

**MOVEMENT PATTERNS, BEHAVIORS, AND WHISTLE SOUNDS  
OF DOLPHIN GROUPS OFF KAIKOURA,  
NEW ZEALAND**

A Thesis

by

SUZANNE E. YIN

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**

August 1999

Major Subject: Wildlife and Fisheries Sciences

**MOVEMENT PATTERNS, BEHAVIORS, AND WHISTLE SOUNDS  
OF DOLPHIN GROUPS OFF KAIKOURA,  
NEW ZEALAND**

A Thesis

by

SUZANNE E. YIN

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

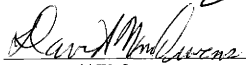
MASTER OF SCIENCE

Approved as to style and content by:



Bernd Würsig

(Chair of Committee)



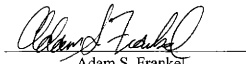
David W. Owens

(Member)



Robert B. Ditton

(Member)



Adam S. Frankel

(Member)



Robert Brown

(Head of Department)

August 1999

Major Subject: Wildlife and Fisheries Sciences

## ABSTRACT

Movement Patterns, Behaviors, and Whistle Sounds of Dolphin

Groups off Kaikoura, New Zealand. (August 1999)

Suzanne E. Yin, B.A., Brown University;

Chair of Advisory Committee: Dr. Bernd Würsig

The dusky dolphin (*Lagenorhynchus obscurus*) is a small delphinid that occurs in temperate waters near Southern Hemisphere land masses. Off Kaikoura, New Zealand, duskies are targeted for interactions by tourist vessels, swimmers and recreational vessels. To determine if human activity influenced dolphin behavior, I conducted shore- and vessel-based studies to examine movement patterns and acoustic behavior of duskies during three field seasons. Small groups of 25 or fewer dolphins were tracked from shore with a theodolite. Three variables; mean leg speed, linearity, and reorientation rate, were examined to determine possible influence of year, season, presence of a calf, time of day, group size, or presence of vessels within 100m, 101-300m and 301-1,000m. Mean leg speeds did not differ significantly by year, season, presence of a calf, or time of day. For group size comparisons, a post-hoc linear regression found a significant relationship between mean leg speeds and group size ( $p=0.0472$ ). Mean speeds for groups containing 6-10, 11-15, and 16-20 animals increased as group sizes increased. Mean leg speeds did not differ by presence of a vessel within 100m, 101-300m, or 300-1,000m. For shore-based studies, mean leg speed may not be the most appropriate parameter to determine effects of human activity. Linearity, a measure of how straight a course was traveled, increased when boats were within 100-300m. Higher values were recorded during boat and post boat conditions than during no boat conditions, indicating that dolphin groups traveled in a more direct fashion during these times. A post-hoc analysis revealed a significant difference between no boat and a combined boat/post boat condition ( $p=0.0419$ ). Reorientation rates were higher when boats were within 101-300m, indicating that dolphins changed course more often when boats were present.

Whistles were recorded when duskies were associated with common dolphins (*Delphinus delphis*), with swimmers, or when duskies were alone. Over 97% of analyzed whistles were recorded when duskies were found in inter-species groups. Whistles may be an indication of excitement levels within the group. More work is necessary to determine if whistles can be used as a reliable indicator of disturbance.

## ACKNOWLEDGMENTS

Like many other bodies of work, this thesis could not have been completed without help from countless numbers of other people. It's wrong to say this is 'my' thesis, because I had tremendous help and support from friends and family.

First, let me thank my committee chair, Bernd Würsig, the paragon of an advisor who took me on as a student after I had spent years wandering around, not a yinking of what was to come. Bernd, you are amazing, helping in the field and lab during data collection and analysis, or purchasing field equipment with personal funds (including a turkey from Christchurch, yum), or providing avuncular advice about what to do when Jordan retired. Thanks for your friendship.

Thanks to my committee members for all of their help, support and patience: Dr. Robert Ditton, Dr. Dave Owens (Daveo) and Dr. Adam Frankel.

Many organizations provided funding for research and travel to scientific meetings: Earthwatch Expeditions, Marine Biology Department at Texas A&M Galveston, Department of Wildlife and Fisheries Sciences in College Station, Marine Research Offshore Fishing Tournament, Galveston Graduate Student Association, and Texas Institute of Oceanography.

In the field, lots of folks helped collect data including Mel and Bernd Würsig, Colin French and Ginny Collins, Nadine Parker, Janet Doherty, Rochelle Constantine, Elizabeth Zúñiga, Stefan Bräger, Jack van Berkel, Chris Gabriele, Kirsty Barr, plus wonderful crews of Earthwatch volunteers, too many to mention here but all part of an unforgettable Kiwi experience. Many thanks to the DE folks who allowed us to tag along with them on many occasions and kept an eye on our wee boat.

Whitlow Au, Ania Driscoll-Lind, Kurt Fristrup, Vincent Janik, Barbara McCowan, Laela Sayigh, Wang Ding, Jeff Norris, Troy Sparks and William Evans all provided helpful suggestions on dolphin vocalization analyses. Jeff, Troy and Dr. Bill graciously allowed me to use their acoustics lab for my acoustic analysis. Dr. Christopher Clark allowed me to visit his Cornell lab for help with Aardvark and Canary.

Many thanks to folks in College Station, especially to Janice Crenshaw who should be the first person any WFSC grad student meets. Thanks to Jane Packard who provided office space in a very crowded Nagle Hall (I will now always react to prairie chicken vocalizations and words like "dialect and repertoire").

In Galveston thanks to Stacie Arms, Theo Byrne, Tammy Holliday, “yinterns” and 485 students who wrestled with Aardvark (repeatedly) and duskies nawnawing: Orianne Aymard, Dani Cholwiak, Silvana Cipriano, Glenn Gailey, Krystal Hill, Jennifer Pettis, Josh Sheldon and Dan Engelhaupt (Giddyup).

Fellow graduate students (in reverse alphabetical order): Elizabeth Züñiga (for being so mean but also for driving me around while I slept), Dave Weller (all the Aardvark help but mostly for starting the short hair trend), Jon Stern (fellow HMMCer), LJ Smith (who is still following me around), Shannon Rankin (for stressing with me), Joel “Stud” Ortega (my buffet food getter), Paco Ollervides (for the many laughs while watching YOU watch Friends, and my massive arm muscles after lugging Dr Pepper to Monaco), Kathy Maze (big hugs and sloppy kisses to you, Cuppycake), Tim Markowitz (thanks for the Toffeepops), April Harlin (we still have that bet going), Glenn Gailey (who was stressing as much as I was during my defense), Holly Fortenberry (a fellow Aardvark survivor), and Avocado (the fan episode still makes me laugh).

Giant hugs to my limousine crew who helped with rides to PT after that horrendous knee surgery (I have the video): Stacie, Lori, Chris Palochik, Karla Klay, Joel, Paco, April, Holly and Jason Turner (thanks also for that stats help). A few folks were especially instrumental in helping me cope with being a peripatetic Yankee who suddenly found herself owning furniture in a land of fried okra and chicken-fried steak: Sarah Stienessen always kept me amused with new words like biff, dahk, cheese curds, Ernesto, and Lienenkoogles, patiently paid my bills while I was off having fun in New Zealand, sent care packages each week to Kaikoura with XFiles, Friends and Cowboys and Bulls games, got me through 652, put up with me as a roommate even though I wasn’t a PG or GLW, and showed me a wonderful new use for salsa. Alison Roberts has become an amazingly close friend in a short period of time. Al, I can’t tell you how much I appreciate the time you spent in Galveston struggling through those bins, the days I’ve spent talking to you on the phone, Zoe leaving (just kidding), Shiner, smoothies, all the support you gave me when I wasn’t my usual self. Thanks for moving to Maui and giving me another reason (unnecessary, of course) for visiting Hawai’i, and the \$20 you owe me for kissing Gator; JTM bud. Rochelle Constantine, my collaborator, who made an American feel at home in a place where All Blacks and Speights rule, sent me toffeepops, introduced me to Ani, placed long international phone calls, thanks Brave-but don’t forget I have a signed promise from you when you take over the marine mammal world. Lori Harrison took me to movies when I needed a break, learned how to open

childproof caps, and gave me really interesting reading by MBE. Joel Ortega helped with Surfer and stats, did not succeed in turning me to the dark side of computers, but left me behind at Foam. Many thanks to Drs. Kruskal, Wallis, Mann, Whitney, Bartlett and Dunn, and Mr. T.

Finally thanks to my family: Mom, Dad, Cliff, and Chris. Thanks for all the love and support and funding during those lean years, for letting me live this crazy life and being patient enough to bear with me. Charles Bah-bah and Auntie Donna for being such wonderful proprietors of the Yin Inn (now closed) and providing a second home. I couldn't have done it without you.

# TABLE OF CONTENTS

CHAPTER	Page
I INTRODUCTION.....	1
Human interactions.....	4
Acoustic behavior.....	6
Objectives and hypotheses .....	7
II MOVEMENT PATTERNS AND BEHAVIORS OF DOLPHIN GROUPS....	9
Introduction .....	9
Study area .....	11
Shore-based observations.....	11
Methods.....	13
Data analysis.....	16
Statistical analysis.....	17
Results.....	19
Case studies .....	36
Discussion .....	38
Future research .....	46
III WHISTLE SOUNDS OF DOLPHIN GROUPS .....	48
Introduction .....	48
Methods.....	48
Statistical analysis.....	52
Results .....	54
Discussion .....	67
Recommendations for future work .....	74
IV CONCLUSIONS.....	77
REFERENCES.....	80
APPENDIX 1 .....	92
APPENDIX 2 .....	104
VITA.....	108



# LIST OF TABLES

	Page
TABLE	
1 Definitions and comments for each activity code .....	18
2 Variables examined in statistical comparisons.....	19
3 Summary of effort.....	19
4 Summary of results of statistical tests for mean leg speed comparisons .....	21
5 Summary of mean leg speeds by group size .....	21
6 Summary of mean leg speeds by time.....	21
7 Summary of mean leg speeds by 100m boat condition .....	22
8 Summary of groups tracked.....	22
9 Summary of results of statistical tests for linearity and reorientation rates.....	36
10 Acoustic recording effort .....	55
11 Breakdown of whistles for each season .....	55
12 Whistles by situation and whistle rate.....	56
13 Behavior and group size of duskies when whistles were recorded.....	57
14 Whistle parameter measurements for all dusky group whistles .....	65
15 Summary of mean values for all groups .....	65
16 ANOVA for SIW and dusky .....	66
17 Comparison of mean values for whistle parameters measured in this study and other acoustic studies .....	68

# LIST OF FIGURES

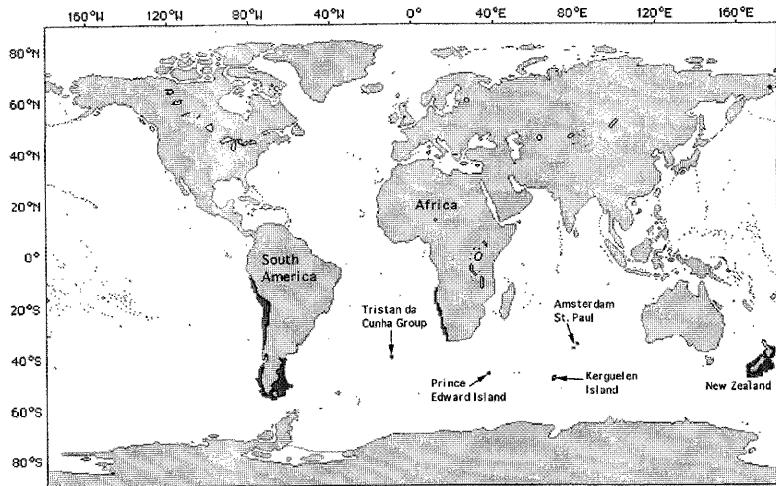
FIGURE		Page
1	World map showing distribution of dusky dolphins .....	2
2	Distribution of dusky dolphins off New Zealand.....	3
3	Map of study area .....	12
4	Mean leg speeds by year.....	23
5	Mean leg speeds separate by season.....	24
6	Mean leg speed by calf .....	25
7	Mean leg speed by group size .....	26
8	Mean leg speeds by time of day .....	27
9a	Mean leg speeds by boat condition using 100m boat criteria.....	28
9b	Mean leg speeds by post boat condition, broken down by time using 100m criteria.....	29
10	Mean leg speeds by boat condition using 300m criteria .....	30
11	Linearity by calf/no calf presence .....	31
12	Reorientation score as a function of calf/no calf groups .....	32
13	Linearity by boat condition with 300m criteria with outliers removed .....	33
14	Reorientation score as a function of 300m boat distance .....	34
15	Spectrogram depicting parameters measured .....	53
16	Comparison of end frequency by whistle condition.....	58
17	Comparison of start frequency by whistle condition.....	60
18	Comparison of low frequency by whistle condition .....	61

FIGURE		Page
19	Comparison of high frequency by whistle condition .....	62
20	Comparison of change in frequency by whistle condition .....	63
21	Comparison of duration by whistle condition.....	64

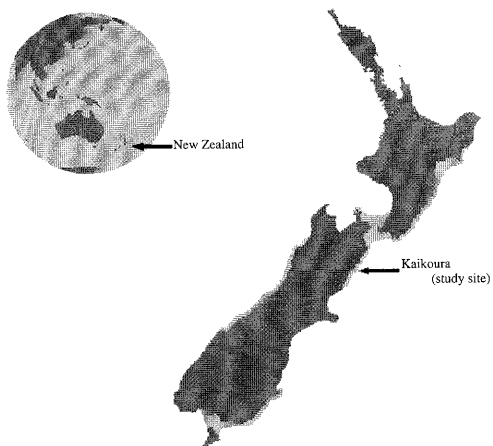
## CHAPTER 1

### INTRODUCTION

The dusky dolphin (*Lagenorhynchus obscurus*) is a small delphinid that occurs in temperate waters near land masses of the Southern Hemisphere (Brownell 1974, Jefferson *et al.* 1993, Brownell and Cipriano 1999). Dusky's, as they are commonly known, are one of six species in the genus *Lagenorhynchus*, a group characterized by an antitropical distribution (Davies 1963, Brownell 1974), stocky body and lack of a prominent rostrum (Gaskin 1968b, Leatherwood and Reeves 1983). Other members of this genus include the white-beaked (*L. albirostris*), Atlantic white-sided (*L. acutus*) and Pacific white-sided dolphin (*L. obliquidens*) of the Northern Hemisphere; and the Peale's (*L. australis*) and hourglass dolphin (*L. cruciger*) of the Southern Hemisphere (Fraser 1966, Gaskin 1968b, Leatherwood and Reeves 1983). Dusky's occur over continental shelf and slope regions off New Zealand, South Africa and South America (Bierman and Slipper 1948a, b; Brownell 1965; Gaskin 1968a, b; Webb 1973a, b; Webber 1987, Findlay *et al.* 1992, Jefferson *et al.* 1993, Van Waerebeek *et al.* 1995, Dans *et al.* 1997b, Rice 1998); as well as off some islands in the South Atlantic and eastern Indian Ocean (Van Waerebeek 1992b, Van Waerebeek *et al.* 1995) (Figure 1). The dusky's of these many areas probably do not mix (Gaskin 1968b, Brownell 1974), though genetic work is currently underway to determine degrees of separation between apparently disjunct populations (Cipriano 1997). Off New Zealand, distribution appears to be associated with the Subtropical Convergence and Canterbury Current (Gaskin 1968a), and has been summarized by Gaskin (1968a, b), Webb (1973a, b), Webber (1987), Constantine (1996), and Würsig *et al.* (1997) (Figure 2). Dusky's in all areas are rarely found in deeper waters away from the continental shelf area (Würsig and Bastida 1986, Jefferson *et al.* 1993, Van Waerebeek *et al.* 1995), though they are occasionally found in waters deeper than 2000m (Findlay *et al.* 1992). Descriptions of biology and behavioral ecology were conducted by Würsig and Würsig (1980) in Argentina; Würsig



*Figure 1.* World map showing distribution of dusky dolphins (dark areas). Adapted from Jefferson et al. 1993 and Van Waerebeek 1995.



*Figure 2.* Distribution of dusky dolphins off New Zealand (shaded areas).

*et al.* (1991) and Cipriano (1992) in New Zealand; and Van Waerebeek (1992a) and Van Waerebeek and Read (1994) in Perú; with other behavioral studies by Webber (1987), McKinnon (1994), Barr (1997), Crespo *et al.* (1997b) and Dans *et al.* (1997a, b). Würsig *et al.* (1997) summarize the recent status of knowledge of dusky dolphins for New Zealand and Brownell and Cipriano (1999) do so worldwide.

### **Human interactions**

Like many coastal delphinids (*e.g.*, Hector's dolphin *Cephalorhynchus hectori* Dawson 1991), interactions between duskies and humans are common. Dusky dolphins have been harpooned and purposefully netted for human consumption in South Africa (Best and Ross 1977) and off ports in Perú and Chile (Read *et al.* 1988, Van Waerebeek and Reyes 1990, Van Waerebeek *et al.* 1997). In the 1980's, the most serious threat to dusky dolphins came from the fisheries off Perú and Chile, where thousands of animals were killed for crab bait and human consumption (Read *et al.* 1988, Van Waerebeek and Reyes 1990, Van Waerebeek *et al.* 1997). This practice is reported to have been discontinued or at least strongly curtailed as of 1997 (Crespo *et al.* 1997a). Duskies also have been killed incidentally in South African purse seines and other nets (Mitchell 1975a, b; Best and Ross 1977), and accidental entanglements are a significant problem in areas of South America (Van Waerebeek and Reyes 1990; Crespo *et al.* 1994, 1997a; Dans *et al.* 1997a) and New Zealand (Cipriano 1992).

Increasing interest in the outdoors, specifically in the marine environment, has led to a different type of interaction between humans and marine mammals. There has been a recent rapid worldwide growth of whale-and dolphin-watching tourism (Hoyt 1992; 1995a, b). Between 1992 and 1994, the last years for which worldwide figures are available (Hoyt 1999 pers. comm.), this industry grew from a 300 million dollar venture into a half billion dollar a year business in over 65 countries (Hoyt 1995a, b; IFAW Tethys Research Institute and Europe Conservation 1995). Over 5.4 million people viewed whales and dolphins in 1994 (Hoyt 1995a, b). This burgeoning tourism trade has dramatically increased interactions between humans and cetaceans (Beach and Weinrich

1989, Constantine and Baker 1997, Gisiner 1998, Jasny 1999, review by Richardson *et al.* 1995) and generated research on tourism on cetaceans (*e.g.*, Watkins 1986, Constantine 1995, Corkeron 1995, Ollervides 1997, Ransom 1998, Williams *et al.* 1998, Bejder *et al.* 1999, Constantine 1999). Many of these studies have documented short-term behavioral reactions, including changes in distribution and speed, avoidance of vessels or swimmers, or changes in vocalizations<sup>1</sup> (Baker *et al.* 1982, Bryant *et al.* 1984, Bauer and Herman 1986, Baker and Herman 1989, Kruse 1991, Constantine 1995, Norris 1995, Bejder 1997, Lesage *et al.* 1999). Though in most instances, studies have not found tourism related effects in survivorship or reproductive success, a minke whale (*Balaenoptera acutorostrata*) was killed and a humpback whale (*Megaptera novaeangliae*) was injured after collisions with whale-watching vessels on Stellwagen Bank, Massachusetts (AP September 15, 1998). Given the long lifespan of many cetaceans and the overwhelming number of possible confounding variables, documenting more subtle long-term effects is a difficult task. This does not diminish the importance of further research, but helps to indicate the critical necessity for long-term studies (Scott *et al.* 1990).

Due to the booming tourist industry and the large possibilities for lucrative financial returns, many communities have changed from primarily fishing or agriculturally-based economies to ones geared more towards tourism, incorporating diving, birdwatching, and whalewatching (Hoyt 1995a, b; IFAW Tethys Research Institute and Europe Conservation 1995). One of the more striking examples of this dramatic transformation to whale- and dolphin- watching has been in New Zealand, especially in the small fishing town of Kaikoura, located on the east coast of the South Island. The waters off Kaikoura provide an excellent place to see dusky dolphins and sperm whales (*Physeter macrocephalus*) in nature. Since 1989, tourist operators seasonally take hundreds of paying passengers out each day weather permitting, by boat, helicopter, and fixed wing airplane to view the marine mammals that are found year-

---

<sup>1</sup> The term vocalization is used in this study, but is not meant to suggest that vocal cords are used in the production of sounds by dolphins. Here the term is used interchangeably with the term sounds to describe sounds produced in the head region.



round in this area. During spring, summer and fall, operators take passengers out every day to see the dolphins. Trips occur during winter months, but only when tourist numbers are sufficient to warrant a trip. New Zealand regulations allow individuals to enter the water and swim with dolphins. Operators are licensed by the New Zealand Department of Conservation (DoC) under the Marine Mammals Protection Regulations (1992) (Appendix 1). Regulations are enforced on number of boat trips per day, number of boats near dolphins or whales, and number of swimmers allowed in the water at any one time. Swimming with mother and juvenile dolphins and whales is not allowed. Within 300m of the animals, vessels should operate at a 'no wake' speed. In Kaikoura, weather permitting, two licensed businesses may take a total of 7 trips and up to 180 passengers each day to swim with duskie and common dolphins (*Delphinus delphis*, frequently called commons) that are often associated with duskie (Würsig *et al.* 1995, pers. obs.).

### Acoustic behavior

Little research has been undertaken to describe vocalizations produced by *Lagenorhynchus* species (e. g., for *L. albirostris* Mitson 1990; for *L. obliquidens* Goley 1991). Vocalizations of *L. australis* were briefly discussed by Schevill and Watkins (1971), but only recently have any acoustic data on duskie been published (Wang *et al.* 1995), and in those cases, sample sizes were small and behavioral data were not analyzed. Würsig *et al.* (1989) suggested that foraging duskie in Argentina may vocalize to stay in contact with dispersed group members, and emit different vocalizations when prey items are found. No physical descriptions of vocalizations were provided, but they suggested that duskie in New Zealand probably also coordinate interactions acoustically. This acoustic coordination was also discussed in general for cetaceans by Norris and Dohl (1980b). Wang *et al.* (1995) compared whistle frequency and duration among seven cetacean species, including dusky dolphins. Dusky whistles were found to be similar in contour shape to those of bottlenose dolphins (*Tursiops truncatus*), but at a higher frequency. Wang *et al.* (1995) did not address the possibility

that at least some vocalizations attributed to duskies were potentially being made by other species, such as by common dolphins. In fact, I recently re-analyzed these same tapes and noted behavioral comments stating common dolphins were present during these recording sessions.

