

**Nearshore Marine Vital Signs Monitoring
in the
Southwest Alaska Network of National Parks**



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Acronyms:

ASC	Alaska Science Center
CRA	Coastal Resource Associates
GIS	Geographic Information System
I&M	Inventory and Monitoring
NPS	National Park Service
SWAN	Southwest Alaska Network
KATM	Katmai National Park and Preserve
KEFJ	Kenai Fjords National Park
USGS	US Geological Survey

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Abstract:

In 2007, we successfully completed the second year of development and field sampling for the Southwest Area Network's (SWAN) Nearshore Vital Signs monitoring program. The protocol narrative for the program was revised, standard operating procedures (SOPs) were revised based on 2006 sampling, and standardized data entry and database management functions were further developed. In addition, sampling was conducted in accordance with protocols set forth for each of six vital signs (kelp and seagrass, marine intertidal invertebrates, marine birds, black oystercatcher, sea otter, and marine water chemistry and quality). At Katmai National Park and Preserve (KATM), we tested several newly developed preliminary sampling protocols for kelp and eelgrass; measured water temperature; collected mussel tissue for estimation of levels of contaminants; and conducted a second year of sampling for marine intertidal invertebrates and algae, marine birds, black oystercatchers and sea otters. Methods for evaluating the abundance of eelgrass provided sufficient confidence to allow us to develop a SOP for implementation of monitoring in 2008. Methods for estimating the abundance of kelp were unsatisfactory and will be reevaluated. Temperature data were obtained from two sites and mussel tissues were obtained from six sites and have been submitted for analysis for a suite of heavy metal and organic toxicants. Newly established sites were sampled to estimate the abundance of clams on sand-gravel beaches. A second year of sampling was conducted to estimate species composition and abundance of intertidal invertebrates and algae on rocky shores; estimate species composition and abundance of marine birds; estimate abundance, nesting success, and prey composition black oystercatchers; and estimate survival and prey composition for sea otters. Aerial surveys for estimation of sea otter abundance were postponed until 2008 because of difficulties in obtaining plane charters. As of yet there is insufficient data for establishing meaningful trends in any of the metrics examined, but for those in which we have two years of data, there was relatively little inter-annual variation and no alarming trends. At Kenai Fjords National Park (KEFJ) we conducted preliminary eelgrass surveys; deployed instruments to measure temperature; collected mussels for contaminant analyses; established sites for sampling of intertidal invertebrates; established and sampled sand-gravel beaches for estimation of the abundance of clams; conducted marine bird surveys; estimated abundance, nesting success, and prey composition for black oystercatchers; estimated abundance, survival, and prey composition for sea otters. In 2008, we plan to continue revision of the sampling protocol and SOPs, continue to develop data entry and data management procedures, and continue sampling of vital signs at both KATM and KEFJ. Sampling will include an initial winter survey of birds, initial sampling of invertebrates and algae on rocky shores in KEFJ, and an initial aerial survey of sea otter abundance at KATM.

Executive Summary

Introduction

In 2007, we continued the development of the SWAN Vital Signs Monitoring Program for the nearshore marine habitat. The goal of the program is to evaluate the status of the nearshore marine resources within the SWAN network. The program focuses on 6 “vital signs” that provide a means of evaluating the nearshore. These are: kelp and seagrass, marine intertidal invertebrates, marine birds, black oystercatcher, sea otter, and marine water chemistry and quality. This annual report summarizes the accomplishments with a focus on presentation of data obtained in 2007.

Reporting and database development

Over the past agreement period, we have revised the Protocol Narrative and Standard Operating Procedures (SOPs) for each of the vital signs based on comments of the reviewers and submitted a report summarizing field activities in 2007. We anticipated that further revisions to both the Protocol Narrative and SOPs as the program develops and will be provided as required. In addition, we have continued to develop data entry and data management protocols. A more automated data entry procedure was established for sampling of marine invertebrates and several other similar data entry modifications are being currently being developed. A contractor has been hired to assist us in further development of databases and data management procedures and initial steps have been taken to develop Microsoft Access databases for several vital sign metrics.

2007 sampling

In 2007, we conducted a second year of sampling at Katmai National Park and Preserve (KATM) and initiated sampling at Kenai Fjords National Park (KEFJ). The following summarizes the work for each of the six vital signs.

Kelps and seagrass

Preliminary surveys and tests of methods for sampling of kelp and eelgrass were carried out in KATM and KEFJ in 2007. The abundance of canopy forming kelps was evaluated using a variety of techniques including visual counts of individual plants on the surface, sonar estimates of plant cover, and underwater video estimates of cover. None of these methods produced reliable estimates of kelp abundance. We will continue to evaluate methods for evaluating this vital sign. Eelgrass abundance was estimated using an underwater video system in conjunction with a GPS. The underwater video system proved a valuable tool in estimating cover by eelgrass, but synchronization of the GPS positioning and underwater video observations need improvement. Based on these preliminary tests of methods, an SOP for estimating eelgrass abundance is being developed and will be implemented in 2008 at both KATM and KEFJ.

Marine intertidal invertebrates

At KATM in 2007 we estimated species composition abundance of marine intertidal invertebrates and algae at five sites on rocky shores that were initially sampled in 2006 and at a newly established site. Predominant algal and invertebrate species included the brown algae *Fucus gardneri* and *Alaria* sp., several species of red algae, barnacles, and several species of limpets and snails. There was little change

in the number of species and relative abundance of most species between 2006 and 2007. An increase in cover by *Alaria* and a decrease in cover by the red alga *Pterisiphonia bipinata* were noted, but it is not clear whether these changes represent region-wide trends or normal inter-annual variation. At KEFJ, we established five new rocky intertidal sampling sites. The sites were marked and slope characteristics were measured. We were able to sample at only one of these and sampling at all sites will be initiated in 2008.

Sampling was initiated at sand-gravel beaches at six sites in KATM and at five sites in KEFJ during 2007 to estimate the species composition and abundance of clams. Nine clam taxa were observed at KATM and 10 at KEFJ. At both KATM and KEFJ the predominant clam was *Macoma* spp.

Marine birds

Marine birds were surveyed at both KATM and KEFJ in 2007. This was the second year of sampling of marine birds at KATM. Thirty-one taxa of marine birds were identified, with glaucous-winged gulls, black-legged kittiwakes, and tufted puffins the most common. Of species generally associated with the nearshore, harlequin ducks, surf scoters, and mergansers (both common and red-breasted) were most abundant. The relative abundances of most species were generally similar in the two parks, although somewhat higher densities of tufted puffins and harlequin ducks were noted at KATM.

Black oystercatcher

Thirty-two active black oystercatcher nest sites were found at KATM and 7 nest sites were found at KEFJ (on 6 and 5 transects of approximately 20 km in length at each park, respectively). At KATM, 69% of the sites had eggs or chicks present and there was an average of about 1.8 chicks or eggs per nest. A larger percentage of sites (86%) were active at KEFJ and active nests had an average of 1.7 eggs or chicks per nest. Numbers of black oystercatchers were similar at KATM in 2006 and 2007, totaling 93 (se=1.2) and 85 (se=0.73), respectively, on the 5 transects sampled in both 2006 and 2007. Only half of the active nests found at KATM in 2006 were active in 2007, but it is unclear if this represents “abandonment” or relocation of birds to nearby nest sites.

Limpets and mussels were the dominant prey items represented in the shell remains at black oystercatcher nest sites. The prey composition varied greatly among nest sites but was relatively consistent among years at sites in KATM that were sampled in both 2006 and 2007. At KEFJ, mussels comprised 48% and limpets 52% of the prey remains collected, compared to 18% mussels and 77% limpets at KATM. The greater proportion of mussels in the diet of black oystercatchers at KEFJ is consistent with greater proportions of mussels observed in the sea otter diet and suggestive of a greater reliance of the higher trophic levels on mussels at KEFJ compared to KATM.

Sea otter

For sea otters, we completed an aerial survey to estimate abundance of sea otters in KEFJ, estimated density and distribution of adults and pups from boat surveys, examined diets, and collected sea otter carcass specimens for determination of age at death. We were unable to conduct an aerial survey at KATM because aircraft were not available. This survey will be completed in summer 2008. Based on 2007 aerial survey results, we estimated the abundance of sea otters at KEFJ was 1511 (se = 625). In boat based surveys, we estimated the ratio of adults to pups at approximately 5:1 at KATM and 3:1 at KEFJ. At KATM, the ratio of adults to pups was similar to that observed in 2006 at approximately 5:1

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adults to pups.

Sea otters were successful at obtaining prey (87% of the foraging dives in KATM and 91% of foraging dives in KEFJ resulted in obtaining prey.) At KATM, clams were the predominant prey item, consisting of 71% of the prey items identified. The prey composition was similar to that observed at KATM in 2006 with almost 80% of the diet consisting of clams. Mussels were a much more important part of the diet for sea otters at KEFJ making up 53% of the prey items identified.

Of the sea otter carcasses found at KATM in 2006, approximately two-thirds were juveniles. Such a high proportion of young animals suggests that the population is newly founded and has not reached a stable age distribution. Carcasses collected from KATM in 2007 are currently being analyzed to determine age at death. Only one carcass was obtained from KEFJ in 2007, and additional efforts are planned to collect a larger number of carcasses there in 2008.

Marine water chemistry and quality

Temperatures were recorded at an elevation of 1.5 m above mean lower-low water (MLLW) at two sites in KATM in June 2006 through June 2007. The seasonal patterns of temperature were similar at both sites, with a maximum yearly range of over 40° C (from less than -10° C to greater than 30° C), and ranges of greater than 20° C occurring on some days. The largest daily excursions in temperature were observed during periods of Spring tides, when periods of exposure to air were greatest. Temperature recording devices placed at three additional sites in KATM in 2006 were lost. New recording devices were placed at all rocky intertidal sampling sites in both KATM and KEFJ in 2007.

Mussels were collected from six intertidal sites at KATM and from five sites at KEFJ in 2007. These samples were submitted to an analytical laboratory for determination of levels of metal and organic contaminants. Results are not yet available.

Planned sampling activities for 2008

Field surveys to evaluate each of the vital signs are slated for 2008. In addition to the activities conducted in 2007, we will initiate sampling of eelgrass at KATM and KEFJ, initiate sampling of intertidal invertebrates on rocky shores in KEFJ, conduct winter surveys of marine birds at both KATM and KEFJ, and conduct an aerial survey of sea otter abundance at KATM. It is anticipated that modifications will be made to standard operating procedures for most vital signs. The major modifications will include a reduction in effort in sampling intertidal invertebrates on rocky shores and evaluation of methods for estimating size and abundance of mussels.

1 Introduction:

Variation in species composition and abundance over time is a ubiquitous feature of ecosystems. Such variation is evident in historical records that long precede modern human occupancy across the globe. However, ecosystems and populations worldwide are increasingly influenced by human activities, largely as a consequence of requirements imposed by continually increasing and expanding human populations. Conservation and restoration of functioning ecosystems will be facilitated by minimizing adverse human effects such as habitat modification and pollution. In order to manage and mitigate the affects of human activities on ecosystems, it will be essential to understand the relative contribution of human versus non-human sources of ecosystem change. Therefore, perhaps no other activity is more fundamental to the long-term conservation of ecosystems than the acquisition of data that describes changes in ecosystems over time that promotes understanding of the causes of those changes.

In 2006 we implemented the nearshore monitoring protocol in Katmai National Park and Preserve (KATM). The protocol incorporates sampling of six SWAN vital signs; marine water quality, kelps and seagrasses, marine invertebrates, marine birds, black oystercatcher (*Haematopus bachmani*), and sea otter (*Enhydra lutris*). In 2007, we continued implementation of the nearshore protocols in KATM as well as implementing them for the first time in KEFJ. Taken collectively, data describing each of these vital signs over time should provide a powerful tool to both describe change in nearshore ecosystems, and to provide inference about the cause of those changes. Following is a brief description of each of these “vital signs”. One or more standard operating procedures (SOP) provide explicit detail on methods to estimate specific vital sign metrics (Dean and Bodkin 2006).

Marine water chemistry, including temperature and salinity, is critical to intertidal fauna and flora and are likely to be important determinants of both long-term and short-term fluctuations in the intertidal biotic community. Basic water quality parameters provide a record of environmental conditions at the time of sampling and are used in assessing the condition of biological assemblages.

Kelps and seagrasses are “living habitats” that serve as a nutrient filter, provide structural habitat for planktivorous and predatory fish, clams, urchins, and a physical substrate for other invertebrates and algae. The kelps and seagrasses also provide spawning and nursery habitats for forage fish and juvenile crustaceans. Kelps are major primary producers in the marine nearshore and because they are located in shallow water they could be significantly impacted should there be an oil spill. Other stresses include activities that disturb the beds directly such as dredging and anchor scars, events that reduce the ability for light to penetrate into the water column, such as runoff (increased turbidity) or nutrient addition.

Marine intertidal invertebrates provide a critical prey resource for shorebirds, ducks, fish, bears, sea otters, and other marine invertebrate predators. Benthic invertebrates are ecologically diverse in terms of habitat and trophic requirements; have a wide range of physiological tolerances and feeding modes; are relatively sedentary and have short generation times. They integrate environmental conditions over relatively long periods of time (up to decades) and are therefore good biological indicators of change.

Marine birds are predators near the top of marine nearshore food webs. Marine birds are long-lived, conspicuous, abundant, widespread members of the marine ecosystem and are sensitive to change. Relations between environmental conditions and sea bird behavior, diet, productivity, and survival are well documented. Public concern exists for the welfare of seabirds because they are affected by human

activities like oil pollution and commercial fishing. Because of these characteristics, marine birds are good indicators of change in the marine ecosystem.

Black oystercatchers are well suited for inclusion into a long-term monitoring program of nearshore habitats because they are long-lived; reside and rely on intertidal habitats; consume a diet dominated by mussels, limpets, and chitons; and provision chicks near nest sites for extended periods. Additionally, as a conspicuous species sensitive to disturbance, the black oystercatcher would likely serve as a sentinel species in detecting change in nearshore community resulting from human or other disturbances.

Sea otters (Western Alaska Stock) were federally listed in October 2005 as threatened under the Endangered Species Act. Sea otters dramatically change the structure and complexity of the nearshore ecological community and are a prime example of the top-down cascade type of interaction web where the highest trophic level can determine the populations of the lower trophic levels. Sea otter tend to be relatively sedentary in comparison to other marine mammals; eat large amounts of food and are readily observable; may be susceptible to contaminant associated disease; and have broad appeal to the public.

In this report we summarize results of sampling and testing of nearshore vital sign protocols conducted in 2007. All of the work was done in KATM and KEFJ (Figure 1.1). This is the initial phase of a program that will incorporate sampling in Lake Clark National Park and Preserve (LACL) in coming years (Dean and Bodkin 2006). In addition we provide recommendations for improving future data collection through revision of the nearshore protocol and the associated SOPs. The results provided are primarily descriptive.

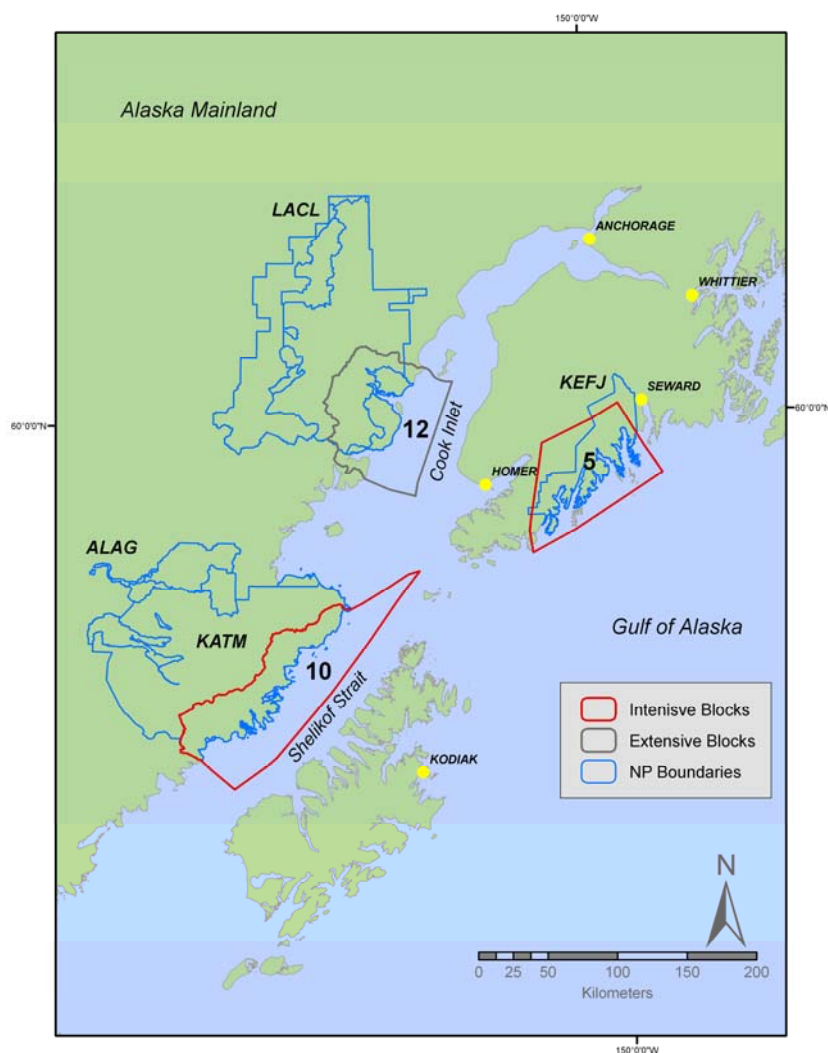


Figure 1.1. Sampling locations for the SWAN nearshore vital signs monitoring. Intensive sampling blocks (indicated in red) are locations for monitoring of all vital signs. Less frequent monitoring of a limited number of vital signs is to be conducted in the extensive block at LACL (indicated in grey). Sampling block numbers are those assigned as part of a larger Gulf of Alaska wide sampling design. Park boundaries are indicated in blue.

The report is organized by the six vital signs identified above. The objectives for each vital sign are:

Marine water chemistry

- Acquire regional synoptic nearshore oceanographic data collected by the Alaska Ocean Observing System (AOOS) and incorporate into regional (SWAN) data sets.
- Document daily, seasonal, and annual variability and gradients in temperature and salinity at randomly selected shallow water (<20 m) nearshore sampling sites.
- Collect mussel (*Mytilus trossulus*) tissue for contaminant analysis.

Kelps and seagrasses

- Estimate long-term trends in abundance and distribution of kelps and seagrass.
- Estimate intertidal algal diversity.

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- Estimate species composition and percent cover of intertidal algae at two tidal levels (+0.5 and +1.5 m).

Intertidal invertebrates

- Estimate percent cover of dominant sessile intertidal invertebrates (e.g. barnacles, mussels, snails, and limpets).
- Estimate densities of large intertidal invertebrates (e.g. stars, chitons, urchins).
- Document how the size distribution of limpets (*Tectura persona*) and mussels (*Mytilus trossulus*) is changing annually.
- Estimate long-term trends in abundance of littleneck clam (*Protothaca staminea*).
- Document how the size distributions and growth rates of littleneck clams are changing annually.
- Monitor status and trends in the concentration of metals, organochlorides, PCBs, and mercury in mussel tissue.

Marine birds

- Estimate densities (se) of marine birds and mammals in coastal transects.
- Document change in populations of marine birds and mammals over time.

Black oystercatcher

- Estimate black oystercatcher density (se) in coastal transects.
- Estimate black oystercatcher nest density.
- Estimate number of eggs/chicks per nest.
- Estimate species composition and sizes of prey returned to nests.
- Document change in black oystercatcher density, productivity, and diet over time.

Sea otter

- Estimate sea otter density (se) in coastal transects.
- Estimate prey species composition, prey number, and prey sizes.
- Estimate forage dive attributes (success, dive times, surface times).
- Estimate energy recovery rates of foraging sea otters.
- Estimate age class distribution of beach cast sea otters.
- Document change in sea otter density, diet, and survival over time.
- Estimate sea otter abundance by aerial surveys

Sampling protocols, including evaluation of kelps and seagrasses, sampling of invertebrates in soft sediments, and aerial surveys of sea otter abundance were initiated in 2007. The sea otter aerial survey was only conducted in KEFJ. In 2008, an aerial sea otter survey will be completed in KATM. Soft sediment sampling was successfully implemented in both KATM and KEFJ. Kelp and eelgrass bed sampling protocols were tested in each park, but will be fully implemented in 2008 after SOP revision.

In addition to the field testing of the nearshore monitoring protocol and associated SOPs, several other tasks were identified under the 2006 Inter-Agency Agreement between the National Park Service and the U.S. Geological Service Alaska Science Center (USGS, ASC). These included: 1) Review and revision of the draft monitoring protocol; 2) Review and revision of each of the SOPs; 3) Design, development, and testing of data management plans specific to the protocol and each SOP. The following summarizes the progress made toward accomplishing each of these tasks.

In 2006 we drafted a monitoring protocol for sampling nearshore vital signs in SWAN national parks. The protocol received initial review by SWAN staff prior to field testing in spring and summer 2006. Following the initial field testing, the protocol was reviewed and is undergoing additional revision to incorporate lessons learned during 2006-2007 field trials and additional design considerations. We anticipate that a revised protocol will be completed prior to continuation of field testing in KATM and KEFJ in summer 2008.

In 2006 draft SOPs were completed providing a background and rationale for the inclusion of the data collection associated with each nearshore vital sign and describing each data collection procedure. The water chemistry/temperature vital sign data collection procedures are described in the HOBOSOP and the rocky intertidal algae and invertebrate SOP. The rocky intertidal algae and invertebrate SOP is under revision and will be submitted to NPS for review and revision in 2008. Following NPS review this SOP will be submitted for additional external peer review.

The SOP to monitor the subtidal seagrass and kelps vital sign has not been completed. Intertidal kelps are sampled under the intertidal algae and invertebrate SOP. During the field trip to KATM in summer 2006 seagrass and canopy forming kelp beds were identified and preliminary sampling methods conceived. In 2007 we explored skiff based sampling methods using fathometers, GPS, underwater video, and observations of kelp surface canopies to monitor this vital sign. We anticipate drafting a SOP for seagrass and kelp monitoring in 2008, following field surveys and testing.

The marine intertidal invertebrate vital sign is monitored under two SOPs: the rocky marine algae and invertebrate SOP identified above, and the soft sediment invertebrate SOP. The soft sediment intertidal invertebrate SOP has been drafted and is under revision. The revised draft was completed prior to field testing in KATM and KEFJ in 2007. Field testing was completed in both KATM and KEFJ in 2007.

The marine bird vital sign is monitored under the marine bird and mammal SOP. This SOP has been extensively field tested and applied in Prince William Sound, SE Alaska, Cook Inlet and the Kenai Peninsula, and Kodiak Island since 1984. The marine bird and mammal SOP as drafted includes only sampling of transects adjacent to shorelines. This SOP may be revised in 2008 following field testing of the addition of a subset of transects that sample marine waters perpendicular to the shoreline.

The black oystercatcher vital sign is monitored under the black oystercatcher nest density/occupancy and chick diet SOP. This SOP was drafted and revised in 2006 incorporating outside peer review, prior to field testing during summer 2006 at KATM. Further field testing and SOP review is anticipated in 2008.

The sea otter vital sign is monitored under the sea otter aerial survey SOP, the sea otter forage SOP, and the coastline survey SOP. The sea otter aerial survey SOP has been implemented in Prince William Sound, SE AK, Kodiak, and Cook Inlet and the Kenai Peninsula, incorporates peer review and has been published. An aerial survey was completed in KEFJ in 2007. An aerial survey is currently scheduled for KATM in 2008. The sea otter forage SOP has been implemented at many locations throughout the sea otters' range and has undergone peer review and employed in multiple publications. Both of these SOPs have received USGS, ASC Institutional Animal Care and Use Committee approval. The coastline survey SOP was drafted and field tested in 2006 in KATM. The collection of sea otter carcasses was one of the main objectives in this SOP with the purpose of monitoring sea otter mortality through estimates of ages at death obtained from beach cast carcasses. Preliminary field efforts in 2006 indicate

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that sea otter carcasses in KATM may be more efficiently acquired through collections of carcasses at haul-out sites. In 2007, collections of carcasses were focused on the haul-out sites within KATM. No haul-outs or beach transects were established in KEFJ in 2007. Revision of this SOP will consider the relative value of the sea otter component compared to the monitoring of other beach-cast species or debris.

Development of a data management plan to guide data collection, quality, integrity, and analysis was an identified task and initiated in 2006. This effort was in collaboration between USGS and NPS staff. Design and development of data management plans specific to the nearshore monitoring protocol, and each SOP will benefit from having a protocol and SOP that have undergone field testing and at least preliminary validation. In 2006, following preliminary protocol implementation and SOP testing we began drafting database flow charts, data structures, and data entry procedures, beginning with those SOPs that have undergone prior field testing and implementation at other locations. Data management development will continue in 2008-2009, proceeding from the most well-developed SOPs to the least.

2 Intertidal Invertebrates and Marine Water Quality

INTRODUCTION

Intertidal invertebrate and algal communities provide an important source of primary production; are an important conduit of energy, nutrients, and pollutants between terrestrial and marine environments; provide resources for subsistence, sport, and commercial harvests; and are important for recreational activities such as wildlife viewing and fishing. The intertidal is particularly susceptible to human disturbance including oil spills; trampling by recreational visitors; harvesting activities; pollutants from terrestrial, airborne and marine sources; and shoreline development. Changes in the structure of the intertidal community serve as valuable indicators of disturbance, both natural (e.g. Dayton 1971, Sousa 1979) and human induced (e.g. Barry et al. 1995; Keough and Quinn 1998, Jamieson et al. 1998; Murray et al. 1999; Shiel and Taylor 1999; Sagarin et al. 1999; Peterson et al. 2001, 2003).

In this section, we describe results of intertidal sampling conducted in 2006 and 2007 in KATM and in 2007 in KEFJ. This chapter is divided into sections describing results from sampling along rocky shores and on gravel/sand beaches, and further subdivided with respect to sampling within KATM and KEFJ respectively. For the rocky intertidal, we focus on results from sampling at five sites in KATM sampled in both 2006 and 2007. Five rocky intertidal sampling sites were established in KEFJ in 2007, but only one was sampled and results for that site will not be reported here. Sampling of intertidal invertebrates and algae at these sites is designed to detect changes in these communities over time as part of the SWAN Vital Signs program. The specific objectives of this sampling on rocky shores are to assess changes in: 1) the relative abundance of algae, sessile invertebrates, and motile invertebrates in the intertidal zone, 2) the diversity of algae and invertebrates 3) the size distribution of limpets (*Tectura persona*) and mussels (*Mytilus trossulus*), and 4) the concentration of contaminants in mussel tissue, and temperature (either sea or air depending on tidal stage). For sand/gravel shorelines, we focus on results from sampling at 6 sites at KATM and five sites at KEFJ established and sampled in 2007. Specific objectives are to assess changes in: 1) the relative abundance of clams in the intertidal zone, 2) the diversity of clams, and 3) the size distribution of numerically abundant clam species (including *Protothaca staminea* and *Macoma* sp.). For both rocky sand sand/gravel sampling, we will focus on a general description of sampling activities conducted in 2006 and 2007, and give a description of the communities at each of the sites sampled.

METHODS

Rocky Intertidal - Sampling was conducted at five sites in sheltered rocky habitats within KATM in both 2006 and 2007 (Figure 1.1). Sampling was only conducted at one site in KEFJ (KP-B5-RI4), but four remaining sites were established and sampling will be conducted in 2008 (Figure 1.2). These sites were selected using a GRTS sampling protocol (Stevens and Olsen 2004) designed to provide a random, spatially balanced design. The shoreline classification system used to identify sheltered rocky habitat has known errors (Sundberg et al. 1996) and in several instances, initial visits to potential sampling sites found predominantly gravel or mixed sand and gravel substrates. In these instances alternate nearby sites from the ordered GRTS list were substituted. One additional site (AP-B10-RS1) was established in 2007 at KATM and will be sampled in 2008. This site at Ninagiak Island was specifically selected for sampling because it represented a site of high productivity (e.g. an important nesting area for many birds) and was of special interest.

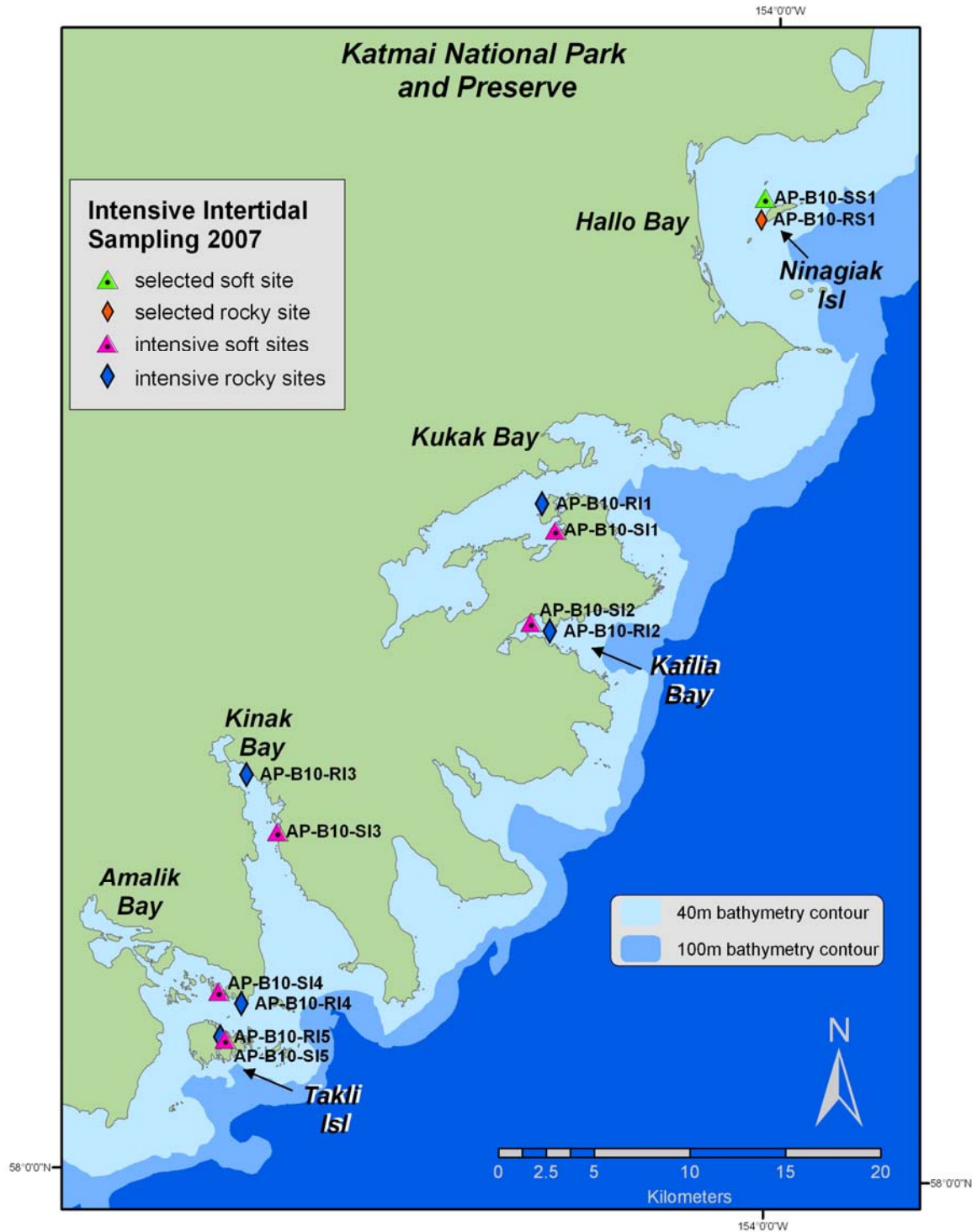


Figure 2.1. Locations of rocky and soft intertidal sites (RI1 - RI5 and SI1 - SI5) sampled in KATM 2007. Two additional selected sites (RS1 and SS1) were established and the soft site was sampled in 2007 and the rocky site will be sampled in 2008.

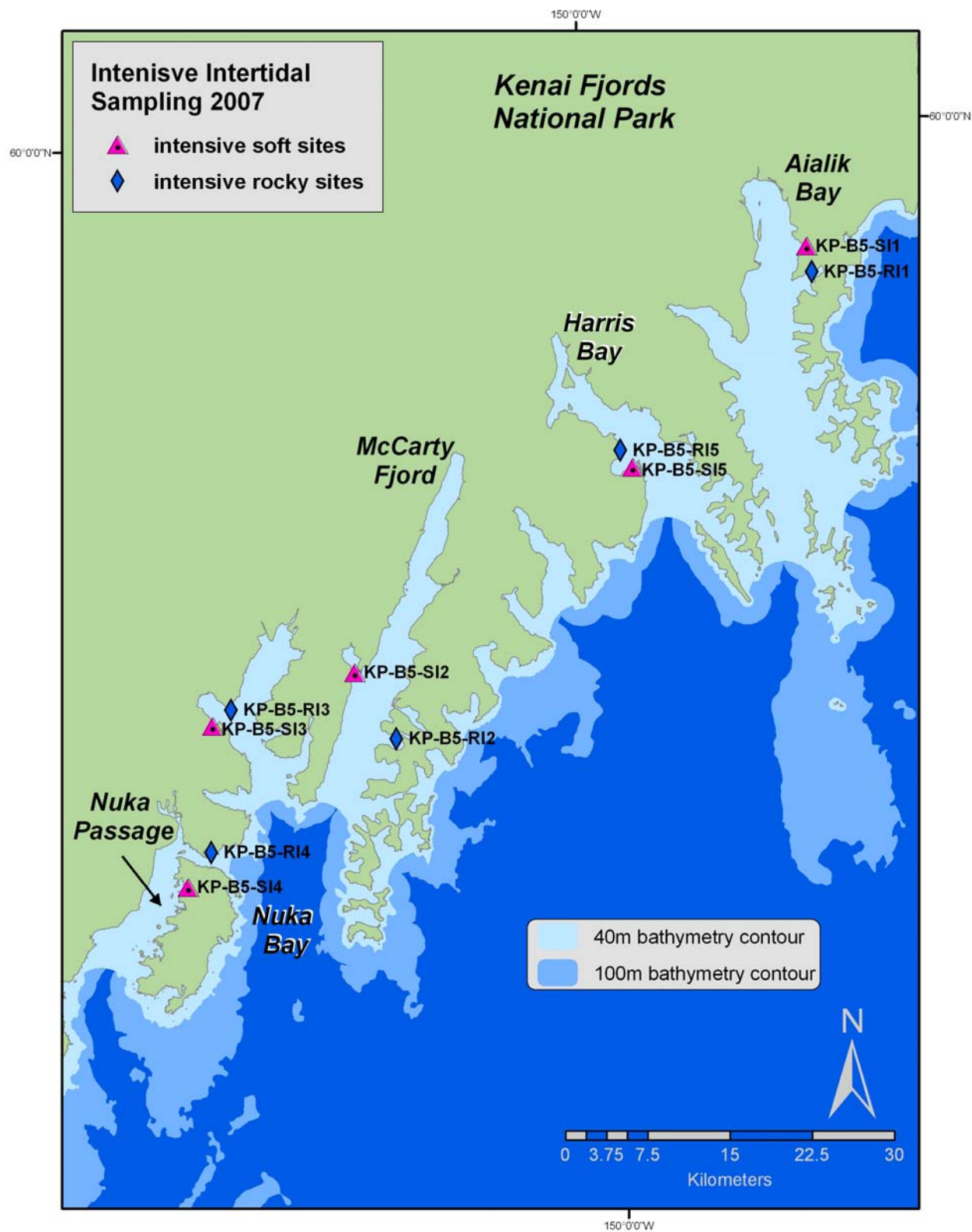


Figure 2.2. Five rocky and five soft sites were established in 2007 in KEFJ. Only one of these rocky sites (AP-B5 -I4) was sampled in 2007. All five soft sites were sampled in 2007.

Permanent markers were installed at the 0.5 m and 1.5 m tidal elevations at each site. A “Hobo” temperature recording device was placed at the 0.5 m marker at each site. Slope profiles were measured at each site. The profiles for GRTS sites in KATM are reported in Bodkin et al. (2007). The profiles for KEFJ are in table 2.5 of this report.

Detailed descriptions of the methods used to sample intertidal algae and invertebrates as well as water temperature are available in Dean and Bodkin 2006. The following is a general description of the methods employed. A 50-m (in 2007) to 100-m long (in 2006) tape was stretched from each marker along the shoreline parallel to the waters edge. In 2006, we counted the number of sea stars and sea urchins within a 4 m wide band that extended 4 m upslope from MLLW along a 100 m transect at each site. Only those individuals that were visible without moving rocks or overlying algae were counted. Large sea stars and sea urchins were not sampled in 2007. The percent cover of substrate types, percent cover of algae, percent cover of sessile invertebrates, and counts of motile invertebrates were estimated within 12 evenly spaced $\frac{1}{4}$ m² quadrats placed along transects that were parallel to the shoreline at the 0.5 m and 1.5 m tidal elevations respectively. Quadrats were placed at a random start points and at equally spaced intervals thereafter. Percent cover estimates and counts of small motile invertebrates were made within 0.25 m² quadrats. Intermediate-sized motile invertebrates (primarily larger snails and limpets) were counted within one square meter quadrats. Percent cover was estimated visually (for substrate type) or by estimating the percentage occurrence under 49 systematically placed points within each quadrat.

A minimum of 114 individual limpets (*Tectura persona*) were measured at each site for estimation of size distributions. Duplicate samples of 60 large mussels were collected to provide tissue for determination of contaminants (metals and organics).

Sand and Gravel Beaches Intertidal – The sampling protocol was similar to that detailed in Bodkin and Kloecker, (1999, and Bodkin et al. 2000) and was adapted from an intertidal clam sampling protocol originally used in Prince William Sound, Alaska (Appendix A). These sites were selected using a GRTS sampling protocol (Stevens and Olsen 2004) designed to provide a random, spatially balanced sample. Once all the potential soft sediment sites were identified, due to logistics, only the soft sediment sites that were located in proximity to the rocky sites were examined as potential permanent soft sediment sites. Presence of shell litter was the indicator used to decide on a sampling location. If there was no shell litter present or some other aspect of the GRTS segment was not conducive to invertebrate recruitment, alternate nearby sites from the ordered GRTS list were substituted. A handheld GPS was used to navigate to the segment. At each site a 50m transect was positioned horizontally along the beach at the +0.5 m MLLW tide level. A random starting meter was chosen and twelve 0.25 m² quadrats placed roughly 4.2 m apart were excavated to a depth of 25 cm (Figure 2.3). On site, all sediments were sieved through a 10 mm mesh screen and all clams (as well as crabs, mussels, and urchins at most sites) were identified to the lowest possible taxa, counted, and measured to the nearest millimeter using dial calipers. Sediments were returned to the quadrat during the sieving process, whereas biota was returned following measurements. Sediment core samples for grain size analysis were collected from 3 quadrats and each site. The samples from each site were composited prior to shipment for analysis.



Figure 2.3. a. Quadrat frame placed along transect line prior to sampling. b. mussels, urchins, crabs, and other visible biota are removed from the surface by hand prior to digging to avoid crushing them; c. pits are excavated to 25 cm; d. sediments are sieved on site through 10 mm mesh (14 mm diagonal) and clams are retained for identification and measurement.

At each site, we measured the abundance (number of individuals per unit area) of larger bivalve species (e.g. *Protothaca staminea*, *Clinocardium* sp., *Macoma* sp., *Mya arenaria*, *Mytilus trossulus*, and *Saxidomus gigantea*) and the size distributions of any species observed in large enough numbers. For some sites, notable coverage of *Mytilus trossulus* was present, so we counted and measured the mussels from the quadrats as well.

For each site sampled we calculated the following: 1) Shannon-Weiner diversity index (H') for clam species only, 2) mean density of clams / 0.25 m^2 by species and in aggregate, 3) mean biomass ($\text{g}/0.25 \text{ m}^2$) by species and in aggregate, and 4) the size class distribution of clams collected from each area by species. Biomass was calculated by multiplying the length of the clams by a dry weight conversion factor distinctive for each species. Because the data set collected to date is intended to be compared against identical data collected from the same sites in the future, we do not perform or report statistical tests of significance in this report.

A modification of the Wentworth scale for substrate classification protocol was used to categorize the primary and secondary substrate of each quadrat. The primary substrate (Table 2.1) is the type that comprised a majority of the volume of the excavated sediments while a secondary substrate was the next most abundant type based on visual estimates.

Table 2.1. Substrate descriptions used for sediment classification.

Substrate Type	Description	Diameter
Boulder/Cobble	Billiard ball to > head	64 - > 256 mm
Pebble/Gravel	BB to billiard ball	2 - 64 mm
Coarse Sand	Pin head to BB	1 - 2 mm
Fine Sand/Silt/Mud/Clay	Fine, non-gritty to pin head	. - 1 mm
Mixed	Mixture of > 2 types	.

RESULTS

KATM

Rocky Intertidal - The number of algal and sessile invertebrates species observed at each of the two tidal elevations at each site in 2006 and 2007 ranged from 12 to 22 (Table 2.2). At the lower elevation (0.5 m) dominant species included *Fucus*, barnacles, and a variety of red (*Palmaria callophyloides*, *Neorhodomela oregona*, *Halosaccion glandiforme*, *Pterosiphonia bipinnata*), green (*Ulva* sp. and *Cladophora* and *Rhizoclonium* sp.), and brown (*Alaria marginata*) algae (Figure 2.5). The relative abundance for most species changed relatively little from year to year. A large increase in cover by barnacle spat was observed at Kukak. A general increase in cover by *Alaria marginata* and a decrease in cover by *Pterisiphonia bipinnata* were observed at all sites suggesting possible region wide trends. At the mid intertidal elevation (1.5 m) dominant species (those with an average percent cover of at least 10% at any one tidal elevation and site) included the algae *Fucus gardneri* and *Porphyra* sp., mussels (*Mytilus trossulus*), and barnacles (*Balanus* and *Semibalanus* sp. and unidentified barnacle spat) (Figure 2.4). As observed in the lower intertidal, the relative abundance of most species changed little between years. Exceptions were for barnacle spat which increased over two fold at Kukak and Takli and decreased by more than half at Amalik. These differences are not surprising given the highly variable nature of barnacle recruitment. There was also a general trend of a slight increase in cover by both *Mytilus trossulus* and *Fucus gardneri* at all sites between 2006 and 2007.

