

**HABITAT ASSOCIATIONS AND PHOTO-IDENTIFICATION OF
SEA OTTERS IN SIMPSON BAY, PRINCE WILLIAM SOUND,
ALASKA**

A Thesis

by

ANDREA KARIN GILKINSON

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

December 2004

Major Subject: Wildlife and Fisheries Sciences

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ABSTRACT

Habitat Associations and Photo-identification of Sea Otters in Simpson Bay, Prince

William Sound, Alaska. (December 2004)

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Habitat associations of sea otters during resting and feeding were investigated in Simpson Bay, Prince William Sound, Alaska during the summer months of 2001-2003. Sea otter locations collected during boat surveys were overlaid on bathymetry and sediment maps and water depth, sediment type, distance from shore, and position in the bay (peripheral vs. central) was determined for each. Logistic regression analysis was used to determine whether sea otter habitat use was non-random according to any of these habitat variables. Water depth was the most significant habitat association for feeding behavior, with the majority of feeding dives occurring in shallow water less than 20m deep. Position in the bay was the most significant habitat association for resting behavior, with more otters resting in the center of the bay.

In addition, digital images taken of the sea otters during the boat surveys of 2002 and 2003 were used to examine the potential of using nose scars to photo-identify individual sea otters. Both male and female sea otters bore nose scars. Forty-five percent of all individuals encountered were considered identifiable from nose scars and a total of 114 individuals were identified. This compares favorably with the results of

photo-identification studies of other marine mammals, suggesting that photo-identification may be a useful tool for the individual identification of sea otters as well.

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INTRODUCTION

The sea otter (*Enhydra lutris*) belongs to the order Carnivora, family Mustelidae, and is the only species in the genus *Enhydra*. This genus arose in the North Pacific about 1-3 million years ago and has been restricted to this basin ever since (Riedman and Estes 1990). Their present distribution is in the nearshore waters of the Pacific Rim from Baja California north along the North American coast to southern Alaska, west through the Aleutian Islands to the Kamchatka Peninsula and south to Japan. There are currently three recognized subspecies, each covering a different part of the total range: *E. l. lutris*, ranging from Japan to the Commander Islands, *E. l. kenyoni*, from the Aleutians east to Prince William Sound and south to Oregon, and *E. l. nereis*, from northern California south to Punta Abreojos, Baja California (Riedman and Estes 1990, Reeves *et al.* 2002).

The largest member of Mustelidae and the smallest marine mammal, the sea otter weighs between 35-100 lbs (16-45.4 kg) and is 1.2-1.48 m long as an adult (Kenyon 1975, 1981, Riedman and Estes 1990). There is moderate sexual dimorphism with males on average 34% heavier and 8% longer than females, typically with a muscular head and neck (Estes 1980, Riedman and Estes 1990). Other key descriptive physical characteristics include a dense fur coat covering almost the entire body, lack of anal glands (unique among Mustelids), flattened hind feet (flippers) with an elongated fifth digit, retractile claws on the forepaws, a loose flap of skin under each foreleg used

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

to store food items, flattened molars, and a dorso-ventrally flattened tail (Kenyon 1975, Estes 1980, Reeves *et al.* 2002).

Compared with other otter species, sea otters show several adaptations for the marine environment. The body form, with large hind flippers, loosely articulated skeleton, and loss of clavicle allow for better aquatic movement and sea otters swim with the dorsoventral undulations of pinnipeds and cetaceans, as opposed to the paddling motion of other otters. The lungs also show adaptations for diving with increased lung volume and cartilage-reinforced airways (Riedman and Estes 1990). Compared to cetaceans, pinnipeds, and sirenians, however, which all evolved much earlier, sea otters are not as well adapted to the marine environment. Vision is good both above and below the water and, like pinnipeds, the tapetum lucidum is well developed, allowing sea otters to see at night and in the poorly lit depths; but there are no cranial modifications for underwater hearing nor reduction in olfactory sensitivity as seen in cetaceans and pinnipeds (Riedman and Estes 1990). Sea otters also do not have the subcutaneous blubber that other marine mammals have, instead relying on their dense fur coat and a very high metabolism that is about twice that of a terrestrial mammal of the same size (Miller 1974, Kenyon 1981).

Habitat occupied by sea otters includes both rocky and soft-sediment (mud and sand) sea bottoms of shallow coastal waters. They are typically found within a few miles of shore and depths shallower than 40m (Kenyon 1975, Rotterman and Simon-Jackson 1988, Riedman and Estes 1990, Reeves *et al.* 2002). Canopy-forming kelp beds are an important component of sea otter habitat throughout much of their range, used by

the otters for resting and foraging; they are not, however, a necessary component as many sea otter populations occur in areas without kelp beds (Miller 1974, Rotterman and Simon-Jackson 1988, Riedman and Estes 1990).

Sea otters exert a strong influence on their habitat and community in their role as predator. Consuming 23-37% of their body weight daily (Rotterman and Simon-Jackson 1988), sea otters are capable of not only limiting, but severely depleting invertebrate prey populations. Among the invertebrate species known to be limited by sea otters are sea urchins, Pismo clams, abalone, Dungeness crabs, and mussels (Riedman and Estes 1990). In kelp communities, sea otter predation on sea urchins allows the kelp forests to flourish (Duggins 1980, Breen *et al.* 1982, Estes and Duggins 1995). In soft sediment communities, sediment disturbance from excavation and discarded shells of bivalve prey re-shape the sea floor (Kvitek and Oliver 1988). The sea otter, in turn, has very few predators as an adult and mortality rates after the age of 1 year are low (Kenyon 1975, Estes and Bodkin 2002).

The activities of sea otters can be classified into five basic types: feeding, grooming, resting, swimming, and interacting. Most of an otter's time is spent feeding and resting, with approximately 21-40% and 51-63% of daylight hours in those activities, respectively (Loughlin 1979, Estes *et al.* 1986, Garshelis *et al.* 1986, Riedman and Estes 1990). Both of these activities tend to occur in long bouts (<20 min) and display peaks at different times of the day within a population (Loughlin 1979, Estes 1980, Garshelis 1983, Ralls and Siniff 1988). There appears to be some degree of spatial separation between the two activities, with several studies reporting different

areas used for feeding and resting (Shimek and Monk 1977, Loughlin 1979, 1980, Ribic 1982, Garshelis and Garshelis 1984). Grooming, which is essential to maintaining the insulative properties of the fur, takes up 5-16% of a day (Riedman and Estes 1990, Estes and Bodkin 2002). Bouts of grooming are relatively short (<15 min) and generally occur before and after feeding and resting periods (Sandegren *et al.* 1973, Riedman and Estes 1990). The amount of time spent in these activities, especially feeding, varies according to sex, age, reproductive status, population status, weather conditions and individual (Loughlin 1979, Estes 1980, Estes *et al.* 1982, Garshelis 1983). Resting is the only activity, other than interacting, in which otters tend to associate with others; feeding, swimming, and grooming tend to be solitary activities (Riedman and Estes 1990).

Foraging takes place on the sea floor and, where present, within the kelp canopy and understory. Foraging dives occur most commonly in water <25 m deep, although foraging at depths up to 40m is not uncommon, particularly in certain areas, such as the Aleutians (Miller 1974, Shimek and Monk 1977, Calkins 1978, Loughlin 1979, Estes 1980, Kenyon 1981, Garshelis 1983, Riedman and Estes 1988). Sea otters are capable of diving much deeper, though it is uncommon. In general, females forage in shallower depths than males, however, there is also a great deal of individual variation in dive depth distribution (Estes and Bodkin 2002, Bodkin *et al.* 2004). The deepest dives recorded are 76m for a female and 100m for a male (Newby 1975, Estes and Bodkin 2002). Prey is located using primarily tactile methods, although vision is also used (Kenyon 1975, Estes 1980, Hines and Loughlin 1980, Rotterman and Simon-Jackson

1988). Capture of burrowing prey, such as clams, requires excavation of sediment. Sea otters are capable of displacing considerable volumes of sediment and excavations may be up to 1m deep (Kvitek and Oliver 1988, Estes and Bodkin 2002). After capturing prey, it is stored in the pouches under the forearms and taken to the surface where it is consumed while the otter floats on its back (Kenyon 1975). Sometimes sea otters use rocks or other hard objects as tools to crack open the exoskeletons of prey (Garshelis 1983, Riedman and Estes 1990, Estes and Bodkin 2002).

Sea otter diet is composed primarily of benthic invertebrates, most commonly crustaceans, mollusks (bivalves, gastropods, and cephalopods), and echinoderms (Estes *et al.* 1981, Riedman and Estes 1990, Estes and Bodkin 2002). Additionally, fish are consumed regularly in the Aleutian Island populations and consumption of birds has also been reported in the Aleutians and California (Estes *et al.* 1981, Riedman and Estes 1990). Estes and Bodkin (2002) provide a comprehensive list of the over 150 species reported as sea otter prey. Diet varies according to habitat type, with epibenthic prey, such as crabs and sea urchins, predominating the diet in rocky habitats and bivalve mollusks, such as clams, predominating in soft-sediment habitats (Estes 1980, Riedman and Estes 1988). Diet also varies with population status and length of sea otter occupation, with a broader number of species in populations of higher density (Estes 1980, Estes *et al.* 1981, Garshelis 1983). Though sea otter diet may be broad on the population level, individual diets are fairly specialized, usually restricted to 1-3 species, and show a great deal of variation between individuals (VanBlaricom 1988, Estes *et al.*

2003). These individual dietary patterns are similar between mothers and pups, indicating maternal transmission (Estes *et al.* 2003).

The sexes are spatially segregated into “male areas” and “female areas.” Male areas are strongly predominated by males, both juveniles and breeding-age adults; reports indicate that around 97% of the otters in these locations are male (Garshelis 1983). These areas are typically on the leading edges of sea otter expansion and are more densely populated, less protected from stormy weather, and have a more abundant food supply compared to female areas (Estes 1980, Garshelis *et al.* 1984, Rotterman and Simon-Jackson 1988, Riedman and Estes 1990). Female areas are predominated by females, but sex ratios are less extreme than male areas, as males enter female areas for breeding purposes. Males account for 11-31% of the population in these areas, varying with time of year (Garshelis *et al.* 1984, Jameson 1989).

Most of the males within female areas form and defend territories for the purpose of breeding, excluding other males and interrogating females that enter the territory. When a receptive female is found, copulation takes place. Sometimes the male and female will form a pair-bond, conducting all activities together and mating several times within a 1-4 day period. At other times, however, the pair simply mate and part ways (Riedman and Estes 1990). During the actual mating process, the male grasps the female’s nose or lip in his mouth and the pair rolls around vigorously (Estes and Bodkin 2002). This process can be risky for females, who often suffer wounds to the nose, sometimes severe. Some studies report cases in which females have died from infected nose wounds or drowning during the mating process itself (Foott 1970, Riedman and

Estes 1990). Males may mate with several females over the course of a year, but females typically mate with only one male per estrus period (Riedman and Estes 1990).

Breeding takes place during all seasons, although there is a peak of activity in late fall to winter in Alaska and January to March in California (Kenyon 1975, Garshelis 1983).

Females reach sexual maturity at around 4 years old (Kenyon 1975, Garshelis 1983, Jameson and Johnson 1993). Males reach sexual maturity a little later at 5-6 years old, although they may not be able to hold territories until 8-10 years old (Garshelis 1983, Rotterman and Simon-Jackson 1988). Pregnancy length is variable from 5-7.8 months, with an unimplanted phase lasting 2-3 months and an implanted phase lasting 4 months (Jameson and Johnson 1993). Parturition takes place on the surface of the water (Riedman and Estes 1990). Pups are highly dependent on their mothers and the dependency period lasts 5-8 months (Estes 1980, Garshelis *et al.* 1984, Jameson and Johnson 1993). Females give birth once every 1-2 years (Riedman and Estes 1990, Siniff and Ralls 1991).

Unregulated commercial hunting of the sea otter for its fur, which began shortly after it was first scientifically described in 1741, nearly drove the species to extinction by the end of the 19th century (Kenyon 1975). An estimated 1,000-2,000 sea otters in 13 populations remained, from an estimated pre-exploitation 150,000-300,00 total population, in 1911 when the species received protection from the International Fur Seal Treaty (Kenyon 1975, Riedman and Estes 1990). Sea otter populations recovered substantially under the Fur Seal Treaty and the additional protection in the United States from the Marine Mammal Protection Act of 1977, however, they have not fully re-

occupied their historical range (US Fish and Wildlife Service 1994, Reeves *et al.* 2002). A recent population trend of concern is a severe decline in the number of sea otters throughout the Aleutian Islands through the 1990s (Estes *et al.* 1998). The reason for this decline is unknown, although predation by killer whales has been suggested by Estes *et al.* (1998).

This study took place in Simpson Bay, located in northeastern Prince William Sound, Alaska. The Prince William Sound sea otter population expanded from a small remnant population in the southwest following the 1911 Fur Sea Treaty and had reoccupied the entire sound by 1980 (US Fish and Wildlife Service 1994). Simpson Bay specifically was reoccupied in 1977-1978 and served as a male area until 1983-1985 when it became a predominantly female area (Garshelis 1983). The sea otter population in the Simpson Bay area was unaffected by the *Exxon Valdez* oil spill in 1989 which killed an estimated 2,787 otters in other parts of the sound (US Fish and Wildlife Service 1994).

This area has a maritime climate, experiencing heavy precipitation throughout the year, especially during the fall and winter. Sea surface temperatures range from 3°C to 12°C and surface salinities are around 18-20 gm kg⁻¹ (VanBlaricom 1988). The bay is relatively well protected from ocean swells. Benthic habitat is predominantly soft-sediments with no large-bodied kelp. Clams are the principle prey item (Garshelis 1983, Garshelis *et al.* 1986, Riedman and Estes 1988, Estes and Bodkin 2002).

Siniff and Monnett (1985) and Monnett and Rotterman (1988) found that female sea otters traveled extensively throughout eastern Prince William Sound on an annual

basis, using certain smaller sections during specific times of the year. Simpson Bay and its neighboring bay, Sheep Bay, are used most heavily during August-November.

Females move into the area from the west during the course of the summer and continue moving to the east toward Cordova, after the breeding season (Monnett and Rotterman 1988). While in the area, females travel freely between Simpson and Sheep Bays (Siniff and Monnett 1985).