In addition to describing and comparing physical parameters of vocalizations among and between species (Steiner 1981, Wang *et al.* 1995, Stienessen 1998), researchers have attempted to correlate vocalizations to various behavioral contexts in such species as pilot whales (*Globicephala melas*, Weilgart and Whitehead 1990), white whales (*Delphinapterus leucas*, Sjare and Smith 1986a, b; Lesage *et al.* 1999), spinner dolphins (*Stenella longirostris*, Brownlee and Norris 1994) and bottlenose dolphins (Caldwell *et al.* 1990). For each of these studies, associations between behavioral state and types of vocalizations were found. For example, Weilgart and Whitehead (1990) found that simple whistles were recorded more often when pilot whales were in a restful, milling state, while complex whistles and pulsed signals were recorded during more energetic, surface active behaviors. Caldwell *et al.* (1990) found a variation in the rates of whistling by bottlenose dolphins during times of stress, such as changing water levels in the pool or when animals were isolated. They concluded that stressful conditions could either repress or stimulate whistle production. No work has been done on the possible effects of tourist vessels and swimmers on the acoustic behavior of duskies off Kaikoura, potentially of great concern given the probable heavy reliance on acoustic communication for cetaceans.

### **Objectives and hypotheses**

The objectives of this study were to 1) document movement patterns of small groups composed of less than 25 dusky dolphins in relation to human activity, and 2) determine if dolphins responded differently to different levels of human activities. Small satellite groups of mothers and calves and mating adults may be more susceptible to disturbance than animals in larger groups. Additionally, this study provides a description of dusky dolphin vocalizations with corresponding behavioral state, time of

day and group size. There is a great need to determine indicators of potential disturbance, and this study sought to determine if changes in vocal behavior occurred based on human activity. The null hypotheses of this study are: 1) there is no difference in movement patterns of small groups of dusky dolphins with or without human activity; 2) there is no difference in behavior of small groups of dusky dolphins with or without human activity; 3) there is no difference in whistle parameters and rate based on group size, time of day or behavior.

## CHAPTER 2

### MOVEMENT PATTERNS AND BEHAVIORS OF DOLPHIN GROUPS

#### Introduction

Because dolphins often occur near shore, Kaikoura affords on-shore researchers an outstanding opportunity to observe dolphins and their reactions to human activity without potentially influencing dolphin behavior. Although individuals are not often identified from the distant on-shore vantage, the overall behaviors of groups of dolphins may be used as a measure of disturbance, social state, energy level, and potential disturbance (Würsig *et al.* 1991). Cipriano (1985, 1992) and Würsig *et al.* (1989, 1991) conducted a long-term research study on dusky dolphin behavior and movement patterns in the Kaikoura area. Their work, undertaken before the start of tourist operations, provides a basic description of dolphin behavior without the influence of tourist vessels. Their results are summarized below.

With the help of radio and theodolite tracking techniques, Cipriano (1985, 1992) and Würsig *et al.* (1991) found that dusky dolphins behave more like Hawai'ian spinner dolphins and somewhat like dusksies in Argentina (Würsig and Würsig 1980). In New Zealand, dusky prey were identified from stomach content analyses of net-entangled dolphins as mesopelagic fishes and squid, organisms associated with the Deep Scattering Layer, or DSL (Cipriano 1992). Spinner dolphins in Hawai'i feed in deep water as in New Zealand, and have a fission-fusion society related to daytime rest and nighttime deep water feeding (Norris and Dohl 1980a, b; Norris and Johnson 1994). New Zealand dusksies do not exhibit the strong fission-fusion society of Hawai'i and coastal Argentina (Würsig *et al.* 1991). Off the shallow near-shore waters of Argentina, dusky dolphins feed mainly on southern anchovy (*Engraulis anchoita*), herding these into tight bait balls at the surface. There, the society is of a fission-fusion nature in association with social feeding (Würsig and Würsig 1980, Würsig 1982).

Off Kaikoura, group sizes and some behaviors often changed with season (Cipriano 1992). These observations were conducted on the large 'main' group of

dolphins, ranging in size from 100 to 1,000 animals. During summer and fall, duskies spent morning and early afternoon hours near shore, and moved offshore in late afternoon. Activity levels increased throughout the day as animals moved into deeper water. During winter and spring, dolphins spent more time in somewhat larger groups further from shore, and did not display a regular diel onshore/offshore movement pattern. During the spring through fall seasons, swimming in a zigzag fashion was the most frequently observed behavioral state. During winter, 'directional travel' was the most common state. Widely scattered groups were seen more often in spring and fall than in summer. Dive times of tagged dolphins demonstrated a daily cycle, with most longer dives occurring at night and twilight. Seasonal movement patterns probably occurred due to a combination of seasonal changes in prey distribution and predator avoidance (Cipriano 1992).

Barr (1997) conducted a theodolite study from November 1993 to April 1995 from the same shore station used by Cipriano (1992), but after the start of the tourist industry. Barr recorded movement patterns of dolphins and tourist vessels from this shore station. She found short-term changes in speed and behavioral state, as well as increased aerial activity, when vessels approached within 300m. For 72% of the observation time, at least one boat was within 300m of the dolphins. Additionally, there was a significant increase in the numbers of boats viewing the dolphins from 1994 to 1995. Barr suggested that even though there was no documented movement of the duskies away from the Kaikoura area, caution would warrant keeping boat activity near the dolphins no higher than the levels present during her study (Barr 1997).

Würsig and Würsig (1980) described different spatial groupings for different age classes, a pattern seen in a variety of terrestrial and aquatic species ranging from little brown bats (*Myotis lucifugus*, Adams 1997), to infant sable antelope (*Hippotragus niger*, Thompson 1998), red deer (*Cervus elaphus*, Conradt 1999) to bottlenose dolphins (Wells *et al.* 1980) and humpback whales (Smultea 1994). It is probable that some age classes of animals are more susceptible to disturbance or predation, such as groups of mothers and calves or mating adults (Jones and Swartz 1984, Smultea 1994). Cipriano (1992)

and Würsig *et al.* (1997) suggest that duskies spend time in nearshore waters to avoid the threat of predation from sharks and killer whales (*Orcinus orca*). Indeed, killer whales have been observed to feed on dusky dolphins near Kaikoura (Constantine *et al.* 1998). It is unknown if groups of dolphins split off from the main group during periods of human activity, or if smaller groups coordinate their movements with this main group, coalescing at twilight to move offshore to feed.

The objectives of this study were to focus upon the behavior of these smaller groups of dolphins in order to determine if human activity, specifically the presence of vessels within 100 and 101-300m, elicited changes in dolphin speed and direction of travel. The behavior of groups of greater than 25 dolphins was not analyzed for this study.

### **Study area**

Research was conducted in the area of the Kaikoura Peninsula (42°30'S 173°35'E) on the east coast of the South Island, New Zealand. The majority of shore-based observations were conducted from Otamatu (42°29'S 173°31'E), the same location used by Cipriano (1992) and Barr (1997) (Figure 3). This elevated shore station (height 72.6m at mean low water) overlooks Goose Bay, providing a nearly 180° view of an area, designated the 'arena', generally frequented by duskies during daylight hours. It was within this arena that all behaviors were recorded. The Water Tower (height 102m) and Meteorological (Met) Station (height 108m) are two sites located on the Peninsula, approximately 13 km north of Otamatu, that occasionally served as shore stations, depending on dolphin location. The Water Tower was employed when the dolphins moved north out of Goose Bay into South Bay, or north of the Peninsula into Ingles Bay. The Met Station was used when dolphins moved north and offshore into deeper waters.

### **Shore-based observations**

One of the greatest advantages of shore-based observations for cetaceans is that animals being watched are not affected by the observers. This makes a shore station an

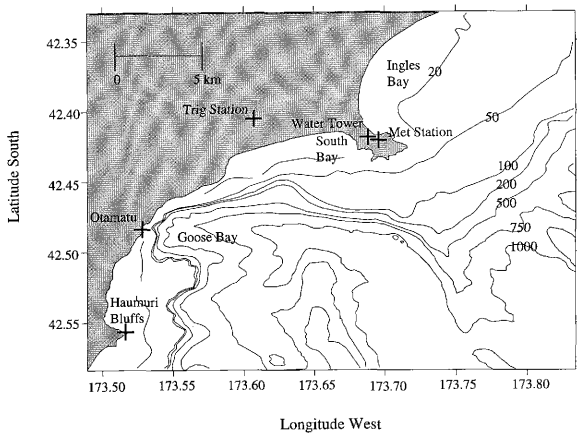


Figure 3. Map of study area. Depths are listed in meters.

excellent platform from which to document potential vessel-induced disturbance.

However, shore-based observations require that animals are found reasonably close to shore and under good observational conditions, with minimal rain, fog, haze, wind and sunstreak. One important set of parameters influencing dolphin ecology and behavior, with and without human presence, includes their location, speed of travel, orientation, and group configuration. These can be described with a theodolite, or surveyor's transit. At the same time, the theodolite can obtain information on near-shore human activities at sea. The theodolite measures horizontal readings in relation to a specific zero reference point and vertical readings in relation to gravity. These readings can be converted into x-y (or Cartesian) coordinates. The conversion requires knowing locations of the shore station and reference point on a chart, and the shore station height above sea level. The algorithm incorporates corrections for curvature of the earth, tidal variation and eye height. These values can then be converted to latitude and longitude. Each theodolite-based reading of a position is referred to as a 'fix' or 'mark'. When tracking animals or vessels by theodolite, a shore station should be sufficiently high in elevation to avoid errors associated with the small angle subtended from shore and water surface to the horizon. The further from shore the animals are found, the higher the theodolite site must be for accurate readings. Würsig *et al.* (1991) summarize several of the necessary elements for a successful theodolite shore station.

## Methods

I followed methods described in Würsig and Würsig (1979) and Würsig *et al.* (1991), to use a theodolite to track dolphins from shore. Lietz/Sokkisha Model DT5A and DT5 theodolites with  $\pm 5$ -sec precision and 30 power magnification were used for the present study. Other land-based studies of cetaceans have employed theodolite tracking to describe movement patterns for such species as bottlenose and dusky dolphins in Argentina (Würsig and Würsig 1979, 1980), spinner dolphins in Hawai'i (Barber *et al.* 1995), dusky dolphins in New Zealand (Cipriano 1992), humpback whales in Hawai'i



(Smultea 1994, Frankel and Clark 1998), and gray whales, *Eschrichtius robustus*, in far eastern Russia (Würsig *et al.* 1999).

Dolphin movement patterns and behavioral data were collected during three field seasons: September 1994-April 1995, October 1995-April 1996, and October 1996-April 1997. A pilot study was conducted from February-May 1994 to become familiar with the area and to finalize data collection procedures. Each shore observation day started when weather conditions were appropriate and dolphins were seen close to shore. At least three persons were present at the shore station at all times during observational periods; a theodolite operator who also served as a behavioral observer, a computer operator or theodolite reading recorder, and a notetaker. Often a fourth person was present as an additional observer/notetaker. An attempt was made to limit the number of theodolite operators to reduce inter-observer error. All observers were trained and monitored by the principal observer in order to standardize data collection procedures, but in the short term, it is possible that decisions made in the field may have varied by behavioral observer. All observers visually scanned for dolphins with binoculars, (usually 10 x 40 or 7 x 35). A notetaker recorded the number of boats visible within the arena; identified vessels present with dolphins; and noted environmental conditions. These variables included wind speed and direction, swell height and direction, Beaufort sea state, air temperature, cloud cover (expressed in a percentage), visibility (rated on a scale of 1-3 with 1 being excellent and 3 equal to poor), and sunstreak. Sunstreak was measured on a subjective scale by noting the percentage of the arena obscured by glare. Groups with fewer than 25 dolphins were not tracked when Beaufort sea conditions reached 3 or greater, as it became very difficult to confidently track small groups. The ethogram, computer behavioral codes, weather, sea conditions and vessel descriptions used in the field are presented in Appendix 2. During the first two field seasons, vertical and horizontal readings from the theodolite display were spoken by the theodolite operator to a notetaker, who recorded local time and theodolite readings onto data sheets. A separate notetaker recorded detailed behavioral comments and other remarks, including approach of tourist boats or other vessels. These notes were entered into

spreadsheets each day upon return to the field camp. The activities of tourist vessels in the area of the focal group were noted in detail. Two companies are currently conducting permitted dolphin-swim tours in the Kaikoura area, with tours lasting approximately three hours in duration. One company, Dolphin Encounter, runs three trips a day, weather permitting, starting at 6:00 a.m. The second company, New Zealand Sea Adventures, runs two trips a day, five days a week. For the 1996-97 season, software developed by personnel at Cornell University for tracking humpback whales was made available, which allowed the theodolite to communicate with a Macintosh Powerbook 190 in real-time. Time, vertical and horizontal readings, and short comments were entered directly into the laptop computer. Detailed comments were recorded onto data sheets and later integrated into each computer file. This data collection program, called Aardvark Editor, allowed ethograms, commands, and grammars to be customized appropriately for describing dolphin behavior (Mills 1998). Environmental conditions were updated each hour and upon change of any variable. Sessions from Otamatu started with theodolite fixes on three reference points: a large marker for a trigonometric station ('Trig Station') which served as the zero bearing point or 'zero', the Water Tower, and the edge of the Haumuri Bluffs (Figure 3). Eye height above my ground reference point was measured with a tape measure each morning and noted on either data sheets or within the Aardvark computer file. An appropriate focal group was selected, usually a small group located close to shore, away from other small groups in order to avoid initial group confusion. Only one group at a time was designated as a focal group, but the main group and vessels associated with or near dolphins were also tracked simultaneously by the theodolite operator. Groups which were not clearly visible (*i.e.*, within a region of glare, or traveling in such a direction as to be soon lost from view of the shore station) were not selected as focal groups, but were fixed if they approached the focal group. Group size was estimated by experienced observers. Presence and number of calves were noted, with a calf defined as a smaller dolphin in close association with a particular adult. Dolphins were fixed at the water line as often as possible, especially upon change in direction, approach or departure of a

vessel, or when swimmers entered or exited the water. Dolphins were also fixed at the closest point of approach by any vessel. For these small subgroups, fixes were taken in the center of the group. Sessions were ended when dolphins moved out of range (either offshore or to the north or south), or upon an adverse change in sighting conditions (rain, fog, sea state of Beaufort 3 or higher, *etc.*).

### **Data analysis**

Upon return from the field, all data were re-checked and tidal information from commercial tide charts was added to each edited file. Files from the first two seasons were transformed into Aardvark format files. All files were examined with the Aardvark Viewer application, which allows the operator to view tracklines of dolphins and/or vessels. In order to avoid inflating small changes in behavior and to provide a more complete view of a group's movements, only groups tracked for greater than 30 minutes were selected for further analysis. Any fixes which were considered mislabeled or unlikely (*e.g.*, speed of dolphin group was  $>20$  km/hr) were deleted and not used in subsequent analyses. The Viewer calculated summary statistics from the Editor data file. Several variables from this output were examined including leg speed, track linearity index and track reorientation rate. A leg is the distance between two sequential fixes. Leg speed values were calculated as total distance between two fixes divided by time. Track linearity index is a measure of the straightness of a course. It is a ratio between distance 'made good' and the total distance traveled. A value closer to one indicates a more straight or linear track while a smaller number denotes a less linear track. Reorientation rate is the total sum of all changes in a group's bearing divided by number of seconds over the entire trackline. It is based strictly on the movement of the group alone and does not take into account the movement patterns of other groups or vessels.

To avoid problems associated with non-linear travel, fixes greater than 120 seconds apart were not used in determination of leg speed. This value is intermediate in value between those of Bejder (1997) who used a 60 second criterion for Hector's

dolphin; Cipriano (1992) who used 130 seconds, and Barr (1997) who used 240 seconds, for their respective dusky dolphin investigations. Thus, my shorter time criterion may provide a more accurate depiction of distances travelled over time by tracked dolphins (Cipriano 1999 pers. comm.).

Each field season was classified as either spring or summer, with 21 December being used as the first day of summer. In order to evaluate if speed of travel varied with time of day, each day was then subdivided into one of twelve one-hour blocks. Separation from the closest vessel was calculated, and each fix was labeled according to an activity code (see Table 1). Two different measures of distance from dolphin group to vessel were used. Initially, a 1,000m distance was chosen, but resulted in no periods without boats being recorded. Therefore, distances of <100m ('100m') and 101-300m ('300m') were chosen, as these distances are specified for their use in the New Zealand Marine Mammals Protection Regulations (1992) (Appendix 1), and each fix was given two different codes depending on vessel distance. For example, a vessel located 200 meters from a focal dolphin group was labeled 'no boat' for the 100m bins, but labeled 'boat' using the 300m definition. 'Post boat' indicated that the vessel was no longer within the selected distance (either 100m or 300m). Additionally, in order to determine if leg speed differed from a baseline value as a function of time, post boat fixes were subdivided into categories, or 'bins', defined by time when the vessel was no longer found within the specified distance. Therefore, codes 4 through 6 are a subset of Code 3. In order to determine track linearity index and reorientation rate for each group by activity code, each group was re-labeled as a different group within Aardvark Editor. Summary statistics were generated for group by condition. This output gives a separate track linearity index and reorientation rate for each group as a function of distance from the vessel.

### **Statistical analysis**

Frequency distributions of each bin (Table 2) were checked for normality using a Kolmogorov-Smirnov method with Instat GraphPad software Version 3.00 (San Diego,

CA). Non-normal data were transformed using log, reciprocal or arcsine functions as appropriate. I analyzed the data with one-way parametric and non-parametric Analysis of Variance (ANOVA) at an alpha significance value of  $p < 0.05$ . To determine if

*Table 1.* Definitions and comments for each activity code.

Activity code	Definition	Comment
1	No boat	No vessel within 100m/300m of group
2	With boat	Vessel within 100m/300m of group
3	Post boat	Vessel beyond the distance criterion
4	Post boat (<15 min)	Vessel beyond the distance criterion <15 min
5	Post boat (>15 min)	Vessel beyond the distance criterion >15 min
6	Post boat (>30 min)	Vessel beyond the distance criterion >30 min
7	Post boat (>45 min)	Vessel beyond the distance criterion >45 min

standard deviations of the groups were equal, I used a Bartlett statistic (corrected), as the ANOVA assumes that data are sampled from populations with identical standard deviations. For parametric tests, unpaired t-tests (two tailed) were used for pairwise comparisons, while Tukey-Kramer multiple comparison tests were used for more than two groups (Zar 1996). Additionally, for some non-normal data, the alternate (Welch) t-test was used as this test does not assume equal variances. For non-parametric tests, the Mann-Whitney test was used for pair-wise comparisons, with a Kruskal-Wallis test for multiple comparisons.

A common problem of behavioral studies has been the pooling effect, where multiple measurements of the same individual or group are considered independent of each other (Martin and Bateson 1993). In order to avoid the potential for pseudoreplication and lack of independence of fixes for a group, mean scores were calculated for each group and track and used as individual raw data for the ANOVA comparisons (Würsig et al. 1999, J. Zar 1999 pers. comm.).

*Table 2. Variables examined in statistical comparisons*

Variables
Year
Season
Calf/no calf presence
Group size
Time of day
Boat presence

## Results

During the three field seasons, a total of 34,825 minutes was spent on station. Of this period, 23,472 minutes were spent observing and tracking dolphins (67% of the time). The distribution by year is presented in Table 3.

*Table 3. Summary of effort.*

Field season	Days	Time on station (minutes)	Time with dolphins (minutes)	# of Dolphin fixes
94-95	68	12,299	7,879	2,318
95-96	62	17,062	13,348	5,306
96-97	32	5,464	2,245	841
Totals	162	34,825	23,472	8,465

Mean leg speeds varied by year, from 4.27 km/h for 1995, 4.52 km/h for 1996, and 6.49 km/h for 1997. Only two groups fit all of the selection criteria for 1997, so it was not possible to test this group for normality. Data from 1995 and 1996 were both normal (Kolmogorov-Smirnov test,  $p > 0.10$ ). No significant differences were found in mean leg speeds by year (Table 4, one way ANOVA,  $p = 0.2353$ ), so I pooled data from all years for further analysis.

Mean leg speeds did not differ significantly by season (4.21 km/h for spring, 4.88 km/h for summer) or presence of calf (4.21 km/h for calf, 4.75 km/h for non-calf groups)

(Table 4). For group size comparisons, mean leg speed values ranged from 3.68 km/h for 1-5 dolphins, to 6.08 km/h for 21-25 animals (Table 5). There were too few values for group sizes containing 1-5 or 21-25 animals, so only groups containing 6-10, 11-15 and 16-20 animals were compared statistically. Mean speeds increased as group sizes increased, though differences were not significant (Table 5). For time of day comparisons, mean leg speeds ranged from 3.23 km/h from 8:00-9:00 a.m. to a maximum mean leg speed of 5.32 km/h from 11:01-12:00 p.m. (Table 6). Due to small sample sizes, only groups tracked between 8:00 and 14:00 were included in the statistical analysis, and no significant differences were found.

For comparisons by 100m boat condition, mean leg speeds ranged from 4.78 km/h for no boat periods to 3.59 km/h for the boat condition and 4.22 km/h for post boat condition (Table 7). No significant results were found for any comparisons of variables (Table 4). A post-hoc power analysis using computer software G-Power version 2.1.1 (Buchner *et al.* 1996) with  $\alpha=0.05$  revealed low power for all of the comparisons (Table 4).

I examined mean leg speed by the presence of a boat within 300m during no boat, boat and post boat conditions and found no significant differences between boat condition. When I examined mean leg speed for the 100m boat conditions, I also found no significant differences by presence of a boat, but the amount of no boat time increased and the number of groups tracked with vessels decreased as fewer vessels were found within the 100m area (Table 8). This means that most vessels were greater than 100m away from the groups that I tracked. Mean speeds for the boat condition were lower than those for no boat and post boat conditions (Table 7).

Box plots of each comparison are given on the following pages (Figures 4-14). Though results were not significantly different and caution is warranted due to small sample sizes, trends can be seen from examination of the data.

For instance, it is apparent from the box plots, that there is a great deal of variation in mean leg speeds for each category examined. This could be a result of the

*Table 4. Summary of results of statistical tests for mean leg speed comparisons.*

Description	Test	p value	Power
By year (95 vs 96 vs 97)	One way ANOVA	p=0.2353	0.3077
By season (spring vs summer)	Unpaired t-test	p=0.3055	0.1720
By calf (calf vs no calf)	Unpaired t-test	p=0.4807	0.1072
By group size (see Table 5)	One way ANOVA	p=0.4340	0.2718
By time (see Table 6)	One way ANOVA	p=0.2388	0.1305
By 100m boat condition (no boat vs boat vs post boat)	One way ANOVA	p=0.2130	0.2520
By 300m boat condition (no boat vs boat vs post boat)	One way ANOVA	p=0.3792	0.1614

*Table 5. Summary of mean leg speeds by group size.*

Number of dolphins	Mean leg speed (km/h)	Number of groups
1-5	3.68	3
6-10	4.37	12
11-15	4.79	10
16-20	5.51	6
21-25	6.08	4

*Table 6. Summary of mean leg speeds by time.*

Time	Mean leg speed (km/h)	Number of groups
8:01-9:00	3.23	4
9:01-10:00	4.38	9
10:01-11:00	4.92	11
11:01-12:00	5.32	11
12:01-13:00	4.88	9
13:01-14:00	4.31	6
14:01-15:00	2.69	2
15:01-16:00	2.02	2



sampling procedure, as well as a function of different pod compositions, behaviors, small sample size and other external factors.