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Table 2.2. Species of intertidal algae and sessile invertebrates at lower (0.5m MLLW) and mid (1.5m MLLW) intertidal sites at KATM, June 2006. xo = present in 2006 only, ox = present in 2007 only, oo = absent both years, xx = present both years.

Lower Intertidal

Species	Common Name	Kukak AB B10 RI1	Kaflia AB B10 RI2	Kinak AB B10 RI3	Amalik AB B10 RI4	Takli AB B10 RI5
<i>Acrosiphonia</i> sp.	Green alga	OX	XO	XX	XX	XO
<i>Alaria marginata</i>	Brown alga	XX	XX	XX	XX	XX
<i>Analipus japonicus</i>	Brown alga	OO	XX	OO	XX	XO
<i>Balanophyllia elegans</i>	Barnacle	OO	XO	OO	XO	OO
<i>Balanus</i> / <i>Semibalanus</i> sp.	Barnacle	XX	XX	XX	XX	XX
<i>Chthamalus dalli</i>	Barnacle	XO	XX	OX	XX	XX
<i>Clodophora</i> / <i>Rhizoclonium</i> sp.	Green alga	OX	OX	XX	OX	XX
<i>Corallina</i> sp.	Red alga	OO	OO	XX	OX	OO
<i>Cryptosiphonia woodii</i>	Red alga	OO	OO	XO	OO	OO
<i>Desmarestia aculeate</i>	Brown alga	OO	OO	OO	OX	OO
<i>Elachista fucicola</i>	Brown alga	OO	OO	OX	OO	XX
<i>Endocladia muricata</i>	Red alga	OO	OO	OO	OO	XO
<i>Fucus gardneri</i>	Brown alga	XX	XX	XX	XX	XX
<i>Gloiopeltis furcata</i>	Red alga	OX	OX	OX	XO	XO
<i>Halosaccion glandiforme</i>	Red alga	XX	OO	XX	OO	OO
<i>Laminaria saccharina</i>	Brown alga	OO	XO	OO	OX	OO
<i>Lithothamnion</i> sp.	Red alga	OO	XO	XO	XX	OX
<i>Mastocarpus papillatus</i>	Red alga	XO	XO	XX	OX	OO
<i>Melanosiphon intestinalis</i>	Brown alga	OX	XX	XX	OO	XX
<i>Microcladia borealis</i>	Red alga	OO	OO	XO	OO	OO
<i>Mytilus trossulus</i>	Mussel	OX	XX	OX	XX	XX
<i>Neorhodomela larix</i>	Red alga	OO	OO	XO	XO	OO
<i>Neorhodomela oregona</i>	Red alga	XX	OX	XX	XX	XX
<i>Odonthalia floccose</i>	Red alga	OO	OO	XO	OO	OO
<i>Palmaria colophylloides</i>	Red alga	XX	XX	XX	OO	OO
<i>Palmaria hecatensis</i>	Red alga	XO	OO	OO	XO	XX
<i>Palmaria mollis</i>	Red alga	OX	OO	OO	OO	OO
<i>Pilayella littoralis</i>	Brown alga	XX	OO	XX	OO	XO
<i>Polysiphonia</i> sp.	Red alga	XX	OX	XX	OX	XX
<i>Porphyra</i> sp.	Red alga	OX	XX	OX	XX	OX
<i>Pterosiphonia bipinnata</i>	Red alga	XO	XO	XO	XO	XO
<i>Ralfsia</i> sp.	Red alga	OO	OX	XX	OO	OO
<i>Scytosiphon simplicissimus</i>	Brown alga	XO	OO	XO	XO	XO
<i>Tokidadendron kurilensis</i>	Red alga	XX	OO	OX	OO	OO
<i>Ulothrix flacca</i>	Green alga	OO	OO	OO	XO	OO
<i>Ulva</i> sp.	Green alga	XX	XX	XX	XX	XX
Total Species 2006		15	16	22	18	17
Total Species 2007		17	15	21	17	14
Total No. Species		22	21	28	24	19

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Table 2.2 cont.

Mid Intertidal		Kukak	Kafli	Kinak	Amalik	Takli
Species	Common Name	AB B10 RI1	AB B10 RI2	AB B10 RI3	AB B10 RI4	AB B10 RI5
<i>Acrosiphonia</i> sp.	Green alga	XX	XX	XX	XX	XX
<i>Alaria marginata</i>	Brown alga	XO	XO	OO	XX	XO
<i>Analipus japonicus</i>	Brown alga	OO	OO	XO	OO	XX
<i>Anthopleura elegantissima</i>	Sea anemone	OO	OO	OO	XO	OX
<i>Balanus</i> / <i>Semibalanus</i> sp.	Barnacle	XX	XX	XX	XX	XX
<i>Chthamalus dalli</i>	Barnacle	XO	XX	XX	XX	XO
<i>Clodophora</i> / <i>Rhizoclonium</i> sp.	Green alga	OX	OO	XX	XX	OX
<i>Corallina</i> sp.	Red alga	OO	OO	OO	XO	OO
<i>Cryptosiphonia woodii</i>	Red alga	XO	OO	OO	OO	OX
<i>Elachista fucicola</i>	Brown alga	XX	OO	OX	OO	XX
<i>Endocladia muricata</i>	Red alga	OO	XX	XO	XX	XX
<i>Fucus gardneri</i>	Brown alga	XX	XX	XX	XX	XX
<i>Gloiopeltis furcata</i>	Red alga	XX	XX	XX	XX	XX
<i>Halosaccion glandiforme</i>	Red alga	XX	OO	XX	OO	OO
<i>Lithothamnion</i> sp.	Red alga	OO	OO	OO	XX	OO
<i>Mastocarpus papillatus</i>	Red alga	XX	OO	XO	XO	OO
<i>Melanosiphon intestinalis</i>	Brown alga	XX	XX	XX	XX	XX
<i>Mytilus trossulus</i>	Mussel	XX	XX	XX	XX	XX
<i>Neorhodomela oregona</i>	Red alga	XX	OX	XX	XX	XX
<i>Odonthalia floccose</i>	Red alga	OX	XO	OO	OO	OO
<i>Palmaria colophylloides</i>	Red alga	XO	OO	XO	XO	OO
<i>Pilayella littoralis</i>	Brown alga	XX	OO	XX	OO	XX
<i>Polysiphonia</i> sp.	Red alga	XX	OX	XX	XX	XX
<i>Porphyra</i> sp.	Red alga	XX	XX	XX	XX	XX
<i>Pterosiphonia bipinnata</i>	Red alga	XO	XO	XO	XO	XO
<i>Ralfsia</i> sp.	Red alga	OO	OX	XX	OO	OO
<i>Scytosiphon simplicissimus</i>	Brown alga	OO	XO	OO	XO	OO
<i>Ulva</i> sp.	Green alga	XX	XO	XX	XX	XX
Total Species 2006		19	14	20	21	16
Total Species 2007		16	12	16	15	17
Total No. Species		21	17	21	21	20

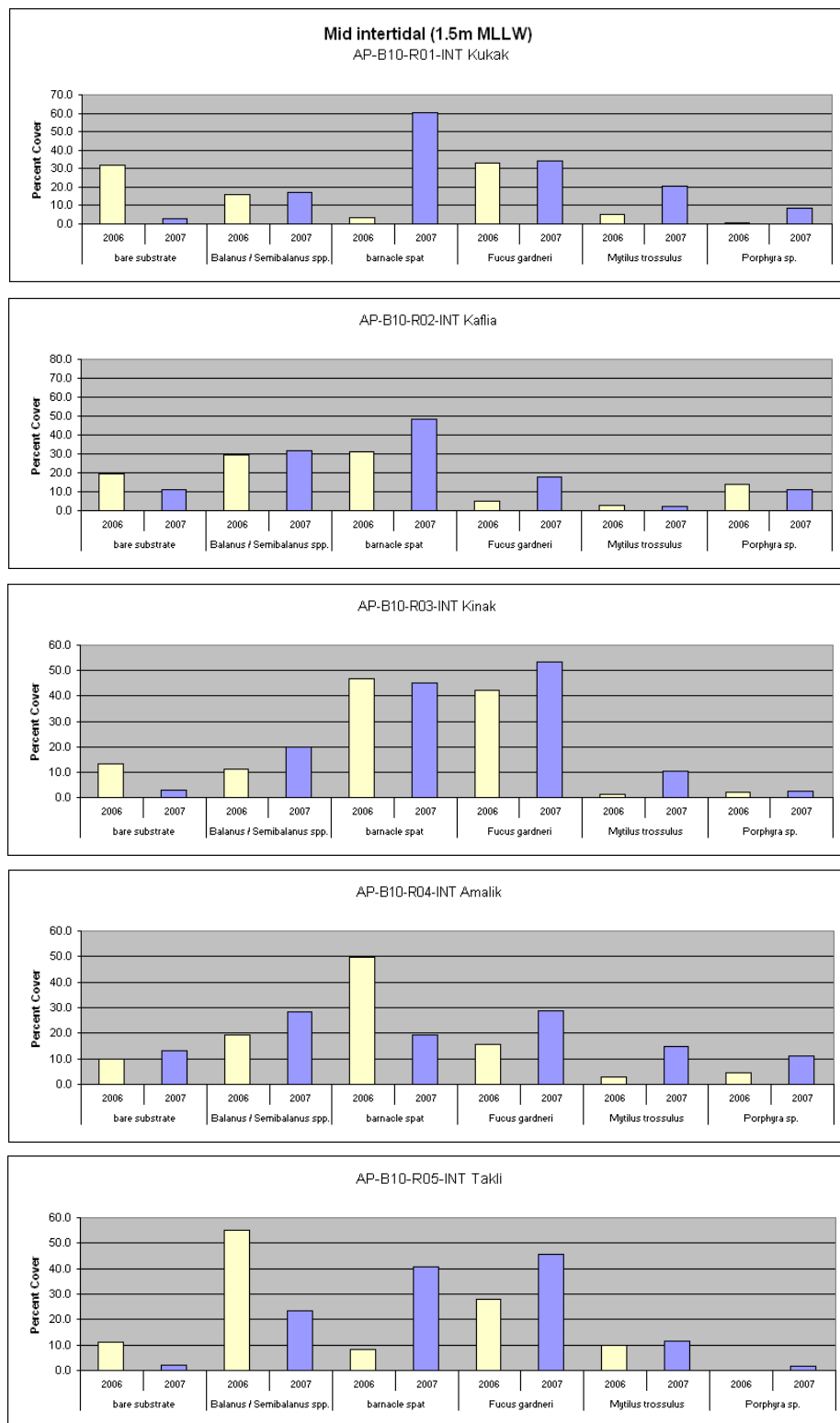


Figure 2.4. Mean percent cover of dominant intertidal algae and invertebrates at mid (1.5m MLLW) intertidal sites at KATM in 2006 and 2007.

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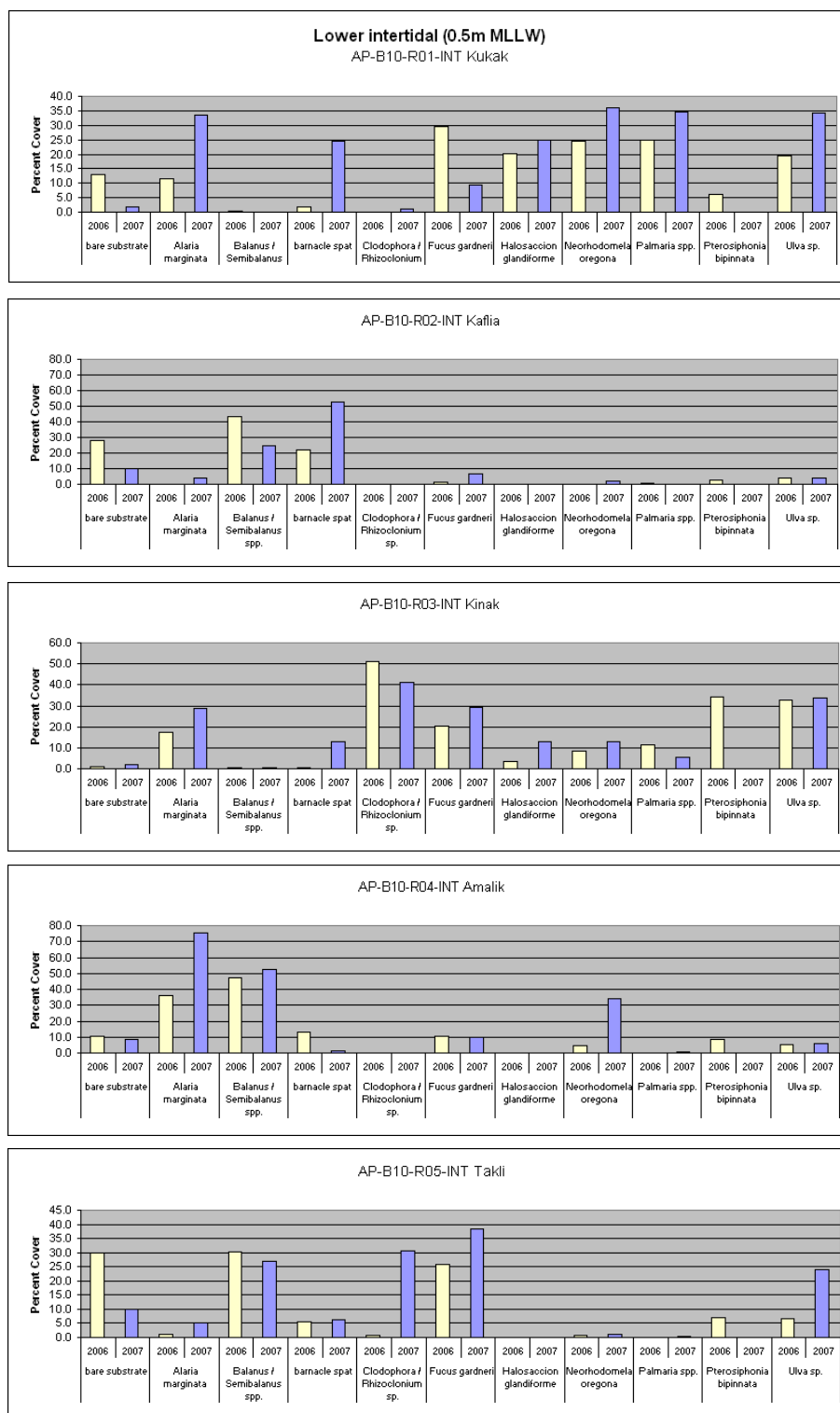


Figure 2.5. Mean percent cover of dominant algae and sessile invertebrates at lower (0.5m MLLW) intertidal sites in KATM in 2006 and 2007.

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From one to five intermediate-sized invertebrates were observed at each tidal elevation and site (Table 2.3). The numerically dominant species were the predatory snail, *Nucella* sp. and the chiton, *Katherina tunicata*. Sites differed in species composition and abundance (Figure 2.6). Notably there were no *Katherina* at Kukak Bay (AP-B10-RI1) and no *Nucella* spp. at Kinak Bay (AP-B10-RI3) in either 2006 or 2007.

Table 2.3. Species of intermediate size invertebrates at lower (0.5 m MLLW) and mid (1.5 m MLLW) intertidal sites at KATM, June 2006. xo = present in 2006 only, ox = present in 2007 only, oo = absent both years, xx = present both years.

		Site				
Species	Common Name	Kukak AB B10 RI1	Kaflia AB B10 RI2	Kinak AB B10 RI3	Amalik AB B10 RI4	Takli AB B10 RI5
Lower Intertidal (0.5 m MLLW)						
<i>Anthopleura elegantissima</i>	Sea anemone	OO	XO	OO	OO	OO
<i>Buccinum baeri</i>	Snail	XX	OO	OO	OX	OO
<i>Katharina tunicate</i>	Chiton	OO	XX	XX	XX	XX
<i>Leptasterias epichlora</i>	Sea star	OO	OX	OO	XX	OO
<i>Metridium senile</i>	Sea anemone	OO	OO	OO	OO	OX
<i>Nucella lamellose</i>	Snail	XO	XX	OO	XX	XO
<i>Strongylocentrotus droebachiensis</i>	Sea urchin	OO	OO	OO	XX	XO
<i>Tonicella lineate</i>	Chiton	OO	OO	OO	XO	OO
<i>unknown anemone</i>	Sea anemone	OO	OO	XO	OO	OO
<i>Utricina crassicornis</i>	Sea anemone	OO	XO	OO	OO	OO
Total Species 2006		2	4	2	5	3
Total Species 2007		1	3	1	5	2
Total Number of Species		2	4	2	6	4
Mid Intertidal (1.5 m MLLW)						
<i>Anthopleura elegantissima</i>	Sea anemone	XO	OO	XO	XO	XX
<i>Anthopleura xanthogrammica</i>	Sea anemone	XO	OO	OO	OO	OO
<i>Buccinum baeri</i>	Snail	OX	OO	OO	XX	OO
<i>Katharina tunicate</i>	Chiton	OO	XX	XO	XX	XX
<i>Leptasterias epichlora</i>	Sea star	OO	OO	OO	XX	XO
<i>Metridium senile</i>	Sea anemone	OO	XO	OO	OO	OO
<i>Nucella lamellose</i>	Snail	XO	XO	OO	XX	XX
<i>Nucella lima</i>	Snail	OX	OX	OX	OX	OX
<i>Utricina crassicornis</i>	Sea anemone	OO	XO	XO	OO	OO
Total Species 2006		3	4	3	5	4
Total Species 2007		2	2	1	5	4
Total Number of Species		5	5	4	6	5

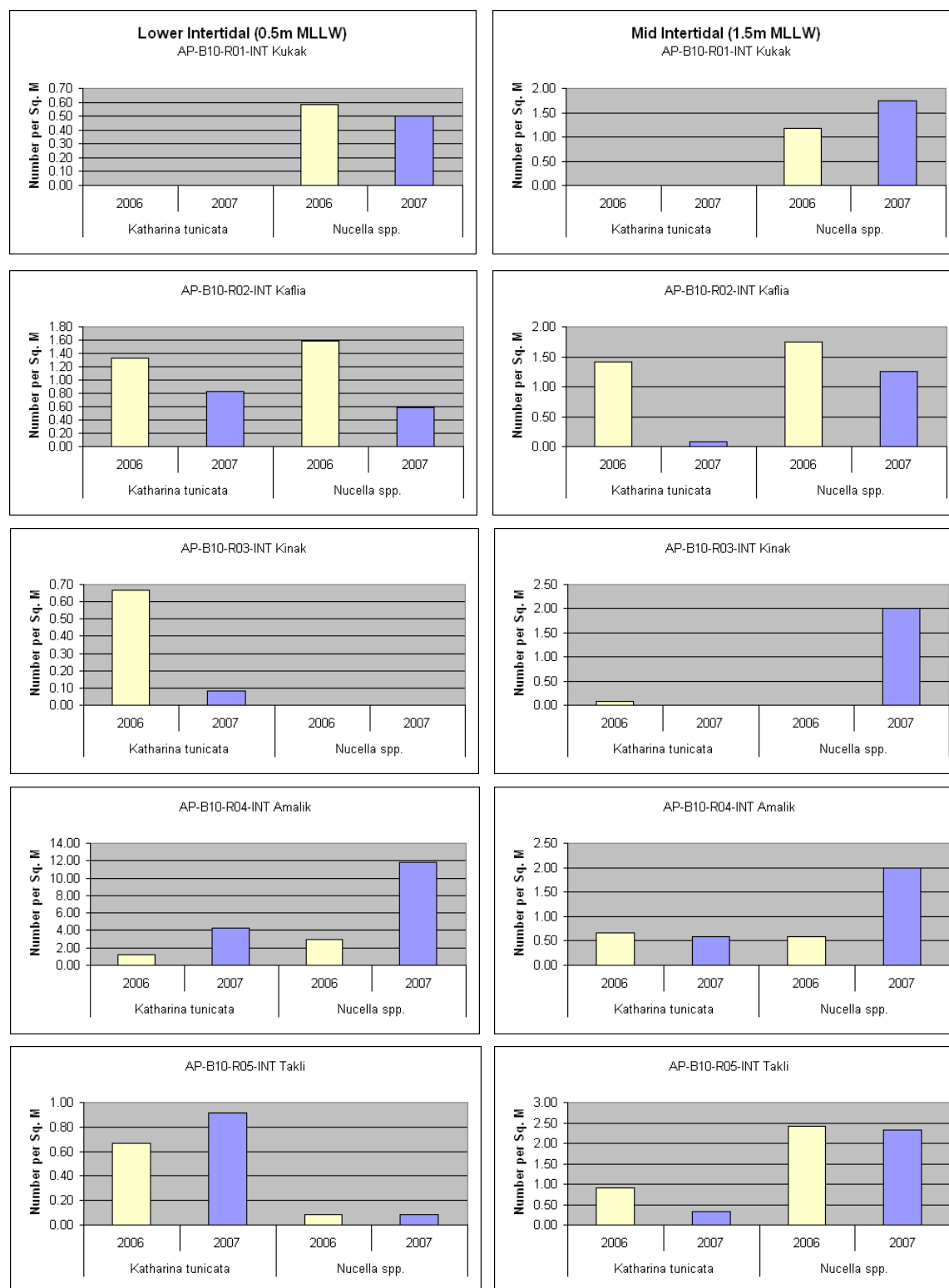


Figure 2.6. Density (number per m²) of dominant intermediate-sized intertidal species at KATM in 2006 and 2007.

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The number of smaller motile invertebrates at each elevation and site ranged from 6 to 16 (Table 2.4). At both tidal elevations in both 2006 and 2007, the largest number of species was observed at Amalik Bay (AP-B10-RI4) and the fewest number were observed at Kukak (AP-B10-RI1) and Kinak (AP-B10-RI3) Bays. In both years, numerically dominant species included littorine snails (*Littorina sitkana*) and limpets (both *Lottia pelta* and small unidentified limpets classified as *Lottiidae*) (Figure 2.7). A relatively large increase in the number of *Littorina sitkana* was observed in 2007, especially in the lower intertidal zone.

Table 2.4. Species of small motile invertebrates at lower (0.5 m MLLW) and mid (1.5 m MLLW) intertidal sites at KATM in 2006. xo = present in 2006 only, ox = present in 2007 only, oo = absent both years, xx = present both years.

Species	Common Name	Site				
		Kukak AP B10 RI1	Kaflia AP B10 RI2	Kinak AP B10 RI3	Amalik AP B10 RI4	Takli AP B10 RI5
Lower Intertidal (0.5 m MLLW)						
<i>Aeolidia papillosa</i>	sea slug	OO	OO	OO	OX	OO
<i>Amphiporus formidabilis</i>	Ribbon worm	OO	OX	XX	OX	OX
<i>Calliostoma ligulata</i>	Snail	OO	OX	OO	OX	OO
<i>Cancer orregonensis</i>	Crab	OO	OO	OO	XO	OO
<i>Cucumaria vegae</i>	Sea cucumber	XO	OO	OO	XO	OO
<i>Emplectonema gracile</i>	Ribbon worm	OO	XX	OX	XX	OX
<i>Haplogaster mertensii</i>	Crab	OO	OO	OO	XO	OO
<i>Lepasterius epichlora</i>	Sea star	XO	OO	OO	XO	XO
<i>Littorina scutulata</i>	Snail	OX	OX	OX	XX	XX
<i>Littorina sitkana</i>	Snail	XX	XX	XX	XX	XX
<i>Lophopanopeus</i> sp.	Crab	OO	OO	OO	OX	OO
<i>Lottia digitalis</i>	Limpet	OO	XO	OO	OO	OO
<i>Lottia pelta</i>	Limpet	XX	XX	XX	XX	XX
<i>Margarites pupillus</i>	Snail	OO	XO	XX	XX	XX
<i>Margurites helicinus</i>	Snail	OO	XO	OO	XO	OO
<i>Mopalia</i> sp.	Chiton	OO	OO	XO	OO	OO
<i>Neomolgus littoralis</i>	Mite	OO	OO	XO	OO	OO
<i>Onchidella borealis</i>	Unshelled snail	OO	OO	OO	XX	OX
<i>Pagurus</i> sp.	Crab	XX	XX	XX	XX	XX
<i>Paranemertes perigrina</i>	Ribbon worm	XX	XO	OX	XO	OX
<i>Pentidotea wosnesenskii</i>	Isopod	OO	OO	OO	XX	XO
<i>Phidiana crassicornis</i>	Sea slug	OO	XO	OO	OO	OO
<i>Siphonaria thersites</i>	Unshelled snail	OO	XX	OX	OX	OO
<i>Tectura scutum</i>	Limpet	OX	OX	OO	OO	OO
<i>Tectura scutum</i>	Limpet	XX	XX	OO	XX	XX
<i>Tonicella lineata</i>	Chiton	OO	OO	OO	XX	OO
Total species 2006		7	11	7	16	8
Total species 2007		7	10	9	15	10
Total number of species		9	15	11	21	12

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Table 2.4 Continued

Species	Common Name	Site				
		Kukak AP B10 RI1	Kafliia AP B10 RI2	Kinak AP B10 RI3	Amalik AP B10 RI4	Takli AP B10 RI5
Mid Intertidal (1.5 m MLLW)						
<i>Amphiporus formidabilis</i>		OO	OX	XX	OX	OX
<i>Anthopluera elegantissima</i>	Sea Anemone	OO	OO	OO	XO	OX
<i>Emplectonema gracile</i>	Snail	OX	OX	OX	XX	XX
<i>Lepasterius epichlora</i>	Sea star	OO	OO	OO	XO	OO
<i>Littorina scutulata</i>	Snail	XX	XX	XX	XX	XX
<i>Littorina sitkana</i>	Snail	XX	XX	XX	XX	XX
<i>Lottia digitalis</i>	Limpet	OX	OO	OO	OX	XO
<i>Lottia pelta</i>	Limpet	XX	XX	XX	XX	XX
<i>Margarites pupillus</i>	Snail	OO	OO	OO	XO	OO
<i>Margurites helicinus</i>	Snail	OO	XO	OO	XO	XO
<i>Neomolgus littoralis</i>	Mite	OO	OO	XO	OO	XO
<i>Onchidella borealis</i>	Unshelled snail	OO	OO	OX	XX	XX
<i>Pagurus</i> sp.	Crab	XX	XO	XX	XX	XX
<i>Paranemertes perigrina</i>	Ribbon worm	OX	OX	OO	XO	OX
<i>Pentidotea wosnesenskii</i>	Isopod	OO	OO	OO	XX	OO
<i>Siphonaria thersites</i>	Unshelled snail	OO	XX	OX	XX	OX
<i>Tectura persona</i>	Limpet	XO	XO	OO	OO	OO
<i>Tectura scutum</i>	Limpet	XO	XX	OO	XX	XX
<i>Tonicella lineata</i>	Chiton	OO	OO	OO	XO	OO
Total species 2006		6	8	6	15	10
Total species 2007		7	8	7	11	11
Total number of species		9	11	8	17	14

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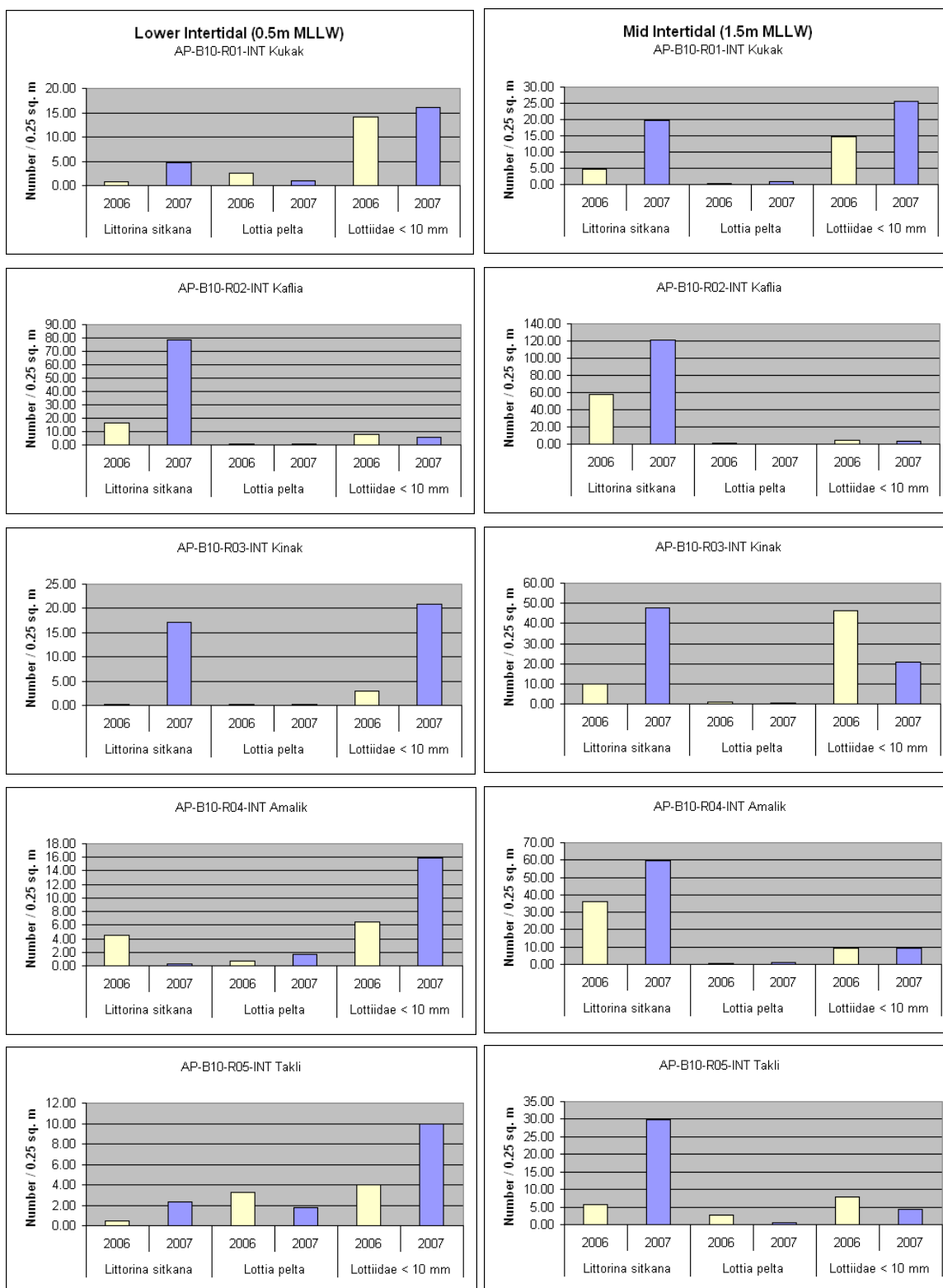


Figure 2.7. Density (number per 0.25 m²) of dominant smaller motile intertidal species at KATM in 2006 and 2007.

Size distributions of limpets (*Tectura persona*) are given in Figure 2.8. 2006 and 2007 size distributions were similar at all sites. In both years, size distributions at Kukak were skewed toward larger sizes, with a median size of 18 to 20 mm. At other sites, median shell lengths were 14 mm or less.

Mussels (*Mytilus trossulus*) were collected at each site in 2007 for determination of contaminants in tissue. These samples were shipped to TDI Brooks laboratory for analysis. No results are available at this time.

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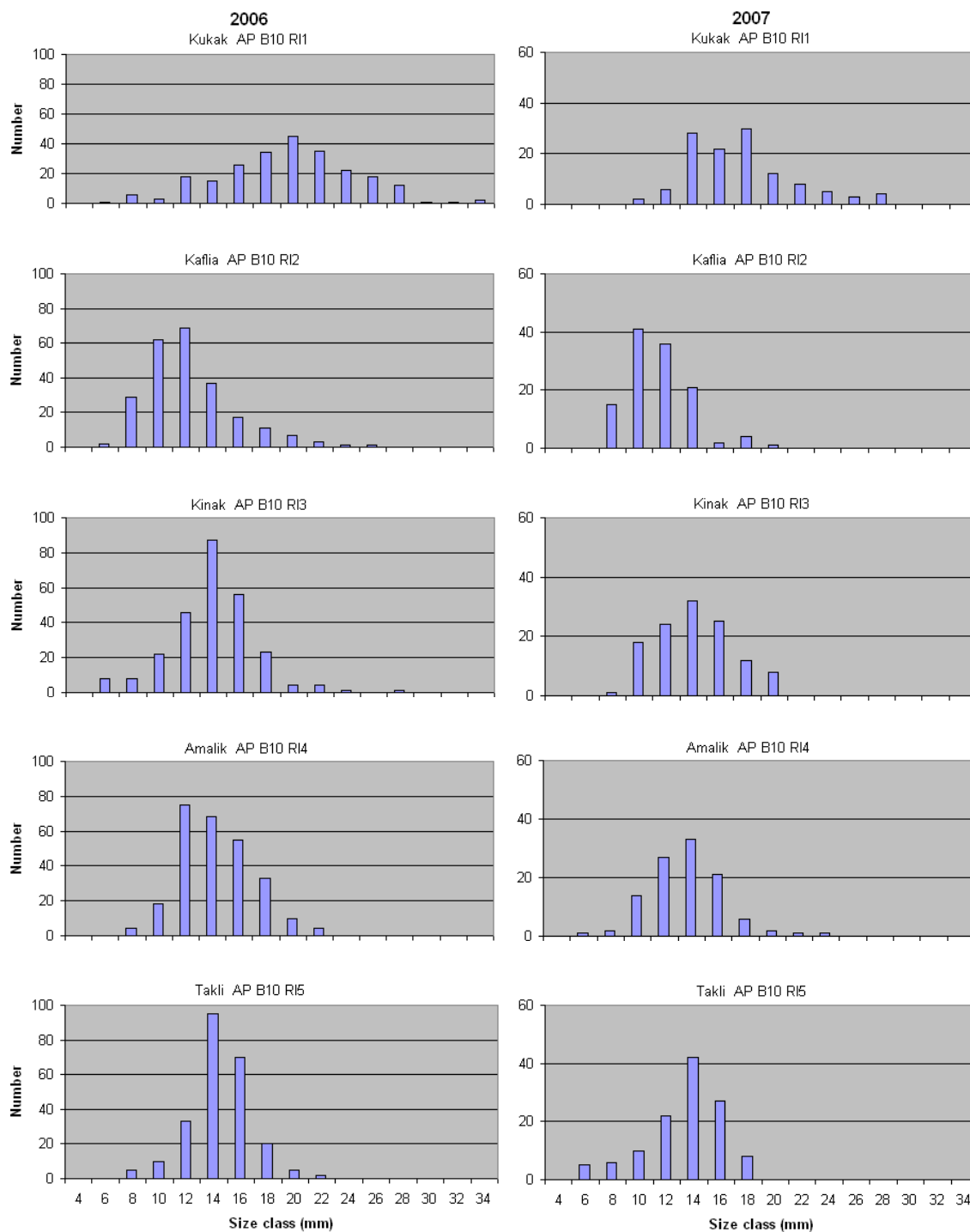


Figure 2.8. Size frequency distribution of *Tectura persona* at KATM sites in 2006 and 2007. Size classes are in mm shell length.

Temperature Data - Hobo temperature loggers were deployed at 0.5m MLLW at each of the five intertidal sites at KATM in summer 2006. Instruments were recovered from Takli Island and Kinak Bay in 2007 while instruments placed at Kukak Bay, Kaflia Bay, and Amalik Bay were lost. Maximum temperatures were slightly higher at Takli Island than at Kinak Bay in summer 2006, but otherwise seasonal trends in temperature were similar at the two sites (Figure 2.9). There was a wide range of temperatures observed at both sites, with the maximum yearly range of over 40° C (from less than -10° C to greater than 30° C), and ranges of greater than 20° C occurring on some days. The largest ranges in temperature occurred during spring tides when the 0.5m tidal elevation was exposed to air. In spring and summer (April through August), when air temperatures generally exceed water temperatures, deviations during spring tides were generally positive. In fall and winter (October through February), when air temperatures were generally lower than water temperatures, deviations were generally negative. Temperature loggers were redeployed at all five sites in 2007.

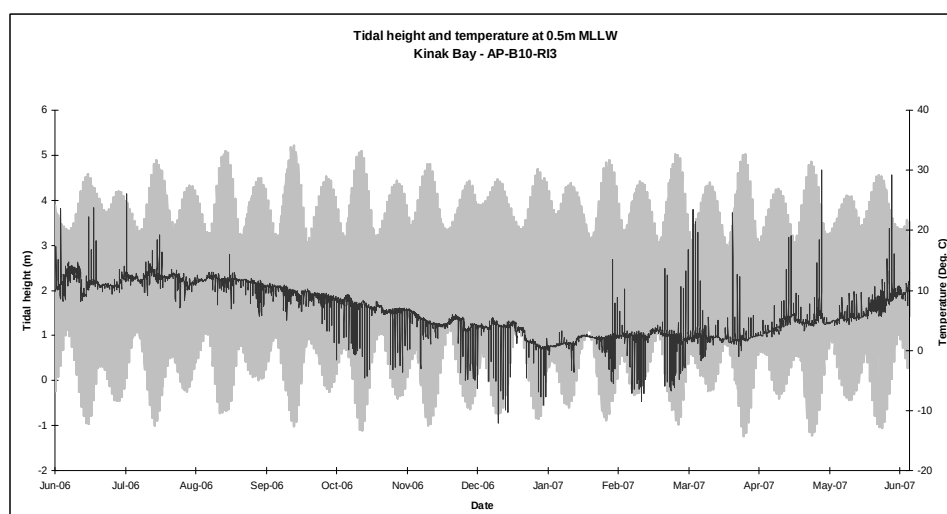
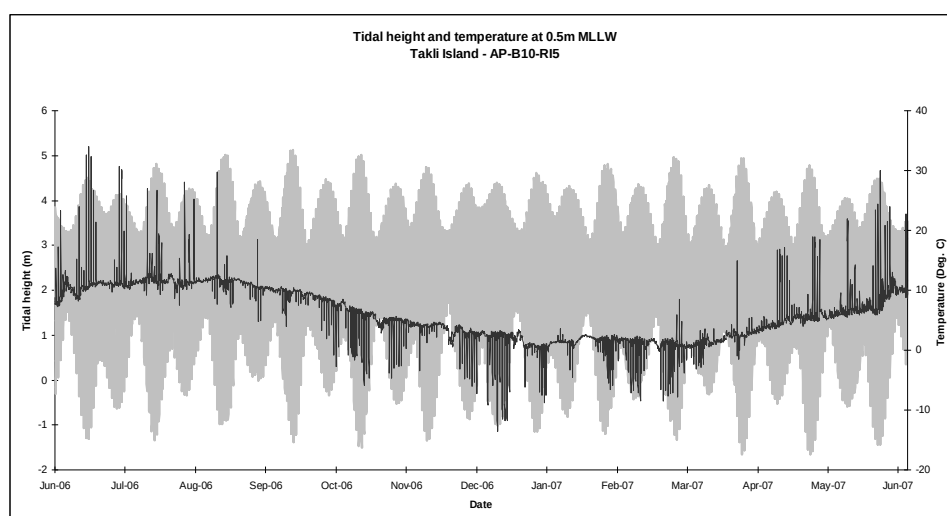


Figure 2.9. Temperature at 0.5m MLLW (black) and tidal height (gray) at Takli Island and Kinak Bay from June 2006 through June 2007.

KEFJ

Rocky Intertidal - A total of five rocky intertidal sites were established in KEFJ in 2007. Markers were placed at each site and shoreline profiles were measured. Average slopes over a 3 m rise in vertical elevation (starting at MLLW) ranged from 18° to 27° (Table Rocky 4). At the Nuka Pass site (AP B5 RI4) the intertidal zone sloped downward to a bay behind at between 2 and 3 m elevation and was not measured.

Table 2.5. Average slope (degrees) at intertidal sampling sites in KEFJ in 2007.

Site name	Site number	Slope (degrees)			Mean
		0 to 1 m	1 to 2 m	2 to 3 m	
Aialik	AP B5 RI1	24	17	13	18
McCarty	AP B5 RI2	25	25	24	25
Nuka Bay	AP B5 RI3	21	16	23	20
Nuka Pass	AP B5 RI4	10	32	-	21
Harris	AP B5 RI5	31	29	22	27

Sampling was conducted at only one site (Nuka Pass) in 2007 because of time constraints. Sampling at all sites is planned for 2008.

Temperature Data – Hobos were deployed at all five established rocky sites and temperature data from those Hobos will be collected during the 2008 sampling season.

KATM & KEFJ

Soft Intertidal - For each site sampled we calculated the following: 1) Shannon-Weiner diversity index (H') for clam species only, 2) mean density of clams / 0.25 m² by species and in aggregate, 3) mean biomass (g/0.25 m²) by species and in aggregate, and 4) the size class distribution of clams collected from each area by species. Biomass was calculated by multiplying the length of the clams by a dry weight conversion factor distinctive for each species. Because the data set collected to date is intended to be compared against identical data collected from the same sites in the future, we do not perform or report statistical tests of significance in this report.

The Shannon-Wiener diversity index (H') was calculated for each site. This index accounts for species richness (total number of species present) as well as their relative proportions so rare individuals do not have undue influence on H' . The theoretical maximum for H' is $\log_2(\text{total \# species})$, in this case $H'_{\text{max AP}} = 3.17$ while $H'_{\text{max KP}} = 3.32$. H' ranged from 0 (i.e. only one species present) to 2.27 (mean $\pm$ sd: 1.53 ± 0.6) (Table 2.6).

Table 2.6. Shannon-Weiner diversity index values (H') for intertidal clam sampling areas. $H' = 0$ when only 1 species is present, $H'_{\max AP} = 3.17$, $H'_{\max KP} = 3.32$. S = total number of clam species observed. E = evenness = $H'/\log(S)$. $E = 1$ when all species are present in similar proportions, $E > 1$ when abundances are dissimilar, $E < 1$ if 1 species dominates.

Region	Site	H'	S	E
KATM		0.83	9	0.87
	SI1	0.36	5	0.52
	SI2	1.01	7	1.20
	SI3	0	1	
	SI4	1.1	6	1.41
	SI5	0.72	5	1.03
	SS1	1.72	7	2.04
KEFJ		0.84	10	0.84
	SI1	0.86	6	1.11
	SI2	1.92	7	2.27
	SI3	0	1	
	SI4	1.01	7	1.20
	SI5	0.43	5	0.62

The range of values for the Shannon-Wiener index, number of clam species observed (S), and the evenness (E) was similar across sites within each sampling block.

