G^2 = 42.0$	$\Delta df = 12$	$p < 0.001$
8	IS, IPS	$\Delta G^2 = 10.2$	$\Delta df = 6$	not significant
9	BS, BPS	$\Delta G^2 = 64.0$	$\Delta df = 12$	$p < 0.001$
10	BGPS	$\Delta G^2 = 21.3$	$\Delta df = 24$	not significant
11	IS, IPS	$\Delta G^2 = 9.6$	$\Delta df = 6$	not significant
12	GS, GPS	$\Delta G^2 = 46.8$	$\Delta df = 12$	$p < 0.001$
13	BS, BPS	$\Delta G^2 = 68.8$	$\Delta df = 12$	$p < 0.001$
14	IGPS	$\Delta G^2 = 18.3$	$\Delta df = 12$	not significant
15	BIPS	$\Delta G^2 = 12.9$	$\Delta df = 12$	not significant
16	IS, IPS	$\Delta G^2 = 21.7$	$\Delta df = 24$	not significant
17	GS, GPS	$\Delta G^2 = 13.2$	$\Delta df = 12$	not significant
18	BS, BPS	$\Delta G^2 = 17.8$	$\Delta df = 12$	not significant

Effects of Swimmer Interactions on Behavioral Transitions

When all data were pooled and analyzed, regardless of group composition or interaction type, swimmer interactions had a significant effect (Z-test for 2 proportions, $p < 0.05$) on four behavioral transitions. Transitions from Resting to Resting (i.e., remaining in a resting state) and Surface Active/Social to Surface Active/Social both showed a significant decrease of 29%. Resting to Traveling transitions significantly increased by 24% and Surface Active/Social to Traveling showed a significant increase of 26%. The results for all behavioral transitions are shown below, with negative numbers indicating a decrease in behavioral transition (Figure 6).

Three transitions remained significantly altered after the swimmer interaction was finished. Resting to Resting (-10%) and Traveling to Traveling (-5%) both showed significant decreases. Traveling to Resting showed a significant increase of 3% (Figure 7).

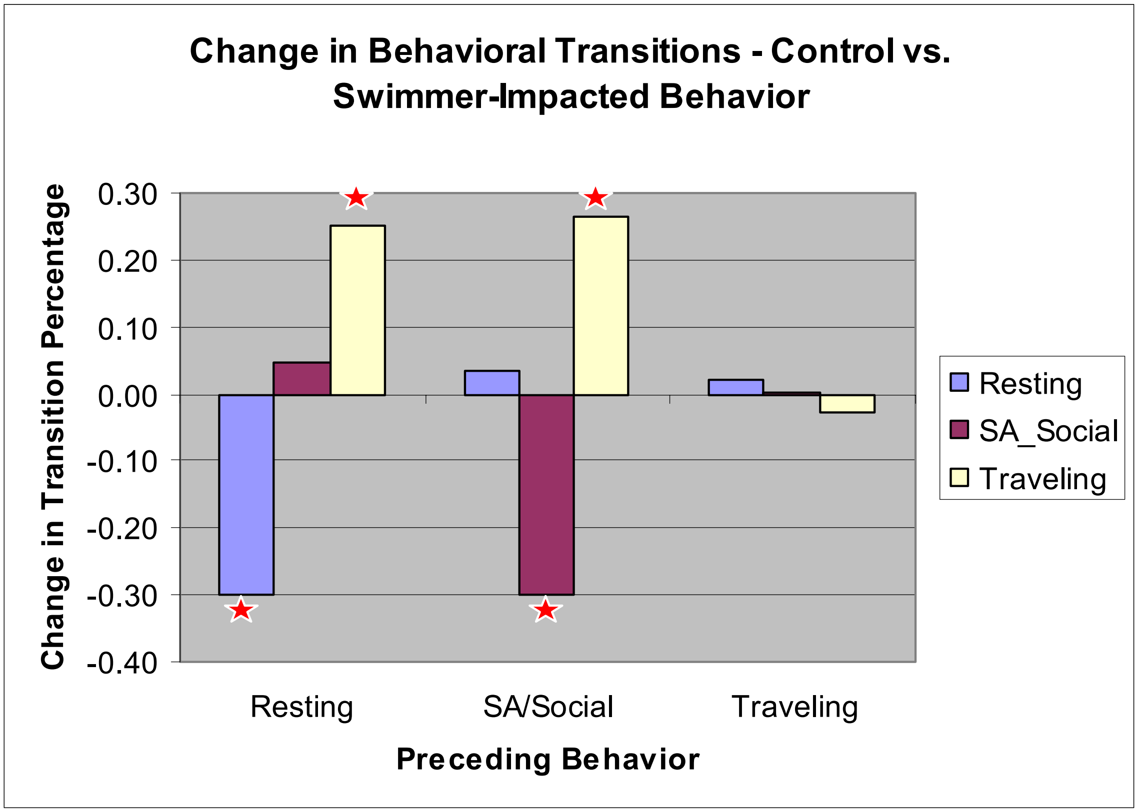

Figure 6. Difference in transition probability between control (before) and swimmer-impacted (during) behavior. Transitions with significant differences ($p < 0.05$) are marked with a star.

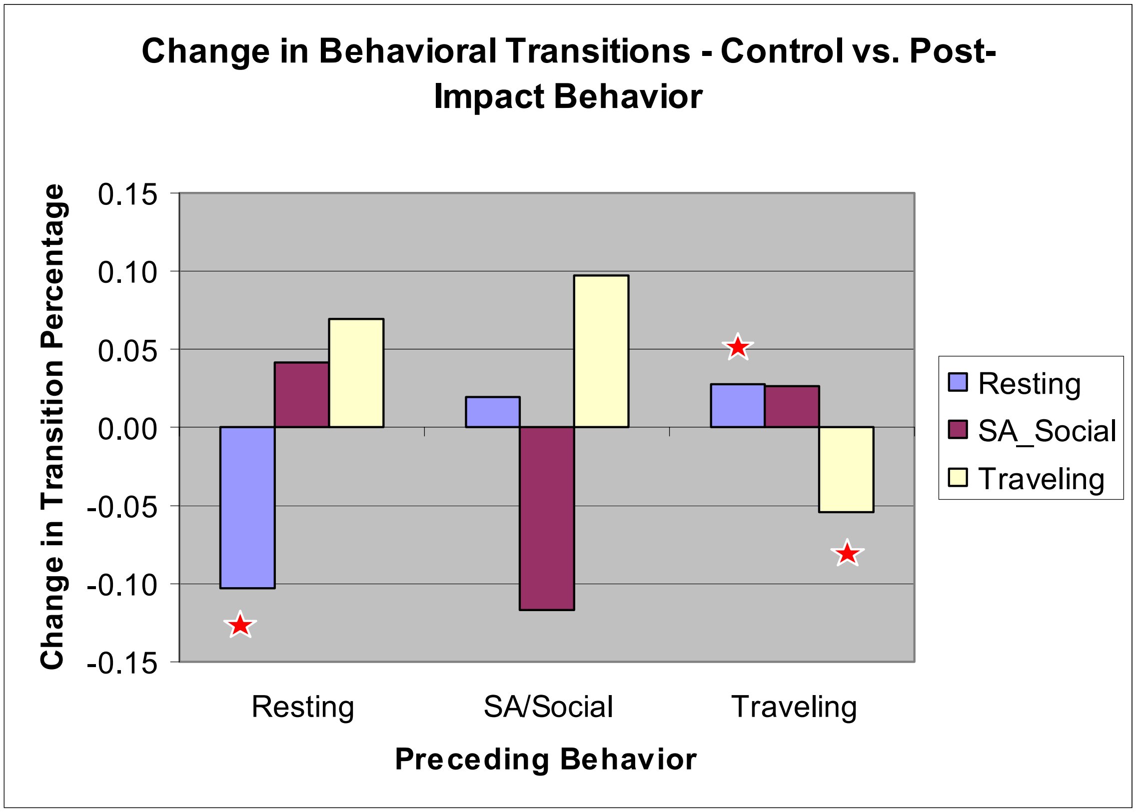

Figure 7. Difference in transition probability between control (before) and post-impact (after) behavior. Transitions with significant differences ($p < 0.05$) are marked with a star.

Effects of Group Composition on Behavioral Transitions

For analysis of behavioral effects on groups of different composition, all Traveling and Surface Active/Social behaviors were aggregated into the category of Active behaviors to compensate for small sample sizes. For mother/calf pairs and juveniles, there was a significant decrease in Resting to Resting transitions (-31% and -24%, respectively) during swimmer interactions, and a significant increase in Resting to Active transitions (31% and 24%, respectively). Other groups – those composed of adults or a mix of adults and juveniles – had a non-significant decrease in Resting to Resting transitions (-24%) and an increase in Resting to Active transitions (24%) (Figure 8). No significant effects were found when comparing Before and After transitions, although Resting to Resting transitions remained at a slightly decreased level (-11%, -9% and -8% for Mother/calf, juvenile and other groups, respectively) and Resting to Active transitions remained at an increased level (11%, 9% and 8% for Mother/calf, juvenile and other groups, respectively).

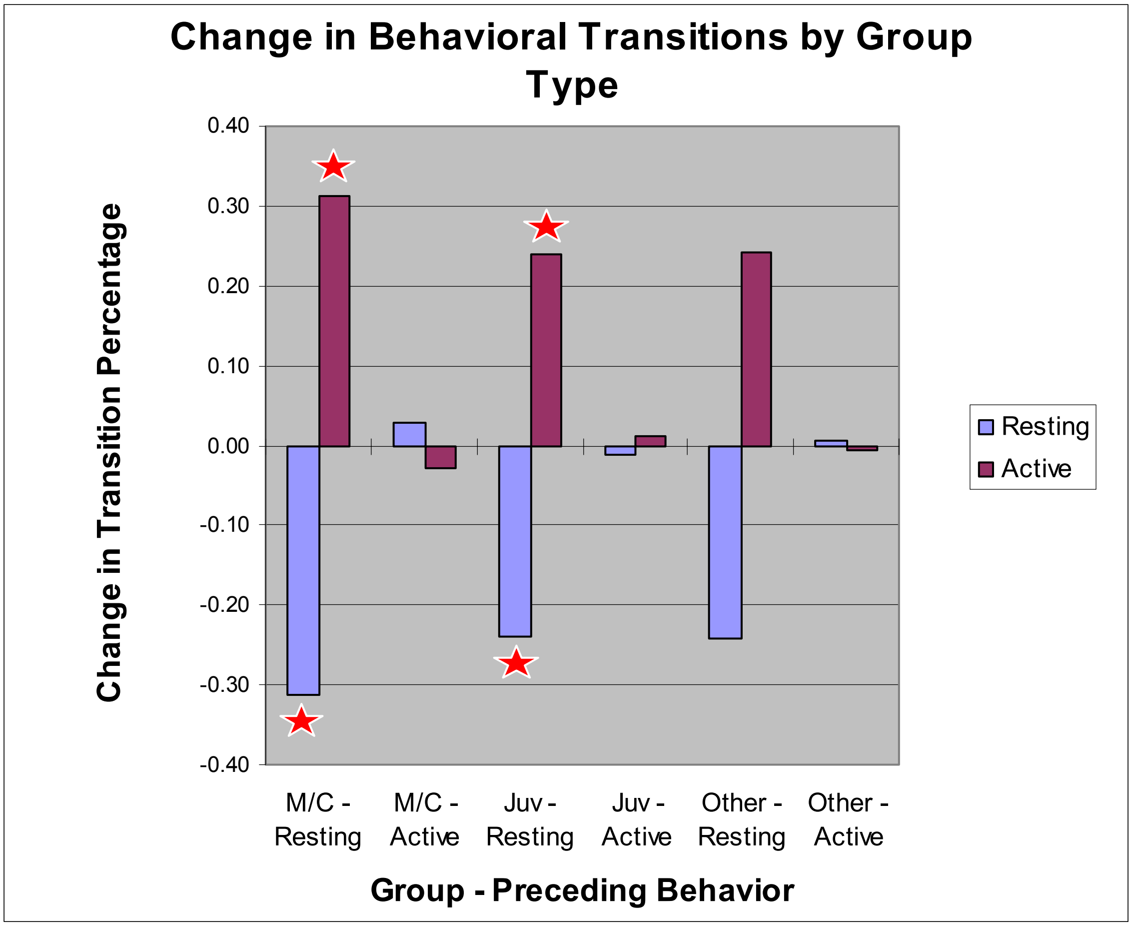

Figure 8. Difference in transition probability between control and swimmer-impacted behavior for groups of different composition. Transitions with significant differences ($p < 0.05$) are marked with a star.

Effects of Interaction Type on Behavioral Transitions

For both calm and noisy interactions, a significant effect was seen during swimmer interactions for all behavioral transitions where the whale was initially Resting. Transitions from Resting to Resting decreased significantly for both calm (-32%) and noisy (-25%) interactions, while Resting to Active increased significantly for calm (32%) and noisy (25%) interactions. No significant effect was found for behavioral transitions where the animal was initially Active (Figure 9). No significant effects were found when comparing Before and After transitions, though Resting to Resting transitions remained at a slightly decreased level (-12% and -9% for Calm and Noisy interactions, respectively) and Resting to Active transitions remained at an increased level (12% and 9% for Calm and Noisy interactions, respectively).

Effects of Swimmer Interactions on Bout Length

Bout length showed significant differences for all behavioral categories when the control was compared to swimmer-impacted behavior. All categories showed a decrease in length, with resting and socializing bouts decreasing substantially. The whales spent less than a third as long resting and socializing when swimmers were in the water than when there were no swimmers present (Figure 10).

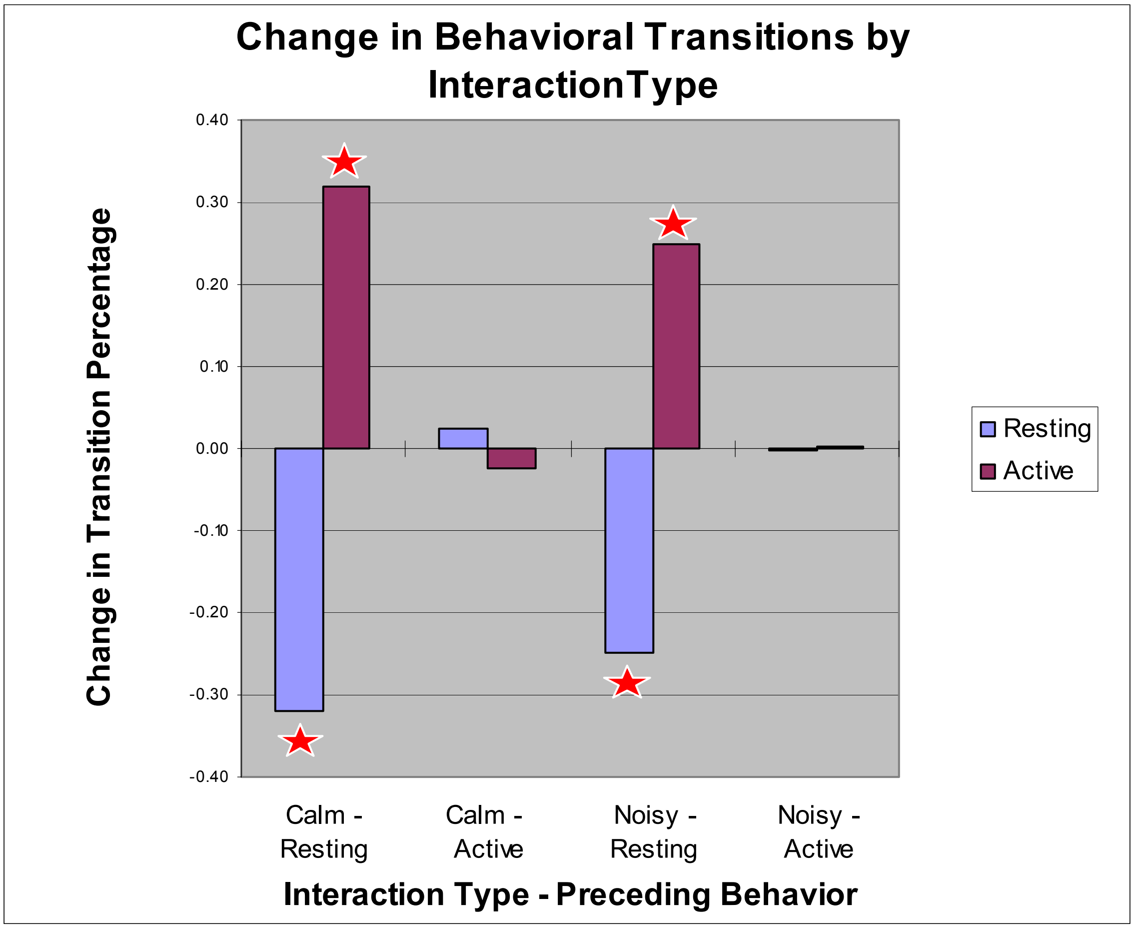

Figure 9. Difference in transition probability between control (before) and swimmer-impacted (during) behavior by interaction type, with stars indicating a significant difference was found ($p < 0.05$).