*Table 7. Summary of mean leg speeds by 100m boat condition.*

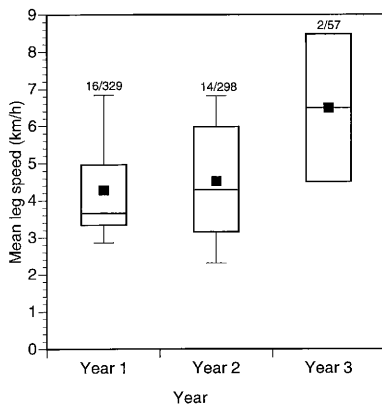
Boat condition	Mean leg speed (km/h)	# of groups
No boat	4.78	30
Boat	3.59	6
Post boat	4.22	6
Post boat <15	4.13	6
Post boat >15	4.36	6
Post boat >30	4.69	6

*Table 8. Summary of groups tracked.*

Distance from group	# of groups tracked			# of fixes		
	No boat	Boat	Post boat	No boat	Boat	Post boat
100m	30	7	6	590	12	82
300m	28	15	14	463	69	107

Mean leg speed appears to be relatively constant from year 1 to year 2 (Figure 4). Though there appears to be a large difference in mean leg speeds for the 1997 season versus 1995 and 1996, sample sizes were small for 1997. Due to an increased emphasis on gathering acoustic recordings, only two groups fitting all the sampling and analysis criteria were tracked for that year; one during spring and one during summer. A slight potential increase in speeds for summer was observed versus speeds recorded in the spring, but this was not statistically significant (Figure 5). No difference was seen in mean leg speeds for calf versus no calf groups (Figure 6).

There appears to be a trend towards a slight increase in mean leg speeds for larger than smaller groups (Figure 7). This result could be a function of the relative diffuseness of larger groups versus very small groups. However a concerted effort was



*Figure 4.* Mean leg speeds by year. Lines represent the 10<sup>th</sup>, 25<sup>th</sup>, median, 75<sup>th</sup>, and 90<sup>th</sup> percentile. Means are represented by black boxes. Value labels depict number of groups and fixes.

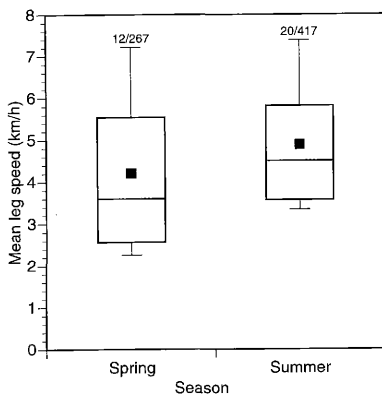


Figure 5. Mean leg speeds separate by season. Lines represent the 10<sup>th</sup>, 25<sup>th</sup>, median, 75<sup>th</sup>, and 90<sup>th</sup> percentile. Means are represented by black boxes. Value labels depict number of groups and fixes.

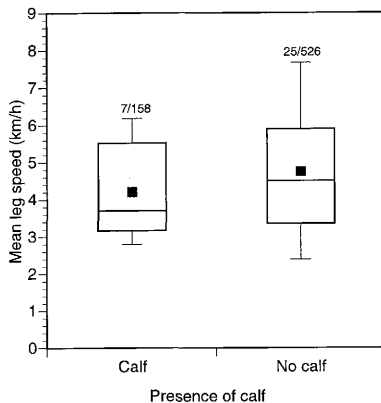


Figure 6. Mean leg speed by calf. Lines represent the 10<sup>th</sup>, 25<sup>th</sup>, median, 75<sup>th</sup>, and 90<sup>th</sup> percentile. Means are represented by black boxes. Value labels depict number of groups and fixes.

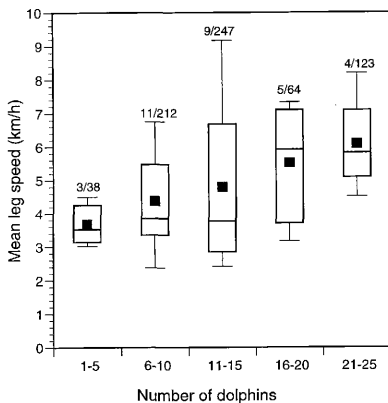


Figure 7. Mean leg speeds by group size. Lines represent the 10<sup>th</sup>, 25<sup>th</sup>, median, 75<sup>th</sup>, and 90<sup>th</sup> percentile. Means are represented by black boxes. Value labels depict number of groups and fixes.

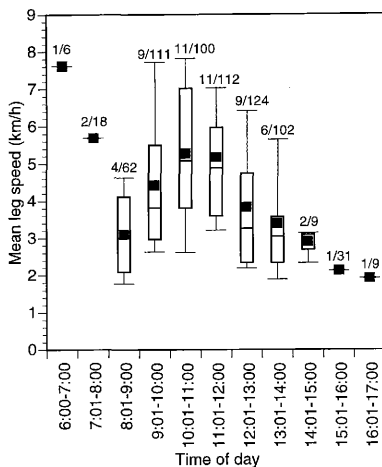


Figure 8. Mean leg speeds by time of day. Lines represent the 10<sup>th</sup>, 25<sup>th</sup>, median, 75<sup>th</sup>, and 90<sup>th</sup> percentile. Means are represented by black boxes. Value labels depict number of groups and fixes.

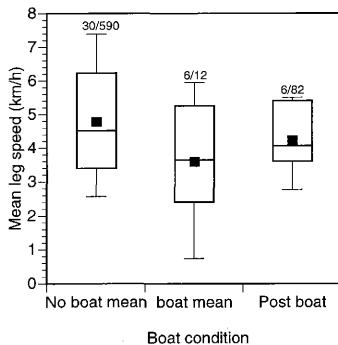


Figure 9a. Mean leg speeds by boat condition using 100m criteria. Lines represent the 10<sup>th</sup>, 25<sup>th</sup>, median, 75<sup>th</sup>, and 90<sup>th</sup> percentile. Means are represented by black boxes. Value labels depict number of groups and fixes.

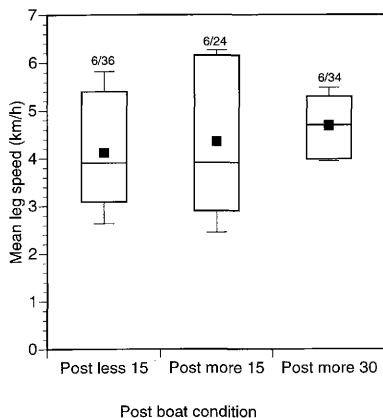
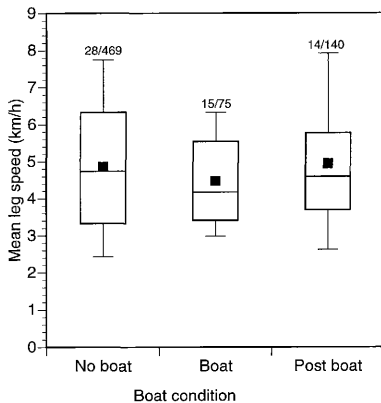
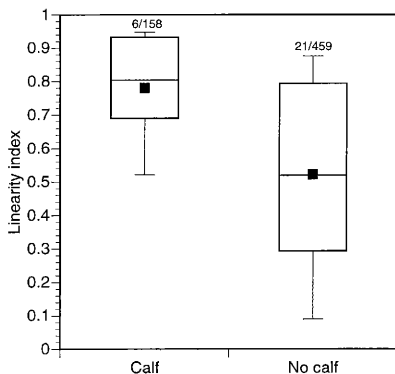


Figure 9b. Mean leg speeds by post boat condition, broken down by time using 100m criteria. Lines represent the 10<sup>th</sup>, 25<sup>th</sup>, median, 75<sup>th</sup>, and 90<sup>th</sup> percentile. Means are represented by black boxes. Value labels depict number of groups and fixes.



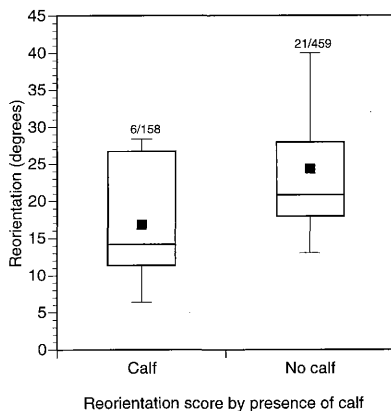


*Figure 10.* Mean leg speeds by boat condition using 300m criteria. Lines represent the 10<sup>th</sup>, 25<sup>th</sup>, median, 75<sup>th</sup>, and 90<sup>th</sup> percentile. Means are represented by black boxes. Value labels depict number of groups and fixes.

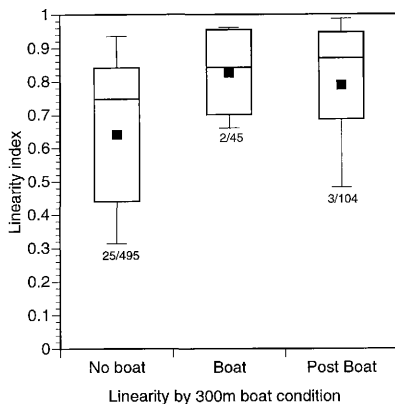


Linearity by presence of calf

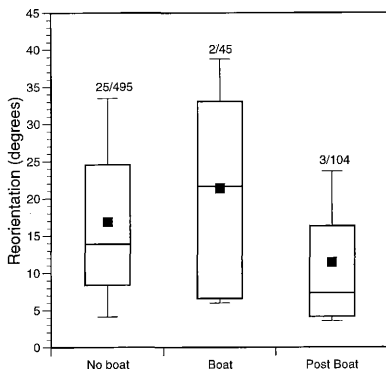
*Figure 11.* Linearity by calf/no calf presence. Lines represent the 10<sup>th</sup>, 25<sup>th</sup>, median, 75<sup>th</sup>, and 90<sup>th</sup> percentile. Means are represented by black boxes. Value labels depict number of groups and fixes.



*Figure 12.* Reorientation score as a function of calf/no calf groups. Lines represent the 10<sup>th</sup>, 25<sup>th</sup>, median, 75<sup>th</sup>, and 90<sup>th</sup> percentile. Means are represented by black boxes. Value labels depict number of groups.



*Figure 13.* Linearity by boat condition with 300m criteria with outliers removed. Lines represent the 10<sup>th</sup>, 25<sup>th</sup>, median, 75<sup>th</sup>, and 90<sup>th</sup> percentile. Means are represented by black boxes. Value labels depict number of groups and fixes.



Reorientation by 300m boat condition

Figure 14. Reorientation score as a function of 300m boat distance. Lines represent the 10<sup>th</sup>, 25<sup>th</sup>, median, 75<sup>th</sup>, and 90<sup>th</sup> percentile. Means are represented by black boxes. Value labels depict number of groups and fixes.

made to consistently take positions from the same area of a dolphin group. Larger groups of dolphins travelled more rapidly, possibly indicating a higher general level of activity. A post-hoc linear regression found a significant difference between increasing mean leg speed and increasing group sizes (linear regression  $p=0.0472$ ).

Mean leg speeds increase from early morning into mid-morning, and then decrease during early afternoon (Figure 8). Again, there was a great deal of variation within each hour and sample sizes are small. The hour between 10:01-11:00 a.m. had the highest recorded mean leg speed.

Mean speeds for dolphins were higher during 100m no boat conditions than during boat and post boat conditions (Figure 9a). Mean leg speeds during boat conditions were lower than those during no boat and post boat conditions. After 30 minutes post boat, mean leg speeds are increasing toward levels recorded during no boat conditions (Figure 9b). No difference was seen for the 300m conditions (Figure 10).

A comparison of linearity for calf/no calf groups revealed a higher linearity index for calf groups versus no calf groups (Figure 11). These differences were statistically significant (unpaired t-test,  $p=0.0485$ , Table 9). Reorientation rates for calf and no calf groups were not significantly different (Table 4), though a trend for more course changes was seen for no calf groups (Figure 12).

A trend towards higher linearity values during boat and post boat conditions than during no boat conditions was recorded (Figure 13), but this comparison was not statistically significant (Table 9). During post-hoc analysis, values for boat and post boat condition were grouped and tested against the no boat condition. There was a significant difference between no boat and boat/post boat conditions (unpaired t-test  $p=0.0419$ ).

These sample sizes are smaller than those for the 100m and 300m boat conditions because a minimum of three fixes was necessary to calculate linearity and extreme outliers were removed before analysis. Values closer to one indicate a much straighter, more direct course of travel (Figure 14). Higher reorientation rates occurred during boat conditions than during no boat or post boat, though results were not statistically

significant (Table 9). Thus, the average number of degrees that are passed through in one second was higher during the boat condition than during no boat and post boat conditions.

*Table 9.* Summary of results of statistical tests for linearity and reorientation rates.

Description	Test	p value	Power
By linearity 300m	One way ANOVA	p=0.2300	0.0641
By reorientation rate 300m	One way ANOVA	p=0.1263	0.4238
By calf linearity	Unpaired t-test	p=0.0485	0.0650
By calf reorientation rate	Unpaired t-test	p=0.1458	0.2541

### Case studies

Though most comparisons undertaken in my study did not show significant differences, two case studies are included to provide a descriptive depiction of observed behavior of the dolphins. Caution is warranted as these are anecdotal observations summarized from field notes and have not been quantified. Though some of these descriptions describe behavior of the main group, these descriptions are all in relation to smaller groups of dolphins. These short-term changes in behavior were often observed during my study period.

On December 12, 1994, observations started at 13:18 on subgroup 3 (S3), a group of 5-8 dolphins. Several leaps were observed. In general, the group was slowly moving southeast, but the animals were very loose in group orientation, with animals heading in different directions. A tourist vessel approached S3 at 13:36 and 3 dolphins moved towards the boat and began to ride the pressure wave created by the movement of the vessel, also known as 'bowriding'. A subgroup of 5 dolphins, including a mother-calf pair (S4), broke off from S3 and moved away from the vessel. At 13:40, the dolphin tourist boat moved in a circle around the bowriding dolphins (S3). S4 continued to move away, and the vessel followed them. S4 stopped travelling and began milling. Several dolphins joined S4, and the group size increased to 8-10 dolphins. The tourist

boat left at 13:48. S4 increased speed and joined the main group at 14:25. This was one of the few instances where a subgroup was observed joining the main group, as well as one of the few times a tourist vessel approached and followed a small group we had been tracking. Many animals, especially mother/calf pairs, seem to either ignore or move away from tourist vessels and swimmers (pers. obs.), while other smaller groups of dolphins readily approach both swimmers and vessels.

On March 8, 1995, observations started at 8:00 a.m. on the main group of dolphins consisting of 200 animals, which was accompanied by two dolphin-swim boats. One vessel was stationary, with an unknown number of swimmers in the water. The other vessel was moving slowly with the main group, with at least 5 dolphins bowriding. At 8:43 a.m. as one of the dolphin boats left the main group, a whale watch boat (V34) approached from the east. A wake was clearly visible from the shore station. This vessel continued to approach the main group, with one dolphin bowriding. Twenty meters in front of V34, five to six dolphins were 'slicing' or moving quickly with dorsal fins cutting through the water surface. The whale watch boat decreased speed and traveled through the middle of the dolphin group. Even though the vessel had decreased its speed, a wake was still visible from my observation site. At 8:49:27, 50 dolphins split off from the main group, and moved away from the boat and the rest of the dolphins. From shore, this group appeared tighter in formation than what had been observed earlier. Several mother-calf pairs lagged behind the rest of the group. Increased aerial activity was seen, with more dolphins leaping and somersaulting. At 8:56 a.m., the whale watch vessel left the dolphins. The main group headed south, though it appeared less tight in formation than before the arrival of the whale watch vessel. During the three seasons I spent in Kaikoura, on several instances I observed groups splitting into smaller groups when boats drove through the middle of the group in a fast fashion. Driving through the middle of a group is not permitted under the Marine Mammals Protection Regulations (1992).



## Discussion

For the most part, mean leg speeds reported from this study are within the ranges reported from other studies of dusky dolphins as well as other delphinids. Würsig and Würsig (1980) reported average speeds of 7.7 km/h from their Argentina study, slightly higher than speeds reported here. Unlike results from my study, they found that dolphin groups tracked by theodolite usually traveled more rapidly in the afternoon versus the morning. This increase in speeds was correlated to the amount of surface feeding that occurred during that month. When groups were separated into feeding and non-feeding groups, speeds of non-feeding groups averaged 6.3 km/h, while speeds of groups during feeding averaged 15 km/h. Very few instances of surface feeding were observed during my study, so direct comparisons are not possible. Additionally the amount of human activity observed during Würsig and Würsig's (1980) study was considerably less than that observed in Kaikoura (Würsig 1999 pers. comm.).

Würsig (1982) reported 'minimum mean speeds' of 2.28 km/h and 3.18 km/h for 10 radio-tracked dolphins, with faster speeds recorded near the mouth of the bay of their study area than away from it. Animals traveled faster during summer than winter, and traveled over larger areas. My field season did not include any winter months, but no differences were found in mean speeds between spring and summer.

Mean speeds from this study are not different from the range of mean speeds reported by Cipriano (1992) and Barr and Slooten (1999). Speeds ranged from 4.54 km/h to 12.17 km/h, (Cipriano 1992) and from 7.2 km/h in the morning and 5.87 km/h during midday (Barr and Slooten 1999). Speeds from this study ranged from 0.18 km/h to 15.99 km/h, with minimum speeds slightly slower, and maximum scores slightly higher than those reported from other studies of dusky dolphins. It is not evident whether this difference reflects the group composition of focal groups selected, an increase in the variation of mean speeds, or other external factors.

Acevedo (1991) documented interactions between vessels and bottlenose dolphins at the entrance to Ensenada De La Paz, a coastal bay system located near the

southeast tip of Baja California, México. Dolphin behavior was related to the type of approach made by the boat. Vessels moving through the area did not affect dolphin behavior, and Acevedo suggested that bottlenose dolphins in this area possibly had become habituated to the presence of transiting boats. Dolphins changed their behavior when followed by vessels, resulting in dives then resumption of previous behavior, or erratic movements when vessels were within 5m (Acevedo 1991). For my study, in general, boats did not follow the small groups of dolphins but instead focused on the larger main group of dolphins. Therefore, most of the boat approaches closer than 100 or 300m to small dolphin groups involved boats that were travelling through the area with a constant speed and direction. These vessels may not be as disruptive to dolphin behavior as vessels that move in a predictable manner through the area. Vessels with erratic changes in speed and direction are known to disturb cetaceans more so than vessels with a constant course. Baleen whales often reacted to rapid changes in engine noise, associated with changes in speed and direction (Walkins 1986, Beach and Weinrich 1989).

Overall, this study adds to our understanding of the behavior of small groups of dusky dolphins. Sample sizes were generally small, leading to low power of statistical tests. Nevertheless, it is possible to observe several trends from these data. Mean speeds between year 1 and year 2 did not significantly increase. This may mean that dolphins are not reacting to presence of tourist and recreational vessels with an increase in mean leg speed. It may be that animals may be reacting at distances further than those selected for this study or may be habituated to the presence of vessels. Additionally, mean speeds were similar to those reported by groups tracked before the advent of the tourist industry in this area (Cipriano 1992). This does not imply that dolphins are not reacting to the approach of boats, merely that mean leg speed may not be the appropriate variable with which to document a change in behavior. On the other hand, there is a great deal of variability in inter- and intra-group mean leg speeds. Small groups of dolphins do not appear to travel at a constant speed, but increase and decrease their speeds throughout the day. Factors that may determine these changes in speeds may

have to do with the presence or absence of boats, but more likely are determined by other external factors. For instance, on several occasions, fixes of less than one kilometer per hour were followed by speeds of 10 km/h. During these occasions, no boats or other dolphin groups were observed in the area. Dolphins may react, with a sudden burst of speed, to the behavior of other dolphins, or to the presence of prey. I believe that this innate variability in speeds may explain why there was no statistical difference in speeds by boat/no boat condition.

Though no significant differences were found between mean leg speeds of calf and no-calf groups, sample sizes were too small to do an in-depth analysis of calf groups by time of year. Mother/calf groups may travel at different speeds depending on the age of the calf and time of the year. Pooling data within and between years may obscure the small but perhaps relevant differences between behavior of different age/sex classes of dolphins, including groups of mother/calf pairs. More information is necessary to determine if seasonal changes in mean leg speed occur with pods of different composition.

This study has found a trend for mean leg speeds to increase with group size. There are several possible reasons for this increase. One may be an artifact of the sampling process. It is more difficult to accurately track groups of dolphins from shore than it is to track larger slow-moving marine mammals, such as baleen whales. When tracking large whales, such as humpback whales, speeds are generally slow and it is sometimes possible to track the same individual from one surfacing to the next. With a group of dolphins, identification of animals is often impossible and it is more than likely that different animals within the group are fixed from one position to the next, especially with groups spread out over a large area. But on average, these differences in fixes within a group should tend to cancel themselves out. A more likely reason may have to do with the behavior of the groups themselves. Larger groups may have higher activity levels, leading to greater speeds of travel. Often larger groups are composed of socializing adults, with much chasing and leaping (pers. obs.). Additionally, larger numbers of dolphins mean that it is likely at least some of the animals are in an active

state. It is possible that other dolphins may join active groups of dolphins, increasing the excitement level within the group.