One of the main aims of this project was to improve our understanding of sea otter ecology. The sea otter populations in Prince William Sound, and soft-sediment habitats in general, have received relatively little attention compared to the populations in the rocky, kelp-dominated habitats of California and the Aleutians. Therefore, I sought to address the relative paucity of information on sea otter habitat use in this type of environment by examining habitat associations of sea otters within Simpson Bay, specifically focusing on habitat use during feeding and resting. In addition, I evaluated the potential of using photo-identification of sea otter nose scars for individual recognition. This method may contribute to a more detailed understanding of sea otter behavior and ecology in the future by providing a non-invasive method of identifying individuals within a population.

HABITAT ASSOCIATIONS OF FEEDING AND RESTING SEA OTTERS IN SIMPSON BAY, ALASKA

INTRODUCTION

Many mammalian species, both terrestrial and marine, are distributed in non-uniform patterns that can be attributed to habitat heterogeneity (Croll *et al.* 1998, Ingram and Rogan 2002, Naud *et al.* 2003). When a resource or habitat type is used disproportionately to its availability, it is considered to be “selected” (Johnson 1980, Alldredge *et al.* 1998, Manly *et al.* 2002). Understanding habitat selection provides key insights into a species’ ecology. Since it is assumed that animals will select high-quality resources, discerning which resources are selected for or against provides information on how animals meet their survival requirements and provides the power to assess or predict habitat quality for different areas (Alldredge *et al.* 1998, McConnaughey and Smith 2000, Manly *et al.* 2002). Habitat characteristics that have been shown to influence the distribution of marine mammals include water depth, depth gradient, sea surface temperature, and sediment type (Croll *et al.* 1998, Ingram and Rogan 2002).

Among marine mammals, sea otters have great potential to be influenced by their habitat due to high energy requirements and a benthic invertebrate diet. Lacking blubber, sea otters rely on their dense fur coat and a highly elevated metabolism to keep warm (Miller 1974, Kenyon 1975, Riedman and Estes 1990). This high metabolism requires a great deal of feeding and carefully balanced activity budget, without much room for extra energy expenditure (Kenyon 1981, Rotterman and Simon-Jackson 1988,

Riedman and Estes 1990). A diet of benthic invertebrates ties sea otters to the benthic habitat, requiring diving through the entire water column and excavating bottom sediments.

Sea otters occupy both rocky and soft-sediment habitats along the coast of the North Pacific (Kenyon 1975, Riedman and Estes 1990). They are generally found close to shore and within relatively shallow water, generally within the 20-fathom curve, and they appear to prefer areas sheltered from wind and waves (Kenyon 1975, Rotterman and Simon-Jackson 1988). Throughout most of their range sea otters are associated with large-bodied kelp forests (Miller 1974, Kenyon 1975, Ribic 1982, Rotterman and Simon-Jackson 1988). Several researchers have observed that sea otters are associated with different areas while feeding and resting (Loughlin 1979, Estes 1980, Ribic 1982, Garshelis 1983, Estes *et al.* 1986). No one, however, has investigated the types of habitat characteristics associated with feeding and resting areas. In this regard, sea otter habitat associations remain poorly understood. In addition, most information comes from populations occupying rocky habitats, with less information on sea otters occupying soft-sediment habitats (Kvitek and Oliver 1988, Kvitek *et al.* 1993).

Recently, sea otter populations have started to decline dramatically throughout the Aleutian Islands (Estes *et al.* 1998). Numbers have been reduced to the point that this population has been listed as threatened under the United States Endangered Species Act. Factors contributing to this decline are not well understood. This lack of understanding highlights the need for more detailed information on stable sea otter populations to enable better management.

This study examined sea otter habitat-associations in Simpson Bay, an area of soft-sediment habitat in northeastern Prince William Sound, an area of stable population. I collected information on both otter locations and available habitat to identify environmental variables influencing sea otter distribution. To better determine the function of selected habitats, as suggested by North and Reynolds (1996), I examined the habitat associations of sea otters while resting and feeding, and then compared the locations of the two behaviors to determine what variables the otters are using to partition their habitat use.

METHODS

Study Area

Simpson Bay (ca. 60.6°N Lat., 145.9°W Long.), located in northeastern Prince William Sound, Alaska (Fig. 2.1), was chosen as the study site because of its reasonable size, protection from rough seas, and reliable presence of sea otters. It is approximately 13 square-kilometers in area, 7.5 km long in the northwestern arm, 5 km long in the southeastern arm, and 2.5 km across at the widest point. It has a mostly soft-sediment bottom with some areas of rocky hard bottom, but contains no large-bodied kelp (i.e., macrocystes). The bay was recolonized by male sea otters in 1977 and was occupied by females between 1983-1985 (Garshelis 1983, VanBlaricom 1988). It is currently occupied during the summer by 100-150 sea otters, including adults, subadults and pups. This research was conducted under a Letter of Confirmation No. MA-043219 from the U.S. Fish and Wildlife Service.

Otter Surveys

Data were collected in conjunction with a photo-identification study during July and August 2001 and from June to August of 2002 and 2003. Each of three areas of the bay (Fig. 2.2) was surveyed separately in a systematic rotation. In this manner, the entire bay was covered once for every three surveys during the course of the summer. Surveys were conducted every day, weather permitting, for a week, followed by a week without surveys.

Surveys were conducted from a 6-m skiff equipped with a 55-horsepower outboard engine. An area of the bay was searched in a non-systematic fashion to determine the location of as many otters as possible within that section while attempting to avoid approaching an individual more than once during a survey. The survey continued until the entire section had been covered, typically lasting 3 h, depending on weather.

When an otter was sighted, the skiff approached the animal slowly, attempting to get as close as possible without causing vigorous avoidance behavior. Time, location, behavior before disturbance, gender, and presence of a pup were recorded. Location was determined using a global positioning system (GPS 126, Garmin International Inc., Olathe, KS). Behavior was classified as resting, feeding, grooming, swimming, or interacting as described by Shimek and Monk (1977) and Packard and Ribic (1982). Gender was determined by noting the presence of a penile or testicular bulge for males or the presence of abdominal mammae or a young pup for females (Kenyon 1975, Estes 1980, Riedman and Estes 1990). Gender was not recorded unless two observers

concluded or there was an obvious presence of a pup. If an animal fled before the boat came within 40m, no behavior was recorded and that individual was not included in the analysis.

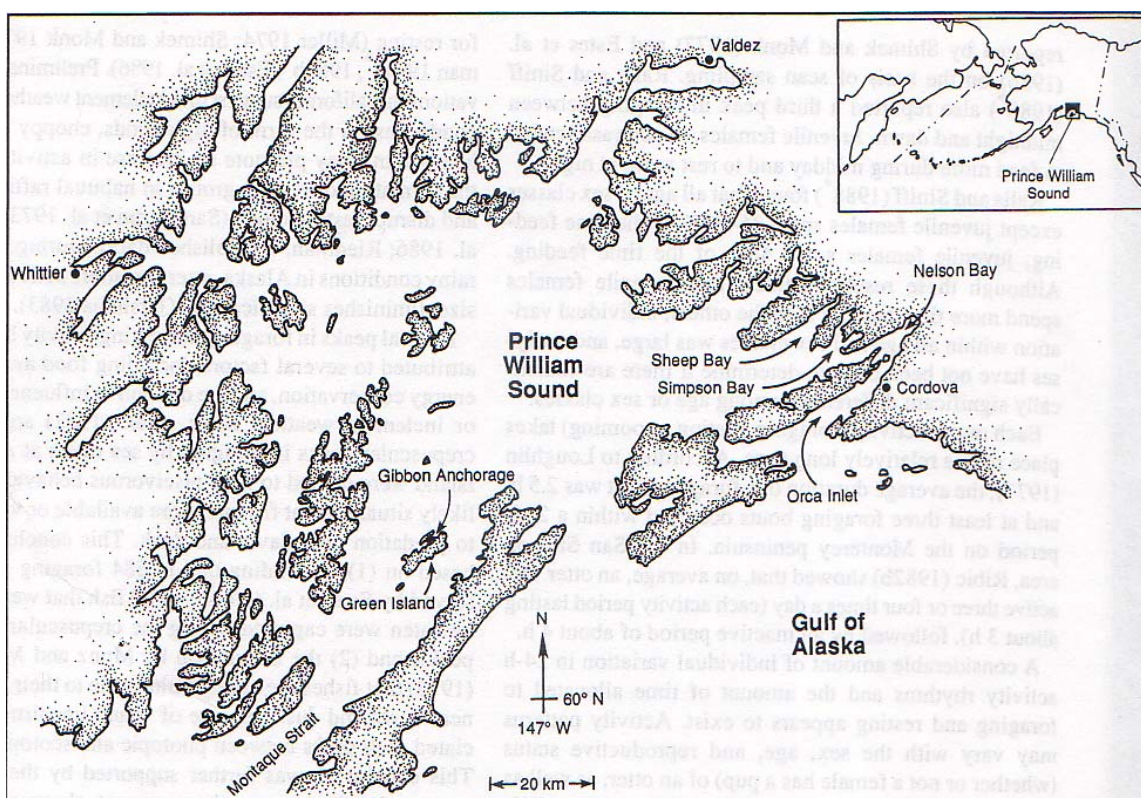


Figure 2.1. Map of Prince William Sound, Alaska (Riedman and Estes 1990).

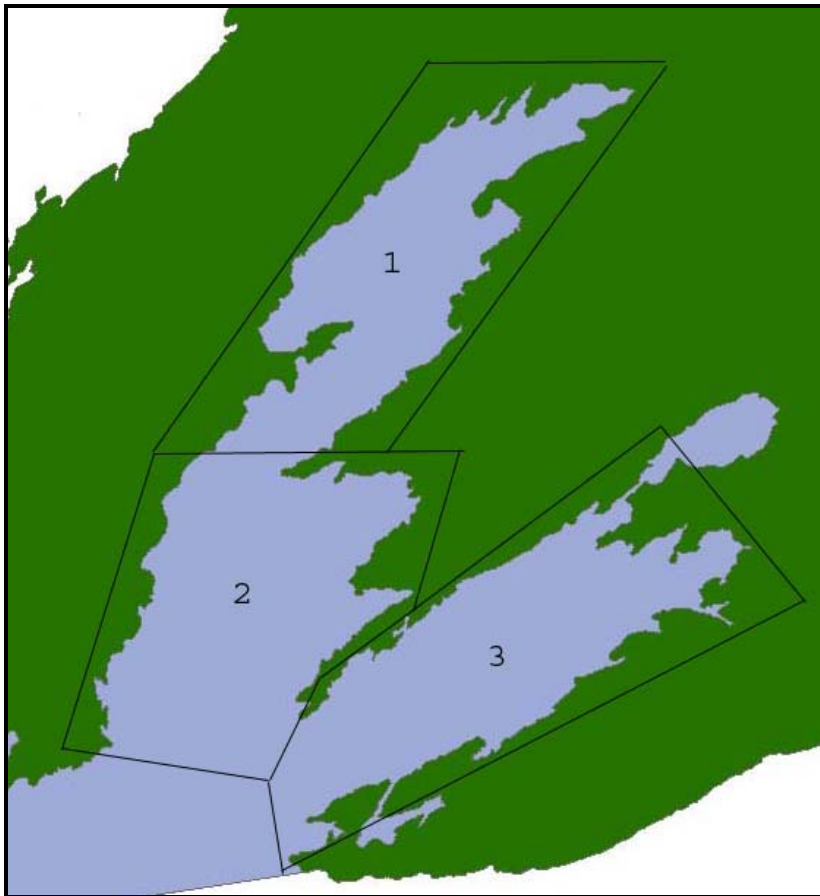


Figure 2.2. Simpson Bay otter survey sections.

Habitat Data Collection

Habitat characteristics were determined by sampling 198 stations spaced 400m apart along a rectangular grid throughout the bay (Fig. 2.3). Horizontal distance between stations was less than 400m near the shoreline in order to better define the complexity in this area. At each station, depth was measured (corrected for the state of the tide) with a bathymeter (Garmin International Inc., Olathe, KS) and sediment samples were taken. Three sediment samples were collected with either an Eckman grab or a gravity corer at each station and combined for analysis. The seafloor around each

station was also visually examined with a black-and-white video camera to describe surficial rock and sediments, algae, and benthic organisms.

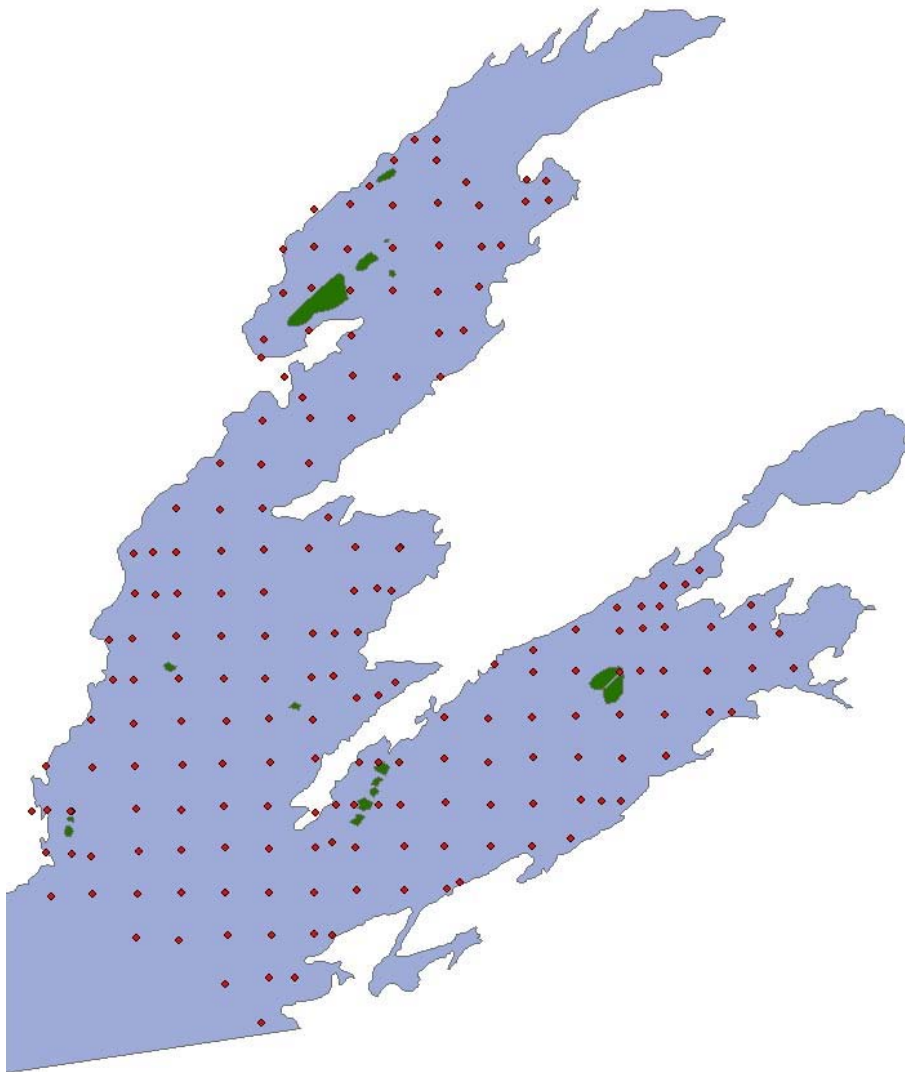


Figure 2.3. Habitat sampling stations in Simpson Bay.

