CHAPTER I

INTRODUCTION

Documented Reactions of Cetaceans to Disturbance

The majority of information on reactions of marine mammals to human activities is anecdotal (e.g. Richardson et al. 1991, Richardson 1995). However, in the past two decades, several studies have examined effects of industrial noise and vessel traffic on short-term behavioral responses of baleen whales in arctic waters and off the coasts of Alaska, California, and Hawai'i (Richardson 1995).

Man-made noises such as seismic exploration, drilling, engine noise, and other sounds may mask echoes from echolocation pulses of dolphins or other important natural sounds produced by potential dolphin predators or prey. The sounds may also interfere with communication, interrupt normal behavior, cause short-term avoidance, induce stress, and if loud enough, create hearing loss (Richardson and Malme 1995, Richardson and Würsig 1995, Gordon and Moscrop 1996, Richardson and Würsig 1997). Interruptions of normal behaviors may reduce foraging time; cause movement to less favorable areas; disrupt mother-calf bonds, social ordering, or sexual activity; and in the long-term, decrease survival (Richardson and Würsig 1995, Thompson et al. 1995)**.** Disturbances resulting in lowered surfacing intervals may influence dive times and foraging efficiency (Gordon and Moscrop 1996). Disturbances that cause long-term

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This thesis follows the style and format of Marine Mammal Science.

abandonment from preferred locations have serious consequences for the animals that leave (Richardson and Würsig 1995, Wiley et al. 1995, Gordon and Moscrop 1996). How cetaceans react to man-made noise and other human activities varies between species, school/pod composition, habitat, animal activity/behavior, water depth and other factors (Watkins 1986, Heimlich-Boran and Heimlich-Boran 1995, Richardson and Malme 1995, Gordon and Moscrop 1996, Richardson and Würsig 1997).

Reactions to Industrial Activities

Responses of migrating gray whales, *Eschrichtius robustus*, to recorded stimuli of industrial noise were measured in studies off the California coast (Tyack et al. 1989, Richardson 1995). The degree of disturbance was determined by the sound level that caused the whales to alter their course around the source of the noise. Whales responded similarly to recordings of drilling platform, drillship, helicopter, and production platform noise by moving around the playback source, generally maintaining a distance greater than 500 m (Malme et al. 1987; Tyack et al. 1989, Richardson 1995). Playbacks of recorded drillship noise produced the greatest avoidance, while those of the production platform produced the lowest avoidance. Similar results were obtained in playback experiments with feeding gray whales in the Bering Sea (Malme et al. 1987, Richardson 1995).

Bowhead whales, *Balaena mysticetus*, also exhibited avoidance reactions to industrial noise. In experiments using playbacks of recorded noise, bowheads oriented away from and sometimes avoided drillship and dredge sounds (Richardson et al. 1985; Richardson et al. 1990, Richardson 1995). Migrating bowheads have been observed to avoid areas within 10 km of active drillships (Richardson 1995). However, bowheads also have been observed within 2.5 km of drillships (Richardson 1995). Habituation and variation of individual sensitivity may account for the discrepancy in the reaction of bowheads to industrial noise (Richardson et al. 1990, Richardson 1995). Blow rate, surfacing duration, and re-orientation rate of baleen whales of an undetermined species appeared to change in response to transmissions from a loud, low-frequency (57 Hz) "hum" played during a temperature-measuring feasibility test (Bowles et al. 1994).

Pilot whales, *Globicephala* spp (Kapel 1979, Sorensen et al. 1984), bottlenose dolphins, *Tursiops truncatus* (personal observation, Sorensen et al. 1984), Risso's dolphins, *Grampus griseus* (Sorensen et al. 1984), common dolphins, *Delphinus delphis* (Sorensen et al. 1984); and unidentified species of *Stenella* and beaked dolphins (Sorensen et al. 1984) have been sighted within visual range of drillrigs and appear to show considerable tolerance to the noise usually associated with these structures (Richardson 1995). Belugas, *Delphinapterus leucas*, also have been observed within 20 km of operational drillships (Sorenson et al.1984, Richardson 1995). The reactions of belugas to playbacks of drillships were tested in captivity by Thomas et al. (1984). Belugas were at times startled by the onset of the playback. However, they showed no behavioral or physiological response to sustained playbacks and often swam within 1 m of the noise source, where the sound levels were greater than 153 dB re 1 μPa (Thomas et al. 1984).

Gray whales responded to seismic noise produced from airguns, when the decibel level was greater than 160 dB re 1 μPa, by moving away from the noise source and increasing their respiration rates (Malme et al. 1984). Bowhead whales also interrupted their normal behaviors and swam away from seismic vessels that were operating within 7.5 km (Richardson et al. 1986, Richardson 1995). The mean blow intervals from these whales and their mean dive durations were significantly longer in the presence of seismic noise levels (142-157 dB re 1 μPa) (Richardson et al. 1986, Richardson 1995).

Data on the reaction of odontocetes to seismic exploration are limited. It is possible that sperm whales in the Gulf of Mexico moved away from seismic surveys that were located over 50 km away (Mate et al. 1994), but this assertion has no direct data to support it (Würsig, pers. comm.). Small odontocetes may be relatively insensitive to airgun pulses at distances of several kilometers (Richardson 1995).

Reactions to Aircraft

Reactions of cetaceans to aircraft have been reported on several occasions. Norris et al. (1978) noted that spinner dolphins in the Eastern Tropical Pacific (ETP) reacted to a helicopter at 213-305 m above sea level (asl). However, spinner dolphins did not react to a helicopter at 366-549 m asl during a series of aerial surveys in the ETP (Au & Perryman 1982). Industrial workers have described belugas diving in response to low-flying helicopters (Richardson et al. 1991). Several researchers conducting aerial surveys have noted that bowhead whales responded when aircraft circled below 305 m asl (Richardson et al. 1985), by making sudden dives and moving away from the area under observation (Fraker et al. 1981; Richardson et al. 1983; Richardson et al. 1985). Bowhead whales spent significantly less time at the surface, displayed a significant reduction in the intervals between blows, and showed a decrease in the number of blows per surfacing in the presence of low flying aircraft (Richardson et al. 1983). Humpback whales, *Megaptera novaeangliae*, changed surface duration, blow rates, orientation, and swimming speed in response to a twin engine Cessna at 457 m (Smultea et al. 1995). Other researchers noted little or no response by the whales to aircraft (Ljungblad et al. 1980). The wide range of reactions to aircraft seems to indicate that responsiveness depends on activity state, situation, and species of cetacean.

Reactions to Ships and Recreational Vessels

Whale watching is a rapidly growing industry worldwide (IFAW 1995). Near-shore cetacean populations of a variety of species are easily accessible to humans off the coasts of Hawai'i (Norris and Dohl 1980), Massachusetts (Watkins 1986, Wiley et al. 1995), Florida (Seideman 1997), Vancouver (Duffus 1993, Duffus 1996), Bahamas (St John 1988, Herzing 1991), Iceland (Fisher 1998), Ireland (Lockyer and Morris 1986, Lockyer 1990), Scotland (Arnold 1997), Australia (Lockyer 1990, Green and Corkeron 1991, Orams et al. 1996, Findlay 1997, Corkeron 1998), New Zealand (Beasley 1997, Constantine 1995, Donoghue 1996, Constantine 1998), within the Mediterranean Sea (Kemp 1996), and elsewhere (Heimlich-Boran and Heimlich-Boran 1995, Kemp 1996, Findlay 1997, DeNardo 1998). An increase in recreational use of critical habitat can have adverse effects on marine mammal populations (FAO 1978). Collisions with whale watching boats or other vessels can injure or even kill marine mammals (FAO 1978, Bloom and Jager 1994, Fertl 1994, Richardson and Würsig 1995, Wiley et al. 1995). Tourist activities have been correlated with a variety of behavioral reactions ranging from short-term behavioral changes (Findlay 1997) to both avoidance of vessels and areas in which vessels operate (Findlay 1997) and habituation to whale watching activities (Watkins 1986).

Marine vessels are known to cause significant behavioral reactions in some cetaceans, resulting in animal movement away from vessels, even if they are a great distance away, especially if the animals associate these vessels with harassment (Irvine et al. 1981, Au & Perryman 1982). Spinner dolphins in the ETP were observed to initiate avoidance reactions when tuna vessels approached to within 12 km (Au & Perryman 1982). Aggregation of relatively dispersed individuals occurred when the ship was within 2 km, and dolphins began radical evasive maneuvers when the ship came within 200 m (Au & Perryman 1982). Spinner and spotted dolphins, *Stenella attenuata*, also fled at high speeds from the tuna netting area following their release from purse seines (Leatherwood and Ljungblad 1979). Other cetaceans also have been observed fleeing from ships and boats, especially from vessels that are traveling erratically or rapidly towards the whales (Richardson et al. 1991). Narwhals, *Monodon monoceros*, and belugas appear to be extremely sensitive to the sounds produced by icebreaking ships. These animals produced alarm calls when icebreaking vessels were 80 km away, and fled the area entirely when the ship approached within 35 km (Cosens & Dueck 1993).

Differences in humpback whale behaviors have been correlated with pod composition (calf pods and non-calf pods) (Salden 1993, Corkeron 1995), and vessel speed, number, size and proximity (Baker & Herman 1983, Bauer 1986). Frankel et al. (1995) found that when natural and vessel variables were simultaneously considered in a linear model, the vessel explained less of the total variance than the natural factors, suggesting that vessel traffic had less of an effect on humpback whale behavior than does pod composition and other natural influences (Frankel et al. 1995). However, changes in diving behavior have been correlated to the presence of certain vessels (Baker & Herman 1983, Bauer 1986, Corkeron 1995). At high densities of vessels, the frequency of aerial behaviors was inversely correlated to vessel distance (Baker & Herman 1983). Humpback whale displays are caused by other humpbacks as well as events outside the group (Smith and Dolphin 1993). Humpbacks exhibited decreases in dive times, increases in short pauses at the surface, and faster swimming speeds within 2 km of approaching large ships off southeast Alaska (Baker and Herman 1983). A positive relationship between the number of vessels and swimming speed also was detected in Hawai'i (Bauer 1986). While increased swimming speeds may be a form of horizontal avoidance, changes in diving behavior may indicate hiding and vertical avoidance when vessels are in closer proximity (Bauer 1986, Richardson 1995). It is possible that humpbacks are trying to evade vessels by eliminating highly visible cues, i.e. tail flukes and plumes from blows (Bauer 1986). Increases in no-blow rise rates and fluke-down dives were associated with the number and proximity of the vessels (Bauer 1986). The increase in fluke-up dives when vessels were in close proximity or following whales may indicate a vertical escape strategy (Bauer 1986). In addition, singing humpbacks may increase song tempo in response to boat noise (Norris 1995).