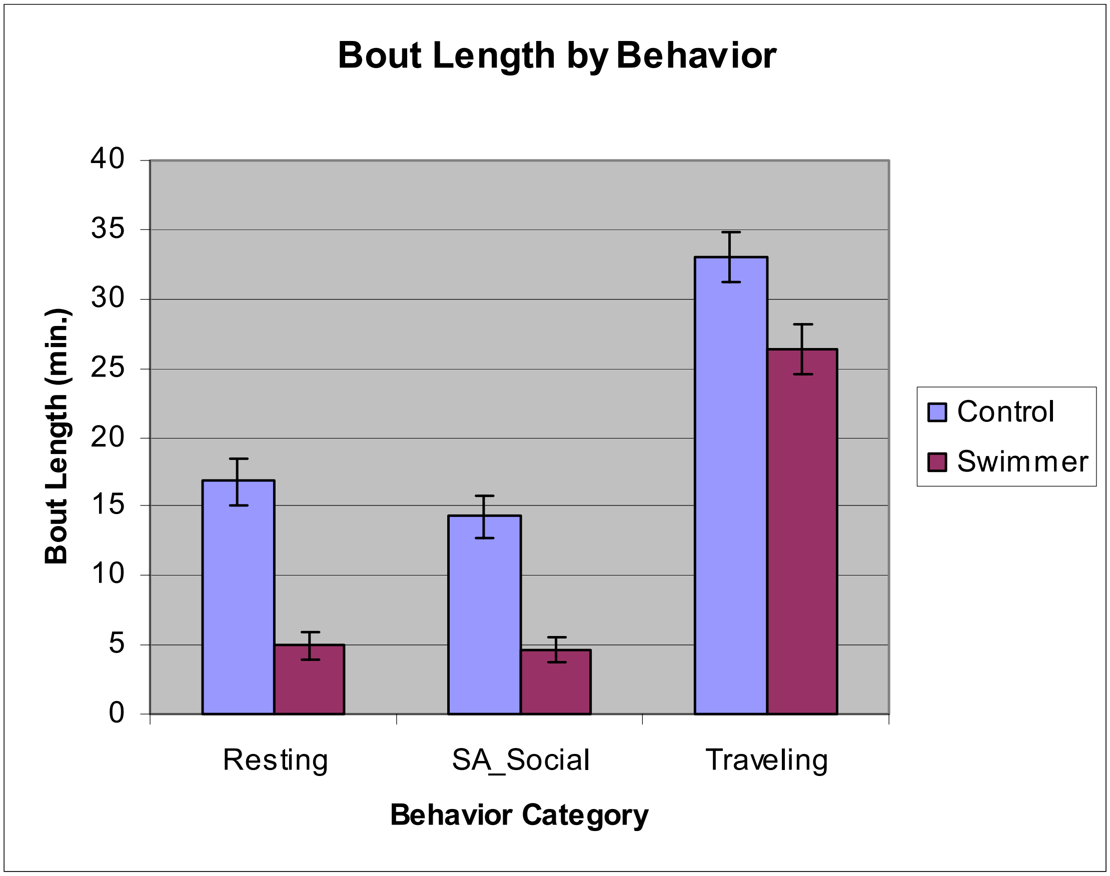

Figure 10. Bout length in minutes by behavior category. Error bars are 95% confidence intervals.

Effects on Respiration Intervals

No statistically significant effects on respiration interval were found when comparing all interactions combined. However, mothers had a significant increase in respiration interval after the interaction compared to before the interaction. No other age class showed a significant effect due to the interaction (Table 4).

Table 4. Respiration intervals (in seconds) before (B), during (D) and after (A) swimmer interactions for different age classes of whales. Significance values are shown for comparison (1) B vs. D, (2) D vs. A, and (3) B vs. A, with an "NS" indicating the difference was not significant at the level p = 0.05.

Age Class	Before	During	After	Significance
All (n = 64)	77 ± 5.7	77 ± 4.1	96 ± 8.5	(1) NS (2) NS (3) NS
Mother (n = 18)	**66 ± 5.2**	78 ± 4.2	**119 ± 20.4**	(1) NS (2) NS **(3) p = 0.003**
Calf (n = 14)	46 ± 5.3	58 ± 8.7	69 ± 16.9	(1) NS (2) NS (3) NS
Juvenile (n = 21)	98 ± 13.2	86 ± 8.7	91 ± 11.5	(1) NS (2) NS (3) NS
Adult (n = 11)	104 ± 9.6	85 ± 9.8	105 ± 17.4	(1) NS (2) NS (3) NS

In the Before time segment, calves had statistically significant differences in respiration intervals compared to juvenile ($p = 0.001$) and adult whales ($p < 0.001$), but not to mothers ($p = 0.11$). During the interaction, the only significant difference was between calves and juveniles ($p = 0.03$). After the interaction, mothers and calves were the only groups with significant differences ($p = 0.03$).

Case Studies

Response of Whales to Physical Contact with Swimmers

Whales and swimmers made physical contact on a number of occasions during the course of this study. On August 20th, 2006, an adult female (without a calf, but in the presence of several other adults) was touched by the hands and flippers of several swimmers. Each time she was touched, she reacted by thrashing her tail and swimming away. On September 5th, 2006, a small juvenile male was touched on the face by a swimmer. He responded by rapidly turning away from the swimmer. In both cases, the whale reacted relatively violently to the contact, but did not swim far enough away to end the interaction. Even a small reaction by the whale is very dangerous to a swimmer who is within a few feet of the animal.

Response of Whales to Attire of Swimmers

On several occasions, juvenile whales appeared to react with curiosity toward one of the three swimmers in the water. In all the cases when a differential response of the whales to one individual swimmer was evident, the swimmer was wearing colorful diving gear while the other two wore mostly black outfits. Colorful gear included red, orange or yellow fins, and red, orange and blue dry suits with contrasting color patterns. On August 9th, 2006, a juvenile approached one of the swimmers who was wearing a blue and orange dry suit. The whale ignored the boat and other two swimmers and repeatedly turned in the direction of the swimmer wearing orange, thrusting its head in her direction and thrashing its tail and flippers about. Though no physical contact was made with the swimmer, it created a situation that was dangerous for everyone involved. The swimmers had to constantly move away from the animal to keep from being struck by the animal, and the potential for injury was high.

On August 28th, 2006, a male juvenile reacted similarly to a swimmer wearing red flippers. This juvenile followed the swimmer with the red flippers until the swimmer became exhausted and had to be picked up by the dive boat. Then the whale turned toward a second swimmer. As the whale approached him, the swimmer had to extend his arms to protect himself from being hit by the whale, touching the whale on its head. The whale then reacted violently with its head causing much white water at the surface, and the interaction ended when the two divers were approached by the boat and taken out of the water. The swimmers reported that the whale “seemed angry” and the swimmer with the red flippers (a professional diver) was quite frightened by the interaction. Such an episode with a non-professional tourist could certainly result in panic and injury even if contact was not made with the whale.

Socializing Activity of Juveniles Interrupted by Presence of Swimmers

An example of this was seen with a pair of juveniles on August 25th, 2006. Early in the morning, the boat approached the two animals and the swimmers entered the water. The juveniles approached the swimmers and interacted for a period of time. After a short period of time, juvenile A left the swimmers and swam a short distance away, while juvenile B continued the interaction. Juvenile A then began slapping its “chin” on the surface. Juvenile B left the swimmers and rejoined juvenile A.

Late in the afternoon, we approached the same two juveniles with the boat again. The swimmers entered the water and again the whales approached. Juvenile A left shortly thereafter and swam a kilometer or more away. At this point it commenced chin-slapping at the surface, just as it had in the morning. Juvenile B left the swimmers again. It began swimming toward Juvenile A, but encountered a third juvenile. Juveniles B and C then engaged in social behavior for a time, until Juvenile A began chin-slapping once again. The three juveniles then converged into one group.

The chin-slapping was a very unusual behavior, and not one we saw often during interactions. Typically, if whales we approached split up, they would travel in different directions and not reform into their previous group. This example illustrates that whales are capable of initiating and terminating encounters with swimmers as they wish. But it also shows that the swim-with activity was interrupting their "normal" behavior. In this case, behavior was altered to the extent that one of the juveniles was provoked into terminating the interaction with the swimmers and may have engaged in an unusual behavior to in an attempt to re-initiate social behavior with the other juvenile.

Mother/calf Pairs Split Up by Interaction

We observed at least three cases where mother/calf pairs were separated from one another by the interaction with the boat. On September 16th, 2005, the boat approached a mother/calf pair, who proceeded to avoid the approach. In the resulting confusion, the mother and calf swam in different directions. The calf joined a second mother/calf pair nearby. The mother swam around the general area, apparently searching for her calf. The calf left the second mother/calf pair and moved a short distance away. When the first mother came upon the second mother/calf pair, it appeared that she tried to begin escorting the second calf. After a minute or so, she began searching for her calf again. The two animals then swam directly toward one another and exited the area at a high speed. If they had not been able to find one another, the calf certainly would have died of starvation.

DISCUSSION

Experimental swimmer interactions with whales had a significant effect on the behavioral state of the whales compared to their behavioral state prior to the interaction. Effects lasted throughout the duration of the interaction and some were still seen after the interaction had ceased. Group composition was shown to be an important factor in predicting the behavioral response of the whale to the interaction, while swimmer behavior was substantially less important.

Overall Effects on Behavior due To Experimental Interactions with Swimmers

Overall, whales were significantly more likely to cease resting or socializing and begin traveling when approached by the boat and swimmers. After the interaction, whales that were initially resting were less likely to remain resting, while traveling whales were more likely to transition to resting. These changes in behavioral state are reflected in significantly decreased bout lengths for each activity. Resting and socializing bouts, in particular, are reduced to less than one-third of their length compared to the control data.

While the behavioral effects of this activity on whales may be short-lived, the overall effect of adding swim-with tourism in addition to whale-watching, industrial boat traffic, and other human activities at Península Valdés has the potential to result in detrimental effects for whales in the long term. Rowntree et al. (1998) found that attacks by kelp gulls (*Larus dominicanus*) on mother/calf right whale pairs in the area resulted in altered behavior for as long as 30-60 minutes after the attack. This raises concerns that right whales at Península Valdés are being subjected to a growing set of disturbance factors. It has been suggested that cumulative effects of stress due to near-constant disturbance may reduce the fitness of individuals (Baker and Herman 1989).

Animals may shift to other areas to avoid the activity, or worse, be forced to cope with the effects of it because they are unable to avoid it (Bejder et al. 2006). Whether these short-term changes add up to a significant deleterious effect in the long-term may be driven by the level of swim-with activity allowed, as reported for bottlenose dolphins in New Zealand (Lusseau 2004). If it is low-density and confined to specific areas and times of year, the effects may be minimal. Alternatively, if it is widespread and high-density, the animals may be sensitized or habituated (Fowler 1999; Constantine 2001) or they may leave preferred areas for sub-optimal habitat (Reeves 1977; Gibeau et al. 2002).

Effects of Experimental Interactions with Swimmers on the Behavior of Different Group Types

Relative to group composition, significant behavioral effects were seen for both mother/calf pairs and juveniles, but not groups containing adults or a mix of juveniles and adults. Mother/calf pairs and juveniles both stopped resting and began engaging in active behaviors when the interaction with swimmers occurred. Prior to the interaction, there was no significant difference between the respiration intervals of mothers and calves. After the interaction, mothers almost doubled the time between respirations, and there was a significant difference between mothers and calves. This may be an indication that mothers were disturbed by the interaction, or that calves may be unable to react to the disturbance in the same way as mothers and may be more profoundly affected by it. Given the small sample size collected for this study, these results should be interpreted cautiously.

Juvenile right whales spend as much as one-fifth of their time resting and one-half of their time playing or socializing at Península Valdés (Sironi 2004). Interrupting resting and socializing bouts may result in deleterious effects on the development of the juveniles. The magnitude of the behavioral effect for adult/mixed-age groups was equal to that of juveniles, but was not statistically significant, most likely due to a small sample size. No statistically significant effects were seen when comparing control data to data collected after the interaction was finished, but resting behaviors remained lower and active behaviors remained elevated.

The behavior of mother/calf pairs is significantly affected by the interaction with swimmers. This is a group of animals that are particularly vulnerable to disturbance effects, as the mothers are fasting while nursing their calves and preparing them for the long journey to the feeding grounds at the end of the season (Payne 1986). Human disturbance has been shown to have negative effects on reproductive success in terrestrial mammals such as elk calves (Shively et al. 2005) and hoatzin chicks (Mullner et al. 2004). Magellanic penguin chicks appear to have a heightened adrenocortical response to handling when they have been previously exposed to tourists (Walker et al. 2005). Since right whales are using the Península Valdés area as a nursing and resting area (particularly mothers and calves) and are generally not feeding, if the activity becomes widespread and frequent enough to significantly alter behavior of mother/calf pairs over the course of an entire calving season, it may have a negative effect on survival rates of calves. A study which examined the energetic balance of right whale calves would provide needed information on the effects of this and other human activities.

Though we did not show statistically significant effects for adult/mixed-age groups, there are circumstances when approaching one of these groups had a clearly negative effect. In particular, we interacted with at least 7 active mating groups out of 30 adult/mixed-age groups. Four of these mating groups were split up by the approach of the boat and swimmers. Not only does this perhaps reduce the likelihood of conception, it is also dangerous for the swimmers to enter the water while the animals are so active.

Effects due to Swimmer Behavior

Swimmer behavior did not have a statistically significant effect on the reaction of whales. Rather, the best predictor of the reaction was the initial state of the whales. If the whales were resting initially, they were significantly less likely to remain resting and more likely to begin traveling, regardless of how swimmers behaved. It is possible that this is because whales are likely to acoustically detect the approach of the boat long before the swimmers enter the water and act either “quiet” or “noisy” in their presence.

The fact that the whales do not react differently to noisy vs. calm interactions should not imply that swimmer behavior is inconsequential. Noisy swimmers – those who are not only making noise, but also thrashing about, not listening to the captain or dive master, not paying attention to the whereabouts of the other swimmers – are at a higher risk of having problems while in the water. Swimmers who become excited are much more likely to swim away from the boat or other divers, approach the animals too closely or endanger other swimmers through their actions. In fact, animals as large as these whales can do a great deal of harm in the course of their normal, everyday movements. In the case studies section above, I outlined several scenarios which occurred during this study where the swimmers were put at risk by their own actions – intentionally or unintentionally.

Underestimation of Effects

The effects shown here are underestimated, particularly for mother/calf pairs. There were 31 groups that we attempted to approach and swim with, but were unable to because the animals 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. There were 60 groups eliminated from the analysis during data filtering, generally because the During time period was too small to be of value. Again, over half (34) of these groups were mother/calf pairs. These groups typically avoided the boat and swimmers, reducing the interaction to less than 10 minutes. In total, 61% of M/C pairs approached (60 of 98 total) evaded the boat or swimmers.

Comparison Between Swim-with and Whale-Watching Boats

There is an established and growing whale-watch industry in Puerto Pirámide, the only town on Península Valdés. Much of the observed effect on the behavior of the whales during swim-with activities is related to the approach of the boat. The current whale-watch regulations in Chubut Province establish a minimum approach distance to right whales of 100 meters with engines on and 50 meters with engines off (Provincial Law #2381/84). That is, the operators must shut their engines off when within 100 meters of an animal and must never approach closer than 50 meters. These regulations are currently being revisited, as operators are in violation of them on nearly every trip. Our study, however, has shown that significant effects are seen when the boat is up to 500 meters from the animal. These results should be taken into account when the new whale-watch regulations are developed.

Because the swim-with boats must approach the whales close enough to put swimmers in the water within visual contact of the whales (in order for the activity to be considered "successful" by the tourists), we would expect the effect of these boats on the whales being approached to be greater. The rate of speed of approach for swim-with boats is also significantly higher. Coupled with the additive effect of humans in the water, we would expect the overall effect on the behavior of the whales to be significantly larger. This doesn't rule out, however, that whale-watch boats are affecting the animals in a similar manner from distances much greater than the current regulations permit. It would be insightful to conduct a comparative study between the effects of whale-watch boats and swim-with boats.

CHAPTER III

SHORT-TERM EFFECTS OF EXPERIMENTAL SWIMMER INTERACTIONS ON THE MOVEMENT OF SOUTHERN RIGHT WHALES

INTRODUCTION

Theodolite tracking has been used by researchers for many years to record 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). The movements of different marine mammal species have been studied using a theodolite, 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 orcas (*Orcinus orca)* (Williams et al. 2002) and gray whales (*Eschrichtius robustus*) (Gailey et al. 2004).

This technique can be useful in evaluating potential disturbances to the animals (Würsig et al. 1991). Changes may be evaluated relative to movement patterns (speed, acceleration, path linearity, ranging indices, etc.), social characteristics (group cohesion, group dispersion), or habitat use (distribution). Analysis of the magnitude and significance of the changes allows us to quantify the effects that human activities have on the movement patterns of cetaceans.

Disturbance studies using a theodolite to measure the effects of boats and/or swimmers on animals have been conducted a number of times in recent years. Most studies rely upon opportunistic observations of interactions between humans and animals, while only a small number used controlled, experimental approaches. Opportunistic observations have been used to quantify effects on Hector's dolphins (Bejder et al. 1999), sperm whales (Richter et al. 2001), orcas (Bain et al. in press), and many other species. Experimental observations have been used for bottlenose dolphins (Nowacek et al. 2001) and orcas (Williams et al. 2002).

This chapter expands upon earlier descriptions of the natural movement patterns of right whales at Península Valdés (Garciarena 1988; Alvarez Colombo et al. 1990; Arias et al. 1992; Campagna et al. 1995) with a focus on the effects of boat approaches and interactions with swimmers. This information can be used as input to the current discussions surrounding swim-with-whale tourism in the area. Perhaps more importantly, it forms the baseline data set for long-term analyses of the impact on southern right whales of this form of tourism should the activity be legalized.