Sediment Sample Analysis

The grain size distributions of each sediment sample were determined using standard wet sieve and pipette analysis procedures (Folk 1980, Boggs 1995). Grain size is a fundamental physical property of sediments, frequently used by both sedimentologists (Folk 1980, Boggs 1995) and biologists (Kvitek *et al.* 1989, Snelgrove and Butman 1994, McConnaughey and Smith 2000) to describe and classify benthic sediments. To determine grain size for each station, dispersant was mixed with a 15-20g sample of wet sediment and the sample was wet sieved through sieves of US standard mesh size 5, 10, and 230 into a one liter graduated cylinder to separate out the gravel and sand fractions. The graduated cylinder was filled to one liter with deionized water and homogenized. Two 20 ml-pipette draws were taken from specific depths within the cylinder at a certain time interval, which varied according to room temperature, to determine the silt (4Φ) and clay (8Φ) fractions. All fractions were dried and weighed. Sediment type was then classified using a gravel-sand-mud (GSM) ternary diagram modified from Shepard (1954) (Fig. 2.4).

Habitat Mapping

Full-coverage maps of the bathymetry and sediment of Simpson Bay were created using inverse distance-weighted interpolation in ArcGIS 8.1. Prior to creating the maps, all depth measurements were adjusted to the 0-tide level. To enable creation of the sediment map, sediment category at each station was ranked from coarsest (Gravel) to finest (Mud), 1-10 in the GSM system. Interpolation was based on these ranks. To check the accuracy of these maps, they were compared to a detailed

bathymetry map and side scan sonar mosaic of Simpson Bay created by Noll and Delapena (unpublished data) during a study of the geology of the bay. Both maps compared favorably in terms of distribution of water depths and sediment types throughout the bay.

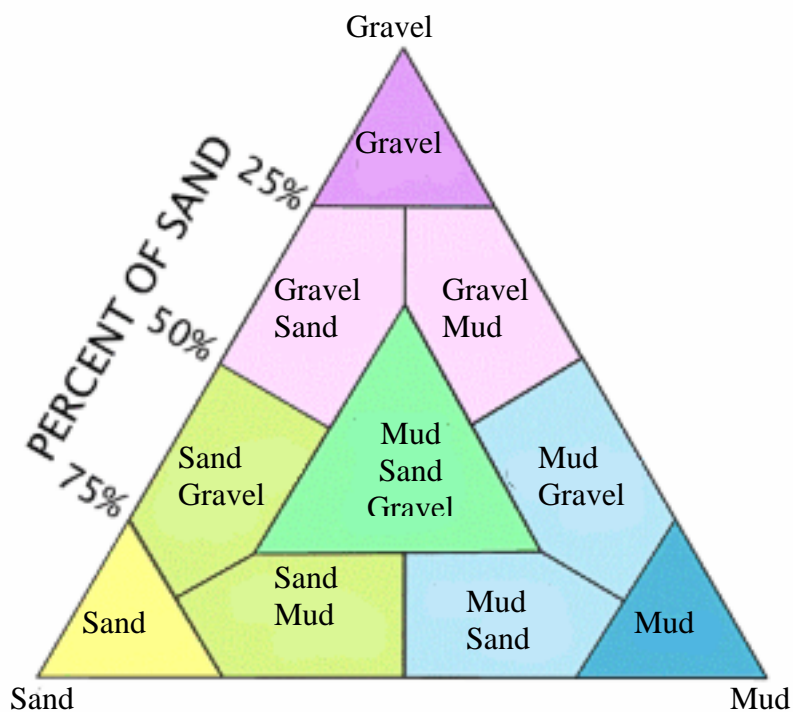


Figure 2.4. Modified Shepard's diagram for Gravel-Sand-Mud sediment classification (Noll and Dellapena, unpublished).

Otter feeding and resting locations were overlaid on the bathymetry and sediment maps. A 40m buffer was placed around each point to account for distance from the boat to the otter. The following information was determined for each location: depth,

sediment type, distance from shore and position within the bay. Depth was tabulated in 10m increments from 0-80m, or >80m. GSM sediment type was recorded as Gravel, Mixed Gravel (including sandy gravel and muddy gravel), Sand, Mixed Sand (including gravelly sand and muddy sand), Mud, or Mixed Mud (including sandy mud and gravelly mud). Position within the bay indicated position between the two shores and was recorded as either central or peripheral, with central representing the middle third of the distance between the two shores. In all cases the value recorded for the environmental variables represented the average for the buffered area around each point.

To determine whether sea otters were using habitat variables differently for feeding than for resting, the locations for the two behaviors were compared using logistic regression. To determine which environmental variables affected the locations of each behavior separately, resting and feeding locations were compared to randomly selected unused locations using logistic regression. Regressions were run using SPSS (SPSS Inc. Chicago, IL). The presence of correlations between habitat variables was determined by G test and correlated variables were not used in the same model. Final model selection was based on Hosmer-Lemeshow goodness-of-fit statistics and lowest AIC values.

RESULTS

A total of approximately 644 h during 127 days were spent over the three years in conducting otter surveys: 124 h over 24 days in 2001, 278 h over 54 days in 2002, and 239 h over 49 days in 2003. The bay was surveyed during 18 weeks (4 weeks in

2001 and 7 weeks each in 2002 and 2003) and the entire study area was covered approximately three times for every survey week.

Otters were encountered during every survey with a total of 2013 encounters – 248 in 2001, 824 in 2002 and 941 in 2003. Of these, 303 were feeding and 653 were resting. The majority of all observations were adults of undetermined gender and females with pups (Table 2.1). A greater number of otters, of all behaviors, were observed in section 2 as opposed to sections 1 and 3 (Table 2.2). This remained constant through all years.

Table 2.1. Otter observations by behavior and gender. All pairs and rafts were recorded as single observations, without determining the gender of the individuals. Each “group” contained 2-20 individuals

	Behavior		
Gender	Feeding	Resting	Total
Males	46 (15%)	59 (9%)	105 (11%)
Females with pups	98 (32%)	311 (48%)	409 (43%)
Undetermined	149 (49%)	233 (36%)	382 (40%)
Groups	15 (5%)	50 (8%)	65 (7%)

Table 2.2. Otter observations by survey section.

Section of the Bay	Feeding			Resting		
	2001	2002	2003	2001	2002	2003
1	12 (29%)	20 (19%)	37 (24%)	21 (17%)	36 (16%)	62 (21%)
2	23 (56%)	67 (63%)	69 (44%)	83 (66%)	125 (56%)	155 (51%)
3	6 (15%)	19 (18%)	50 (32%)	21 (17%)	64 (28%)	85 (28%)

The bathymetry map resulted in a typical pattern of depth distribution with shallower depths at the edges and deeper depths in the middle (Fig. 2.5). Maximum depth in the bay was 125m, recorded at the mouth. The majority of the bay was much shallower with almost 70% between 0-40m deep. The deepest areas within the bay were the mouth, the lower portion of section 1, and the center of section 3. Depth was significantly correlated to all other habitat variables ($p < 0.05$).

Sediment variability within the bay was not very great, mostly mud (silt and clay) with some gravel and relatively little sand (Fig. 2.6). Mud was the most frequent sediment type covering almost 40% of the bay, followed by mixed mud (30%) and then mixed gravel (19%). The sediment map displays a general pattern of coarser sediments toward the edges of the bay with finer sediments in the center (Fig. 2.7). Section 1 was almost entirely fine sediments while section 3 displayed a larger amount of coarse sediments. Sediment type was significantly correlated to all other habitat variables ($p < 0.05$).

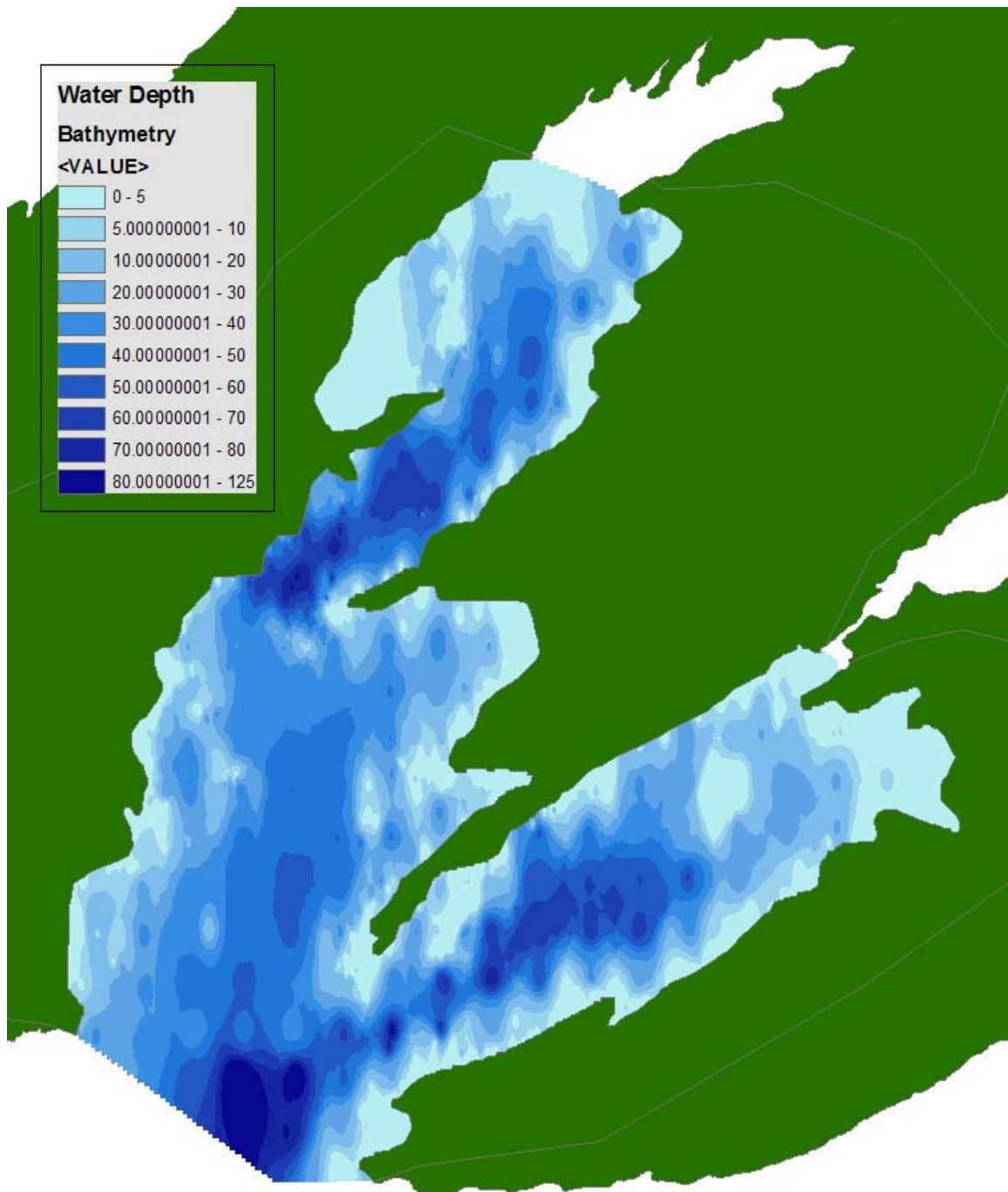


Figure 2.5. Bathymetry map of Simpson Bay.

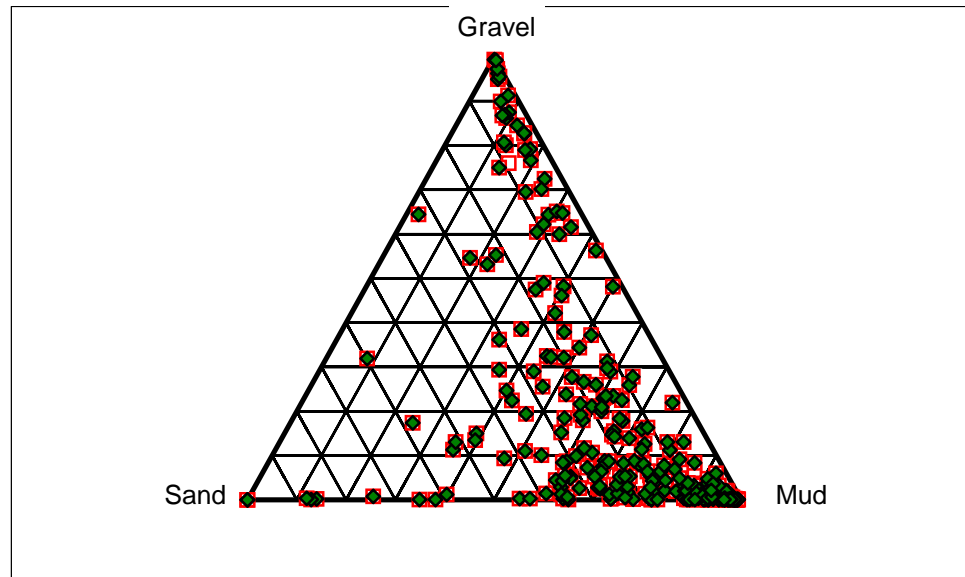


Figure 2.6. Sediment sample distributions on Gravel-Sand-Mud Shepard's diagram.