Bowhead whales have been observed to orient away from approaching vessels, and swim away from vessels within approximately 4 km (Fraker et al., 1981; Richardson et al. 1983; Richardson et al. 1985). The whales also exhibited significantly reduced blow intervals (Richardson et al. 1983; Richardson et al. 1985), durations of surfacing (Fraker et al. 1981; Richardson et al. 1983), and number of respirations per surfacing (Richardson et al. 1985).

Responses of southern right whales, *Eubalaena australis*, to whale watching vessels in Patagonia varied with composition of the pod (mother and calf pair, mating group, etc.) and type and distance of approaching whale watching vessel (Campagna et al. 1995, Rivarola et al. 1995). Whales usually responded to whale watching vessels by changing swimming direction away from the boat, and whales were more likely to move away from vessels which directly approached, followed, or encircled them. The percentage of whales responding to whale watching vessels increased as the distance between the whale and boats decreased.

Dwarf minke whales (*Balaenoptera acutorostrata*) exhibited mixed reactions to swimmers and whale watching boats off Northern Queensland, Australia (Arnold 1998). While some whales avoided swimmers and boats, others approached the boat and maintained a position within 5 m of swimmers (Arnold 1998).

The normal northward migration route of gray whales off the coast of California may have moved seaward as a result of increased vessel traffic (FAO 1978). Duffus (1996) observed gray whales off Vancouver and found that their foraging sites became increasingly more distant from whale watching ports. In addition, while their blow intervals were significantly altered in response to vessels, Gray whales may also have changed swimming speed and direction (Ollervides 1997).

Odontocetes also display a variety of behavioral responses to vessels. Sperm whales reacted to whale watching boats by shortening their respiratory intervals and decreasing their surface times (Constantine 1998). Killer whales, *Orcinus orca*, in Johnstone Strait, Canada, have been reported to respond to approaching boats by increasing their speed and heading for open water. Their swimming speed tended to increase as the number of vessels operating within 400 m increased (Kruse 1991). Likewise, killer whales became more active and changed course to avoid small vessels that moved erratically or approached to within 3 to 5 m (Jacobsen 1986). However, in contrast to the observations made in Johnstone Strait, no relationship was found between vessel activity and whale behavior in Haro Strait, Washington (Burgan and Otis 1995).

Bottlenose dolphins seem generally tolerant to human activity and freely swim in ship canals within close proximity to industry and vessel traffic (Henningsen and Würsig 1992). However, they responded to vessels approaching to within 150 - 300 m by orienting away from the boat and by increasing their dive time (Evans et al. 1992). Furthermore, Evans et al. (1992) found that the response was greater when the disturbance was repeated in short succession. Acevedo (1991) and Janik and Thompson (1996) observed that bottlenose dolphins did not respond to boats (typically fishing vessels) that passed through the study area in a straight line. However, they modified their behavior when followed by boats (Acevedo 1991, Janik and Thompson 1996). Harbor porpoises, *Phocoena phocoena*, off the coast of southeast Shetland, Britain, responded at greater distances to larger more highly-powered boats than smaller ones, and the effect was greater when the porpoises were approached directly (Evans et al. 1993).

Barr and Slooten (1998) noted that the responsiveness of dusky dolphins (*Lagenorhynchus obscurus*) to vessels depended upon the dolphins' activity state as well as the type, number, and behavior of the vessels. Dusky dolphins appeared to be more sensitive to human activities during the afternoon. This could be due to sensitization to human activities from repeated contact, or perhaps that they are more vulnerable to disturbance during the afternoon because they are usually in a more restful state at that time of day (Barr and Slooten 1998). The presence of a combination of vessel types (fishing, whale watching, and private boats) in the afternoon was correlated with a significant increase in the number of dusky dolphin aerial activities and directional changes (Barr and Slooten 1998). Barr and Slooten (1998) hypothesized that combinations of different vessel types caused the greatest disturbance, because it may be difficult for dolphins to predict the behavior of individual boats.

Reactions to Tourist Vessels and Swimmers

The strategy used by tour boat operators significantly affected bottlenose and common dolphin responses to swimmers, and dolphin responses varied by species (Constantine 1995, Weir et al. 1996, Constantine and Baker 1997). Only a small proportion of bottlenose and common dolphin schools in the Bay of Islands, New Zealand, interacted with swimmers (Constantine 1998). Barr (1995) also observed that few dusky dolphins per school (as few as 9 out of 350) would interact with swimmers off the Kaikoura coast of New Zealand.

Hector's dolphins, *Cephalorhynchus hectori*, in Porpoise Bay, New Zealand, formed significantly tighter pods when boats were present (Bejder 1997, Bejder and Dawson 1998, Bejder et al. 1999). The presence of swimmers increased the probability that Hector's dolphins remained in a tight group (Bejder 1997, Bejder and Dawson 1998).

Pilot whales off the Canary Islands have been observed to respond differently to boats than to swimmers, with reactions towards swimmers being more negative than those towards boats (Heimlich-Boran and Heimlich-Boran 1995). Whales could be observed 5 - 7 meters from a boat, but would immediately move away if swimmers entered the water. Changes in behavior, such as groups splitting and moving off in different directions or individuals staying away from the surface longer, were more common with swimmers than with boats. Responsiveness varied according to age/sex composition of the dolphin group, and the number and dispersion of swimmers in the water. While mothers with young calves were the least approachable, calves without adults close to them would approach the swimmers much more closely (Heimlich-Boran and Heimlich-Boran 1995). Respiratory intervals also differed in relation to presence and absence of boats (Montero et al. 1993).

"Swim With the Dolphins" Programs

Two recent studies monitored commercial swim with the dolphin tours operating in The Bay of Islands, New Zealand, and Southern Post Phillip Bay, Australia (Constantine 1995; Weir et al. 1996). Both studies found that the more aggressive approaches used by some tour operators resulted in a higher frequency of avoidance behavior. Constantine (1995) also found that responses to different tour boat approach strategies varied by species.

Aggressive and sexual behaviors performed by dolphins and directed towards swimmers have been documented in both captive (Samuels and Spradlin 1994, Frohoff and Packard 1995) and wild dolphins (Lockyer 1990, Bloom 1991, Shane 1993, Dudzinski et al. 1995, Santos 1995, Seideman 1997). Defecation, the creation of bubble trains, jaw clapping, and head wagging in proximity of swimmers have all been interpreted as aggressive displays made by captive marine mammals. Interpretation of "annoyance" which leads to direct aggression, is difficult to measure, with differences occurring even among researchers with vast experience (Heimlich-Boran and Heimlich-Boran 1995). This point is exemplified by interpretations of a video tape of a Hawai'ian pilot whale interacting with a swimmer, where aggressive playfulness and sexual intentions were interpreted by different viewers as the intent of the male whale as it dragged the female human underwater (Shane 1995).

In a study of captive "swim with the dolphin" programs in the United States, Samuels and Spradlin (1994) found that high risk activities (such as aggressive or sexual behaviors performed by dolphins and directed towards swimmers) comprised as much as 61% of dolphin-swimmer social time during non-controlled swims. Submissive behavior displayed by dolphins during dolphin-swimmer social time was also considered to be a high risk activity because in the wild, this type of behavior is commonly elicited by aggression, and therefore, a part of agonistic interactions (Samuels and Spradlin 1994). Aggressive behaviors of captive marine mammals have resulted in injury and, in one instance, death when a trainer was pinned to the bottom by a killer whale (Herman and Tavolga 1980). Swimmers also have been seriously injured by dolphins while participating in captive swim-with-dolphin programs (Samuels and Spradlin 1994, Frohoff and Packard 1995).

Aggressive interactions are not restricted to captivity. Despite a commonly-held belief by the general public that dolphins are always gentle, there are several examples of swimmers being seriously injured by delphinids (Lockyer and Morris 1986, Lockyer 1990, Bloom 1991, Shane 1993, Santos 1995). The majority of documented injuries have occurred in the wild, and have resulted from interactions with solitary, male bottlenose dolphins that have become tourist attractions (Lockyer 1990, Bloom 1991, Dudzinski et al. 1995, Santos 1995).

Threatening and aggressive behavior was observed regularly with at least four male bottlenose dolphins: "Percy" off the coast of Cornwell (Lockyer and Morris 1986); "JoJo" in the Turks and Caicos Islands (Perrine 1990); "Donald" off the west coast of England (Bloom 1991), "Taio" off the coast of Brazil (Santos 1995, Kemp 1996); and one female bottlenose dolphin "Pita" off the coast of Belize (Dudzinski et al. 1995). The most serious incidents involved attacks by "Taio" in which one swimmer was killed and 29 others were injured (Santos 1995).