No significant difference was seen in the comparison of mean leg speeds by hour of the day, but some interesting points were raised. For instance, though not statistically significant and with very small sample sizes, mean leg speeds of groups tracked between 7:01 am and 8:00 a.m. were greater than of groups tracked between 8:01-9:00 a.m. During early morning hours, dolphins moved inshore in scattered groups from offshore feeding areas, and were often travelling rapidly (pers. obs.). Mean leg speeds increased until late morning (11:01 a.m. to 12:00 p.m.) and began to decline in early afternoon. No groups of dolphins were tracked late in the day, but it would be interesting to determine if mean leg speeds increase later in the afternoon, as animals move offshore to feed. Tracking could be more difficult at this time as the dolphins are further from shore and observational conditions tend to deteriorate with increasing wind conditions that occur later in the day. The period in which mean leg speeds are decreasing is associated with the middle of the second dolphin swim trip, between 11:01 a.m. and 12:00 p.m. Voluntary guidelines have been adopted recently by the operators in Kaikoura to allow the dolphins time to rest during this period of the day. No swimmers are allowed in the water after 11:00 a.m. and all vessels must stay at least 200m away from the dolphins. From 12:00 p.m. until 13:00, no commercial vessels are permitted to interact with dolphins and from 13:00 to 13:30, swimming is not allowed and vessels must remain at least 200m away. These new guidelines were implemented after my field seasons, and it would be very interesting to track duskie before, during and after this break period to determine if levels of activity are different between the three conditions, and if leg speeds change with the time of day and presence or absence of boats at this time.

No differences were found in mean leg speed by boat condition for either the 100m or 300m distances. A tendency towards a decrease in mean leg speed from no boat to boat condition was observed for both the distances examined, with a slight increase in mean leg speed during post boat condition. As with the comparisons by year, sample sizes were small and differences were not statistically significant. It is possible

that these animals may be reacting to the approach of the vessels at distance greater than 100m or 300m, and that any change in behavior in terms of leg speed will be missed at this distance.

Additionally, initial selection of a focal group was usually of one estimated by the behavioral observer to be separated by at least 500m from other groups to avoid group confusion. These smaller groups often were seen closer to shore, as groups farther from shore were more difficult to see and to track. Dolphins in these small groups were often the only animals in the immediate area. Commercial tourist vessels and recreational vessels tended to approach and view the larger groups of dolphins versus the small subgroups discussed here. Small groups tracked in this study usually were not targeted by tourist operators and recreational vessels. Therefore, many of the boats that came within the 100m and 300m criteria were vessels that were crossing through the area and did not stop to view the dolphins. Boats that pass through the area are probably not as likely to disturb the animals, as these boats often maintain constant course and speed and quickly pass through the area.

The similarity between speeds from Cipriano's 1980's observations (with little boat presence) to mine (with much boat activity) suggests that the presence of the tourist vessels has not changed the overall mean speeds of dolphins in this area. Caution is necessary as there is a great deal of variation in mean leg speed recorded within and between groups of animals.

The linearity and reorientation rates both revealed slight differences between no boat and boat condition. Sample sizes are small with only three groups tracked during the boat condition. Dolphins in the 300m no boat condition traveled in less direct tracks than dolphins in boat and post boat conditions. Duskie in Kaikoura may meander more and move in a less directed manner when no boats are nearby. This result is the opposite of that seen by Acevedo (1991) for bottlenose dolphins. Different species of dolphins may react in different ways to human activity. In this study, the two groups of duskie during the 'with boat' condition traveled in a more direct line than other groups without

boats. Mean linearity decreased slightly from the boat to no boat condition, suggesting a possible return to no boat levels.

From the results of the reorientation rate tests, dolphins exhibited more course changes during boat conditions than during no boat and post boat periods. This is surprising, as the linearity index of the two groups tracked during the boat condition was higher than for the two other conditions. This means that dolphins in the boat condition traveled in a straighter course than during the other two conditions, but made more course changes in the same period of time. One possible explanation is that over the time period tracked, dolphins were making small but frequent course changes in a short period of time. That would mean that the ratio between distance *made good* and actual distance traveled would be close to one, but that dolphins were moving back and forth quickly during this period. The reorientation rate for the post boat condition revealed that dolphins decrease the number of course changes made from those of boat or no boat conditions. Thus, small groups of dolphins may be returning to a more direct course with few quick course changes after the departure of vessels. It would be beneficial to look more closely at the behavior of small groups of dolphins with boats nearby, with large sample sizes that would allow differences to be detected statistically. These observations should focus on periods when boats are just transiting by the dolphins, as well as during periods when boats actively seek out and view the dolphins. It is possible that my initial selection of focal groups away from the main group and other groups of dolphins introduced a bias towards tracking groups that had already segregated themselves away from vessel and dolphin activity. These groups could be more easily impacted by human activity, though more work is necessary to determine levels of human activity tolerated by these animals.

Shore-based observations are useful in documenting potential disturbance studies, but our inability to recognize individuals, due to distance from the animals, means that subtle behavioral actions are missed. As well, most dolphin behavior is probably dependent on underwater activity, whereas all of our observations are based on the brief amount of time that the animals are at the surface. Therefore, we may be able to

only document disturbance when changes in behavior are very different from one condition to the next. This may especially be true for dolphins in an area such as Kaikoura, where vessels and dolphins have co-existed for years and dolphins are at least in part habituated to boats.

For this study, group formation, relatedness and acoustic behavior were all variables that could not be recorded from shore. Relatedness of individuals or familiarity of conspecifics may also partially determine behavior. For example, in schooling Trinidad guppies (*Poecilia reticulata*), familiarity of individuals plays a greater role in schooling decisions than kin, as guppies will prefer to school with known associates than unfamiliar kin (Griffiths and Marurran 1999). Long-term associations between related individuals have also been found in killer whales (Bigg *et al.* 1990) and bottlenose dolphins (Wells *et al.* 1987). Individuals may display preferences for certain areas or prey items, which may influence the movement of the entire group. Concurrent behavioral observations, photo-identification of individuals, and acoustic recordings would allow us to more accurately identify individuals and document changes in behavioral state.

It was not possible during this study to determine if the presence of swimmers in the water within the main group affected the behavior of the smaller groups. It was difficult to determine when and how many swimmers were in the water with the dolphins, without coordination of observations from shore and tourist vessel. The number of dolphins around the swimmers, whether the engine was on, and the method in which swimmers entered the water were important factors that could not be accurately assessed from the shore station.

This study was biased in its selection of focal pods, as smaller groups closer to shore were easier to track than groups further from shore. No attempt was made to determine the behavior of dolphins further offshore where other factors could affect behavior. Additionally, selection of focal groups was based on animals that were clearly within the arena, close to shore and away from other groups to avoid group confusion.

My 100m and 300m criteria may therefore not be valid for these groups, as they may have already distanced themselves from other dolphins and vessels.

Though no significant differences in mean leg speed and reorientation rate were shown for 300m criteria, it is recommended that current guidelines and regulations are not changed from the current standards. Observable trends were evident that are potentially important enough that a conservative approach is recommended. Caution is warranted, as sample sizes in this study are small. One interesting aspect of this research is that I initially started out with a 1,000m criteria for the boat condition. This led to virtually little to zero no boat time, meaning that dolphin groups, even those that we had selected that were away from the main group of dolphins, were almost always within 1,000m of a vessel. This is easily within the detection range of dolphins. The biological significance of this association with vessels is unknown, and future studies incorporating vessel noise profiles could be helpful to determine maximum vessel detection ranges of the dolphins.

As it appears that the New Zealand dolphin- and whale-watching industry will continue to remain a stable and lucrative business, it is important to continue to involve all of the concerned parties in management decisions regarding these animals. With the different interests of commercial, recreational, and scientific research groups, conflicts can easily arise over access to dolphins and whales. But without the cooperation of local operators, residents, government employees and researchers, mandatory regulations would be difficult to enforce with the shortage of available enforcement personnel. What is especially remarkable in Kaikoura, is that the new voluntary guidelines were adopted by the operators, without a top-down management decision made by the DoC. The operators did not wait for an overt change in behavior or distribution by the animals. Instead they took the initiative by modifying their trip schedules to avoid a period of the day when the animals could be most susceptible to disturbance. By taking a farsighted approach to the management of this industry, these operators show that their interest in the dolphins and the tourist industry in the Kaikoura area are long-term. Because amending or changing government regulations is often a slow process, and as the tourist



industry grows almost exponentially, it will be difficult for lawmakers to keep up with the development of this industry. Thus the responsibility for management that sustains this business activity without causing undue disturbance to the animals falls on the shoulders of those who have a vested interest in the resource. The greatest chance of success for protection of and continued access to dusky dolphins for the public will occur only with the cooperation of all involved local parties. With the current atmosphere of foresight displayed in Kaikoura, it is very possible that dusky dolphins and humans may continue to use this area for generations.

### **Future research**

Identifying animals and coordinating observations from shore and from tourist vessels would allow us to generate a more complete picture of the effects of human activity on small groups of dusky dolphins. After the completion of the fieldwork for this study, a photo-identification investigation was started by colleagues in Kaikoura (Markowitz, Harlin, and Würsig 1998 pers. comm.). It is possible that long-term effects can be discerned, once the animals within this region are identified and monitored through several years. Nicholette Brown, a master's student from the University of Auckland, has recently completed her fieldwork and is analyzing theodolite and behavioral data from the Kaikoura area. Her study, undertaken with an observation period during the middle of the day with no boats, will allow her to examine in greater detail if changes in behavior occur before, during, and after vessel approach periods. If this no boat period could be coordinated with controlled experimental vessel approaches during other time periods, a more complete picture of dolphin responses to human activity could become evident.

Personal observations from tourist vessels have revealed that only a small percentage of dolphins interact with swimmers and tourist vessels. If we could ascertain the identity of dolphins, it would be interesting to determine if the same animals are repeatedly approaching the tourist vessels and swimmers from one day to the next, while the majority of other dolphins essentially ignore the boats by simply swimming past.

A more detailed study of the movement patterns of the mother/calf groups throughout the season would be helpful to determine if swimming speeds change with the age of the calf. If for instance, it was found that young calves do not move as rapidly as older calves, this knowledge would allow us to make decisions on special regulations or guidelines for mother/calf groups early in the calving season.

Even though no effect of boat condition was found when boats were within 100m or 300m of the small dolphin groups, sample sizes were small and resulting power was low. Thus, it is recommended that current guidelines and regulations not be changed and that dolphins in this area should continue to be monitored closely.

## CHAPTER 3

### WHISTLE SOUNDS OF DOLPHIN GROUPS

#### Introduction

Dolphin signals have generally been classified into three types: click train, burst pulse, and whistle. A click train is a series of individual clicks, that are usually broadband signals with a rapid rise time (Caldwell and Caldwell 1971). Burst pulses are composed of individual clicks, but the repetition rate is so high that it is indistinguishable to humans as anything but a buzzing sound. Whistles are pure-tone, narrow-band frequency modulated signals that usually vary in frequency with time (Caldwell *et al.* 1990). In general, most research has focused on whistles (Sayigh 1992, Driscoll 1995), as they are relatively easy to classify and measure. Dusky dolphins have been recorded making all three types of delphinid sounds, though the majority of the calls seem to be burst pulses (pers. obs.). Whistles usually can be distinguished from burst pulses aurally, and also as a visual representation called a spectrogram. A spectrogram is a three dimensional view of frequency versus time, with a gray scale denoting intensity. Software packages are now commercially available that allow researchers to digitize and analyze sounds. One computer program, Canary™ (Charif *et al.* 1995), will be discussed in greater detail later in this section.

The objectives of this study were to 1) describe the sounds, specifically whistles, of dusky dolphins, and 2) determine if there is a correlation between whistle rate and group size, behavior, and time of day.

#### Methods

We launched a 4.5m inflatable powered by a 25 Hp engine on days when weather and sea conditions were amenable for acoustic recordings, dolphins were within range of the research vessel, and sufficient crew (at least two) were available. Occasionally, due to weather conditions or location of dolphins, behavioral observations and acoustic recordings were made from other platforms, including tourist boats. The tourist vessels

turned out to be noisy platforms, with overwhelming amounts of boat and other background noise, making for poor recordings. Therefore, the majority of the acoustic recordings were made from the research vessel. For the research vessel, at least two crew members were necessary for acoustic recordings, a notetaker and a driver/acoustic monitor. Vessel and dolphin positions were recorded by handheld Global Positioning System (GPS) and noted on data sheets. Beaufort sea state, wind speed and direction, swell height and direction, air and water temperature, cloud cover, and salinity were noted at the start and end of acoustic recordings for each group. Group size, composition, and behavioral state were also noted for each group. Though an attempt was made to sample as many different-sized dolphin groups in different behavioral states and composition in order to record the full repertoire of acoustic behavior, often groups were selected due to absence of associated vessels and engine noise or location away from areas of shorebreak or pistol or snapping shrimp (Genus *Alpheidae*). Additionally, under the New Zealand Marine Mammals Protection Regulations (1992), only three vessels may be associated within 300m of any one group. Kaikoura has two dolphin-swim companies, totaling three vessels, plus at least four other whale watch boats that periodically come to view dolphins. Therefore, human activity around the dolphins was often high, leading to increased levels of boat noise and subsequent poor conditions for recording.

Dolphins were recorded in one of two methods: while the research boat was stationary and while the engine was engaged and the vessel was underway. Both methods were put to use in the 1996-97 season, during which the bulk of recordings were made. For each method, the research vessel was maneuvered as close as possible to each group in order to obtain the highest signal to noise ratio. The vessel was positioned ahead of the animals' path of travel, then stopped off to one side to avoid being directly in the path of travel. The engine was shut off, the boat was allowed to drift, and the hydrophone (Model #HTI-94-SSQ High Tech, Gulfport MS) was deployed at a depth of between 5-10m. PVC tubing was occasionally used to keep the cable from rubbing on the side of the boat. Dolphin signals were monitored with headphones and

recorded by either a Marantz PMD430 analog cassette recorder or SONY DAT Walkman TCD-D7. A word of caution is necessary here due to the frequency limitations of the field recording equipment; high frequency measurements reported here do not accurately depict the maximum frequency capabilities of dolphins. The Marantz has a relatively flat frequency response to 17 kHz, while the DAT records to approximately 22 kHz. The hydrophone has a frequency response from 20 Hz to 20 kHz. Occasionally, very intense measured signals would exceed this range (*e.g.*, high frequencies of 19 kHz were recorded with the Marantz), but any signals over 25 kHz were not recorded, and are outside the hearing range of humans. Recordings were made until the signal to noise ratio was such that dolphins could no longer be heard over background noise, or had moved off so that signals became too faint to hear. When this occurred, the recorder was switched off, the hydrophone retrieved from the water, and the engine re-started. The boat was again maneuvered to the side of the dolphins and the process was repeated. Concurrent with the acoustic recordings, an observer noted behavioral state, speed of travel, group size and dispersion (tight, dispersed, *etc.*), and the general activity state of the dolphins. Dispersion was judged by eye by experienced observers and defined as 1) tight: animals grouped closely together with less than two body lengths between animals; and 2) dispersed: animals with a greater than two body length distance between individuals. Species associated with the duskies were also noted (feeding or diving birds, common dolphins, sperm whales, killer whales, *etc.*). During the summer months, dusky dolphins in the Kaikoura area are often seen in mixed species groups with common dolphins. Commons comprise only a very small percentage of the total number of dolphins in these groups, usually numbering less than 10% of total dolphin numbers. In general, commons do not approach boats, staying in a clump within the larger group of dolphins. Comments on dolphin behavior were also recorded on the comment channel of the Marantz analog recorder. Marantz counter numbers and time were recorded onto data sheets to correlate times, observed behaviors and vocalizations during later analysis. The DAT has a digital time function so that times were easily correlated with synchronized behavioral notes during analysis.

The second method of recording was performed while the vessel was underway. A 1-2 kHz high pass filter (Allen Avionics Inc., Mineola, NY) allowed recordings to be made while the engine was on. This device filtered out most elements of motor sounds, so that dolphin signals could be recorded while vessel and dolphins were traveling together. This method allowed for longer recording sessions, as dolphins were not out of the range of the hydrophone. During the latter part of the study, a 1-2 kHz high pass filter was built directly into our hydrophone, which replaced the use of the Allen filter. At faster speeds, engine noise occasionally overloaded all other signals, or there were excessive strumming noises from the hydrophone cable during travel.

Boat noises and rough seas created excessive background noise and would often obscure or overpower the sounds of the dolphins. Recordings were stopped when environmental and acoustic conditions deteriorated. Successful acoustic recordings were occasionally made in the vicinity of tourist operators and swimmers, but this was fairly rare. Field notes were entered into spreadsheets and all tapes were monitored upon return to the field camp. For each tape, I created a preliminary log of all whistles, interesting sounds, and comments.

At the end of the field season, all tapes were analyzed with Canary<sup>TM</sup> (Charif *et al.* 1995) and Signal<sup>TM</sup> software at the Bioacoustics Laboratory of Texas A&M University, Galveston. Sampling was set at 50 kHz for Signal<sup>TM</sup>. Signal<sup>TM</sup> has a real-time spectrogram capability, which allowed concurrent visual inspection of vocalizations with aural monitoring as signals were played through two sets of speakers. This dual monitoring system proved to be extremely efficient in recognizing whistles and other desired vocalizations. Occasionally, signals were too faint to distinguish by ear, but were recognized visually on the screen, while at other times, aural monitoring identified signals too faint for Signal<sup>TM</sup> to display. With Canary<sup>TM</sup>, vocalizations were then stored as Audio Interchange File Format files (AIFF) files on Macintosh computers for later detailed analysis. Canary<sup>TM</sup> spectrogram settings were: filter bandwidth 349.70 Hz, grid resolution time 5.805 sec, grid resolution frequency 43.07 Hz, frame length 512, overlap 50%, FFT size 1024 points, Hamming window, display smooth, clipping level -80 dB,

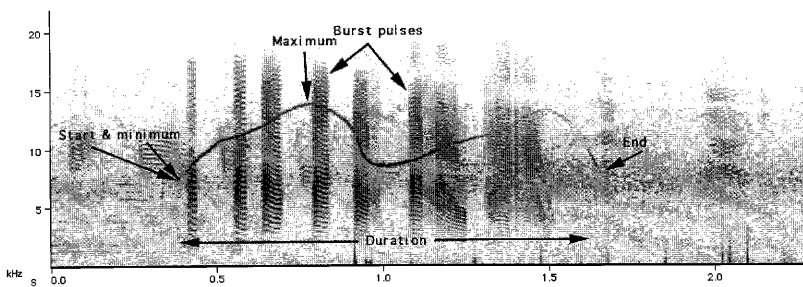
sampling rate of 44.1 kHz. Depending on availability, a Sometic Laboratories Professional Power Amplifier SA185 or Alesis RA100 Reference Amplifier was used to amplify faint signals. For either system, an Ashly Stereo 15 Band Graphic Equalizer GQX Series (Model 1502) was employed to eliminate background noise below 800 hertz, which is below the frequency range of dolphin whistles (pers. obs.).

All digitized signals were then individually checked to determine type of vocalization. As whistles were the main focus of this study, all other signal types were logged, but not subjected to further analysis. For all whistles, measurements were taken of start and end frequency, high and low frequency, change in frequency (difference between high and low frequency) and duration (Figure 15). Time, group size and behavioral state for each signal were determined from coordinated inspection of data sheets and field remarks on the comment channel. Whistle parameters were divided into three groups corresponding to whistles made in the presence of common dolphins (simplified and called the ‘common’ group, though this does not mean that common dolphins necessarily made these signals); whistles made while swimmers were in the water (‘SIW’), with remaining whistles lumped into an other category (‘dusky’). It is probable that some whistles recorded in the presence of commons were from either duskies or commons. The Wang *et al.* (1995) dataset was added during post-hoc analysis and labeled the ‘Wang’ group.

### Statistical analysis

To determine if whistle parameters could be used to discriminate between years, I first tested for normality, then ran a one-way analysis of variance (ANOVA) for normal data for each variable by year with the statistics analysis program Instat Version 3.00 (GraphPad Software, San Diego CA).

For non-normal data, I ran a non-parametric ANOVA (Kruskal-Wallis test). Tests were considered significant at  $p < 0.05$ . I included data on dusky dolphin vocalizations from Wang *et al.* (1995). In addition, I analyzed 66 whistles from the Wang *et al.* (1995) dataset to determine if methodology in whistle parameter



*Figure 15.* Spectrogram depicting parameters measured. Frequency is measured in kilohertz (kHz), while time is measured in seconds. In this instance, start frequency and minimum frequency are the same, but this is not the case for all whistles. Burst pulses are shown, but were not measured for this study.



measurement was different. Wang used the IBM based software Signal™ for analysis. It was not possible to determine which whistles in my data set corresponded to Wang's data, as different file naming protocols and tape counters were used. A subset of approximately 15 signals was chosen to test for classification agreement (whistle versus burst pulse versus click train). Both Wang and I independently classified all the signals in the same fashion.

A k-means cluster analysis was run with two (common and SIW) and three groups (common, SIW, and dusky) selected for classification. This analysis does not need an *a priori* known group, a requirement of discriminant analysis (W. Smith pers. 1999 comm., Statistica 4.1 manual 1994). The operator determines the number of clusters (k), and a statistics program will move each case or variable between clusters in order to reduce variability within clusters and maximize variability between clusters. The goal is to make each cluster as distinct as possible (Statistica 4.1 manual 1994) and to make the most significant ANOVA results. From the k-means computer output, means for each cluster on each variable were examined to determine the difference between clusters.

## Results

During three field seasons, 2,059 minutes of audiotape from 55 days were recorded: 270 minutes from 1995 (10 days), 45 minutes from 1996 (3 days), and 1,744 minutes from 1997 (1,144 from Marantz, 600 from DAT, 42 days) (Table 10). Shore-based observations were the primary goal in the first two seasons, however an effort was made in the 1997 season to concentrate on obtaining acoustic data, which accounts for the discrepancy in sample size. All recordings were made between 6 November and 28 April, corresponding to spring/summer seasons, with the majority of recordings made from January through April.

From these tapes, 1,641 files were recorded (or 'clipped') into Canary files. Upon further data reduction, 985 were classified as whistles. From this subset, 785 whistles with appropriate signal to noise ratio were measured (Table 11).

*Table 10: Acoustic recording effort.*

Season	Minutes analyzed	Days	Marantz or DAT
1995	270	10	Marantz
1996	45	3	Marantz
1997	1,744	42	Marantz (1,144 minutes) DAT (600 minutes)
Total	2,059 (34 hr 19 min)	55	

*Table 11. Breakdown of whistles for each season.*

Season	Number of files	Number of signals	Identified whistles	Measured whistles
1995	425	925	706	597
1996	90	145	78	75
1997	1,076	1,646	201	113
Total	1,641	2,716	985	785

Data reduction started with recordings from 1997, so that at first, any signal resembling a whistle in structure from the spectrogram or by ear from the recording was clipped. With greater experience, I was able to distinguish whistles from burst pulses and click trains more efficiently during the initial process of analysis, resulting in fewer clipped signals.

By coordinating time of sounds and behavioral data from the field notes and spoken comments, I categorized each whistle to a particular context. The majority of analyzed whistles were recorded during two different contexts. Five hundred and seventy whistles were measured on days when common dolphins were seen (31 whistles on days when commons were seen but not during recording sessions ), while 164 whistles were recorded when swimmers were in the water (SIW), but no commons were seen (Table 12). The remaining 20 whistles were recorded from small groups (5-10 dolphins) and large groups (200-500 dolphins), during rest, mill and travel behavioral states (Table 13).