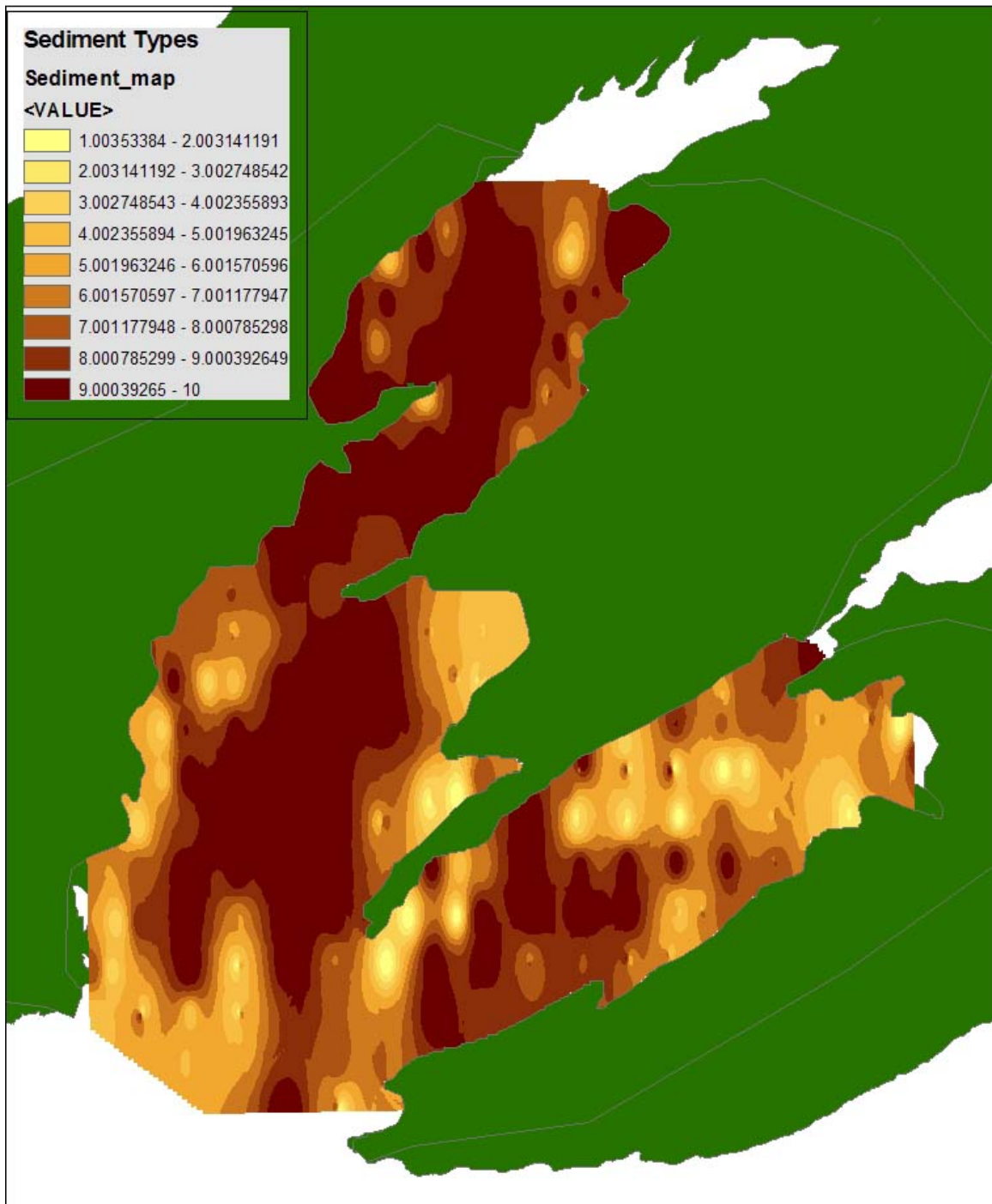


Figure 2.7. Sediment map of Simpson Bay.

Comparison of feeding, resting, and available Simpson Bay habitat shows that feeding was most abundant in shallow water, with frequency of sightings in 0-10m depths much higher than the abundance of those depths within the bay (Fig. 2.8 and 2.9). Resting was most abundant in depths of 30-50m, with depths of 40-50m used at higher frequency than their occurrence (Fig. 2.8 and 2.10). Feeding was distributed among the sediment types approximately according to abundance, while resting was more associated with mud (Fig. 2.11, 2.12 and 2.13). Feeding took place more in the periphery, while resting occurred more toward the center of the bay (Fig. 2.14).

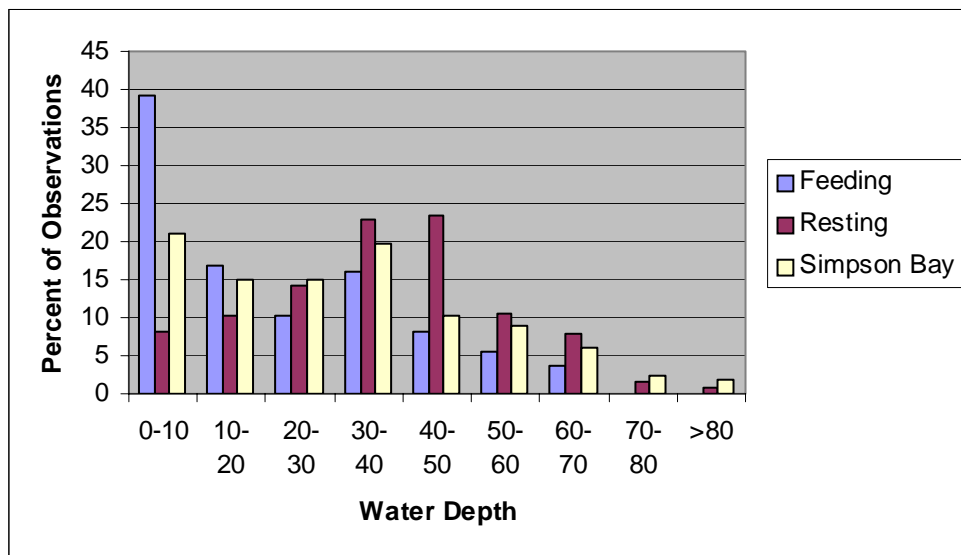


Figure 2.8. Frequency of water depths for feeding sightings, resting sightings, and available habitat.

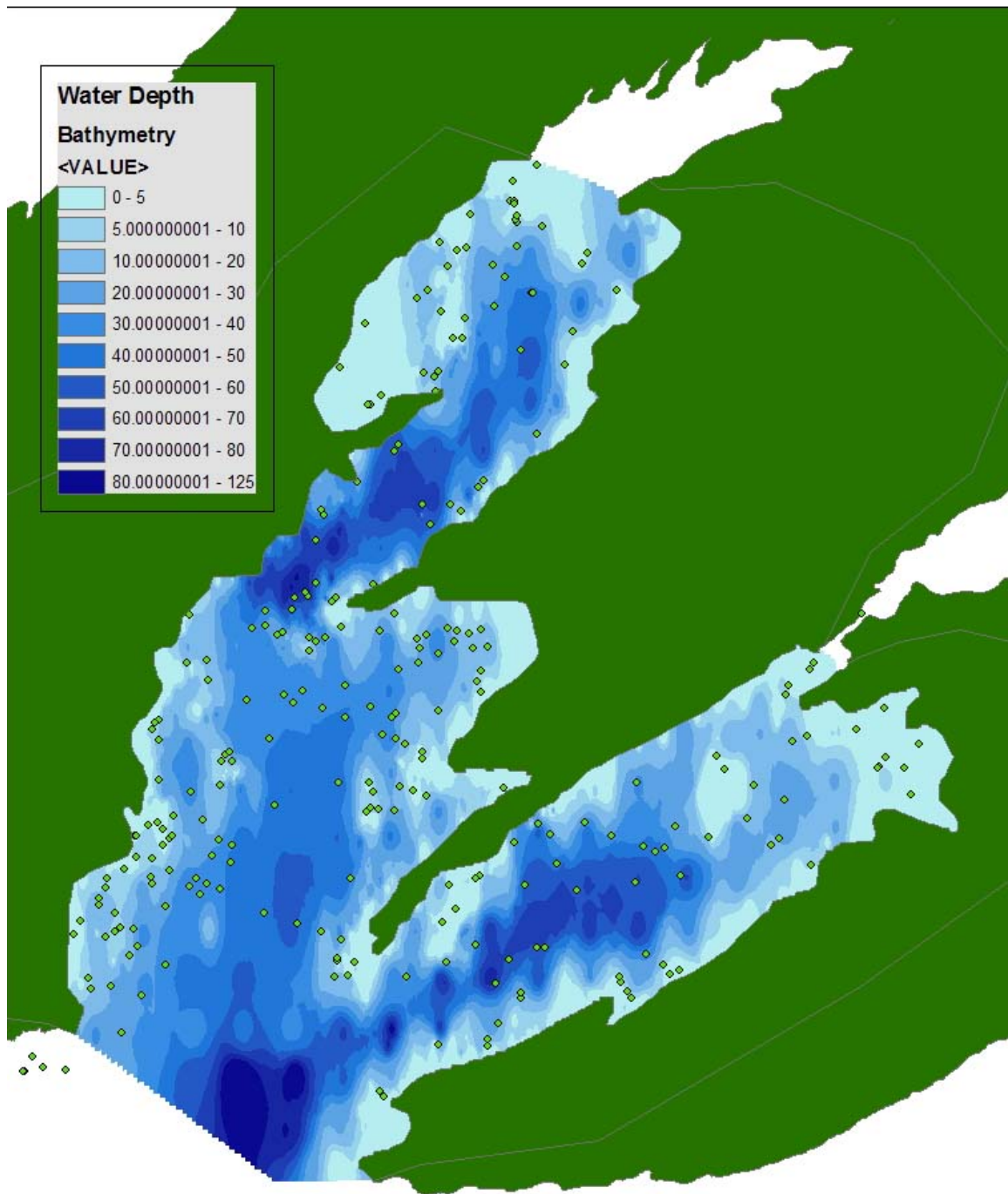


Figure 2.9. Bathymetry map of Simpson Bay with sea otter feeding locations.

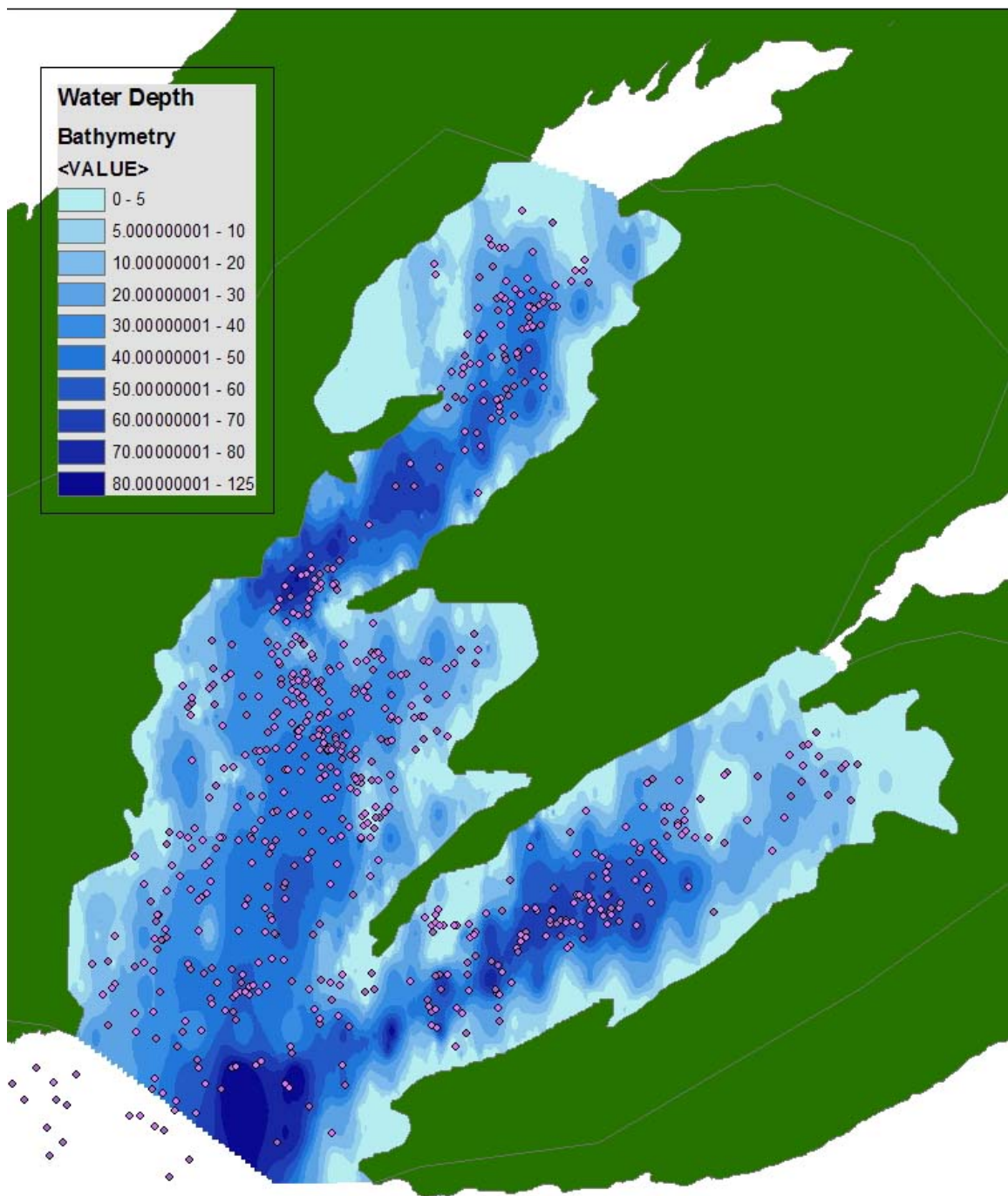


Figure 2.10. Bathymetry map of Simpson Bay with sea otter resting locations.

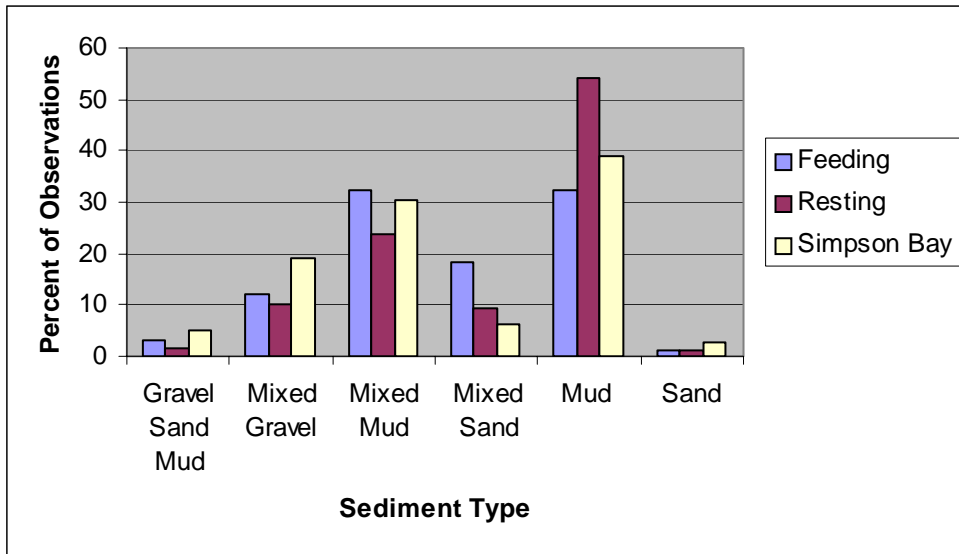


Figure 2.11. Frequency of sediment types for feeding sightings, resting sightings, and available habitat.