While some attacks have resulted from self defense on the part of the dolphin (Santos 1995), others seem to be unprovoked. "Percy", "Donald", "JoJo" and "Pita" have all been observed to push and butt swimmers. "JoJo" (Perrine 1990), and "Donald"(Bloom 1991) have tail-smacked swimmers. "Percy", "JoJo" and "Pita" acted aggressively towards swimmers trying to exit the water. "Donald" (Lockyer 1990), "Percy" (Lockyer and Morris 1986), and "JoJo" (Perrine 1990) have all pulled swimmers under water and out to sea. "Percy" (Lockyer and Morris 1986), "JoJo" (Perrine 1990), and "Donald"(Bloom 1991) have bitten the hands and arms of swimmers. Copulatory behavior (Lockyer and Morris 1986, Perrine 1990) and genital rubbing (Dudzinski et al. 1995) were also observed with "Percy", "JoJo", and "Pita". On several occasions, "Donald" was observed to have an erect penis while he was pushing swimmers to the side of the boat and holding them there (Bloom 1991). It has been theorized that reports of bottlenose dolphins saving humans by pushing them towards shore or against a boat may actually have been manifestations of sexual behavior (Bloom 1991).

Aggressive interactions between humans and wild dolphins are also common in areas where feeding programs occur (Orams et al. 1996, Seideman 1997). The feeding of dolphins is a popular tourist activity at Monkey Mia in Shark Bay, Western Australia. Feeding stations have been established elsewhere (Green and Corkeron 1991), even though researchers have found a correlation between provisioning of mothers and a high juvenile mortality rate of their calves (Rafic 1998). Wild dolphin feeding programs have also resulted in injuries to both humans and dolphins. In some cases, swimmers have been bitten after teasing dolphins (Seideman 1997). Likewise, dolphins have been seriously injured during feedings in which they were fed firecrackers, golf balls, or hooks baited with fish (Frohoff and Packard 1995). In addition, dolphins have been injured when humans have attempted to spear them during feeding activities (Burgess 1992)

Marine Mammal Protection Act

The Marine Mammal Protection Act (MMPA) states that it is unlawful to "take" any marine mammal. Take is defined as: to harass, attempt to harass, capture or kill any marine mammal (United States Code 1994). Harassment is broken down into two levels. Level A harassment is defined as any act of pursuit, torment or annoyance that has the potential to injure a marine mammal or marine mammal stock in the wild. Level B harassment is defined as any act of pursuit, torment or annoyance which has the potential to disturb a marine mammal or marine mammal population in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering (United States Code, 1994).

The National Marine Fisheries Service (NMFS) has been charged with the enforcement of the MMPA for cetaceans and most pinnipeds; however, there are only two NMFS Law Enforcement agents in the entire state of Hawai'i. These officers are based in Honolulu, and the minimum response time for violations reported in Kealake’kua Bay, on the Kona coast of the Big Island, is 45 minutes. Since it is impractical for NMFS agents to fly 45 minutes every time a violation of the MMPA is reported, NMFS is forced to rely largely upon voluntary compliance with MMPA regulations in this area.

Rationale For Study

This current investigation was initiated due to concern that an increase in the number of swimmers, kayakers and other human activity in Kealake’kua Bay, Hawai'i, might be disturbing the natural behavior of spinner dolphins (*Stenella longirostris*). It has been documented that increases in the recreational use of critical habitat can have adverse effects on marine mammal populations (FAO 1978). Hawai'ian spinner dolphins, that feed in nearby deepwaters at night and inhabit shallow coastal waters to rest during the day, may be especially vulnerable to human disturbance.

Disturbance of spinner dolphins may have both short and long-term effects. Association and interaction with humans may disrupt critical behaviors such as reproduction, feeding, and rest (Duffus and Dearden 1993, Thompson et al. 1995, Weir et al. 1996). Occasional short-term avoidance and interruptions of normal behavior may not have measurable effects on general parameters, such as energy balance, reproductive rates, health and general welfare of cetaceans (Richardson 1995, Richardson and Würsig 1995, Gordon and Moscrop 1996). However, these acute interferences in the dolphin environment have been shown to affect more specific physiological parameters, including elevated heart rates (MacArthur et al. 1979), hormonal changes (Weiss 1972, Friend 1991, Richardson and Würsig 1995, Gordon and Moscrop 1996), and other physiological responses even though the human activities may not induce obvious behavioral reactions (Richardson et al. 1985, IFAW 1995, Richardson 1995, Gordon and Moscrop 1996, Kemp 1996). In the short-term, repeated contact with humans may generate stress in individual dolphins and groups (Thompson et al. 1995, Kemp 1996, Findlay 1997, Barr and Slooten 1998). Although long-term effects of disturbance on marine mammals have not been well-documented and remain largely unknown (Richardson et al. 1991, Heimlich-Boran and Heimlich-Boran 1995, Richardson 1995, Gordon and Moscrop 1996, Richardson and Würsig), there is the potential for a reduction in either the viability, displacement of the dolphin population, habitat degradation, or habituation to human activities (Watkins 1986, Duffus and

Dearden 1993, Thompson et al. 1995, Kemp 1996, Weir et al. 1996, Arnold 1997, Findlay 1997).

In order to address questions of potential human disturbances on Hawai'ian spinner dolphins, I formulated the following objectives and hypotheses, to be addressed in chapters 3 and 4.

Objectives

1) To document dolphin behaviors and occurrence in Kealake'kua Bay
2) To document human activities in Kealake'kua Bay
3) To document dolphin - human interactions in Kealake'kua Bay
4) To determine which, if any, human activities disturb the dolphins
5) To determine the level of disturbance (measured by the frequency of aerial activities and surfacing behavior) caused by these activities
6) To determine if dolphins respond differently to different human activities

Null Hypotheses

1) Spinner dolphins are not disturbed by human activities in Kealake'kua Bay .
2) Human - dolphin interactions in the bay do not affect the frequency of aerial activities, surfacing behavior, school size, or residency patterns of spinner dolphins in Kealake'kua Bay.
3) Different types of human activities do not differentially affect the frequency of aerial activities or surfacing behavior of spinner dolphins.

CHAPTER II

DAILY ACTIVITY CYCLE AND BEHAVIORS OF SPINNER DOLPHINS IN KEALAKE’KUA BAY, HAWAI'I.

Spinner Dolphins, A Species Description

Spinner dolphins occur in tropical and subtropical areas of the Pacific, Atlantic, and Indian Oceans (Mead et al. 1980, Leatherwood and Reeves 1983, Perrin 1990, Cooke 1991, Norris et al. 1994a), and have even been observed in the deeper areas of the mainly-enclosed Red Sea (Robineau and Rose 1983). Four subspecies of spinner dolphins have been described, including a dwarf form from the Gulf of Thailand (Perrin et al. 1989). *Stenella longirostris orientalis* and *S. l. centroamericana* are only found in the eastern tropical Pacific, while *S. l. longirostris* occurs in the tropics world wide (Perrin 1990). Although spinners typically inhabit deep offshore waters, the dwarf form from the Gulf of Thailand, the subspecies which occur along the Pacific coast of central America (*S. l. centroamericana*), and the subspecies near Hawai'i (*S. l. longirostris*), all approach shore at least occasionally (Leatherwood and Reeves 1983, Perrin et al. 1989, Perrin 1990).

Most of the information on spinner dolphins comes from animals incidentally taken in the purse seine fishery for yellowfin tuna in the eastern tropical Pacific and from behavioral studies of a population off the Big Island of Hawai'i. The Hawai’ian spinner dolphins (from now on referred to simply as "spinner dolphins") occur as single-species aggregations near many Pacific Ocean islands (Leatherwood and Reeves 1983, Perrin 1990). They are slender animals characterized by a distinct tripartite color pattern. The light gray lateral field is sharply contrasted by a dark gray cape over the dorsal surface and a white ventral surface (Figure 1). A dark eyeband extends from the rostrum to the flippers. Spinner dolphins of Hawai'i also exhibit a slight degree of sexual dimorphism. While females reach approximately 2 m in length and have a falcate dorsal fin, males are slightly larger and acquire secondary sexual characteristics of an erect dorsal fin and small post-anal keel upon reaching sexual maturity (Perrin 1990, Norris et al. 1994b).

The population size of spinner dolphins around the island of Hawai'i has been estimated to be between 1000 (Würsig, Wells, Würsig and Norris1994) and 2334 animals (Östman 1994). These spinner dolphins follow a diel activity pattern that was described in detail by Norris and Dohl (1980), Norris et al. (1985) and Norris et al. (1994b).

Figure 1. Spinner dolphin, Kealake'kua Bay, Hawai'i

Daily Activity Cycle

Spinner dolphins feed offshore on mesopelagic fish and squid of the deep sea scattering layer at night and move into near-shore waters, often protected bays, during the day to rest (Norris and Dohl 1980). Feeding dives may start at dusk and continue throughout the night (Würsig, Wells, Norris and Würsig 1994), often with several schools coalescing to form large feeding aggregations that surface synchronously or sub-synchronously (Norris and Dohl 1980).

Bays are thought to provide protection from rough seas and pelagic shark predation during periods of rest. Kealake’kua Bay on the island of Hawai'i is an established resting site for spinner dolphins (Norris et al. 1985, Norris 1991; Wells and Norris 1994). Dolphins usually arrive in the bays just after sunrise and slowly descend into a period of rest (Würsig and Würsig 1983), as evidenced by a decrease in the frequencies of aerial activity and vocalizations. Dolphins become more active in the afternoon and begin to socialize before moving offshore again to feed during the night (Norris and Dohl 1980, Würsig et al. 1994).

Dolphin rest areas are distributed discontinuously along coastlines, for there are several coastal areas where schools of dolphins congregate, and other regions of the coast that are devoid of dolphins (Norris and Dohl 1980). Rest areas which may, or may not, contain coves seem to be chosen for their physical characteristics and proximity to feeding grounds (Norris and Dohl 1980, Wells and Norris 1994). They are typically less than 50 m deep, but within a few km of deep water (greater than 500 m depth) and have sandy bottoms which may be dotted with coral formations. Some rest areas are visited on a regular basis, while others are used less frequently. Furthermore, some areas consistently have more dolphins than other areas (Norris and Dohl 1980, Wells and Norris 1994).