In our 2007 sampling we found the intertidal clam species: *Clinocardium nuttallii* (CLN), *Diplodonta impolita* (DII), *Hiatella arcticus* (HIS), *Macoma* spp. (MAS, pooled with *M. nasuta* (MAN), *M. balthica* (MAB)), *Mya* sp. (MYS, pooled *M. truncata* (MYT) and *M. arenaria* (MYA)), *Protothaca staminea* (PRS), *Pseudopythina compressa* (PSC), and *Saxidomus gigantea* (SAG). We also found a few unidentifiable clams that were lumped under the category other clam (CLA).

Clam Density

KATM

The overall number of clams per quadrat per site ranged from 0 to 205 clams per 0.25 m² (mean $\pm$ sd: 16.3 $\pm$ 6). When looking at the abundance per quad of individual species of clams, *Macoma* was the most abundant taxa across sites, except sites SI4 and SS1 at which *Saxidomus* was predominant. The number of clams per quadrat varied extensively within sites as well as among sites and areas. For *Protothaca*, the minimum number per quadrat was zero in at least one quadrat per site. The maximum number per quadrat was 166 *Macoma*, 8 *Protothaca*, 29 *Hiatella*, 60 *Saxidomus*, and 11 *Mya*. Figure 2.10 shows the mean total number of clams per quadrat as well as the contribution of each species to the total at each site. Figure 2.12 shows the mean number per quadrat of each clam species for all sites pooled across parks.

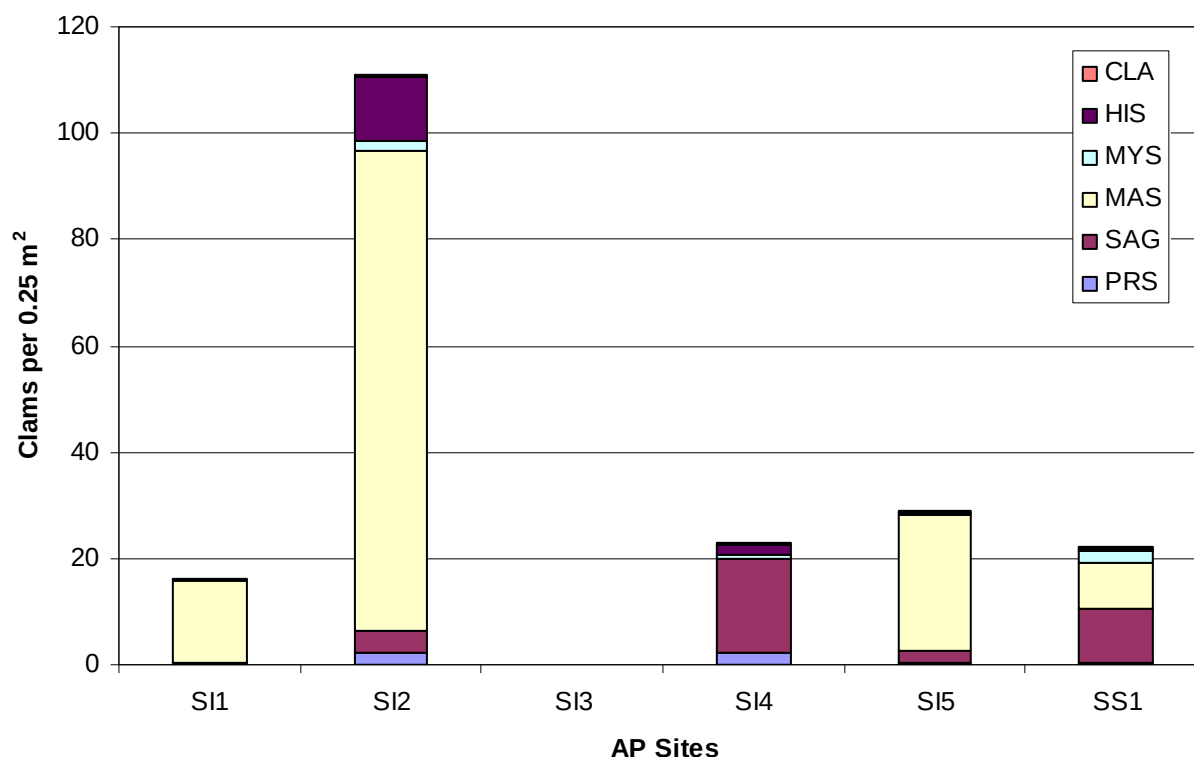


Figure 2.10. Mean numbers of clams per quadrat at 5 soft intensive (SI) sites and 1 soft selected (SS) site in KATM, 2007. Clam species abbreviations are: *Hiatella arcticus* (HIS), *Macoma* spp. (MAS, pooled with *M. nasuta* (MAN), *M. balthica* (MAB)), *Mya* spp. (MYS, pooled *M. truncata* (MYT) and *M. arenaria* (MYA)), *Protothaca staminea* (PRS), *Pseudopythina compressa* (PSC), and *Saxidomus gigantea* (SAG), species occurring in low frequencies and pooled in the category other clam (CLA).

KEFJ

The overall number of clams per quadrat per site ranged from 0 to 109 clams per 0.25 m² (mean $\pm$ sd: 16.3 $\pm$ 6). When looking at the abundance per quad of individual species of clams, *Macoma* was the most abundant taxa across sites. The number of clams per quadrat varied extensively within sites as well as among sites and areas. For *Protothaca*, the minimum number per quadrat was zero in at least one quadrat per site. The maximum number per quadrat was 102 *Macoma*, 14 *Protothaca*, 9 *Hiatella*, 5 *Saxidomus*, and 10 *Mya*. Figure 2.11 shows the mean total number of clams per quadrat as well as the contribution of each species to the total at each site. Figure 2.12 shows the mean number per quadrat of each clam species for all sites pooled across parks.

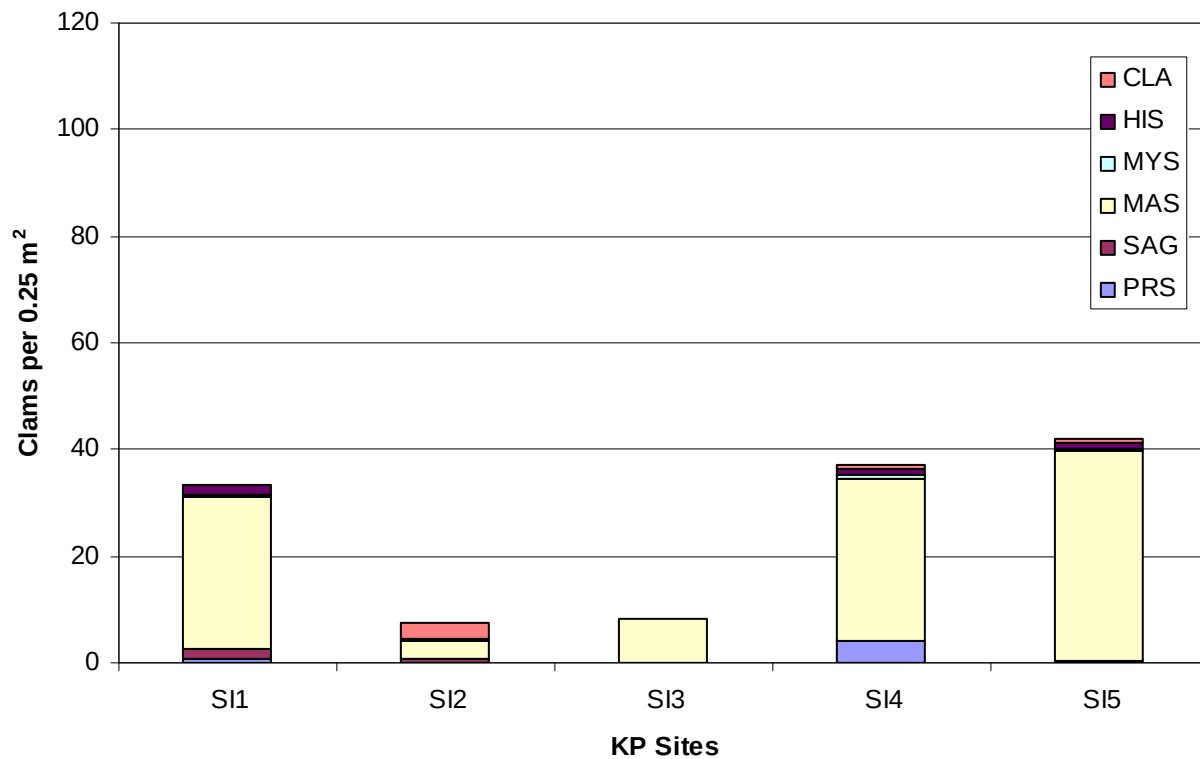


Figure 2.11. Mean numbers of clams per quadrat at 5 soft intensive (SI) sites in KEFJ, 2007. Clam species abbreviations are: *Hiatella arcticus* (HIS), *Macoma* spp. (MAS, pooled with *M. nasuta* (MAN), *M. balthica* (MAB)), *Mya* spp. (MYS, pooled *M. truncata* (MYT) and *M. arenaria* (MYA)), *Protothaca staminea* (PRS), *Pseudopythina compressa* (PSC), and *Saxidomus gigantea* (SAG), species occurring in low frequencies and pooled in the category other clam (CLA).

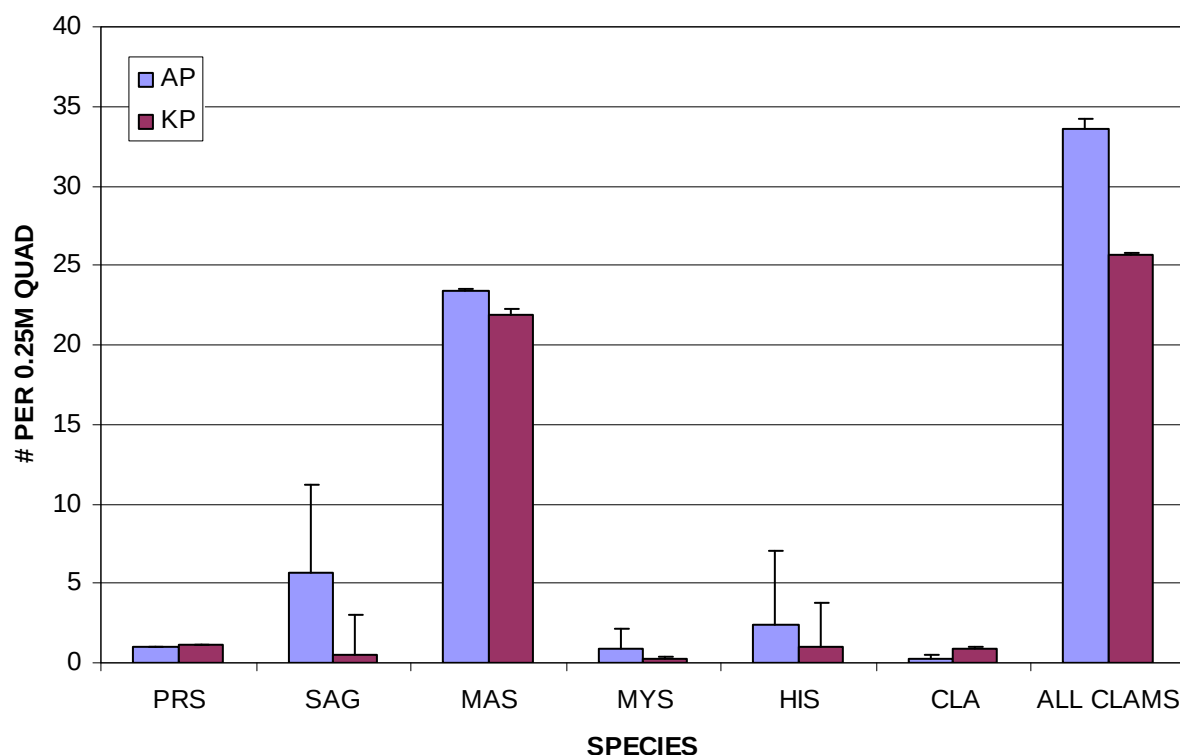


Figure 2.12. Mean numbers of clams per quadrat at 6 sites in KATM, 2007 and 5 sites in KEFJ, 2007. Clam species abbreviations are: *Hiatella arcticus* (HIS), *Macoma* spp. (MAS, pooled with *M. nasuta* (MAN), *M. balthica* (MAB)), *Mya* spp. (MYS, pooled *M. truncata* (MYT) and *M. arenaria* (MYA)), *Protothaca staminea* (PRS), *Pseudopythina compressa* (PSC), and *Saxidomus gigantea* (SAG), species occurring in low frequencies and pooled in the category other clam (CLA). Error bars represent 1 standard error.

Mean Size and Size Frequency Distributions KATM

The overall means for clam size were 26.1, 24.2, 41.5, 33.7, and 35.7 mm for *Hiatella*, *Macoma*, *Mya*, *Protothaca*, and *Saxidomas*, respectively. The overall means for mussel size was 26.1. See Figure 2.13 for sizes of clam species per site. Figure 2.15 shows mean sizes of each clam species and mussels for all sites pooled. Of the *Hiatellas* measured, >40% were in the 25-30 mm size class, while the majority of *Macomas* were in the 15-20 mm class (Figure 10). Nearly 80% of *Mya* species and 60% of *Saxidomas* were in the 25-50 mm size class. More than 50% of *Protothaca* were greater than 35mm, although there was a second (substantially smaller) peak in the 15-20 mm size class. Mussels (*Mytilus trossulus*) were small, with 60% < 25 mm (Figure 11). Only *Macoma* and *Mytilus* were present in high enough numbers to examine size frequency by site. *Macoma* at SI2 and SS1 were predominantly small (>50% were smaller than 25 mm). *Macoma* at SI1 were more evenly distributed across size classes. *Macoma* at SI5 showed a peak in the 25-30 mm class, but were otherwise well represented across size classes. There were not enough *Macoma* at SI3 or SI4 for size frequency plotting. At SI3 and SI4 mussels smaller than 25 mm were predominant, with a smaller peak in the >35 mm size class. At SI2, however, most mussels were larger than 30 mm (Figure 2.18).

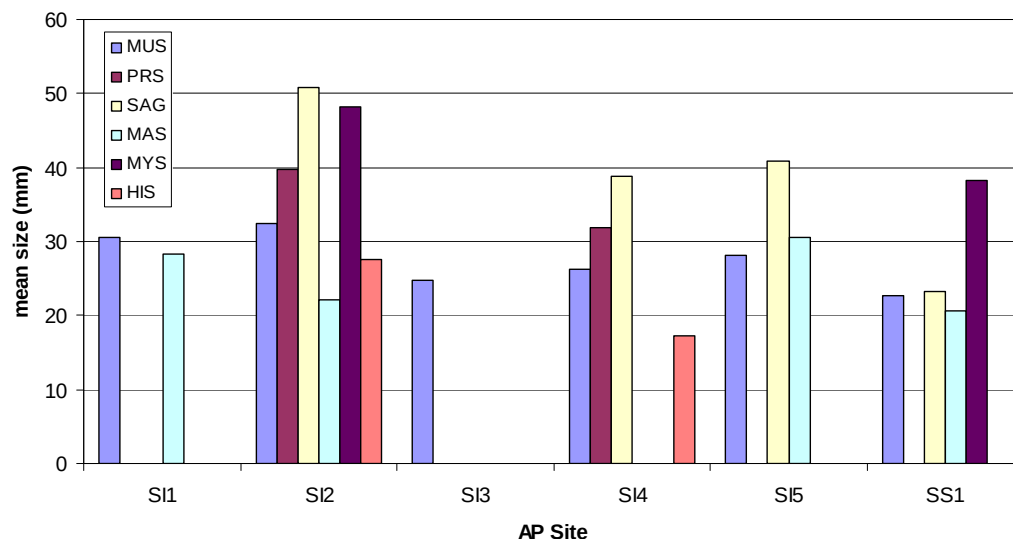


Figure 2.13. Mean sizes of mussels and clams at 5 soft intensive (SI) sites and 1 soft selected (SS) site in KATM. Clam species abbreviations are: *Hiattella arcticus* (HIS), *Macoma* spp. (MAS, pooled with *M. nasuta* (MAN), *M. balthica* (MAB)), *Mya* spp. (MYS, pooled *M. truncata* (MYT) and *M. arenaria* (MYA)), *Protothaca staminea* (PRS), *Pseudopythina compressa* (PSC), and *Saxidomus gigantea* (SAG), species occurring in low frequencies and pooled in the category other clam (CLA). Mussels are *Mytilus trossulus* (MTR).

KEFJ

The overall means for clam size were 22.9, 24.2, 37.8, 30.9, and 37.6 mm for HIS, MAS, MYS, PRS, and SAG, respectively. The overall means for mussel size was 31.0. See Figure 2.14 for sizes of clam species per site. Figure 2.15 shows mean sizes of each clam species and mussels for all sites pooled across parks. Of the *Hiattellas* measured, 35% were in the 25-30 mm size class, while *Macomas* were split amongst the 15-20, 20-25, and 25-30 mm classes (Figure 2.16). *Mya* and *Saxidomas* size frequency distributions were similar to KATM, however the numbers were too low to draw definite conclusions in KEFJ. Similar to *Macoma*, *Protothaca* were distributed across several size classes, tending towards larger sizes. Mussels (*Mytilus trossulus*) were larger in KEFJ than KATM, with 55% >30 mm (Figure 2.16). Only *macoma* and *mytilus* were present in high enough numbers to examine size frequency by site. *Macoma* at SI1 were evenly distributed across size classes. *Macoma* at SI3 and SI5 were predominantly small (>90% were smaller than 20 mm at SI3, >60% smaller than 25 mm at SI5). *Macoma* at SI4 showed a peak in the 20-25 mm class and tailed off evenly on both sides of this. There were not enough *Macoma* at SI3 for size frequency plotting (Figure 2.17). Only SI1 had enough mussels for size frequency plotting, and they tended to the larger size classes with 90% larger than 25 mm (Figure 2.18).

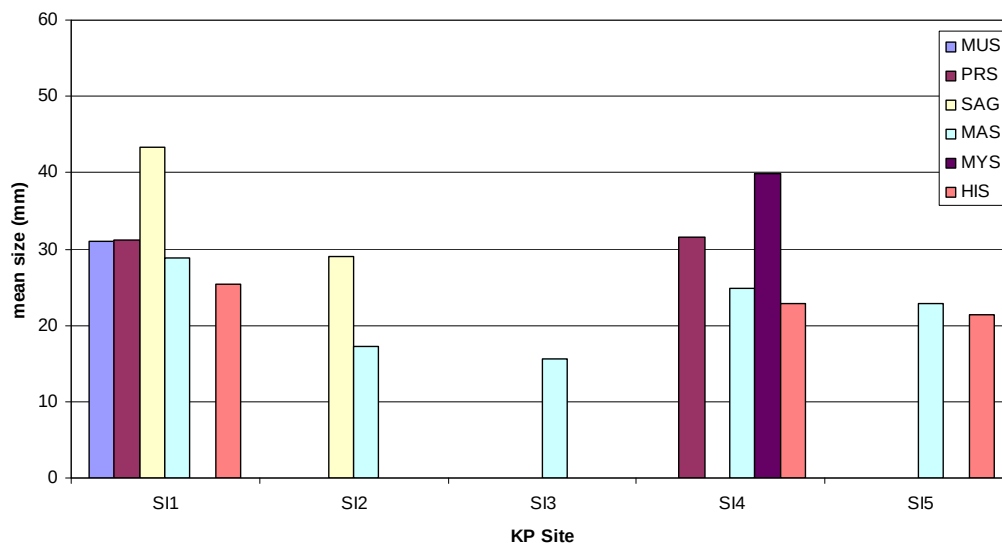


Figure 2.14. Mean sizes of clams and mussels at 5 soft intensive (SI) sites in KEFJ, 2007. Clam species abbreviations are: *Hiatella arcticus* (HIS), *Macoma* spp. (MAS, pooled with *M. nasuta* (MAN), *M. balthica* (MAB)), *Mya* spp. (MYS, pooled *M. truncata* (MYT) and *M. arenaria* (MYA)), *Protothaca staminea* (PRS), *Pseudopythina compressa* (PSC), and *Saxidomus gigantea* (SAG), species occurring in low frequencies and pooled in the category other clam (CLA). Mussels are *Mytilus trossolus* (MTR).

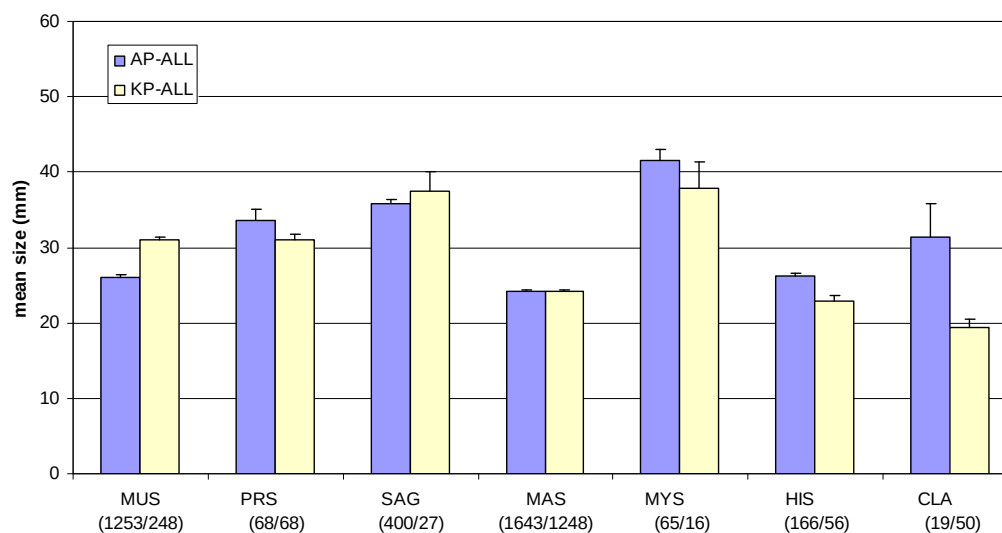


Figure 2.15. Mean sizes of clams and mussels per quadrat at 6 sites in KATM, 2007 and 5 sites in KEFJ, 2007. Clam species abbreviations are: *Hiatella arcticus* (HIS), *Macoma* spp. (MAS, pooled with *M. nasuta* (MAN), *M. balthica* (MAB)), *Mya* spp. (MYS, pooled *M. truncata* (MYT) and *M. arenaria* (MYA)), *Protothaca staminea* (PRS), *Pseudopythina compressa* (PSC), and *Saxidomus gigantea* (SAG), species occurring in low frequencies and pooled in the category other clam (CLA). Mussels are *Mytilus trossolus* (MTR). Error bars represent 1 standard error. Numbers in parentheses are sample sizes for AP/KP.

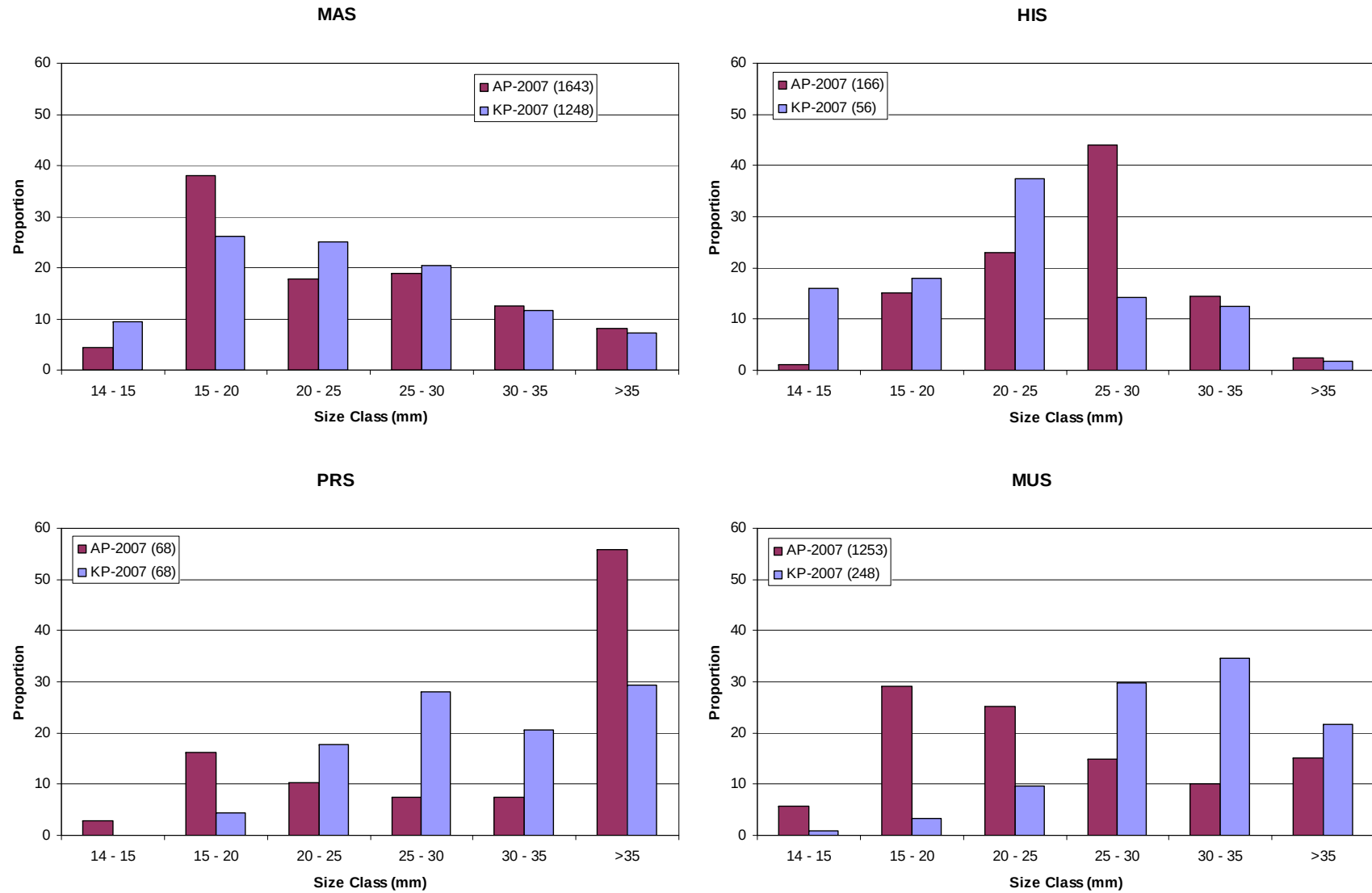


Figure 2.16. Comparison of size classes of *Macoma*, *Hiatella*, *Prototheca* and *Mytilus* by park.

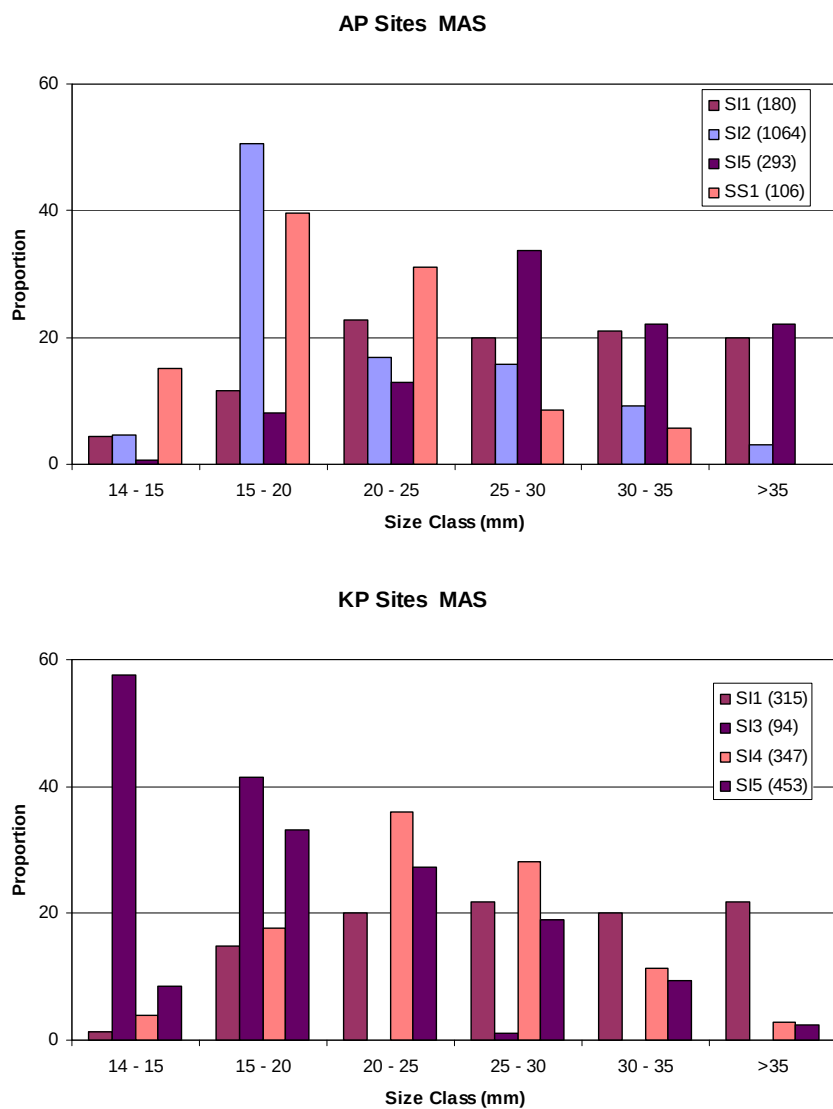


Figure 2.17. Comparison of size classes of *Macoma* by park.

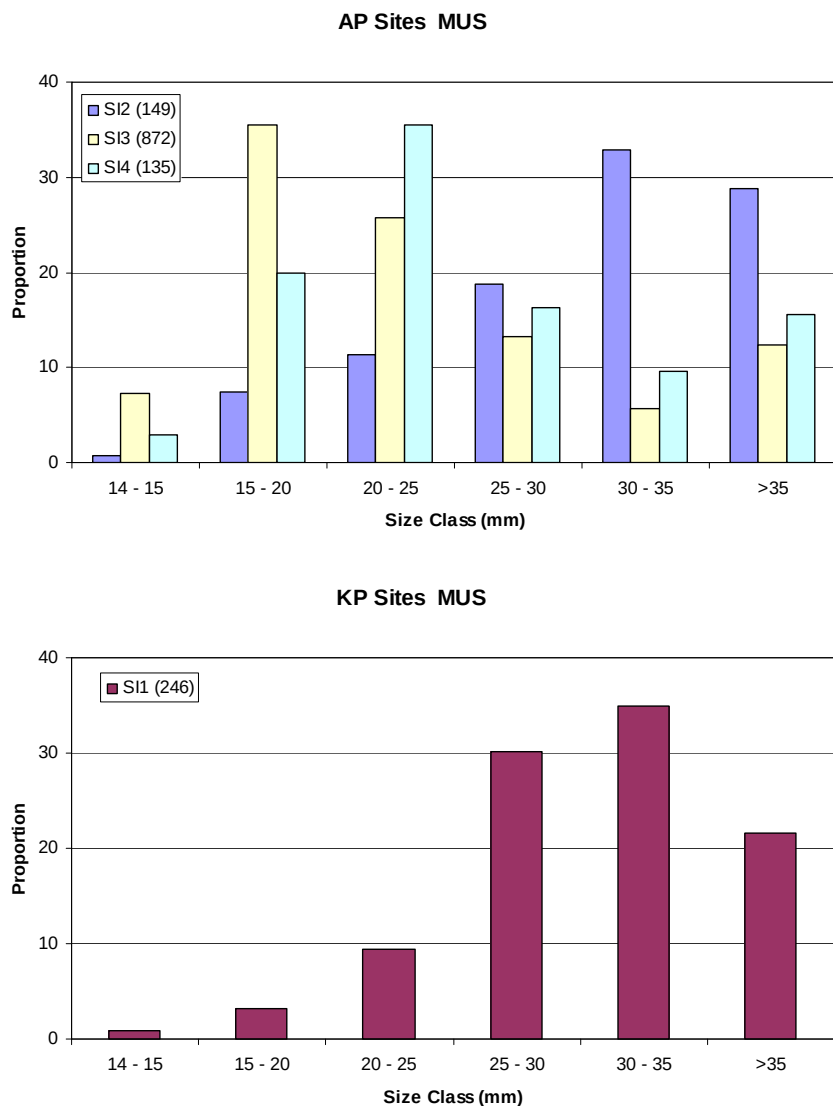


Figure 2.18. Comparison of size classes of *Mytilus* by park.

Clam Biomass

KATM

The biomass of clams per quadrat varied within sites as well as among sites and regions (Figures 13 and 15). Mean biomass of all clams per quadrat ranged between 0 – 33 grams ash-free dry weight (g AFDW). For *Protothaca*, the minimum biomass was zero in at least one quadrat per site, for other species the minimum was zero in at least one quad per site for 4 of 6 sites. Maximum biomass estimates by species are 11.5 g AFDW for *Macoma*; 1.9 g AFDW for *Protothaca*; 23.4 g AFDW, for *Saxidomus*; 6.6 g AFDW for *Mya*; and 2.5 g AFDW for *Hiatella*. Although *Macoma* dominated intertidal clam densities, biomass estimates are influenced by the size of the different species of clams. The contribution to overall biomass from the larger species, *Mya* and *Saxidomus*, is apparent when comparing Figure 2.19 with Figure 2.10.

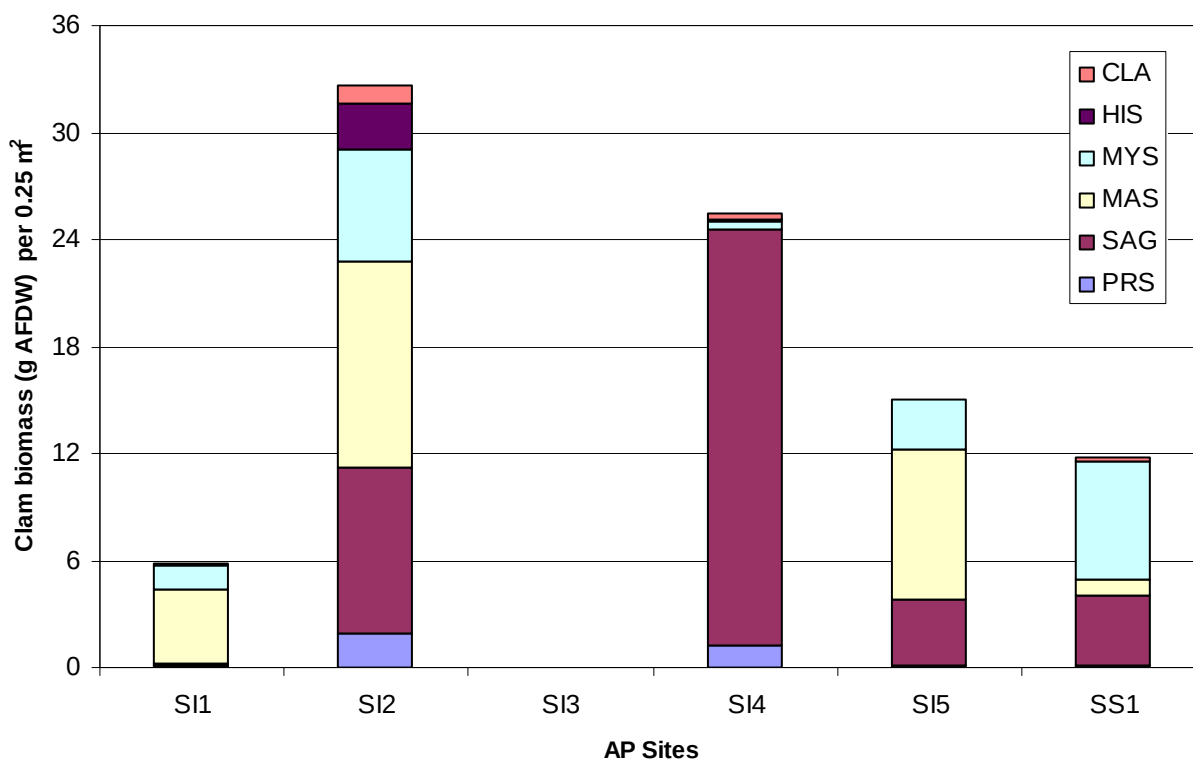


Figure 2.19. Clam biomass per quad in KATM, 2007.

KEFJ

The biomass of clams per quadrat varied within sites as well as among sites and regions (Figures 2.20 and 2.21). Mean biomass of all clams per quadrat ranged between 0 – 11.4 grams ash-free dry weight (g AFDW). For all species but *Macoma*, the minimum biomass was zero in at least one quadrat per site, for *Macoma* the minimum was zero in at least one quad per site for 3 of 5 sites. Maximum biomass estimates by species are 7.6 g AFDW for *Macoma*; 1.9 g AFDW for *Protothaca*; 2.3 g AFDW, for *Saxidomus*; 3.9 g AFDW for *Mya*; and 0.4 g AFDW for *Hiatella*. As in KATM, although *Macoma* dominated intertidal clam densities, biomass estimates are influenced by the size of the different species of clams. The contribution to overall biomass from the larger species, *Mya* and *Saxidomus*, is apparent when comparing Figure 2.20 with Figure 2.11.

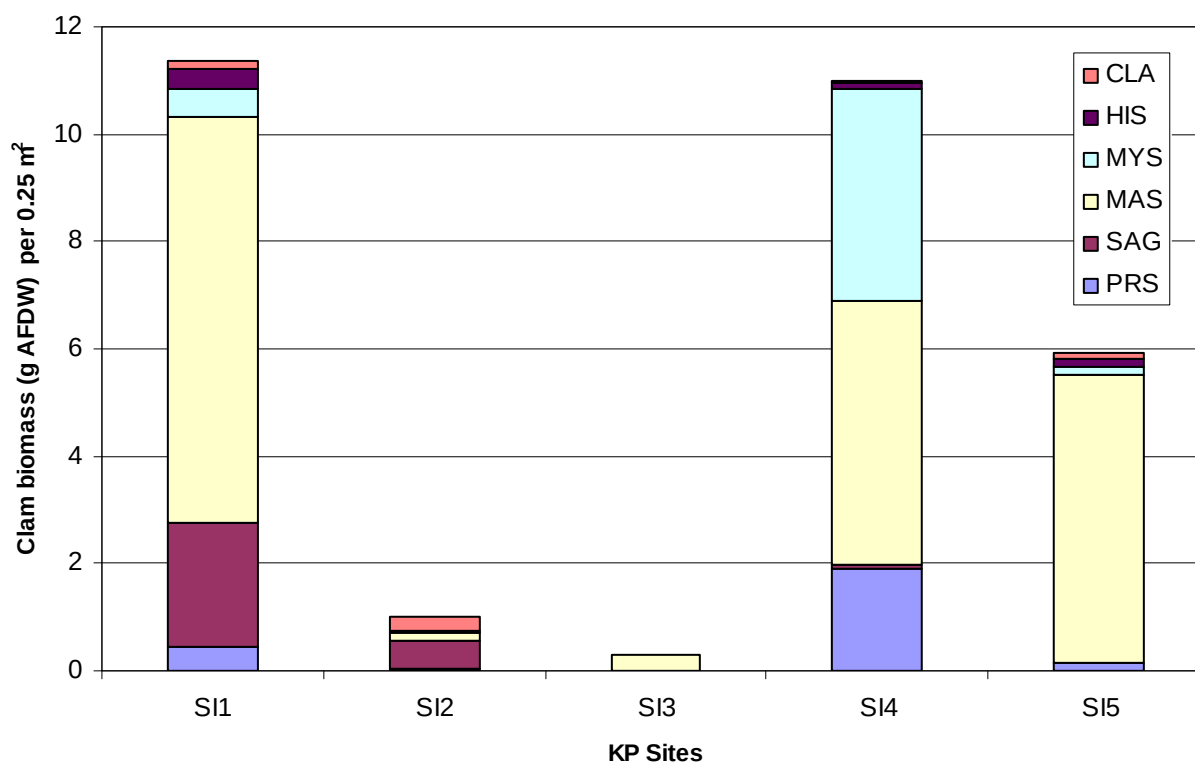


Figure 2.20. Clam biomass per quad in KEFJ, 2007

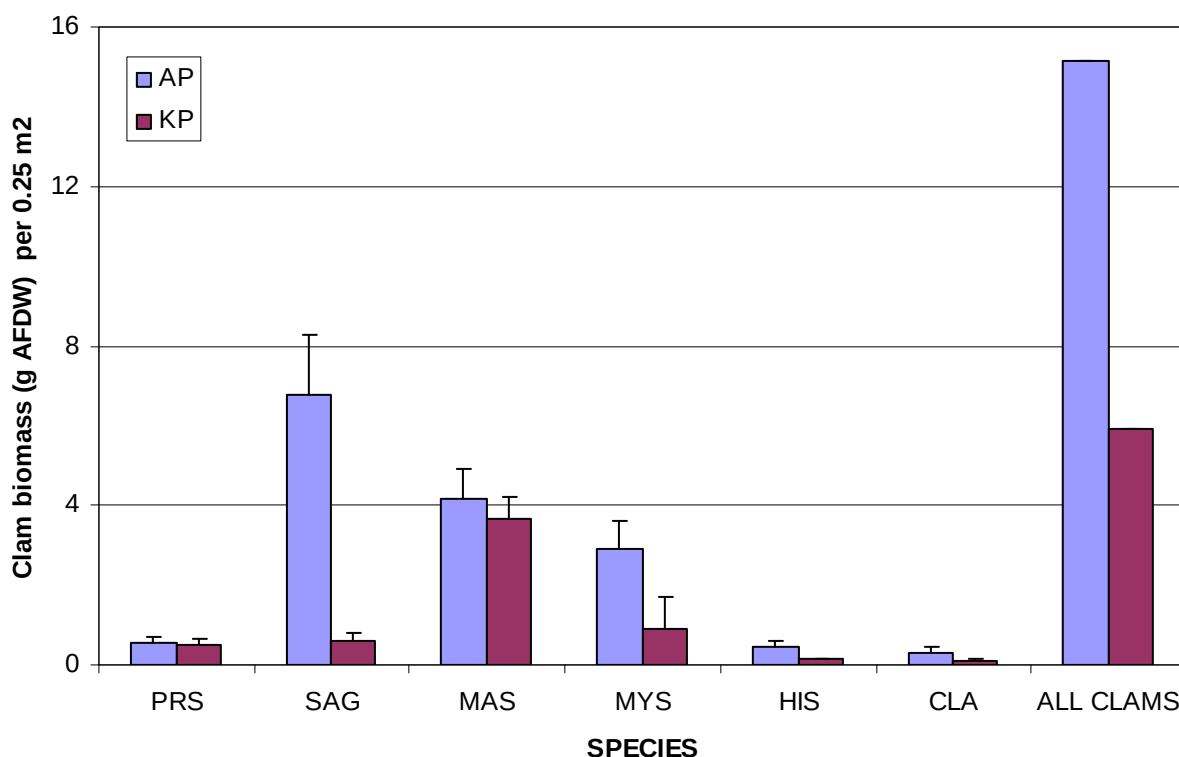


Figure 2.21. Clam biomass per quad in both KATM and KEFJ

DISCUSSION

Rocky Intertidal - The intertidal communities on sheltered rocky shores in KATM are typical of those found elsewhere in the Gulf of Alaska (Nybakken 1969; Haven 1971; Feder and Kaiser 1980; O'Clair and Zimmerman 1986; Highsmith et al. 1994, 1996) and are characterized by *Fucus* and various red, green, and brown algae in the lower intertidal (0.5 m) and by barnacles and *Fucus* in the mid intertidal zone (1.5 m). There was considerable variation in the species composition and relative abundance of species between sites. This is not surprising given that site locations were randomly selected and represent differing habitats with respect to exposure, slope, substrate type, and other physical characteristics. The most notable site differences were the lack of large predatory sea stars at the Kukak Bay in 2006 (Bodkin et al 2007) and the higher proportion of large *Tectura persona* limpets and mussels at that site. We do not know the cause for these differences, but hypothesize that the lack of sea stars may relate to somewhat lower salinity at the Kukak site, and the higher proportion of large limpets and mussels may relate to the lack of sea stars.