METHODS

Use of Theodolite to Track Animals

Using a theodolite to track marine mammals requires several characteristics of both the field site and the behavior of the animals. First, the animals must be found reasonably close to shore. Second, the observation site should ideally be elevated high above sea level to avoid calculation errors associated with the small angle found between the position being calculated and the horizon (Würsig et al. 1991). This elevation must be precisely known relative to mean low tide to accurately calculate positions of objects at sea level.

A theodolite measures horizontal and vertical angles to the object being "fixed". The horizontal angle is relative to a stationary "zero point" of known location, usually an obvious landmark in the area. The vertical angle is measured relative to gravity. Given the exact position of the theodolite and the height above sea level, these angles can be converted to x-y coordinates – latitude and longitude – with reasonable accuracy. Successive fixes can then be used to determine speed of travel, reorientation, and other movement parameters. Error in these measurements is directly related to the accuracy of the height measurements and the theodolite itself. A 10 centimeter error in height measurement for a 20 meter site (ours were 25 meters at Cerro Prisma and 18 meters at Playa Manara) would result in a position error of 5 meters for a target 1 km away (Würsig et al. 1991). For this reason it was important to accurately measure the height of each site, as well as account for tidal fluctuations during the course of a day.

Data Collection

Positions of focal animals, boats and swimmers in this study were measured 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). This program calculates a real-time conversion of horizontal and vertical angles collected by the theodolite into geographic positions of latitude and longitude each time a fix is initiated. The simultaneous tracking of whales, boats, and swimmers over time provides information on the speed and orientation of the whales, as well as their movements in relation to the 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 (Gailey and Ortega-Ortiz, 2002):

- Group number
- Horizontal and vertical angles
- Geographic latitude and longitude
- Date
- Time
- Bearing referenced to true North.

Data were collected as described in Chapter II, with the theodolite operator tracking the animals and verbally relaying behavior and fix information to the computer operator for input into *Pythagoras*. An attempt was made to fix the animal each time it was at the surface, or every 2 minutes if it remained at the surface for an extended period of time. The author was the theodolite operator for all days of the study except two, in order to reduce inter-observer variability.

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 the readings. Weather was assumed to be a non-factor in the analysis, as the operating conditions required by the boats were such that there was little variability in weather conditions from day to day.

Data Preparation and Filtering

While an attempt was made to collect fixes at 2-minute intervals during the course of a focal follow, often this was not possible as the animals were underwater. Therefore, each "leg" – the period of time between two consecutive fixes – was of a different length of time. The During time period was most likely to have shorter leg times, as it was easier to spot the whales when the boat was near. Also, we were fixing positions of as many as three objects at once (whale, swimmers and boat) and therefore rotating between the three as quickly as possible. This creates a higher path resolution for the During time period. To reduce this bias, we calculated the mean leg length for each segment (Before, During and After) and interpolated all movements based on this leg length. The interpolation assumed the focal animal traveled in a straight line at a constant speed between fixes.

The resulting tracks were filtered as described in Chapter II. Only those which had at least ten minutes of Before, During and After data were used in the analysis. For each of these animals, 10 minutes of each segment were randomly selected for analysis and all other data 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 animal. 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 an animal is generally increasing or decreasing speed during the track. Reorientation rate is a measure of how much the animal 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 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).

Histograms were generated for the mean values of each of the movement characteristics in order to assess normality. 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.

Approach Distance

We defined approach distance as the greatest distance between the boat and whale at which statistically significant effects on movement are observed. In order to determine this distance, we performed analyses comparing movement variables (leg speed, acceleration, reorientation rate and linearity) when the boat was at varying distances from the whale. The data from the "Before" segment was split based on distance from the boat. It was assumed that behavior which occurred when the whale was more than 1 kilometer from the boat was natural, undisturbed behavior. Movement variables for this set of data were compared with movement variables for the set of data when the boat was less than 500 meters from the whale and when the boat was between 500 and 1000 meters from the whale. Only those animals which had at least 5 minutes of movement data in each distance segment were considered in the analysis. This low threshold was used to maximize the amount of data in each distance segment.

Statistical Analysis

Analysis of variance (ANOVA) tests were conducted using SPSS version 13.0.1 for Windows (SPSS Inc. 2004) to determine the effects of the experimental approaches on the movement characteristics of the animals. Significance values were set at α = 0.05. For the "approach distance" analysis, tests were conducted with data from all animals combined, regardless of group type, interaction type or reaction of the animal to the boat or swimmers. Once the approach distance was determined, lower-level analyses were performed splitting the data by group type (mother/calf pair, juvenile or other), interaction type (noisy or calm), reaction to boat (approach, neutral or avoid) and reaction to swimmers (approach, neutral or avoid). Post-hoc analyses were conducted to determine the significance of the effects on each of these groups and sub-groups.

RESULTS

Calculation of Approach Distance

Due to sample size considerations, it was not possible to compare data for the 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 animal until beginning an approach, and then approached the animal quickly and directly. There were a total of 78 (of the original 153) whale groups which had at least 5 minutes of movement data in the distance segments under consideration.

When comparing data from the 500 to 1000 meter segment with the over-1000 meter segment, no significant differences were found in leg speed, acceleration, reorientation rate or linearity (Table 4). Comparison between the under-500 meter and over-1000 meter segments yielded a statistically significant effect in reorientation rate (Table 5). The 500-meter limit was therefore used as the approach distance in all subsequent analyses of behavior and movement.

Table 5. Movement characteristics at different distances between boat and whale. Significance values are shown for comparison (1) 0-500m vs. >1000m and (2) 500-1000m vs. >1000m.

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

Overall Effects of Interaction

A statistically significant effect was found on both linearity and reorientation rate when comparing the Before (B), During (D) and After (A) segments for all animals combined. Linearity decreased during the interaction and increased after it was over. Reorientation rate increased during the interaction and decreased after it was over. No significant effects were found when comparing the before and after periods, though linearity remained slightly lower and reorientation slightly higher. No significant effects were found on leg speed or acceleration. All results are shown in Table 6, with box plots of each individual variable in Figures 11 – 14. Trends are shown in Figures 15 – 18.

Table 6. Movement characteristics before (B), during (D) and after (A) for all interactions. Significance values are shown for comparison (1) B vs. D, (2) D vs. A, and (3) B vs. A.

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

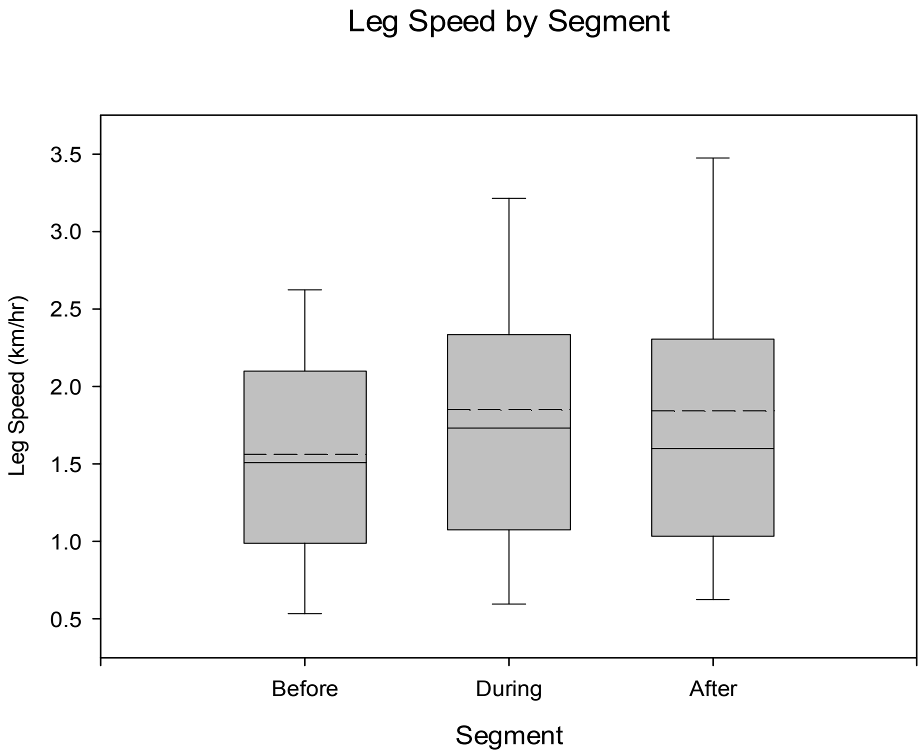

Figure 11. Leg speed for all whales before, during and after interaction with swimmers. The box represents the 25th to 75th percentiles, while the whiskers represent the 10th and 90th percentiles. The solid line is the 50th percentile and the dashed line the mean.

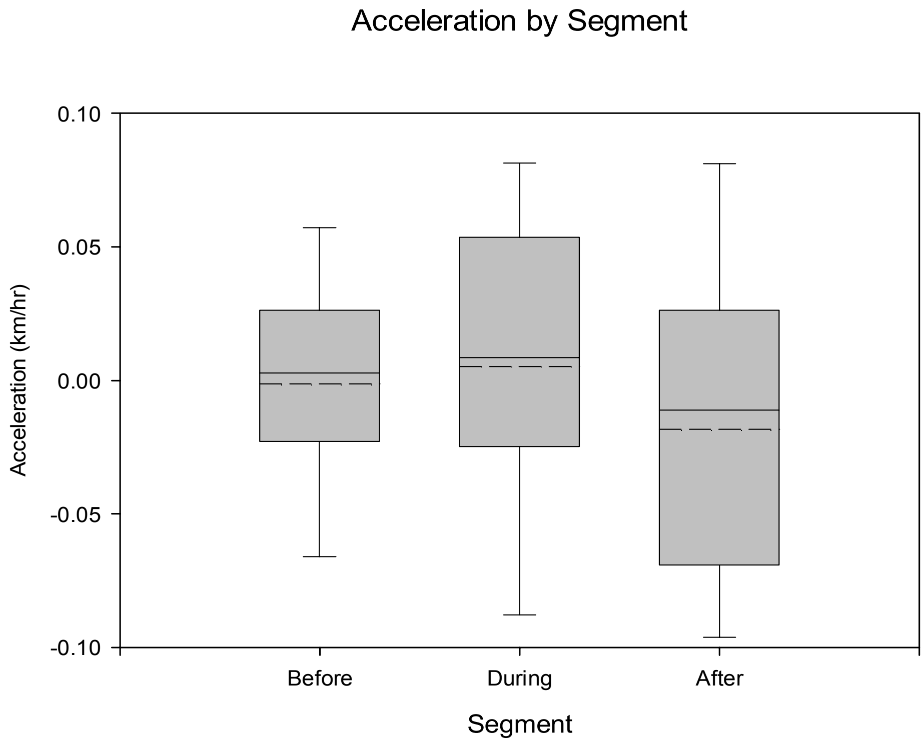

Figure 12. Acceleration for all whales before, during and after interaction with swimmers. The box represents the 25th to 75th percentiles, while the whiskers represent the 10th and 90th percentiles. The solid line is the 50th percentile and the dashed line the mean.

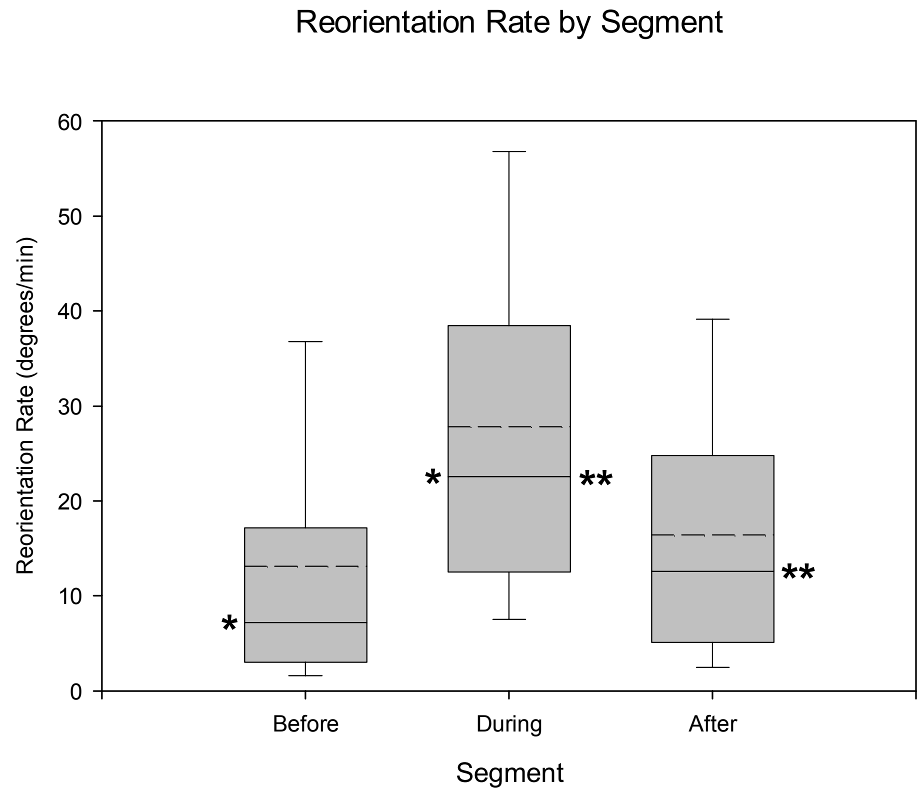

Figure 13. Reorientation rate for all whales before, during and after interaction with swimmers. The box represents the 25th to 75th percentiles, while the whiskers represent the 10th and 90th percentiles. The solid line is the 50th percentile and the dashed line the mean. Significant differences are indicated by one (Before-During) or two (During-After) asterisks.

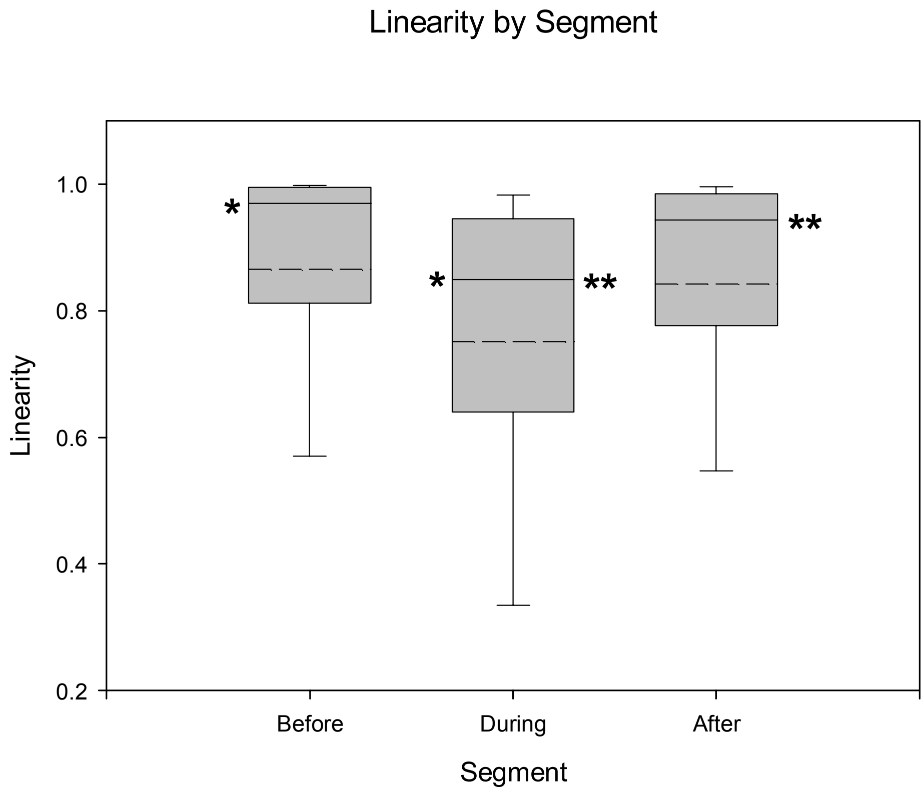

Figure 14. Linearity for all whales before, during and after interaction with swimmers. The box represents the 25th to 75th percentiles, while the whiskers represent the 10th and 90th percentiles. The solid line is the 50th percentile and the dashed line the mean. Significant differences are indicated by one (Before-During) or two (During-After) asterisks.

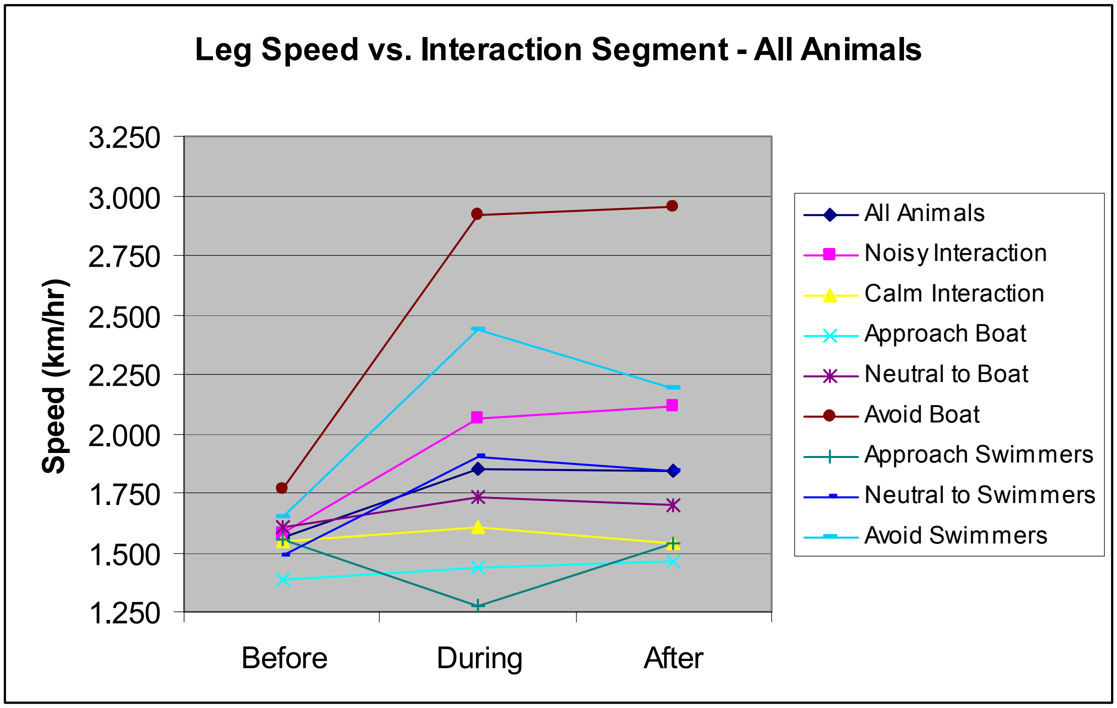

Figure 15. Leg speed for all whales before, during and after interaction with swimmers relative to interaction type, reaction to boat and reaction to swimmers.