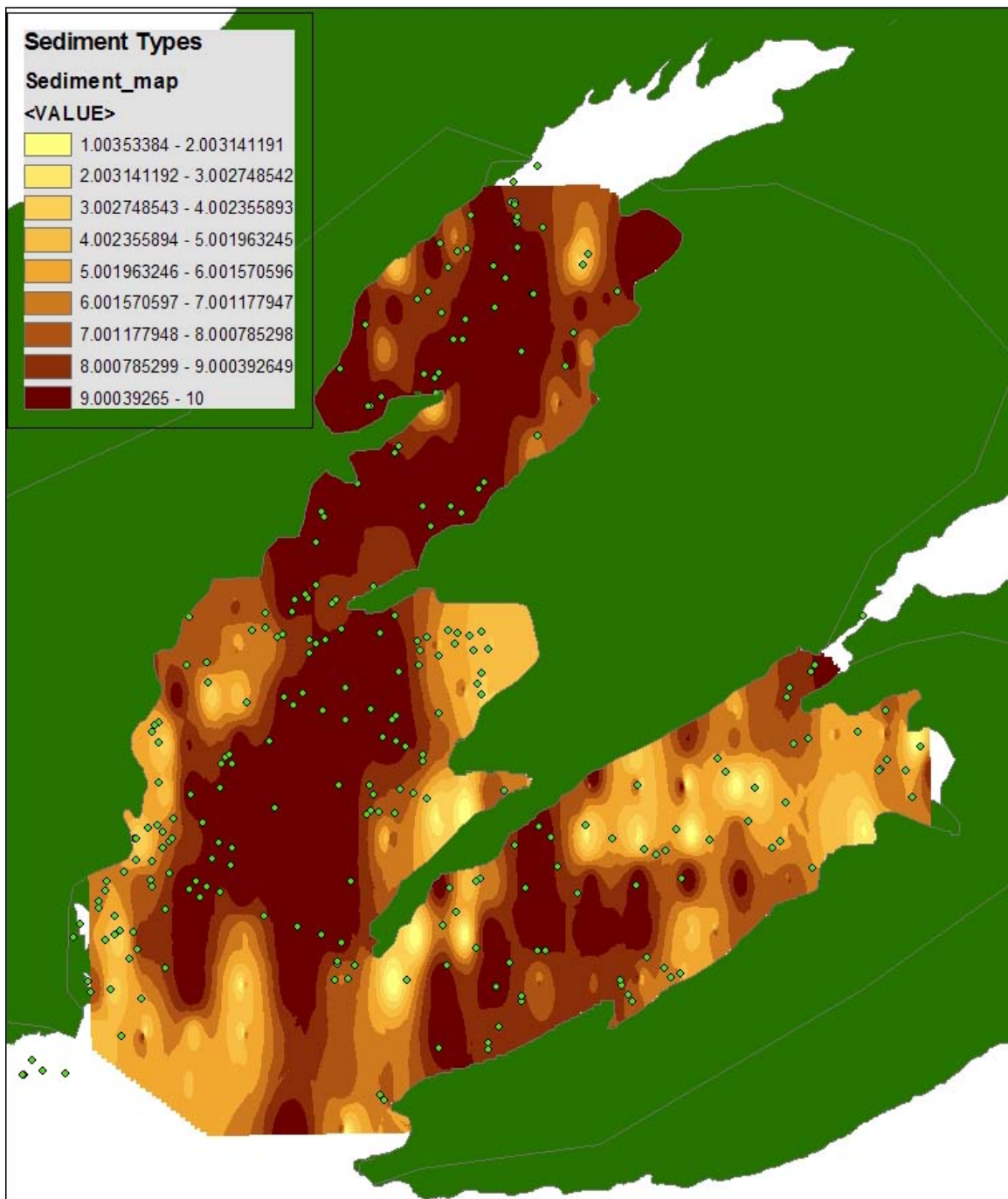


Figure 2.12. Sediment map of Simpson Bay with sea otter feeding locations.

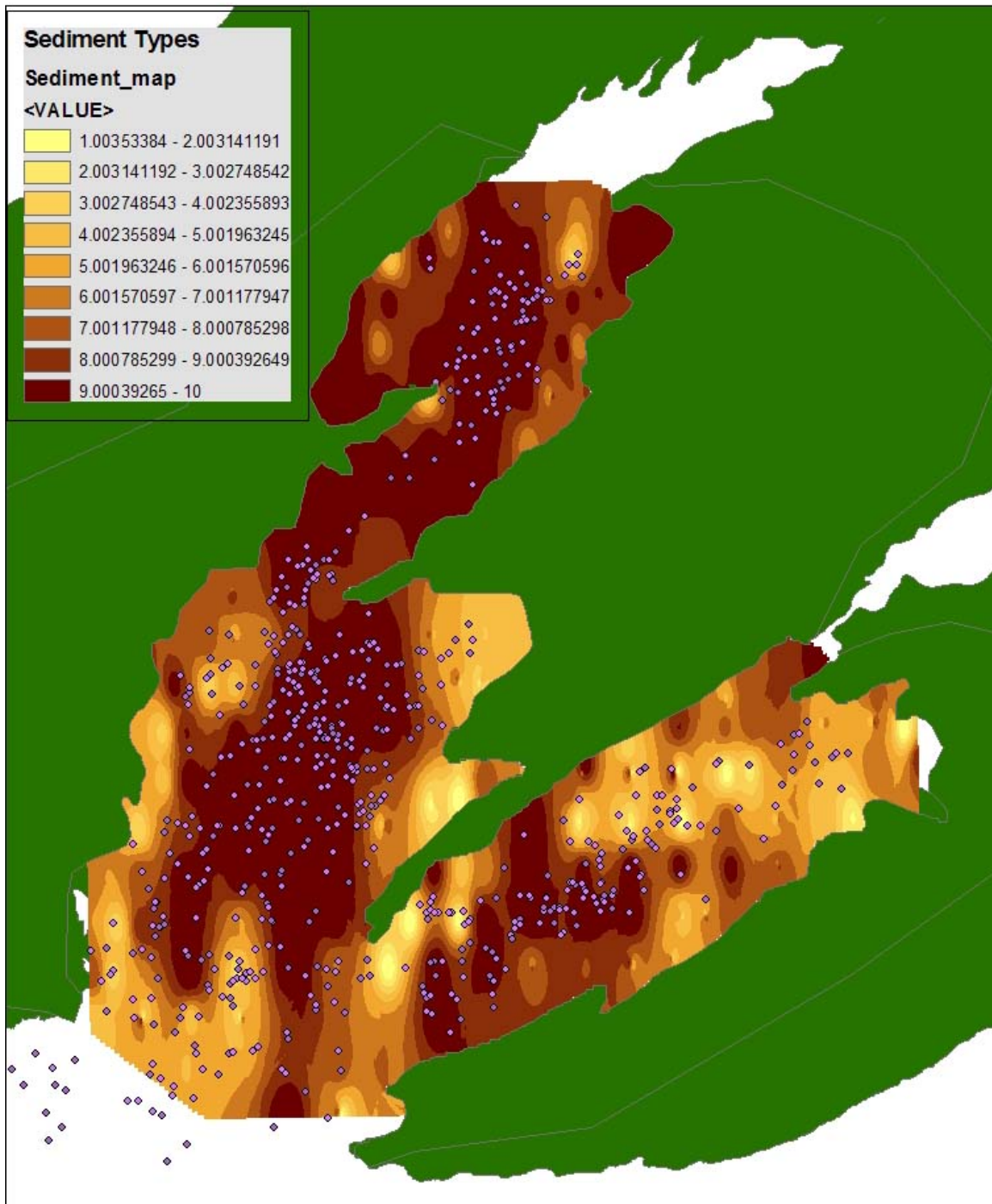


Figure 2.13. Sediment map of Simpson Bay with sea otter resting locations.

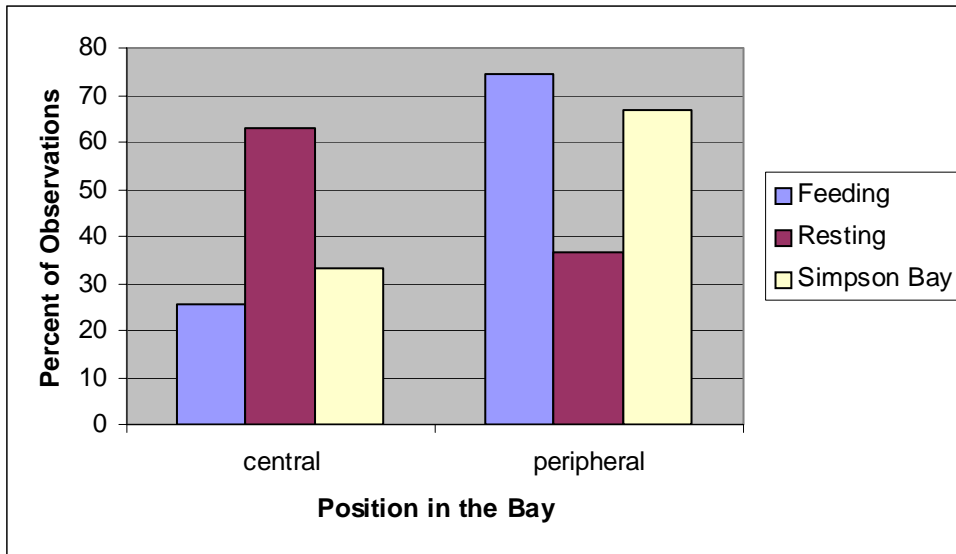


Figure 2.14. Frequency of central vs. peripheral position in the bay for feeding sightings, resting sightings, and available habitat.

Due to significant correlations between all the habitat variables, the logistic regression analysis consisted entirely of single variable models. All distance from shore models had significantly poor Hosmer-Lemeshow goodness-of-fit test scores ($p < 0.01$) and were thus rejected. The remaining models indicated that depth was the most significant habitat association for feeding behavior (Table 2.3) and position in the bay was the most significant habitat association for resting behavior (Table 2.4). In all models for both feeding and resting, the models more successfully predicted unused locations. Water depth was the habitat variable that most strongly distinguished feeding and resting habitat (Table 2.5).

Table 2.3. Logistic regression models for feeding locations. Models are ordered from worst to best fit. Δ AIC is the change in AIC value from the no selection model.

Model	Residual Deviance	AIC	ΔAIC
Null	867.181	1738.382	0
Sediment Type	856.774	1727.729	10.653
Position in the Bay	842.489	1691.017	47.365
Water Depth	781.963	1584.284	154.098

Table 2.4. Logistic regression models for resting locations. Models are ordered from worst to best fit. Δ AIC is the change in AIC value from the no selection model.

Model	Residual Deviance	AIC	ΔAIC
Null	1947.939	3899.887	0
Sediment Type	1822.231	3658.542	241.345
Water Depth	1793.116	3606.389	293.498
Position in the Bay	1711.210	3428.437	471.450

Table 2.5. Logistic regression models for feeding vs. resting locations. Models are ordered from worst to best fit. Δ AIC is the change in AIC value from the no selection model.

Model	Residual Deviance	AIC	ΔAIC
Null	1193.368	2390.749	0
Sediment Type	1148.313	2310.744	80.005
Position in the Bay	1071.454	2148.933	241.816
Water Depth	1027.737	2075.707	315.042

DISCUSSION

Sea otters in Simpson Bay are not using their habitat uniformly for either feeding or resting. For feeding, it is expected that sea otters will select their habitat according to the optimal foraging theory. This means that the habitat selected should allow the otter to maximize energy intake while minimizing risks or energy expenditure (Pyke *et al.* 1977, Quammen 1982). While this is expected from the habitat selection of any predator, sea otters may be especially expected to conform to optimal foraging predictions because of their very high metabolism. Without blubber for insulation, sea otters must rely on their dense fur and metabolism that is 2-3 times higher than a land mammal of similar size (Miller 1974, Kenyon 1981, Riedman and Estes 1990). Ostfeld (1982) points out that sea otters are good candidates for conforming to optimal foraging models, not only because of their high metabolism, but also because they are asocial when feeding (habitat selection is independent of others), virtually without predators as adults (choice of feeding location should not be a compromise between searching for food and avoiding predators), and energy-limited (no nutrient-based need for consuming more than one prey type).

Sea otters in soft-sediment habitats, like Simpson Bay, prey principally on burrowing bivalves (Estes *et al.* 1981, Kvitek *et al.* 1993, Estes and Bodkin 2002). Foraging, therefore, involves diving the entire depth of the water column and excavating sediment. The amount of sediment excavated can be considerable; sea otters have been known to make pits up to a meter deep (Estes and Bodkin 2002). It was hypothesized

that both water depth and sediment type may influence the amount of energy spent on foraging and thus show associations with sea otter feeding locations.

Depth was hypothesized to influence selection of feeding locations because the deeper the dive, the more energy and breath-hold time is used in reaching the bottom, reducing the amount of energy available for search and capture of prey. Boyd (1997) found that the most efficient reoxygenation rates for diving mammals are achieved when both dives and surface times are short. Therefore, the most energy efficient approach for sea otters should be to forage in shallow depths. This, of course, assumes that any prey density differences between shallow and deep depths are negligible. Since foraging success rates in Simpson Bay were very high at all depths (personal observation), it may be confidently assumed that this is the case. Depth may also influence invertebrate distribution such that the prey in shallower depths are a more energy efficient food source. Thouzeau *et al.* (1991) found that species diversity, density, and total biomass of benthic megainvertebrates decreased with increasing depth. The results presented here show that depth did influence feeding distribution and, in fact, was the primary habitat variable associated with feeding behavior, with sea otters foraging more frequently in shallow water between 0-20m deep. This result is consistent with what others, such as Shimek and Monk (1977), Loughlin (1979) Garshelis (1983) and Bodkin *et al.* (2004), have found with regards to sea otter dive depths. The tendency of feeding sea otters to be in the periphery of the bay, as opposed to the center, is probably due to the fact that shallower water depths are in the periphery.