Table 12. Whistles by situation and whistle rate. Asterisks designate total recording time for duskies, including days when no whistles were heard.

Situation	Number of whistles	Percentage of total	Days	Minutes recorded	Rate (whistles/min)
Commons present	570	72.6	6	105	5.43
Commons seen earlier in day	31	3.9	3	36	0.86
Swimmers in water	164	21	8	265	0.62
Only duskies seen (with all recordings)	20	2.5	8 (41)	281* (1673)	.07 (0.01)

Over ninety seven percent of whistles were recorded during 406 minutes of recording (6 hours 46 minutes) of recording on 12 days, while the remaining 20 whistles were recorded in 281 minutes (4 hours, 41 minutes) on eight days. When all effort is included, including days when no whistles were recorded, but omitting days when commons were seen or swimmers were observed in the water, 20 whistles were recorded in 1673 minutes of recording on 41 days (Table 12, numbers in parentheses). In other words, only 20 whistles from dusky groups were recorded on eight days out of a total of 41 recording days. To determine approximate whistle rate, numbers of whistles were divided by minutes recorded (Table 12). This included only those distinct enough to be chosen for analysis and does not include the “cacophony” of whistles often heard in mixed species groups. I did not standardize each of the situations by group size; however group sizes for both common and dusky groups were approximately 300 animals. For SIW, group sizes ranged from 2-8 dolphins. Even without this correction, it is apparent that more whistling is recorded during periods when commons are seen, or when swimmers were in the water with duskies. During these SIW periods, I am confident that duskies were the only species of dolphin present.

Of 785 total measured whistles, 725 whistles were made during the months of January through March. Even though I recorded over 1,270 minutes of dolphin sounds during April, only 60 whistles were recorded (whistle rate: 0.05/min). Dolphins were easier to record in April as there were much fewer recreational and tourist vessels with

the dolphins, as it was past the peak of the summer season. During April for all years, only one common dolphin was seen (on two days). Whistles recorded in April tended to be sporadic occurrences, with no sessions having more than seven recorded whistles, even though recording sessions could last 220 minutes. Whistles tended to occur in bouts. For instance, on March 30, 1995, 390 whistles were recorded in 23 minutes of recording. On January 9, 1997, 163 whistles were counted in five minutes of recording, though only 80 were analyzed, due to overlap of signals.

Frequency measurements for the dusky group are provided in Table 14. The majority of dusky whistles come from the 1997 season, with only 2 whistles from 1996 and none from 1995. Whistle parameters are similar both to those published for other delphinid species (e.g., Moore and Ridgway 1995), and to those of Wang *et al.* (1995).

*Table 13: Behavior and group size of duskies when whistles were recorded. No observed commons or swimmers in the water.*

Minutes recorded	Number of whistles	Group size	Behavior
3	2	150	Slow travel/rest
30	1	5-10	Travel
30	2	250	Travel
55	2	500	Mill/travel
30	4	6	Mill/rolling
30	4	200-300	Slow travel
30	1	200-300	Slow travel
73	7	300	Travel/rest

Comparisons between different groups were all highly significant at  $p < 0.001$  by the Kruskal-Wallis test for all parameters. The common group low frequency values were higher than those for the other three groups, with a value of 9.207 kHz versus 8.111 kHz for the SIW group, 8.155 kHz for the dusky group and 8.037 kHz for the Wang group (Table 15). Similarly, the end frequency for commons was higher than the other groups, but there is a great deal of overlap (Figure 16). Comparisons for start, low, high

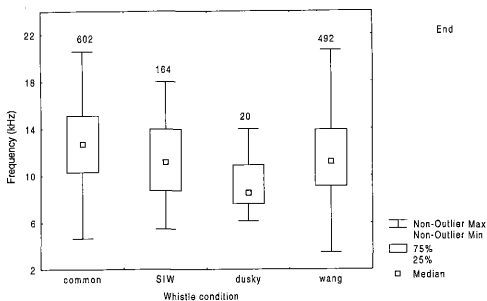


Figure 16. Comparison of end frequency by whistle condition. Value labels signify number of whistles.

and change in frequency along with duration showed similar levels of overlap (Figures 17-21). Values for SIW and dusky frequency measurements were all lower in value than those from the common or Wang group. From these results, I ran a k-means cluster analysis to see if whistles could be accurately classified from these variables.

By use of the random number generator in Microsoft Excel (Excel 5.0, 1995), I randomly selected 12 whistles per group for statistical analysis. Forty-eight cases were selected as 50 samples is the maximum allowable case size for Statistica 4.1. I standardized the data so that each variable had a mean of zero and a standard deviation of one. This was necessary because different cases have different scales (frequency measurements in kilohertz and duration in milliseconds), which would have biased the analysis used to compute differences between clusters. The k-Means cluster analysis that was run on a subset of my data showed poor classification when the common whistle group was included, intermingling all three classes, for both two and three cluster cases. A k-means cluster analysis with JMP version 3.00 (SAS Institute Inc.) using all whistles, found similar results.

To remove possible sources of variation between years, I examined SIW and dusky whistles for 1997 only (Table 16). Again, I repeated the process of selection of cases with Excel, and re-ran the k-Means cluster analysis. Though it is possible to see that low, high, change, and start frequency and duration were important variables in classifying a case to a cluster, classification between duskies and SIW was poor, with SIW and dusky divided between the two clusters.

Overall, none of the different variables could cluster whistles back to the groups that I had originally set. It is not apparent from these data if the original groups were misclassified, or if there is a large amount of overlap in whistle parameters between behavioral state and possibly by species. Sample size for the dusky group was small, which may have limited my ability to correctly classify groups.

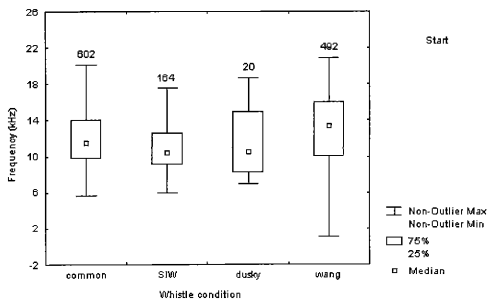


Figure 17. Comparison of start frequency by whistle condition. Value labels signify number of whistles.

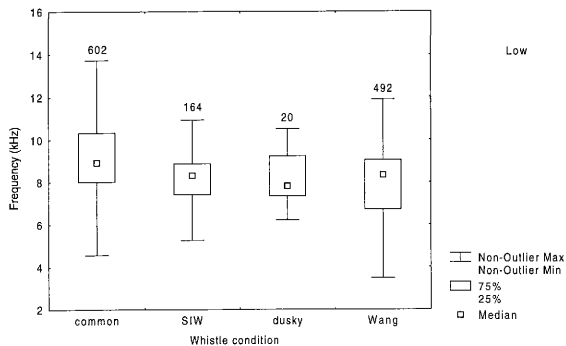


Figure 18. Comparison of low frequency by whistle condition. Value labels signify number of whistles.



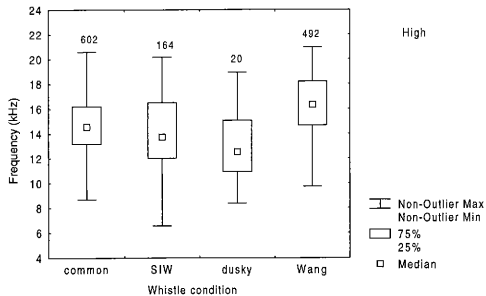


Figure 19. Comparison of high frequency by whistle condition. Value labels signify number of whistles.

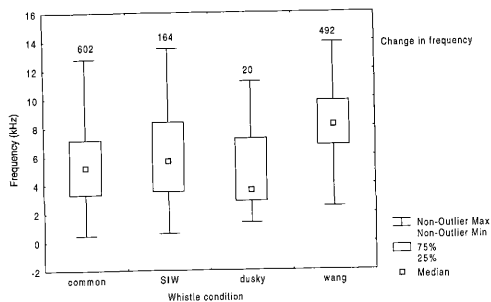


Figure 20. Comparison of change in frequency by whistle condition. Value labels signify number of whistles.

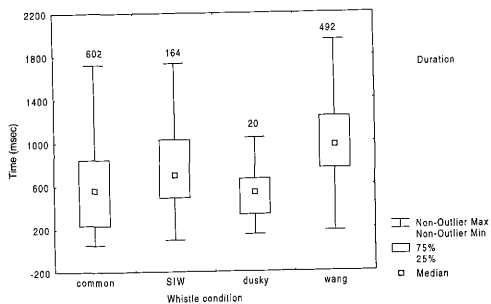


Figure 21. Comparison of duration by whistle condition. Value labels signify number of whistles.

Table 14. Whistle parameter measurements for all dusky group whistles. Frequency measurements are provided in kilohertz (kHz), and duration is measured in milliseconds (msec).

Low frequency	High frequency	Change frequency	Duration	Start frequency	End frequency
10.521	13.544	3.023	144.597	11.306	13.108
9.213	17.392	8.179	980.221	17.177	13.991
7.103	10.762	3.659	691.834	10.676	7.275
8.028	11.553	3.525	406.706	8.159	11.52
8.207	11.345	3.138	191.224	8.253	11.283
7.512	12.815	5.303	561.846	7.866	12.255
9.81	12.432	2.622	284.572	12.314	9.987
7.858	11.194	3.336	560.849	7.918	7.999
9.242	12.626	3.384	454.976	10.433	10.106
6.231	10.993	4.762	576.709	6.966	6.173
7.584	10.082	2.498	379.667	9.083	7.642
7.407	13.609	6.202	1,043	13.492	7.584
9.428	10.805	1.378	232.773	10.289	9.557
9.374	10.842	1.469	281.294	10.443	10.541
7.275	16.445	9.17	554.688	16.359	7.405
7.749	18.942	11.193	811.337	18.684	8.007
7.06	8.395	1.335	516.364	8.179	8.524
8.395	13.69	5.295	512.997	13.259	8.567
7.77	17.542	9.772	647.583	17.435	7.964
7.146	17.909	10.762	675.295	17.78	7.318

Table 15. Summary of mean values for all groups. Values from Wang *et al.* (1995) are included for comparison. Frequency measurements are provided in kilohertz (kHz), and duration is measured in milliseconds (msec).

	Low frequency	High frequency	Duration	Start frequency	End frequency
Common	9.207	14.522	583.613	11.913	12.658
SIW	8.111	14.160	777.504	10.863	11.379
Dusky	8.155	13.224	535.890	10.697	9.302
Wang	8.037	16.486	1030	11.687	12.225

Table 16. ANOVA for SIW and dusky

Variable	Between SS	df	Within SS	df	signif. F	p
Low frequency	9.14542	1	37.85458	46	11.1133	0.0016997
High frequency	30.56552	1	16.43448	46	85.5527	0.0000000
Change in frequency	36.84628	1	10.15372	46	166.9270	0.0000000
Duration	13.03316	1	33.96684	46	17.6503	0.0001207
Start frequency	3.86510	1	43.13490	46	4.1218	0.0481387
End frequency	2.46657	1	44.53343	46	2.5478	0.1172961

Members of Cluster Number 1 and Distances from Respective Cluster Center  
Cluster contains 25 cases

	95-siw	96-siw	96-siw	96-siw	96-siw
	96-siw	96-siw	96-siw	96-siw	96-siw
	96-siw	96-siw	96-siw	97-dusky	97-dusky
	97-dusky	97-dusky	97-dusky	97-siw	97-siw
	97-siw	97-siw	97-siw	97-siw	97-siw
Distance	1.270846	1.131619	.9503737	1.198793	1.059752
	.7316337	1.251620	.5972450	.9213735	1.146521
	.5629182	.9483861	.7689395	.9684550	.9623204
	.8804352	.7341728	.8359717	.5737599	.5079201
	1.119377	.8138589	.7656099	.7346987	.8510631

Members of Cluster Number 2 and Distances from Respective Cluster Center  
Cluster contains 23 cases

	95-siw	95-siw	95-siw	95-siw	95-siw
	95-siw	95-siw	95-siw	95-siw	95-siw
	95-siw	97-dusky	97-dusky	97-dusky	97-dusky
	97-dusky	97-dusky	97-dusky	97-siw	97-siw
	97-siw	97-siw	97-siw		
Distance	.5328503	.5499554	.8247650	.6696280	.6321937
	1.047017	1.031789	.5393279	.3462073	.4314611
	.4030729	.6888140	.2102529	.9951391	.8245373
	.8087063	.5534733	.5265346	.6931925	.4710142
	.4249995	.7085309	.3851311		

## Discussion

This study represents the second investigation undertaken to describe frequency and duration characteristics of vocalizations recorded in the presence of dusky dolphins (after Wang *et al.* 1995). Though neither study has solved the issue of the source of these whistles, this study has found an interesting behavioral correlation between whistle rate and the presence of dusky dolphins with commons or with human swimmers.

There is an increase in numbers of recorded whistles when duskies are associated with commons and when swimmers are in the water. Whistles can occur in bouts, with many whistles occurring in a short amount of time. When no commons are observed and no swimmers are in the water, long periods of travel and milling may occur without any recorded whistles. Contrary to findings by Wang (1993), whistles do not appear to play a predominant role in the day to day repertoire of sounds produced by duskies in New Zealand. This is not to say that whistles do not play an overall important role, but that the majority of daytime vocalizations are not whistles. No work has been conducted at night, a shortfall that should be addressed in future studies. A concentrated effort to record dusky sounds (a greater than six-fold increase from 1995) during the 1997 season failed to record as many whistles as the number found in only two hours of recordings made in the presence of commons. W. E. Evans (1998 pers. comm.) has remarked that in general, Pacific white-sided dolphins, another *Lagenorhynchus* species, do not whistle often, a finding in agreement with my results. His observations are contrary to those of Fahner *et al.* (1998) who found that captive Pacific white-sided dolphins whistled often (though no rates were provided). However, these captive dolphins were recorded when they were isolated, a period when dolphins could be under stress and more prone to whistle, as found by Caldwell *et al.* (1990) for bottlenose dolphins. Though it is not possible to determine if whistlers in this study were experiencing stressful circumstances, the general behavior of the dolphins at the time of the recording did not appear to be overly stressed, with dolphins slowly traveling and little aerial activity. But the possibility that duskies, like bottlenose dolphins, may whistle when under stress should be addressed in future studies.

The frequencies reported for whistles for dusky dolphins are within the range reported for other *Lagenorhynchus* species as well as for *Delphinus* (Table 17). Steiner (1981) reported mean values for *L. acutus* that are similar to values reported for duskies from this study. Other acoustic studies on *Lagenorhynchus* species have not provided specific information on the parameters measured in this study (e.g., Schevill and Watkins 1971, Fahner *et al.* 1998).

Table 17. Comparison of mean values for whistle parameters measured in this study and other acoustic studies. Asterisks (\*) denote mean values calculated from reported values. Frequency measurements are provided in kilohertz (kHz), and duration is measured in milliseconds (msec).

Species	Low frequency	High frequency	Duration	Start frequency	End frequency
<i>L. obscurus</i> (this study)	8.155	13.224	535.890	10.697	9.302
<i>L. obscurus</i> with <i>D. delphis</i>	9.207	14.522	583.613	11.913	12.658
<i>L. obscurus</i> with SIW	8.11	14.160	777.504	10.863	11.379
<i>L. obscurus</i> (Wang <i>et al.</i> 1995)	8.037	16.486	1030	11.687	12.225
<i>L. acutus</i> (Steiner 1981)	8.210	12.140	0.500	11.506	9.625
<i>D. delphis</i> (Moore and Ridgway 1995)	5.9*	10.14*	0.316*	6.6*	10.06*

A great deal of overlap in frequency ranges can be seen between different species. In this study, whistles recorded in the presence of common dolphins were higher in frequency than those recorded with duskies alone. This is surprising as the frequency levels provided by Moore and Ridgway (1995) are lower in frequency than those reported for my common group. One possibility is that mixed species groups may have a higher level of excitement, leading to higher frequency levels. These values cannot be directly compared as population geographic variation in whistle parameters is probable (W. E. Evans 1998 pers. comm.), as has been seen in *Orcinus* (Jehl *et al.* 1980).

Analysis of variance analyses revealed significant differences between variables for each dusky/common and swimmer groups, but k-means cluster analysis failed to correctly classify whistles to the correct group. I believe these results are due to two factors. Mean scores of two or three samples may differ by only a small amount, yet this difference can still be highly significant with large sample sizes (Martin and Bateson 1993). For example, with large sample sizes, a difference of two hundred hertz in start and end frequency may be statistically significant, but may not be biologically significant to the animals. Therefore, even though the results from the ANOVA found significant differences between each of the groups, the large sample sizes may have inflated small differences. On the other hand, dolphins are highly attuned to frequency modulation and should be able to detect small differences in frequency, though no work has been conducted on this subject. The more likely reason is that whistles within the common group were probably composed of calls by both species. This means that even if there are differences in frequency or duration parameters for whistles of duskies and commons, they would be obscured by a "contaminated" group containing whistles from both groups. This would apply for either the ANOVA or k-means statistical analysis.

Many researchers have found a correlation between behavioral state and type of vocalization (*e. g.*, Sjare and Smith 1986a, b; Weilgart and Whitehead 1990, Lesage *et al.* 1999). From this study, whistles were more commonly recorded during times when common dolphins were present or when swimmers were in the water. More work is necessary to determine if mixed species groups are more apt to whistle than groups composed solely of duskies. Duskies are occasionally seen in mixed groups with southern right whale dolphins (*Lissodelphis peroni*) though no recordings are available for analysis. No whistles were found in sixty one minutes of recordings of dusky dolphins with a lone sociable bottlenose dolphin, but all animals appeared to be resting. This female bottlenose dolphin was frequently seen with duskies (Müller *et al.* 1998) and it is possible that the duskies may have habituated to this particular animal.

Whistling may be a sign of excitement as suggested for bottlenose and spinner dolphins (Caldwell *et al.* 1990, A. Driscoll-Lind 1998 pers. comm.). However, during



several instances, duskies were recorded while engaged in heavy social bouts, with mating thrusts and a great deal of rolling at the surface, and few whistles (4) were recorded. These duskies appeared almost silent as very few dolphin vocalizations were recorded, even though the dolphins were less than 6m from the hydrophone and the equipment was functioning properly. It is possible that when duskies become very excited they may emit signals in the ultrasonic range, out of the recording range of our equipment. Recordings made with high frequency recording equipment are necessary to test this theory. At other times during several occasions, duskies were observed chasing fish and squid, and very few vocalizations, including echolocation clicks were recorded. This is in stark contrast to the high number of echolocation clicks, recorded during close approaches to the hydrophone by small groups of duskies. During these periods, dolphins often rub and bite on the hydrophone element as well as on the cable.

Brownlee and Norris (1994) suggest that for spinner dolphins, whistles relay to other group members information about the group's physical limits and general activity state. In this 'phatic system' of communication, whistles are an open communication channel, where variations in rate, intensity or how much a whistle modulates or 'quavers' may provide details on emotional state, activity levels and presence of potential prey or predators. For duskies, it does not appear that whistles are the main carrier of information on group limits and activity states during daytime periods. Whistles were only recorded during very limited instances when swimmers were in the water or common dolphins were seen. It is possible that when excitement levels rise above some threshold point, whistles may become a very frequently emitted signal, and then convey much information on emotional or motivational states. The rate of whistling may be different at night, when the animals are feeding and often not oriented in the tight groups seen during the day. Further work in this area is necessary to determine if daytime and nighttime sounds are similar in proportion of emitted vocalizations.

No tests have been conducted on the hearing sensitivity of duskies, but Tremel *et al.* (1998) describe the underwater hearing sensitivity of a Pacific white-sided dolphin, a

closely related species to duskies. An audiogram, or a visual depiction of the relationship between threshold and response levels to sounds of different frequencies was provided, based on the hearing of one female dolphin. Highest sensitivity in hearing was between 8 kHz and 90 kHz. It is unknown if duskies have a similar hearing sensitivity.

Though it is apparent that techniques must be found to identify the source of calls from free-ranging wild dolphins, difficulties arise due to large group sizes and our inability to conduct direct observations of the animals. Air bubbles are sometimes, though not always, released when dolphins are whistling, so this release of air cannot be used as a reliable identifier of the whistling animal (Caldwell *et al.* 1990). For captive dolphins, Tyack (1991) developed a device he called a “vocalight”, a small instrument placed on the forehead of a dolphin that would light up when the animal vocalized. The use of a similar device on free-ranging dusky dolphins would not be feasible, as it necessitates catching and placing a vocalight on each animal. Additionally, as the animals are not confined to a pool, it would be difficult to see the lights and identify the signallers. Other techniques, perhaps use of acoustic arrays or concomitant underwater observations, may aid in identifying the vocalizing animals.

Though it is not possible to determine with absolute certainty the identity of the whistlers during this study, no commons were seen on ‘dusky’ whistle days by experienced crew from the tourist and research vessels during long periods of observation (D. Buurman 1997 pers. comm.), occasionally up to eleven hours a day. Additionally, I believe it is unlikely that many of the whistles recorded during the “swimmer” sessions were made by commons. Many of the whistles were very clear, with a high SNR, and appeared loud enough that they probably were not produced by a distant animal.

The number of whistles recorded was not equal from month to month. Though it was possible to test for whistle rate by time of the year or water temperature, these tests were not done, as results would be biased due to the absence of whistles recorded during all months. The majority of apparent dusky whistles were recorded in April, when fewer

commons were seen and past the height of the tourist season. The month of April is also past the peak of the breeding season. Most of the common group whistles were recorded during January and February. Thus, it is possible that duskies whistle more often during the breeding season, and that commons contribute little to the number of whistles recorded during these periods. These factors cannot be controlled in this study area. Commons often are seen in small groups during much of the summer, while tourist operators are running at full capacity during the summer months of December through February. Therefore, for most days during this period, vessels are near the dolphins, and recording conditions are poor due to engine noise.

If it is possible to determine the origin of whistles made during this study, it may be possible to acoustically determine when dolphins are 'in the mood' for social interactions with humans. This knowledge would prove beneficial to both parties, as tourist operators may be able to gauge how 'in the mood' dolphins may be towards swimmers. Dolphins could benefit by being left alone during periods of rest, a period correlated with low vocal activity. If much whistling indicates high stress, dolphins should not be approached at these times. However, there is no clear behavioral indication of such a whistling-stress relationship for duskies. As this link seems unlikely, other approaches for determination of stress levels, such as work on a hormonal indicator of stress levels, could be of value.