Relatively few differences were noted in the rocky intertidal between 2006 and 2007. Increases in the percent cover by barnacles were observed at some sites. This is not surprising given the highly variable nature of barnacle recruitment. Region-wide increases for the intertidal kelp *Alaria marginata*, the mussel *Mytilus trossulus*, and littorine snails *Littorina sitka*; and decreases

in cover by the red alga *Pterisiphonia bipinata* were observed. At this point in time, we can not be certain if these represent longer-term trends or normal inter-annual variation.

Soft Intertidal - We found nine different clam species/groups in our KATM sampling and 10 in our KEFJ sampling. Lees (2006) found 22 clam species in KATM and 21 in KEFJ, however, due to our protocol, we would not expect to find that many. Table 2.7 lists the species found in 2007 during this study as well as those found during Lees' study. We expect to encounter additional species (from the Lees report or novel sightings) as this monitoring program progresses.

Table 2.7. List of species found in KATM and KEFJ compared to Lees (2006)

Species	This Study		Lees 2006		Notes
	KATM	KEFJ	KATM	KEFJ	
<i>Axinopsida serricata</i>				X	Too small for our SOP
<i>Clinocardium blandum</i>			X		Harbo says subtidal species
<i>C. nuttallii</i>	X	X	X	X	
<i>Diplodonta impolita</i>	X	X		X	
<i>D. orbella</i>	X				Foster & Harbo say this is a southern species. So either range expansion or actually <i>D. impolita</i>
<i>Glycymeris septentrionalis</i>				X	
<i>Hiatella arctica</i>	X	X		X	
<i>Kellia suborbicularis</i>				X	
<i>Macoma balthica</i>	X	X	X	X	
<i>M. expansa</i>			X	X	Our SOP doesn't distinguish most <i>Macomas</i> as it would be too time consuming and often requires destruction of the clam.
<i>M. golikovi</i>			X	X	
<i>M. inquinata</i>			X	X	
<i>M. nasuta</i>			X		
<i>M. spp.</i>	X	X			
<i>Mactromeris polynyma</i>			X		
<i>Mya arenaria</i>	X	X	X	X	
<i>M. pseudoarenaria</i>			X	X	
<i>M. truncate</i>	X	X	X	X	
<i>Neaeromya compressa</i>	X	X		X	AKA <i>Pseudopythina compressa</i>
<i>Nutricula lordii</i>			X		Too small for our SOP
<i>Protothaca staminea</i>	X	X	X	X	
<i>Rochefortia tumida</i>			X	X	Too small for our SOP
<i>Saxidomas giganteus</i>	X	X	X	X	
<i>Serripes laperousii</i>		X			
<i>Siliqua alta</i>			X		Habitat not part of our SOP
<i>S. patula</i>			X		Habitat not part of our SOP
<i>Turtonia minata</i>			X	X	Too small for our SOP
<i>Tellina lutea</i>			X		
<i>T. nuculoides</i>			X	X	
<i>Tresus capax</i>			X		

Intertidal clam densities at KATM and KEFJ was equal at 16.3 ± 6 clams per 0.25m^2 quadrat and *Macoma* sp. were the most abundant clam at each park. However, in both KATM and KEFJ the number of clams per quadrat varied extensively within sites as well as among sites and parks.

A gross examination of substrate data shows no differences across sites that correspond to differences observed in either clam densities nor species composition. Lab results have not yet been received for sediment grain size analysis so we have not yet been able to determine the relationship between substrate and clam populations. Once additional data has been collected and lab results received, it is anticipated that a spatial analysis could be conducted to examine the role of variables such as substrate qualities, aspect, slope, distance from freshwater influx, presence of predators (sea otters, seaducks) on intertidal clam communities in KATM and KEFJ.

Mean sizes of *Protothaca* were larger at KATM than KEFJ, but the opposite was true for *Saxidomus*. For *Mya* and *Hiatella*, KATM mean sizes were larger than those measured in KEFJ. *Macoma* mean sizes were the same at both parks.

Mean clam sizes and the distribution of clam sizes by species will provide some of the best evidence of a possible sea otter foraging effect at our sampling sites. In KATM mean sizes of *Protothaca* and *Saxidomus* are about 34 mm and 36 mm, respectively and 31 mm and 38 mm respectively for KEFJ. In Glacier Bay, at random and preferred clam habitat sites sampled prior to sea otter foraging pressures, respective mean sizes of *Protothaca* and *Saxidomus* are about 40 and 70 mm (Bodkin et al. 1999). *Saxidomus* and *Protothaca* are preferred clam prey of sea otters in Alaska (Kvitek et al. 1992, JLB unpub. data) and larger clams are preferentially selected by foraging sea otters (Kvitek et al. 1992, Kvitek et al. 1993). The clam populations that persist in areas with prolonged sea otter foraging are characterized by reduced densities and size distributions that are truncated near the minimum size clams that are regularly consumed. However, this study has not yet determined the impact of sea otter predation on prey communities in KATM or KEFJ.

We expect that as sea otters continue to exert foraging pressure on intertidal communities that the overall abundance of preferred clams will decrease and that the size distributions of those clams will shift toward higher proportions of smaller individuals. In some instances, very few clams were present at our sites. Perhaps a more representative site needs to be sampled or the sampling effort should be focused a bit lower in the intertidal to adequately sample the community.

RECOMMENDATIONS

Data are currently being examined to determine if the sampling effort at rocky sites can be reduced by reducing the number of quadrats sampled or reducing the frequency of sampling for some rarer species. Also, methods for sampling of larger mussels and limpets that are important prey items for black oystercatchers and other vertebrate predators are being explored. The larger size classes are rare and high concentrations of larger individuals are widely dispersed. As a result, they are clearly under-sampled in our current sampling design.

In a few instances, very few or no clams were found at in some quadrats at the 0.5 m tidal height. If time allowed during the sampling season in 2007, test quads were dug at lower tidal elevations to search for the presence of clams. In many cases, clams were found at tidal elevations lower than the specified 0.5 m. Our specific objectives in this SOP are to detect and assess changes in: 1) the relative abundance of clams in the intertidal zone, 2) the diversity of clams, and 3) the size distribution of numerically abundant clam species (including *Protothaca staminea* and *Macoma* sp. We recommend returning to the established soft sediment sites, where the invertebrate sample was inadequate to meeting SOP objectives, and conduct vertical quad sampling of the intertidal to determine the appropriate tidal height at which to measure clam density, distribution and species composition. A standardized method for mussel collection at the soft sediment sites should be completed prior to the 2008 field sampling season.

3 Marine Birds

INTRODUCTION

Marine birds and mammals are important constituents of marine ecosystems and are sensitive to variation in marine conditions. Our focus on nearshore marine bird monitoring will be on species that are trophically linked to the nearshore food web, and include species of sea ducks (harlequin ducks, Barrow's (*Bucephala islandica*) and common goldeneye (*Bucephala clangula*), bufflehead (*Bucephala albeola*), long-tail ducks (*Clangula hyemalis*), and scoters, mergansers (common (*Mergus merganser*) and red-breasted (*Mergus serrator*)), and shorebirds, specifically the black oystercatcher (see section 4). Because other birds and mammals will be encountered in the course of monitoring nearshore species, observations of all marine birds and mammals will be recorded and reported on.

The sea ducks and black oystercatcher were selected for focus because of their reliance on habitats and prey associated with nearshore marine communities. These species are top level consumers of nearshore invertebrates such as mussels, clams, snails, and limpets that are being monitored under the algal and intertidal invertebrate SOP (see section 2). Because these species are recognized to play important roles as consumers of marine invertebrates (Draulans 1982, Marsh 1986a and b, Meire 1993, Lindberg et al. 1998, Hamilton and Nudds 2003, Lewis et al. 2007), understanding cause of change in abundance over time of these nearshore seabirds will be facilitated through the direct estimates of their prey populations provided through nearshore invertebrate monitoring. Moreover, monitoring trends in abundance of the various guilds of other marine birds, e.g. the *Alcids*, loons (*Gavia* sp.), grebes (*Podicipedidae* sp.), gulls, and cormorants that occupy other food webs or habitats may improve the ability to discriminate among potential causes of change in seabird populations and the nearshore ecosystem. For example, concurrent changes in sea ducks, which forage on nearshore invertebrates, and the *Alcids* that forage on zooplankton or small schooling fish, may suggest a common cause of change, one that may be independent of food. Such an approach may provide insights related to competing hypothesis relative to cause of change within or among populations (Petersen et al. 2003). In addition many of these species, including the harlequin duck, Barrow's goldeneye, and black oystercatcher were impacted by the Exxon Valdez oil spill, and exhibited protracted recovery periods as a consequence of lingering oil in nearshore habitats in Prince William Sound (Andres 1999, Trust et al. 2000, Esler et al. 2000, Esler et al. 2002). Long-term monitoring of these species at different locations will likely provide increased confidence in assessment of the status of these populations relative to restoration and recovery from the 1989 spill. Additionally, existing data collected using comparable methods are available from other nearshore habitats in the Gulf of Alaska for periods up to 20 years (Irons et al. 1988, Irons et al. 2000). Because marine bird sampling focuses on species associated with nearshore intertidal and subtidal habitats, species of marine birds and mammals that occur further offshore will be underrepresented. The distribution of most marine birds and mammals includes habitats that extend beyond 200 m from shore, thus estimates derived from these surveys will be improved by including sampling of offshore areas.

Monitoring of marine bird and mammal species and populations will provide a potentially powerful tool in identifying the magnitude and causes of inevitable change in Gulf of Alaska nearshore habitats and communities. The direct sampling of invertebrate populations of clams,

mussels, and limpets will support inference regarding causes of change in sea duck and shorebird populations over time. Because the methods used to sample focal species of sea ducks and shorebirds are inclusive of other marine birds and mammals, we will obtain indices of abundance of other species that will provide evaluation of trends in abundance over time. Contrasts of population trends over time and locations among marine birds and mammals that occupy different food webs or habitats should be informative in discriminating among competing hypothesis related to causes of change in nearshore marine ecosystems.

METHODS

Standardized surveys of marine birds and mammals were conducted in KATM and KEFJ in June and July, 2007. Detailed descriptions of methods and procedures can be found in the Marine Bird and Mammal Survey SOP (Dean and Bodkin 2006). Following is a brief review of those methods. Surveys were conducted from small vessels (5-8 m length) that were navigated along selected sections of coastline that represented independent transects. Transect width was 200 m and two observers searched each side of the vessel out 100 m. All marine birds and mammals identified were counted within the 200 m transect width that includes 100 m ahead of, behind, and over the vessel. One observer navigated the skiff, and generally surveyed the offshore portion of the transect. The second observer counted birds and mammals on the shore side of the survey transect, and a third member of the team was responsible for entering observations into a computer program (dLOG2) designed specifically for these surveys (Dean and Bodkin 2006), and assisted in observations.

The survey vessel traveled at a speed of approximately 8-12 knots along the transect. Observers scanned each side of the vessel from the bow to the stern, and provided the numbers, species, and activity of all marine birds and mammals detected to the data recorder. Included in each observation was the number of individuals observed by species or lowest possible taxa. Starting and ending points of the transect were noted and recorded in dLOG2

The survey design consisted of a series of systematically placed transects along shorelines such that a minimum of 20% of the shoreline is surveyed (Figure 3.1). Transects were systematically selected beginning at a random starting point from the pool of contiguous ~2-5 km transects that were adjacent to the mainland or islands, plus the lengths of transects that were associated with islands or groups of islands with less than 5 km of shoreline. Additional transects of 5 km in length that were centered on each intensive rocky site were also implemented in some cases. In KATM, ten pelagic transects (>200m offshore, 5 km in length) were sampled as well to address the likely biases associated with sampling only transects adjacent to shorelines (Figures 3.1).

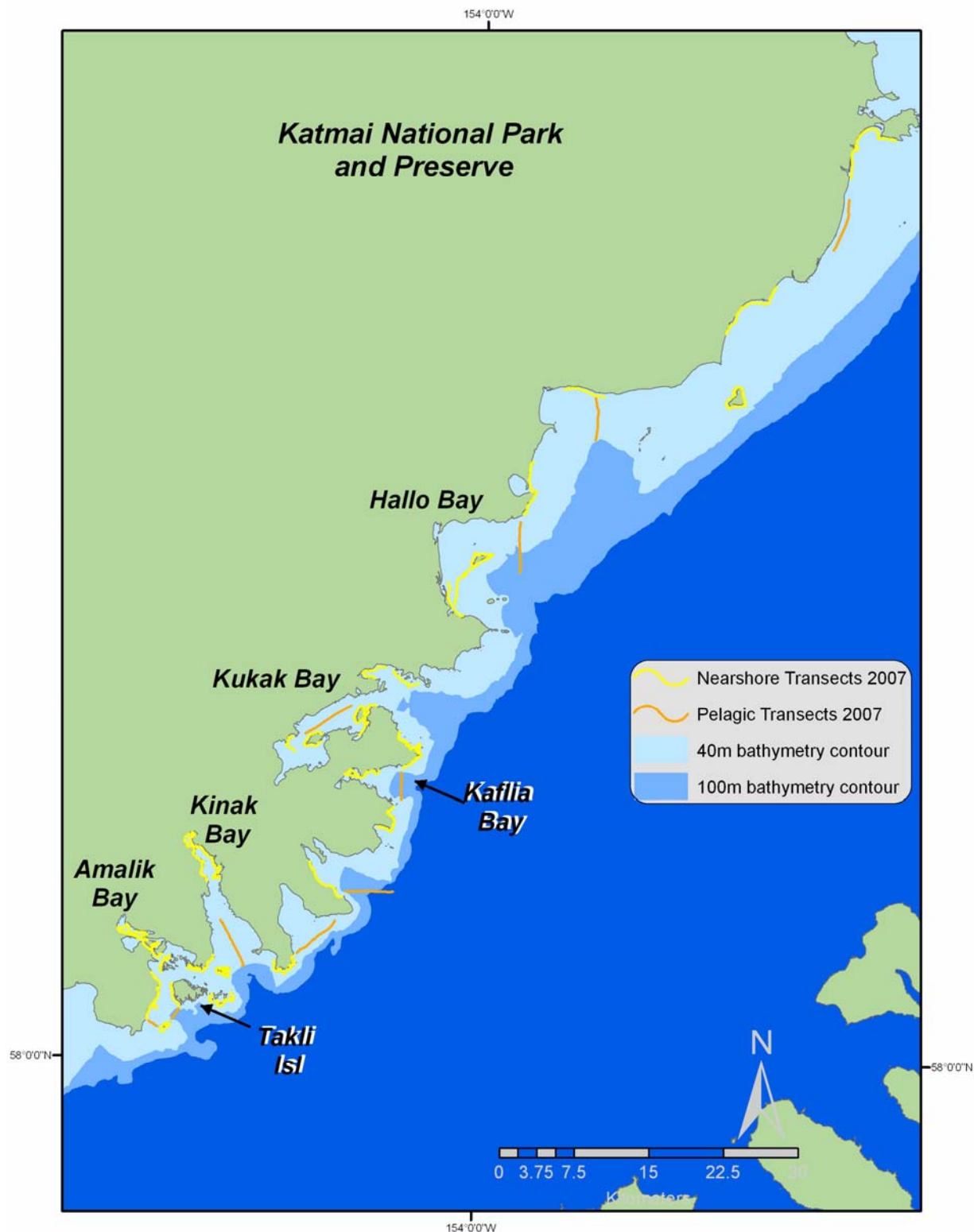


Figure 3.1 Locations of marine bird and mammal transects sampled in KATM, June and July 2007.

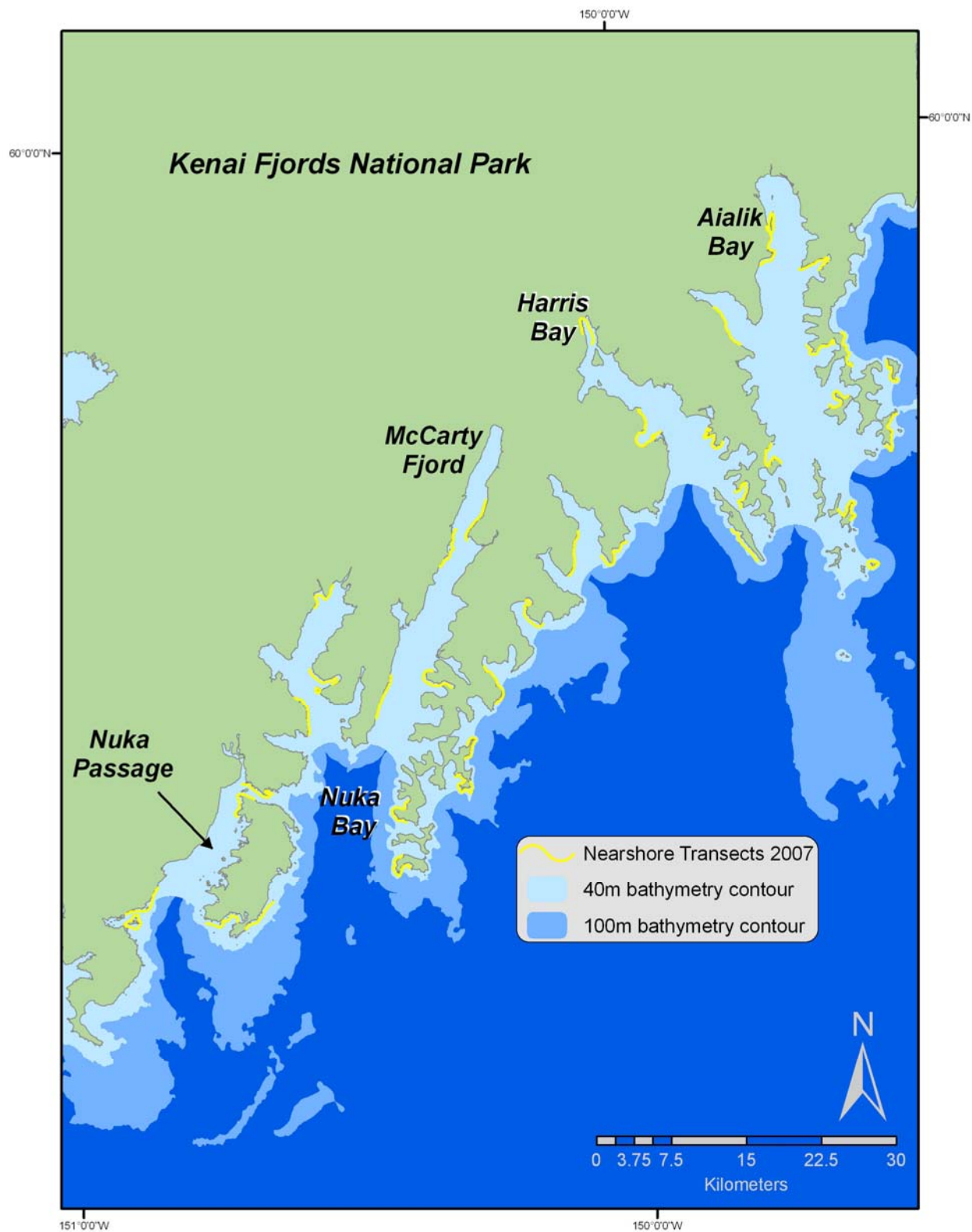


Figure 3.2 Locations of marine bird and mammal transects sampled in KEFJ, June 2007.

RESULTS

KATM

Between June 25 and July 5, 2007 we surveyed 40 transects in KATM, 10 pelagic transects and 30 nearshore transects. Transect lengths ranged from 1.0 km to 15.1 km and averaged 5.5km. We sampled approximately 181 km, or about 27% of the 675 km of surveyable shoreline in the KATM sampling block. We sampled 40 km of pelagic transects to begin to alleviate the likely biases associated with sampling only transects adjacent to shorelines. The most common birds observed on the nearshore transects were the glaucous-winged gull ($121.1/\text{km}^2$), and the black-legged kittiwake ($60.9/\text{km}^2$). Species considered reliant on nearshore habitats included the harlequin duck ($26.43/\text{km}^2$, $\text{se}=6.3$); the surf scoter ($5.0/\text{km}^2$, $\text{se}=3.6$), the common merganser ($4.3/\text{km}^2$, $\text{se}=2.5$), and the red-breasted merganser ($0.3/\text{km}^2$, $\text{se}=0.3$). The most common birds observed on the pelagic transects were the black-legged kittiwake ($25.21/\text{km}^2$, $\text{se}=16.42$) and the glaucous-winged gull ($5.88/\text{km}^2$, $\text{se}=3.59$). Densities of other marine birds and mammals detected on shoreline transects can be found in Table 3.1. Densities of other marine birds and mammals detected on pelagic transects can be found in Table 3.2.

Sea otters were the most widely distributed marine mammal and were observed on 18 of 40 transects (five groups were observed on pelagic transects). Sea otters also had the highest density of the marine mammals at $4.8/\text{km}^2$ ($\text{se}=2.5$) (including pups), which includes pelagic observations. Sea otters were followed by Steller sea lions with a density of $2.6/\text{km}^2$ ($\text{se}=2.1$). Densities were calculated using weighted averages by transect length.

Distribution maps for marine bird and mammals that were relatively abundant or of special interest (e.g. loons and murrelets) are given in Figures 3.3 through 3.20. Harlequin ducks, black oystercatchers, glaucous-winged gulls, black-legged kittiwakes, pigeon guillemots, sea otters, and harbor seals were relatively abundant and uniformly distributed along the nearshore transects. Other species, including the scoters, cormorants, mew gulls, puffins, common mergansers, and Steller sea lions were relatively abundant but had highly aggregated nearshore distributions. Red-breasted mergansers, common loons, and marbled murrelets were rare along the nearshore. No Kittlitz's murrelets were observed in 2007. Black-legged kittiwakes, glaucous-winged gulls, marbled murrelets and sea otters were relatively common along the 10 pelagic transects that were added to the survey in 2007. Although not detected on transect during the survey, the presence of approximately 600 horned puffins and 400 tufted puffins were in the proximity of Ninagiak Island in Hallo Bay. The presence of a peregrine falcon and possible eyrie was also observed off transect in the vicinity of Takli Island.

Table 3.1. Species and densities (se) of marine birds and mammals in the nearshore marine zone in KATM, June-July 2007. Approximately 27% of the total shoreline length was sampled. Min. and Max. are the minimum and maximum number of individuals per group and sum is the total number of individuals observed in all groups. Yellow shaded rows indicate focal species in the nearshore sampling protocol.

Species (marine birds)	# of groups observed	Min	Max	Sum	Average density (#/km ²)	SE
American wigeon (<i>Anas americana</i>)	1	1	1	1	0.04	0.04
Arctic tern (<i>Sterna paradisaea</i>)	5	1	4	8	0.29	0.16
Bald eagle (<i>Haliaeetus leucocephalus</i>)	79	1	5	100	2.89	0.46
Barrow's goldeneye (<i>Bucephala islandica</i>)	2	6	8	14	0.15	0.15
Black-billed magpie (<i>Pica hudsonia</i>)	4	1	2	5	0.12	0.07
Belted kingfisher (<i>Ceryle alcyon</i>)	3	1	1	3	0.06	0.03
Black-legged kittiwake (<i>Rissa tridactyla</i>)	134	1	280	2411	60.85	29.38
Black oystercatcher (<i>Haematopus bachmani</i>)	55	1	4	85	2.33	0.73
Black scoter (<i>Melanitta nigra</i>)	3	1	16	19	0.90	0.84
Brant (<i>Branta bernicla</i>)	1	1	1	1	0.03	0.03
Common eider (<i>Somateria mollissima</i>)	1	1	1	1	0.02	0.02
Common loon (<i>Gavia immer</i>)	4	1	3	6	0.11	0.09
Common merganser (<i>Mergus merganser</i>)	16	1	95	235	4.33	2.51
Common murre (<i>Uria aalge</i>)	1	1	1	1	0.02	0.02
Common raven (<i>Corvus corax</i>)	1	1	1	1	0.02	0.02
Double-crested cormorant (<i>Phalacrocorax auritus</i>)	20	1	6	38	1.12	0.55
Glaucous-winged gull (<i>Larus glaucescens</i>)	291	1	817	4280	121.13	34.28
Harlequin duck (<i>Histrionicus histrionicus</i>)	97	1	104	976	26.43	6.33
Horned puffin (<i>Fratercula corniculata</i>)	12	1	22	63	1.54	1.17
Mallard (<i>Anas platyrhynchos</i>)	4	1	6	16	0.56	0.34
Marbled murrelet (<i>Brachyramphus marmoratus</i>)	9	1	4	17	0.55	0.39
Mew gull (<i>Larus canus</i>)	34	1	24	171	3.73	1.84
Northern crow (<i>Corvus caurinus</i>)	41	1	8	86	1.96	0.46
Northern pintail (<i>Anas acuta</i>)	2	5	5	10	0.39	0.39
Pelagic cormorant (<i>Phalacrocorax pelagicus</i>)	31	1	100	295	8.67	4.13
Pigeon guillemot (<i>Cepphus columba</i>)	97	1	56	216	6.33	2.08
Red-breasted merganser (<i>Mergus serrator</i>)	2	2	5	7	0.29	0.29
Red-faced cormorant (<i>Phalacrocorax urile</i>)	27	1	48	286	15.09	14.15

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Surf scoter (<i>Melanitta perspicillata</i>)	8	2	310	373	5.04	3.64
Tufted puffin (<i>Fratercula cirrhata</i>)	14	1	12	31	1.48	1.14
Unid. Cormorant (<i>Phalacrocoracidae</i> sp.)	17	1	108	161	7.40	6.12
Unid. Gull (<i>Laridae</i> sp.)	19	1	90	243	5.10	4.44
Unid. Loon (<i>Gavia</i> sp.)	2	1	3	4	0.07	0.07
Unid. Merganser (<i>Mergus</i> sp.)	5	1	4	11	0.32	0.16
Unid. Murrelet (<i>Brachyramphus</i> sp.)	7	1	2	9	0.28	0.13
Unid. Scoter (<i>Melanitta</i> sp.)	2	2	5	7	0.21	0.14
Unid. Shearwater (<i>Puffinus</i> sp.)	1	8	8	8	0.20	0.20
White-winged scoter (<i>Melanitta fusca</i>)	6	1	26	40	1.31	0.88

Species (marine mammals)	# of groups observed	Min	Max	Sum	Average density (#/km ²)	SE
Harbor seal (<i>Phoca vitulina</i>)	50	1	12	82	2.17	0.49
Sea otter (adult) (<i>Enhydra lutris</i>)	49	1	64	135	4.48	2.68
Sea otter (pup) (<i>Enhydra lutris</i>)	7	1	11	24	0.74	0.56
Steller sea lion (<i>Eumetopias jubatus</i>)	11	1	35	64	2.60	2.08
Brown bear (<i>Ursus arctos</i>)	19	1	9	37	0.91	0.27
Moose (<i>Alces alces</i>)	1	1	1	1	0.01	0.01
River otter (<i>Lutra canadensis</i>)	1	1	1	1	0.04	0.04

Table 3.2. Species and densities (se) of marine birds and mammals in the pelagic marine zone in KATM, June-July 2007. Approximately 27% of the total shoreline length was sampled. Min. and Max. are the minimum and maximum number of individuals per group and sum is the total number of individuals observed in all groups. Yellow shaded rows indicate focal species in the nearshore sampling protocol.

Species	# of groups observed	Min	Max	Sum	Average density (#/km ²)	SE
Black-legged kittiwake (<i>Rissa tridactyla</i>)	31	1	18	81	25.21	16.42
Black scoter (<i>Melanitta nigra</i>)	1	2	2	2	0.96	0.96
Common murre (<i>Uria aalge</i>)	7	1	2	9	1.06	0.46
Glaucous-winged gull (<i>Larus glaucescens</i>)	26	1	15	57	5.88	3.59
Horned puffin (<i>Fratercula corniculata</i>)	5	1	3	9	0.89	0.77
Marbled murrelet (<i>Brachyramphus marmoratus</i>)	18	1	6	30	2.91	1.53
Pigeon guillemot (<i>Cepphus columba</i>)	4	1	2	6	2.14	1.91
Unid. cormorant (<i>Phalacrocoracidae</i> sp.)	1	1	1	1	0.48	0.48
Unid. murre (<i>Uria</i> sp.)	1	1	1	1	0.10	0.10
Unid. murrelet (<i>Brachyramphus</i> sp.)	9	1	2	14	1.37	0.85
Yellow-billed loon (<i>Gavia adamsii</i>)	1	1	1	1	0.09	0.09
Sea otter (adult) (<i>Enhydra lutris</i>)	14	1	7	25	2.91	2.40
Sea otter (pup) (<i>Enhydra lutris</i>)	5	1	2	7	0.81	0.81

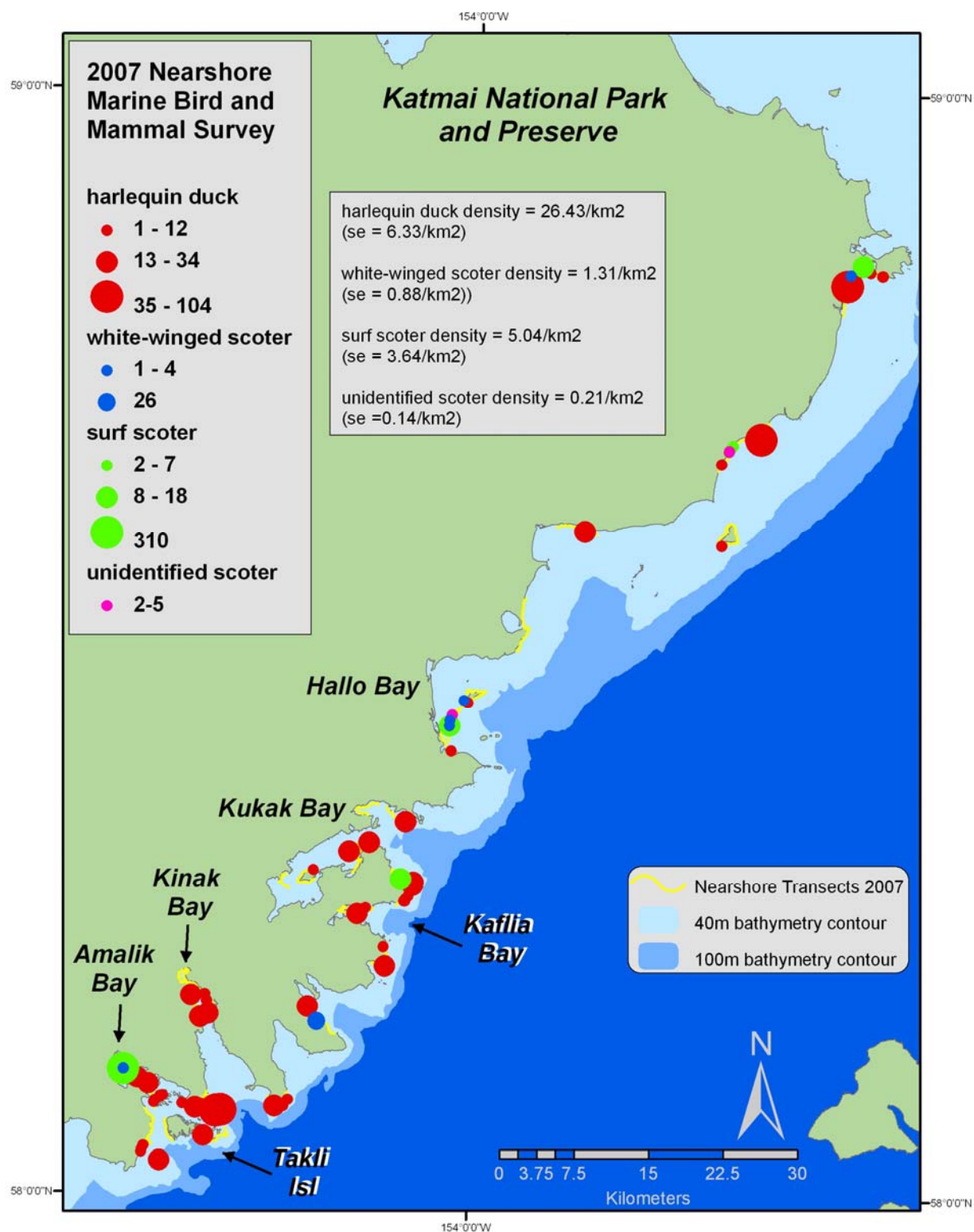


Figure 3.3. Distribution, abundance, and density of sea ducks (harlequin duck, white-wing scoter, surf scoter, and unidentified scoters) in block 10 KATM, June-July 2007.

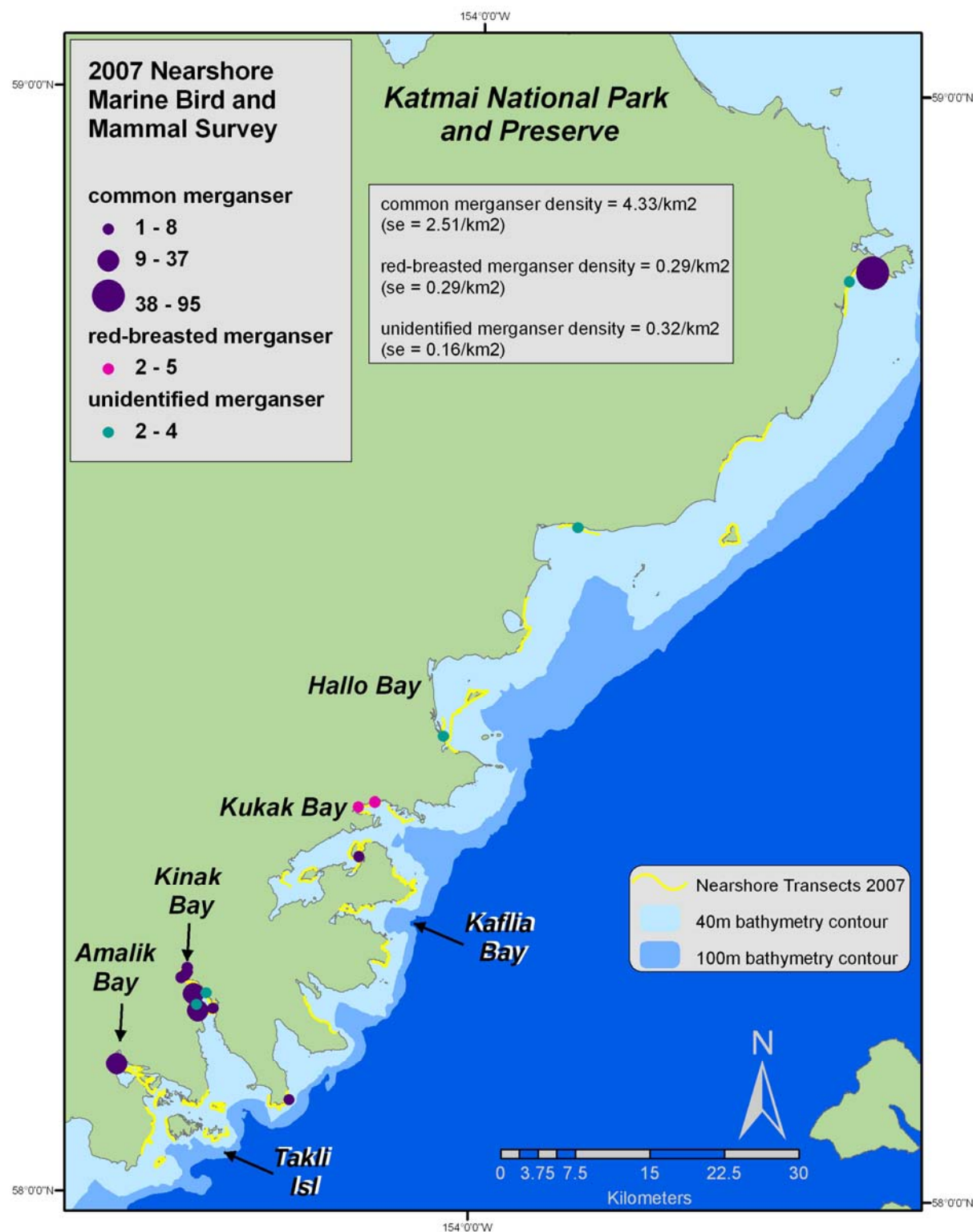


Figure 3.4. Distribution, abundance, and density of common, red-breasted mergansers and unidentified mergansers in block 10 KATM, June-July 2007.

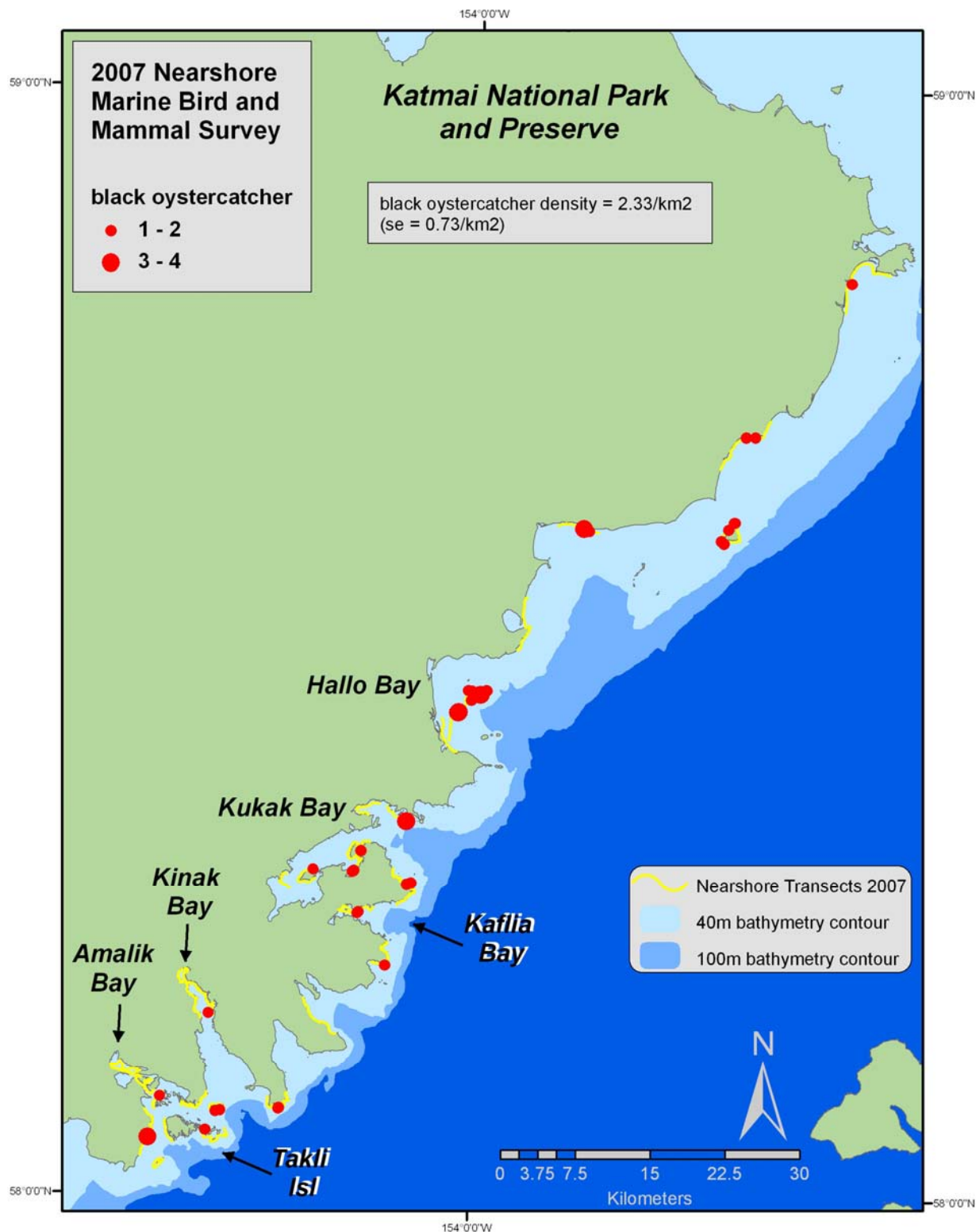


Figure 3.5. Distribution, abundance, and density of black oystercatchers in block 10 KATM, June-July 2007.