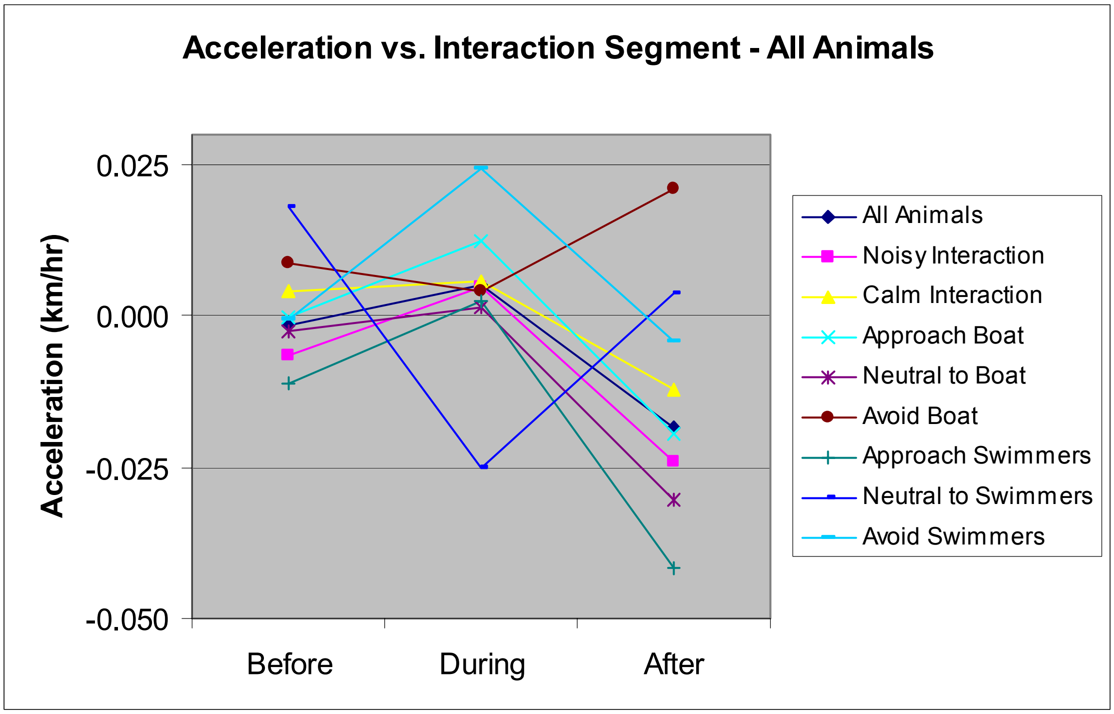

Figure 16. Acceleration for all whales before, during and after interaction with swimmers relative to interaction type, reaction to boat and reaction to swimmers.

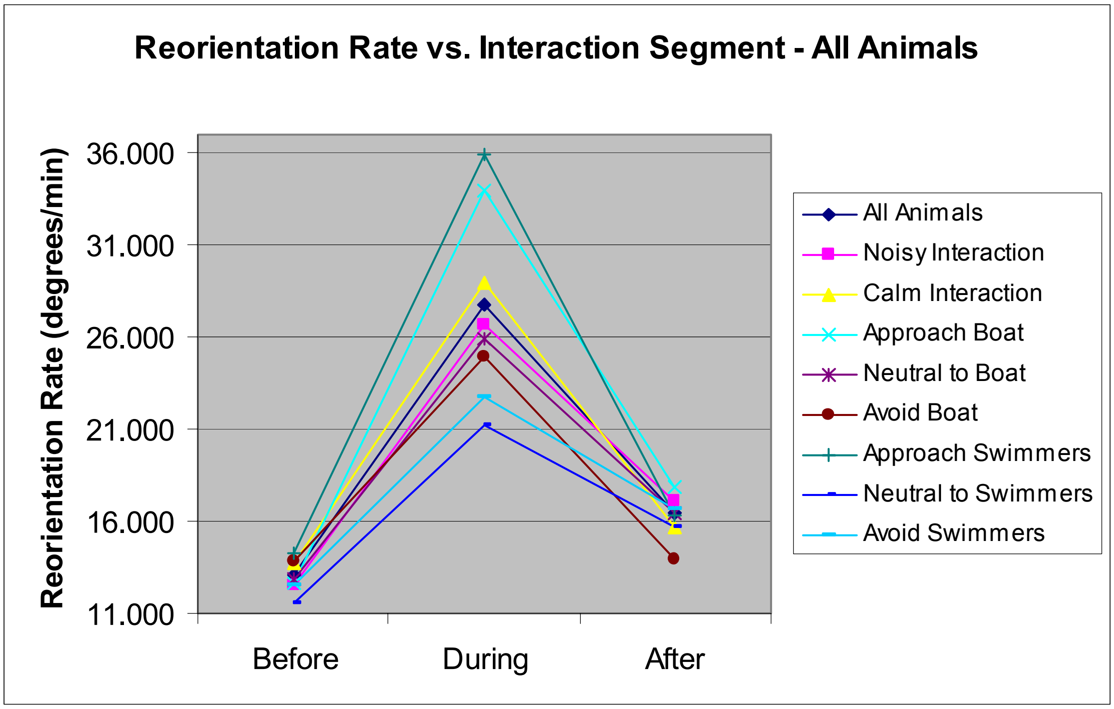

Figure 17. Reorientation rate for all whales before, during and after interaction with swimmers relative to interaction type, reaction to boat and reaction to swimmers.

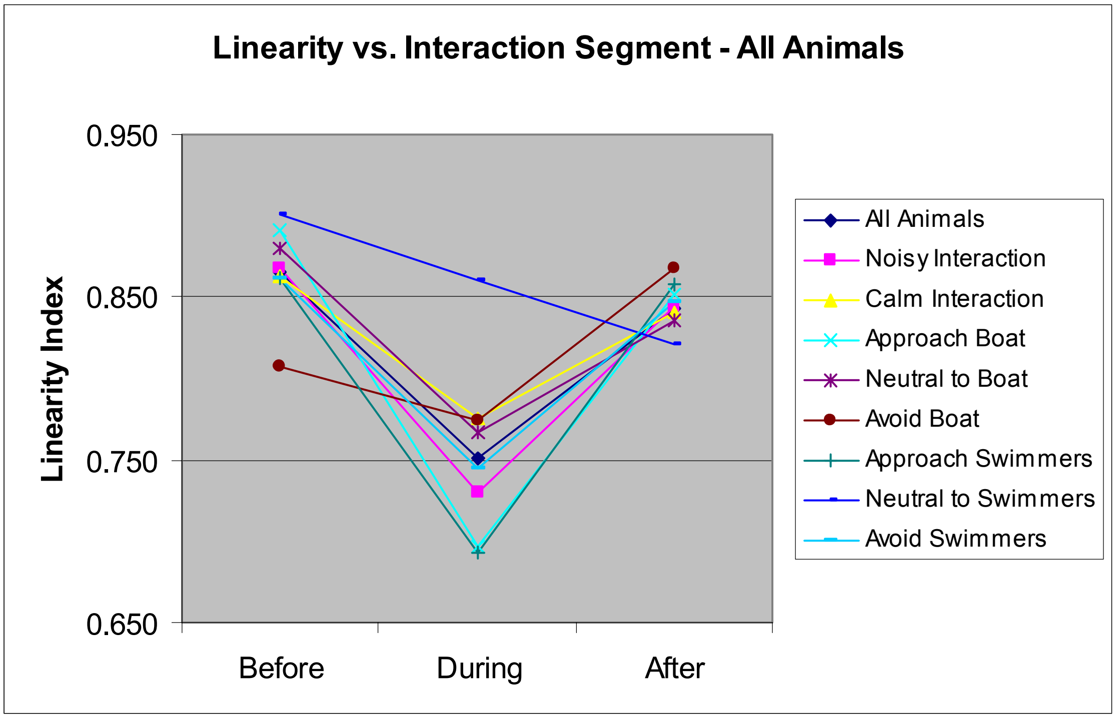

Figure 18. Linearity for all whales before, during and after interaction with swimmers relative to interaction type, reaction to boat and reaction to swimmers.

Effect of Interaction Relative to Swimmer Behavior

A statistically significant effect on both linearity and reorientation rate was found for both interactions where swimmers behaved noisily and where swimmers behaved calmly when comparing the Before (B), During (D) and After (A) segments. Linearity decreased significantly during the interaction for both noisy and calm swimmer behavior and increased significantly for calm interactions after it was over. Reorientation rate increased during the interaction and decreased after it was over for both types of swimmer behavior (Tables 7 and 8).

Table 7. Movement characteristics before (B), during (D) and after (A) a noisy interaction. Significance values are shown for comparison (1) B vs. D, (2) D vs. A, and (3) B vs. A.

Variable	Before	During	After	Significance
Leg Speed (km/h) (n = 49)	1.58 ± 0.78	2.07 ± 1.09	2.11 ± 1.43	(1) NS (2) NS (3) NS
Acceleration (km/h) (n = 45)	-.01 ± .08	.01 ± .09	-.02 ± .08	(1) NS (2) NS (3) NS
Reorientation rate (°/min) (n = 45)	**12.5 ± 13.7**	**26.7 ± 21.5**	**17.1 ± 14.9**	**(1) p < 0.001** **(2) p = 0.03** (3) NS
Linearity Index (n = 49)	**.87 ± .21**	**.73 ± .27**	.85 ± .20	**(1) p = 0.001** (2) NS (3) NS

Table 8. Movement characteristics before (B), during (D) and after (A) a calm interaction. Significance values are shown for comparison (1) B vs. D, (2) D vs. A, and (3) B vs. A.

Variable	Before	During	After	Significance
Leg Speed (km/h) (n = 44)	1.55 ± 0.77	1.61 ± 0.93	1.54 ± 0.79	(1) NS (2) NS (3) NS
Acceleration (km/h) (n = 43)	.00 ± .04	.01 ± .07	-.01 ± .07	(1) NS (2) NS (3) NS
Reorientation rate (°/min) (n = 43)	**13.7 ± 17.0**	**28.9 ± 18.4**	**15.7 ± 12.3**	**(1) p < 0.001** **(2) p = 0.001** (3) NS
Linearity Index (n = 44)	**.86 ± .19**	**.78 ± .21**	**.84 ± .20**	**(1) p = 0.003** **(2) p = 0.04** (3) NS

Effect of Interaction Relative to Whale's Reaction to the Boat

A statistically significant effect on linearity and reorientation rate was found when comparing the Before (B), During (D) and After (A) segments for animals which approached or were neutral to the approach of the boat. Linearity decreased significantly during the interaction for both Approach- and Neutral-reacting animals. Reorientation rate increased during the interaction and decreased after it was over for Approach and Neutral-reacting animals. For Neutral-reacting animals, the reorientation rate remained significantly increased relative to the initial rate after the interaction ended. Animals which avoided the boat showed a significant increase in leg speed during the interaction and a significant decrease afterwards (Table 9).

Effect of Interaction Relative to Whale's Reaction to the Swimmers

A statistically significant effect on linearity and reorientation rate was found when comparing the Before (B), During (D) and After (A) segments for animals which approached or avoided the swimmers in the water. Linearity decreased significantly during the interaction for both Approach- and Neutral-reacting animals and increased significantly once the interaction was over. Reorientation rate increased during the interaction for both Approach- and Avoid-reacting animals and decreased after it was over for Approach -reacting animals. Animals which avoided swimmers showed a significant increase in leg speed during the interaction and animals which approached swimmers showed a significant decrease in acceleration after the interaction was over (Table 10).

Table 9. Movement characteristics before (B), during (D) and after (A) the interaction distributed with respect to the reaction of the animal to the boat. Significance values are shown for comparison (1) B vs. D, (2) D vs. A and (3) B vs. A.

Variable	Before	During	After	Significance
Leg Speed (km/h)				
Approach (n = 24)	1.35 ± 0.70	1.44 ± 0.79	1.46 ± 0.68	(1) NS (2) NS (3) NS
Neutral (n = 52)	1.61 ± 0.72	1.73 ± 0.93	1.70 ± 1.07	(1) NS (2) NS (3) NS
Avoid (n = 16)	**1.77 ± 0.97**	**2.92 ± 1.05**	**2.95 ± 1.58**	**(1) p = 0.006** (2) NS **(3) p = 0.017**
Acceleration (km/h)				
Approach (n = 23)	.00 ± .04	.01 ± .07	-.02 ± .07	(1) NS (2) NS (3) NS
Neutral (n = 48)	-.00 ± .05	.00 ± .08	-.03 ± .08	(1) NS (2) NS (3) NS
Avoid (n = 16)	.01 ± .11	.00 ± .10	.02 ± .06	(1) NS (2) NS (3) NS
Reorientation rate (°/min)				
Approach (n = 23)	**12.7 ± 18.8**	**34.0 ± 24.9**	**17.8 ± 14.4**	**(1) p < 0.001** **(2) p = 0.020** (3) NS
Neutral (n = 48)	**12.9 ± 13.3**	**25.9 ± 16.6**	**16.4 ± 12.1**	**(1) p < 0.001** **(2) p = 0.017** **(3) p = 0.041**
Avoid (n = 16)	13.9 ± 16.8	25.0 ± 21.5	13.9 ± 17.4	(1) NS (2) NS (3) NS
Linearity Index				
Approach (n = 24)	**.89 ± .16**	**.70 ± .29**	.85 ± .16	**(1) p = 0.003** (2) NS (3) NS
Neutral (n = 52)	**.88 ± .18**	**.77 ± .22**	.84 ± .21	(1) **p < 0.001** (2) NS (3) NS
Avoid (n = 16)	.81 ± .28	.77 ± .26	.87 ± .23	(1) NS (2) NS (3) NS

Table 10. Movement characteristics before (B), during (D) and after (A) the interaction split based on the whale's reaction to the swimmers. Significance values are shown for comparison (1) B vs. D, (2) D vs. A, and (3) B vs. A.

Variable	Before	During	After	Significance
Leg Speed (km/h)				
Approach (n = 36)	1.55 ± 0.78	1.27 ± 0.63	1.54 ± 0.98	(1) NS (2) NS (3) NS
Neutral (n = 20)	1.49 ± 0.68	1.90 ± 1.04	1.84 ± 0.87	(1) NS (2) NS (3) NS
Avoid (n = 36)	**1.65 ± 0.81**	**2.43 ± 1.06**	2.19 ± 1.46	**(1) p = 0.006** (2) NS (3) NS
Acceleration (km/h)				
Approach (n = 36)	-.01 ± .05	**.00 ± .08**	**-.04 ± .08**	(1) NS **(2) p = 0.03** (3) NS
Neutral (n = 17)	.02 ± .06	-.03 ± .08	.00 ± .09	(1) NS (2) NS (3) NS
Avoid (n = 34)	-.00 ± .08	.03 ± .08	-.00 ± .06	(1) NS (2) NS (3) NS
Reorientation rate (°/min)				
Approach (n = 36)	**14.2 ± 17.9**	**35. 9 ± 21.3**	**16.4 ± 11.5**	**(1) p < 0.001** **(2) p < 0.001** (3) NS
Neutral (n = 17)	11.5 ± 12.8	21.2 ± 15.8	15.7 ± 13.2	(1) NS (2) NS (3) NS
Avoid (n = 34)	**12.5 ± 14.0**	**22.7 ± 18.1**	16.6 ± 16.2	**(1) p = 0.028** (2) NS (3) NS
Linearity Index				
Approach (n = 36)	**.86 ± .18**	**.69 ± .23**	**.86 ± .17**	**(1) p < 0.001** **(2) p = 0.002** (3) NS
Neutral (n = 20)	.90 ± .15	.86 ± .17	.82 ± .20	(1) NS (2) NS (3) NS
Avoid (n = 36)	**.86 ± .24**	**.75 ± .27**	**.85 ± .22**	**(1) p = 0.021** **(2) p = 0.037** (3) NS

Effect of Interaction on the Movement Patterns of Mother/Calf Pairs

A statistically significant effect on linearity and reorientation rate was found when comparing the Before (B), During (D) and After (A) segments for mother/calf pairs. Linearity decreased significantly during the interaction and increased significantly once the interaction was over. Reorientation rate increased during the interaction and decreased after it was over.

During calm interactions, linearity decreased significantly during the interaction and increased significantly once the interaction was over and reorientation rate increased during the interaction and decreased after it was over. Noisy interactions resulted in an increase in reorientation rate during the interaction.