Sediment type was hypothesized to influence feeding locations because of its potential to influence prey distribution. Several studies have found distribution and abundance of benthic invertebrates to be influenced by sediment type (Quammen 1982, Thouzeau et al. 1991, McConnaughey and Smith 2000, Wong and Barbeau 2003). Kvitek et al. (1988) found that sediment affected the burrow depth of sea otter prey. In addition, sediment type has the potential to influence the energetic cost of excavation, with certain substrates easier to displace than others, and the prey encounter rate, with certain grain sizes making prey more difficult to detect (Kotler *et al.* 2001). The ability of other benthic-invertebrate predators to detect prey is reduced in sediments of larger grain size (Quammen 1982, Lipcius and Hines 1986, Wong and Barbeau 2003) and higher heterogeneity (Sponaugle and Lawton 1990, Wong and Barbeau 2003). Clams, for example, are likely more easily detectable for sea otters in sediments that are pure mud as opposed to those with rocks that may be mistaken for clams.

Logistic regression analysis found that sediment is not a strong influence on sea otter feeding locations. The weak pattern that was displayed indicates a tendency to associate more often with heterogenous substrates, the opposite of what was found for other predators. The other predators studied, however, were invertebrates (crabs and starfish), and birds, none of which are close to the sea otter in their ability to excavate sediment or tactilely distinguish prey. Gravel and other rocks may not be the deterrent to sea otters than they are to other species, as sea otters have been observed moving even large rocks (up to 100cm) (VanBlaricom 1988, Kvitek *et al.* 1989).

It is also possible that the association with more heterogeneous substrates is due to an association between depth and sediment type. Although this relationship was not statistically significant, visual inspection of the habitat maps show mud concentrated more in the center of the bay, with the deeper water, especially in section 2 where the majority of feeding observations occurred. It is therefore possible that the negative association with mud may be due to the negative association with deeper depths and not the sediment type. In fact, Snelgrove and Butman (1994), in their review of invertebrate distribution, concluded that the majority of studies indicate that sediment grain size is not a strong determinant of invertebrate distribution. Even if different species of sea otter prey are associated with different sediment types, as Ostfeld (1982) found, it is possible not to see a strong association between otters and sediment type at the population level as sea otters show a great deal of individual variation in diet, with most individuals “specializing” on 1-4 prey types (Ralls *et al.* 1988b, Riedman and Estes 1990, Estes *et al.* 2003). Thus, different individuals may have associations with specific sediment types but the population as a whole does not.

It is also expected that resting locations be optimal, however, what makes a resting location optimal is not clear. Certainly a location that is protected from waves and generally allows the otters to rest without drifting far should be desirable, but beyond that, no preferred habitat trait has been apparent in other studies (Garshelis 1983, Garshelis and Garshelis 1984). Patterns of boat traffic, water currents and temperature gradients have also been proposed as possible influences (Garshelis and Garshelis 1984).

The results of this study indicate that resting is associated primarily with the center area of the bay. The benefits that may be derived from this are not immediately apparent. One possibility may be that it is a response to historical hunting or predation pressure. In discussing the evolution of rafting, Garshelis *et al.* (1984) provided evidence that a historic land predator, perhaps aboriginal man, may have influenced the social behavior of sea otters. The tendency to rest away from the shore would also have provided protection from a land-based predator. Water currents and temperature may also differ between the center and periphery of the bay.

Sediment type was a secondary factor associated with sea otter resting locations. While it is not reasonable to believe that sediment type is directly associated with resting locations, it may be a correlate of a habitat factor that is. Sedimentation is influenced by differences in water current strength or turbulence, which may be why resting otters are associated with muddy sediments. Increased turbulence, which is typically found more prominently along the shore, will keep fine sediments suspended, leading to benthic sediments of larger grain size (Dellapena, personal communication). Areas of mud, therefore, should be associated with less turbulent waters.

Resting and feeding behaviors, in general, take place in separate microhabitats differing in depth, sediment type, and position in the bay. Although the primary factor influencing location is different for each behavior, all aspects of the microhabitat differ because of associations between the habitat variables themselves. Depth is the primary habitat variable distinguishing feeding and resting habitats due to the strong correlation between depth and position in the bay, with shallow waters (primary feeding habitat) in

the periphery of the bay and deeper waters in the center part of the bay (primary resting habitat). There are many other potential habitat variables that may be associated with these two behaviors. The fact that the models predict unused locations best indicates that this is very likely the case. Understanding how invertebrate distribution in the bay is related to depth and sediment type is key to better understanding sea otter feeding distribution. Examination of water currents and temperature are the next step in exploring the habitat associations of resting locations.

It is important to remember that habitat selection occurs on many different spatial scales and that the factors influencing an animal's location may be different at each scale (Johnson 1980, Alldredge *et al.* 1998, Manly *et al.* 2002). This study looked at microhabitat, or third-order, selection by examining the factors associated with location within the bay, but the fact that otters are present in Simpson Bay is also the result of selection, just on a different scale. It is possible that the area as a whole is superior for either resting or feeding in some way when compared to other bays of lower sea otter density. The habitat variables associated with these behaviors may also be different in different parts of the sea otter's range, such as the California coast and the Aleutians where habitats are more rocky, exposed to waves and dominated by kelp forests.

PHOTO-IDENTIFICATION OF NOSE SCARS FOR INDIVIDUAL RECOGNITION OF SEA OTTERS

INTRODUCTION

The importance of individual recognition to the understanding of species' ecology and behavior has long been acknowledged (Wursig and Jefferson 1990, McGregor and Peake 1998). It allows for detailed studies of survival, movement patterns, reproduction, foraging, and life histories, to name a few, enabling an understanding of individual variation within a population. As a result, many systems of artificial marks have been used to identify individual animals from insects and fish to mammals. These systems include notching of the ear, toe, fin or scale; tattoos, dyes, and brands; colored or numbered tags; and radio and satellite transmitters (McGregor and Peake 1998). However, applying artificial tags or transmitters requires animal capture, which may injure the animal or handler and alter the animal's behavior or relationship with other individuals (McGregor and Peake 1998, Markowitz *et al.* 2003). To reduce these risks, some researchers have taken advantage of naturally occurring variation in physical appearance to recognize individuals. Individual phenotypic variation in color patterns (e.g. zebras, giraffes, cheetahs), facial characteristics (e.g. Bewick's swans, chimpanzees), and even wrinkle patterns (e.g. black rhinos, ostriches) have been used, while others have made use of marks created by natural injury (e.g. ear nicks in elephants) (Pennycuick 1978, Slooten *et al.* 1992, McGregor and Peake 1998).

Using natural marks to identify individuals has become a widespread practice in the study of marine mammals over the last twenty years. The use of photographs to compare individuals has revealed a high degree of variation in either pigmentation or scar patterns in many species. Photo-identification has been used in studies of cetaceans (reviewed by IWC 1990) including both toothed (e.g. Arnborn 1987, Whitehead *et al.* 1997, reviewed by Wursig and Jefferson 1990) and baleen whales (e.g. Rugh 1990, Calambokidis and Barlow 2004), sirenians (e.g. Reid *et al.* 1991, Langtimm *et al.* 1998), and even some pinnipeds (e.g. Forcada and Aguilar 2000, Abt *et al.* 2002). Applications of this technique include mark-recapture population estimates (e.g. Karczmarski *et al.* 1999), short- and long-distance movements (e.g. Rugh 1990, Neumann *et al.* 2002), residency patterns (e.g. Bejder and Dawson 2001), reproduction (e.g. Thayer *et al.* 2003), social relationships (e.g. Shane and McSweeney 1990), survival rates (e.g. Langtimm *et al.* 1998), and disease patterns (e.g. Wilson *et al.* 2000).

One of the few marine mammals with which photo-identification has not been attempted on is sea otters (*Enhydra lutris*), even though it has long been acknowledged that some individuals are recognizable. Foott (1970) first noted that female nose scars incurred during copulation could be used as a natural feature to identify them. Since then, several other studies have causally used this method of identification to a limited extent (Calkins and Lent 1975, Loughlin 1980, Garshelis 1983), but no study has systematically explored the prevalence of scarring in sea otters nor the degree to which nose scars may be used for natural identification. The purpose of this study was to assess the prevalence of nose scars and their potential for individual recognition.

METHODS

Study Area

Simpson Bay (ca. 60.6°N Lat., 145.9°W Long.), located in northeastern Prince William Sound, Alaska (Fig. 3.1), was used in the study site because of its reasonable size, protection from rough seas, and reliable presence of sea otters. It is approximately 13 square kilometers in area, 7.5 km long in the northwestern arm, 5 km long in the southeastern arm, and 2.5 km across at the widest point. Maximum water depth is 125m, with an average depth of about 30m. Bottom sediments consist of glacial clay, silt, and gravel with some rocky hard reefs, but there are no large-bodied kelp (e.g., macrocystes) beds. The bay was recolonized by male sea otters in 1977 and became a female area between 1983 and 1985 (Garshelis 1983, Rotterman and Simon-Jackson 1988, VanBlaricom 1988). It is currently used during the summer by 100-150 sea otters, including adults, subadults and pups. This research was conducted under a Letter of Confirmation No. MA-043219 from the U.S. Fish and Wildlife Service.

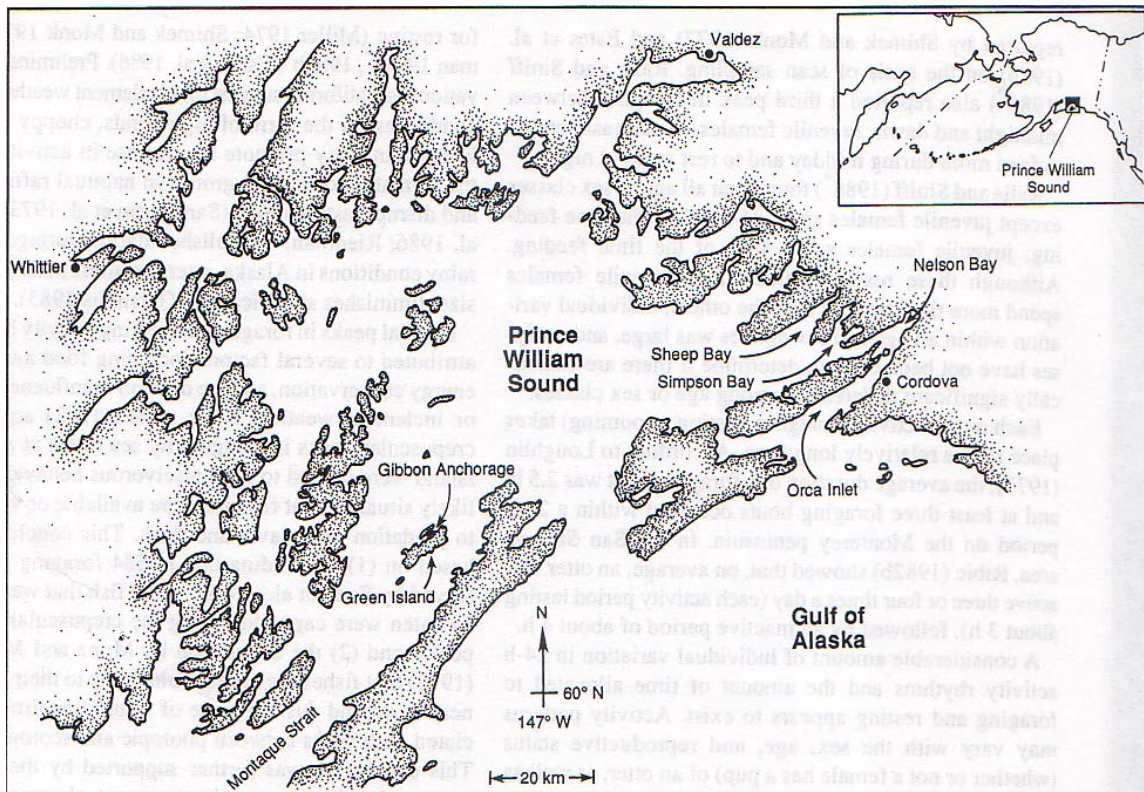


Figure 3.1. Prince William Sound, Alaska (Riedman and Estes 1990).

Photo-Identification Surveys

Digital images of sea otters were taken during June, July, and August of 2002 and 2003. The study area was divided into three parts (Fig. 3.2) and each area was surveyed separately in a systematic rotation. In this manner, the entire bay was covered once for every three surveys. Throughout the summer, surveys were conducted during consecutive days for a week, weather permitting, followed by a week of no effort.

Surveys were conducted from a 17-ft skiff with a 55-horsepower outboard motor. The research team was composed of a driver, photographer, recorder and spotter. In order to maximize otter encounters, no systematic vessel track was followed. The boat opportunistically approached as many otters as possible but avoided approaching an

individual more than once during a session. The survey continued until the entire section had been covered, which typically lasted 3-4 hours. Digital images were taken with a Nikon D1H digital camera with an 80-400 mm image-stabilized telephoto lens. Markowitz *et al.* (2003) reported that digital images were superior to slide film for the purposes of photo-identification.

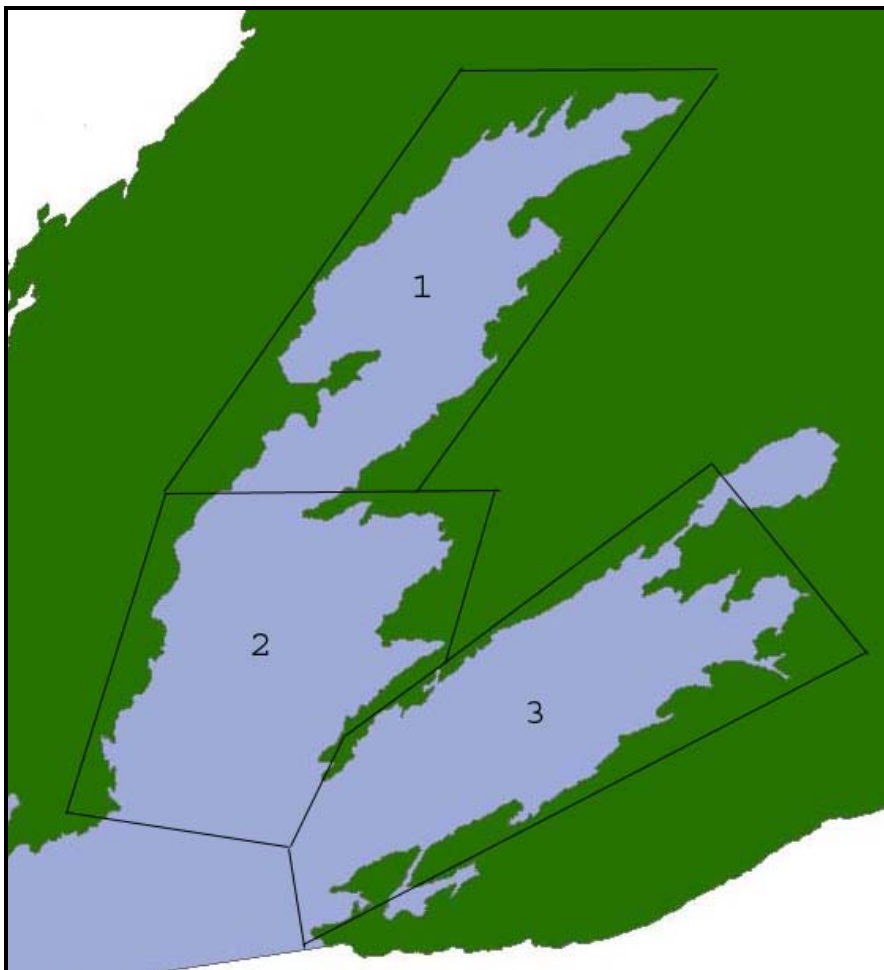


Figure 3.2. Photo-identification survey sections.