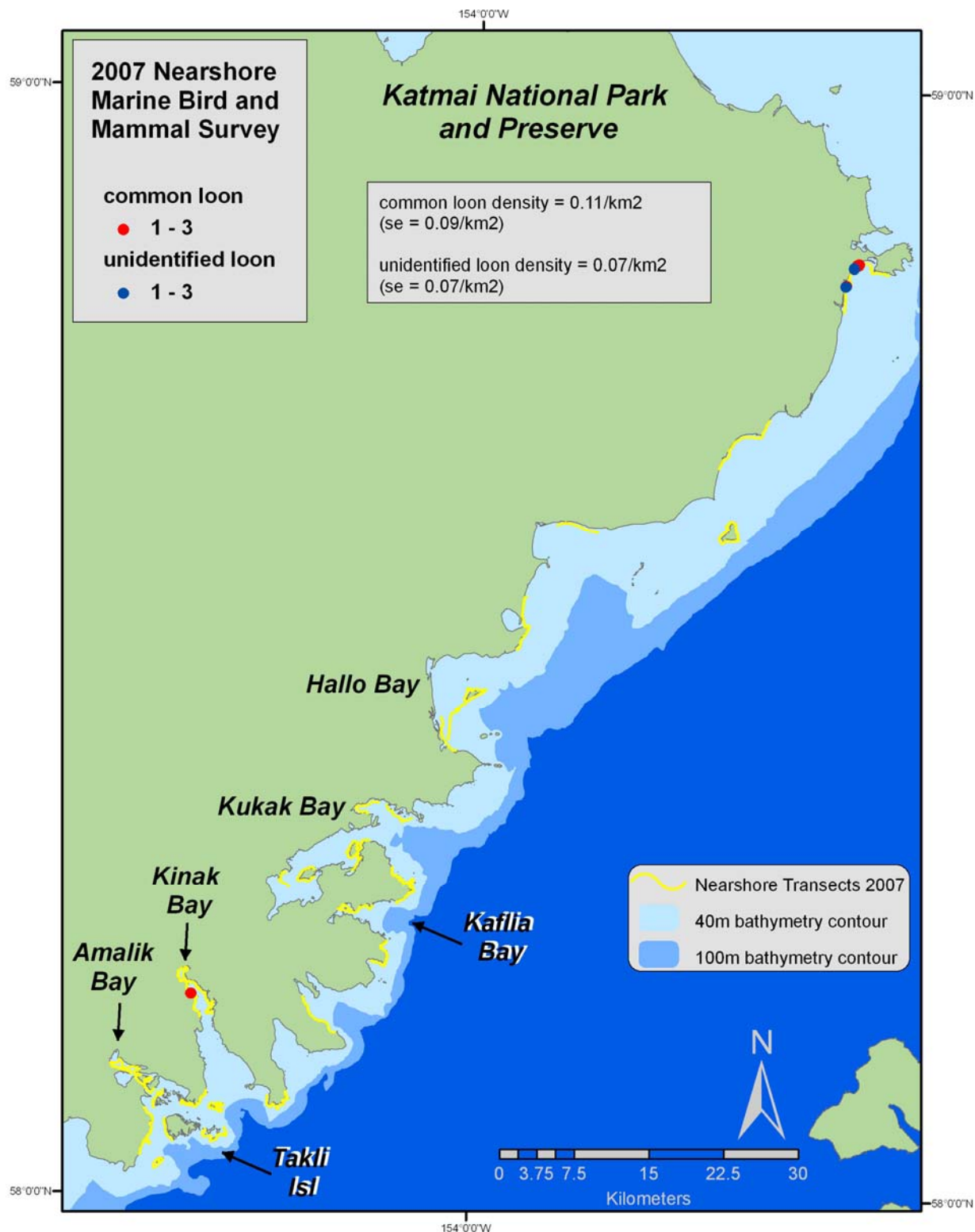


Figure 3.6. Distribution, abundance, and density of Pacific loons and unidentified loons in block 10 KATM, June-July 2007.

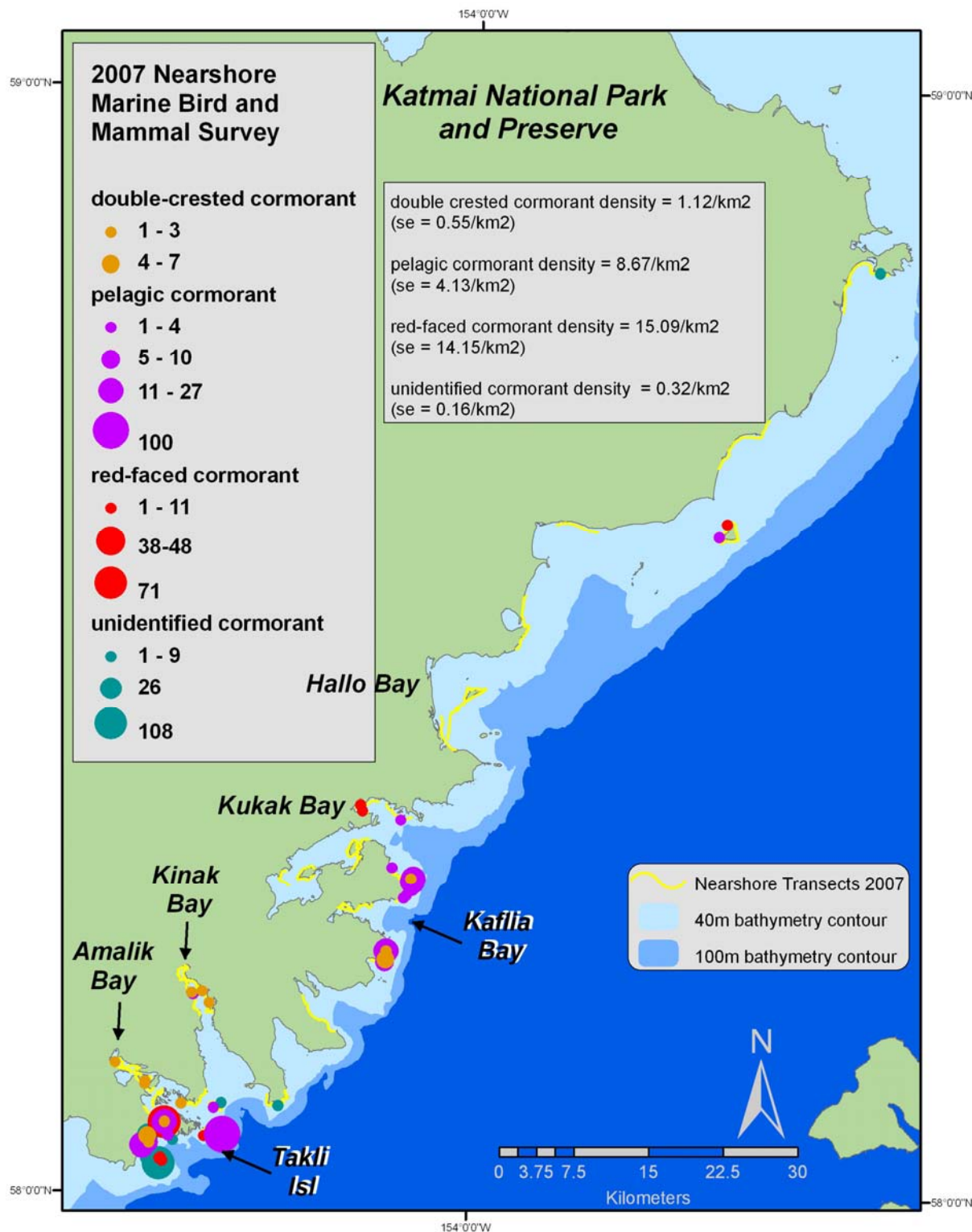


Figure 3.7. Distribution, abundance, and density of double-crested, pelagic, red-faced and unidentified cormorants in block 10 KATM, June-July 2007.

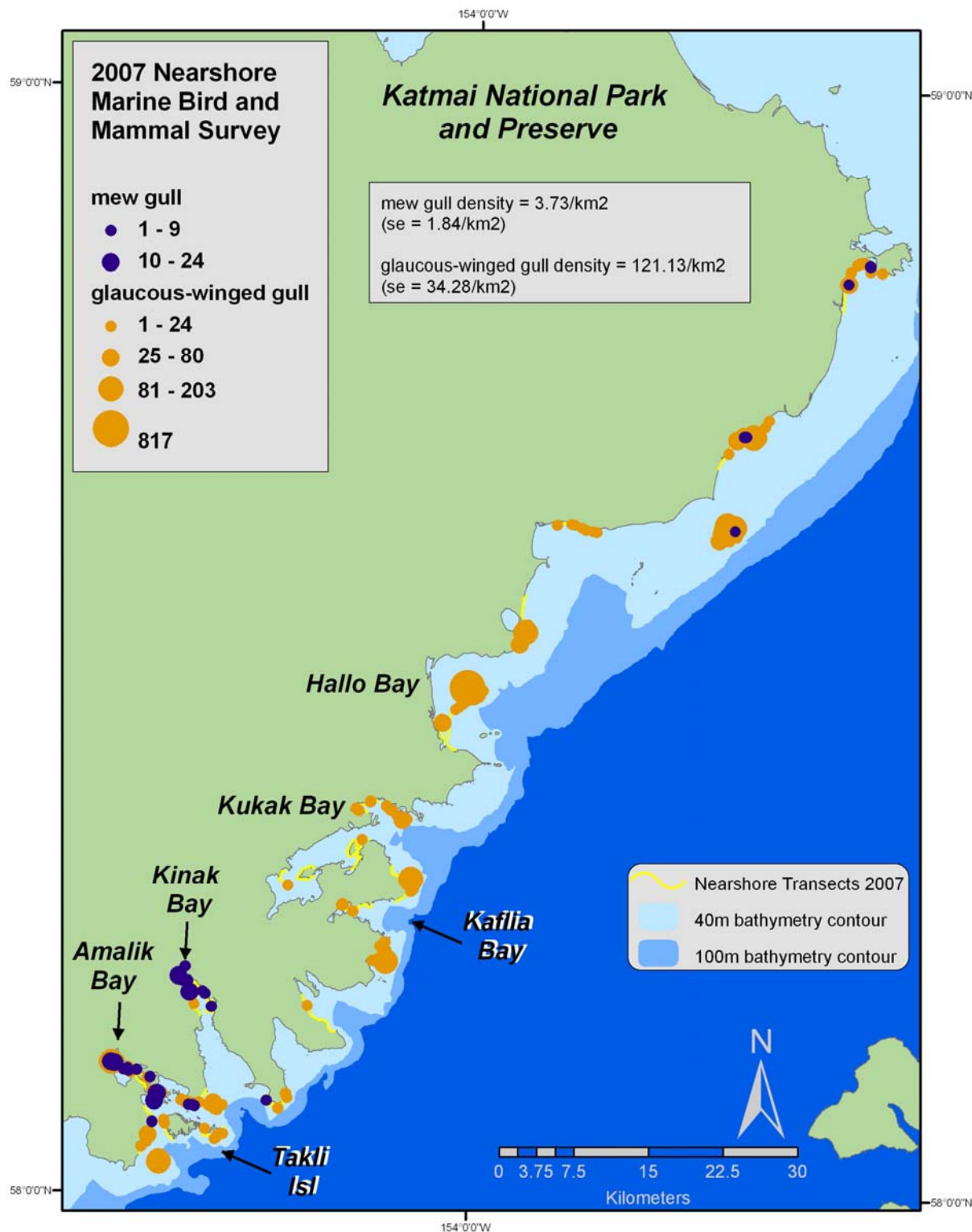


Figure 3.8. Distribution, abundance, and density of mew and glaucous-winged gulls in block 10 KATM, June-July 2007.

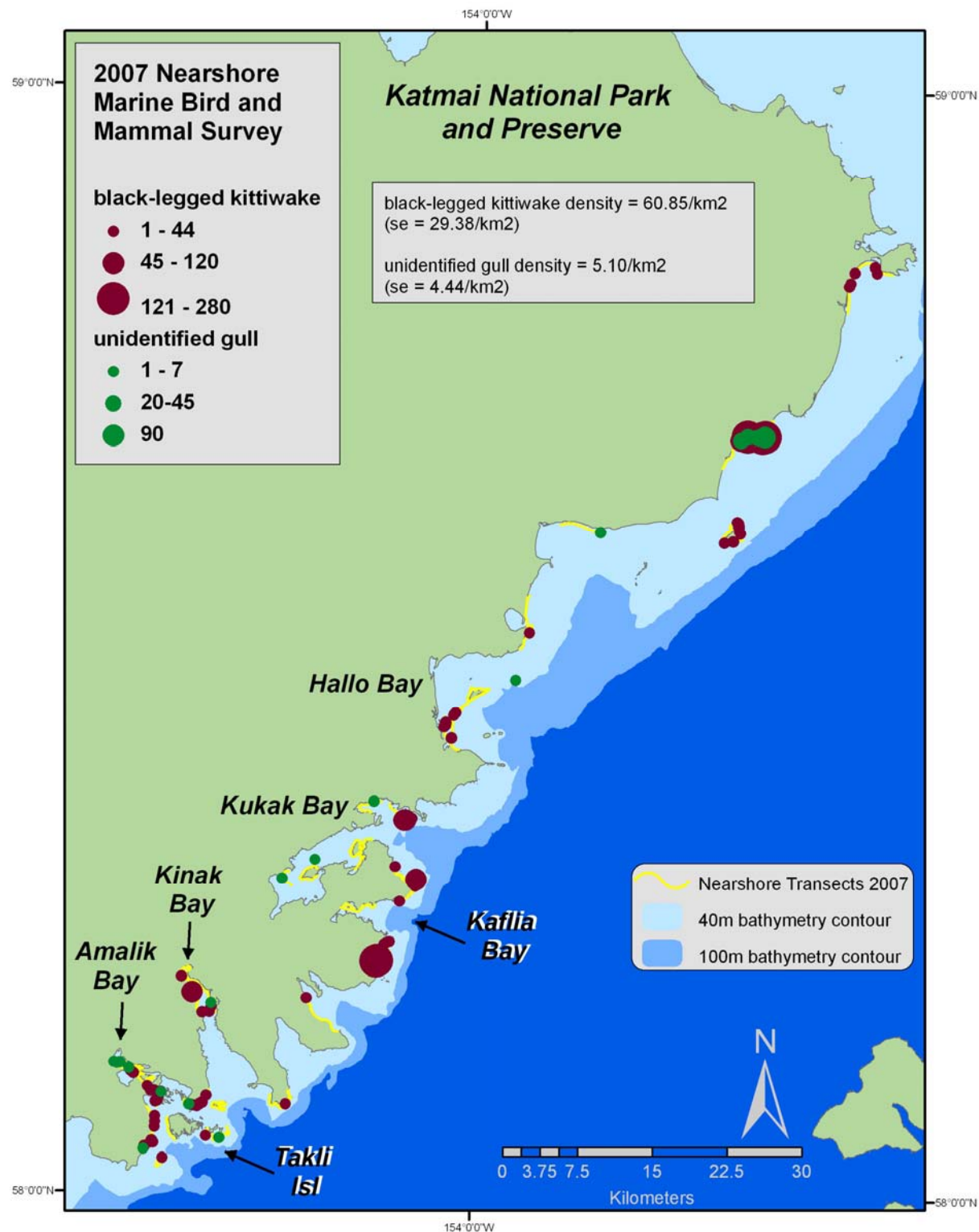


Figure 3.9. Distribution, abundance, and density of black-legged kittiwakes and unidentified gulls in block 10 KATM, June-July 2007.

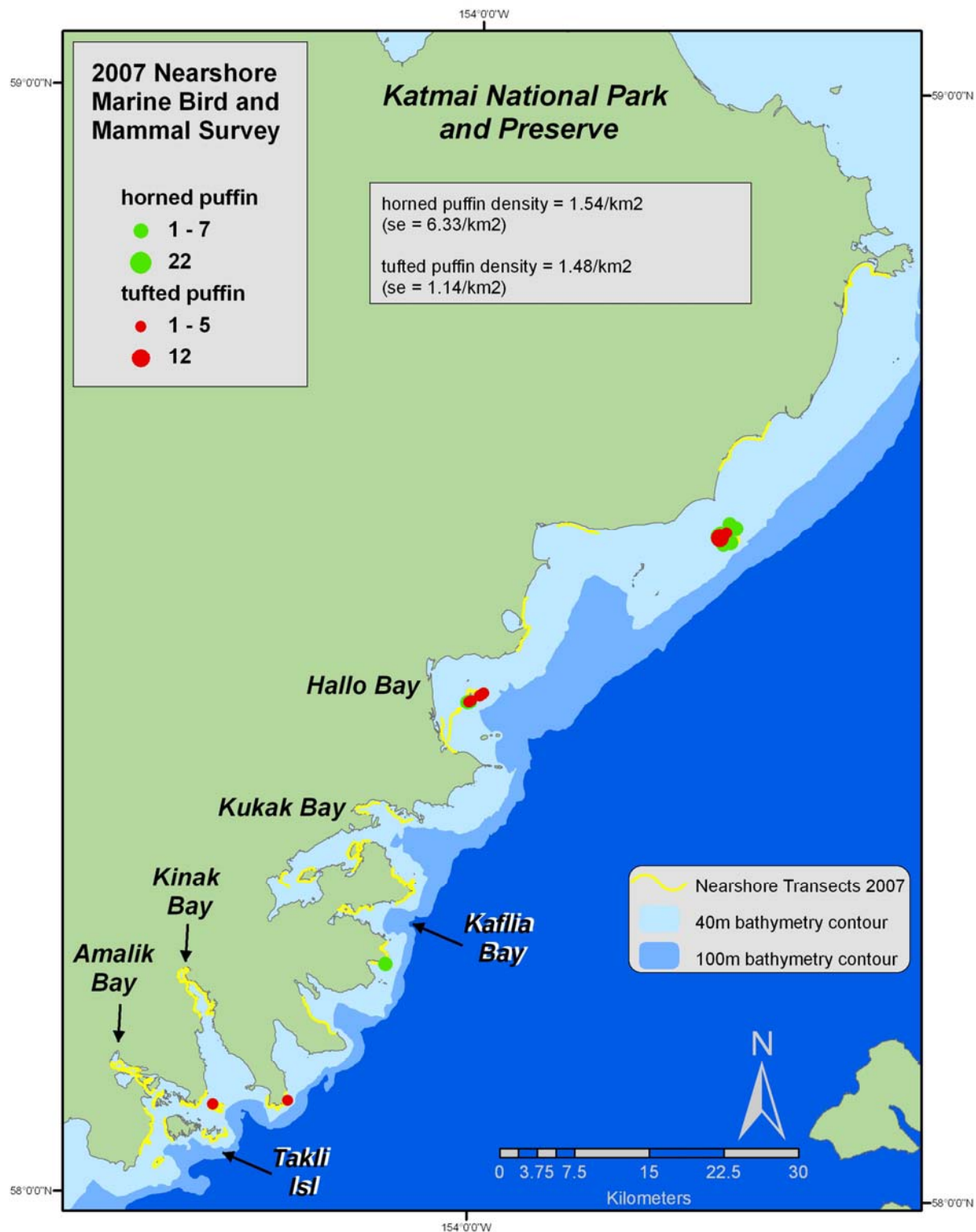


Figure 3.10. Distribution, abundance, and density of tufted and horned puffins in block 10 KATM, June-July 2007.

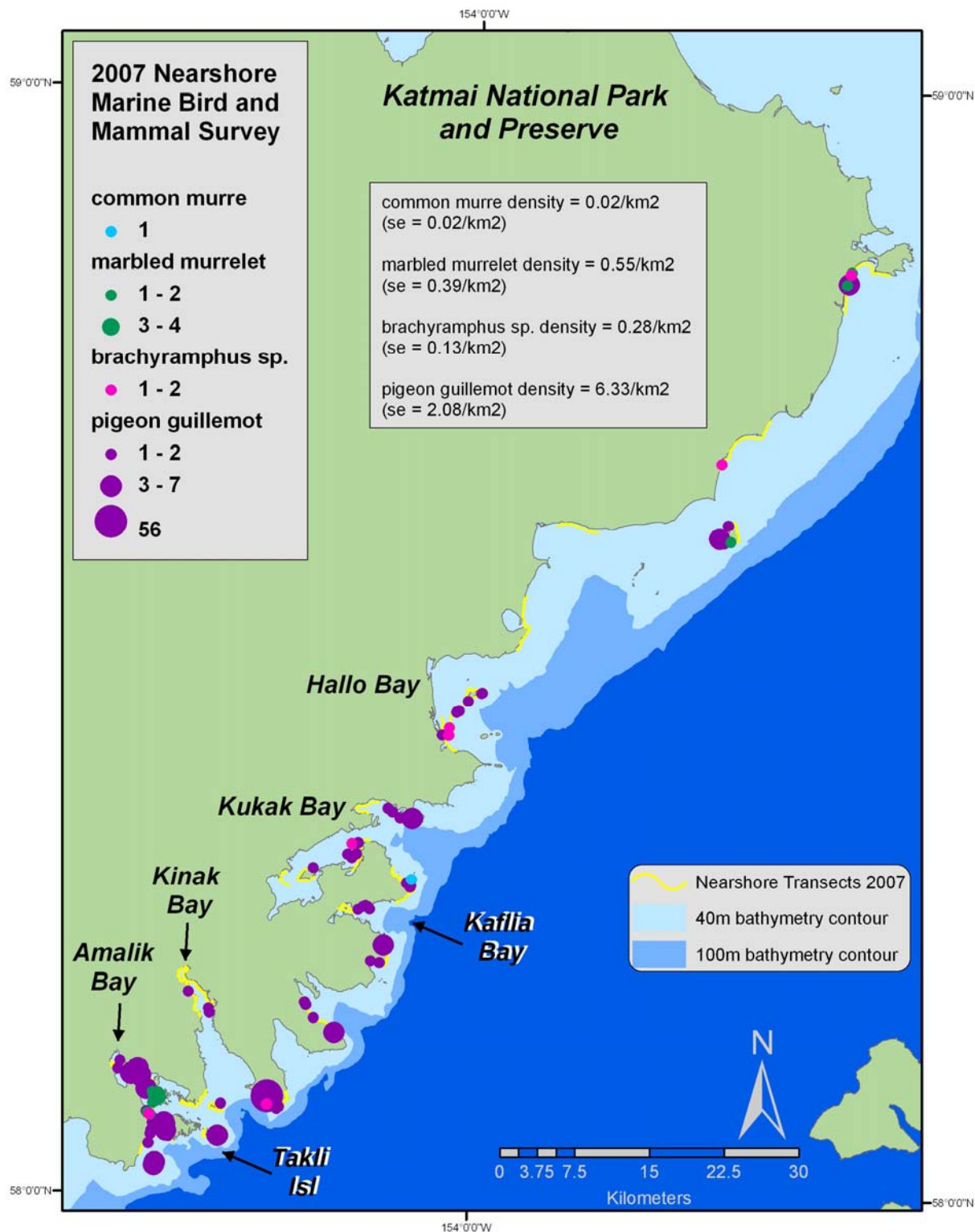


Figure 3.11. Distribution, abundance, and density of common murres, marbled and *branchyramphus* murrelets and pigeon guillemots in block 10 KATM, June-July 2007.

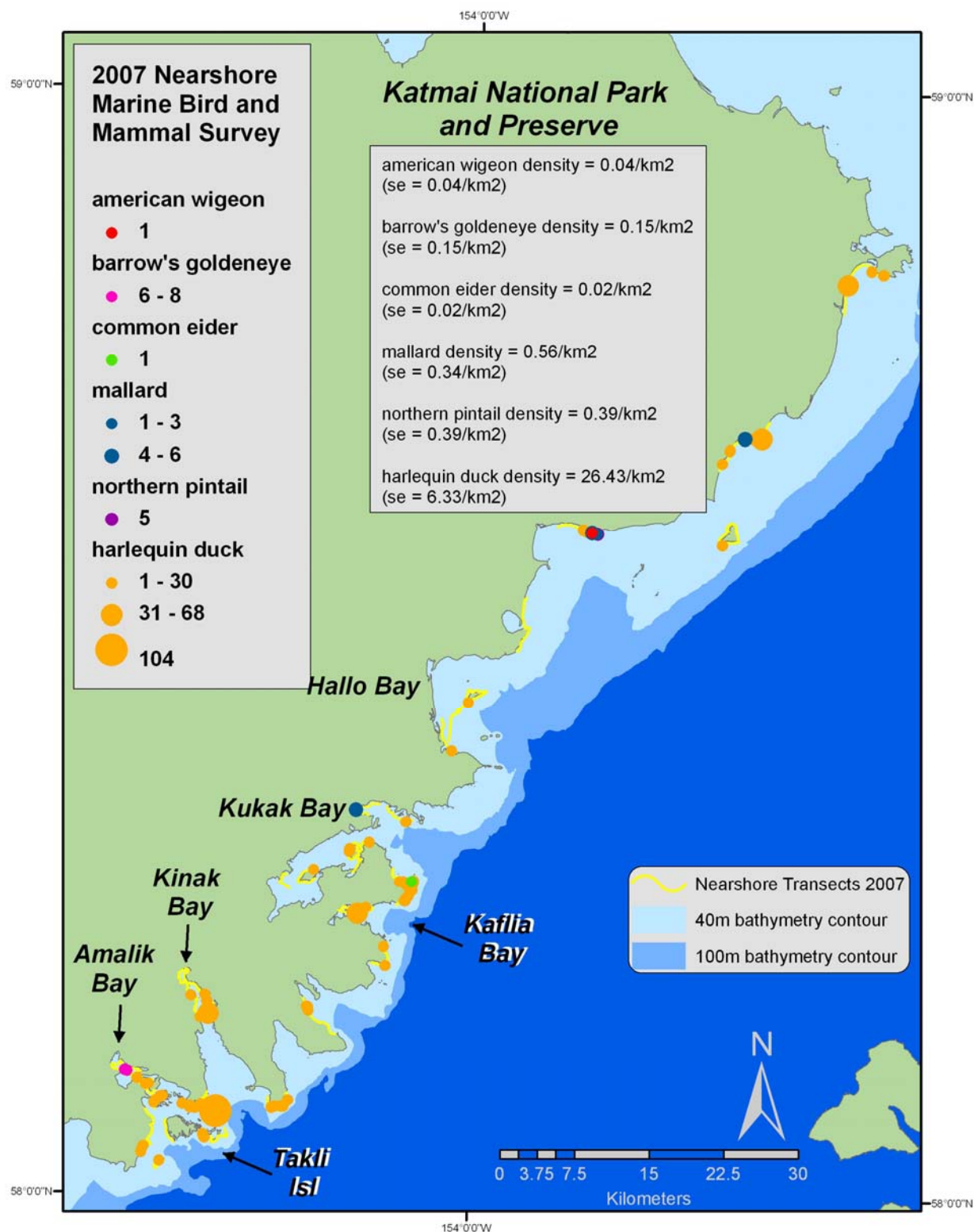


Figure 3.12. Distribution, abundance, and density of American wigeon, Barrow's goldeneye, common eider, mallard, northern pintail and harlequin duck in block 10 KATM, June-July 2007.

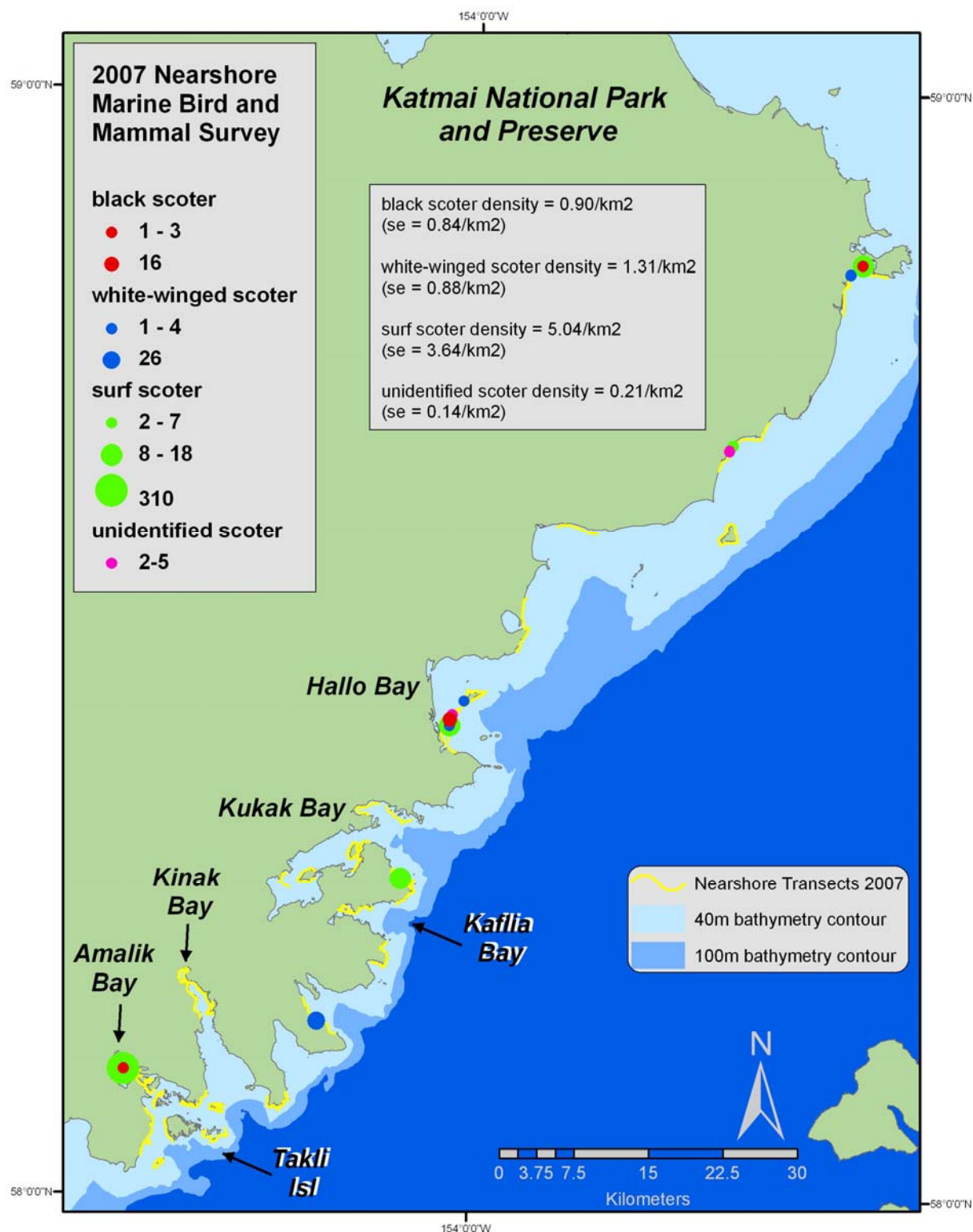


Figure 3.13. Distribution, abundance, and density of black scoter, white-winged scoter, surf scoter and unidentified scoter in block 10 KATM, June-July 2007.

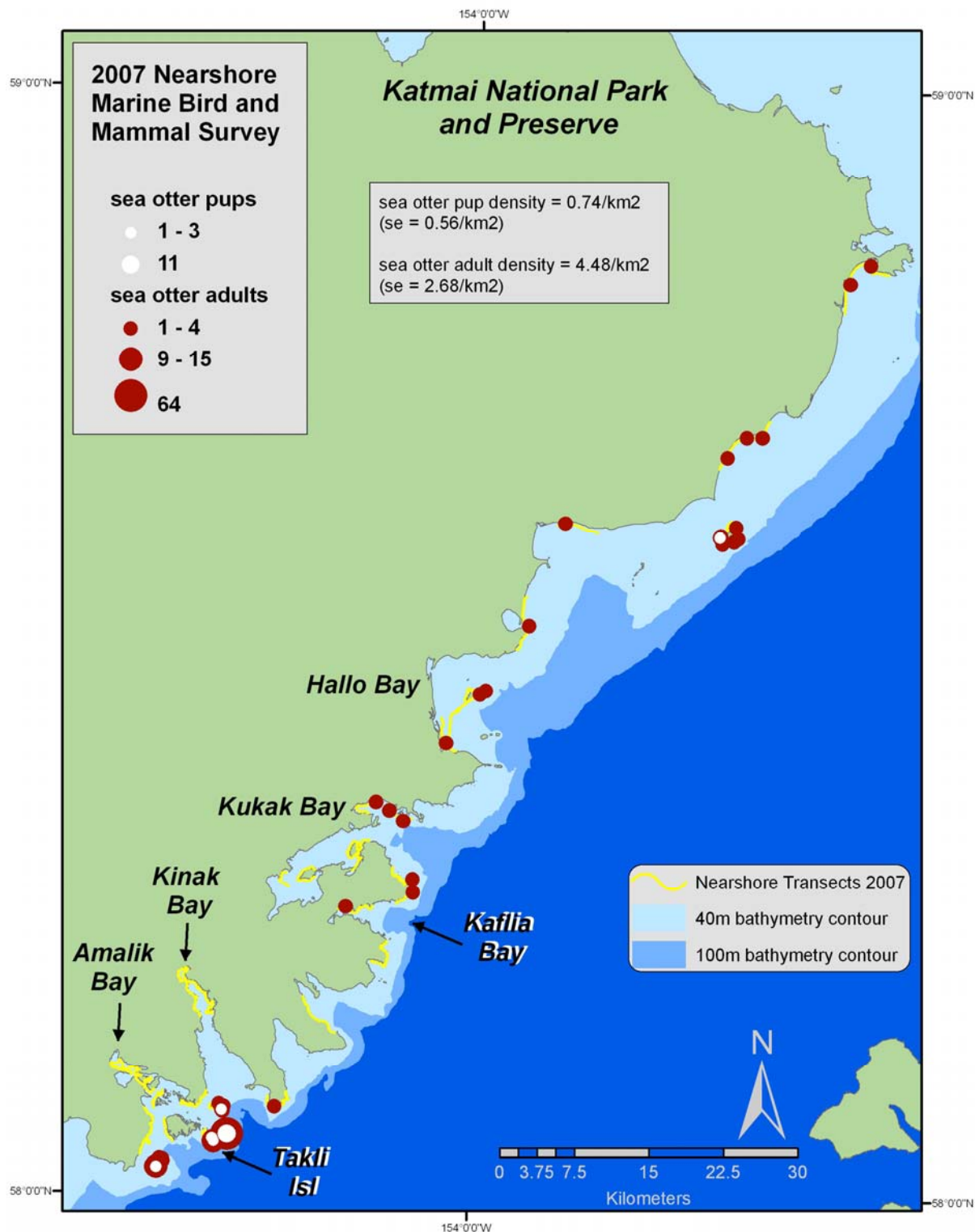


Figure 3.14. Distribution, abundance, and density of sea otters and pups in block 10 KATM, June-July 2007.

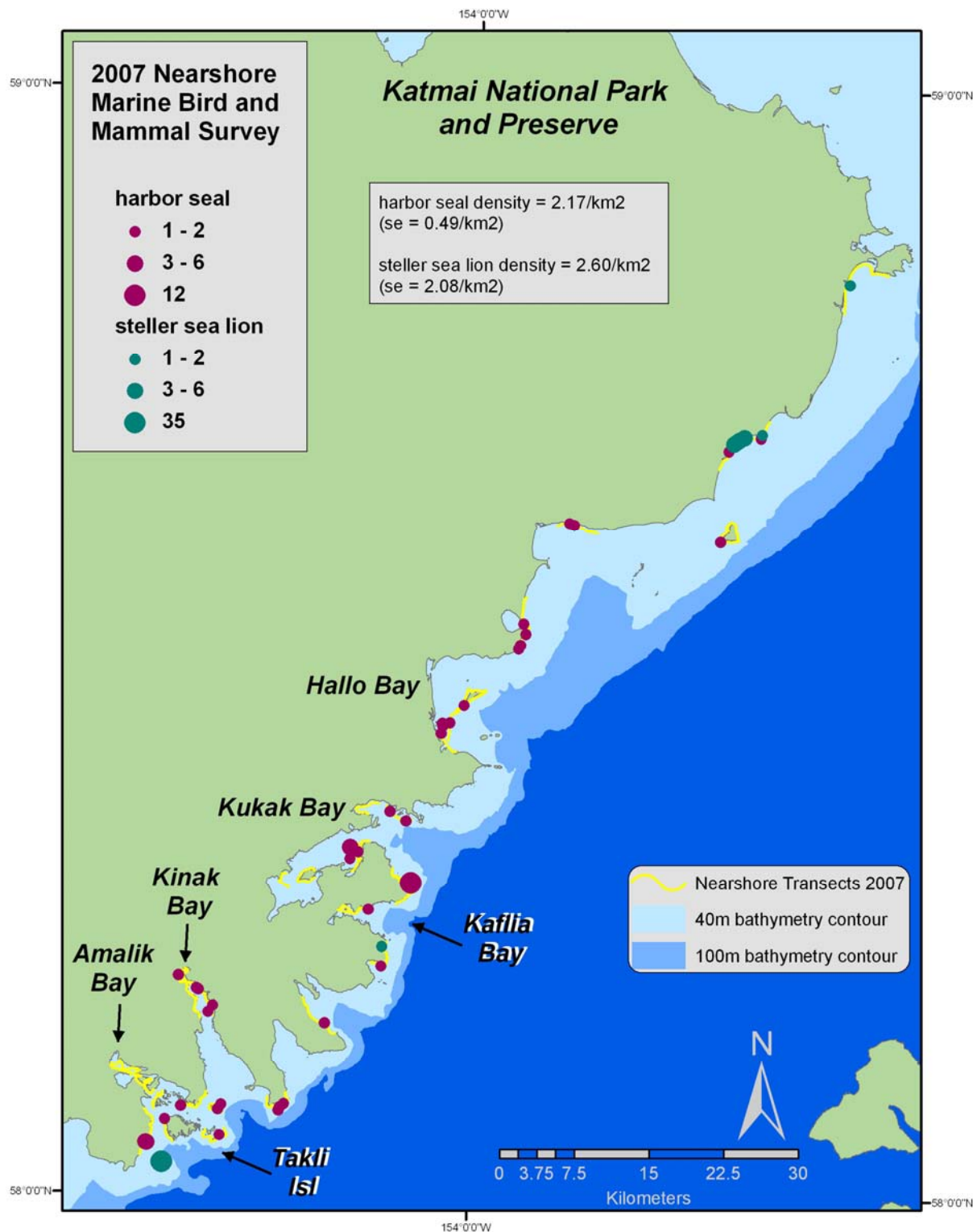


Figure 3.15. Distribution, abundance, and density of Steller sea lions and harbor seals in block 10 KATM, June-July 2007.

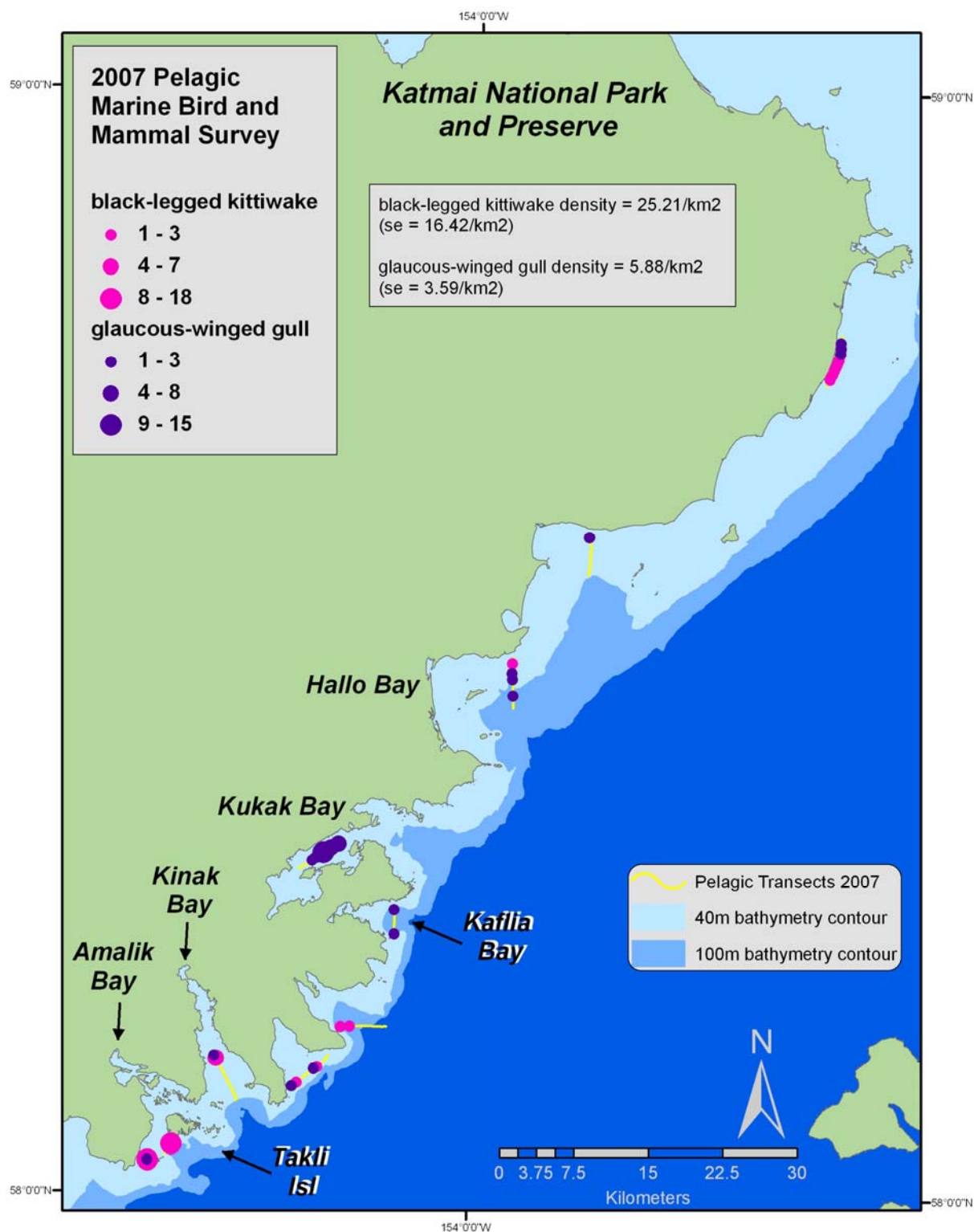


Figure 3.16. Distribution, abundance, and density of black-legged kittiwake and glaucous-winged gull on pelagic transects in block 10 KATM, June-July 2007.