Mother/calf pairs which approached the boat showed a significant decrease in acceleration after the interaction and a significant increase in reorientation during the interaction. Pairs which were neutral to the boat showed significantly decreased linearity during the interaction and significantly increased linearity once the interaction was over. Their reorientation rate also increased during the interaction and decreased after it was over. Pairs which avoided the boat had a significant increase in leg speed during the interaction and it remained significantly high once it was over.

Mother/calf pairs which approached the swimmers showed significantly decreased linearity during the interaction and significantly increased linearity once the interaction was over. Their reorientation rate also increased during the interaction and decreased after it was over. Pairs which were neutral to the swimmers showed significantly increased reorientation rate during the interaction. Pairs which avoided the swimmers had a significant increase in leg speed during the interaction (Tables 11 – 13).

General Trends of Effects on the Movement Patterns of Mother/Calf Pairs

Mother/calf pairs showed a general trend of increasing speed during the interaction, with a slight decline afterwards. Pairs which avoided the boat and swimmers swam at higher speeds than those which were neutral or approached the boat or swimmers. Pairs which avoided the boat had the highest mean speeds observed for any group (mean = 3.1 km/h). Noisy interactions elicited higher speeds than calm interactions. Acceleration rates showed a variety of responses, with no clear trends observed.

Reorientation rates also rose for all mother/calf groups during the interaction, with a subsequent decline back to the original rate afterward. Animals which approached the boat or swimmers showed greater effects than neutral and avoiding animals. Mother/calf pairs which approached the swimmers had the highest reorientation rates observed for any group in the study (mean = 40.9 °/min). Behavior of the swimmers did not have an observed effect on their reorientation rate.

Linearity generally decreased during interactions with mother/calf pairs and returned to pre-interaction levels after it was over. Pairs that approached the boat or swimmers typically traveled in a less linear fashion than those that avoided the boat or swimmers. Noisy swimmer behavior resulted in less linear travel than calm swimmer behavior (Figures 19 – 22).

Table 11. Movement characteristics before (B), during (D) and after (A) the interaction for all mother/calf pairs, including split by interaction type. Significance values are shown for comparison (1) B vs D, (2) D vs A, and (3) B vs A.

Variable	Before	During	After	Significance
Leg Speed (km/h) (n = 38)	**1.54 ± 0.85**	**2.25 ± 1.21**	2.11 ± 1.45	**(1) p = 0.033** (2) NS (3) NS
Noisy Interaction (n = 22)	1.48 ± 0.80	2.41 ± 1.24	2.44 ± 1.64	(1) NS (2) NS (3) NS
Calm Interaction (n = 16)	1.62 ± 0.93	2.04 ± 1.15	1.65 ± 1.01	(1) NS (2) NS (3) NS
Acceleration (km/h) (n = 36)	.01 ± .04	.01 ± .10	-.01 ± .07	(1) NS (2) NS (3) NS
Noisy Interaction (n = 20)	.00 ± .04	-.00 ± .12	-.01 ± .08	(1) NS (2) NS (3) NS
Calm Interaction (n = 16)	.01 ± .05	.02 ± .09	-.01 ± .06	(1) NS (2) NS (3) NS
Reorientation rate (°/min) (n = 36)	**10.9 ± 10.2**	**29.7 ± 19.7**	**14.4 ± 13.3**	**(1) p < 0.001** **(2) p = 0.002** (3) NS
Noisy Interaction (n = 20)	**10.8 ± 9.9**	**28.6 ± 22.1**	15.4 ± 14.2	**(1) p = 0.027** (2) NS (3) NS
Calm Interaction (n = 16)	**11.1 ± 10.9**	**31.1 ± 16.9**	**13.2 ± 12.3**	**(1) p = 0.001** **(2) p = 0.007** (3) NS
Linearity Index (n = 38)	**.85 ± .22**	**.71 ± .25**	**.87 ± .17**	**(1) p = 0.005** **(2) p = 0.008** (3) NS
Noisy Interaction (n = 22)	.83 ± .25	.70 ± .26	.85 ± .16	(1) NS (2) NS (3) NS
Calm Interaction (n = 16)	**.88 ± .16**	**.74 ± .24**	**.89 ± .18**	**(1) p = 0.037** **(2) p = 0.021** (3) NS

Table 12. Movement characteristics before (B), during (D) and after (A) the interaction for mother/calf pairs split by the reaction of the whale to the boat. Significance values are shown for comparison (1) B vs D, (2) D vs A, and (3) B vs A.

Variable	Before	During	After	Significance
Leg Speed (km/h)				
Approach (n = 8)	1.44 ± 0.73	1.41 ± 0.73	1.31 ± 0.70	(1) NS (2) NS (3) NS
Neutral (n = 18)	1.55 ± 0.10	2.16 ± 1.06	1.97 ± 1.43	(1) NS (2) NS (3) NS
Avoid (n = 11)	**1.70 ± 1.02**	**3.15 ± 1.17**	**3.05 ± 1.49**	**(1) p = 0.027** (2) NS **(3) p = 0.041**
Acceleration (km/h)				
Approach (n = 7)	-.00 ± .04	**.04 ± .04**	**-.04 ± .05**	(1) NS **(2) p = 0.012** (3) NS
Neutral (n = 17)	-.01 ± .04	-.01 ± .12	-.03 ± .08	(1) NS (2) NS (3) NS
Avoid (n = 11)	.03 ± .05	.01 ± .11	.04 ± .05	(1) NS (2) NS (3) NS
Reorientation rate (°/min)				
Approach (n = 7)	**6.1 ± 4.5**	**32.0 ± 14.0**	17.0 ± 13.2	**(1) p = 0.002** (2) NS (3) NS
Neutral (n = 17)	**11.2 ± 11.7**	**31.7 ± 18.7**	**14.1 ± 12.4**	**(1) p < 0.001** **(2) p = 0.013** (3) NS
Avoid (n = 11)	12.6 ± 10.1	26.1 ± 25.5	12.7 ± 15.9	(1) NS (2) NS (3) NS
Linearity Index				
Approach (n = 8)	.92 ± .12	.68 ± .28	.81 ± .15	(1) NS (2) NS (3) NS
Neutral (n = 18)	**.88 ± .21**	**.66 ± .24**	**.89 ± .16**	**(1) p < 0.001** **(2) p = 0.003** (3) NS
Avoid (n = 11)	.80 ± .25	.81 ± .23	.89 ± .19	(1) NS (2) NS (3) NS

Table 13. Movement characteristics before (B), during (D) and after (A) the interaction for mother/calf pairs split by the reaction of the whale to the swimmers. Significance values are shown for comparison (1) B vs D, (2) D vs A and (3) B vs A.

Variable	Before	During	After	Significance
Leg Speed (km/h)				
Approach (n = 9)	1.55 ± 0.82	1.80 ± 0.54	1.93 ± 1.55	(1) NS (2) NS (3) NS
Neutral (n = 6)	1.33 ± 0.99	1.98 ± 1.49	1.89 ± 0.92	(1) NS (2) NS (3) NS
Avoid (n = 22)	**1.65 ± 0.83**	**2.58 ± 1.25**	2.31 ± 1.55	**(1) p = 0.041** (2) NS (3) NS
Acceleration (km/h)				
Approach (n = 9)	-.00 ± .04	-.03 ± .13	-.07 ± .07	(1) NS (2) NS (3) NS
Neutral (n = 5)	.00 ± .03	-.06 ± .10	.03 ± .05	(1) NS (2) NS (3) NS
Avoid (n = 21)	.01 ± .05	.03 ± .09	.01 ± .07	(1) NS (2) NS (3) NS
Reorientation rate (°/min)				
Approach (n = 9)	**12.6 ± 14.8**	**40.9 ± 13.7**	**15.6 ± 12.7**	**(1) p = 0.001** **(2) p = 0.029** (3) NS
Neutral (n = 5)	**6.1 ± 4.0**	**28.1 ± 18.8**	9.9 ± 7.2	**(1) p = 0.021** (2) NS (3) NS
Avoid (n = 21)	10.9 ± 8.9	25.8 ± 21.4	14.7 ± 15.0	(1) NS (2) NS (3) NS
Linearity Index				
Approach (n = 9)	**.88 ± .15**	**.59 ± .23**	**.91 ± .07**	**(1) p = 0.001** **(2) p = 0.006** (3) NS
Neutral (n = 6)	.91 ± .09	.82 ± .17	.85 ± .16	(1) NS (2) NS (3) NS
Avoid (n = 22)	.84 ± .25	.73 ± .26	.87 ± .19	(1) NS (2) NS (3) NS

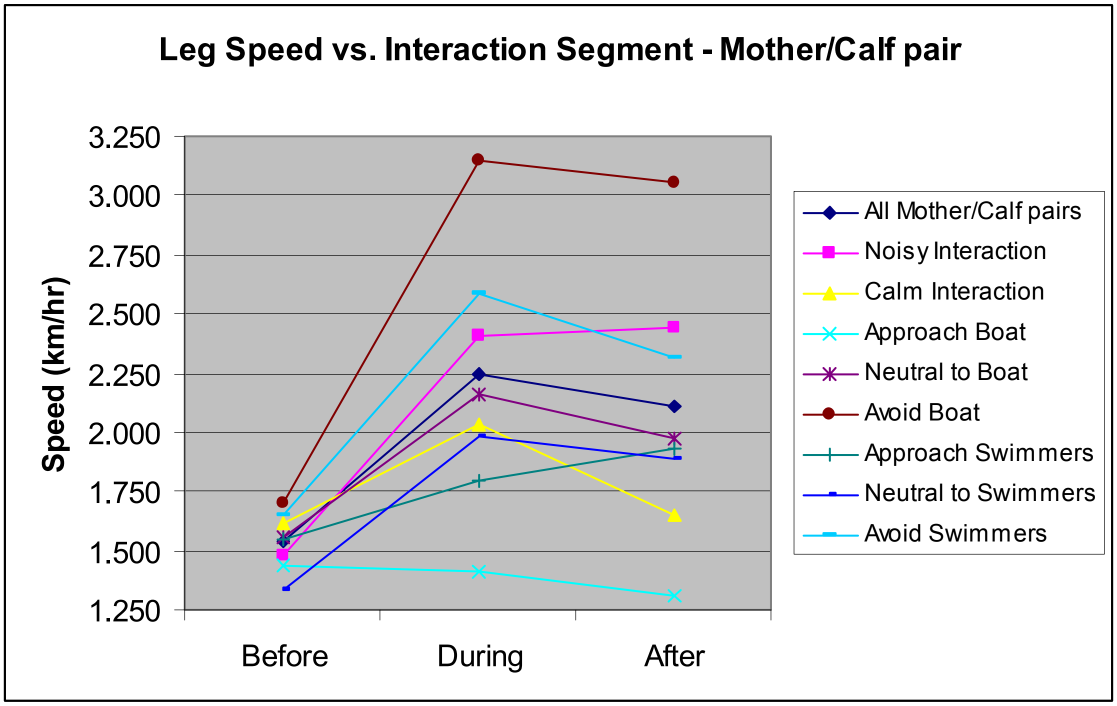

Figure 19. Leg speed for mother/calf pairs before, during and after interaction with swimmers relative to interaction type, reaction to boat and reaction to swimmers.

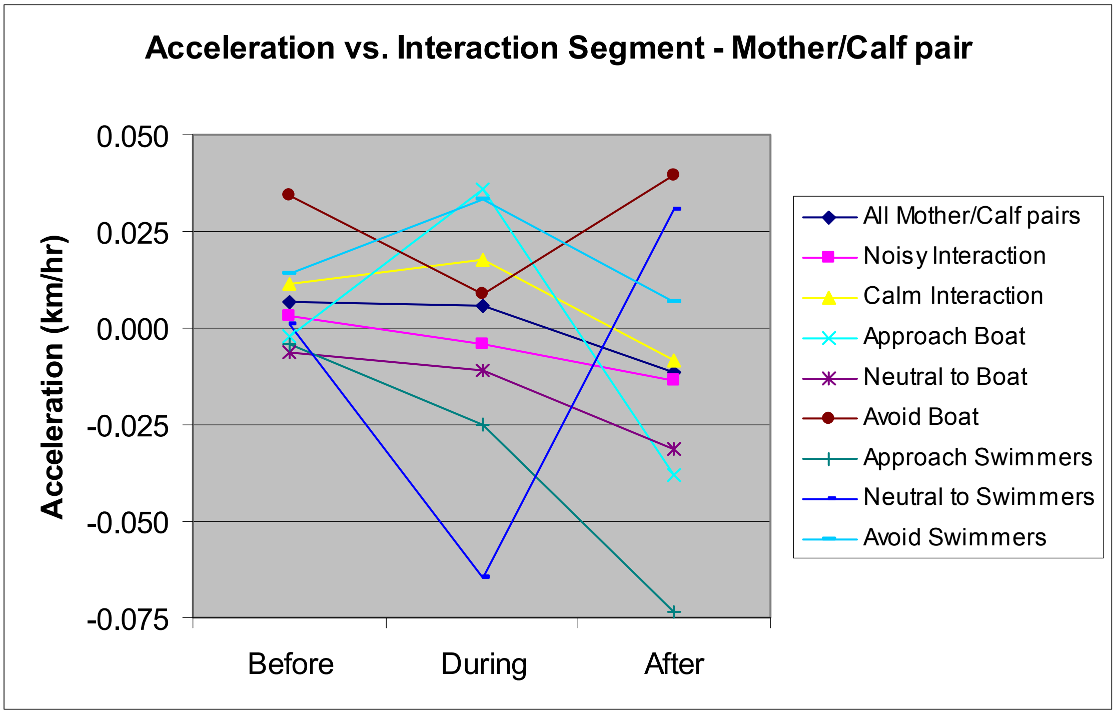

Figure 20. Acceleration for mother/calf pairs before, during and after interaction with swimmers relative to interaction type, reaction to boat and reaction to swimmers.

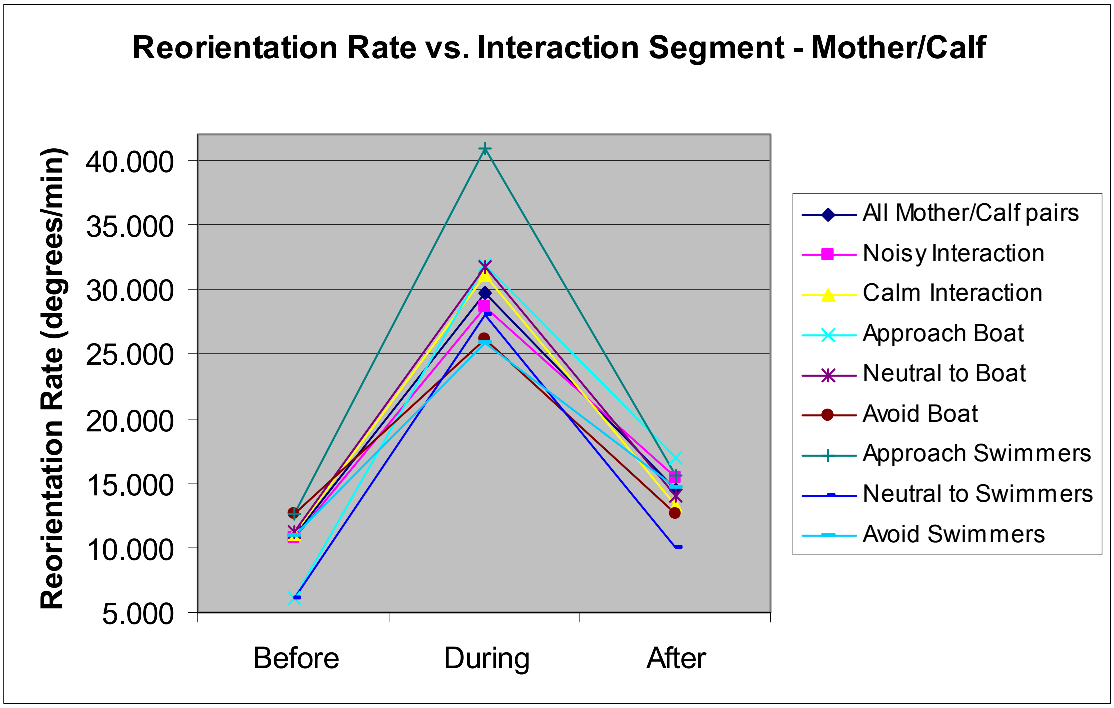

Figure 21. Reorientation rate for mother/calf pairs before, during and after interaction with swimmers relative to interaction type, reaction to boat and reaction to swimmers.