Morning shoreward movement may start as early as 0300, with subgroups becoming less evident as dolphin schools gradually move closer to shore (Würsig et al. 1994). When schools reach near-shore waters, they remain transient unless rest coves are encountered. In general, congregation patterns suggest that bays and coves used for rest may not be the target of shoreward movement; the bays may simply collect dolphin schools (Norris and Dohl 1980).

Subsidence into rest is a gradual process that begins as schools reach resting areas. The entire process, which may require two or more hours, is characterized by a gradual reduction in aerial activities and vocalizations. During this descending into rest, the school tightens and dives become more synchronous (Würsig et al. 1994). Larger schools of more than 50 animals typically exhibit higher levels of aerial activity and require more time to subside into rest.

Norris and Dohl (1980) defined rest to occur when a 10-minute observation period revealed no aerial behavior, although sporadic low-intensity aerial behavior may occur during rest. Norris and Dohl (1980) found that synchronous diving by the entire school typically indicated the onset of rest. Resting dolphin schools are usually confined to shallow water less than 10 to 20 m deep (Norris and Dohl 1980); and such resting dolphins exhibit longer dive times, shorter surface intervals, and decreased inter-individual and inter-group distances as they move slowly back and forth, deep within the bay (Würsig et al. 1994).

The highest frequency of aerial activities during the day occurs during arousal from rest (Norris and Dohl 1980). In completely quiescent spinner dolphin schools, arousal was marked by an abrupt aerial behavior such as a headslap or spinning leap (Norris and Dohl 1980). Schools were often fully alert within 10 minutes, with aerial activities occurring throughout the dolphin school (Norris and Dohl 1980). Swimming speed quickens as spinners enter a "zigzag swimming" period.

Zigzag swimming consists of a period where dolphins exhibit great changes in their swimming speed, vocalizations, and social behavior while swimming back and forth within the bay. This activity culminates with the dolphins swimming toward the margin of the bay, and then back and forth, repeatedly entering and exiting the bay (Norris and Dohl 1980). Schools begin to traverse deep water as individual dolphins move towards the mouth of the bay at high speed. Dolphins gradually slow down as the mouth of the bay is reached and may mill about before moving back into the bay. At this point, spinner dolphins may return to their restful behavior within the bay or turn around and again swim towards deep water. Zigzag swimming typically lasts two to three hours and ends with fast swimming that takes the school beyond the confines of the bay. Aerial activities, aggressive chases and other social behaviors including mating are evident as the school travels towards the feeding grounds in deeper oceanic waters. As the school reaches the feeding grounds, subsynchronous dives begin (Norris and Dohl 1980, Norris et al. 1994a).

Aerial Behaviors

Spinner dolphins are named for their spinning leaps. Spinning leaps are often performed in series by a single animal. The dolphin leaps from the water and completes up to five and one-half rotations around its longitudinal axis before crashing back into the water (Norris and Dohl 1980). Spinning leaps also involve a well-defined precursor pattern with stereotypical body movement and vocalizations (Norris et al. 1994a). This behavior is initiated by the spinner dolphin swimming horizontally for a few meters below the surface, making a rapid slicing motion with it's pectoral fins and emitting a series of barks. These rapid, jerky movements are followed by an upward arc that takes the dolphin out of water. When the dolphin is airborne, it throws its body into a twist, causing it to rotate along the longitudinal axis. Animals may spin vertically or horizontally in relationship to the water but hit the water on their backs or sides upon reentry. Spinner dolphins also exhibit at least six other aerial behaviors (Norris and Dohl 1980, Norris et al. 1994a). All but one of these, the arcuate leap, involves slapping the water upon re-entry.

Arcuate leaps are made by fast-moving dolphins. These clean, arching leaps seem to improve efficiency of locomotion and produce little noise or bubbles upon reentry (Norris et al. 1994a). The salmon leap was named after its resemblance to salmon leaping up rapids or falls. Dolphins leap and fall back onto the water with slightly-arched (to the side) and stiff body. Salmon leaps are typically seen in fast-moving schools.

The flip or tail-over-head leap is also an energetic/athletic leap that spinner dolphins perform (Norris et al. 1994a). Dolphins exit the water in a high arcuate leap and then throw their tail over their head, reentering the water tail first and slapping their dorsal surface against the water. Dolphins occasionally combine tail-over-head leaps with a spin.

Tail slaps involve dolphins slapping their tail flukes against the water in either the normal or inverted position (Norris and Dohl 1980, Norris et al. 1994a). Tail slaps produce a loud noise which can be heard for several hundred meters in the air and I assume that there is a loud underwater component as well. Tail slaps which are repeated in succession produce a sound similar to a slow outboard engine and have hence been termed motorboating (Norris and Dohl 1980). Shane (1990) hypothesized that tail slaps were at least at times associated with aggression in bottlenose dolphins.

In the head slap, the dolphin emerges from the water, as far as mid belly, and slaps its anterior ventral surface against the water. Backslaps are the inverse of headslaps. Dolphins exit the water as far as mid body, and slap their dorsal surface against the surface of the water (Norris and Dohl 1980).

Norris et al. (1985) discovered that spinner dolphins were easily disturbed by humans in the mornings, just before they descended into rest. At times, dolphins were disturbed to such an extent that they left the bay and re-initiated morning travel along the coast. Human activity could change the activity level of a school (usually from low to high) at anytime during the day, causing dolphins to scatter, leap, aggregate, initiate evasive maneuvers, or undergo a combination of these behavioral changes (Norris et al. 1985). The frequency and type of aerial activities has been used as an index of the arousal of individual cetaceans and of schools as a whole (Herman and Tavolga 1980, Norris and Dohl 1980). Increases in aerial displays may be caused by conspecifics or events outside the group (Smith and Dolphin 1993).

Study Site

Kealake’kua Bay is located on the leeward side of the island of Hawai'i (Figure 2). The 127.48 hectare bay is backed by an abrupt cliff formed by the scarp of the Kealake’kua fault, which follows the island contour to the north and south, frequently disappearing below a lava mantel (Wells and Norris 1994). Lava that flowed over the scarp fanned outward to form both the northern and southern limb of the bay, the deepest part of which (57 m) is located in a channel which runs between the two flows near the Ka'awaloa shoreline (Wells and Norris 1994). Kealake’kua Bay was established as a Marine Life Conservation District (MLCD) and as an underwater state park in 1969. The MLCD extends from the highwater mark seaward to a line that extends from Captain Cook Point to Manini Beach Point. A line from Cook Point to the north end of Napo'opo'o Beach divides the MLCD into subzone A to the north, and subzone B to the south (Figure 3). The anchoring of boats, fishing, and the taking or injuring of any type of marine life are all prohibited in subzone A. Fishing without the use of traps and the anchoring of boats are permitted in subzone B.

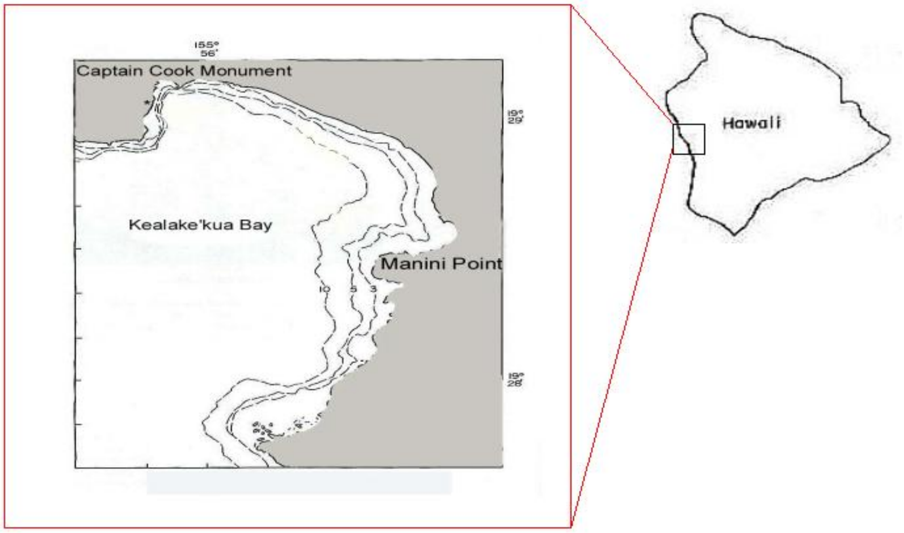

Figure 2. The island of Hawai’i and Kealake’kua Bay.

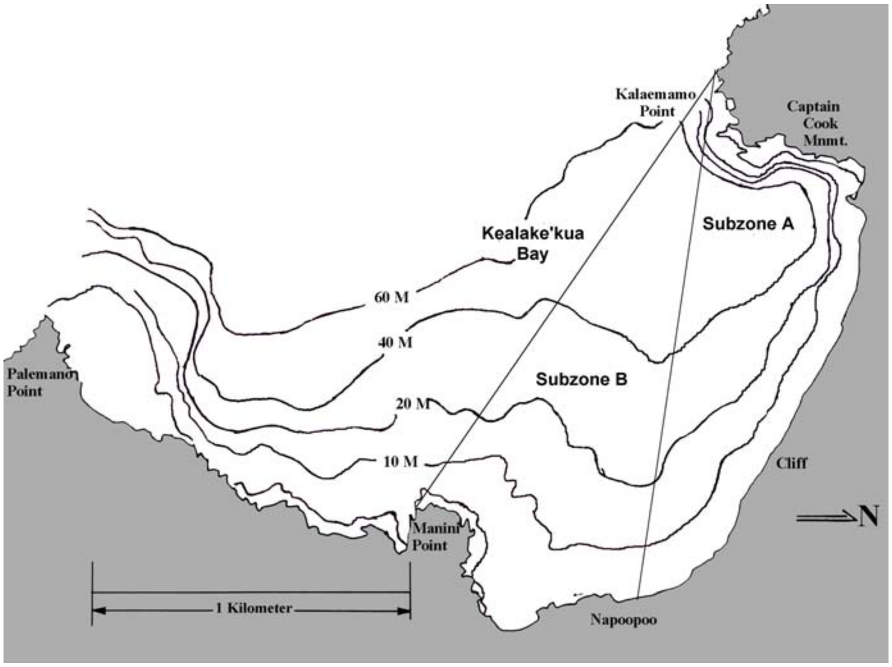

Figure 3. Kealake’kua Bay Marine Life Conservation District depicting subzones A and B

CHAPTER III

OCCURRENCE AND BEHAVIORS OF SPINNER DOLPHINS AND HUMANS IN KEALAKE’KUA BAY, HAWAI'I.