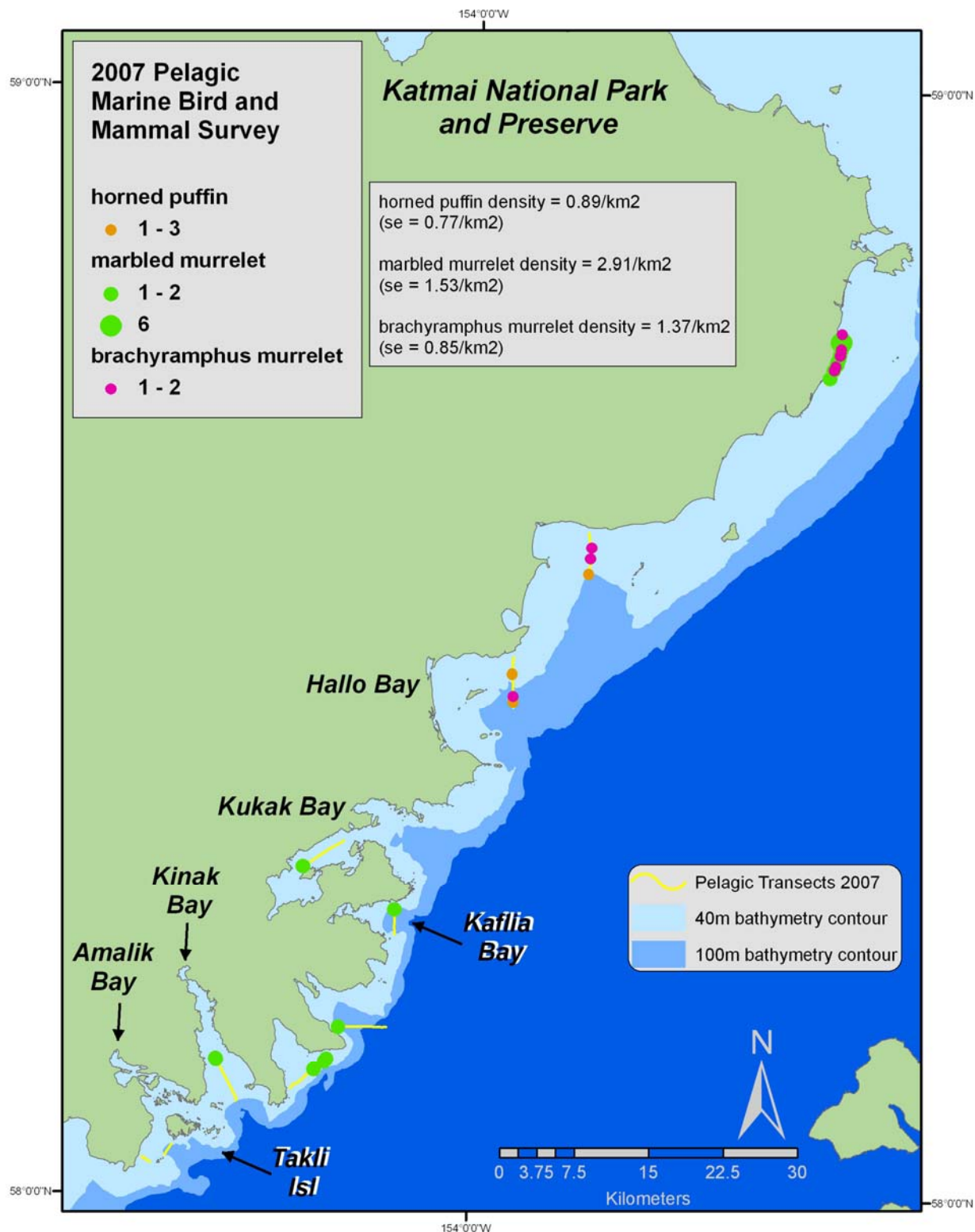


Figure 3.17. Distribution, abundance, and density of horned puffin, marbled and brachyramphus murrelet on pelagic transects in block 10 KATM, June-July 2007.

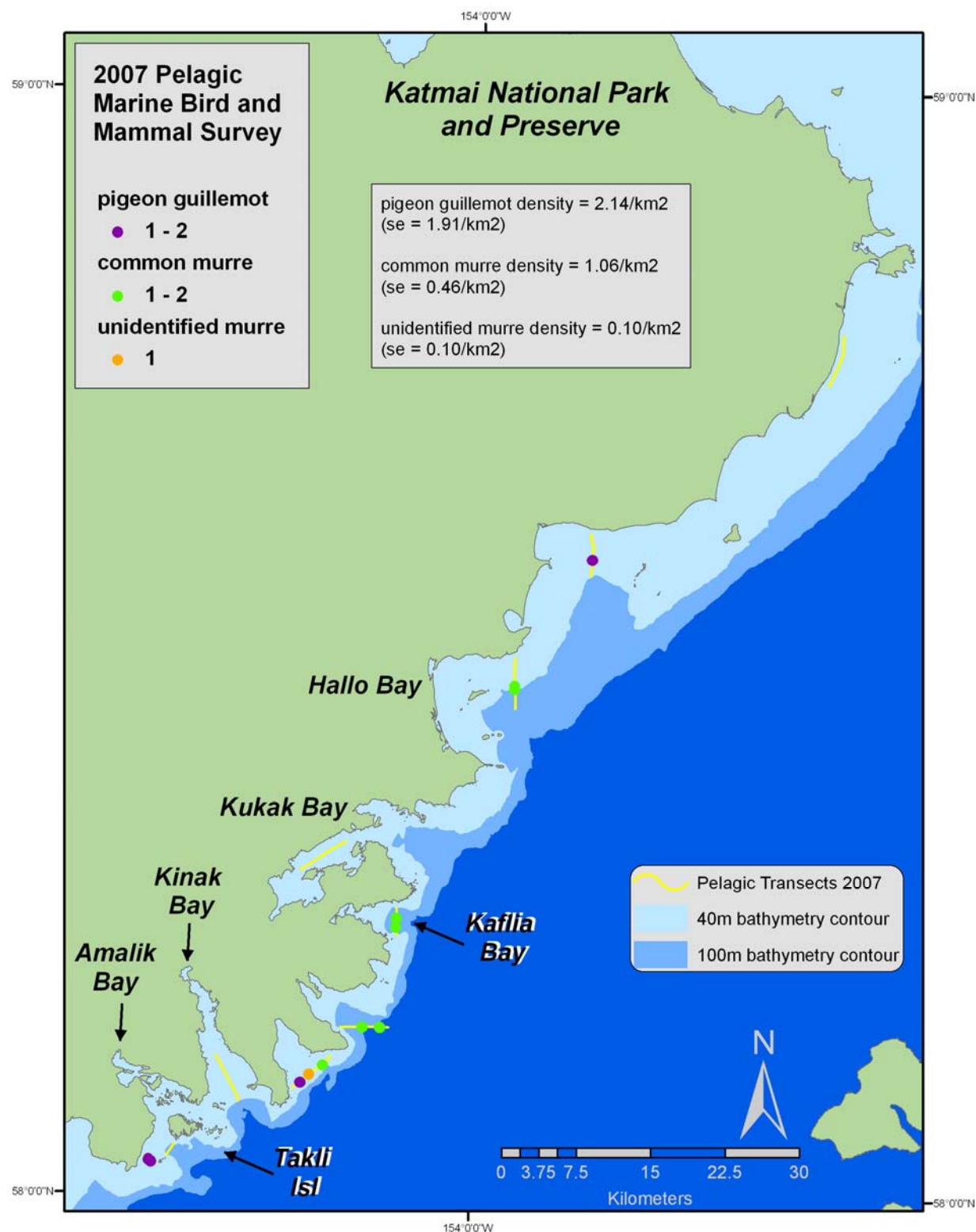


Figure 3.18. Distribution, abundance, and density of pigeon guillemot, common and unidentified murre on pelagic transects in block 10 KATM, June-July 2007.

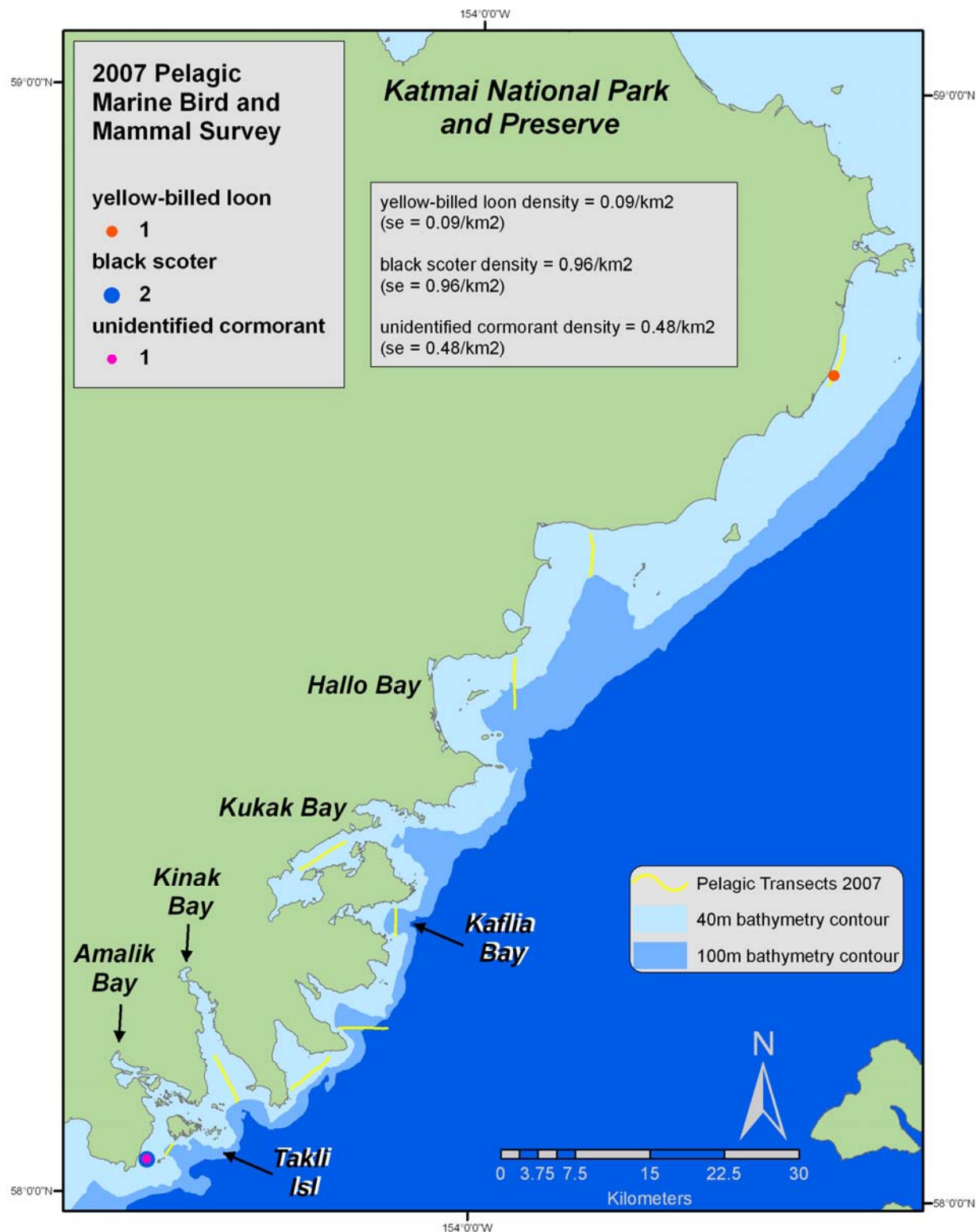


Figure 3.19. Distribution, abundance, and density of yellow-billed loon, black scoter and unidentified cormorant on pelagic transects in block 10 KATM, June-July 2007.

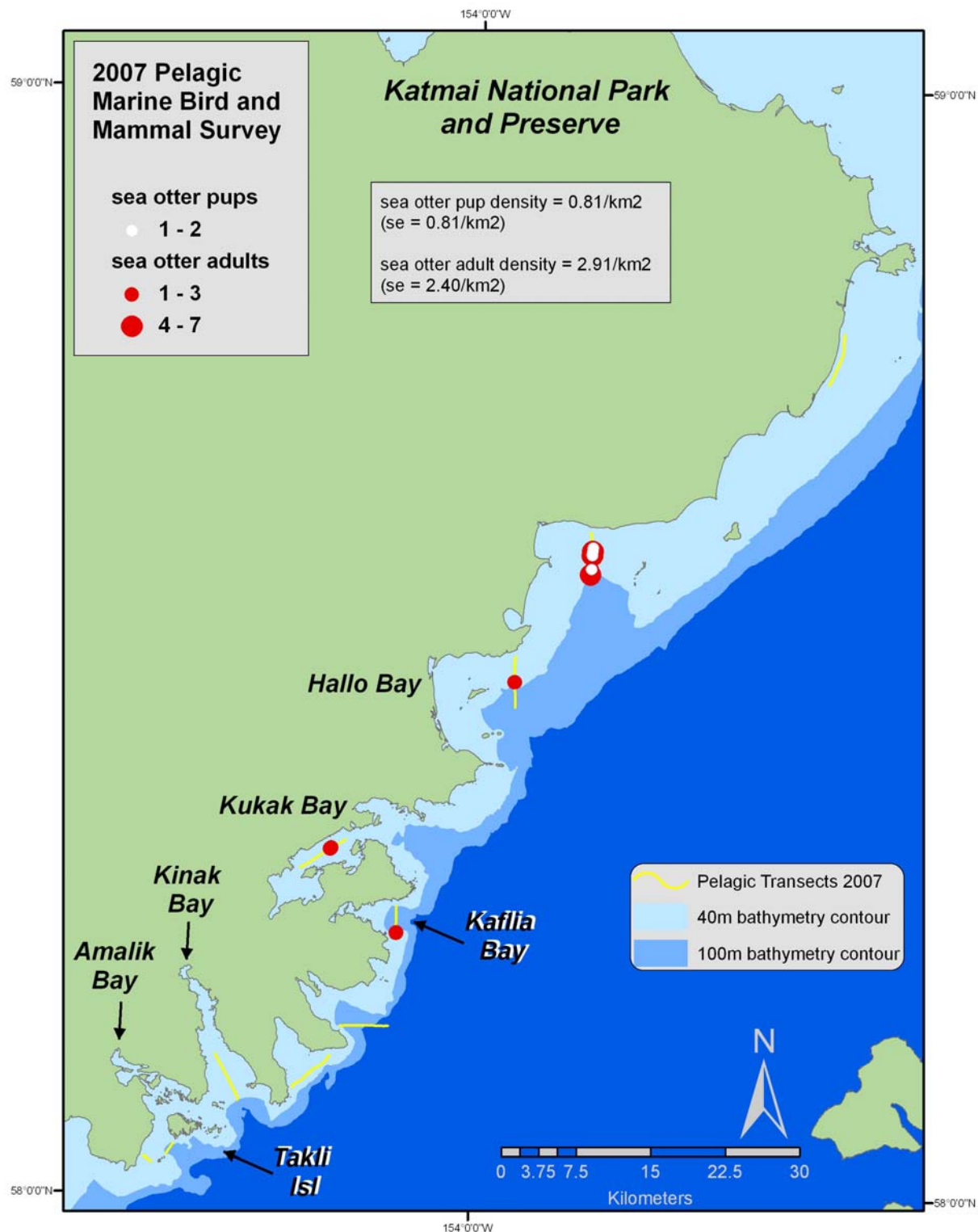


Figure 3.20. Distribution, abundance, and density of sea otters and pups on pelagic transects in block 10 KATM, June-July 2007.

KEFJ

Between June 10 and June 20, 2007 we surveyed 38 shoreline transects in KEFJ. Transect lengths ranged from 1.6 km to 9.6 km and averaged 4.7 km. We sampled approximately 185 km, or about 20% of the shoreline that is acceptable for surveying in the KEFJ sampling block. The most common birds observed were the glaucous-winged gull ($180.2/\text{km}^2$), tufted puffin ($51.1/\text{km}^2$), and the black-legged kittiwake ($45.8/\text{km}^2$). Species considered reliant on nearshore habitats included the harlequin duck ($12.53/\text{km}^2$, $\text{se}=8.87$); the surf scoter ($1.0/\text{km}^2$, $\text{se}=0.52$), and the common merganser ($1.31/\text{km}^2$, $\text{se}=0.68$). Densities of other marine birds and mammals detected on shoreline transects can be found in Table 3.3.

Sea otters were the most widely distributed marine mammal and were observed on 19 of 38 transects. Steller sea lions had the highest density of the marine mammals at $7.7/\text{km}^2$ ($\text{se}=3.7$) followed by harbor seals with a density of $5.4/\text{km}^2$ ($\text{se}=1.6$). Densities were calculated using weighted averages by transect length.

Distribution maps for marine bird and mammals that were relatively abundant or of special interest (e.g. loons and murrelets) are given in Figures 3.21 through 3.33. Harlequin ducks, black oystercatchers, pelagic and double-crested cormorants, glaucous-winged gulls, black-legged kittiwakes, pigeon guillemots, marbled murrelets, sea otters, and harbor seals were relatively abundant and uniformly distributed along the transects. Other species, including puffins, common murres, red-faced cormorants, rhinoceros auklets and Steller sea lions were relatively abundant but had highly aggregated nearshore distributions. Ancient murrelets, Kittlitz's murrelets, yellow-billed loons, and Barrow's goldeneye were rarely observed along the nearshore.

Table 3.3. Species and densities (se) of marine birds and mammals in the nearshore marine zone in KEFJ, June 2007. Approximately 16% of the total shoreline length was sampled. Min. and Max. are the minimum and maximum number of individuals per group and sum is the total number of individuals observed in all groups. Yellow shaded rows indicate focal species in the nearshore sampling protocol.

Species (marine birds)	# of groups observed	Min	Max	Sum	Average density (#/km ²)	SE
Ancient murrelet (<i>Synthliboramphus antiquus</i>)	3	1	1	3	0.08	0.04
Bald eagle (<i>Haliaeetus leucocephalus</i>)	31	1	2	36	1.01	0.23
Barrow's goldeneye (<i>Bucephala islandica</i>)	2	3	7	10	0.19	0.14
Black-legged kittiwake (<i>Rissa tridactyla</i>)	226	1	200	1389	45.78	21.59
Black oystercatcher (<i>Haematopus bachmani</i>)	17	1	4	29	0.74	0.03
Black scoter (<i>Melanitta nigra</i>)	2	1	3	4	0.13	0.10
Common merganser (<i>Mergus merganser</i>)	11	1	12	54	1.31	0.68
Common murre (<i>Uria aalge</i>)	87	1	258	1022	34.41	18.03
Common raven (<i>Corvus corax</i>)	3	1	1	3	0.09	0.06
Double-crested cormorant (<i>Phalacrocorax auritus</i>)	42	1	170	308	7.72	4.36
Glaucous gull (<i>Larus hyperboreus</i>)	3	2	6	11	0.54	0.42
Glaucous-winged gull (<i>Larus glaucescens</i>)	463	1	310	6064	180.19	56.86
Greater scaup (<i>Aythya marila</i>)	2	1	4	5	0.13	0.11
Harlequin duck (<i>Histrionicus histrionicus</i>)	32	1	33	253	12.45	8.87
Herring gull (<i>Larus argentatus</i>)	2	1	1	2	0.06	0.04
Horned puffin (<i>Fratercula corniculata</i>)	91	1	40	277	7.34	2.88
Kittlitz's murrelet (<i>Brachyramphus brevirostris</i>)	17	1	2	26	0.65	0.17
Mallard (<i>Anas platyrhynchos</i>)	4	1	8	18	0.49	0.33
Marbled murrelet (<i>Brachyramphus marmoratus</i>)	81	1	20	182	4.42	1.41
Mew gull (<i>Larus canus</i>)	9	1	22	41	0.60	0.44
Northern crow (<i>Corvus caurinus</i>)	15	1	12	37	0.93	0.34
Parakeet auklet (<i>Aethia psittacula</i>)	2	3	3	6	0.14	0.14
Pelagic cormorant (<i>Phalacrocorax pelagicus</i>)	68	1	75	354	9.80	3.62
Pigeon guillemot (<i>Cephus columba</i>)	147	1	12	255	6.49	1.34
Red-faced cormorant (<i>Phalacrocorax urile</i>)	45	1	61	318	7.97	5.39
Rhinoceros auklet (<i>Cerorhinca monocerata</i>)	12	1	204	257	6.99	5.97
Steller's jay (<i>Cyanocitta stelleri</i>)	1	1	1	1	0.03	0.03
Surf scoter (<i>Melanitta perspicillata</i>)	5	2	12	35	1.00	0.52
Tufted puffin (<i>Fratercula cirrhata</i>)	140	1	190	1583	51.06	27.56

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Unid. auklet (<i>Alcid</i> sp.)	4	1	5	14	0.37	0.26
Unid. cormorant (<i>Phalacrocoracidae</i> sp.)	45	1	87	315	8.84	3.47
Unid. duck (<i>Anatidae</i> sp.)	4	1	2	7	0.20	0.10
Unid. gull (<i>Laridae</i> sp.)	28	1	24	81	2.20	1.04
Unid. loon (<i>Gavia</i> sp.)	2	1	1	2	0.04	0.03
Unid. merganser (<i>Mergus</i> sp.)	3	1	2	5	0.09	0.07
Unid. murre (<i>Uria</i> sp.)	1	1	1	1	0.03	0.03
Unid. murrelet (<i>Brachyramphus</i> sp.)	31	1	5	53	1.50	0.38
Unid. puffin (<i>Fratercula</i> sp.)	4	1	2	7	0.22	0.11
Unid. shearwater (<i>Puffinus</i> sp.)	3	1	50	81	1.94	1.39
White-winged scoter (<i>Melanitta fusca</i>)	1	1	3	3	0.04	0.04
Yellow-billed loon (<i>Gavia adamsii</i>)	1	1	1	1	0.03	0.03

Species (marine mammals)	# of groups observed	Min	Max	Sum	Average density (#/km ²)	SE
Humpback whale (<i>Megaptera novaeangliae</i>)	5	1	2	7	0.20	0.10
Sea otter (adult) (<i>Enhydra lutris</i>)	72	1	9	114	3.60	1.36
Sea otter (pup) (<i>Enhydra lutris</i>)	26	1	6	39	1.36	0.77
Steller sea lion (<i>Eumetopias jubatus</i>)	28	1	86	264	7.71	3.72
Black bear (<i>Ursus americanus</i>)	6	1	1	6	0.14	0.08
Mountain goat (<i>Oreamnos americanus</i>)	2	1	4	5	0.14	0.34

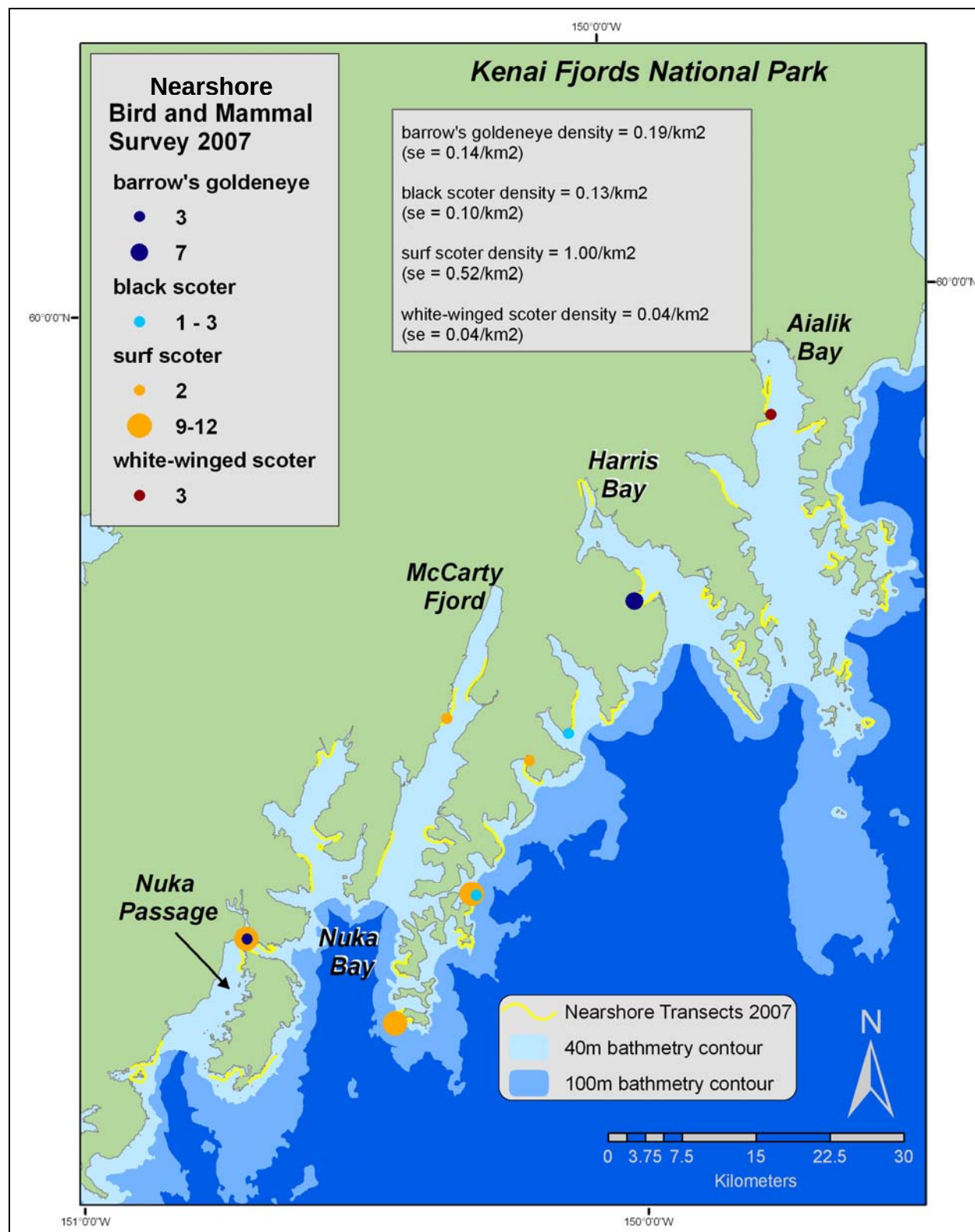


Figure 3.21. Distribution, abundance, and density of Barrow's goldeneye, black scoter, surf scoter and white-winged scoter on transects in block 5 KEFJ, June 2007.

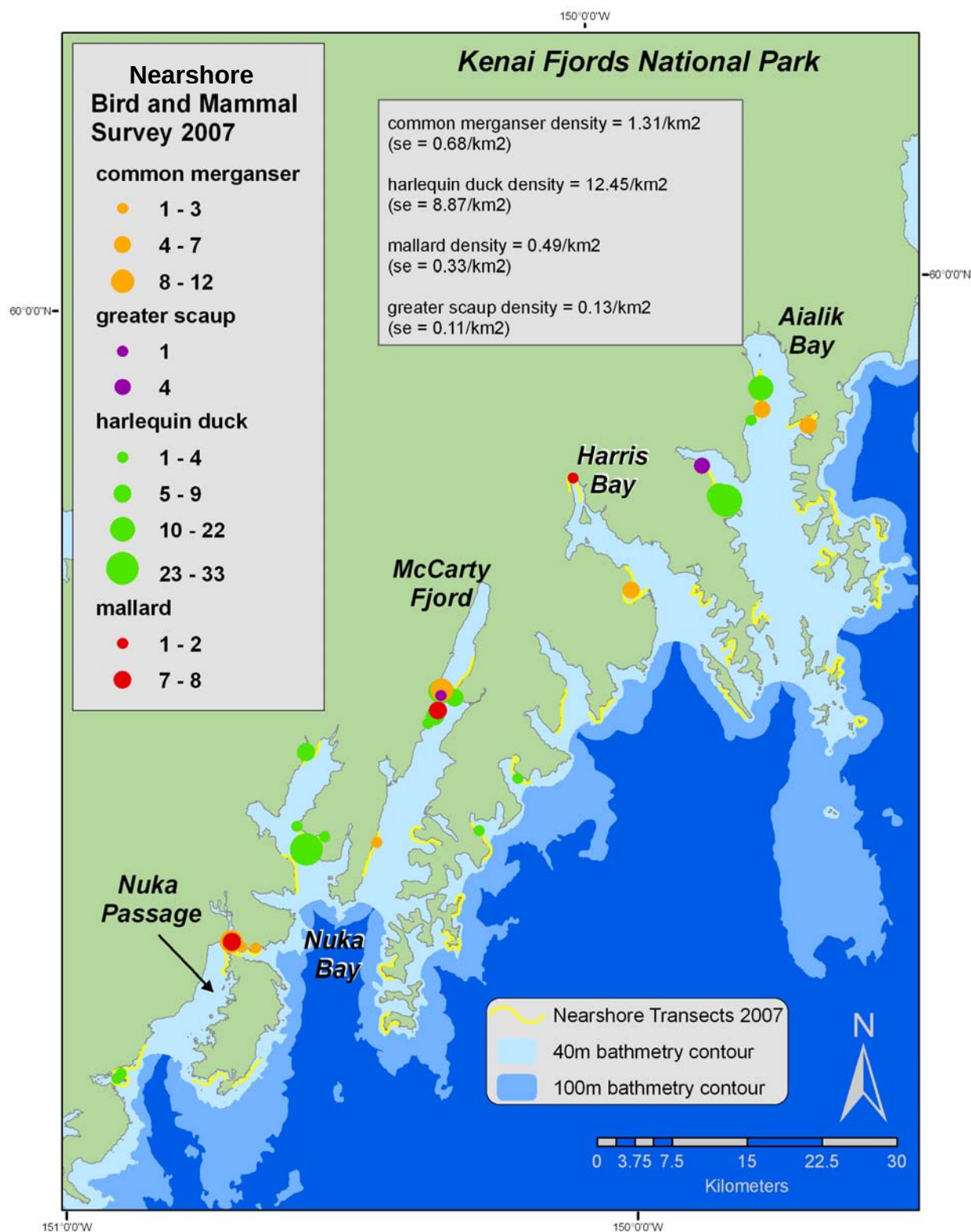


Figure 3.22. Distribution, abundance, and density of common merganser, greater scaup, harlequin duck and mallard on transects in block 5 KEFJ, June 2007.

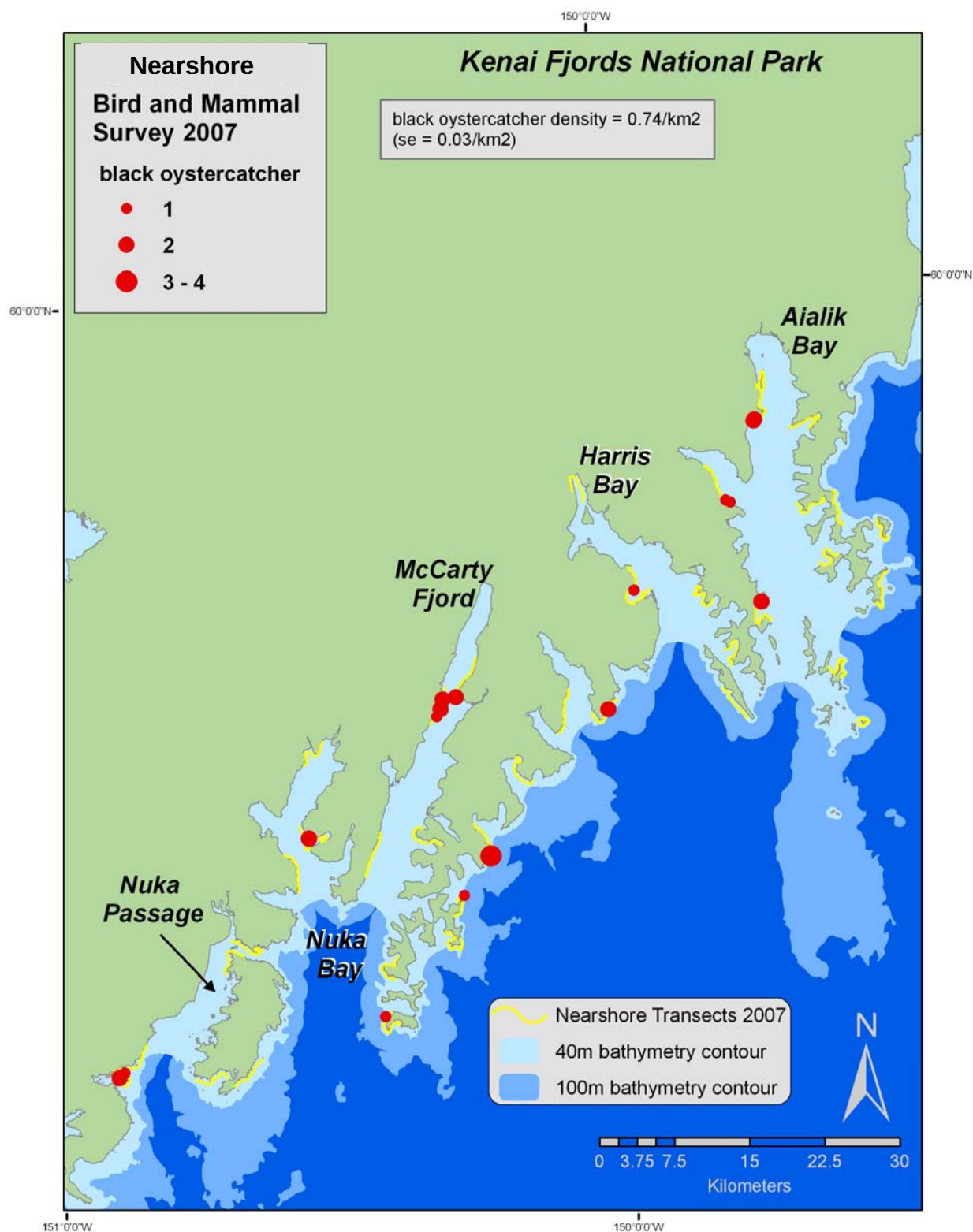


Figure 3.23. Distribution, abundance, and density of black oystercatchers on transects in block 5 KEFJ, June 2007.

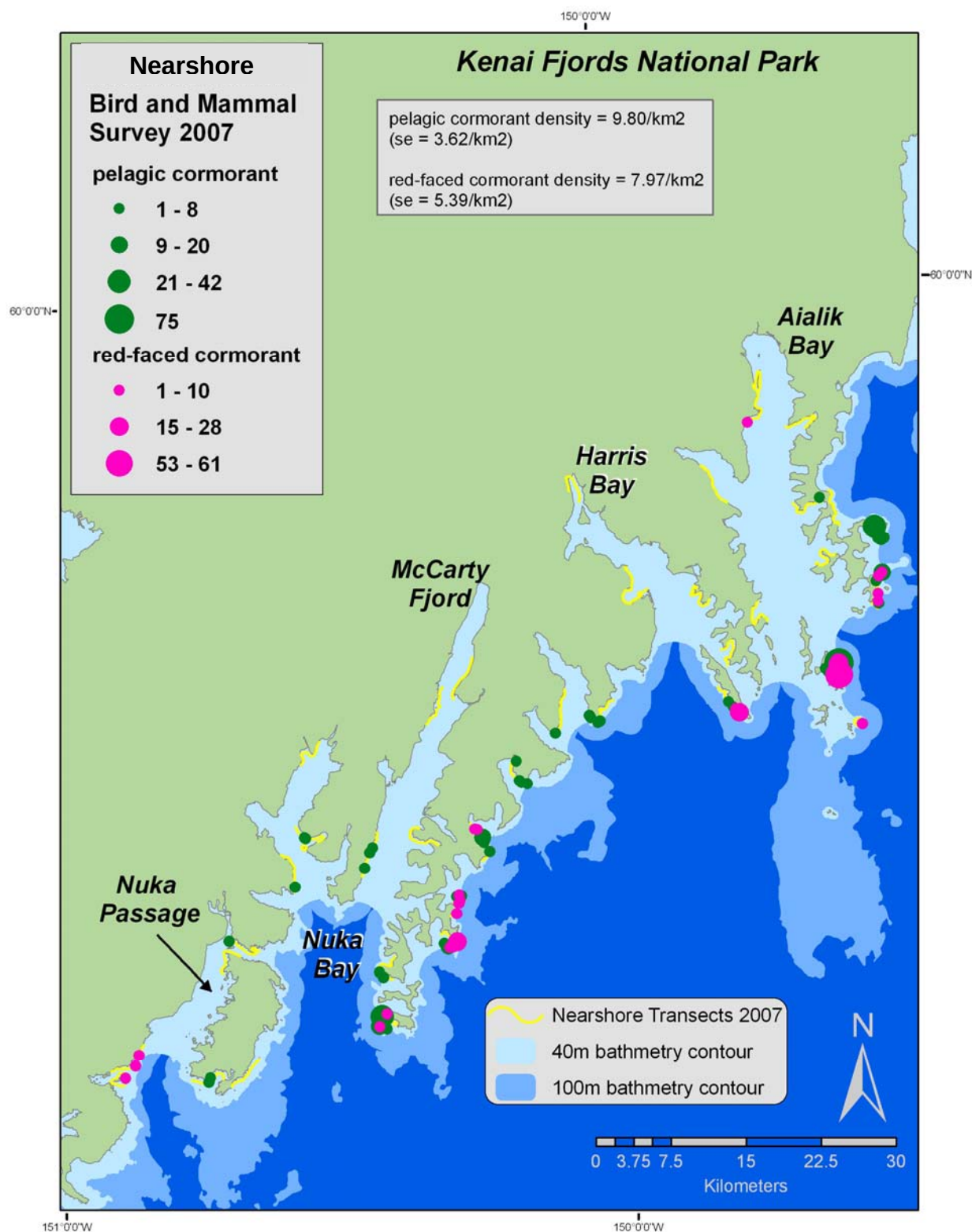


Figure 3.24. Distribution, abundance, and density of pelagic and red-faced cormorants on transects in block 5 KEFJ, June 2007.

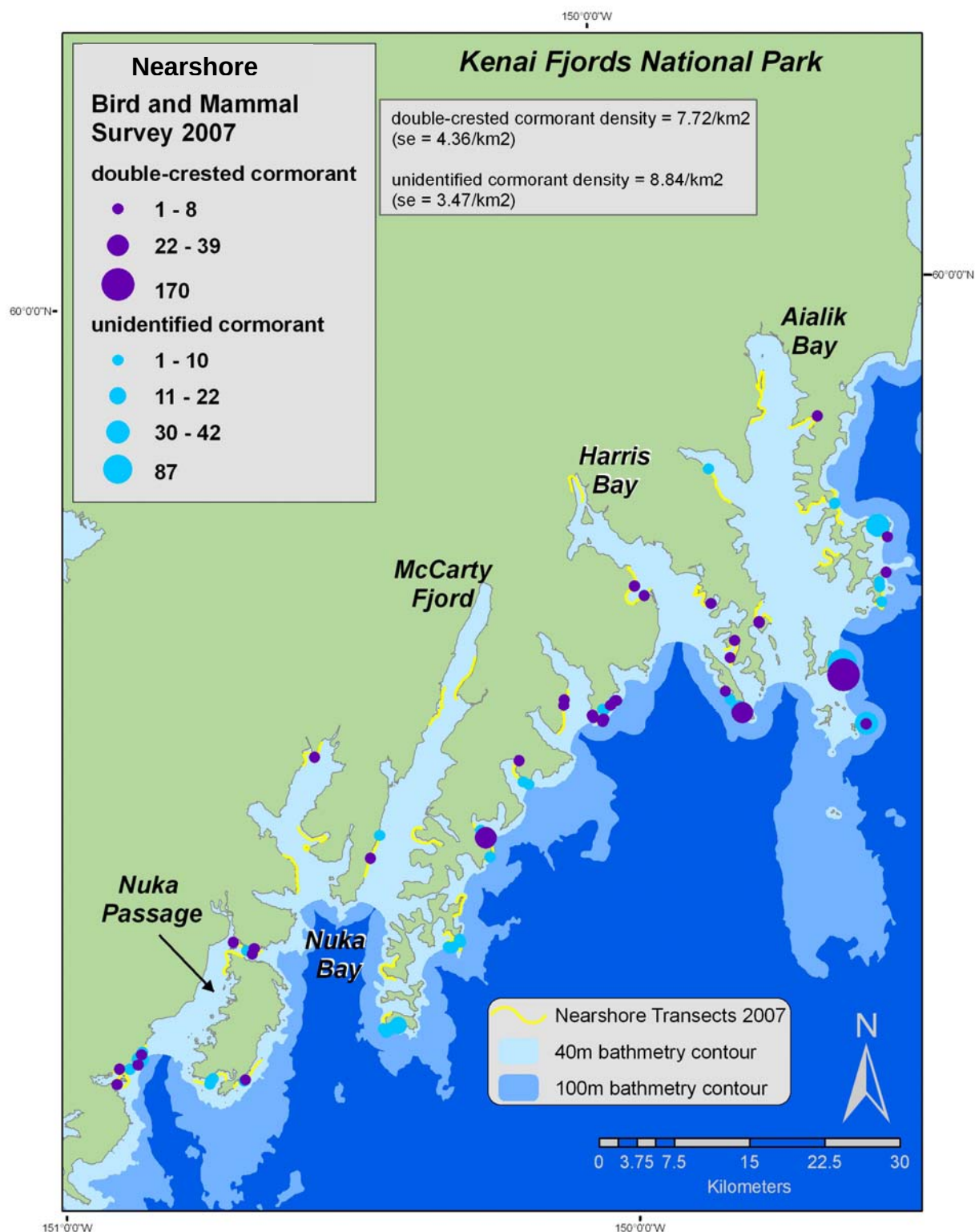


Figure 3.25. Distribution, abundance, and density of double-crested and unidentified cormorants on transects in block 5 KEFJ, June 2007.