When an otter was sighted, the driver approached the animal slowly while the photographer attempted to obtain a head-on image of the otter's face. Time, location, behavior before disturbance, gender, and presence of a pup were recorded. Location was determined using a Global Positioning System (GPS 126, Garmin International Inc., Olathe, KS). Gender was determined when possible by noting the presence of a penile or testicular bulge for males or the presence of abdominal mammae or a young pup for females (Kenyon 1975, Estes 1980, Rotterman and Simon-Jackson 1988, Reidman and Estes 1990). Contact was maintained with the animal until either the photographer expressed confidence in capturing a good image or the otter actively avoided the boat.

Photo-Identification Analysis

The images from each survey were sorted and the best image of each individual were selected and then cropped to isolate the face using Adobe Photoshop 7.0 (San Jose, CA). Only these images were used for subsequent analysis. Rating systems for image quality and individual distinctiveness were adapted from Arnbom (1987), Chilvers and Corkerson (2003), and Read *et al.* (2003). Each image was rated for photographic quality (Q) based on focus, angle of the nose to the camera, lighting and contrast, visibility of the nose, and distance to the animal on a scale of 1-4 (Table 3.1). All images of quality rating Q2 or above were then rated for individual distinctiveness (D) according to the size, shape, and placement of the nose scar on a scale of 1-5 (Table 3.2, Fig. 3.3). Images rated Q1 were considered too poor to accurately assess distinctiveness (Friday *et al.* 2000) and were not used for any further analysis. Images rated Q3 and D3

or higher were considered suitable for individual identification. In addition, those Q2 images that contained a D5 individual were also used.

Image matching was performed independently by two experienced observers (A. Gilkinson and H. Pearson), and only those which both agreed on were considered matches. During the first year, each image was compared with every other image to determine the number of individuals and number of matches for each individual. Each identifiable otter was then assigned a number and entered into an image-catalogue.

After the catalogue was established, new images were compared to those in the catalogue. If an image could not be matched, it was entered as a new individual.

Table 3.1. Rating system for picture quality. Rating system is Q1-Q4 with Q4 representing the highest quality photographs

Rating	Criteria
Q1	Very poor quality image. Displays two or more of the flaws listed in Q2 or more than three flaws listed in Q3.
Q2	Poor quality image. Displays one of the following flaws or two to three of the flaws listed in Q3: image out of focus, otter head turned so that not all of nose is visible or exact location or scars is questionable, image is very light or very dark, visibility of nose surface is distorted by water or glare, nose is partially blocked by a food item or another otter, nose is small in the frame.
Q3	Good quality image. Presence, location, and shape of nose scars can be identified with a high degree of confidence. May have one to two of the following minor flaws: image slightly out of focus, head is turned slightly to the side or tilted slightly forward or backward, image exposure somewhat light or dark, nose appears of medium size in the frame.
Q4	Excellent quality image. Image is clear, otter is directly facing camera, good contrast (not under or over exposed), visibility of nose is not distorted by water or glare, nose appears large in frame

Table 3.2. Rating system for individual distinctiveness. Rating system is D1-D5 with D5 indicating the most distinctively marked individuals

Rating	Criteria
D1	No nose scars or other identifying features
D2	Nose has some scars, but they are indistinct
D3	Nose has one small scar/identifying feature of distinctive location or shape OR two or more very small scars forming a distinctive pattern
D4	Nose has at least one distinctive medium-sized scar OR has two or more small or less distinctive scar/identifying features that form a distinctive pattern
D5	Nose scars are highly distinctive including a large scar or scar pattern that is evident/distinctive even in a poor quality image

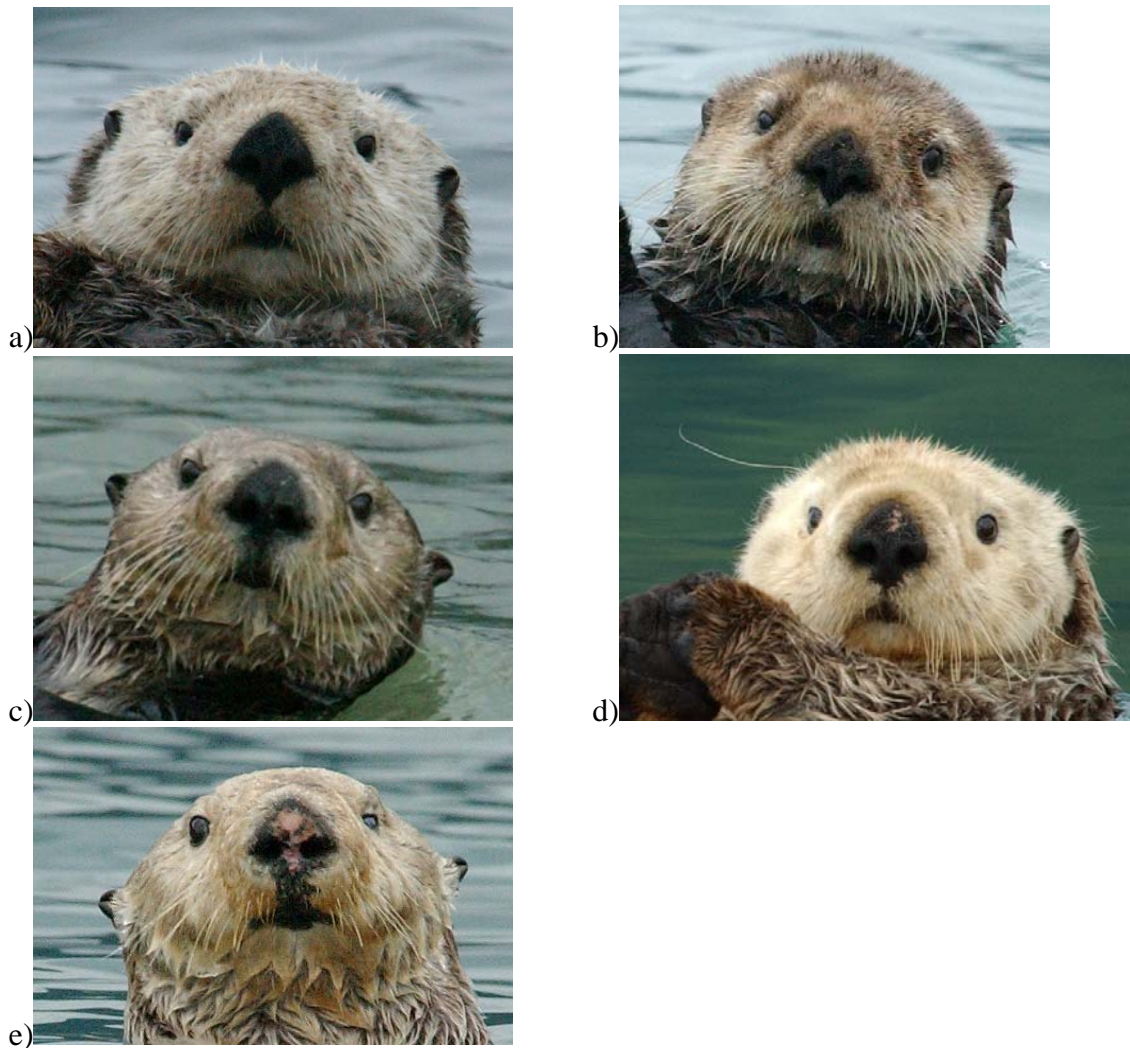


Figure 3.3. Otters with scars of different degrees of distinctiveness. a) D1, b) D2, c) D3, d) D4, e) D5

Prevalence and Demographics of Scarring

Percentage of the population bearing distinctive scars was estimated by comparing the number of unscarred individuals (rated D1 and D2) to the number of individuals in the catalog (rated $D \geq 3$). All images of quality rating Q3 and Q4 were used. To estimate the number of individuals seen without scars, gender-specific re-

sighting frequencies of scarred otters were calculated and the number of individuals within each category (male, female, unknown) without scars were divided by these frequencies, as it was assumed that scarring did not affect sighting frequencies. For example, there were 65 sightings of unscarred males and the average number of sightings per scarred male was 6.1; so the estimated number of unscarred males in the study area is 65 divided by 6.1, which is 11. Prevalence of scarring was determined for both the population as a whole and for each gender category.

RESULTS

A total of approximately 520 h during 103 days were spent over the two years in conducting photo-identification surveys: 278 h over 54 days in 2002 and 239 h over 49 days in 2003. The bay was surveyed during 14 weeks (7 weeks each summer) and the entire study area was covered approximately three times for every survey week. Otters were encountered during every survey with a total of 1765 encounters, 824 in 2002 and 941 in 2003.

Overall, 816 good quality ($Q \geq 3$) images were obtained, with 380 containing distinctively scarred individuals ($D \geq 3$) from which 114 individual sea otters, representing 19 males, 45 females, 1 pup, and 49 adults of undetermined gender, were identified. The number of individuals identified increased continuously throughout the sampling period (Fig. 3.4). Number of sightings per individual ranged from 1 to 26, with up to 19 sightings within one year (Fig. 3.5) and a mean of 3.3 sightings per individual overall. Fifty-four otters (47%) were seen on more than one day with a mean of 8.1

sightings per individual for those seen more than once. Eight individuals (19% of those identified in 2002) were identified in both years.

There was a distinct difference between years in both the number of good quality ($\geq Q3$) images and the number of individuals identified. In 2002, only 298 (36%) encounters produced good quality images and 42 individuals were identified. In 2003, 518 encounters (55%) produced good quality images and 80 individuals were identified. The discovery curve started to plateau toward the end of 2002 as the number of new individuals identified decreased with each month. However, the curve from 2003 showed no signs of flattening by the end of the season with approximately equal numbers of new individuals identified during each month (Fig. 3.4, Table 3.3). The average number of sightings for all identified otters was approximately three sightings per individual in both years, but average number of sightings for re-sighted animals increased slightly from 4.6 sightings per individual in 2002 to 5.5 sightings per individual in 2003.

Analysis of sighting patterns by gender and the month of first sighting indicate that males and individuals first sighted in June had the highest sighting rates (Tables 3.4 and 3.5). Monthly sighting patterns also show that, a majority of those individuals re-sighted in more than one month were seen in consecutive months (Fig. 3.6).

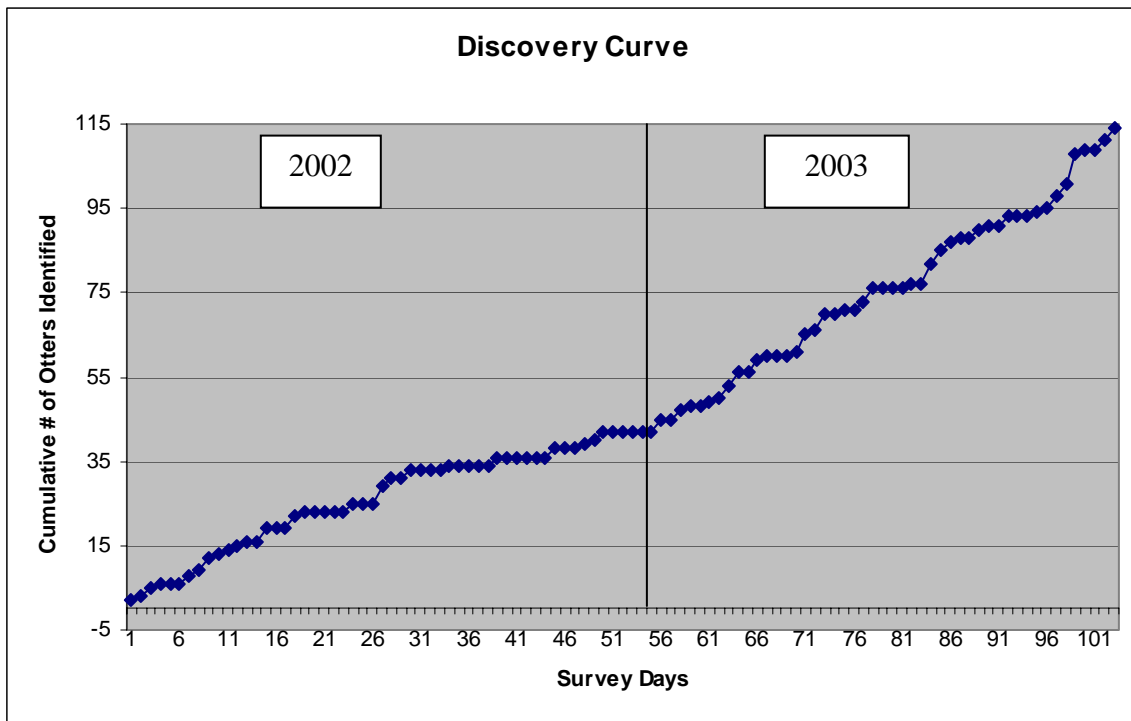


Figure 3.4. Discovery curve for sea otters identified in 2002 and 2003.