Objectives

The specific objectives to be discussed in this chapter are:

1) To document dolphin behaviors and occurrence in Kealake’kua Bay
2) To document human activities in Kealake’kua Bay

Methods

Data were collected from an observation site 55 m above the mean low water level on a steep slope at the back of the bay, just north of the beach at Kealake’kua Bay State Park, Napo'opo'o, Hawai'i. The entire confines of the Kealake’kua Bay were visible from this observation platform. This same cliff-site was used in studies conducted between 1970 and 1981 by Norris et al. (1994). My assistants and I monitored Kealake’kua Bay between 28 August, 1993 and 7 July, 1994, on days when visibility was clear enough to see the entire confines of the bay, and the waters within Kealake’kua Bay were generally of Beaufort sea state (BSS) 3 or less. On days when dolphins were present within the bay, observations of their activities were made until they left or until weather conditions (BSS or sunlight) rendered observations unreliable. Daily observations were concluded by noon if dolphins had not arrived by that time.

The total number of dolphins and humans (swimmers, kayaks, & motor boats) in Kealake’kua Bay were counted at the start of every hour. Swimmers near the Captain

Cook monument were not counted because they were often blocked from view by tourist vessels. Instantaneous scans (Altman 1974) were also conducted every 15 minutes to determine environmental conditions and the number of swimmers, kayaks, and motor boats within 100 m of a dolphin school.

Numbers and types of dolphin aerial activities and human activities were observed using 10x binoculars and continuously recorded onto microcassette between each instantaneous scan (see Introduction). Definitions of aerial activities were obtained from Norris et al. (1994a). Data were collected on the following dolphin activities: head slaps, tail slaps, back and side slaps, salmon leaps, spinning leaps, flips (tail-over-head leaps) and the number of times dolphins were observed bow riding in front of kayaks and motorboats. The types of human activities recorded include number of times motor boats approach, drive through, or follow within 10 m of dolphins, number of swimmers following within 10 m of dolphins, and number of kayaks following within 10 m of dolphins. Individual swimmers were identified by gender and color of swimsuit. Kayaks were identified by boat color and gender of occupants.

Data Analysis

Hourly scans from 128 days (57 days without dolphins and 71 days with dolphins) were analyzed by a Mann-Whitney U test to determine if significant changes in human activity in Kealake’kua Bay occur between days with and without dolphins. Transcripts from 10 days with BSS 3 or less and over five hours of continuous observations of dolphins were compared using a Mann-Whitney U test to determine if the bay is utilized equally by males and females on days when dolphins were present.

Thirty-five observation days with five hours or more of continuous observations (x = 5 hours 58 minutes) with BSS 3 or less were selected to determine the frequency of dolphin aerial activities. Frequency of aerial activities per dolphin per hour, dolphin occurrence, time of dolphin entry, dolphin exit, and residency time in Kealake'kua Bay were compared, using a 2 sample t-test, with data from Norris et al. (1994). A one-way MANCOVA was used to test for a relationship between dolphin school size and residency pattern within Kealake'kua Bay, as well as between hour of day and frequency of dolphin aerial activities per dolphin per hour. Frequency of aerial activity data were tested for normal distribution by plotting the residuals.

Results: Frequency and Residency Patterns

Dolphins were observed within the confines of Kealake'kua Bay on 135 of the 232 observation days, or 58% of the time. Estimated school sizes ranged from 4 to 90 individuals, with a mean school size of 33. Mean school size varied by month, with smaller mean school sizes, (mean < 20) observed during the fall and winter months (November and December), and a mean school size of 40 animals observed during spring months (March and April, Figure 4). Dolphin entry into Kealake'kua Bay was observed on 46 days. The time of dolphin arrival varied greatly and ranged from 0600 to 1330, with a mean entry time of 0802 (Figure 5a). Larger schools with over 50 dolphins tended to enter Kealake'kua Bay earlier than schools with 25 or fewer dolphins ($p \leq 0.066$) (Figure 5b). Dolphin departure was monitored on 32 days and ranged from 1045 to 1730, with a mean exit time of 1449 (Figure 6a). No relationship was found between dolphin school size and time of departure from Kealake'kua Bay (p

≥ 0.39) (Figure 6b). The entire residency period of the dolphins was monitored on 12 days, in which dolphins spent an average of 7 hours 13 minutes in the bay (Figure 7a). No relationship was found between dolphin school size and residency period within Kealake'kua Bay ($p \geq 0.60$) (Figure 7b).

Of the twelve days in which the entire residency period of spinner dolphins was observed, six had a BSS of 3 or less. Residency periods for these six days were plotted against potential disturbances by humans. Residency times were correlated to number of human activities/ dolphin/ hour of observations. As expected, the longer the dolphins stayed in Kealake'kua Bay, the more human activities per dolphin were recorded ($p = 0.016$, Multiple Regression).

Dolphin aerial activities exhibited a bimodal distribution. Higher rates of aerial activities occurred before 0715 and after 1515 ($p < 0.01$). Dolphins generally were active as they arrived in Kealake'kua Bay, with the frequency of aerial activities decreasing over the next 2 hours. Aerial activities remained at a low level until 1315 when dolphins prepared to leave the bay (Figure 8a). Slapping activities (head slaps, tail slaps, and back and side slaps) occurred most frequently in the morning, just after arriving in the bay, and in the afternoon prior to exiting the bay for night time feeding grounds (Figure 8b). Leaping activities (salmon leaps and spins) tended to peak in the afternoon. A peak was not observed in the frequency of flips, which occurred at a low level throughout the day (Figure 8c).

Figure 4

Figure 5a,b

Figure 6a,b

Figure 7a,b

Figure 8a

Figure 8b,c

Most human activities that were centered around dolphins in Kealake'kua Bay occurred before noon. Swimmers comprised the bulk of this activity, while kayak and motor boats predominated during afternoons (Figure 9). Kayaks were commonly used as a means of approaching dolphins in the bay. The mean number of motorboats on both days with and without dolphins displayed a bimodal distribution which coincided with motorboat tour schedules in the bay. No significant relationship was found between dolphin school size and number of swimmers, kayaks, and motor boats following the dolphins. However, the maximum number of swimmers, kayaks, and motor boats observed following dolphins tended to increase with school size (Table 1).

The presence of dolphins was found to be significantly correlated with human activities within Kealake'kua Bay. The mean number of swimmers, kayaks and motorboats was higher on days with dolphins than on days when dolphins did not enter the Bay (all at p < or = 0.001, Mann-Whitney U, Figure 10). On days when dolphins were present in the bay, there were more female swimmers than male swimmers ($p = 0.0065$, Mann-Whitney U). Although some swimmers used kayaks as a means of traveling to the dolphin group before entering the water, no differences were found between number of male and female kayakers ($p = 0.8798$, Mann-Whitney U).

Figure 9

Table 1

Figure 10

Discussion

Norris et al. (1994) observed dolphin schools within Kealake'kua Bay 79% of the time in 1979 - 1980. Dolphin residency in Kealake'kua Bay during the period of this study had diminished to 58% of the time (Table 2). Although numbers of swimmers, kayakers and other human activities in Kealake'kua Bay have increased since 1989, the decrease in dolphin residency cannot be unequivocally attributed to this increase in human use. The weak El Niño during the study period and other unmonitored factors, such as possible changes in the size of the spinner dolphin population, ocean currents offshore, recruitment of larval reef fishes, distance of the deep sea scattering layer to shore, over-fishing, and other possible alterations to the ecology of the region may have contributed to the reduced occupancy rate in Kealake'kua Bay. Nevertheless, the decrease in dolphin residency is suggestive of a possible human-induced effect.

The half hour difference in time of dolphin entry into Kealake'kua Bay between the study of Norris et al. (1994) and the current study is probably an artifact of the observation schedule and not a real difference, since the observations in this study rarely started before 0700. Although an overall mean residency time was not reported by Norris et al. (1994), dolphins were reported to spend 4 - 5 hours per day in the bay in winter (October - March) and 7 - 9 hours per day during spring (April - June). Differences in the observed seasonal residency data with the findings of Norris et al. (1994) could be due to the extremely small sample sizes in which the entire dolphin residency period was observed (spring n=3, summer n=4, fall and winter n=5, and total n=12) in the present investigation.

Table 2. A comparison of frequency of spinner dolphin schools within Kealake’kua Bay: mean school size, time dolphins entered, resided within and exited Kealake’kua Bay, during 1993-1994 and 1979-1980. Data from 1979 and 1980 were obtained from Norris et al (1994).

	(1993 - 1994)	(1979 - 1980)
Frequency in Bay	58%	79%
n	232	328
School size	33	33
Standard deviation	17.2	19.6
n	135	234
Time of entry	0802	0730
Standard deviation	2 hr 1 min.	1 hr 44 min.
n	46	106
Time of exit	1449	1442
Standard deviation	2 hr 3 min.	2 hr 58 min.
n	33	85
Residency periods		
Spring (Apr. - June)	6 hr 40	7 - 9 hours
Standard deviation	3 hr 10 min.	Not reported
n	3	Not reported
Summer (July - Sept.)	6 hr 52 min.	Not reported
Standard deviation	2 hr 54 min.	
n	4	
Fall & winter (0ct. - Mar.)	7 hr 51 min.	4 - 5 hours
Standard deviation	2 hr 30 min.	Not reported
n	5	Not reported
Total residency period	7 hr 13 min.	Not reported
Standard deviation	2 hr 35 min.	
n	12	

The correlation between number of human activities per dolphin per hour of observation and residency time could be an artifact of small sample size (n = 6) or a real occurrence. If it is a real occurrence, then it might indicate that the dolphins do not rest as efficiently when humans interact with them, and therefore need to spend longer periods in the bay.