The low rates of whistle production by duskies does not mean that these animals were silent. Though not quantified in this study, the majority of calls recorded were burst pulse sounds. For captive bottlenose dolphins, Overstrom (1983) found agonistic behavior was correlated with an open-mouthed position, jaw claps and the emission of burst pulses. An increase in number and duration of emitted burst pulse signals was correlated with an increase in the intensity of aggressive responses between dolphins. Though he was not able to determine if higher numbers of burst pulse signals directly contributed to the higher levels of aggressive behavior, or simply reflected excitement levels, Overstrom suggested that burst pulse signals could cause discomfort if directly projected at another dolphin (Overstrom 1983). Though the intensity of burst pulse

signals was not measured in my study, these signals did not appear to be at very intense levels, as record levels on the recording equipment did not have to be changed when recording these signals. Additionally, burst pulses were recorded during all behavioral states, including rest. If burst pulse signals reflect or contribute to higher levels of aggression in bottlenose dolphins, it would be interesting to monitor the behavior of mixed species groups of duskies and bottlenose dolphins. For instance, Maui, the bottlenose dolphin that spent much of her time in association with duskies, may have had to change her response to burst pulses, since those signals make up the majority of emitted dusky signals.

The question arises as to why whistles do not seem to play as important a role in communication for duskies as it does for many of the 'long-nosed' species of dolphins, such as spinner dolphins. Differences in types of emitted vocalizations may reflect differences in anatomy, behavior or habitat. Anatomical differences may reflect different abilities of dolphins to create sounds. Burst pulses may be easier to produce than whistles for some species. For instance, anatomical differences may explain the manner in which different species echolocate. Evans (1973) suggests that differences in the number of fused cervical vertebrae may be related to how an animal scans a target. Many of the pelagic dolphins have fused cervical vertebrae, which does not allow them to move their heads from side to side or up and down as easily as dolphins with unfused cervical vertebrae. These dolphins seem to roll more when echolocating on a target. Bottlenose dolphins, which have five free cervical vertebrae, seem to scan a target by moving their heads as they approach an object. It is possible that duskies are somehow limited in some way in their whistle production and that it may be easier to emit burst pulses under 'normal' conditions. During periods of higher activity, whistles may play a more important role in communication.

McCowan *et al.* (1998) found that familiarity influences whistle structure in adult female captive bottlenose dolphins. Social group membership and long-term associates may affect contour shape and frequency range of whistles. They suggest that dolphins may change their calls to match calls made by other known associates, and may be one

driving force behind geographic variation. Caution must be taken, as this study was conducted on captive animals. How social bonds affect whistle structure in duskies is unknown.

One last factor influencing acoustic structure may be the type of habitat where the species spends the majority of its time. For instance, Dahlheim *et al.* (1984) found that the majority of vocalizations produced by bottlenose dolphins and gray whales in Laguna San Ignacio, Mexico were either above or below the frequencies of predominant biological background noise. They suggested that animals may shift their vocalizations away from 'noisy' frequencies, and introduced an "acoustic niche" hypothesis. Though correlations between habitat use patterns, biological noise, and dusky vocalizations were not examined in this study, these factors could be important factors in the acoustic behavior of duskies.

Though I was not able to identify whistles to species, the study provides necessary baseline data on frequency and behavioral correlates for dusky dolphins in Kaikoura.

### **Recommendations for future work**

A major limitation of many acoustic studies of free-ranging animals is the possibility that vocalizations attributed to one species were made by some other organism. For this study, it is not possible to state with absolute certainty that all of the whistles examined in this study were emitted by dusky dolphins, a problem also faced by Wang *et al.* (1995). Future research should obtain vocalizations from lone groups of either duskies or commons, preferably from the Kaikoura area to avoid geographical variation in whistles. Additionally, duskies from other areas off New Zealand should be recorded to determine if there is geographical variation in vocalization structure. From there, comparisons with other dusky dolphin populations can be made to vocalizations of mixed dolphin species groups to determine if these groups have different proportions of vocalizations. It would be interesting to determine if duskies that frequently travel with

commons have different acoustic behavior from duskies traveling in single species groups.

Plans are underway to compare vocalizations of duskies recorded in Argentina with New Zealand duskies. A preliminary analysis of several whistles recorded in Argentina shows very similar contour shapes to those recorded in New Zealand. Though contour shapes were not a focus of this study as they are often a very subjective measure, they have been used in past studies for classification of whistles (Sayigh 1992, Stienessen 1998). Common dolphins are seen with duskies in Argentina as well, so more detailed analysis correlated with video and behavioral observations is necessary.

Several colleagues in New Zealand will be recording vocalizations from commons and duskies in separate areas. These new recordings would allow us to have a known set of single species groups from which greater comparisons can be made. Recordings of groups of only common dolphins were not obtained earlier as the presence of commons was not thought to influence the duskies acoustically. Therefore, I did not assume that commons were whistling. However, as I analyzed my data, I found a strong link between whistling and either 1) presence of at least some common dolphins or 2) dusky dolphins and swimmers.

Commons will be recorded off the southern part of the North Island, where similar sized groups to those seen off Kaikoura (<30 animals) are seen (D. Neumann 1999 pers. comm.). No photo-identification studies have been conducted to link animals seen off Kaikoura to those seen off the North Island during the winter months, but commons are seen in northern areas of the South Island at this time (Gaskin 1968b, Webb 1973b). Duskies will be recorded off Kaikoura during June/July. Commons have never been seen at this time in this area, perhaps due to low water temperatures. Additionally, several captive common dolphins in the aquarium in Napier will be recorded and their vocalizations compared to all the data sets, though capture location of these animals must be determined.

Murray *et al.* (1998) recently described the difficulty and subjective nature of classifying whistles versus other pulsed signals. They found that some pulsed signals

may be classified as whistles by some researchers and as clicks by others. It would be extremely beneficial if standard criteria could be established for classification of dolphin vocalizations, as it appears that in some cases, classification can be subjective. For this study, both visual and aural comparisons were simultaneously inspected, with sounds slowed down to rates where individual pulses could be heard for burst pulses. Whistles sounded like a single continuous tone. Though I believe this method functions equally as well, it would be interesting to compare whistle identification by an experienced human observer versus the duty cycle employed by Murray *et al.* (1998).

This study provides a body of information regarding whistles recorded in the presence of dusky and common dolphins. The difference in numbers of whistles recorded during periods when commons were observed or when swimmers were in the water versus periods when only duskies were observed is interesting. Whistles do not appear to play a large role in the communication systems of these animals, except during specific instances. This increase in whistle production may be related to mixed species groups (*i.e.*, common with duskies, swimmers with duskies) leading to elevated excitement levels. Future work should focus on the acoustic behavior of duskies when found in mixed species groups, as well as in obtaining recordings when only one species of dolphin is present.

## **CHAPTER 4**

### **CONCLUSIONS**

This study provides information on the behavior and movement patterns of small groups of dolphins and the potential effect of human activity on mean leg speed, linearity and reorientation score. Though no difference in mean leg speed was observed when vessels were within 1,000m, 300m and 100m, high variability within groups may have obscured differences in the influence of no boat, boat and post boat conditions. Additionally, low sample sizes led to low statistical power for most of the comparisons of boat condition.

I did find statistical differences during post-hoc analysis for reorientation scores by boat conditions and a tendency for more course changes during boat condition. Due to the high variability between and within groups, mean leg speed may not be the most appropriate factor in which to document potential disturbance. In the future, I recommend that researchers focus on several variables in studies of tourism effects on dolphins.

In addition, the small groups of dolphins examined in this study were either not targeted by boats or not viewed for long periods of time. Instead, boats that were in the area of these groups either approached the animals for a short time or passed by without stopping for long interactions. A very different situation exists in the main group of dolphins, which is often accompanied by tourist and recreational vessels for the majority of daylight hours. More work is necessary in this area, and may elucidate the effect of human activity on dusky off Kaikoura.

A southward movement of the main group (pers. obs.) may mean that the animals are shifting their daytime locations to decrease the number and length of interactions with tourist vessels. Indeed, when dolphins are found south of the Haumuri Bluffs, the whale watch vessels do not have enough time to view both dolphins and sperm whales. As these cruises focus on sperm whales, trips often do not observe the main group of dolphins, focussing instead on whales and any small groups of dusky that may be in the area. Thus, the number of vessels that visit the dolphins is dramatically reduced. The



effects of the whale watch vessels on small groups of duskies are unknown and should be further examined. Though other ecological factors may also provide small or large contributions to this habitat shift of the main group, the potential energy expenditure due to increased travel time must be considered. Duffus (1996) documented a similar situation for gray whales in Clayoquot Sound, Canada. In this area, foraging sites for gray whales shifted farther away from the major whale-watching port of Tofino, increasing fuel costs, and decreasing the amount of time tourists were able to spend with the animals. The increased travel time may lead to increasing seasickness among passengers, resulting in decreased satisfaction by the tourists. A better understanding of the costs associated with increased travel is necessary in order to determine possible effects of habitat shifts for both dolphins and tourist operators in Kaikoura. Though I do not believe it is true, it may be inconsequential for the animals to travel an additional 10-20 km per day, which would put them beyond the reach of much of the tourist industry. But the resultant financial burden on the operators, due to decreased number of trips and time spent with the animals as well as increased fuel costs may affect the entire financial feasibility of the industry, especially if the animals increase their daytime distance from Kaikoura.

Duffus (1996) discussed the implications of two possible management approaches to an adjustment in spatial habitat use by gray whales. A risk-adversive approach was recommended over a laissez-faire strategy, as it is much easier to reduce the number of regulations should they be found to be unnecessarily limiting, than it is to increase the amount of regulation. I would recommend this more conservative strategy for the Kaikoura area, as much of the town would suffer financial hardship if the animals were to even temporarily leave the area.

Due to the permitting process mandated by DoC and resultant logkeeping by the operators, there is a great potential in New Zealand for obtaining relevant information regarding users, costs and benefits that is not often available for nature based tourism. Each permit designates the number of boat trips, passengers and swimmers, as well as size and engine type of each tourist vessel, providing information on the age, sex and

nationality of tourists who participate in this activity, as well as the amount of revenue generated by each operator. These types of information would allow us the opportunity to determine how the industry is guided, and what groups of tourists are targeted. Future studies should incorporate a socio-economic aspect, with interviews of commercial operators, tourists, and local government officials to determine satisfaction from the product and long-term goals for the future. A multi-system approach would be beneficial with experts in human dimension related issues, as well as individuals with backgrounds in physiology, behavior, oceanography, sociology and economics, coordinating their efforts in describing the tourism and natural system. The better we can understand the behavioral and ecological factors that determine disturbance, the more able we are to manage interactions of tourism and the resource.

There are many ways to attempt to understand the effects of human activities on the long-term behavior of animals, including documenting mortality, decreased fecundity of animals, long-term movements away from possibly important areas, or abandonment of preferred areas. Including experts from other areas with biologists and tourist operators to institute laws and shape policy is critical if this industry is to be sustained. The question of “when is enough too much” dolphin-targeted tourism is a difficult issue to resolve and a conservative approach may allow all parties involved to make informed management decisions for a sustainable industry.

## REFERENCES

- Acevedo, A. 1991. Interactions between boats and bottlenose dolphins, *Tursiops truncatus*, in the entrance to Ensenada De La Paz, Mexico. *Aquatic Mammals* 17: 120-124.
- Adams, R. A. 1997. Onset of volancy and foraging patterns of juvenile little brown bats, *Myotis lucifugus*. *Journal of Mammalogy* 78: 239-247.
- Anonymous. 1992. Marine Mammal Protection Regulations. Pursuant to Section 2B of the Marine Mammals Protection Act 1978. New Zealand. (From the personal collection of Suzanne Yin).
- Baker, C. S., and L. M. Herman. 1989. Behavioral responses of summering humpback whales to vessel traffic: experimental and opportunistic observations. Final report to the National Park Service, Anchorage, Alaska. Technical Report NPS-NR-TRS-89-01. 50 pp.
- Baker, C. S., L. M. Herman, B. G. Bays and W. F. Stifel. 1982. The impact of vessel traffic on the behavior of humpback whales in southeast Alaska. . Report 81-ABC-00114. Kewalo Basin Marine Mammal Laboratory, University of Hawaii, Honolulu 39 pp. Available from the National Marine Mammal Laboratory, 7600 Sand Point Way N. E. Bldg 32, Seattle, Washington 98115.
- Barber, A., R. Barber and M. Jackson. 1995. The presence of spinner dolphins (*Stenella longirostris*) affects human use and sex ratios of swimmers in Kealahou Bay, Hawaii. Abstracts of the Eleventh Biennial Conference on the Biology of Marine Mammals. 14-18 December 1995. Orlando, FL. p 7.
- Barr, K. 1997. The impacts of marine tourism on the behaviour and movement patterns of dusky dolphins (*Lagenorhynchus obscurus*) at Kaikoura, New Zealand. M.S. thesis. University of Otago, Dunedin, New Zealand. 87 pp.
- Barr, K., and E. Slooten. 1999. Effects of tourism on dusky dolphins at Kaikoura. Conservation Advisory Science Notes No. 229, Department of Conservation, Wellington, New Zealand. 28 pp.
- Bauer, G. B., and L. M. Herman. 1986. Effects of vessel traffic on the behavior of humpback whales in Hawaii. Report for National Marine Fisheries Service. 151 pp.
- Beach, D. W., and M. T. Weinrich. 1989. Watching the whales. *Oceanus* 32: 84-88.

- Bejder, L. 1997. Behaviour and ecology of Hector's dolphins (*Cephalorhynchus hectori*) in Porpoise Bay, New Zealand and the impacts of tourism thereon. M.S. thesis. University of Otago, Dunedin, New Zealand. 101 pp.
- Bejder, L., S. M. Dawson and J. A. Harraway. 1999. Responses by Hector's dolphins to boats and swimmers in Porpoise Bay, New Zealand. *Marine Mammal Science* 15: 738-750.
- Best, P. B., and G. J. B. Ross. 1977. Exploitation of small cetaceans off southern Africa. Report of the International Whaling Commission 27: 494-497.
- Bierman, W. H., and E. J. Slijper. 1948a. Remarks upon the species of the genus *Lagenorhynchus*, Part I. Proceedings Koninklijke Nederlandsche Akademie Van Wetenschappen 50: 1353-64.
- Bierman, W. H., and E. J. Slijper. 1948b. Remarks upon the species of the genus *Lagenorhynchus*, Part II. Proceedings Koninklijke Nederlandsche Akademie Van Wetenschappen 51: 127-33.
- Bigg, M. A., P. F. Olesiuk, G. M. Ellis, J. K. B. Ford and K. C. Balcomb III. 1990. Social organization and genealogy of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washington State. Report of the International Whaling Commission Special Issue 12: 383-405.
- Brownell Jr., R. L. 1965. A record of the dusky dolphin, *Lagenorhynchus obscurus*, from New Zealand. *Norsk Hvalfangst-Tidende* 54: 169-171.
- Brownell Jr., R. L. 1974. Small odontocetes of the Antarctic. Pages 15-19 in V. C. Bushnell, ed. Antarctic mammals, Antarctic Map Folio Series 18. American Geographic Society, New York, NY.
- Brownell, Jr., R. L., and F. Cipriano. 1999. Dusky dolphin *Lagenorhynchus obscurus* (Gray, 1828). Pages 85-104 in S. H. Ridgway and R. Harrison, eds. Handbook of marine mammals, Volume 6, the second book of dolphins and the porpoises. Academic Press Inc., San Diego, CA.
- Brownlee, S. M., and K. S. Norris. 1994. The acoustic domain. Pages 161-185 in K. S. Norris, B. Würsig, R. S. Wells and M. Würsig, eds. The Hawaiian spinner dolphin. University of California Press, Berkeley, CA.
- Bryant, P. J., C. M. Lafferty and S. K. Lafferty. 1984. Reoccupation of Laguna Guerrero Negro, Baja California, Mexico, by gray whales. Pages 375-387 in M. L. Jones, S. L. Swartz and S. Leatherwood, eds. The gray whale *Eschrichtius robustus*. Academic Press Inc., Orlando, FL.

- Buchner, A., F. Faul and E. Erdfelder. 1996. GPower: a priori, post-hoc, and compromise power analyses for the Macintosh. Version 2.1.1. Trier, Germany.
- Caldwell, D. K., and M. C. Caldwell. 1971. Underwater pulsed sounds produced by captive spotted dolphins, *Stenella plagiodon*. *Cetology* 1: 1-7.
- Caldwell, M. C., D. K. Caldwell and P. L. Tyack. 1990. Review of the signature-whistle hypothesis for the Atlantic bottlenose dolphin. Pages 199-234 in S. Leatherwood and R. R. Reeves, eds. The bottlenose dolphin. Academic Press Inc., Orlando, FL.
- Charif, R. A., S. Mitchell and C. W. Clark. 1995. Canary 1.2 User's Manual. Cornell Laboratory of Ornithology, Ithaca, NY.
- Cipriano, F. 1985. Dusky dolphin research at Kaikoura, New Zealand: a progress report. *Mauri Ora* 12: 151-158.
- Cipriano, F. W. 1992. Behavior and occurrence patterns, feeding ecology, and life history of dusky dolphins (*Lagenorhynchus obscurus*) off Kaikoura, New Zealand. Ph.D. dissertation, University of Arizona, Tucson. 216 pp.
- Cipriano, F. 1997. Antitropical distributions and speciation in dolphins of the genus *Lagenorhynchus*: a preliminary analysis. Pages 305-316 in A. E. Dizon, S. J. Chivers and W. F. Perrin, eds. Molecular genetics of marine mammals. Special Publication 3. Society for Marine Mammalogy, Allen Press, Lawrence, KS.
- Constantine, R. L. 1995. Monitoring the commercial swim-with-dolphin operations with the bottlenose (*Tursiops truncatus*) and common dolphins (*Delphinus delphis*) in the Bay of Islands, New Zealand. M.S. thesis. University of Auckland, New Zealand. 98 pp.
- Constantine, R. 1996. Distribution of dusky dolphins (*Lagenorhynchus obscurus*) in New Zealand waters. Report for the New Zealand Department of Conservation (unpublished), Auckland, New Zealand. 6 pp.
- Constantine, R. 1999. Effects of tourism on marine mammals in New Zealand. Science for Conservation Series 106. New Zealand Department of Conservation, Wellington, New Zealand. 60 pp.
- Constantine, R., and C. S. Baker. 1997. Monitoring the commercial swim-with-dolphin operations in the Bay of Islands, New Zealand. Science and Research Series 104. New Zealand Department of Conservation, Wellington, New Zealand. 59 pp.

- Constantine, R., I. Visser, D. Buurman, R. Buurman and B. McFadden. 1998. Killer whale (*Orcinus orca*) predation on dusky dolphins (*Lagenorhynchus obscurus*) in Kaikoura, New Zealand. *Marine Mammal Science* 14: 324-330.
- Conradt, L. 1999. Social segregation is not a consequence of habitat segregation in red deer and feral soay sheep. *Animal Behaviour* 57: 1151-1157.
- Corkeron, P. J. 1995. Humpback whales (*Megaptera novaeangliae*) in Hervey Bay, Queensland: behaviour and responses to whale-watching vessels. *Canadian Journal of Zoology* 73: 1290-1299.
- Crespo, E. A., J. F. Corcuera and A. L. Cazorla. 1994. Interactions between marine mammals and fisheries in some coastal fishing areas of Argentina. Report of the International Whaling Committee Special Issue 15: 269-281.
- Crespo, E. A., S. N. Pedraza, S. L. Dans, M. K. Alonso, L. M. Reyes, N. A. García and M. Coscarella. 1997a. Direct and indirect effects of the highseas fisheries on the marine mammal populations in the northern and central Patagonian coast. *Journal of Northwest Atlantic Fishery Science* 22: 189-207.
- Crespo, E. A., S. N. Pedraza, M. Coscarella, N. A. García, S. L. Dans, M. Iñíguez, L. M. Reyes, M. K. Alonso, A. C. M. Schiavini and R. González. 1997b. Distribution and school size of dusky dolphins *Lagenorhynchus obscurus* (Gray, 1828), in the southwestern south Atlantic Ocean. Report of the International Whaling Committee 47: 693-697.
- Dahlheim, M. E., H. D. Fisher and J. D. Schempp. 1984. Sound production by the gray whale and ambient noise levels in Laguna San Ignacio, Baja California Sur, Mexico. Pages 511-541 in M. L. Jones, S. L. Swartz, and S. Leatherwood, eds. The gray whale *Eschrichtius robustus*. Academic Press Inc., Orlando, FL.
- Dans, S. L., E. A. Crespo, N. A. García, L. M. Reyes, S. N. Pedraza and M. K. Alonso. 1997a. Incidental mortality of Patagonian dusky dolphins in mid-water trawling: retrospective effects from the early 1980s. Report of the International Whaling Commission 47: 699-703.
- Dans, S. L., E. A. Crespo, S. N. Pedraza and M. K. Alonso. 1997b. Notes on the reproductive biology of female dusky dolphins (*Lagenorhynchus obscurus*) off the Patagonian coast. *Marine Mammal Science* 13: 303-307.
- Davies, J. L. 1963. The antitropical factor in cetacean speciation. *Evolution* 17: 107-116.

- Dawson, S. M. 1991. Incidental catch of Hector's dolphins in inshore gillnets. *Marine Mammal Science* 7: 283-295.
- Driscoll, A. 1995. The whistles of the Hawai'ian spinner dolphin (*Stenella longirostris*). M. S. thesis. University of California, Santa Cruz. 84 pp.
- Duffus, D. A. 1996. The recreational use of grey whales in southern Clayoquot Sound, Canada. *Applied Geography* 16: 179-190.
- Evans, W. E. 1973. Echolocation by marine delphinids and one species of fresh-water dolphin. *Journal of the Acoustical Society of America* 54: 191-199.
- Fahner, M., J. Thomas, K. Ramirez and J. Boehm. 1998. Acoustic analysis of sounds produced by Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) at the John G. Shedd Aquarium. Abstracts for the World Marine Mammal Science Conference. 20-24 January 1998, Monaco. p 7.
- Findlay, K. P., P. B. Best, G. J. B. Ross and V. G. Cockcroft. 1992. The distribution of small odontocete cetaceans off the coasts of South Africa and Namibia. *South African Journal of Marine Science* 12: 237-270.
- Frankel, A. S., and C. W. Clark. 1998. Results of low-frequency playback of M-sequence noise to humpback whales, *Megaptera novaeangliae*, in Hawai'i. *Canadian Journal of Zoology* 76: 521-535.
- Fraser, F. C. 1966. Comments on the Delphinoidea. Pages 7-31 in K. S. Norris, ed. *Whales, dolphins and porpoises*. University of California Press, Berkeley, CA.
- Gaskin, D. E. 1968a. Distribution of Delphinidae (Cetacea) in relation to sea surface temperatures off eastern and southern New Zealand. *New Zealand Journal of Marine and Freshwater Research* 2: 527-534.
- Gaskin, D. E. 1968b. The New Zealand Cetacea. *Fisheries Research Bulletin* No. 1 (New Series) 1-92.
- Gisiner, R. C. 1998. Proceedings from the workshop on the effects of anthropogenic noise in the marine environment. Marine Mammal Science Program, Office of Naval Research. 10-12 February 1998, Arlington, VA. 141 pp.
- Goley, P. D. 1991. Dawn/dusk vocal choruses and nighttime resting behavior of captive Pacific white-sided dolphins (*Lagenorhynchus obliquidens*). Presentation for the Ninth Biennial Conference on the Biology of Marine Mammals. 5-9 December 1991, Chicago, IL.