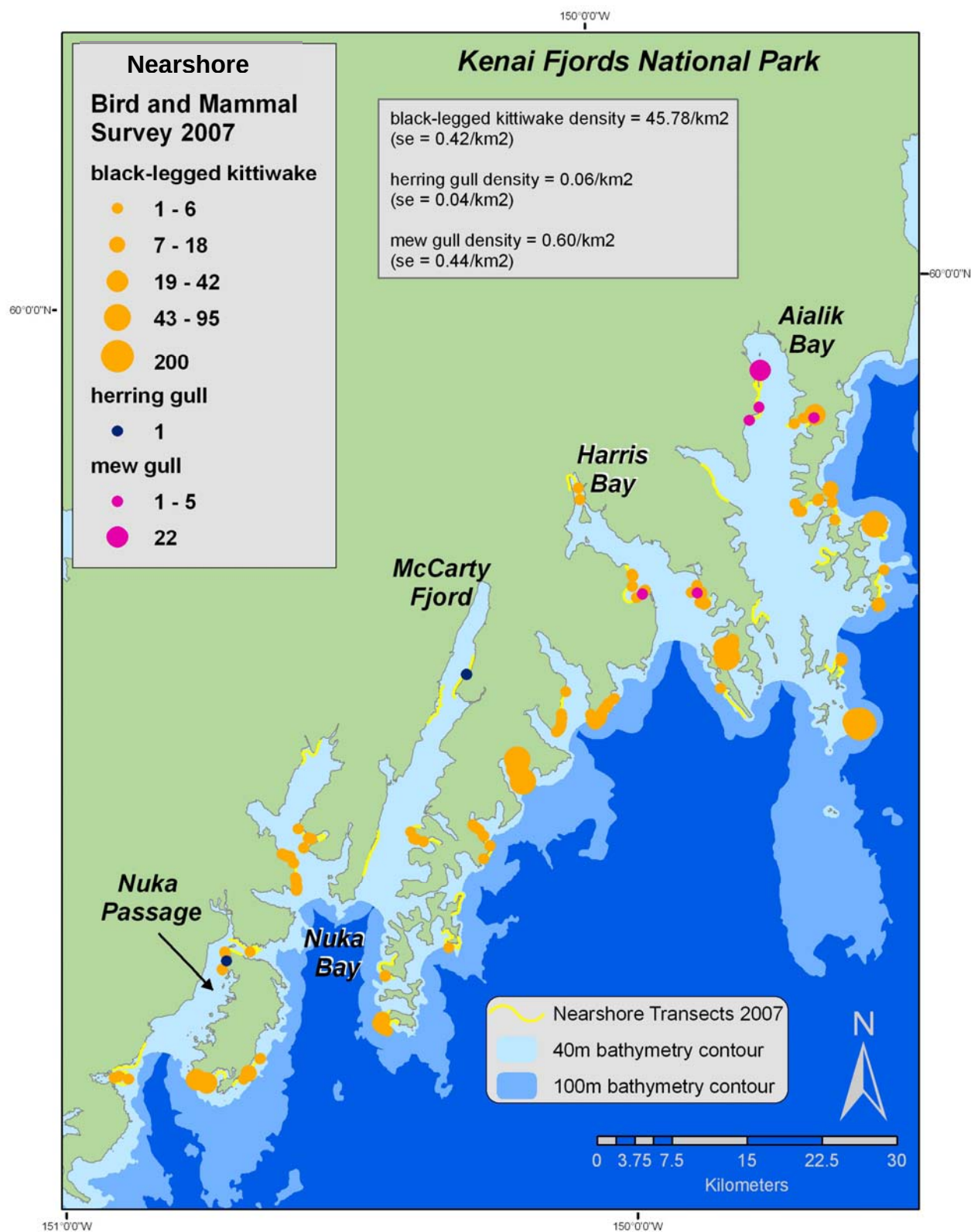


Figure 3.26. Distribution, abundance, and density of black-legged kittiwakes, herring and mew gulls on transects in block 5 KEFJ, June 2007.

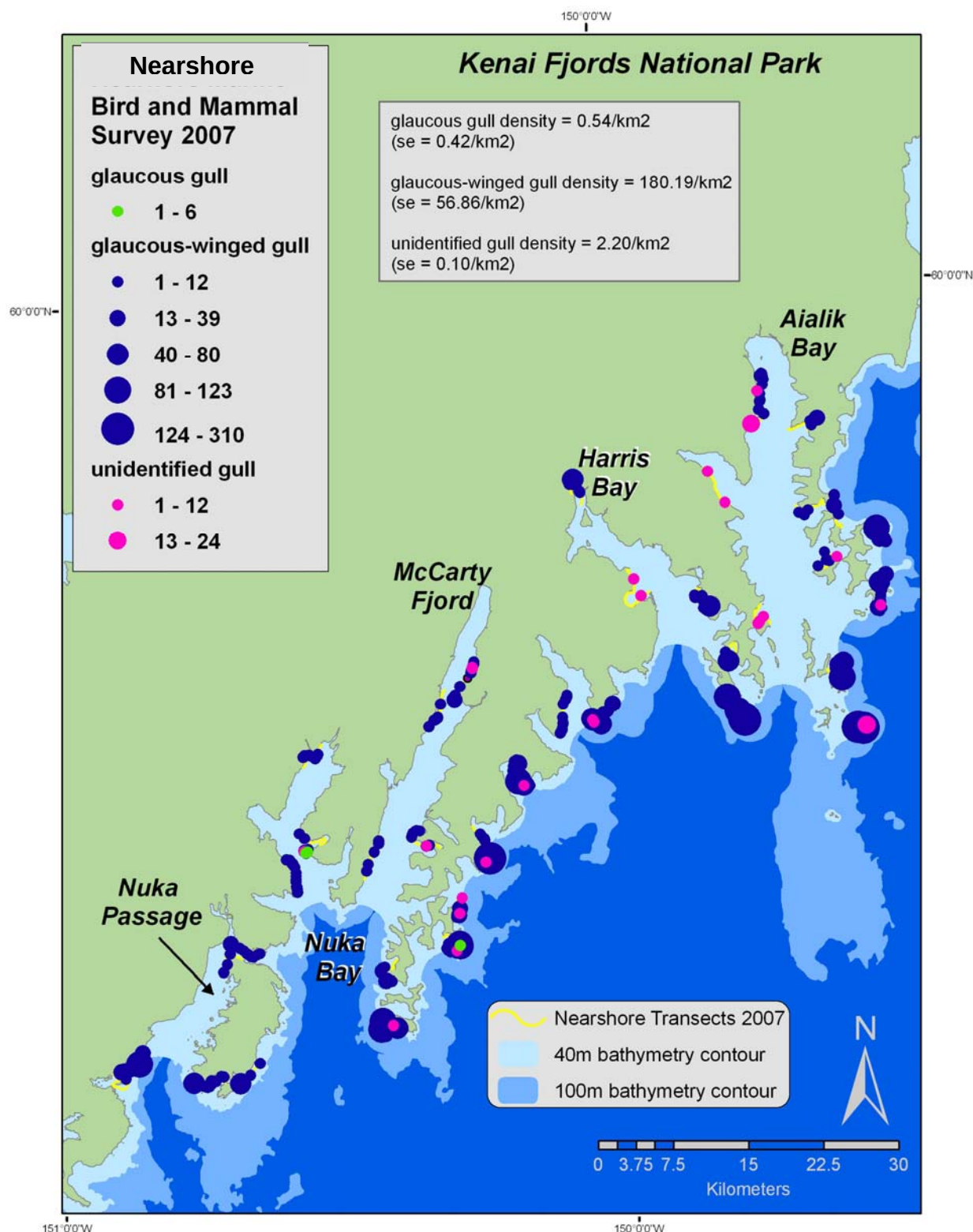


Figure 3.27. Distribution, abundance, and density of glaucous, glaucous-winged and unidentified gulls on transects in block 5 KEFJ, June 2007.

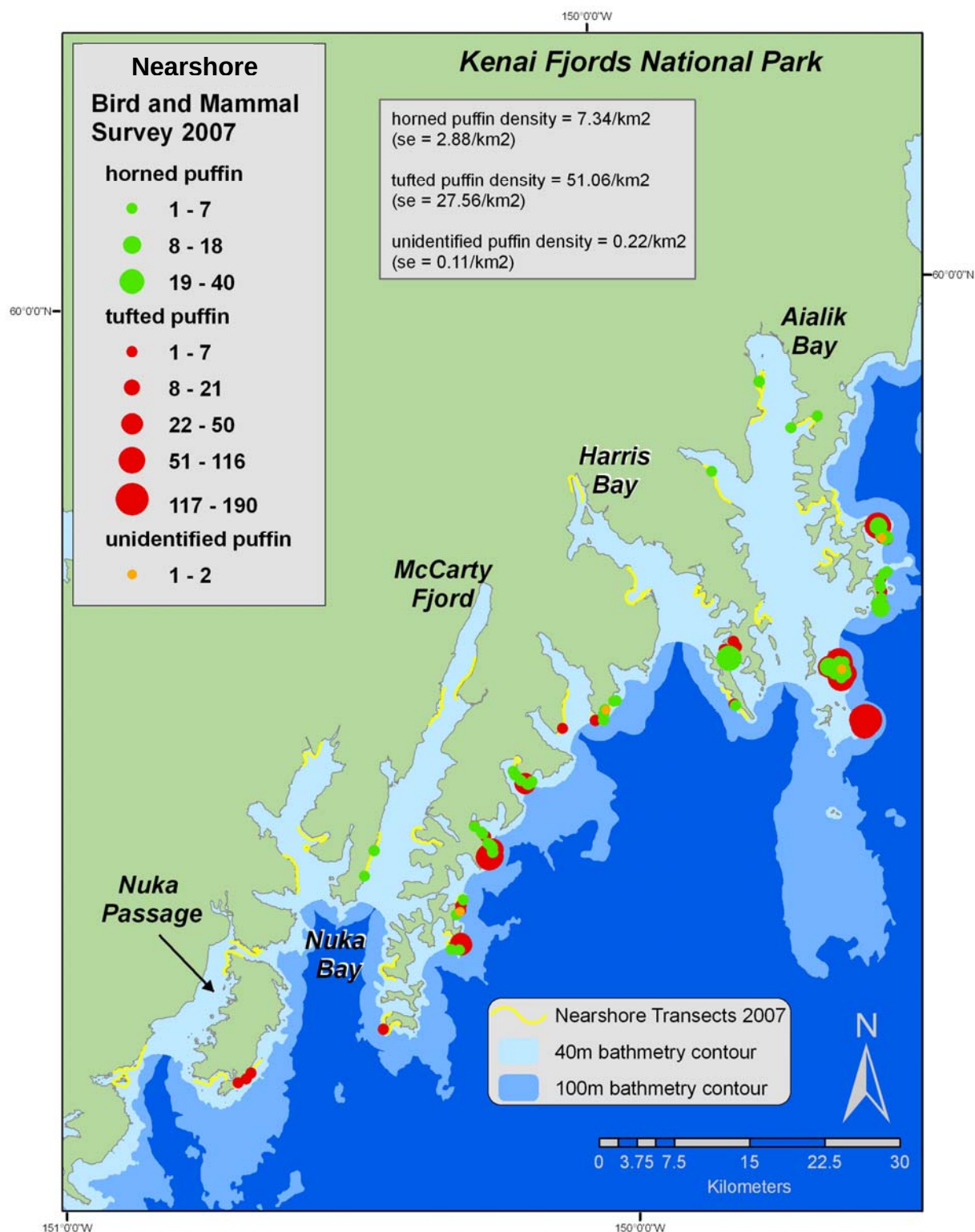


Figure 3.28. Distribution, abundance, and density of horned, tufted and unidentified puffins on transects in block 5 KEFJ, June 2007.

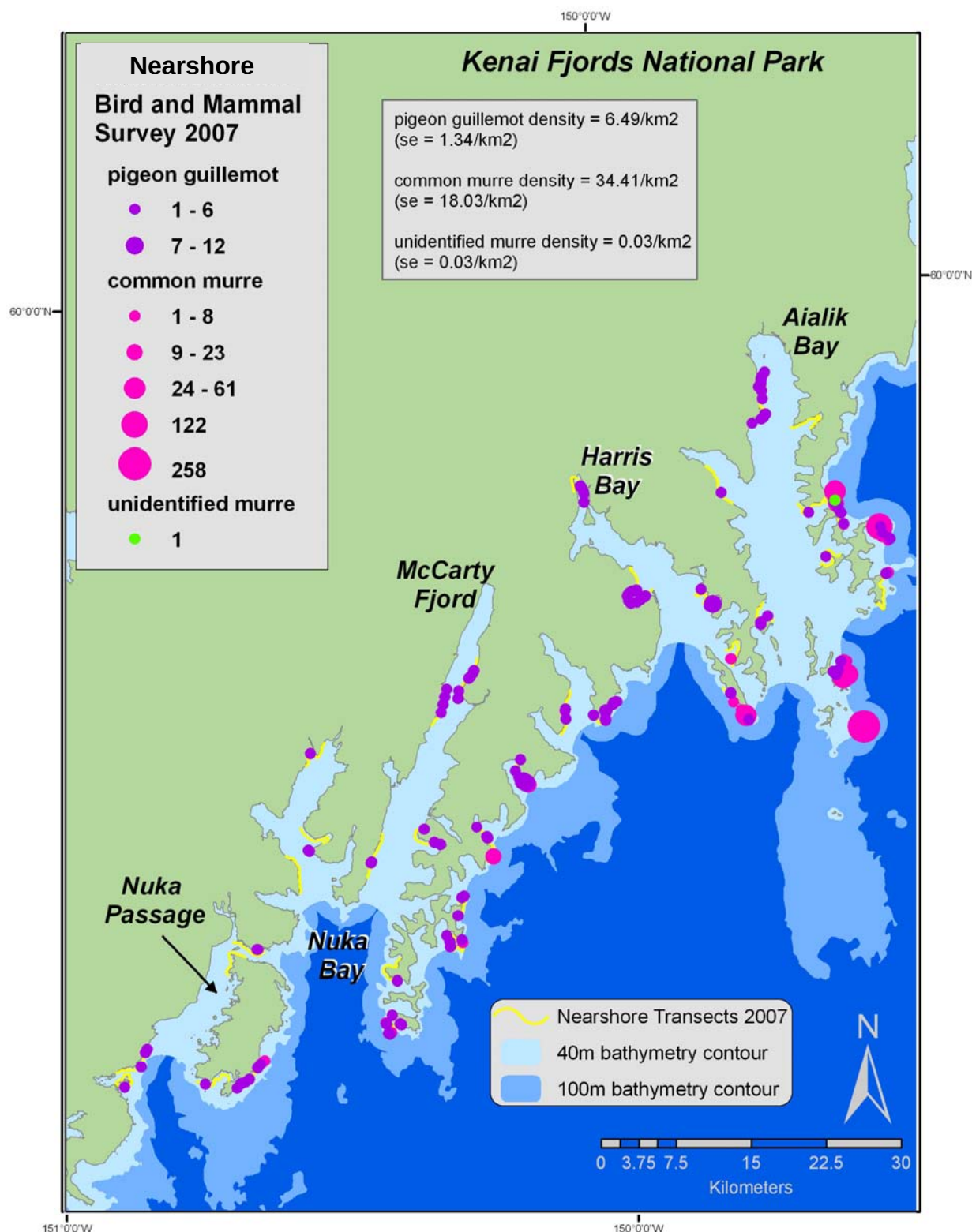


Figure 3.29. Distribution, abundance, and density of pigeon guillemots, common and unidentified murres on transects in block 5 KEFJ, June 2007.

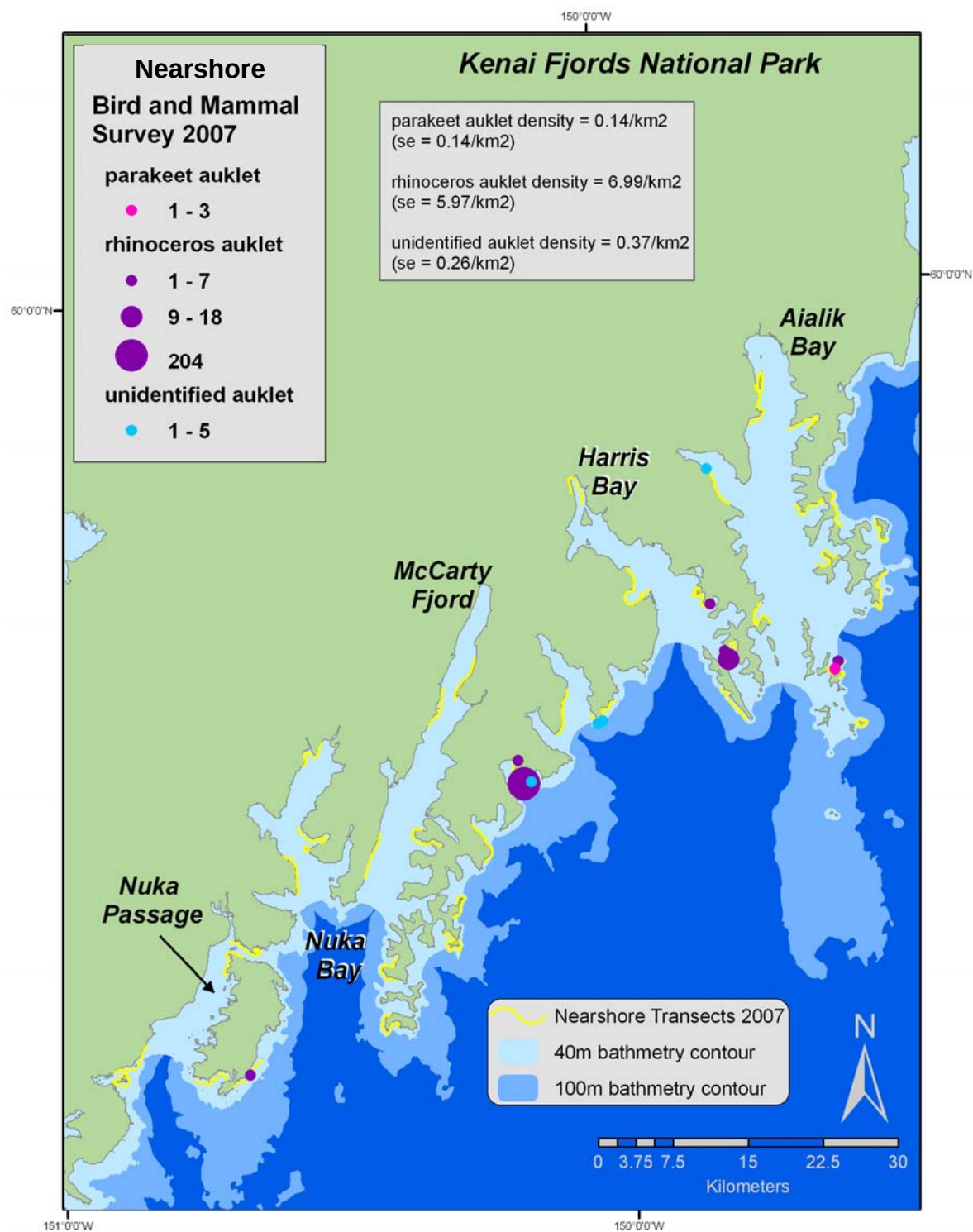


Figure 3.30. Distribution, abundance, and density of parakeet, rhinoceros and unidentified auklets on transects in block 5 KEFJ, June 2007.

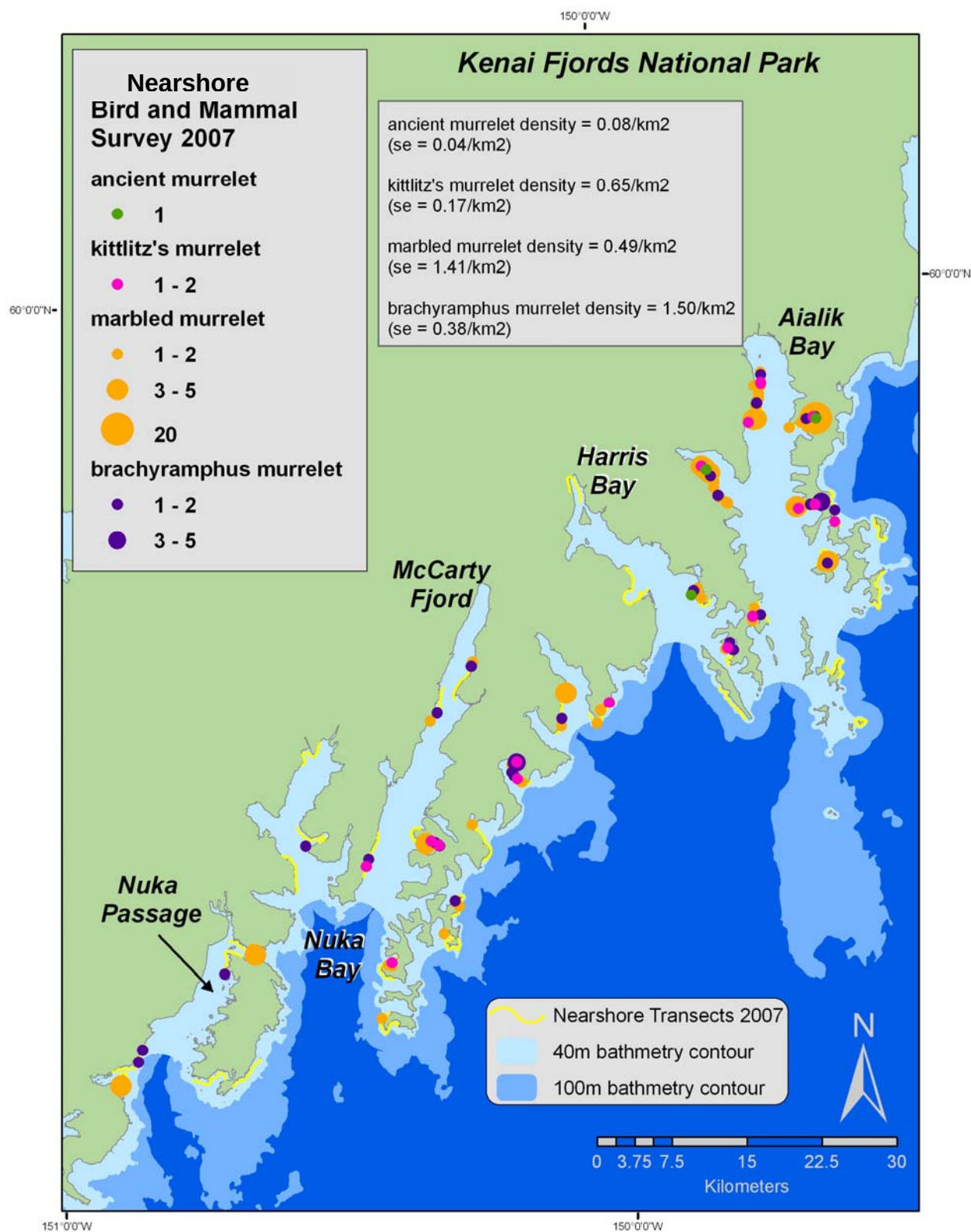


Figure 3.31. Distribution, abundance, and density of ancient, Kittlitz's, marbled and brachyramphus murrelets transects in block 5 KEFJ, June 2007.

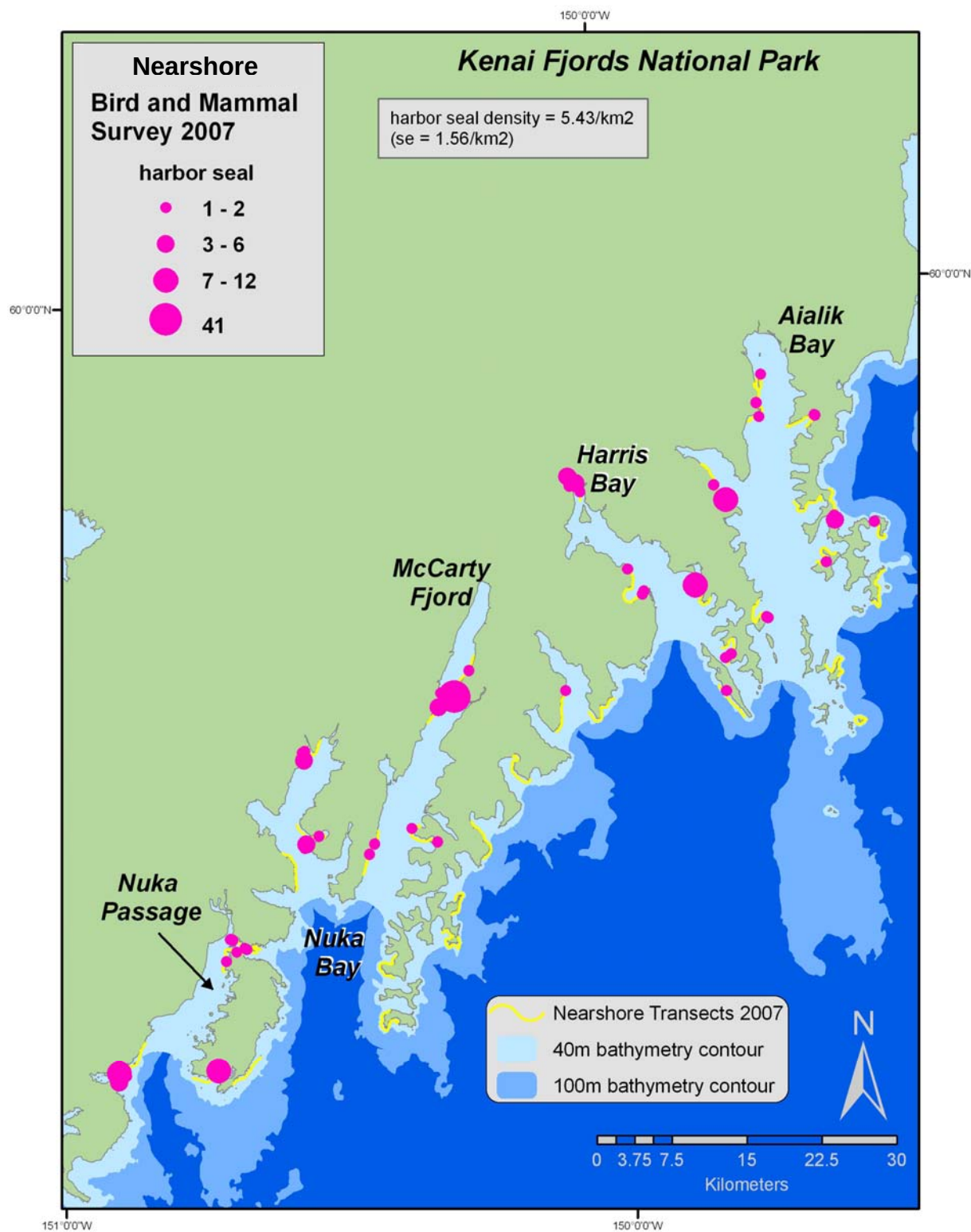


Figure 3.32. Distribution, abundance, and density of harbor seals on transects in block 5 KEFJ, June 2007.

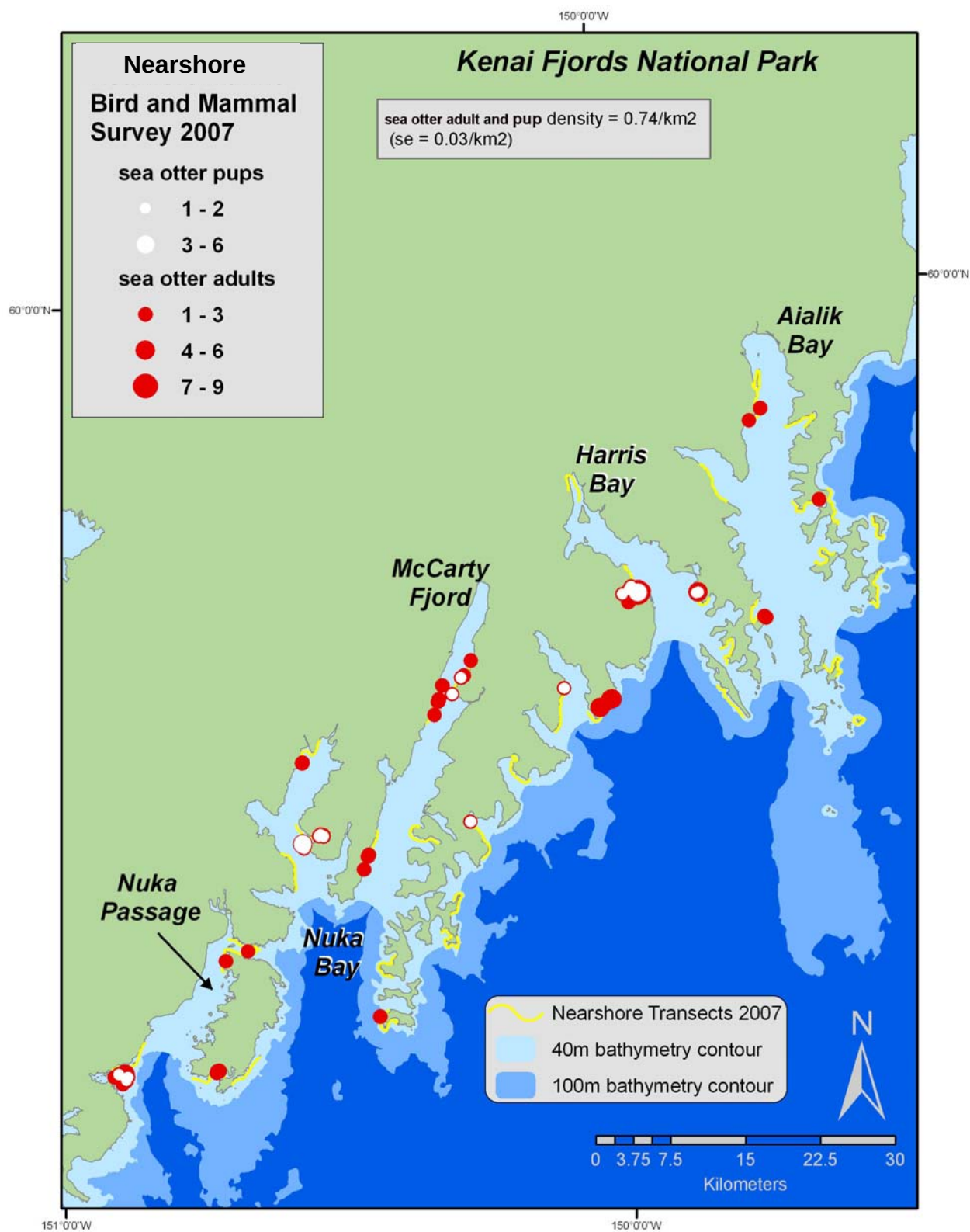


Figure 3.33. Distribution, abundance, and density of sea otters and pups on transects in block 5 KEFJ, June 2007.

DISCUSSION

Shoreline skiff surveys provide an initial description of the species composition, distribution and relative abundance of the summer marine bird and mammal fauna that occur in the nearshore waters of KATM and KEFJ. Because we are primarily focusing our efforts within a 200 m strip contiguous with the shoreline, some species that occupy shallow nearshore habitats > 200 m offshore may be underrepresented. Also because we do not sample habitats > 200 m from shore at an equal intensity to the nearshore survey, the density and abundance estimates will not be comparable to surveys from elsewhere that include offshore habitats. Additionally, because components of the marine bird and mammal fauna may change seasonally, inference to species composition, distribution, and abundance to other seasons cannot be made. In particular it is likely that some sea duck species that were rare or absent in the summer may be more common as over wintering residents (e.g. goldeneye, scoters, and long tailed ducks).

RECOMMENDATIONS

Because of likely biases associated with sampling only transects adjacent to shorelines, establishment of marine bird and mammal transects that sample shallow (<100 m) habitats > 200 m offshore should be considered in KEFJ. Additionally, 5 km transects centered at each of the intensive intertidal sites should be established in KEFJ to increase the percent of shoreline surveyed as well as extend established transects. Similar surveys will be conducted during the late winter period (March) beginning in 2008 in both KATM and KEFJ to provide estimates of abundance of those species that use the Gulf of Alaska as over wintering habitat as well as to provide a winter perspective on the distribution of resident species. The data derived from these transects will increase our ability to draw inference between the intertidal algae and invertebrate data and those marine bird and mammals that prey upon them.

4 Black Oystercatchers

INTRODUCTION

The black oystercatcher (*Haematopus bachmani*) is a common and conspicuous member of the rocky and gravel intertidal marine communities of eastern Pacific shorelines and is completely dependent on nearshore marine habitats for all critical life history components including foraging, breeding, chick-rearing, and resting (Andres and Falxa 1995). During the late spring and summer breeding season pairs establish and defend both nest and forage areas, and these territories and nest sites can persist over many years (Groves 1984, Hazlitt and Butler 2001) with individual life expectancy exceeding 15 years (Andres and Falxa 1995). The diet consists primarily of mussels (*Mytilus* sp.) and a variety of limpets (*Lottia*, *Tectura*, *Acmea*, and *Colisella* sp.) (Andres and Falxa 1995), both of which are ecologically and culturally important constituents of the intertidal community. The species is considered a Management Indicator Species by the Chugach National Forest (Chugach National Forest 2003) and a species of concern nationally (Brown et al. 2000), and regionally (Alaska Shorebird Working Group 2000) and is widely recognized as a species representative of nearshore habitats. Because of their complete reliance on intertidal habitats, their reproductive biology, and foraging ecology, black oystercatchers are particularly amenable to long-term monitoring (Lentfer and Maier 1995, Andres 1998).

As a “keystone” species (Power et al. 1996), the black oystercatcher has a large influence on the structure of intertidal communities that is disproportionate to its abundance. The black oystercatcher receives its recognition as a keystone species through a three-trophic-level cascade initiated by the oystercatcher as a top level consumer in the nearshore (Marsh 1986a and b, Hahan and Denny 1989, Falxa 1992) whose diet consists largely of gastropod (limpets) and bivalve (mussels) mollusks that are ecologically important in the intertidal community. As a consequence of oystercatcher foraging, large numbers of herbivorous limpets can be removed (Frank 1982, Lindberg et al. 1987), resulting in shifts in limpet species composition and reduced size distribution (Marsh 1986a, Lindberg et al. 1987). As a consequence of reduced limpet densities and the diminished grazing intensity that results, algal populations respond through increased production and survival, resulting in enhanced algal populations (Marsh 1986a, Meese 1990, Wootton 1992, Lindberg et al. 1998). Additionally, the oystercatcher’s diet consists of a large fraction of mussels, an important filter feeding bivalve that provides energy to a wide array of invertebrate, avian, and mammalian predators in the nearshore (Knox 2000, Menge and Branch 2001). Because the oystercatcher brings limpets, mussels and other prey back to its nest to provision chicks (Webster 1941, Frank 1982, Hartwick 1976, Lindberg et al. 1987), collections of those shell remains at nests provides an opportunity to obtain an independent sample of the species composition and size distribution of common and important nearshore invertebrate prey species that are directly estimated under intertidal algal and invertebrate vital signs (see section 2 Intertidal Invertebrates and Marine Water Quality). The collection of black oystercatcher diet and prey data offers a unique perspective into processes structuring nearshore communities (Marsh 1986a and b, Lindberg et al. 1987), including the potential consequences of anticipated increases in human presence and disturbance (Lindberg et al. 1998). Further, contrasting relative abundances and size-class composition of invertebrates collected under two independent protocols should increase our understanding of the processes responsible for change in nearshore ecosystems.

At a global scale, intertidal communities have been impacted by human activities (Liddle 1975, Kingsford et al. 1991, Poverly and Keough 1991, Keough et al. 1993, Menge and Branch 2001) and one of the primary capabilities and intents of the nearshore monitoring program is to provide early detection of change in nearshore communities and to separate human from natural causes of change. Because of the critical nature of intertidal habitats for both breeding and foraging, black oystercatchers are particularly sensitive indicators to disturbances in the nearshore (Lindberg et al. 1998). Specifically, black oystercatchers nest exclusively in the intertidal, where eggs are laid in exposed nests consisting of depressions in pebbles, sand, gravel, and shell materials. During the 26-32 d incubation phase of reproduction, eggs are susceptible to predation by other birds (primarily *Corvids*; Lentfer and Meier 1995) and mammals (Vermeer et al. 1992), as well as human disturbance and trampling. Similar disturbance effects occur during the chick rearing stage, which lasts approximately 38 d (Andres and Falxa 1995). Thus, for several months during May-August, typically when human presence in nearshore habitats in Alaska is highest, black oystercatchers are actively incubating or caring for young in a habitat that affords little protection from human induced disturbances. Chronic disturbance from human activities poses a significant threat to breeding black oystercatchers, either preventing nesting altogether, causing nest abandonment after eggs have been laid (Andres 1998), or through direct mortality of eggs or chicks. Monitoring of black oystercatcher abundance, breeding territory density and occupancy, and prey will provide a potentially powerful tool in identifying the magnitude and causes of inevitable change in Gulf of Alaska nearshore habitats and communities, particularly in response to the anticipated increased use and influence of those habitats by humans.

METHODS

There are three components to the sampling related to black oystercatchers: estimation of breeding pair density and nest occupancy through oystercatcher-specific surveys; estimation of species composition and size distributions of prey returned to provision chicks; and estimation of density of breeding and non-breeding black oystercatchers observed during the marine bird and mammal surveys. Detailed methods can be found in the black oystercatcher breeding territory occupancy and chick diet SOP (Dean and Bodkin 2006). The general methods used to obtain marine bird and mammal densities can be found in the marine birds methods section of this report and detailed methods can be found in the marine bird and mammal SOP (Dean and Bodkin 2006).

Black oystercatcher breeding territory density, nest occupancy, and prey data were collected along five 20 km transects each centered on a rocky intertidal invertebrate and algal site at KATM (Figure 4.1) and KEFJ (Figure 4.2). In addition, oystercatcher abundance, productivity, and diet data were collected from a selected site at Ninagiak Island and its surrounding islets in Hallo Bay, at KATM (Figure 4.1). Sampling methods were similar between parks.

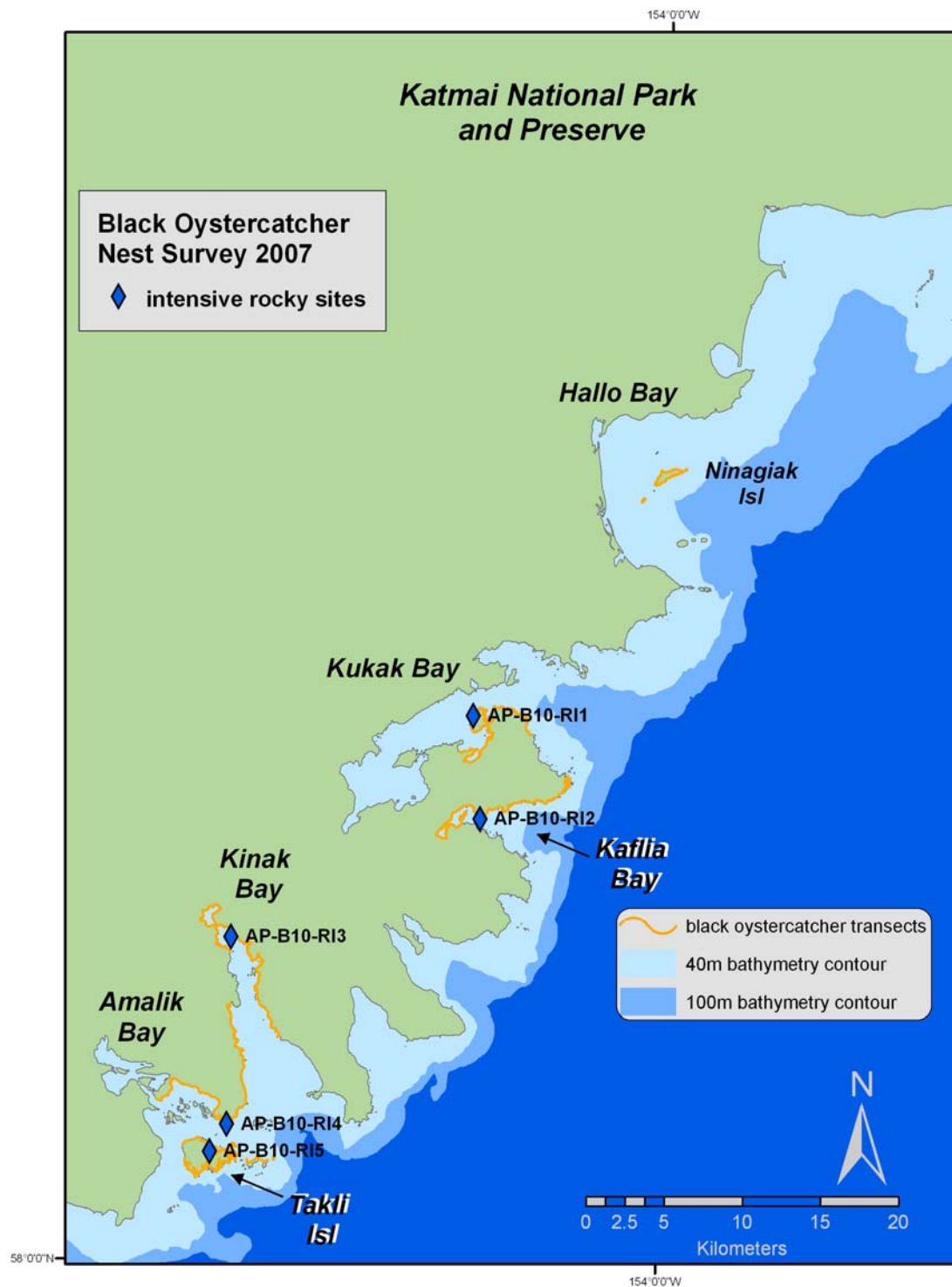


Figure 4.1. Location of transects for black oystercatcher nest surveys in KATM, June 2007.