Frequencies of aerial activities per dolphin per hour were similar to those observed by Norris et al. (1994), with the exception of a lower observed frequency of spins and flips per dolphin per hour reported in the current investigation (Table 3). This lower frequency accounts for the differences between the total rate of aerial activities per dolphin per hour of the two studies.

The frequencies of slapping surface activities (head slap, tail slap, back and side slaps) were similar to those observed by Norris et al. (1984). However, with the exception of the salmon leap, the frequency of leaping behaviors was well below the levels observed by Norris et al. (1994). This indicates that spinner dolphins in Kealake'kua Bay display fewer active surface behaviors per dolphin per hour than they did in 1979 - 1980 (Norris et al. 1994). This reduction could be due to the increase in human activities in the bay. It cannot be ruled out that it could also be due to several unmonitored factors, such as the weak El Niño and possible changes in ocean currents or the recruitment offshore of larval reef fishes and a greater distance of the deep sea scattering layer to shore, which would result in spinner dolphins having reduced energy reserves. This possibility is in concordance with the fact that the aerial activities with the lowest observed frequencies (spins and flips) are also the most athletic aerial activities and require the most energy

Table 3

to perform. If the dolphins do, in fact, have a reduced energy reserve, then the additional energy expenditure spent investigating, interacting with or avoiding humans in Kealake'kua Bay could be detrimental to spinner dolphins and in the long-term result in a reduction in fitness and population levels.

Previous researchers (summarized by Shane 1990) have hypothesized that cetacean tailslaps function, at least at times, to communicate drastic annoyance or fright. The frequency of spinner dolphin tailslaps did not increase significantly during the presence of human activities. Therefore, spinner dolphins may either use other forms of behavior to communicate disturbance or may not have been consistently annoyed or frightened by human activities in Kealake'kua Bay.

Use of the bay by swimmers, kayakers and motorboats was temporally stratified. Swimmers primarily interacted with dolphins in the morning when dolphins were most active. In the afternoon, dolphins were in a resting mode and were much more difficult to approach. This may have accounted for the reduced number of swimmers observed on hourly scans in the afternoon. The reason for the observed bias in the gender ratio of swimmers interacting with dolphins in Kealake'kua Bay is unknown. Although I presume that female humans might be more attracted to interactions with dolphins than males. The majority of kayaks observed in the bay were rented from private vendors operating out of Kealake'kua State Park. Kayak rentals seemed to be highest between 1000 and 1200 and returns were typically made between 1500 and 1700. The average number of motorboats in Kealake'kua Bay was highest between 1000 and 1100 in the mornings, and at 1500 in the afternoon. These peaks coincided with tour boat operations in Kealake'kua Bay.

CHAPTER IV

EFFECTS OF HUMAN ACTIVITIES ON SPINNER DOLPHIN AERIAL ACTIVITIES AND SURFACING SYNCHRONY

Objectives

The specific objectives to be discussed in this chapter were:

1) To document dolphin - human interactions in Kealake'kua Bay
2) To determine which, if any, human activities disturb the dolphins
3) To determine the level of disturbance (measured by the frequency of aerial activities and surfacing behavior) caused by these activities
4) To determine if dolphins respond differently to different human activities

Methods

Data collection for this portion of the investigation was concurrent with that for the previous chapter. The timing, manner and location of data collection were identical for these two studies.

Thirty-five observation days with five hours or more of continuous observations (mean = 5 hours 58 minutes) with a BSS 3 or less were selected to determine the possible level of disturbance by swimmers, kayaks, and motor boats to dolphins. Because swimmers commonly employed kayaks for travel to dolphin groups, possible swimmer and kayak disturbances were grouped prior to analysis. Each 15 minute continuous scan was placed into one of the following six disturbance levels of: 1) number of swimmers and kayaks following the dolphins within 10 m; 2) number of times motor boats approached and stopped near the dolphin school; 3) number of times motor boats followed within 10 m of dolphins; 4) number of times motor boats drove through the dolphin school; 5) all motor boat activities (approaching dolphins, following dolphins, and driving through the school); and 6) total amount of human activity centered around the dolphins (calculated by summing the number of swimmers, kayaks, and motor boat activities within 10 m of the dolphins). Additionally, each 15 minute continuous scan was classified as belonging to one of five categories: 1) pre-disturbance; 2) disturbance; 3) 0 - 15 minutes post-disturbance; 4) 15 - 30 minutes post-disturbance; and 5) 30 - 45 minutes post-disturbance. Scans occurring after the 30 - 45 minutes post-disturbance period were coded as pre-disturbance if no new potential disturbance activity was observed. Because potential swimmer and kayak disturbance often occurred at the same time as potential motor boat disturbance, there is a likelihood that interactions occurred between these two levels of disturbance. In order to account for this potential interaction, data were deleted from areas in which possible interactions might have taken place. This resulted in a data set with only one level of possible disturbance per 15 minute period.

Data Analysis

Frequency of total aerial activities per dolphin per hour was checked for normal distribution with a normal probability plot of residuals. The distribution of the data was found to deviate from a normal distribution, and a square root transformation was performed. A second probability plot of residuals showed the transformed data to be normally distributed. A one-way MANCOVA test revealed significant interaction between time and the frequency of aerial activities. Therefore, a plot of time versus frequency of aerial activities per dolphin per hour was examined, and to correct for interaction, time periods with high frequencies of aerial activities (e.g. before 0715 and after 1515) were eliminated from the data set. A Scheffé test on the modified data set showed no interaction between time of day and level of dolphin aerial activities. Since graphs of human activities showed high levels of swimmers in the morning and few swimmers after 1115, these data were split into two time periods, morning 0715 to 1114 and afternoon 1115 to 1515. Data were analyzed using a one-way MANCOVA because the mean number of swimmers, kayaks and motorboats was higher on days with dolphins than on days when dolphins did not enter the Bay, indicating an interaction between variables. The Scheffé test was used because all possible effects were considered.

Results

Length and type of interaction between swimmers and dolphins varied. Several local swimmers reported playing the "leaf game" with dolphins (personal communication, Johnson 1993, Ocean 1993). This game consisted of a dolphin transporting a piece of algae, leaf, or plastic with its mouth, flukes, flippers or dorsal fin and leaving it in the general proximity of a swimmer. The swimmer retrieved the object and then transported it to a new location where the dolphin retrieved it, and the interaction repeated itself. The leaf game was initiated by either a dolphin or a swimmer and lasted between a few minutes to over one half-hour.

On one occasion, a swimmer observed a dolphin carrying a stick. When the dolphin dropped the stick, the swimmer retrieved it in an attempt to play the "leaf game." The dolphin quickly approached the swimmer and began to tail slap repeatedly near the swimmer's head. The swimmer responded by slapping her fins on the surface of the water. This interaction lasted approximately 1 minute until the swimmer released the stick. The dolphin then retrieved the stick and swam away. The swimmer later reported that she did not think that the dolphin wanted to play the "leaf game" with her, and she was under the impression that the dolphin accidentally dropped the stick while playing alone or with another dolphin.

Several types of kayak - dolphin interactions were observed. Some kayakers simply approached the dolphin school and then watched the dolphin from a stationary position. During apparently quite random meanderings, dolphins at times approached and milled within 1 m of stationary kayaks without any apparent change in behavior. Swimmers also used kayaks to approach dolphins and followed them for short periods of time. Once they were in close proximity or in the path of the dolphins, they entered the water and began to swim. Other kayak operators followed (within 10 m) the dolphins around the bay for more extended periods of time. The most aggressive of these kayak operators repeatedly kayaked through the dolphin school in an attempt to obtain bow riders on their kayak. Dolphins were observed riding the bow of kayaks on 13 occasions.

In the morning, dolphins generally displayed a greater number of aerial activities when no humans were present, compared to when humans were interacting with them. These apparent differences in dolphin behavior were statistically significant only for breaches ($p < 0.05$). For all other aerial activities (all aerial activities, headslaps, tail slaps, leaps, spinning leaps and flips), the presence of humans did not significantly alter dolphin behavior (Figure 11 a). In the afternoon, dolphins were more active when humans were present than when they were not (all aerial activities $p < 0.001$, headslaps $p< 0.003$, tail slaps $p = 0.11$, breaches $p = 0.002$, leaps $p < 0.001$, spinning leaps $p < 0.001$, flips $p= 0.008$,) (Figure 11 b). However, the mean frequency of aerial activities per dolphin per hour in the presence of humans was not significantly different between the morning and afternoon.

Human activities impacted dolphin surfacing behaviors differently in the morning than in the afternoon. Human activities had no impact on dolphin surfacing behavior before 1115 ($p = 0.67$). However, after 1115, dolphins were more likely to surface asynchronously in the presence of human activities ($p < .001$) (Figure 12). Dolphin schools surfacing synchronously displayed fewer aerial activities than dolphin schools surfacing asynchronously ($p < 0.001$) (Figure 13).

The presence and type of human activities had no impact on the number of aerial activities per dolphin per hour in the morning ($p > 0.5$) (Figure 14a). However, swimmers and kayaks following dolphins within 10 m ($p \leq .002$) and motorboats driving through the dolphin school ($p \leq .076$) increased the frequency of aerial activities in the afternoon (Figure 14b). The mean number of aerial activities per dolphin per hour was not related to the number of swimmers (Figure 15) or kayaks (Figure 16) following within 10 m of dolphins.