- Griffiths, S. W., and A. E. Magurran. 1999. Schooling decisions in guppies (*Poecilia reticulata*) are based on familiarity rather than kin recognition by phenotype matching. *Behavioral Ecology and Sociobiology* 45: 437-443.
- Hoyt, E. 1992. Whale watching around the world. *International Whale Bulletin* No. 7. 8 pp.
- Hoyt, E. 1995a. Whalewatching takes off. *Whalewatcher*. Fall/Winter 29: 3-7.
- Hoyt, E. 1995b. The worldwide value and extent of whale watching: 1995. *Whale and Dolphin Conservation Society*, Bath, U. K. 36pp.
- IFAW Tethys Research Institute and Europe Conservation. 1995. Report of the workshop on the scientific aspects of managing whale watching. 30 March-4 April 1995. Montecastello di Vibio, Italy. 40 pp.
- Jasny, M. 1999. Sounding the depths. Supertankers, sonar, and the rise of undersea noise. Report for the Natural Resources Defense Council. 75 pp. (From the personal collection of Bernd Würsig).
- Jefferson, T. A., S. Leatherwood and M. A. Webber. 1993. *FAO species identification guide. Marine mammals of the world*. United Nations Environment Programme, Food and Agriculture Organization of the United Nations. Rome, Italy.
- Jehl Jr., J. R., W. E. Evans, F. T. Awbrey and W. S. Drieschmann. 1980. Distribution and geographic variation in the killer whale (*Orcinus orca*) populations of the Antarctic and adjacent waters. *Antarctic Journal U.S.* 1980 review 15: 161-163.
- Jones, M. L., and S. L. Swartz. 1984. Demography and phenology of gray whales and evaluation of whale-watching activities in Laguna San Ignacio, Baja California Sur, Mexico. Pages 309-374 in M. L. Jones, S. L. Swartz, and S. Leatherwood, eds. *The gray whale Eschrichtius robustus*. Academic Press Inc., Orlando, FL.
- Kruse, S. 1991. The interactions between killer whales and boats in Johnstone Strait, B. C. Pages 148-159 in K. Pryor and K. S. Norris, eds. *Dolphin societies: discoveries and puzzles*. University of California Press, Berkeley, CA.
- Leatherwood, S., and R. R. Reeves. 1983. *The Sierra Club handbook of whales and dolphins*. Sierra Club Books, San Francisco, CA.
- Lesage, V., C. Barrette, M. C. S. Kingsley and B. Sjare. 1999. The effect of vessel noise on the vocal behavior of belugas in the St. Lawrence River estuary, Canada. *Marine Mammal Science* 15: 65-84.



- Martin, P., and P. Bateson. 1993. Measuring behaviour, an introductory guide. Cambridge University Press, Cambridge, U. K.
- McCowan, B., D. Reiss and C. Gubbins. 1998. Social familiarity influences whistle acoustic structure in adult female bottlenose dolphins (*Tursiops truncatus*). *Aquatic Mammals* 24: 27-40.
- McKinnon, J. 1994. Feeding habits of the dusky dolphin, *Lagenorhynchus obscurus*, in the coastal waters of central Peru. *Fishery Bulletin*, U.S. 92: 569-578.
- Mills, H. 1998. Aardvark Manual. Cornell Laboratory of Ornithology, Ithaca, NY.
- Mitchell, E. 1975a. Porpoise, dolphin and small whale fisheries of the world: status and problems. International Union for Conservation of Nature and Natural Resources Monograph. No.3. Unwin Brothers Limited. Morges, Switzerland. 129 pp.
- Mitchell, E. 1975b. Report of the meeting on smaller cetaceans. *Journal of the Fisheries Research Board of Canada* 32: 889-983.
- Mitson, R. B. 1990. Very high-frequency acoustic emissions from the white-beaked dolphin (*Lagenorhynchus albirostris*). Pages 283-294 in J. A. Thomas and R. A. Kastelein, eds. Sensory abilities of cetaceans: laboratory and field evidence. Plenum Press, New York, NY.
- Moore, S. E., and S. H. Ridgway. 1995. Whistles produced by common dolphins from the Southern California Bight. *Aquatic Mammals* 21: 55-63.
- Müller, M., M. Z. Battersby, D. Buurman, M. Bossley and W. Doak. 1998. Range and sociability of a solitary bottlenose dolphin *Tursiops truncatus* in New Zealand. *Aquatic Mammals* 24: 93-104.
- Murray, S. O., E. Mercado and H. L. Roitblat. 1998. Characterizing the graded structure of false killer whale (*Pseudorca crassidens*) vocalizations. *Journal of the Acoustical Society of America* 104: 1679-1688.
- Norris, K. S., and T. P. Dohl. 1980a. Behavior of the Hawaiian spinner dolphin, *Stenella longirostris*. *Fishery Bulletin*, U. S. 77: 821-849.
- Norris, K. S., and T. P. Dohl. 1980b. The structure and function of cetacean schools. Pages 211-261 in L. M. Herman ed. Cetacean behavior: mechanisms and functions. John Wiley and Sons, New York, NY.

- Norris, K. S., and C. M. Johnson. 1994. Schools and schooling. Pages 232-242 in K. S. Norris, B. Würsig, R. S. Wells, and M. Würsig, eds. *The Hawaiian spinner dolphin*. University of California Press, Berkeley, CA.
- Norris, T. F. 1995. Effects of boat noise on the singing behavior of humpback whales (*Megaptera novaeangliae*). M. S. thesis. Moss Landing Marine Laboratory, San Jose State University, CA. 69 pp.
- Ollervides, F. 1997. Effects of boat traffic on the behavior of gray whales *Eschrichtius robustus*, in Bahia Magdalena, Baja California Sur, Mexico: a bioacoustic assessment. M. S. thesis. Texas A&M University, College Station, TX. 61 pp.
- Overstrom, N. A. 1983. Association between burst-pulse sounds and aggressive behavior in captive Atlantic bottlenosed dolphins (*Tursiops truncatus*). *Zoo Biology* 2: 93-103.
- Ransom, A. 1998. Vessel and human impact monitoring of the dolphins of Little Bahama Bank. M. A. thesis. San Francisco State University, CA. 108 pp.
- Read, A. J., K. Van Waerebeek, J. C. Reyes, J. S. McKinnon and L. C. Lehman. 1988. The exploitation of small cetaceans in coastal Peru. *Biological Conservation* 46: 53-70.
- Rice, D. W. 1998. Marine mammals of the world. Systematics and distribution. Special Publication 4. Society for Marine Mammalogy, Allen Press, Lawrence, KS.
- Richardson, W. J., C. R. Greene Jr., C. I. Malme and D. H. Thomson. 1995. Marine mammals and noise. Academic Press Inc., San Diego, CA.
- Sayigh, L. S. 1992. Development and functions of signature whistles of free-ranging bottlenose dolphins, *Tursiops truncatus*. Ph.D. dissertation. Woods Hole Oceanographic Institution and Massachusetts Institute of Technology, Woods Hole, MA. 344 pp.
- Schevill, W. E., and W. A. Watkins. 1971. Pulsed sounds of the porpoise *Lagenorhynchus australis*. *Breviora* 366: 1-10.
- Scott, M. D., R. S. Wells and A. B. Irvine. 1990. A long-term study of bottlenose dolphins on the west coast of Florida. Pages 235-244 in S. Leatherwood and R. R. Reeves, eds. *The bottlenose dolphin*. Academic Press Inc., San Diego, CA.
- Sjare, B. L., and T. G. Smith. 1986a. The relationship between behavioral activity and underwater vocalizations of the white whale, *Delphinapterus leucas*. *Canadian Journal of Zoology* 64: 2824-2831.

- Sjare, B. L., and T. G. Smith. 1986b. The vocal repertoire of white whales, *Delphinapterus leucas*, summering in Cunningham Inlet, Northwest Territories. *Canadian Journal of Zoology* 64: 407-415.
- Smultea, M. A. 1994. Segregation by humpback whale (*Megaptera novaeangliae*) cows with a calf in coastal habitat near the island of Hawaii. *Canadian Journal of Zoology* 72: 805-811.
- StatSoft. 1994. Statistica for the Macintosh Version 4.1 Manual. StatSoft, INC. Tulsa, OK. 1063 pp.
- Steiner, W. W. 1981. Species-specific differences in pure tonal whistle vocalizations of five western North Atlantic dolphin species. *Behavioral Ecology and Sociobiology* 9: 241-246.
- Stienessen, S. C. 1998. Diel, seasonal, and species-specific trends in vocalizations of dolphins in the Gulf of Mexico. M.S. thesis. Texas A&M University, College Station, TX. 73 pp.
- Thompson, K. V. 1998. Spatial integration in infant sable antelope, *Hippotragus niger*. *Animal Behaviour* 56: 1005-1014.
- Tremel, D. P., J. A. Thomas, K. T. Ramirez, G. S. Dye, W. A. Bachman, A. N. Orban and K. K. Grimm. 1998. Underwater hearing sensitivity of a Pacific white-sided dolphin, *Lagenorhynchus obliquidens*. *Aquatic Mammals* 24: 63-69.
- Tyack, P. 1991. Use of a telemetry device to identify which dolphin produces a sound. Pages 318-344 in K. Pryor and K. S. Norris, eds. *Dolphin societies: discoveries and puzzles*. University of California Press, Berkeley, CA.
- Van Waerebeek, K. 1992a. Population identity and general biology of the dusky dolphin *Lagenorhynchus obscurus* (Gray, 1828) in the southeast Pacific. Ph.D. dissertation. Institute for Taxonomic Zoology, University of Amsterdam, The Netherlands. 160 pp.
- Van Waerebeek, K. 1992b. Records of dusky dolphins, *Lagenorhynchus obscurus*, (Gray, 1828) in the eastern South Pacific. *Beaufortia* 43: 45-61.
- Van Waerebeek, K., and A. J. Read. 1994. Reproduction of dusky dolphins, *Lagenorhynchus obscurus*, from coastal Peru. *Journal of Mammalogy* 75: 1054-1062.

- Van Waerebeek, K., and J. C. Reyes. 1990. Catch of small cetaceans at Pucusana Port, central Peru, during 1987. *Biological Conservation* 51: 15-22.
- Van Waerebeek, K., P. J. H. Van Bree and P. B. Best. 1995. On the identity of *Prodelphinus petersii* Lütken, 1889 and records of dusky dolphin *Lagenorhynchus obscurus* (Gray, 1828) from the southern Indian and Atlantic Oceans. *South African Journal of Marine Science* 16: 25-35.
- Van Waerebeek, K., M-F. Van Bressem, F. Félix, J. Alfaro-Shigueto, A. García-Godos, L. Chávez-Lisambart, K. Ontón, D. Montes and R. Bello. 1997. Mortality of dolphins and porpoises in coastal fisheries off Peru and southern Ecuador in 1994. *Biological Conservation* 81: 43-49.
- Wang, D. 1993. Dolphin whistles: comparisons between populations and species. Ph.D. dissertation. The Institute of Hydrobiology, The Chinese Academy of Sciences, Wuhan, China. 247 pp.
- Wang, D., B. Würsig and W. Evans. 1995. Comparisons of whistles among seven odontocete species. Pages 299-323 in R. A. Kastelein, J. A. Thomas, P. E. Nachtigall, eds. *Sensory systems of aquatic mammals*. De Spil Publishers, Woerden, The Netherlands.
- Watkins, W. A. 1986. Whale reactions to human activities in Cape Cod waters. *Marine Mammal Science* 2: 251-262.
- Webb, B. F. 1973a. Cetaceans sighted off the west coast of the South Island, New Zealand, summer 1970. *New Zealand Journal of Marine and Freshwater Research* 7: 179-182.
- Webb, B. F. 1973b. Dolphin sightings, Tasman Bay to Cook Strait, New Zealand, September 1968-June 1969. *New Zealand Journal of Marine and Freshwater Research* 7: 399-405.
- Webber, M. A. 1987. A comparison of dusky and Pacific white-sided dolphins (Genus *Lagenorhynchus*): morphology and distribution. M. A. thesis. San Francisco State University, San Francisco, CA. 102pp.
- Weilgart, L. S., and H. Whitehead. 1990. Vocalizations of the North Atlantic pilot whale (*Globicephala melas*) as related to behavioral contexts. *Behavioral Ecology and Sociobiology* 26: 399-402.
- Wells, R. S., A. B. Irvine and M. D. Scott. 1980. The social ecology of inshore odontocetes. Pages 263-317 in L. M. Herman, ed. *Cetacean behavior: mechanisms and functions*. John Wiley and Sons, New York, NY.

- Wells, R. S., M. D. Scott and A. B. Irvine. 1987. The social structure of free-ranging bottlenose dolphins. Pages 247-305 in H. H. Genoways, ed. Current mammalogy. Plenum Press, New York, NY.
- Williams, R. M., A. W. Trites and D. E. Bain. 1998. Interactions between boats and killer whales (*Orcinus orca*) in Johnstone Strait, BC, Canada. Presentation for the World Marine Mammal Science Conference. 20-24 January 1998. Monaco.
- Würsig, B. 1982. Radio-tracking dusky porpoises in the South Atlantic. Pages 145-160 in United Nations Food and Agriculture Organization, ed. Mammals in the seas, FAO Fisheries Series No. 5, Volume IV. Rome, Italy.
- Würsig, B., and R. Bastida. 1986. Long-range movement and individual associations of two dusky dolphins (*Lagenorhynchus obscurus*) off Argentina. Journal of Mammalogy 67: 773-774.
- Würsig, B., and M. Würsig. 1979. Behavior and ecology of the bottlenose dolphin, *Tursiops truncatus*, in the south Atlantic. Fishery Bulletin, U.S. 77: 399-412.
- Würsig, B., and M. Würsig. 1980. Behavior and ecology of the dusky dolphin, *Lagenorhynchus obscurus*, in the south Atlantic. Fishery Bulletin, U.S. 77: 871-890.
- Würsig, B., M. Würsig and F. Cipriano. 1989. Dolphins in different worlds. Oceanus 32: 71-75.
- Würsig, B., F. Cipriano and M. Würsig. 1991. Dolphin movement patterns: information from radio and theodolite tracking studies. Pages 78-111 in K. Pryor and K. S. Norris, eds. Dolphin societies: discoveries and puzzles. University of California Press, Berkeley, CA.
- Würsig B., K. Barr, R. Constantine, K. Dudzinski, A. Forest and S. Yin. 1995. Swim-with-dolphin programs: monitoring results and needs. Presentation for the Eleventh Biennial Conference on the Biology of Marine Mammals. 14-18 December 1995. Orlando, FL.
- Würsig, B., F. Cipriano, E. Slooten, R. Constantine, K. Barr and S. Yin. 1997. Dusky dolphins (*Lagenorhynchus obscurus*) off New Zealand: status of present knowledge. Report of the International Whaling Commission 47: 715-722.
- Würsig, B., D. Weller, A. Burdin, S. Blokhin, S. Reeve, A. Bradford and R. Brownell Jr. 1999. Gray whales summering off Sakhalin Island, Far East Russia: July-

October 1997. A Joint U.S.-Russian scientific investigation. Report for Sakhalin Energy Investment Company and Exxon Neftegas. February 3, 1999. 79 pp.

Zar, J. H. 1996. Biostatistical analysis. Prentice Hall, Upper Saddle River, NJ.

## APPENDIX 1

### THE MARINE MAMMAL PROTECTION REGULATIONS 1992

CATHERINE A TIZARD, Governor General

#### REGULATIONS

1. **Title and commencement** – (1) These regulations may be cited as the Marine Mammals Protection Regulations 1992.  
(2) These regulations shall come into force on the 1<sup>st</sup> day of January 1993.
  
2. **Interpretation** – In these regulations, unless the context otherwise requires, -
  - “The Act” means the Marine Mammals Protection Act 1978;
  - “Commercial aircraft operation” means a commercial operation using any aircraft (as defined in section 2 of the Civil Aviation Act 1990):
  - “Commercial operation” or “operation” means an operation carried on for any form of hire or reward in which persons are transported, conveyed, conducted, or guided where a purpose is to view or come into contact with any marine mammal in New Zealand or in New Zealand fisheries waters:
  - “Commercial shore-based operation” means a commercial operation that does not use any aircraft or vessel:
  - “Commercial Vessel operation” means a commercial operation using any vessel (being a ship as defined in section 2(1) of the Shipping and Seamen Act 1952) or hovercraft:
  - “Contact”, in relation to a marine mammal, includes any interaction involving a person and the mammal that is likely to produce an effect on the mammal:
  - “Director General” means the Director General of Conservation:
  - “Dolphin” means –
    - (a) All species commonly known as dolphins; and includes dusky dolphins, common dolphins, bottlenose dolphins, and Hector’s dolphins; but
    - (b) Does not include the species known as killer whales and pilot whales:
  - “Harass” includes to do any act that –
    - (a) Causes or is likely to cause injury or distress to any marine mammal; or
    - (b) Disrupts significantly or is likely to disrupt significantly the normal behavioral patterns of any marine mammal:
  - “Permit” means a permit issued under regulation 12 of these regulations:
  - “Seal” means all species commonly known as seals and sea lions, and includes New Zealand fur seals, leopard seals, southern elephant seals, and Hooker’s sea lions:
  - “Whale” means all species commonly known as whales; and includes baleen

whales, sperm whales, beaked whales, killer whales, and pilot whales:

“Working day” means any day except –

- (a) A Saturday, a Sunday, Good Friday, Easter Monday, Anzac Day, Labour Day, the Sovereign’s birthday, and Waitangi Day; and
- (b) A day in the period commencing with the 20<sup>th</sup> day of December in any year and ending with the 15<sup>th</sup> day of January in the following year.

3. **Application** – (1) These regulations shall apply throughout New Zealand and New Zealand fisheries waters.  
(2) Nothing in these regulations applies in respect of any fishing vessel while the vessel is engaged in commercial fishing (as defined in section 2(1) of the Fisheries Act 1983), unless –
  - (a) The vessel is also engaged in a commercial operation; or
  - (b) The vessel deviates off course to engage in recreation viewing of marine mammals.
4. **Purpose** – The purpose of these regulations is to make provision for the protection, conservation, and management of marine mammals and, in particular,–
  - (a) To regulate human contact or behavior with marine mammals either by commercial operators or other persons, in order to prevent adverse effects of and interference with marine mammals;
  - (b) To prescribe appropriate behavior by commercial operators and other persons seeking to come into contact with marine mammals.

## PART I

### REQUIREMENTS RELATING TO PERMITS

5. **Commercial operations carried on without permit prohibited** – No commercial operator shall carry on any commercial operation, except pursuant to a permit issued by the Director General under regulation 12 of these regulations.
6. **Criteria for issuing permits** – Before issuing a permit, the Director General shall be satisfied that there is substantial compliance with the following criteria:
  - (a) That the commercial operation should not be contrary to the purposes and provisions of the Act;
  - (b) That the commercial operation should not be contrary to the purposes and provisions of general policy statements approved under section 3B of the Act, conservation management strategies approved under section 3C of the Act, or conservation management plans approved under section 3D of the Act;



- (c) That the commercial operation should not have any significant adverse effect on the behavioral patterns of the marine mammals to which the application refers, having regard to, among other things, the number and effect of existing commercial operations:
- (d) That it should be in the interests of the conservation, management, or protection of the marine mammals that a permit be issued:
- (e) That the proposed operator, and such of the operator's staff who may come into contact with marine mammals, should have sufficient experience with marine mammals:
- (f) That the proposed operator, and such of the operator's staff who may come into contact with marine mammals, should have sufficient knowledge of local area and of sea and weather conditions:
- (g) That the proposed operator, and such of the operator's staff who may come into contact with marine mammals, should not have convictions for offences involving the mistreatment of animals:
- (h) That the commercial operation should have sufficient educational value to participants or to the public.

**7. Requirements to be satisfied before permit for commercial vessel operation issued** – Every applicant for a permit for a commercial vessel operation shall submit to the Director General for approval an application in writing setting out the following:

- (a) Details of the proposed operation, including –
  - (i) The type and number of vessels intended for use; and
  - (ii) Any known information relating to the noise level of each vessel both above and below the sea; and
  - (iii) The proposed area of operation, including a map showing the boundaries of the proposed area of operation and, where appropriate, the specific locations where contact with marine mammals is proposed;
  - (iv) The maximum number of vessels the operator proposes to operate at any one time;
  - (v) The proposed base of operation;
  - (vi) The duration of trips proposed;
  - (vii) The frequency of trips proposed;
  - (viii) The proposed kind of contact with marine mammals;
  - (ix) The maximum numbers of passengers intended to be taken at any one time;
  - (x) The species of marine mammals with which the operation will have contact;
  - (xi) The masters proposed to be engaged in the commercial operation;
- (b) The experience with marine mammals of the proposed operator and such of the operator's proposed staff who may come into contact with marine mammals:

- (c) The knowledge of the local area and sea conditions of the proposed operator and such of the operator's proposed staff who may come into contact with marine mammals:
- (d) The details of any convictions of the proposed operator and of those employees of the operator who may come into contact with marine mammals, for offences against the Act or any other Act involving the mistreatment of animals:
- (e) The details of any educational material to be provided or educational aspects of the proposed operation.

**8. Requirements to be satisfied before permit for commercial aircraft operation issued** – Every applicant for a permit for a commercial aircraft

operation shall submit to the Director General for approval an application setting out the following:

- (a) The details of the proposed operation including –
  - (i) The type and the number of aircraft intended for use; and
  - (ii) Any known information relating to the noise level of each aircraft both above and below the sea; and
  - (iii) The proposed area of operation, including a map showing the boundaries of the proposed area of operation and, where appropriate, the specific locations where contact with marine mammals is proposed;
  - (iv) The maximum number of aircraft proposed to be operating at any one time;
  - (v) The proposed base of operation;
  - (vi) The duration of trips proposed;
  - (vii) The frequency of trips proposed;
  - (viii) The maximum numbers of passengers to be carried on the aircraft at any one time;
  - (ix) The species of marine mammals with which the operation will have contact;
  - (x) The names of the pilots proposed to be engaged in the commercial aircraft operation;
- (b) The experience with marine mammals of the proposed operator and such of the operator's proposed staff who may come into contact with marine mammals:
- (c) The knowledge of the local area and weather conditions of the proposed operator and such of the operator's proposed staff who may come into contact with marine mammals:
- (d) The details of any convictions of the proposed operator and of those employees of the operator who may come into contact with marine mammals, for offences against the Act or any other Act involving the mistreatment of animals:
- (e) The details of any educational material to be provided or educational aspects of the proposed operation:
- (f) The number of the air service certificate or other aviation document under which the aircraft will be operating.