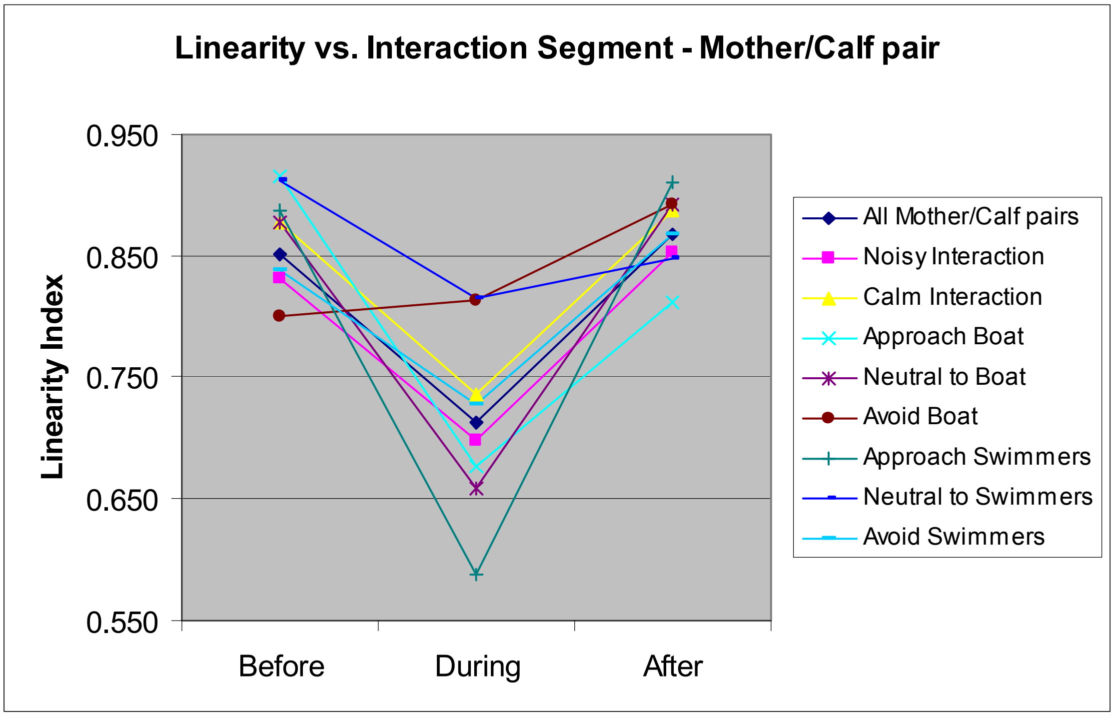

Figure 22. Linearity for mother/calf pairs before, during and after interaction with swimmers relative to interaction type, reaction to boat and reaction to swimmers.

Effect of Interaction on the Movement Patterns of Juvenile Whales

A statistically significant effect on linearity and reorientation rate was found when comparing the Before (B), During (D) and After (A) segments for juvenile whales. Linearity decreased significantly during the interaction. Reorientation rate increased during the interaction and decreased after it was over. During noisy interactions, linearity decreased significantly during the interaction and reorientation rate increased during the interaction. Calm interactions resulted in an increase in reorientation rate during the interaction.

Juvenile whales which approached the boat showed a significant increase in reorientation rate during the interaction. Animals which were neutral to the boat showed significantly decreased linearity and significantly decreased leg speed during the interaction. Their reorientation rate also increased during the interaction. Animals which approached the swimmers showed significantly decreased linearity during the interaction. Their reorientation rate also increased during the interaction and decreased after it was over (Tables 14 – 16).

Table 14. Movement characteristics before (B), during (D) and after (A) the interaction for all juveniles, including split by interaction type. Significance values are shown for comparison (1) B vs. D, (2) D vs. A, and (3) B vs. A.

Variable	Before	During	After	Significance
Leg Speed (km/h) (n = 25)	1.59 ± 0.73	1.34 ± 0.71	1.42 ± 0.60	(1) NS (2) NS (3) NS
Noisy Interaction (n = 11)	1.64 ± 0.63	1.52 ± 0.76	1.33 ± 0.58	(1) NS (2) NS (3) NS
Calm Interaction (n = 14)	1.56 ± 0.82	1.20 ± 0.66	1.49 ± 0.63	(1) NS (2) NS (3) NS
Acceleration (km/h) (n = 24)	-.01 ± .05	.05 ± .07	-.01 ± .07	(1) NS (2) NS (3) NS
Noisy Interaction (n = 11)	-.01 ± .05	.02 ± .07	-.01 ± .06	(1) NS (2) NS (3) NS
Calm Interaction (n = 13)	-.01 ± .04	.00 ± .07	-.02 ± .08	(1) NS (2) NS (3) NS
Reorientation rate (°/min) (n = 24)	**14.6 ± 18.0**	**26.5 ± 20.2**	**17.8 ± 13.8**	**(1) p < 0.001** **(2) p = 0.020** (3) NS
Noisy Interaction (n = 11)	**13.9 ± 16.2**	**25.2 ± 21.3**	18.4 ± 15.5	**(1) p = 0.015** (2) NS (3) NS
Calm Interaction (n = 13)	**15.3 ± 19.8**	**27.7 ± 19.5**	13.2 ± 12.3	**(1) p = 0.002** (2) NS (3) NS
Linearity Index (n = 25)	**.90 ± .17**	**.72 ± .26**	.85 ± .17	**(1) p = 0.001** (2) NS (3) NS
Noisy Interaction (n = 11)	**.93 ± .11**	**.67 ± .30**	.87 ± .12	**(1) p = 0.003** (2) NS (3) NS
Calm Interaction (n = 14)	.88 ± .20	.77 ± .23	.83 ± .20	(1) NS (2) NS (3) NS

Table 15. Movement characteristics before (B), during (D) and after (A) the interaction for juveniles split by the reaction of the whale to the boat. Significance values are shown for comparison (1) B vs. D, (2) D vs. A, and (3) B vs. A.

Variable	Before	During	After	Significance
Leg Speed (km/h)				
Approach (n = 13)	1.34 ± 0.71	1.34 ± 0.68	1.47 ± 0.69	(1) NS (2) NS (3) NS
Neutral (n = 11)	**1.94 ± 0.65**	**1.29 ± 0.80**	1.39 ± 0.52	**(1) p = 0.040** (2) NS (3) N/A
Avoid (n = 1)	1.06 ± 0.00	1.80 ± 0.00	1.06 ± 0.00	(1) N/A (2) N/A (3) N/A
Acceleration (km/h)				
Approach (n = 13)	-.01 ± .04	-.00 ± .08	-.01 ± .08	(1) NS (2) NS (3) NS
Neutral (n = 10)	-.01 ± .06	-.03 ± .05	-.02 ± .05	(1) NS (2) NS (3) NS
Avoid (n = 1)	-.02 ± .00	-.07 ± .00	.04 ± .00	(1) N/A (2) N/A (3) N/A
Reorientation rate (°/min)				
Approach (n = 13)	**15.6 ± 21.9**	**34.8 ± 28.8**	18.2 ± 15.3	**(1) p = 0.023** (2) NS (3) NS
Neutral (n = 10)	**13.8 ± 14.3**	**22.8 ± 14.6**	17.7 ± 11.9	**(1) p = 0.002** (2) NS (3) NS
Avoid (n = 1)	16.6 ± 28.1	22.4 ± 9.9	16.7 ± 22.2	(1) NS (2) NS (3) NS
Linearity Index				
Approach (n = 13)	.87 ± .20	.73 ± .27	.86 ± .17	(1) NS (2) NS (3) NS
Neutral (n = 11)	**.93 ± .12**	**.76 ± .24**	.82 ± .18	**(1) p = 0.029** (2) NS (3) NS
Avoid (n = 1)	.99 ± .00	.26 ± .00	.92 ± .00	(1) N/A (2) N/A (3) N/A

Table 16. Movement characteristics before (B), during (D) and after (A) the interaction for juveniles split by the reaction of the whale to the swimmers. Significance values are shown for comparison (1) B vs. D, (2) D vs. A and (3) B vs. A.

Variable	Before	During	After	Significance
Leg Speed (km/h)				
Approach (n = 17)	1.62 ± 0.81	1.03 ± 0.60	1.25 ± 0.57	(1) NS (2) NS (3) NS
Neutral (n = 5)	1.70 ± 0.65	2.07 ± 0.56	1.95 ± 0.26	(1) NS (2) NS (3) NS
Avoid (n = 3)	1.25 ± 0.26	1.86 ± 0.06	1.52 ± 0.77	(1) NS (2) NS (3) NS
Acceleration (km/h)				
Approach (n = 17)	-.01 ± .05	.02 ± .06	-.02 ± .05	(1) NS (2) NS (3) NS
Neutral (n = 4)	.02 ± .02	-.03 ± .12	-.02 ± .12	(1) NS (2) NS (3) NS
Avoid (n = 3)	.00 ± .02	-.02 ± .04	.04 ± .04	(1) NS (2) NS (3) NS
Reorientation rate (°/min)				
Approach (n = 17)	**14.8 ± 19.0**	**34.2 ± 23.3**	**16.6 ± 11.3**	**(1) p < 0.001** **(2) p = 0.010** (3) NS
Neutral (n = 4)	13.8 ± 14.5	18.3 ± 14.3	18.1 ± 14.6	(1) NS (2) NS (3) NS
Avoid (n = 3)	15.1 ± 19.9	17.9 ± 9.7	19.8 ± 18.2	(1) NS (2) NS (3) NS
Linearity Index				
Approach (n = 17)	**.87 ± .19**	**.69 ± .24**	.83 ± .18	**(1) p = 0.003** (2) NS (3) NS
Neutral (n = 5)	.98 ± .02	.84 ± .28	.84 ± .19	(1) NS (2) NS (3) NS
Avoid (n = 3)	.98 ± .04	.74 ± .42	.92 ± .04	(1) NS (2) NS (3) NS

General Trends of Effects on the Movement Patterns of Juvenile Whales

Juvenile whales tended to swim slightly slower during the interaction with swimmers than they swam before the interaction, but sub-groups showed a variety of different responses. Noisy interactions caused the animals to slow down less than calm interactions. Whales which avoided the boat or swimmers swam faster during the interaction, the opposite of the overall class. Animals which were neutral or approached the boat or swimmers did not show a clear trend in their response. Juvenile whales showed a general trend of increasing their rate of acceleration during the interaction and decreasing it after the interaction. Juveniles which avoided the boat or swimmers showed the opposite trend during and after interactions.

Reorientation rate increased during the interaction for all juvenile sub-groups. It subsequently decreased to near the original rate after the interaction for all groups except those which avoided swimmers. Juveniles that approached the boat or swimmers reoriented much more often than those which were neutral or avoided the boat or swimmers. Linearity decreased during the interaction for all juvenile sub-groups and increased back to near the original rate after the interaction. Whales which avoided the boat or swimmers generally showed a stronger decrease in linearity during the interaction (Figures 23 – 26).

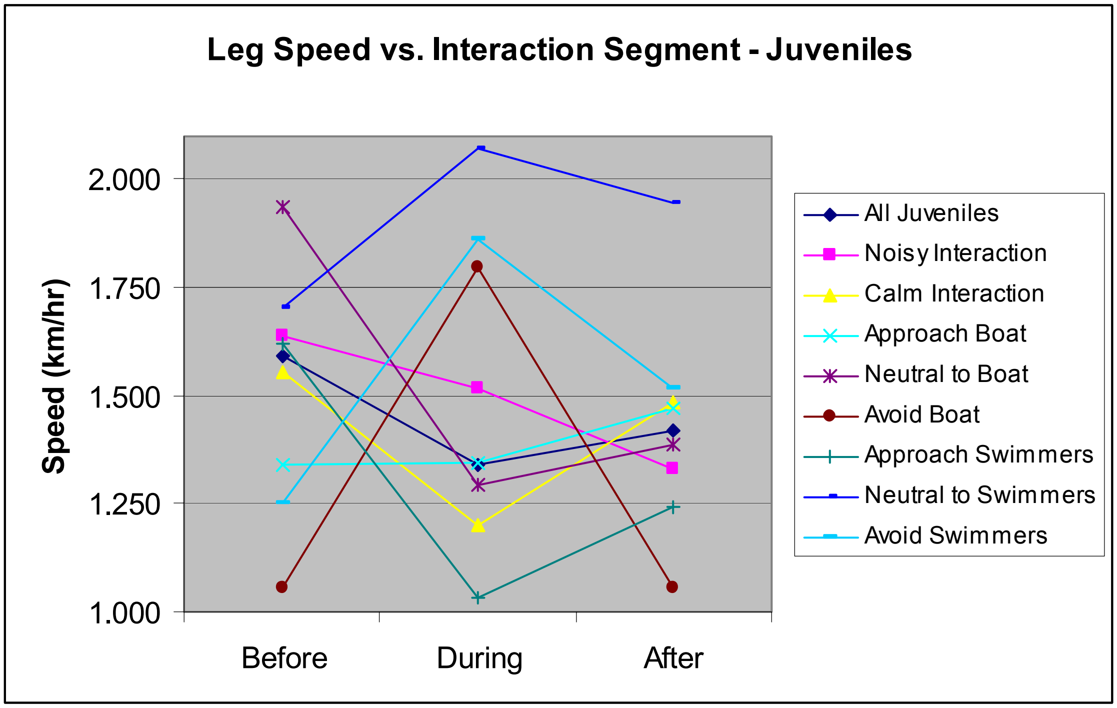

Figure 23. Leg speed for juveniles before, during and after interaction with swimmers relative to interaction type, reaction to boat and reaction to swimmers.

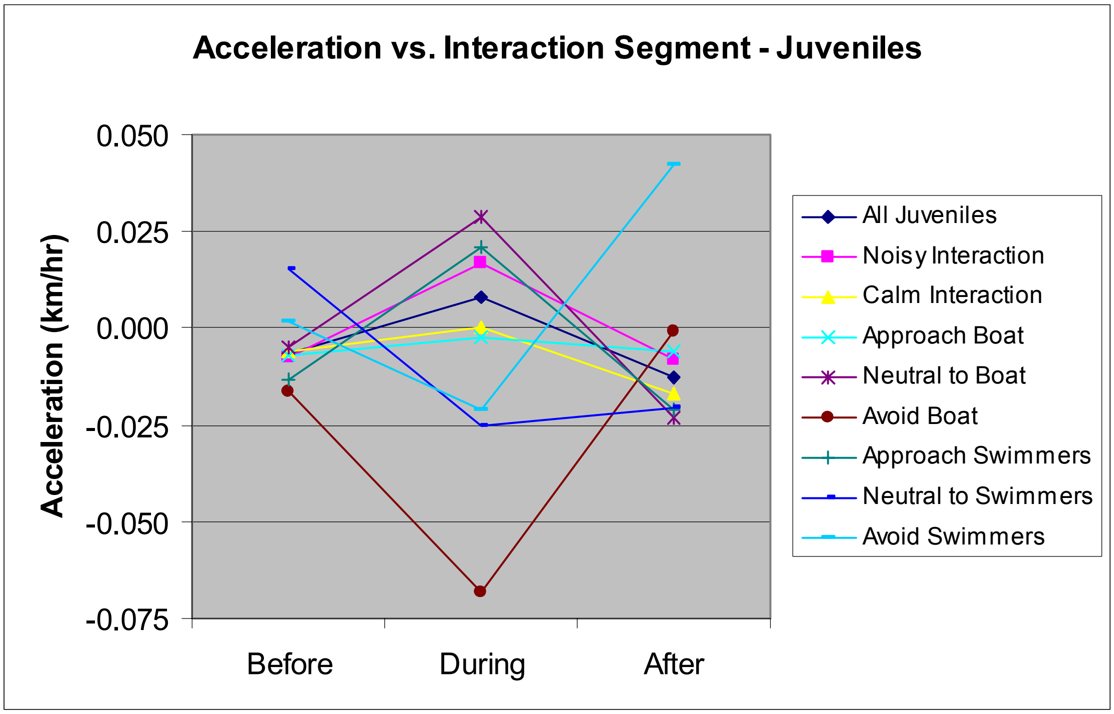

Figure 24. Acceleration for juveniles before, during and after interaction with swimmers relative to interaction type, reaction to boat and reaction to swimmers.

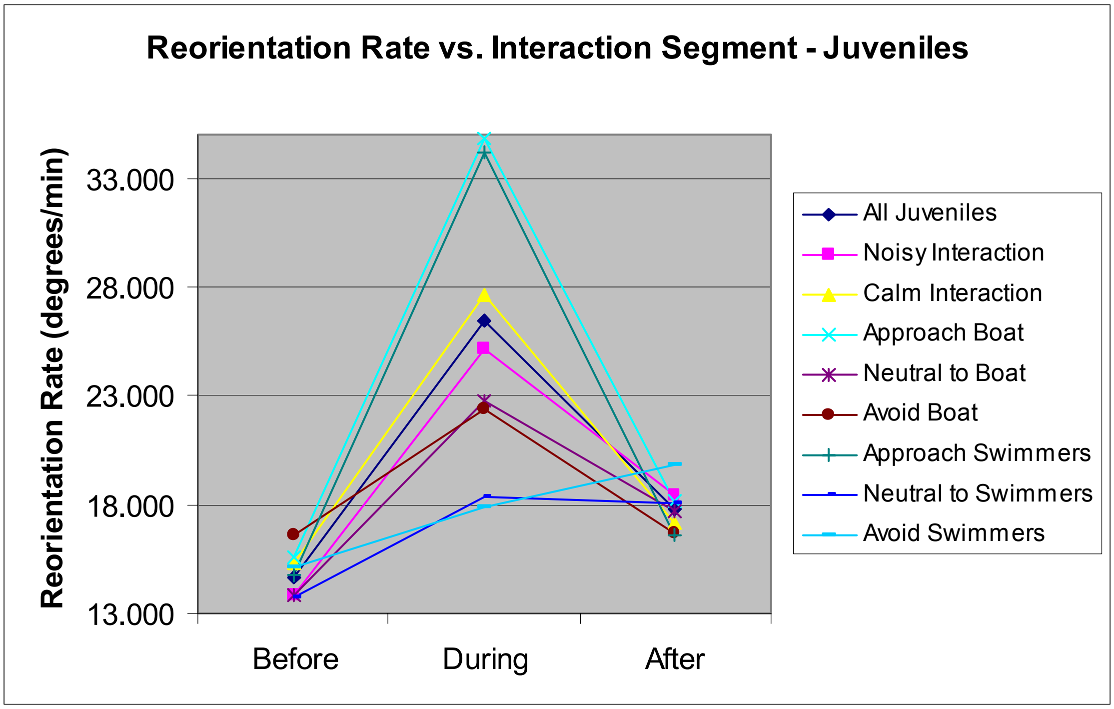

Figure 25. Reorientation rate for juveniles before, during and after interaction with swimmers relative to interaction type, reaction to boat and reaction to swimmers.