Figure 11a, b

Figure 12, 13

Figure 14a, b

No difference was found during the morning between the frequency of aerial activities before, during, or after swimmers and kayaks followed dolphins within 10 m ($p > 0.3$) (Figure 17a). In the afternoon, the frequency of aerial activities was higher in the presence of swimmers and kayaks during disturbance ($p < 0.003$) (Figure 17b). Swimmers and kayaks did not affect synchronicity of surficings in the morning($p > 0.2$) (Figure 18a), but dolphins were more likely to surface asynchronously during and 0 - 15 minutes after swimmer and kayak disturbance in the afternoon ($p < 0.01$) (Figure 18b).

Motor boats were observed to slowly approach and then stop near the dolphin school on 54 occasions. No difference was found between the frequency of aerial activities before, during, or after motor boats slowly approached or stopped near dolphins in the morning ($p > 0.7$) or in the afternoon ($p > 0.4$) (Figure 19 a, 19 b).

On 46 occasions, motor boats were observed following within 10 m of the dolphin school. The frequency of aerial activities per dolphin per hour increased with the number of motor boats observed following within 10 m of the dolphins during each 15 minute continuous scan. The statistical comparison was significant between 0 and 1 motor boats ($p<0.036$), but not between 0 and 2 motor boats ($p<0.3$) (Figure 20). The lack of significance between 0 and 2 motor boats may be a result of Type II error since the sample size ($n=2$) was small. No difference was found between the frequency of aerial activities before, during, or after motor boats were observed following within 10 m, in the morning time period ($p > 0.7$) or in the afternoon ($p > 0.5$) (Figure 21 a, 21 b). In the afternoon, there may be marginal significance even with the low ($n = 5$) sample sizes, as indicated in a MANCOVA LSD test, which showed a $p < 0.05$ increase in aerial activities during disturbance.

Figure 15. Square root of aerial activity per dolphin per hour, by number of swimmers following within 10m of spinner dolphins in Kealake’kua Bay. Data as in Figure 3.

Figure 16. Square root of aerial activity per dolphin per hour by number of kayaks following within 10m of spinner dolphins in Kealake’kua Bay. Data as in Figure 3.

Figure 17a. Square root of aerial activity per dolphin per hour, before during, and after swimmers and kayaks follow within 10m of spinner dolphin schools in Kealake’kua Bay in the morning (0715 – 1114). Data as in Figure 3.

Figure 17b. Square root of aerial activity per dolphin per hour, before during, and after swimmers and kayaks follow within 10m of spinner dolphin schools in Kealake’kua Bay in the afternoon (1115 – 1515). Data as in Figure 3.

Figure 18a. Spinner dolphin surfacing behavior before, during and after swimmer and kayak disturbance in the morning. Data as in Figure 3.

Figure 18b. Spinner dolphin surfacing behavior before, during and after swimmer and kayak disturbance in the afternoon. Data as in Figure 3.

Figure 19a. Square root of aerial activity per dolphin per hour, before during, and after motor boats approach slowly and stop within10m of spinner dolphins in Kealake’kua Bay, in the morning (0715 – 1114). Data as in Figure 3.

Figure 19b. Square root of aerial activity per dolphin per hour, before during, and after motor boats slowly approach and stop within 10m of spinner dolphins in Kealake’kua Bay, in the afternoon (1115 –15151). Data as in Figure 3.

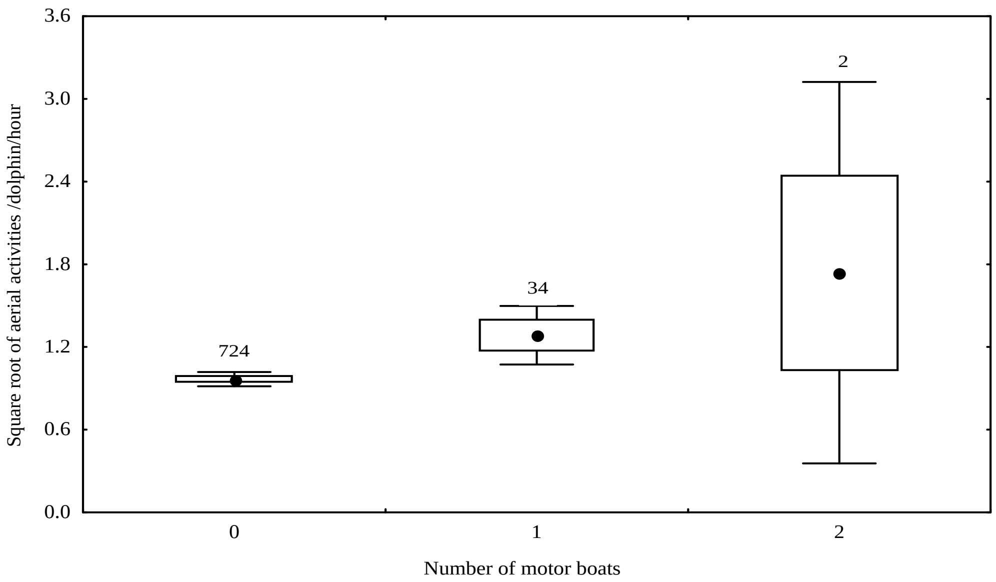

Figure 20. Square root of aerial activity per dolphin per hour, by the number of motor boats following within 10m of spinner dolphins in Kealake'kua Bay, in the afternoon. Data as in Figure 4.

Motor boats drove through spinner dolphin schools on 49 occasions. No difference was observed between the frequency of aerial activities per dolphin per hour and number of motor boats observed driving through the dolphin school during each 15 minute continuous scan (Figure 22). No difference was found between the frequency of aerial activities before, during, or after motor boats drove through dolphin schools in the morning ($p > 0.6$) or in the afternoon ($p > 0.3$) (Figure 23 a, 23 b). Small sample size in both the disturbance and post-disturbance categories ($n = 1 - 15$) increases the likelihood of a Type II error for this latter analysis.

No relationship was observed between the total motor boat activity (approaching, following, and driving through the dolphin school) focused on the dolphins and the frequency of aerial activities per dolphin per hour ($p> 0.095$) (Figure 24). When all motorboat disturbance types were pooled, no difference was found between the frequency of aerial activities before, during, or after motor boat activities in the morning ($p = 0.9$) (Figure 25 a), but the frequency of aerial activities per dolphin per hour was higher during disturbance than pre-disturbance time periods ($p= 0.019$) in the afternoon (Figure 25).

Dolphins were observed riding the bow wake of motor boats on 48 occasions. Motor boats that slowly approached and stopped near the dolphin school acquired bow riders on 2 of 54 (or 3.7 %) instances. Motor boats following dolphins within 10 m acquired dolphins on 10 of 47 occasions (or 21.3%), while 31 of the 49 times (or 63 %), in which motor boats drove through the dolphin school, resulted in dolphins riding the bow wave. On five occasions (or 10.4% of the observed bow riding) dolphins leaped to the bow of vessels traveling in Kealake’kua Bay but not attempting to interact with the

Figure 21a. Square root of aerial activity per dolphin per hour, before during, and after motor boats follow within 10m of spinner dolphins in Kealake'kua Bay, in the morning (0715 – 1114). Data as in Figure 3.

Figure 21b. Square root of aerial activity per dolphin per hour, before during, and after motor boats follow within 10m of spinner dolphins in Kealake'kua Bay, in the afternoon (1115 - 1515). Data as in Figure 3.

Figure 22. Square root of aerial activity per dolphin per hour, by the number of motor boats driving through spinner dolphin schools in Kealake'kua Bay. Data as in Figure 3.

Figure 23a, b

Figure 24. Square root of aerial activity per dolphin per hour, by the total number of motor boat activities (approaching, following, and driving through spinner dolphin schools) centered around the dolphins in Kealake'kua Bay. Data as in Figure 3.

Figure 25a. Square root of aerial activity per dolphin per hour, before during, and after motor boats activities (approaching, following, and driving through the dolphin school) are centered within 10m of dolphins in the morning (0715 – 1114). Data as in Figure 3.

Figure 25b. Square root of aerial activity per dolphin per hour, before during, and after motor boats activities (approaching, following, and driving through the dolphin school) are centered within 10m of dolphins in the afternoon (1115 – 1515). Data as in Figure 3.

dolphins. However, only motor boat activities that directly related to the dolphin school were recorded. The percentage of motor boats that traveled in Kealake'kua Bay and did not attempt to interact with the dolphins acquired bow riders less than 1% of the time (as estimated by the total number of motor boats present during instantaneous hourly scans). The number of motor boats that obtained bow riders during each 15 minute continuous scan was related to activity level of the school ($p < 0.042$) (Figure 26), and the total motor boat activity in the bay ($p \leq 0.001$) (Figure 27).

When the overall data were considered, the total number of human activities (swimmer, kayak, and motor boat activities) centered around dolphins did not seem to affect the frequency of aerial activities per dolphin per hour (Figure 28). No difference was found between the frequency of aerial activities before, during, or after human disturbance in the morning ($p < 0.3$) (Figure 29 a). Small sample sizes in pre-disturbance and post-disturbance categories ($n = 2 - 27$) increased the likelihood of a Type II error. In the afternoon, the frequencies of aerial activities were higher during human disturbance ($p = 0.001$) and 0-15 minutes post-disturbance ($p < 0.053$) (Figure 29 b), than during no disturbance.

Figure 26. Square root of aerial activity per dolphin per hour, by the number of motor boats observed with bow riders during each 15 minute continuous scan. Data as in Figure 3.

Figure 27a. Percentage of motor boats which obtained bow riders by the square root of aerial activities per dolphin per hour.

Figure 27b. Mean number of motor boats obtaining bow riders by total motor boat activity in Kealake’kua Bay. Data as in Figure 3.

Figure 28. Square root of aerial activity per dolphin per hour, by total number of human activities (swimmer, kayak, and motorboat activities) centered around dolphins in Kealake'kua Bay. Data as in Figure 3.

Figure 29a. Square root of aerial activity per dolphin per hour, before during, and after human disturbance (swimmer, kayak, and motor boat activities) in the morning (0715 – 1114). Data as in Figure 3.