- 9. Requirements to be satisfied before permit for commercial shore-based operation issued** – Every applicant for a permit for a commercial shore-based operation shall submit to the Director General for approval an application setting out, where applicable, the following:
- (a) The details of the proposed operation, including –
    - (i) The type and number of vehicles intended to be used; and
    - (ii) The proposed area of operation, including a map showing the boundaries of the proposed area of operation and, where appropriate, the specific locations where contact with marine mammals is proposed;
    - (iii) The proposed guides;
    - (iv) The maximum number of vehicles the operator proposes to operate at any one time;
    - (v) The proposed route of persons to be guided to the colony of marine mammals;
    - (vi) The proposed base of operations;
    - (vii) The duration of trips proposed;
    - (viii) The frequency of trips proposed;
    - (ix) The proposed kind of contact the operation will have with marine mammals;
    - (x) The species of marine mammals with which the operation will have contact;
    - (xi) The maximum number of persons intended to be taken at any one time;
  - (b) The experience with marine mammals of the proposed operator and such of the operator's proposed staff who may come into contact with marine mammals;
  - (c) The details of any convictions of the proposed operator and of those employees of the operator who may come into contact with marine mammals, for offences against the Act involving the mistreatment of animals;
  - (d) The details of any educational material to be provided or educational aspects of the proposed operation;
- 10. Requirements to be satisfied before permit issued** – (1) Before issuing a permit, the Director General shall determine whether or not the application by the proposed operator is acceptable to him or her and the Director General may require the application to be amended by the proposed operator to incorporate such matters as the Director General may specify in writing.
- (2) Once the application is approved, it shall be deemed to form part of the permit issued in respect of the application and shall be complied with accordingly.
- 11. Advertising applications** – (1) Before a permit for a commercial operation, the Director General shall require the applicant, at the applicant's own expense, to

advertise details of the application in a form agreed by the Director General and in such newspapers as may be agreed by the Director General.

(2) The advertisement shall set out such details of the proposed operation as required by the Director General, the name and address of the applicant, and shall call for submissions within 20 working days after publication of the notice.

(3) Submissions shall be sent to the Director General at such place as the Director General may specify in the notice; and the Director General shall send to the applicant a copy of every submission received in respect of the applicant's proposed operation.

(4) The applicant shall make any comments on the submissions to the Director General within 10 working days after the receipt of submissions.

(5) Before deciding whether or not to grant a permit for any commercial operation, the Director General shall consider every submission received under this regulation in respect of the proposed operation and the comments received under sub clause (4) of this regulation.

**12. Permits** – (1) Subject to these regulations, the Director General, on receiving an application made in writing, may issue a permit authorizing any commercial operator to carry on any specified commercial operation.

(2) Every permit issued to a commercial operator shall, where appropriate, specify the following:

(a) The type of aircraft and vessels to be used by operator:

(b) The names of the pilots of aircraft, the masters of vessels, and guides engaged in the commercial operation:

(c) The land and any area of water to which it relates:

(d) That all aircraft and vessels operated under the permit, and their pilots and masters, respectively, must meet the statutory requirements relating to the licensing and safety of the aircraft and vessels and the qualifications and licensing of the pilots and masters, as the case may require.

(3) The Director General shall not issue a permit unless he or she is satisfied –

(a) That the proposed commercial operation will not have or be likely to have any adverse effect on the conservation, protection, or management of marine mammals; and

(b) That the criteria specified in regulation 6 of these regulations have been substantially complied with; and

(c) That sufficient information has been received by the Director General in respect of the application under regulation 7 or regulation 8 or regulation 9 of these regulations.

(4) The Director General may issue a permit for any period of time not exceeding 10 years and may renew the permit from time to time.

(5) The Director General shall, where appropriate, issue to every commercial operator issued with a permit a label identifying each aircraft or vessel as

operating under a valid permit. Each label shall be affixed at all times to the aircraft or vessel, as the case may be.

## PART II

### SUSPENSION, REVOCATION, RESTRICTION, OR AMENDMENT OF PERMITS

13. **Suspension, revocation, restriction, or amendment of permits** – (1) The Director General may at any time suspend or revoke any permit, or restrict the operation authorized by any permit, where the holder -
  - (a) Is convicted of any offense against the Act or is convicted under any other Act of any offence involving the mistreatment of animals; or
  - (b) Contravenes or fails to comply with any statutory requirements relating to the licensing, operation, and safety of any aircraft or vessel used by the person carrying on the commercial operation; or
  - (c) Carries on a commercial operation without an appropriately licensed aircraft pilot or crew, or certificated master; or
  - (d) Contravenes or fails to comply with any condition or requirement specified or notified under Part III of these regulations or specified in the permit.
 (2) Where the Director General believes on reasonable grounds that it is necessary for the protection, conservation, or management of any marine mammals or marine mammals of any class, he or she may –
  - (a) Suspend, revoke, or amend (in a manner not inconsistent with Part III of these regulations) any permit or permits;
  - (b) Restrict in whole or in part the operation authorized by any permit or permits.
 (3) Where any person ceases to be a commercial operator, the Director General may suspend or revoke that person's permit.
- (4) Every suspension of a permit under this regulation shall be for such period as the Director General specifies by notice in writing to the holder.
- (5) The Director General may, at the request of the commercial operator and if he or she is satisfied that the criteria specified in regulation 6 of these regulations have been substantially complied with, amend a permit to allow a change of aircraft or vessel or a change of pilot, master, or guide, as the case may be.
- (6) A permit holder shall comply with the advertising requirements in regulation 11 of these regulations with appropriate modifications, where, in the opinion of the Director General, a major amendment to the permit is sought by the holder.
  
14. **Transfer of permits** – (1) No permit for any commercial operation may be transferred from the holder of the permit to any person without first obtaining the consent in writing of the Director General.
- (2) The Director General may –

- (a) Refuse to consent to the transfer of a permit; or
    - (b) Consent to the transfer of a permit either with or without conditions.
  - (3) Where the holder of a permit is a body corporate, the transfer of control of the management of the holder in whole or in part to another person shall be deemed to be a transfer of the permit.
  - (4) In considering whether or not to consent to a transfer of a permit the Director General, shall have regard to the applicable matters contained in regulations 6 to 9 of these regulations.
  - (5) No permit shall be deemed to allow any person other than the operator specified therein to carry on the commercial operation authorized by the permit.
- 15. Director General may decline to grant permits during specified period – (1)**  
Where the Director General believes on reasonable grounds that it is necessary for the protection, conservation, or management of any marine mammals or any class of marine mammals, he or she may, by notice published in –
- (a) The *Gazette*; and
    - (b) Newspapers circulating in the locality, – declare that no new permits shall be granted in respect of specified commercial operations during the period specified in the notice.
  - (2) In considering whether or not to give notice under sub clause (1) of this regulation, the Director General shall have regard to –
    - (a) The number and effect of existed commercial operations; and
    - (b) Whether or not it is in the interests of the conservation, protection, or management of marine mammals to grant further permits.
  - (3) Any person may appeal to the Minister of conservation against the decision of the Director General to suspend, revoke, restrict, or amend that person's permit; and the Minister may confirm, reverse, or modify the decision appealed against.

### PART III

#### BEHAVIOR AROUND MARINE MAMMALS

- 17. Application of this part –** Nothing in regulation 18 or regulation 19 or regulation 20 of these regulations shall apply to persons, vessels, aircraft, or vehicles rendering assistance to stranded or injured marine mammals.
- 18. Conditions governing commercial operations and behavior of all persons around any marine mammal –** Every commercial operation, and every person coming into contact with any class or marine mammal, shall comply with the following conditions:
- (a) Persons shall use their best endeavors to operate vessels, vehicles, aircraft so as not to disrupt the normal movement or behavior of any marine mammal:

- (b) Contact with any marine mammal shall be abandoned at any stage if it becomes or shows signs of becoming disturbed or alarmed:
- (c) No person shall cause any marine mammal to be separated from a group of marine mammals or cause any members of such a group to be scattered:
- (d) No rubbish or food shall be thrown near or around any marine mammal:
- (e) No sudden or repeated change in the speed or direction of any vessel or aircraft shall be made except in the case of an emergency:
- (f) Where a vessel stops to enable the passengers to watch any marine mammal, the engines shall be either placed in neutral or be switched off within a minute of the vessel stopping:
- (g) No aircraft engaged in a commercial aircraft operation shall be flown below 150 meters (500 feet) above sea level, unless taking off or landing:
- (h) When operating at an altitude of less than 600 meters (2000 feet) above sea level, no aircraft shall be closer than 150 meters (500 feet) horizontally from a point directly above any marine mammal or such lesser or greater distance as may be approved by the Director General, by notice in the *Gazette*, from time to time based on the best available scientific evidence:
- (i) No person shall disturb or harass any marine mammal:
- (j) Vehicles must remain above the mean high water spring tide mark and shall not approach within 50 meters of a marine mammal unless in an official car park or on a public or private slipway or on a public road:
- (k) No person, vehicle, or vessel shall cut off the path of a marine mammal or prevent a marine mammal from leaving the vicinity of any person, vehicle, or vessel:
- (l) Subject to paragraph (m) of this regulation, the master of any vessel less than 300 meters from any marine mammal shall use his or her best endeavors to move the vessel at a constant slow speed no faster than the slowest marine mammal in the vicinity, or at idle or "no wake" speed:
- (m) Vessels departing from the vicinity of any marine mammal shall proceed slowly at idle or "no wake" speed until the vessel is at least 300 meters from the nearest marine mammal, except that, in the case of dolphins, vessels may exceed idle or "no wake" speed in order to outdistance the dolphins but must increase speed gradually, and shall not exceed 10 knots within 300 meters of any dolphin:
- (n) Pilots of aircraft engaged in a commercial aircraft operation shall use their best endeavors to operate the aircraft in such a manner that, without compromising safety, the aircraft's shadow is not imposed directly on any marine mammal.

**19. Special conditions applying to whales** – In addition to complying with the provisions set out in regulation 18 of these regulations, every commercial operation and every person coming into contact with whales shall also comply with the following conditions:

- (a) No person in the water shall be less than 100 meters from a whale, unless authorized by the Director General:

(b) No vessel shall approach within 50 meters of a whale, unless authorized by the Director General:

(c) If a whale approaches a vessel, the master of the vessel shall, wherever practicable, –

(i) Maneuver the vessel so as to keep out of the path of the whale; and

(ii) Maintain a minimum distance of 50 metres from the whale:

(d) No vessel or aircraft shall approach within 300 meters (1000 feet) of any whale for the purpose of enabling passengers to watch the whale, if the number of vessels or aircraft, or both already positioned to enable passengers to watch that whale is 3 or more:

(e) Where 2 or more vessels or aircraft approach an unaccompanied whale, the masters concerned shall co-ordinate their approach and maneuvers, and the pilots concerned shall co-ordinate their approach and maneuvers:

(f) No person or vessel shall approach within 200 meters of any female baleen or sperm whale that is accompanied by a calf or calves:

(g) A vessel shall approach a whale from direction that is parallel to the whale and slightly to the rear of the whale:

(h) No person shall make any loud or disturbing noise near whales:

(i) Where a sperm whale abruptly changes its orientation or starts to make short dives of between 1 and 5 minutes duration without showing its tail flukes, all persons, vessels, and aircraft shall forthwith abandon contact with the whale.

**20. Special conditions applying to dolphins or seals** – In addition to complying with the conditions set out in regulation 18 of these regulations, any commercial operation and any person coming into contact with dolphins or seals shall also comply with the following conditions:

(a) No vessel shall proceed through a pod of dolphins:

(b) Persons may swim with dolphins and seals but not with juvenile dolphins or a pod of dolphins that includes juvenile dolphins:

(c) Commercial operators may use an air horn to call swimmers back to the boat or to the shore:

(d) Except as provided in paragraph (c) of this regulation, no person shall make any loud or disturbing noise near dolphins or seals:

(e) No vessel or aircraft shall approach within 300 meters (1000 feet) of any pod of dolphins or herd of seals for the purpose of enabling passengers to watch the dolphins or seals, if the number of vessels or aircraft, or both, already positioned to enable passengers to watch that pod or herd is 3 or more:

(f) Where 2 or more vessels or aircraft approach an unaccompanied dolphin or seal, the masters concerned shall co-ordinate their approach and maneuvers, and the pilots concerned shall co-ordinate their approach and maneuvers:

(g) A vessel shall approach a dolphin from a direction that is parallel to the dolphin and slightly to the rear of the dolphin.



## PART IV

### MISCELLANEOUS PROVISIONS

21. **Transitional provisions** – (1) Applications (including amended applications) for permits received before the commencement of these regulations shall be dealt with as if the Marine Mammals Protection Regulations 1990 were still in force.  
(2) Applications for permits that are received after the commencement of these regulations shall be dealt with under these regulations.  
(3) Permits issued under the Marine Mammals Protection Regulations 1990 shall be subject to regulations, 13, 14, 16, 17, 18, 19, and 20 of these regulations. The Marine Mammals Protection Regulations 1990 (except regulations 5(4), 5(5), 6(3), 7, 8, and 9) shall continue to apply to such permits as if not revoked, unless inconsistent with these regulations.
22. **Regulations revoked** – The Marine Mammals Protection Regulations 1990 (S. R. 1920/287) are hereby revoked.

BOB MACFALANE,

Acting for Clerk of the Executive Council

### EXPLANATORY NOTE

*This note is not part of the regulations, but is intended to indicate their general effect.*

These regulations, which come into force 1 January 1993, revoke and replace the Marine Mammals Protection Regulations 1990.

The principle changes effected by these regulations are as follows:

- (a) *Regulation 3* provides that the regulations do not apply in respect of a fishing vessel engaged in commercial fishing, unless the vessel is also engaged in a commercial operation as defined in *regulation 2* of these regulations or deviates off course to engage in recreation viewing of marine mammals;
- (b) *Regulation 4* sets out the purposes of the regulations. The principal purpose is the protection, conservation, and management of marine mammals;
- (c) *Regulations 6 to 9* specify matters the Director General of Conservation must have regard to when deciding whether or not to grant a permit;
- (d) *Regulation 11* requires each applicant for a permit to publicly notify the applicant's application;
- (e) *Regulation 16* confers a right of appeal to the Minister of Conservation against the Director General's refusal to renew an existing permit for an existing permit holder.

---

Issues under the authority of the Acts and Regulations Publication Act 1989.

Date of notification in *Gazette*: 19 November 1992.

These regulations are administered in the Department of Conservation.

## APPENDIX 2

### Aardvark codes

#### States

- 1 Resting (rest)
- 2 Milling (mill)
- 3 Travelling (trav)
- 4 Stationary (stat)
- 5 Surface active (sact)
- 6 Unknown (unkn)
- 7 Feeding

#### Most common Vessel identifiers

- V90 YIN'S ZERO
  - V91 WATER TOWER
  - V92 HAMURI BLUFFS
- (note all 3 are taken at start and end of session)

#### Dolphin boats

- V10 DOLPHIN ENCOUNTER (DE)
- V11 DOLPHIN ENCOUNTER 2 (DE2)
- V12 KOTUKU (K)
- V13 THE TINNY (DM)
- V14 SEAQUEST (SQ)

#### Research vessels

- V1 KEIKI NAI'A (KN)
- V2 CETOS (Liz & Steve's vessel)
- V3 ORCA RESEARCH 1 (OR1)
- V4 ORCA RESEARCH 2 (OR2)
- V5 DEPARTMENT OF CONSERVATION DoC)
- V6 BALAENA (Barbara Todd's boat)

#### Whale watch boats

- V30 CACHALOT (C)
- V31 MAKAPHIU (M)
- V32 ORCA (O)
- V33 PAIKIA (P)
- V34 URUAO (U)
- V35 WAWAHIA (W)

#### Fishing vessels

- V50 FINE CATCH (FC)

#### Unidentified vessels

V99 (change to appropriate vessel type once it has been identified).

POD COMPOSITION (pod number, # of adults, # calves # singers)  
 so pc 3 5 1 0 means pod comp of pod 3 is 5 adults, 1 calf, no singers

## OTHER IMPT FIXES

p20 left dolphin (main grp)    p21 ctr dolphin (main grp)    p22 right dolphin (main grp)

Behavior codes (*code, individual ID, then pod ID*). Example: B1 3 is a blow by an adult in pod 3 (and you do need the space there).

1 = adult    2 = mom    3 = calf

## Most commonly used behavior codes for dolphins

b Blow	br Breach (non-forward leap)
nl Noisy leap	us Unidentified large splash
ss Somersaulting	oh Other head behavior
ht Head-first leap (clean)	sl Slicing
pp Porpoising	ts Tail slap (slapping water surface with tail)

## POD EVENTS

All commands take one argument, a pod id.

pd Pod decreases speed  
 pi Pod increases speed  
 px Pod stops  
 p45 Pod changes direction 45 to 90 degrees  
 p90 Pod changes direction 90 to 180 degrees  
 p180 Pod changes direction 180 degrees

## VESSEL EVENTS

All commands take one argument, a vessel id.

vs Vessel starts  
 vc Vessel changes speed  
 vx Vessel stops

## OTHER CODES

### Tail behaviors

te Tail extension (holds in air > 3 sec)  
 to Other tail behavior

Tail slap (slapping water surface with tail)

### Dolphin vocalizations

wr whistles reported (by research vessel)

### Body contact

sb Strike with body part

## POD BEHAVIORAL STATE MODIFIERS (Modifier commands-no arguments).

sync Behaviors synchronous    asyn Behaviors asynchronous

## FIXES

State arguments are behavioral state numbers; see above.

r(id state)	Azimuth reference
by(id state)	Buoy
o(id state)	Other (note object type in comment)
fx(type id state)	Fix with object type specified
bf(observer reticles azimuth type id state)	Binocular fix
st(observer type id state)	Naked eye sighting

## APPENDIX 2 (continued)

### Kaikoura Dusky Dolphin: Visibility and Beaufort Sea State Codes

#### Visibility:

Code	Description
1	Excellent, surface waters calm (Beaufort sea state 0-1) with no sun glare, haze, fog, rain, etc. Small groups easily tracked from shore. Visibility >5 km.
2	Good, may be some slight glare or chop in some areas of arena, though not more than 25% of viewing area.
3	Poor. Beaufort ss >3. Water caps make it very difficult to spot and track small groups of dolphins. Large groups may be seen but not tracked reliably. Often dolphins may only be seen when leaping. Haze or glare covering 50% or more of arena. Observations end.

#### Beaufort Wind Scale

Code	Description	Wind speed	Wave (m)
0	Sea like a mirror	Calm (0-1)	-
1	Light air	Ripples with the appearance (1-3) of scales but without foam crests	0.3
2	Light breeze	Small wavelets, still short but (4-6) more pronounced	0.6
3	Gentle breeze	Large wavelets. Scattered white caps. (7-10)	1.2
4	Moderate breeze	Small waves, fairly frequent white caps (11-16)	1.8

Swell height is measured in meters.

#### Glare

0	No glare, all areas of arena are viewed, high confidence that small dolphin groups can be seen.
1	Slight glare, theodolite tracking continues, slight problems seeing small groups.
2	Bright glare, theodolite tracking is difficult, groups difficult to see.
3	Intense glare, theodolite tracking not possible in glare area. Pain.

<b>COMPANY</b>	<b>NAME</b>	<b>BOAT TYPE</b>	<b>LENGTH</b>	<b>ENGINE TYPE</b>	<b>OTHER</b>	<b>Vessel code</b>
Dolphin Encounter	DE	Cat	8.8 m	twin Volvo 200 Hp's	only take 18 pax	V10
Dolphin Encounter	DE2	Jet boat	8.0 m	single Yanmar 315 Hp	diesel, jet boat	V11
Dolphin Encounter	The Tinny	Stabi-craft	6 m	Yamaha V4 115 Hp		V13
N.Z. Sea Adventures	Kotuku	Stabi-craft	9.55 m	twin Johnson 225 Hp's		V12
N.Z. Sea Adventures	Seaqwest	Stabi-Craft	6.6 m	twin Yamaha 90 Hp's		V14
Whalewatch KK	Makaphiu	Cougar Cat	48 ft	Twin Volvo 500 Hp		V31
Whalewatch KK	Wawahia	Cougar Cat	44 ft	Twin Volvo 500 Hp		V35
Whalewatch KK	Urua	modified Naiad	12.3 m	triple Yamaha 225 Hp's		V34
Whalewatch KK	Orca	Naiad	6.8 m	twin Yamaha 140 Hp's		V32
Whalewatch KK	Cachalot	Naiad	6.7 m	twin Yamaha 140 Hp's		V30
Whalewatch KK	Paikia	Naiad	6.7 m	twin Yamaha 140 Hp's		V33
Earthwatch	Keiki Na'ia	Zodiac	4.0 m	single Johnson 25 Hp	Yamaha 4 Hp kicker	V1
n/a	Fine Catch	cat	33 ft	twin Volvo 150 Hp's	conventional drive	V50
DoC	Tohora	Naiad	6.8 m	single Yamaha 115	Yamaha 25 Hp kicker	V5
(Ingrid Visser)	Orca Research I	Naiad	4.3	single Yamaha 60		V3
(Ingrid Visser)	Orca Research II	Naiad	5.6	twin Yamaha 40 stroke		V4
(Barbara Todd)	Balaena	Zodiac	6.0 m	twin Evinrude 70 Hp's		V6
<b>(Steve &amp; Liz)</b>						
	<b>COMPANY</b>	<b>PLANE TYPE</b>	<b>DESCRIPTION</b>			
	Whalewatch Air	Briton Norman I	(red and white), high wings, seats 10-12 pax plus pilot/co-pilot			
	Whalewatch Air	Cessna 172	white with yellow stripe, high wings, seats 3 pax plus pilot			
		Piper Cherokee	low wings, seats 3 pax plus pilot			
	Aero Club	Piper Cherokee				
	Air Tours	Cessna 206	6 PAX			
		Nomad	14 PAX + 2 pilots			

**VITA**

Suzanne E. Yin  
1483 Sutter Street, Apt #1107  
San Francisco CA 94109

B.A Biology, Brown University, 1985