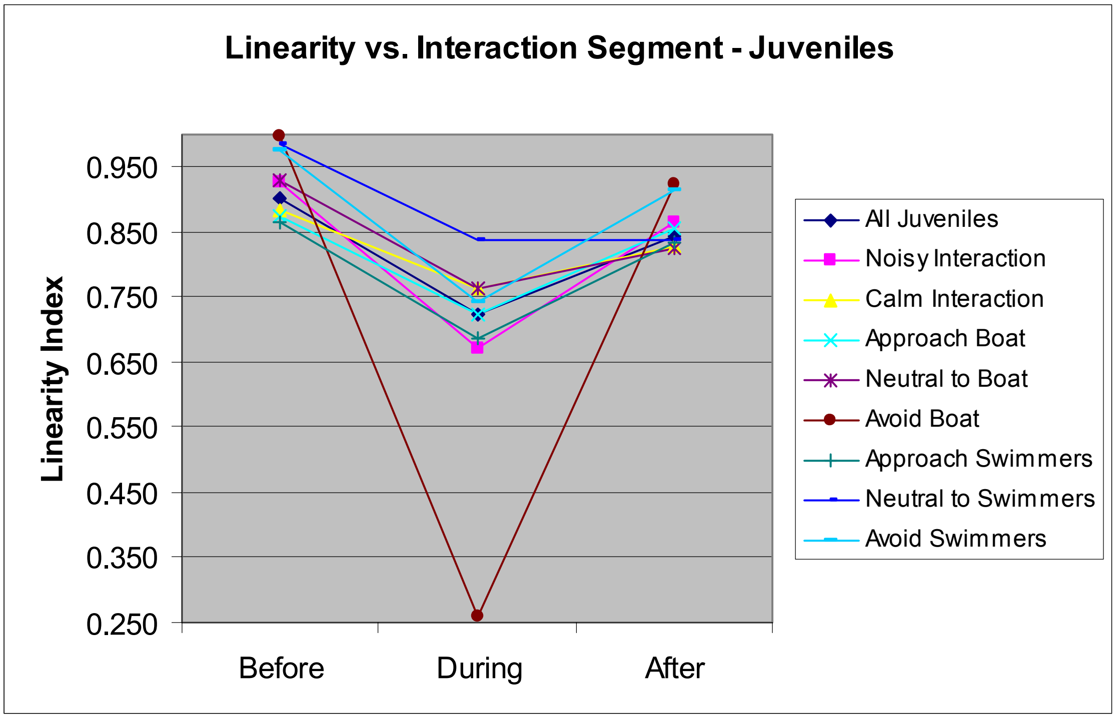

Figure 26. Linearity for juveniles before, during and after interaction with swimmers relative to interaction type, reaction to boat and reaction to swimmers.

Effect of Interaction on the Movement Patterns of Adult and Mixed-Age Groups

No statistically significant effects were found when comparing the Before (B), During (D) and After (A) segments for adult or mixed-age groups of whales. The animals swam faster, reoriented more and swam in a less linear direction during the interaction. They increased their speed further after it was over, reoriented less and swam in a more linear fashion. Noisy interactions resulted in an increase in speed during and after the interaction and almost no change in reorientation or linearity, while the animals returned to their initial speed after calm interactions and reoriented more often during them. At least seven of the 30 adult/mixed-age groups were active mating groups. Four of these groups split up upon the approach of the boat and swimmers (Tables 17 – 19).

Table 17. Movement characteristics before (B), during (D) and after (A) the interaction for all adult/mixed groups, including split by interaction type. Significance values are shown for comparison (1) B vs. D, (2) D vs. A, and (3) B vs. A.

Variable	Before	During	After	Significance
Leg Speed (km/h) (n = 30)	1.57 ± 0.73	1.77 ± 0.86	1.86 ± 1.16	(1) NS (2) NS (3) NS
Noisy Interaction (n = 16)	1.68 ± 0.88	1.98 ± 0.94	2.20 ± 1.39	(1) NS (2) NS (3) NS
Calm Interaction (n = 14)	1.45 ± 0.51	1.53 ± 0.71	1.47 ± 0.67	(1) NS (2) NS (3) NS
Acceleration (km/h) (n = 28)	-.01 ± .09	.00 ± .05	-.03 ± .09	(1) NS (2) NS (3) NS
Noisy Interaction (n = 14)	-.02 ± .13	.01 ± .05	-.05 ± .09	(1) NS (2) NS (3) NS
Calm Interaction (n = 14)	.01 ± .03	-.00 ± .05	-.01 ± .08	(1) NS (2) NS (3) NS
Reorientation rate (°/min) (n = 28)	17.2 ± 17.9	19.0 ± 10.1	16.4 ± 14.5	(1) NS (2) NS (3) NS
Noisy Interaction (n = 14)	18.1 ± 19.7	18.7 ± 11.1	17.6 ± 17.7	(1) NS (2) NS (3) NS
Calm Interaction (n = 14)	16.3 ± 16.7	19.4 ± 9.4	15.2 ± 11.0	(1) NS (2) NS (3) NS
Linearity Index (n = 30)	.85 ± .22	.82 ± .21	.81 ± .25	(1) NS (2) NS (3) NS
Noisy Interaction (n = 16)	.88 ± .21	.82 ± .25	.82 ± .28	(1) NS (2) NS (3) NS
Calm Interaction (n = 14)	.83 ± .23	.83 ± .17	.80 ± .22	(1) NS (2) NS (3) NS

Table 18. Movement characteristics before (B), during (D) and after (A) the interaction for adult/mixed groups split by the reaction of the whale to the boat. Significance values are shown for comparison (1) B vs D, (2) D vs A, and (3) B vs A.

Variable	Before	During	After	Significance
Leg Speed (km/h)				
Approach (n = 3)	1.42 ± 0.79	1.91 ± 1.50	1.82 ± 0.72	(1) NS (2) NS (3) NS
Neutral (n = 23)	1.49 ± 0.68	1.61 ± 0.76	1.64 ± 0.92	(1) NS (2) NS (3) NS
Avoid (n = 4)	2.12 ± 0.93	2.59 ± 0.48	3.12 ± 1.96	(1) NS (2) NS (3) NS
Acceleration (km/h)				
Approach (n = 3)	.04 ± .02	.02 ± .09	-.03 ± .03	(1) NS (2) NS (3) NS
Neutral (n = 21)	.00 ± .07	-.00 ± .04	-.03 ± .10	(1) NS (2) NS (3) NS
Avoid (n = 4)	-.09 ± .20	.01 ± .08	-.02 ± .05	(1) NS (2) NS (3) NS
Reorientation rate (°/min)				
Approach (n = 3)	20.1 ± 16.9	17.2 ± 10.4	8.0 ± 5.1	(1) NS (2) NS (3) NS
Neutral (n = 21)	16.2 ± 16.0	19.2 ± 10.8	17.4 ± 13.1	(1) NS (2) NS (3) NS
Avoid (n = 4)	20.3 ± 31.1	19.5 ± 8.5	17.3 ± 25.6	(1) NS (2) NS (3) NS
Linearity Index				
Approach (n = 3)	.91 ± .08	.61 ± .48	.94 ± .05	(1) NS (2) NS (3) NS
Neutral (n = 23)	.86 ± .19	.85 ± .15	.80 ± .25	(1) NS (2) NS (3) NS
Avoid (n = 4)	.78 ± .42	.79 ± .24	.79 ± .38	(1) NS (2) NS (3) NS

Table 19. Movement characteristics before (B), during (D) and after (A) the interaction for adult/mixed groups split by the reaction of the whale to the swimmers. Significance values are shown for comparison (1) B vs D, (2) D vs A, and (3) B vs A.

Variable	Before	During	After	Significance
Leg Speed (km/h)				
Approach (n = 10)	1.44 ± 0.76	1.21 ± 0.51	1.67 ± 0.84	(1) NS (2) NS (3) NS
Neutral (n = 9)	1.47 ± 0.47	1.75 ± 1.00	1.75 ± 1.11	(1) NS (2) NS (3) NS
Avoid (n = 11)	1.77 ± 0.88	2.29 ± 0.69	2.12 ± 1.47	(1) NS (2) NS (3) NS
Acceleration (km/h)				
Approach (n = 10)	-.01 ± .05	-.01 ± .04	-.05 ± .11	(1) NS (2) NS (3) NS
Neutral (n = 8)	.03 ± .08	.00 ± .05	-.00 ± .10	(1) NS (2) NS (3) NS
Avoid (n = 10)	-.03 ± .13	.02 ± .06	-.04 ± .05	(1) NS (2) NS (3) NS
Reorientation rate (°/min)				
Approach (n = 10)	16.5 ± 16.0	21.0 ± 11.7	14.0 ± 8.9	(1) NS (2) NS (3) NS
Neutral (n = 8)	17.6 ± 16.7	17.4 ± 11.1	16.4 ± 14.1	(1) NS (2) NS (3) NS
Avoid (n = 10)	17.6 ± 22.2	18.4 ± 8.3	18.9 ± 19.7	(1) NS (2) NS (3) NS
Linearity Index				
Approach (n = 10)	.83 ± .21	.80 ± .20	.85 ± .21	(1) NS (2) NS (3) NS
Neutral (n = 9)	.85 ± .20	.90 ± .09	.79 ± .24	(1) NS (2) NS (3) NS
Avoid (n = 11)	.87 ± .25	.78 ± .28	.79 ± .30	(1) NS (2) NS (3) NS

General Trends of Effects on the Movement Patterns of Adult or Mixed-Age Whales

Adult and mixed-age groups generally swam faster during an interaction with swimmers, and continued or slightly increased their speed after it finished. This was true of all sub-groups except those which approached the swimmers, which slowed down during the interaction and sped up afterward. Noisy interactions resulted in faster swimming speeds than calm interactions. Animals which avoided the boat or swimmers swam faster than those which were neutral or approached the boat or swimmers.

Acceleration, reorientation rate and linearity showed no clear trends for adult/mixed-age groups. During the interaction, the animals tended to increase their rate of acceleration, reorient more often and swim in a less linear fashion. Afterward, the animals accelerated less, reoriented less and swam in a slightly less linear fashion. The one strong exception to these trends was among animals which approached the boat. These animals decreased their acceleration, reoriented much less and swam in a less linear path (Figures 27 – 30).

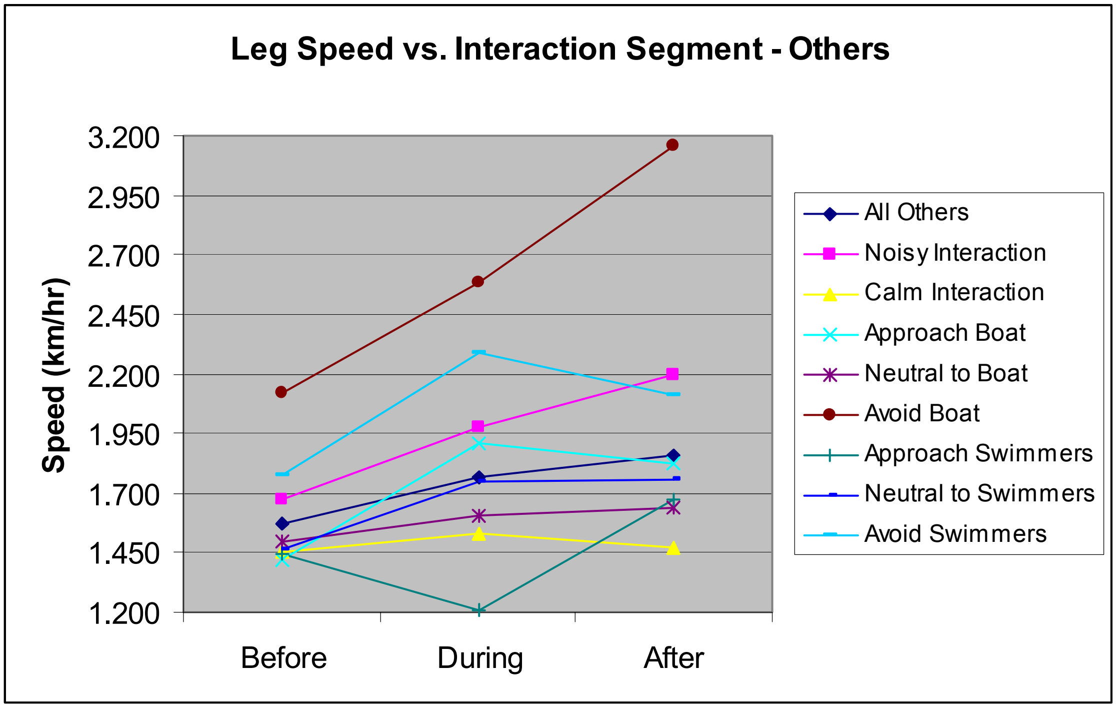

Figure 27. Leg speed for adult/mixed-age groups before, during and after interaction with swimmers relative to interaction type, reaction to boat and reaction to swimmers.

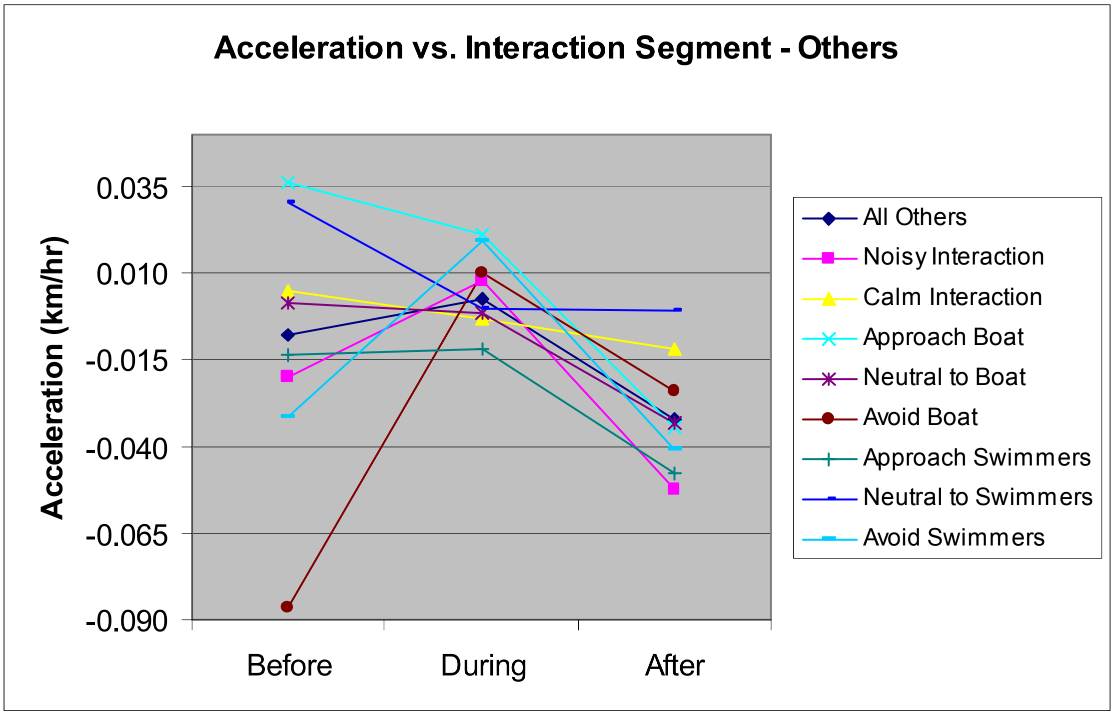

Figure 28. Acceleration for adult/mixed-age groups before, during and after interaction with swimmers relative to interaction type, reaction to boat and reaction to swimmers.

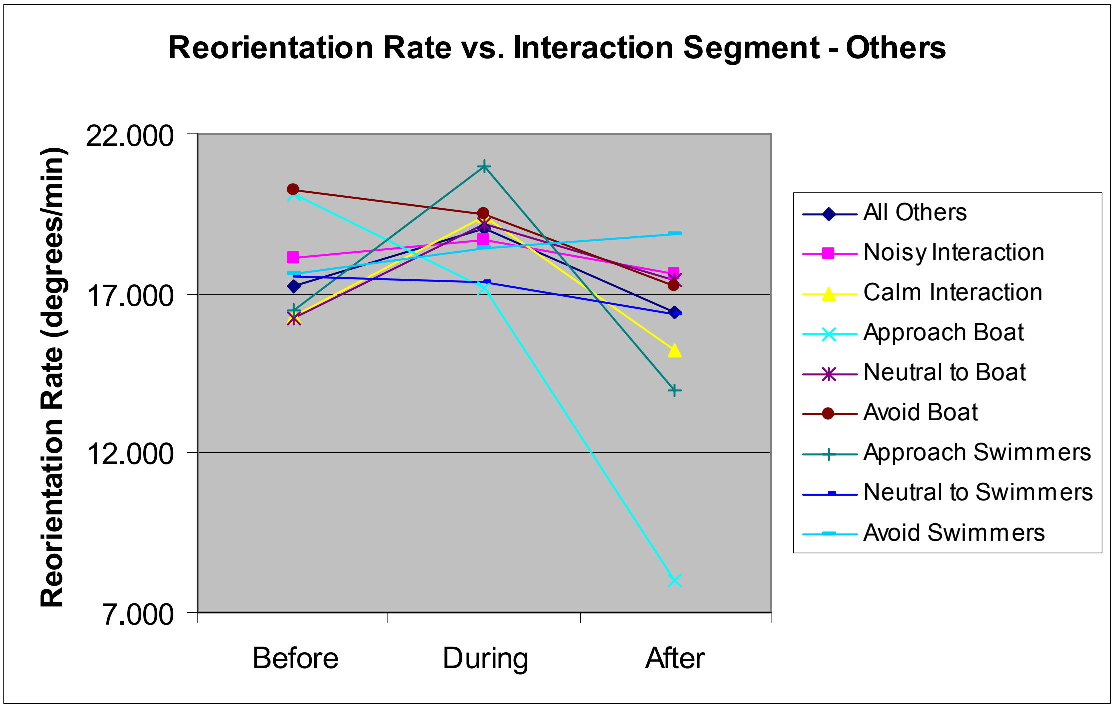

Figure 29. Reorientation rate for adult/mixed-age groups before, during and after interaction with swimmers relative to interaction type, reaction to boat and reaction to swimmers.