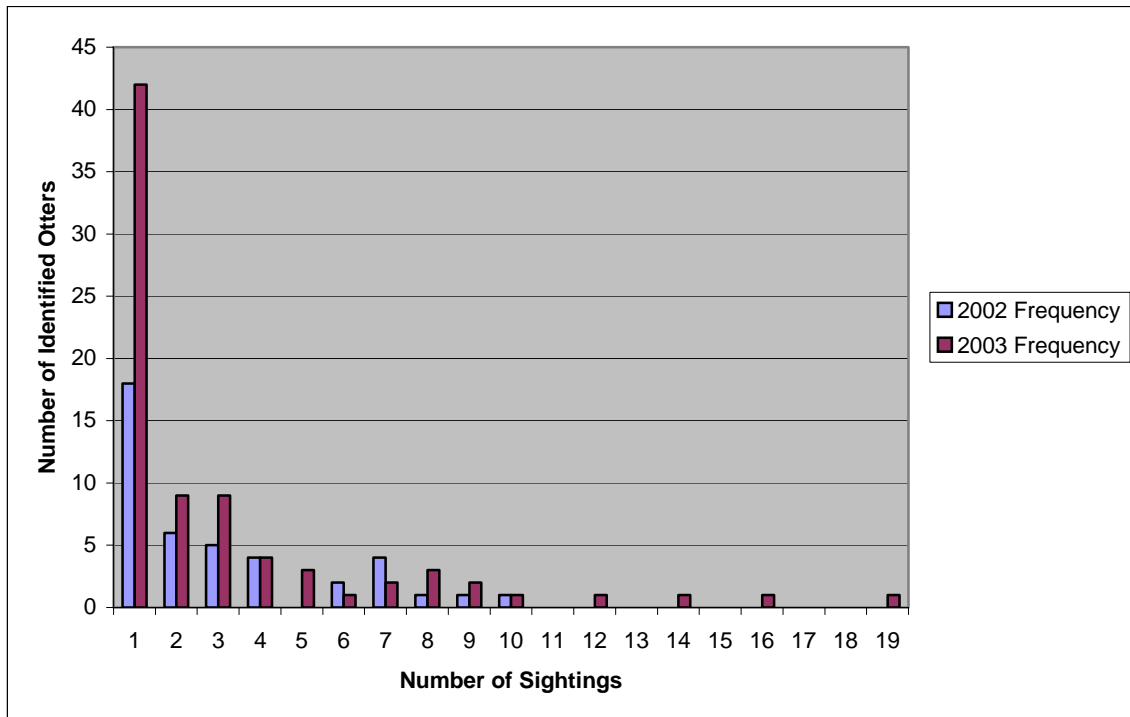


Figure 3.5. Sighting frequencies of identified otters in 2002 and 2003.

Table 3.3. Number of new individuals identified each month

Month	Number of New Otters Identified
June 2002	19
July 2002	15
August 2002	8
June 2003	23
July 2003	28
August 2003	29

Table 3.4. Mean sighting frequencies by gender.

Gender	Mean Sighting Frequency (sightings/individual)
Male	6.1
Female	3.4
Unknown	2.3

Table 3.5. Mean sighting frequencies by month first sighted.

Month	Mean Sighting Frequency (sightings/individual)
June	4.3
July	3.3
August	1.5

June	July	August	Number of Otters	Percentage
			4	6.5%
			4	6.5%
			12	19.4%
			3	4.8%
			21	33.9%
			3	4.8%
			15	24.1%
Total			62	100%

Figure 3.6. Monthly sighting patterns of sea otters in Simpson Bay. Number and percentage of individuals re-sighted in each possible monthly combination during study period.

Overall, approximately 45% of the population had scars by which they could be identified and this was consistent between years. Analysis of scarring by gender revealed that 63% of males, 45% of females, and 40% of adults of undetermined gender bore identifiable nose scars (Table 3.6).

Table 3.6. Number of scarred and unscarred otters by gender.

Gender	# with Scars	# without Scars
Male	19 (63%)	11 (37%)
Female	45 (45%)	55 (55%)
Unknown	49 (40%)	72 (60%)

DISCUSSION

The results from this study indicate that nose scars can be used to identify individual sea otters. Almost half of the sea otters in the study area had recognizable scars, which is within the range reported for other species of marine mammals (Table 3.7). In addition, study results are in agreement with what is known about the movements residency patterns of sea otters in Simpson Bay, indicating that photo-identification can be used to capture these. Simpson Bay otters do not form a closed population. Monnett and Rotterman (1988) have shown that females with pups travel throughout large areas of eastern Prince William Sound, generally using areas west of Sheep Bay (see Fig. 3.1) during late spring and early summer, moving into the area of Sheep and Simpson Bays during August and September, and staying until about November when they move further east. A discovery curve that does not plateau was therefore expected, as new individuals were entering the study area well beyond the end of the study period. Also expected was a high number of re-sightings for those seen in June and the majority of otters first seen in June or July to also be seen in August, since the otters were expected to stay in the area until late fall. Even when staying within the general area of Sheep and Simpson Bays, many females both with and without pups will travel between the two (Siniff and Monnett 1985, Monnett and Rotterman 1988). Territorial males have smaller seasonal ranges than females (Loughlin 1980, Ribic 1982, Ralls *et al.* 1988a, Jameson 1989) and thus are more likely to stay within the boundaries of Simpson Bay. Thus, the higher number of re-sightings for males was also expected.

Table 3.7. Percent of population identifiable from natural markings for various marine mammal species

Species	% Identifiable	Source
Sea Otters	45%	This study
Dusky dolphins	50%	Markowitz <i>et al.</i> 2003
Atlantic bottlenose dolphins	54%	Read <i>et al.</i> 2003
Indo-pacific bottlenose dolphins	57%	Chilvers and Corkerson 2003
Hector's dolphins	37%	Bedjer and Dawson 2001
Pilot whales	33.5-45.3%	Shane and McSweeney 1990
Spinner dolphins	15-20%	Shane and McSweeney 1990, Wursig and Jefferson 1990
Indo-pacific humpback dolphins	92%	Karczmarski <i>et al.</i> 1999
Sperm whales	91%	Arnbom 1987
Killer whales	100%	Bigg 1982
Fin whales	74%	Agler <i>et al.</i> 1990
Humpback whales	92%	Shane and McSweeney 1990

The difference in number of individuals identified in 2002 and 2003 is most likely due to the difference in image quality between the two years. Census data indicate that the population size remained approximately the same between the two years and percentage of the population with nose scars also remained constant between years. Improved image quality should allow the number of individuals seen once to increase, indicating better capture of individuals that were in the study area for only a short time, and also increase the mean number of sightings among re-sighted individuals. Image quality improved significantly between years, with images of Q3 and Q4 increasing from 36% of the total images in 2002 to 55% in 2003. Number of individuals seen only once increased in 2003 to over double that seen in 2002 and mean number of sightings for re-

sighting individuals increased slightly. This result highlights the importance of capturing high quality images.

Previously, scarring on the nose has only been pointed out for female sea otters (Foott 1970, Estes and Bodkin 2002), most likely because it is obvious how they receive them since they are grasped by the nose and/or lip during mating. A couple of studies have used nose scars to identify a limited number of untagged males (Calkins and Lent 1975, Loughlin 1980), but no one has called attention to nose scars in male sea otters. The results from this study indicate that nose scars are just as, if not more, prevalent among territorial males as females. The source of scars among males is unknown, although injury may occur during fights with other males. The fact that a higher percentage of males had scars than female was unexpected. One possible reason for this may be the potential difference in age between the males and females in Simpson Bay. Females reach sexually maturity at around 4 years old (Kenyon 1975, Garshelis 1983, Riedman and Estes 1990, Jameson and Johnson 1993) while males do not become sexually mature until around 6 years of age (Garshelis 1983, Riedman and Estes 1990) and may not hold territories until 8-10 years old (Riedman and Estes 1990). Since the only males in Simpson Bay, a female area, are there to breed and most of them are territory holders, the average age of males is likely higher than that of females, giving the males more years to have accumulated scars. Interestingly, the proportion of females with scars was actually low in this study as compared to Foott (1970), who reported about 65% of females bore nose scars. Since no other known studies report prevalence of nose scars, it is not known which number is more typical of sea otter populations.

A high degree of stability of natural marks is desirable if they are to be used for identification (Pennycuik 1978). The stability of nose scars in sea otters was not investigated in this study and is thus unknown. Eight individuals were identified between years, so some marks are stable for at least a year. Since females typically mate every year (Riedman and Estes 1990, Jameson and Johnson 1993) there is potential for scars to change every year. However, since several females without scars were seen with pups in this study, there is also potential for scars to remain stable longer than one year. Changes in marks were documented in two territorial males in 2003. In one, a large scar expanded until it covered most of the nose. This change occurred gradually and without any observed conflict or source of injury, appearing to possibly be an infection. Infections stemming from nose injuries have been reported previously (Foott 1970, Riedman and Estes 1990). In the other male, a thin scratch healed and disappeared from the nose. Documentation of scar changes in these two otters was possible because as territorial males they were seen frequently and were always in the same general location, assuring their identity in spite of the changes in their scars. In general, we hypothesize that the larger and more distinctive the main mark feature, the longer it may be used to identify an individual.

Another potential problem with sea otter photo-identification is that not all individuals have equal capture probability. Certain otters are more easily approached than others (personal observation), which produces greater quality images for those individuals (IWC 1990). Generally males are the easiest to approach, while females with pups are the most difficult. In addition, individuals with a distinctiveness rating of

D4 or 5 are probably more reliably identified than those of distinctiveness rating D3 (Pennycuick 1978). However, unequal capture probability is a potential problem in all photo-identification data sets and is not a problem unique to sea otters (Pennycuick 1978, Arnbohm 1987, Friday *et al.* 2000, Whitehead 2001).

Methods of individual identification in sea otters based on artificial marks also have their problems. In general, sea otters are very difficult to mark because they are able to manipulate a tag placed anywhere on their body and no marks that interfere with the coat may be used as this may affect their ability to thermoregulate (Thomas *et al.* 1987). One of the most commonly used marks is a colored plastic tag attached to the hind flipper. These tags are relatively inexpensive, but require capture and restraint, if not immobilization, for attachment (Thomas *et al.* 1987). Once attached, many animals bite and manipulate the tags causing their removal, although many also ignore them (Siniff and Ralls 1991). This marking system then, although very useful, lacks stability and may be susceptible to bias due to unequal capturability of individuals (like photo-identification), and also introduces the possibility of disruption and injury to the animal due to capture and restraint. Radio transmitters have been attached to the neck (Estes and Smith 1973, Loughlin 1980, Garshelis and Siniff 1983), ankle (Garshelis and Siniff 1983), hind flipper (Ribic 1982, Garshelis and Siniff 1983, Garshelis and Garshelis 1984) and implanted both subcutaneously and intraperitoneally (Garshelis and Siniff 1983, Garshelis and Garshelis 1984, Ralls *et al.* 1989). Neck and ankle attachments were unsuccessful (Estes and Smith 1973, Garshelis and Siniff 1983). Hind flipper attachments have been used more commonly, but Garshelis and Siniff (1983) reported

they were typically removed within three months, had reduced reception after three weeks due to broken antennas, appeared to be a source of annoyance to the otters, and frequently caused injury to the hind flipper. Intraperitoneal radio transmitter implants have been very successful (Garshelis and Siniff 1983, Ralls *et al.* 1989). The more recent models have allowed otters to be located over 526 days (Ralls *et al.* 1989) and almost no complications have been reported. Intraperitoneal implants as a marking method may be superior to photo-identification in terms of stability and potentially provides more information on individuals as they can be located over long distances and as frequently as the observer wishes. However, although reports of complications are few, it is a very invasive procedure that requires capture (which may not be equal among individuals), chemical immobilization, incision, and release with only a short recovery, all of which impose physical danger and stress on the animal. In addition, the transmitters and the procedures associated with them can be costly (Ralls *et al.* 1989), reducing the number of individuals that may be monitored.

The decision to use photo-identification of sea otters will depend on the application. Examples of applications of photo-identification in other marine mammals that might be used for sea otters are studies of short-distance movements and habitat use, breeding and other social interactions, female reproduction, pup dependency, and other life history parameters. For instance, without specifically designing this study for these applications, photo-identification surveys provided enough information to estimate the birth date of 4 pups, the death date of 2 pups, and the reproductive output of 4 females that were seen between years. Photo-identification has recently been applied to a study

of male territoriality by Pearson *et al.* (in prep). One application for which photo-identification may not be useful in sea otters is mark-recapture estimates of population size as this requires both permanence of markings and equal catchability (IWC 1990).

Overall, photo-identification of sea otter nose scars appears to be a promising new method for identifying individual sea otters. It allows almost half of all individuals in a population to be recognized and, with the right study design, may have many applications. The next recommended step in evaluating its potential is a study that combines artificial tags and photo-identification which will supply information on the stability of nose scars and allow the two identification methods to be directly compared.

SUMMARY

Boat-based surveys were used to determine sea otter locations in Simpson Bay, Prince William Sound, Alaska during the summers of 2001-2003. Beginning in 2002, digital images of the face were taken for all approachable otters during the surveys. Over 640 hours during 127 days were spent in conducting otter surveys over the three years. Sea otters were encountered during every survey with a total of 2013 encounters. Images were obtained during 1765 of those encounters.

The habitat of Simpson Bay was characterized by collecting depth measurements and sediment samples at 198 stations throughout the bay along a rectangular grid. Sediment samples were subjected to grain-size analysis. Habitat data were used to create full-coverage maps of bathymetry and sediment type. Average and maximum depth within the bay were 30m and 125m respectively. Mud (silt and clay) was the predominant sediment type. Water depth and sediment type were correlated with larger grain sizes (gravel and sand) more frequent in shallow depths along the edges of the bay and finer sediments (mud) in the deeper depths in the center of the bay.

Habitat associations of sea otters were examined by overlaying feeding and resting locations from the boat-based surveys on the sediment and bathymetry maps. Depth, sediment type, distance from shore, and position in the bay (peripheral vs. central) was determined for sea otter locations and a set of random unused locations. Logistic regression analysis was used to compare sea otter locations to unused locations. Results indicate that habitat use is not uniform during either feeding or resting behavior.

Water depth was the most significant habitat association for feeding behavior, with the majority of feeding dives occurring in shallow water less than 20m deep. Position in the bay was the most significant habitat association for resting behavior, with more otters resting in the center of the bay. Logistic regression analysis comparing locations of the two behaviors showed water depth to be the habitat variable that most strongly distinguished between feeding and resting habitat.

Digital images taken during the otter surveys were used to examine the possibility of using sea otter nose scars to photo-identify individuals. Images were rated for quality and individual distinctiveness. Out of 816 high quality images, 114 individual sea otters were identified, representing 19 males, 45 females, 1 pup, and 49 adults of undetermined gender. Eight individuals (19% of those identified in 2002) were seen in both years. Overall, forty-five percent of individuals encountered were considered identifiable, which compares favorably with the results of photo-identification studies of other marine mammals. These results indicate that photo-identification of nose scars has great potential as a method of identifying individual sea otters.

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Gilkinson, A.K. and R.W. Davis. "Habitat Associations of Sea Otters in Prince William Sound." Poster presentation and abstract. Biennial Conference on the Biology of Marine Mammals, Greensboro, NC. December 2003