Figure 29b. Square root of aerial activity per dolphin per hour, before during, and after human disturbance (swimmer, kayak, and motor boat activities) in the afternoon (1115 – 1515). Data as in Figure 3.

Discussion

Swimmer and kayak disturbance often occurred at the same time as motor boat disturbance. To test for the effect of a specific type of human activity, data were deleted from the data set in instances where possible interactions might have occurred. This resulted in a data set with only one level of possible disturbance per 15 minute period. However, the higher frequency of aerial activities per dolphin per hour 0-15 minute post-human disturbance indicates that the effect of a disturbance lasts longer than the 15-minute interval in which the disturbance occurred, resulting in interactions between levels of disturbance in consecutive 15 minute continuous scans. This not only makes it more difficult to detect changes in dolphin behavior but causes the 15 minute scans to be dependent, which violates the assumptions implicit in the statistics used to analyze the data.

Swimmers comprised the bulk of potential human disturbances in Kealake'kua Bay. The number of swimmers following within 10 m of dolphins did not affect spinner dolphin behavior in Kealake'kua Bay as measured by the frequency of aerial activities per dolphin per hour. This may have impacted the ability to detect disturbance when all human activities were pooled. Although the sheer numbers of swimmers seeking to interact with the dolphins made the swimmers hard to avoid, interactions with swimmers, kayaks, and motorboats typically only involved a fraction of the dolphin school, while the remainder of the school maintained its normal behavior. Unfortunately, it was not possible to collect data on the number of dolphins interacting with swimmers, kayaks, and motorboats, nor the length of interactions. Interactions could have taken place underwater, where the length of the interaction and the number of dolphins involved were not visible from the surface.

The length and type of interaction between swimmers and dolphins varied by time and day. On some days, dolphins seemed more receptive to swimmers and kayaks than on other days. Additionally, swimmers were frequently able to approach within 1 m of spinner dolphins in the morning and then have extended encounters lasting over one half hour. In the afternoon, swimmers seemed to have difficulty approaching dolphins, and the subsequent encounters were brief. The apparent approachability of the dolphins by time of day may be related to daily fluctuations in swimming speed. Norris et al. (1994) reported that spinner dolphins average approximately 2.5 km/hour in the morning and traveled at increasingly faster speeds in the afternoon. Competent swimmers wearing fins would have little difficulty in keeping up with spinner dolphins in the morning but would probably struggle to keep pace with the dolphins in the afternoon when speeds reached over 4 km/hour. Because kayakers are faster and taller than swimmers in the water, they are capable of following dolphins for more extended periods of time and have a better vantage point from which to locate dolphins. This potentially enables kayaks to cause more disturbance to the dolphins than swimmers. Furthermore, due to the increased speed of travel and improved vantage point provided by kayaks, spinner dolphins may have a more difficult time evading kayaks.

Response of spinner dolphins to human activities varied by time of day and type of activity. Frequencies of dolphin aerial activities decreased in response to human activity in the morning but increased in the afternoon. Although the frequency of aerial activities per dolphin per hour during periods of no disturbance was higher in the morning than in the afternoon, the mean frequency of aerial activities per dolphin per hour during disturbance was similar during both time periods. This indicates that the dolphins may exhibit a standard level of activity when in proximity to human activities. However, the small sample size for the morning non-disturbance category (n = 17) may not have allowed the detection of changes in aerial activity patterns due to human disturbance and thereby increased the likelihood for Type II error. For example, although frequencies of aerial activities were statistically higher during swimmer and kayak interactions in the afternoon, no statistical difference was detected during motorboat interactions even though the mean frequency of aerial activities was higher for motorboat activities than that observed during swimmer and kayak disturbance.

Motor boats that slowly approached and stopped near dolphin schools caused the least disturbance of any motorboat interaction. The number of motor boats that slowly approached and stopped near dolphins during 15 minute continuous scans did not affect the activity level of the school as measured by the frequency of aerial activities. The number of motor boats following within 10 m of dolphins and the number of motor boats driving through the dolphin school during each 15 minute continuous scan were both correlated with increases in frequencies of aerial activities per dolphin per hour. Unfortunately, disturbance and post-disturbance sample sizes of these types of motorboat behavior are small (n = 1 in some cases), and this makes it impossible to draw any scientific conclusions because of the likelihood of a Type II error. However, dolphins changed their behavior to bowride on motorboats following within 10 m of the dolphin 21% of the time and 63% for motor boats driving through the dolphin school. This change in behavior is an obvious disruption of the natural behavioral repertoires of spinner dolphins. Because of the increased "success rate" of bowriding when driving through the school, an unfortunate reinforcement for disruptive behavior is presented to boat operators.

When motor boat activities were pooled, the frequency of aerial activities in the afternoon was significantly higher with disturbance and then returned to pre-disturbance levels over the next 45 minutes. This indicates that motorboat activities disrupted spinner dolphin resting behaviors. The increase in activity could reduce spinner dolphin energy budgets and in the long-term decrease the fitness levels of the dolphins. Barr and Slooten (1998) observed that dusky dolphins off the coast of New Zealand were more sensitive to human activities in the afternoon. Significant increases in number of dusky dolphin aerial activities and directional changes were correlated with the presence of a combination of vessel types (fishing, whale watching, and private boats) after mid- morning (Barr and Slooten 1998). Barr and Slooten (1998) hypothesized that increases in aerial activities could be due to sensitization to human activities from repeated contact, or the dolphins are simply more vulnerable to disturbance since they are usually in a more restful state at that time of day.

Previous studies have determined that the responsiveness of dolphins to vessels depends upon the species of dolphin as well as the dolphin activity state, vessel type, number of vessels, and vessel behavior (Acevedo 1991, Constantine 1995, Janik and Thompson 1996. Weir et al. 1996, Constantine and Baker 1997, and Barr and Slooten 1998). The strategy used by boat operators to approach dolphins affects dolphin behavior (Acevedo 1991, Evans et al. 1993, Constantine 1995, Janik and Thompson 1996, Weir et al. 1996, Constantine and Baker 1997). The more invasive approaches used by some boat operators resulted in higher frequencies of avoidance behaviors in which dolphins clearly moved away from the swimmers. Similar results were found in this study.

The total amount of human activity (swimmer, kayak, and motor boat activities) centered around dolphins did not seem to affect the frequency of aerial activities per dolphin per hour in the morning, but significantly increased frequency of aerial activities in the afternoon. This could be caused by several factors. The small pre-disturbance sample size (n = 17) in the morning could result in a Type II error. Alternatively, the effect of the total amount of human activity (swimmer, kayak, and motor boat activities) on dolphin aerial activities could be negated since swimmers comprised the bulk of potential human disturbances in the morning and did not affect spinner dolphin behavior as measured by the frequency of aerial activities per dolphin per hour. A final possibility is dolphins may become sensitized to human activities in the afternoon due to repeated contact with humans.

CHAPTER V

CONCLUSIONS

Spinner dolphins occurred in Kealake’kua bay 21% less frequently in 1993 - 1994 than they did in 1979 - 1980. Dolphin time of entry into, time of exit from, and residency per day were similar to those observed during 1979 - 1980. However, frequency of aerial activities was less than that observed during 1979 - 1980. The decrease in frequency of use of Kealake’kua Bay could be due to many influences, such as the increase in human activities or changes in population structure or ecology of the region. The size of the population of spinner dolphins around the island of Hawai'i remains uncertain. Östman (1993) and Norris et al. (1994) sampled different areas to estimate population size, which violates assumptions needed to compare the studies. However, Östman (1993) reported 1300 more spinner dolphins than the Norris et al. (1994) estimate for 1980. If the population using this area has increased, then one would expect dolphins to frequent Kealake’kua Bay more often than a decade earlier. My observations therefore suggest that the high level of human activities associated with spinner dolphins in Kealake’kua Bay may have resulted in the bay being less suitable than in 1979 - 1980.

The decrease in frequency of aerial activities can be attributed to reduced frequencies of spinning leaps and flips, which are the most athletic leaps to perform. This may indicate a general reduction in spinner dolphin energy levels. Motor boats caused the greatest increase in frequencies of aerial activities per dolphin per hour, followed by kayaks and finally swimmers. If the spinner dolphins are existing on reduced energy levels, then increased frequency of aerial activities caused by human activities could be detrimental by disrupting critical behaviors such as reproduction, feeding and rest. In the long-term this could possibly influence the viability of the population.

Limitations

This study had several limitations. 1993 -1994 was characterized by a weak El Niño that changed the ecology of the region and may have resulted in changes in the residency periods of spinner dolphins in Kealake'kua Bay. The reduced frequency of dolphin residency and uncooperative weather resulted in only 35 days with five hours or more of observation and a BSS of three or less.

Future Work and a Potential Management Suggestion

To further determine if spinner dolphins are disturbed by human activities in Kealake'kua bay, it may be possible to conduct a more controlled study in which human activities within the Bay are restricted. However, Kealake'kua Bay is an underwater marine sanctuary and a state marine park, so controlling human activities is difficult. A suitable resolution that would not overtly limit human activities within the bay, is to allow swimmers, kayaks, and motor boats to utilize zone A of the marine sanctuary. This area is close to the cliff or pali and would allow snorkelers access to the coral reefs in the bay. If dolphins approached swimmers and kayaks in this area, then they would be allowed to interact with them. Motor boats could be allowed to slowly approach but not follow or drive through dolphin schools in zone A. Swimmers, kayaks, and motorboats would not be able to follow dolphins into zone B of the sanctuary and should avoid all contact with dolphins in this part of the bay. The behaviors and movements of spinner dolphins would be monitored. If the dolphins frequently enter zone A and interact with humans in that part of the bay, then it could be concluded that the activities do not disturb the dolphins. On the other hand, if the dolphins avoided the area, then this would suggest that human activities were disruptive to spinner dolphins. Other criteria such as swimming speed and orientations towards or away from human activities also would be useful in determining the level of disturbance caused by different human activities.

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