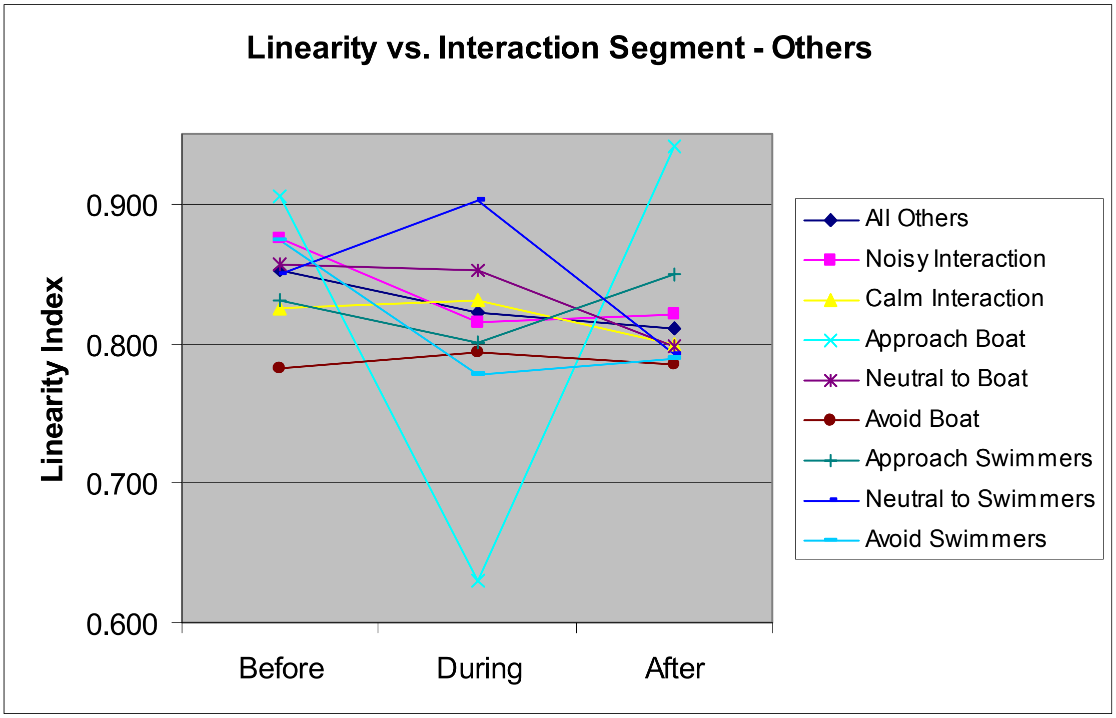

Figure 30. Linearity for adult/mixed-age groups before, during and after interaction with swimmers relative to interaction type, reaction to boat and reaction to swimmers.

Effects on Animals Which Avoided the Interaction

A statistically significant effect was found on Leg Speed when comparing the Before (B), During (D) segments for whales which avoided the interaction ("No Swimmer Interaction"). Whales which did so swam significantly faster when the boat approached within 500 m. No significant effects were found on acceleration, reorientation rate or linearity, though there was a trend toward accelerating faster, reorienting more often and swimming in a less linear path (Table 20).

Table 20. Movement characteristics before (B), during (D) and after (A) the interaction for whales which avoided the interaction.

Variable	Before	During	Significance
Leg Speed (km/h) (n = 12)	**1.88 ± 0.28**	**2.91 ± 0.37**	**(1) p = 0.04**
Acceleration (km/h) (n = 12)	.02 ± .06	.03 ± .09	(1) NS
Reorientation rate (°/min) (n = 12)	7.0 ± 2.5	13.4 ± 3.3	(1) NS
Linearity Index (n = 12)	.94 ± .03	.84 ± .06	(1) NS

DISCUSSION

Experimental swimmer interactions with whales had a significant effect on movement characteristics of whales compared to their movement characteristics prior to the interaction. Effects lasted throughout the duration of the interaction, varying in intensity with group composition. Group composition was the most important factor in predicting the response of whales to the interaction. The initial reaction of whales to the boat and swimmers was another important factor in predicting the response. Swimmer behavior was less important but still affected the magnitude of response. Whales first begin to alter their behavior at an approach distance of 500 meters.

While this 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, particularly in an area which is normally closed to boat traffic. Additionally, other studies of cetaceans have indicated 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 Effects on Movement due to Experimental Interactions with Swimmers

Interactions with the dive boat and swimmers had a clear effect on each of the movement characteristics of whales, regardless of swimmer behavior or the initial reaction of the whales to the boat and swimmers. Whales generally swam faster during the interaction and maintained approximately the same speed after the interaction. Stronger effects on speed were seen for interactions where the swimmers were noisy than interactions where they were calm. Whales that avoided the boat or swimmers showed the greatest increases in speed, followed by whales which were neutral to the boat or swimmers and then whales which approached the boat or swimmers. Whales that approached the swimmers slowed down during the interaction and returned to their "normal" speed after the interaction, showing an opposite trend when compared with all other groups.

In most cases, whales increased their rate of acceleration during the interaction and decreased it after. There were no obvious trends seen relative to noisy versus calm interactions or the initial reaction of the whale to the boat or swimmers. Animals which were neutral to the swimmers actually decelerated during the interaction, which is the opposite of what might be expected. This may be counterintuitive, but we often observed interactions where the initial reaction was neutral (generally meaning the whale was traveling and continued traveling), followed by a period where the whale stopped and turned toward the swimmers.

All whales showed an increase in reorientation rate during the interaction, followed by a decrease back to near the original rate afterward. Whales which approached the boat or swimmers showed the greatest increases, while those which were neutral or avoided showed less of an effect. Noisy and calm swimmer behavior elicited essentially the same change in reorientation rate.

Linearity decreased for all animals during the interaction, and increased back to the original afterward for all but those where the whale was neutral to the swimmers. The effects generally seemed to be stronger for whales which approached the boat or swimmers, with smaller effects for those which were neutral or avoided the interaction. Effects due to noisy swimmers were stronger than those due to calm swimmers.

These results are similar to those reported for other cetacean species relative to approaching boats. Ollervides (2001) reported that gray whales at Bahia Magdalena, Mexico also swam in a less linear path and reoriented more often, but swam at slower speeds when a boat was present within 3500 m. Jahoda et al. (2003) reported that fin whales in the Mediterranean Sea significantly increased their speed when approached by a small craft used for biopsy sampling. Williams et al. (2002) reported that killer whales at Johnstone Strait, British Columbia responded differently to experimental approaches depending on the sex of the animal. Females swam faster during the approach, while males maintained their previous speed but traveled in a less linear path.

Overall, effects on movement of whales followed certain trends. They swam faster, reoriented more often and swam in a less linear fashion during the interaction. These effects were greater for interactions where swimmers were noisy than those where swimmers were quiet. Animals which avoided the boat or swimmers swam faster and in a more linear fashion than those which approached the boat or swimmers. Each of these effects has the potential to result in greater energy expenditure for the whales, 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 the interaction with swimmers may not involve a direct increase in energy expenditure, but they are indicative of changes in the movement patterns of whales compared to those of undisturbed animals. These changes have the potential to result in negative effects on the way right whales use their habitat at Península Valdés and on their socialization patterns at this nursery ground. Whales that were swimming toward their preferred locations in the bays and 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 micro-habitat use were modified, socialization time was reduced and interactions among whales were interrupted.

The reduction in socializing time can have negative effects on 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 the 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.

Effects of Swimmer Interactions on the Movement of Different Group Types

Groups of different composition responded differently to the interaction with swimmers. Mother/calf pairs had statistically significant responses in all interactions, regardless of swimmer behavior or initial reaction of the whales to the boat or swimmers. Juvenile whales had fewer statistically significant reactions, but still showed effects in most scenarios. Adult and mixed-age groups did not show statistically significant effects in any scenario.

Mother/Calf Pairs

Each of the alterations in movement described above has the potential to result in more energy expenditure by mother/calf pairs, regardless of how the swimmers act or how whales react to the interaction. This is important, as Península Valdés is where calves are born, rest, and gain weight and strength in preparation for the long ocean migration at the end of the season (Payne 1986, Payne et al. 1991). Whales are very rarely seen feeding in this area, and the mothers rely upon their fat reserves to keep themselves and their calves alive (Payne 1986). Activities which cause them to expend even more energy have the potential to affect calf mortality by slowing their rate of growth (see Perry 1998 for a review of possible energetic implications).

Right whale mother/calf pairs prefer waters of certain depths in specific bays during their time at the Península (Payne 1986; Rowntree et al. 2001). However, mother/calf pairs repeatedly changed their direction of travel during our experiments, indicating that they may have been forced to move away from their preferred water depths and areas along the shoreline in the study sites. If the animals become displaced to sub-optimal habitat, they may be exposed to greater risk from predators such as orcas (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 the social learning and preparation for migration of the calf (Taber and Thomas 1982, Thomas and Taber 1984).

Previous studies of the movement of right whales (summarized by Campagna et al. 1995) at the Península did not find a significant difference in speed between Golfo San José (where very little boat traffic occurs) and Golfo Nuevo (where whalewatching activity occurs) for mother/calf pairs. 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 speed for mother/calf pairs during an interaction. This difference was attributable to mother/calf pairs that avoided the boat and swimmers. The fact that the research boat in our study approached the whales within a few meters may be the reason why we observed significantly higher speeds. It remains a possibility, however, that mother/calf pairs which were neutral or approached the boat were incapable of swimming fast enough to avoid the boat.

The effects shown here are underestimated, particularly for mother/calf pairs. There were 31 groups that we attempted to approach and swim with, but were unable to because the animals 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 indication that mother/calf pairs are particularly disturbed by boat approaches.

Juveniles

Juvenile whales spend a large portion 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 tourism operator's perspective, these whales are often the "best" for swim-with activities, as they are most likely to approach the swimmers and engage in lengthy up-close encounters. Tourist activity, however, may interrupt or delay the behavioral development which whales normally undergo in this area. In several instances, we observed juvenile animals which had been socializing for several hours 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 animals made them more likely to approach swimmers close enough to make physical contact, creating 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. It may be that there are different sub-types within our designation of "Other" that have very clear and significant reactions to the activity, but we did not identify them (or have a large enough sample size) and could not analyze the data as such. Two such sub-types come to mind – solitary adults and mating groups. During the course of the study, we attempted to interact with several large, solitary adults which were likely pregnant females. Each time the whale actively avoided the boat, diving for an extended period of time and swimming rapidly away. Most calves are born in August (Payne 1986), so disturbing those whales was a particular concern early in the season, when there are more females in the area who have not yet given birth (Payne 1986).

Mating groups are also a concern for swim-with tourism. Approaching with a boat and attempting to put swimmers in the water generally resulted in the group splitting up and swimming in different directions. This has a direct impact on the ability of the animals to mate and conceive. Beyond that, it is inherently dangerous for the swimmers. These groups are quite active and move rather unpredictably, so the potential for a swimmer to be injured is elevated.

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

Based on the trends observed above, the initial reaction of the whale to the approach of the boat or the entry of the swimmers into the water can be used to predict the overall effects on the behavior and movement patterns of the animal. Whales which initially avoid the interaction will swim faster and in a straighter path than those which do not avoid the interaction. Whales which approach the boat/swimmers will slow down and travel in a more circuitous path.

The energetic requirements of the two different responses are unknown, so we cannot say whether the animals avoiding the interaction are expending more energy or experiencing stress associated with the encounter. Stress is a biological response to a perceived threat which 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 which may determine whether “stress” becomes “distress”: length of time the individual is exposed to the stressor, intensity of the stressor, cumulative effects from multiple sources of stress, 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. Stress has been linked to these consequences, however, 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.

CHAPTER IV

SUMMARY OF RESULTS

Interactions with swimmers had a significant effect on the behavior and movement of right whales. Group composition was an important factor in quantifying the magnitude of effects. The initial reaction of the whale to the approach of the boat and entry of swimmers into the water was a good predictor of the overall effects on the behavior and movement patterns of the animal. Whales which initially avoided the interaction swam faster and in a straighter path than those which do not avoid the interaction. Whales which approached the boat/swimmers slowed down and traveled in a more circuitous path. Swimmer behavior did not have a significant effect on the response of the whales.

SUMMARY OF RESULTS FOR MOTHER/CALF PAIRS

The majority of mother/calf pairs actively avoided the approach of the boat and the interaction with swimmers, typically by significantly increasing their swimming speed. This increase in speed continued during and after the interaction. During the interaction, the pairs significantly decreased the amount of time they spent resting and significantly increased the amount of time spent in active behaviors. Pairs which approached or were neutral to the boat or swimmers changed their direction of travel significantly more often during the interaction. Mothers nearly doubled the amount of time between respirations after the interaction was over. All other variables returned to levels near to pre-disturbance values after the interaction was over.

SUMMARY OF RESULTS FOR JUVENILES

During the interaction, juvenile right whales significantly decreased the amount of time they spent resting and significantly increased the amount of time spent in active behaviors. Juveniles significantly altered their swimming patterns during the interaction to travel in a more circuitous path. This was particularly the case for juveniles that approached the boat and/or swimmers, which constituted one-half (13 of 25 for the boat) to two-thirds (17 of 25 for the swimmers) of all juveniles.

SUMMARY OF RESULTS FOR ADULT/MIXED GROUPS

Adult and mixed groups had non-significant decreases in the amount of time spent resting and increases in the amount of time spent in active behaviors. No movement characteristics showed a significant change due to the interaction. The majority of adult/mixed groups (23 of 30) were neutral to the approach of the boat, but showed varying reactions to the swimmers (one-third approach, one-third neutral, one-third avoid).

REGULATING FOR SUSTAINABLE SWIM-WITH TOURISM

If swimming with whales is legalized in the Province of Chubut, there are several issues which must be addressed to ensure that the tourism activity does not have negative impacts on southern right whales. The results of this study may be used to establish a set of preliminary regulations that protect the animals 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, so the results from this study in Argentina may be used as a basis for comparison elsewhere. Other species may react differently, however, so caution should be exercised when interpreting these results in other locations.

Mother/calf pairs are the most vulnerable of all age classes, and show the greatest effects on both behavior and movement when interacting with boats and swimmers. Juveniles are more likely to initiate interactions with swimmers, but may be interrupting normal social development to do so. Adult and mixed-age groups show the least effects of all, but there is a potential for negative effects when approaching mating groups or pregnant females.

With this thesis, I am providing data that may be used by managers, regulators, tour guides, and tourists. I do not believe that it is my position with present data to offer recommendations on whether swimming with southern right whales in Argentina should be legalized, nor what restrictions should be imposed if it is legalized. The exception to this statement is that mother/calf pairs should never be included in this activity. We now know short term behavioral and movement reactions of whales, but do not yet know the long-term biological impact of these reactions.

FUTURE RESEARCH

There are a number of areas of research that would assist in quantifying the impact of these activities. Many of these issues will take broad-based, long-term studies to understand properly. Energetics of the whales is a very important factor which must be understood in order to quantify the effects of the impact. Combining the increased energetic requirements during the interaction with the duration, frequency and distribution of encounters would give us a better idea of the true impact of the activity. If energetic requirements are quite low relative to the lifestyle of the animal (e.g., long migrations which use considerable energy, long periods of no feeding), it may be that the impact of this activity is negligible in the long-term. Certain age classes may have different requirements, particularly mothers and calves. It is also important to understand the effects of human activities on the socialization of these whales. Mating groups, juvenile social groups and mother/calf pairs may all be affected by this activity in ways which 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 may result in avoidance of certain areas, as has been reported as a possibility for bottlenose dolphins relative to tourism activities at Milford Sound, New Zealand (Lusseau 2004).

If swimming with whales is legalized, it will be critical to begin a long-term monitoring program to record behavior and movement of the whales in areas where tourist activity occurs. These data can be used to evaluate whether whales are habituating, tolerating or becoming sensitized to the activity. To assist in this evaluation, it would be valuable to create logs 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 would also be helpful in determining the areas most highly affected. This could then be compared with survey data to evaluate impacts on distribution of the animals. These data should be monitored for potential shifts in localized whale occurrence patterns, by an entire population or a sub-group within the population.

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VITA

Name: David Jeffrey Lundquist

Address: 5007 Avenue U, Galveston, TX 77551

Email: lundquistdave@hotmail.com

Education: B.S., Chemical Engineering, The University of Iowa, May 1995

M.S., Wildlife and Fisheries Sciences, Texas A&M University, May 2007

Work Experience:

January – May 2007:

Teaching assistant for Natural History of Vertebrates laboratory

December 2005 – March 2006:

Data analyst for project assessing Western Gray Whale behavior, movement and occurrence patterns off Sakhalin Island, Russia

June 2005:

Visual observer on SWSS Sperm Whale Tagging Cruise in Gulf of Mexico

July 1995 – March 2004:

Programmer, analyst and IT business consultant with various organizations