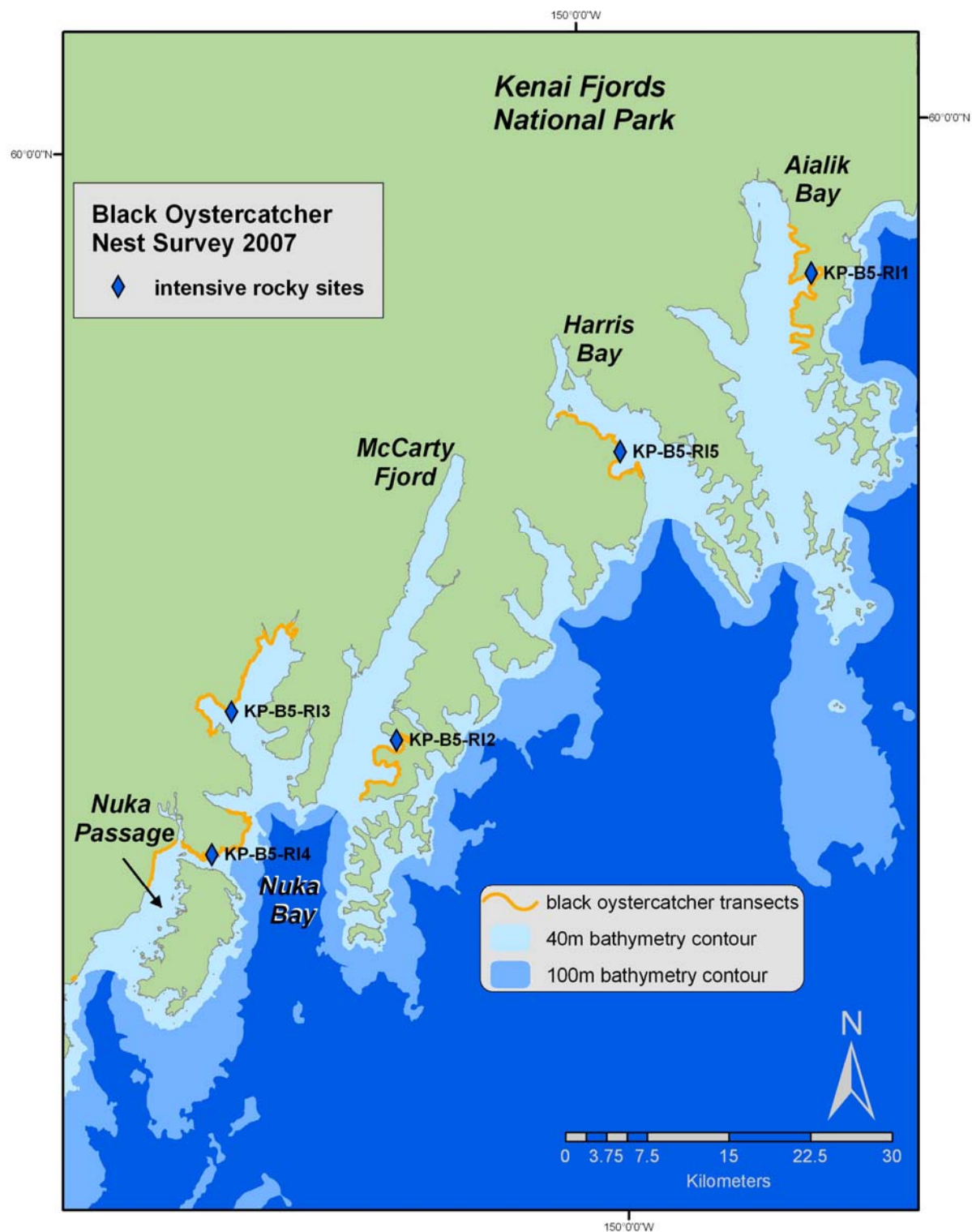


Figure 4.2. Location of transects for black oystercatcher nest surveys in KEFJ, June 2007.

Black oystercatcher breeding territories and nest sites were located and sampled by three observers traveling slowly and methodically along prescribed transects (Figures 4.1 and 4.2) in small skiffs suitable for landing on rocky shorelines. Transects were surveyed at speeds of approximately 5 knots, parallel to the shoreline as close as possible and extended to offshore islands and rock outcrops. Observers searched the shorelines and intertidal zone for black oystercatchers with the aid of high resolution binoculars. Upon detection of one or more oystercatchers, the observers monitored the behavior of the birds to determine if a nest was likely present, and its approximate location. Potential nest sites were then searched for on foot taking care not to damage eggs or chicks (Figure 4.3). Nests, eggs (Figure 4.4), and chicks (Figure 4.5) are cryptic and caution was exercised to minimize disturbance. Nests and chicks are difficult to detect at times, and the behavior of the adults (e.g. feinting injury, Figure 4.6) was a conspicuous indicator of nest presence. A GPS was employed to identify the track line of the survey skiff and identify the positions of all oystercatcher nests.



Figure 4.3. Searching a black oystercatcher nest for adults, eggs or chicks, and prey remains on transect AP B10 RI1, Kinak Bay, block 10, KATM, June 2006.



Figure 4.4. Black oystercatcher nest with eggs.

At the time of the survey, the status of the nesting territory was categorized as either active (eggs or chicks present), abandoned or inactive (not occupied, no eggs, chicks, or adults, only applies to nests active in previous years, not applicable to data collected in 2006 at KATM or 2007 at KEFJ), or failed (evidence of egg shell or presence of adults, but no chicks). At each nest site the number adults, eggs, and chicks were recorded.



Figure 4.5. Black oystercatcher chick and egg in nest.



Figure 4.6. Black oystercatcher feigning injury to lure threats away from eggs or chicks.

Breeding territory densities were calculated for each transect by dividing the total number of active nests by the length of each transect. We used transect end points to calculate transect distance along the shoreline in ArcGIS. For each nest we present the location, the number of adults, eggs, and chicks present and calculate the mean number (se) of eggs, chicks, and eggs plus chicks per transect, and among transects. When a brooding pair was evident and no chicks were observed, the nest was assumed active. In these cases no data were available as to the number of chicks.

After a nest site was located, observers searched for the presence of shell remains indicative of adult birds provisioning their chicks (Figure 4.7). Not all nest sites had prey remains. For example if eggs were not hatched or were depredated prior to hatching, shell prey remains may be absent, or if present representing prey from prior years. Assemblages of shell remains that were indicative of an active nest site were generally concentrated near the nest ($< \sim 5$ m). Care was taken to collect all shell remains available, regardless of size. All shell remains attributable to oystercatcher foraging were collected and placed into a zip-loc bag, with an identification tag that includes date, time, name of observer, the unique nest site number, and GPS coordinates of collection site. Each prey was identified to species and measured to the nearest mm. For each nest site where prey was collected we calculated the mean size (se) of each prey species. For nests where counts of prey species equaled or exceeded 20 individuals we generated size frequency distribution plots in 10 mm size bins and expressed as the proportion of individuals in each bin. Similarly, we generated cumulative size frequency distributions for all nests within a transect when the number of individuals for a species collectively equaled or exceeded 20 individuals.



Figure 4.7. Shell remains of black oystercatcher prey collected from nest site 4, AP-B10-RI1, block 10 KATM, June 2006.

RESULTS

KATM

The mean density of black oystercatchers was $2.3/\text{km}^2$ ($se=0.73$) (Section 3, Table 3.1 and Figure 3.4). Individuals were widely distributed along the KATM shoreline, occurring on 18 of 30 shoreline transects with the highest densities observed at Ninagiak Island and in Kukak Bay.

In 2007 we surveyed five 20-22.5 km transects associated with rocky intensive intertidal sites and one 6.1 km selected transect around Ninagiak Island (Figure 4.7). We located 32 black oystercatcher nests on those 6 transects. The distribution and density of nests was similar to the distribution and abundance of all black oystercatchers as estimated in the marine bird and mammal surveys.

Generally, a pair of adults was present at each nest, except at one nest at Kukak Bay and two nests at Ninagiak where > 2 adults were observed (Table 4.2). Of the 32 nests found, 22 were active, 4 had failed and 6 were inactive, or without evidence of nesting in 2007. We found 28 eggs and 10 chicks in those 22 active nests (Table 4.2). Overall we encountered 0.41 nests/km and nest production was 1.4 eggs or chicks per nest (Table 4.2). Nest density on the five randomly selected intensive transects was 0.13 nest/km of transect.

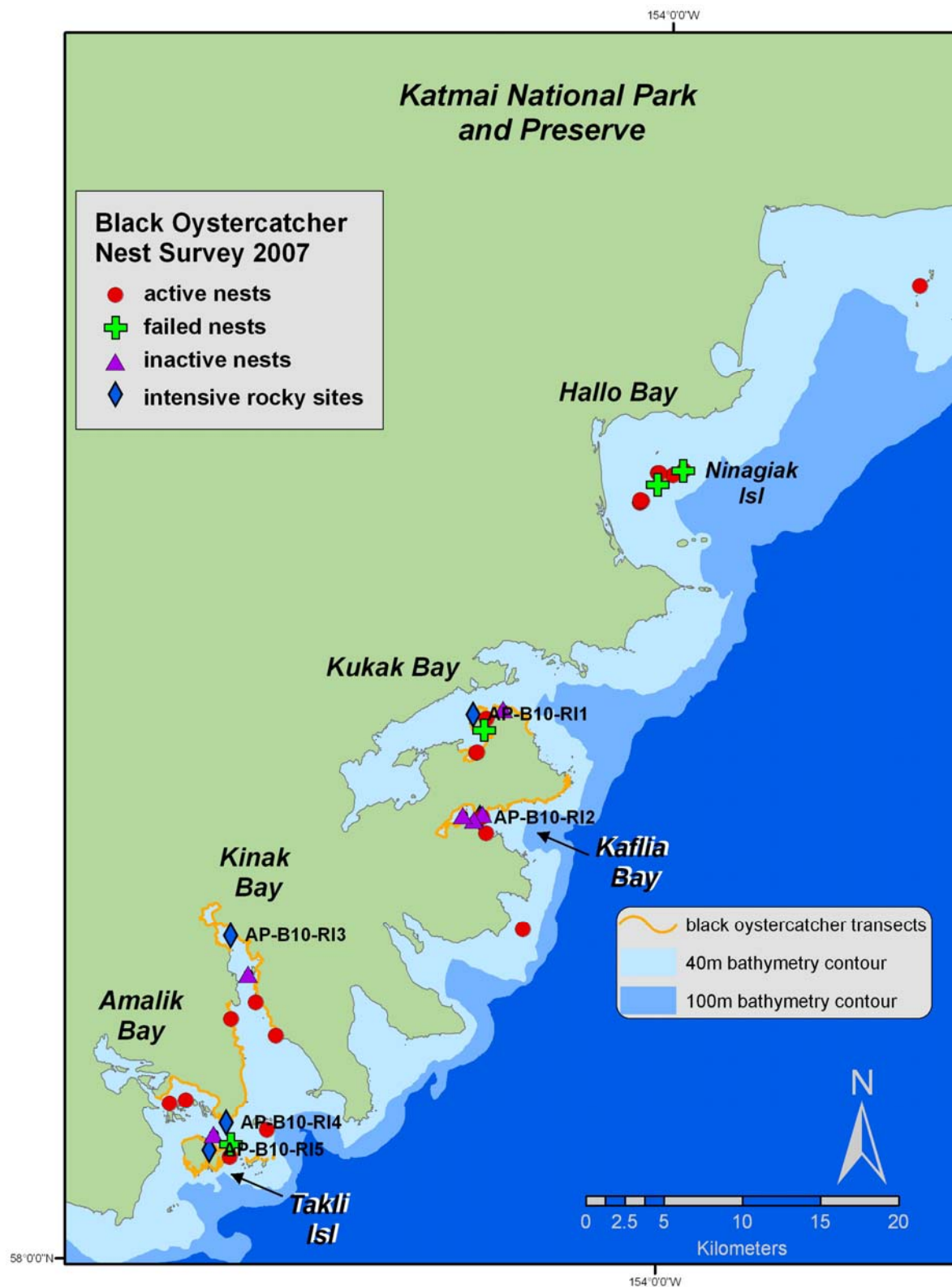


Figure 4.8. Locations of black oystercatcher transects and nest sites in KATM block 10, June 2007.

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Table 4.1. Black oystercatcher nest site numbers, nest status, number of adults, number of eggs, number of chicks and the sum of eggs and chicks per nest KATM 2007. A = active nest; F= failed nest, IA= inactive nest. U = unknown number. ^a Prey remains from prior year.

Site	Length	Nest site #	Status	# Adults	# Eggs	# Chicks	Prey collected
Kukak AP B10 RI1	20 km	1-06	A	2	1	0	N
		2-06	F	2	0	0	Y
		3-06	A	3	1	2	Y
		4-06	IA	2	0	0	Y
		1-07	A	2	2	0	N
Kafliia AP B10 RI2	20 km	1-06	IA	0	0	0	N
		2-06	IA	2	0	0	N
		3-06	IA	0	0	0	N
		1-07	A	2	3	0	N
		2-07	A	2	1	0	N
Kinak AP B10 RI3	20 km	1-06	IA	2	0	0	N
		2-06	A	2	3	0	N
		1-07	A	2	0	2	Y
Amalik AP B10 RI4	20 km	1-06	A	2	2	0	Y ^a
		2-06	A	2	2	0	N
		1-07	A	2	0	2	Y
Takli AP B10 RI5	22.5 km	1-06	F	2	0	0	N
		1-07	A	2	3	0	N
		2-07	IA	3	0	0	N
Ninagiak Island	6.1 km	1-06	F	1	0	0	N
		2-06	F	U	0	0	N
		3-06	A	2	0	0	N
		4-06	A	U	0	0	Y
		5-06	A	U	1	0	N
		6-06	A	2	2	0	N
		1-07	A	2	0	1	Y
		2-07	A	2	0	1	Y
		3-07	A	2	1	0	N
		4-07	A	4	2	0	N
		5-07	A	4	2	0	N
		6-07	A	2	0	2	N
		7-07	A	2	1	0	N

Table 4.2. Black oystercatcher nest density and numbers of eggs and chicks per active nest summarized by transect, KATM 2007. Nests with unknown chick numbers were not used in chick per nest calculations. Means include nest density and number of eggs and chicks per nest and are inclusive of all transects.

Site	Nest density (/km)	# eggs	Eggs/nest	# chicks	Chicks/nest	Eggs + Chicks/ nest
Kukak AP B10 RI1	0.25	4	1.0	2	0.5	1.5
Kaflia AP B10 RI2	0.10	4	2.0	0	0.0	1.0
Kinak AP B10 RI3	0.1	3	1.5	2	1.0	2.50
Amalik AP B10 RI4	0.15	4	1.33	2	0.67	1.50
Takli AP B10 RI5	0.04	3	3.0	0	0.00	3.00
Ninagiak Island	1.8	10	0.91	4	0.36	1.3
Means	0.41		1.62		0.42	1.80
Se	0.28		0.32		0.16	0.32

We recovered the shell remains of prey collected by black oystercatcher adults and brought back to the vicinity of their nests, presumably to provision their chicks. Prey remains were recovered from 10 nest sites, nine of which were active and one from a failed nest where 3 egg remains were present. We presumed this collection represented the previous years diet sample (Table 4.2). Of the eight nests where chicks were present, seven provided shell collections and one did not. Of the 13 nests where eggs only were present, one provided shell remains, also presumably from the prior year.

We collected and measured 1049 shell remains from ten nests representing eight prey species (Table 4.2). The species composition of prey items returned to provision chicks varied among nests (Figure 4.8), but limpets or mussels were found at all nest sites where prey were recovered. Limpets (*Lottia* sp. and *Tectura* sp. comprised 76%, and mussels 19% of all prey brought back to the nests (Figure 4.8). All remaining prey (snails, chitons, and clams) comprised about 4% of the prey on average. The limpet *Tectura scutum*, was the most frequently detected prey type, found in nine of 10 nests (followed *T. persona* and *Lottia* sp. found in eight of 10 nests. The mussel *Mytilus trossulus* was found in five of 10 nests and the chiton *Katharina tunicata* found in four of 10 nests. While relatively few species characterized the diet of black oystercatchers as a whole, we found substantial variation in the proportion of prey species among nests (Table 4.2, Figure 4.9).

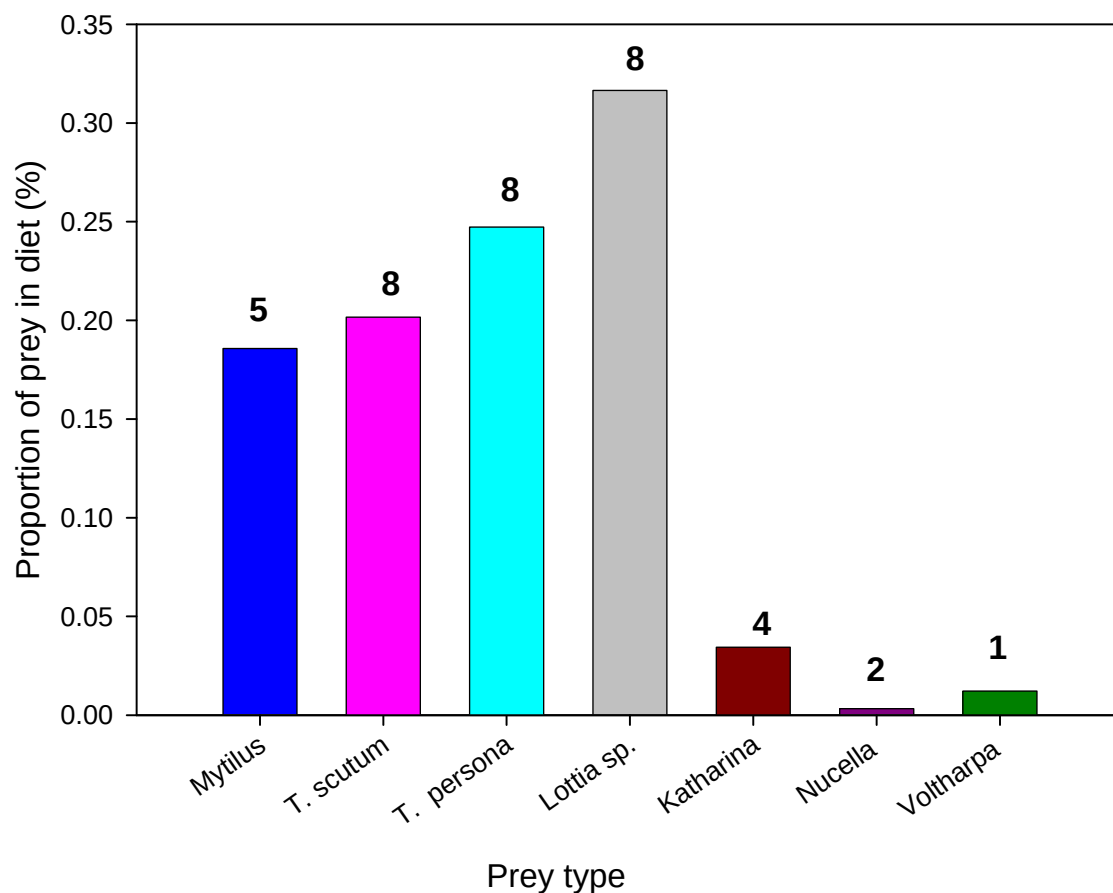


Figure 4.9. Cumulative diet among nine black oystercatcher nests where prey ($n > 5$) were collected in 2007. Numbers above bars indicate frequency of prey type in sample of eight nests. See Table 4.2 for specific nest identification. Diet calculated by averaging proportions of each prey among eight nests where prey were collected.

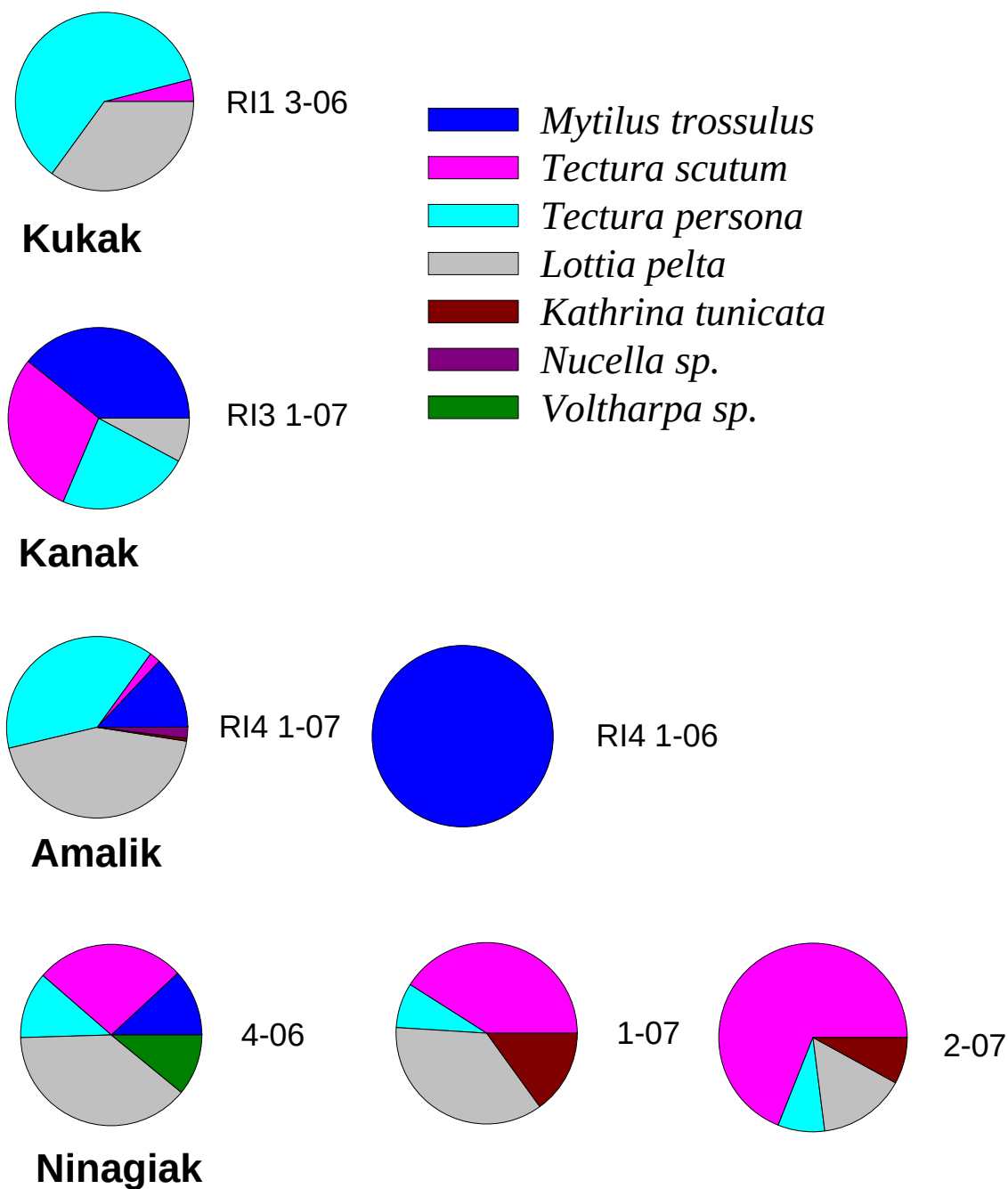


Figure 4.10. Species composition of prey collected from black oystercatcher nests at KATM, June 2007. Each chart represents prey collected from one nest site and nest name and numbers correspond to individual nest identified in Table 4.3. Only nests from intensive transects with $n \geq 18$ are included.

Table 4.3. Species composition, mean sizes, standard errors and total number of prey of each species by nest collected at four of the intensive sites, one selected intensive site, and 2 opportunistic nests (Cape Gull and Cypress Hill). No prey were collected on transects RI-2 or RI-5. Mean sizes and standard deviations are in millimeters. Prey from nest 2-06 from Kukak are not included in diet analyses due to a small sample size of five.

Site	Nest	Species	Mean Size (mm)	SE of size (mm)	Total Measured
AP B10 RI1	2-06	<i>Mytilus trossulus</i>	42.5	5.4	4
Kukak		<i>Tectura scutum</i>	16.0	NA	1
	3-06	<i>Tectura persona</i>	17.4	0.4	51
		<i>Tectura scutum</i>	27.5	0.5	2
		<i>Lottia pelta</i>	19.4	0.5	28
AP B10 RI3	1-07	<i>Mytilus trossulus</i>	44.6	1.2	20
Kinak		<i>Tectura persona</i>	19.6	1.5	12
		<i>Tectura scutum</i>	26.7	1.0	15
		<i>Lottia pelta</i>	19.2	1.6	4
AP B10 RI4	1-06	<i>Mytilus trossulus</i>	46.9	1.5	18
Amalik	1-07	<i>Mytilus trossulus</i>	35.3	1.8	26
		<i>Tectura persona</i>	20.2	0.4	70
		<i>Tectura scutum</i>	28.5	1	4
		<i>Lottia pelta</i>	18.6	0.3	101
		<i>Nucella</i> sp.	25.2	0.5	4
		<i>Katherina tunicata</i>	52	NA	1
Ninagiak	1-07	<i>Tectura persona</i>	19.0	2.5	3
		<i>Tectura scutum</i>	28.4	1.4	16
		<i>Lottia pelta</i>	19.4	0.8	14
		<i>Katherina tunicata</i>	58.3	17.6	6
	2-07	<i>Tectura persona</i>	16	NA	1
		<i>Tectura scutum</i>	27.1	1.2	9
		<i>Lottia pelta</i>	22.5	3.5	3
		<i>Katherina tunicata</i>	57	NA	1
	4-06	<i>Mytilus trossulus</i>	35.5	2.1	10
		<i>Tectura persona</i>	22.3	0.9	10
		<i>Tectura scutum</i>	27.9	0.6	23
		<i>Lottia pelta</i>	22.2	0.6	33
		<i>Voltharpa</i> sp.	23.3	0.6	9
Cape Gull	1-07	<i>Mytilus trossulus</i>	36.8	0.7	5
		<i>Katherina tunicata</i>	42.9	2.3	15
		<i>Tectura persona</i>	27.8	0.6	64
		<i>Tectura scutum</i>	25.3	1.5	3
		<i>Lottia pelta</i>	22.6	0.4	106
		<i>Lottia digitalis</i>	19.1	0.5	17
		<i>Nucella lima</i>	38.0	4.0	2
Cypress Hill	1-07	<i>Katherina tunicata</i>	30.7	5.0	3
		<i>Lottia digitalis</i>	18.7	0.4	26
		<i>Lottia pelta</i>	24.2	0.3	138
		<i>Tectura persona</i>	25.6	0.3	143
		<i>Tectura scutum</i>	26.6	0.4	27

Table 4.4. Mean sizes, standard errors and total number of prey of four common prey species collected within four of the intensive sites and the selected intensive site at Ninagiak Is. No prey were collected at RI2 or RI5.

Species	Site	Mean Size (mm)	SE of size (mm)	Total Collected
<i>Lottia pelta</i>	AP B10 RI1 Kukak	19.4	0.5	28
	AP B10 RI3 Kinak	19.2	1.6	4
	AP B10 RI4 Amalik	18.6	0.3	101
	Ninagiak	21.4	0.5	49
<i>Tectura scutum</i>	AP B10 RI1 Kukak	23.7	3.8	3
	AP B10 RI3 Kinak	26.7	1.0	15
	AP B10 RI4 Amalik	28.5	1.3	4
	Ninagiak	27.9	0.7	48
<i>Tectura persona</i>	AP B10 RI1 Kukak	17.4	0.3	51
	AP B10 RI3 Kinak	19.6	1.5	12
	AP B10 RI4 Amalik	20.2	0.4	70
	Ninagiak	21.1	0.9	14
<i>Mytilus trossulus</i>	AP B10 RI1 Kukak	42.5	5.4	4
	AP B10 RI3 Kinak	44.6	1.2	20
	AP B10 RI4 Amalik	40.0	1.5	44
	Ninagiak	35.5	2.1	10

Mean sizes (se) of shell remains by nest are presented in Table 4.2 and for the dominant prey within each oystercatcher transect in Table 4.3. *Mytilus trossulus* were the largest prey species in four of the eight collections on transects, *Katharina tunicata* the largest in three, and *Tectura scutum* in one. In general, mussels collected from transects RI1-RI4 were larger than mussels collected from Ninagiak Is. nests, while the limpets were generally larger from Ninagiak nests. Among all nests in 2007 *Lottia pelta* averaged 21.8 mm (range 12-36 mm; se = 0.2)(Figure 4.10), *T. scutum* averaged 27.2 (range 16-39 mm; se = 0.4)(Fig 4.11), and *Tectura persona* averaged 23.4 mm (range 10-41 mm; se = 0.3) (Fig 4.12). *Mytilus trossulus* averaged 40.5 mm (range 22-62 mm; se = 1.0) (Figure 4.13).

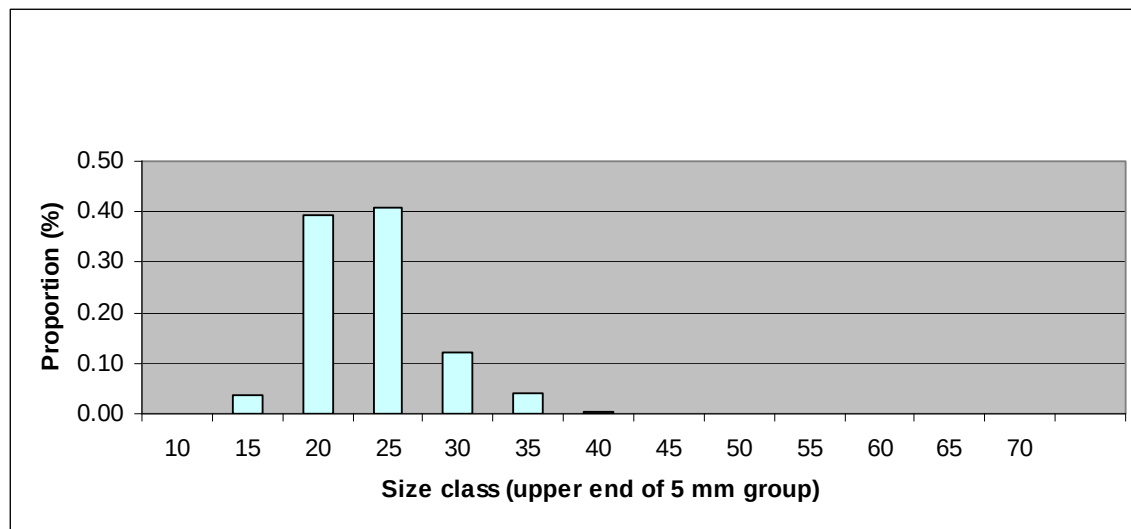


Figure 4.11. Size distribution of *Lottia pelta* collected from all black oystercatcher nest sites at KATM, June 2007 ($n=426$).

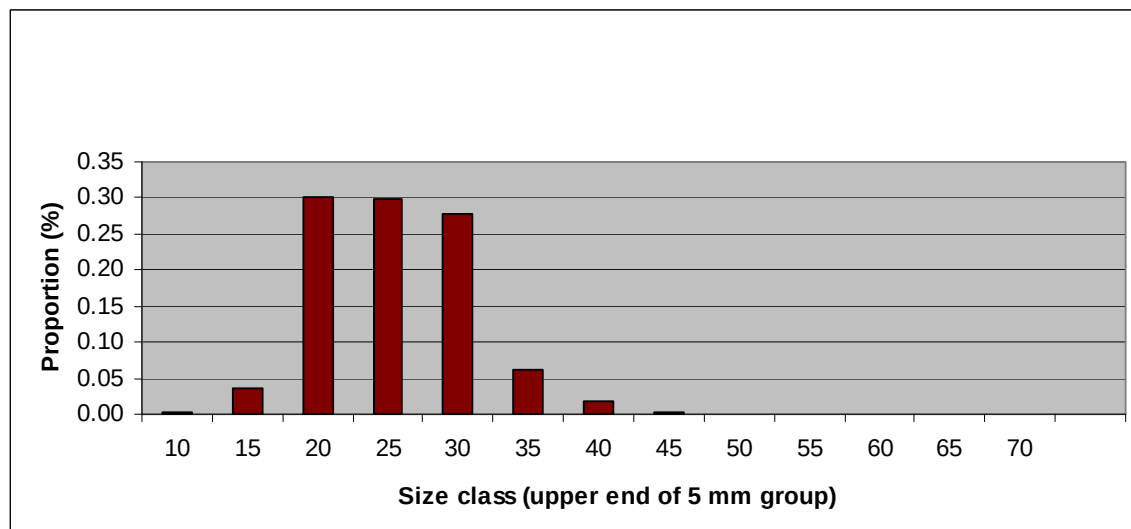


Figure 4.12. Size distribution of *Tectura persona* collected from all black oystercatcher nest sites at KATM, June 2007 ($n=354$).



Figure 4.13. Size distribution of *Tectura scutum* collected from all black oystercatcher nest sites at KATM, June 2007 ($n=100$).

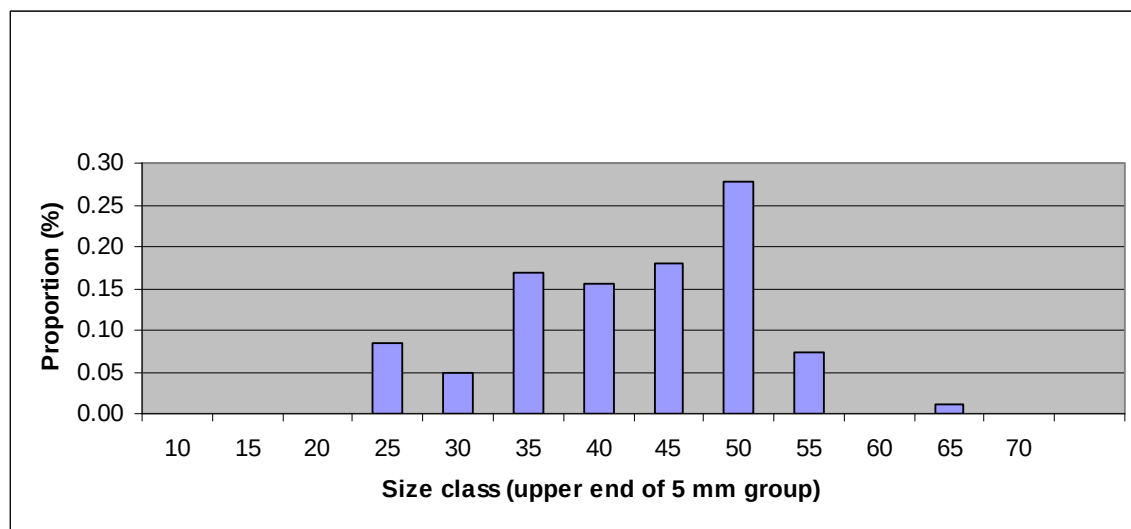


Figure 4.14. Size distribution of *Mytilus trossulus* collected from all black oystercatcher nest sites at KATM, June 2007 ($n=83$).

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KEFJ

The mean density of black oystercatchers was $0.74/\text{km}^2$ ($se = 0.03$) (Section 3, Table 3.3 and Figure 3.23). Individuals were distributed along the KEFJ shorelines on 12 of the 36 transects we sampled for marine birds and mammals.

We located seven black oystercatcher nests on the five transects surveyed for nest density (Figure 4.15). The distribution and density of nests was similar to the distribution and abundance of all black oystercatchers as determined in the marine bird and mammal surveys.

A pair of adults was present at each nest, except at one failed nest on transect RI-1 in Aialik Bay, where one adult was observed (Table 4.5). Of the seven nests found, six were active and one had failed. We found 10 eggs and four chicks in those six active nests (Table 4.5). Overall we encountered 0.07 nests/km and nest production was 1.68 eggs or chicks per nest (Table 4.5). At two nests in Aialik Bay banded black oystercatchers were observed. At nest RI1 2-07 we observed two adults banded with aluminum bands on their left leg. At nest RI1 3-07 NPS staff observed a single similarly banded adult in May of 2007.

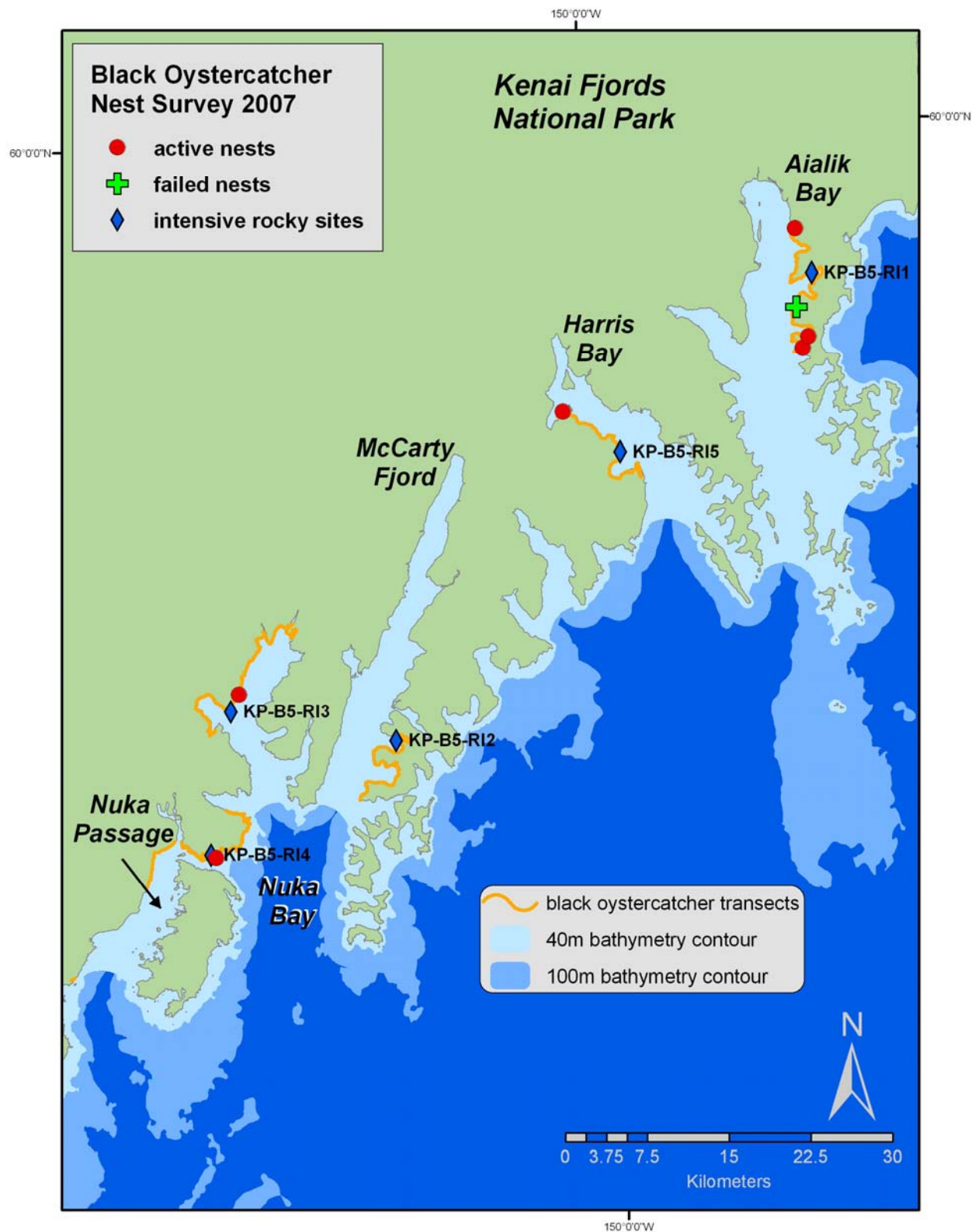


Figure 4.15. Locations of black oystercatcher transects and nest sites in KEFJ block 5, June 2007.

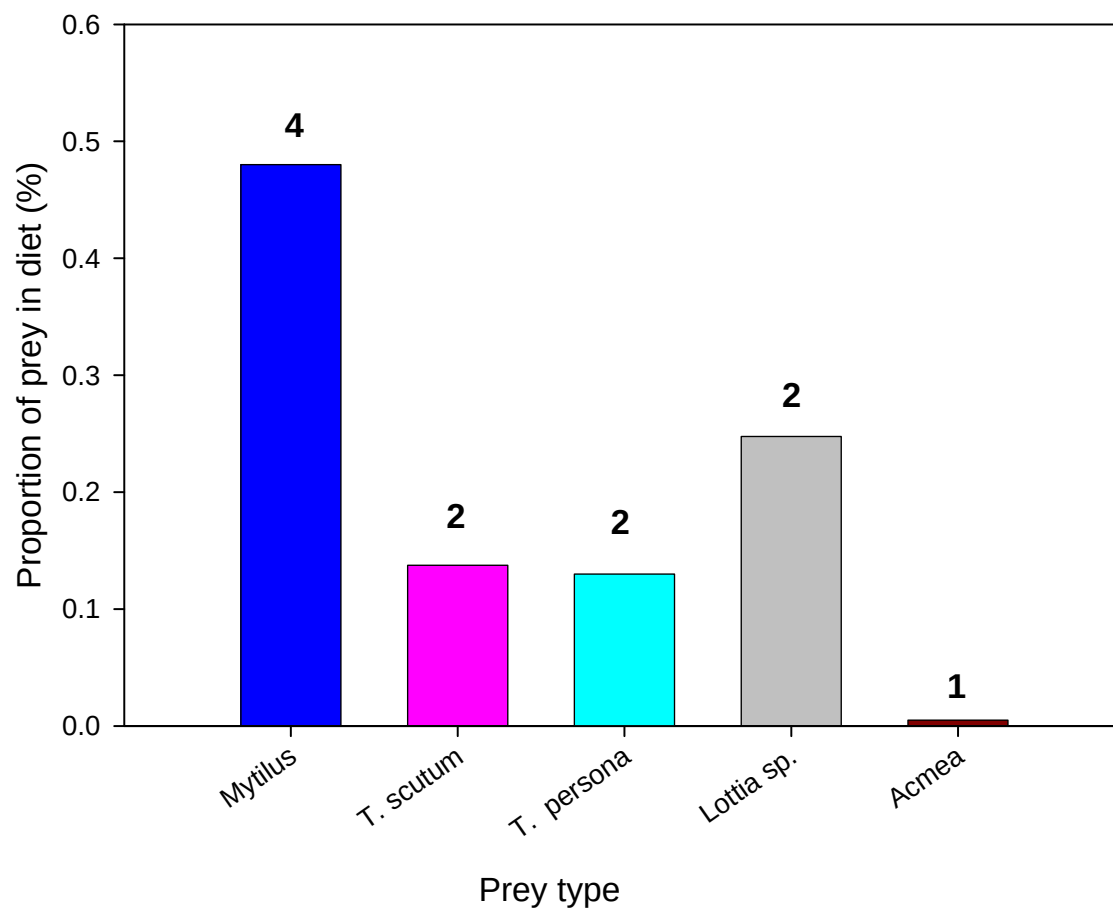


Figure 4.16. Cumulative diet among four black oystercatcher nests in KEFJ where prey were collected in 2007. Numbers above bars indicate frequency of prey type in sample of four nests. See Table 4.7 for specific nest identification. Diet calculated by averaging proportions of each prey among nests where individual prey were collected

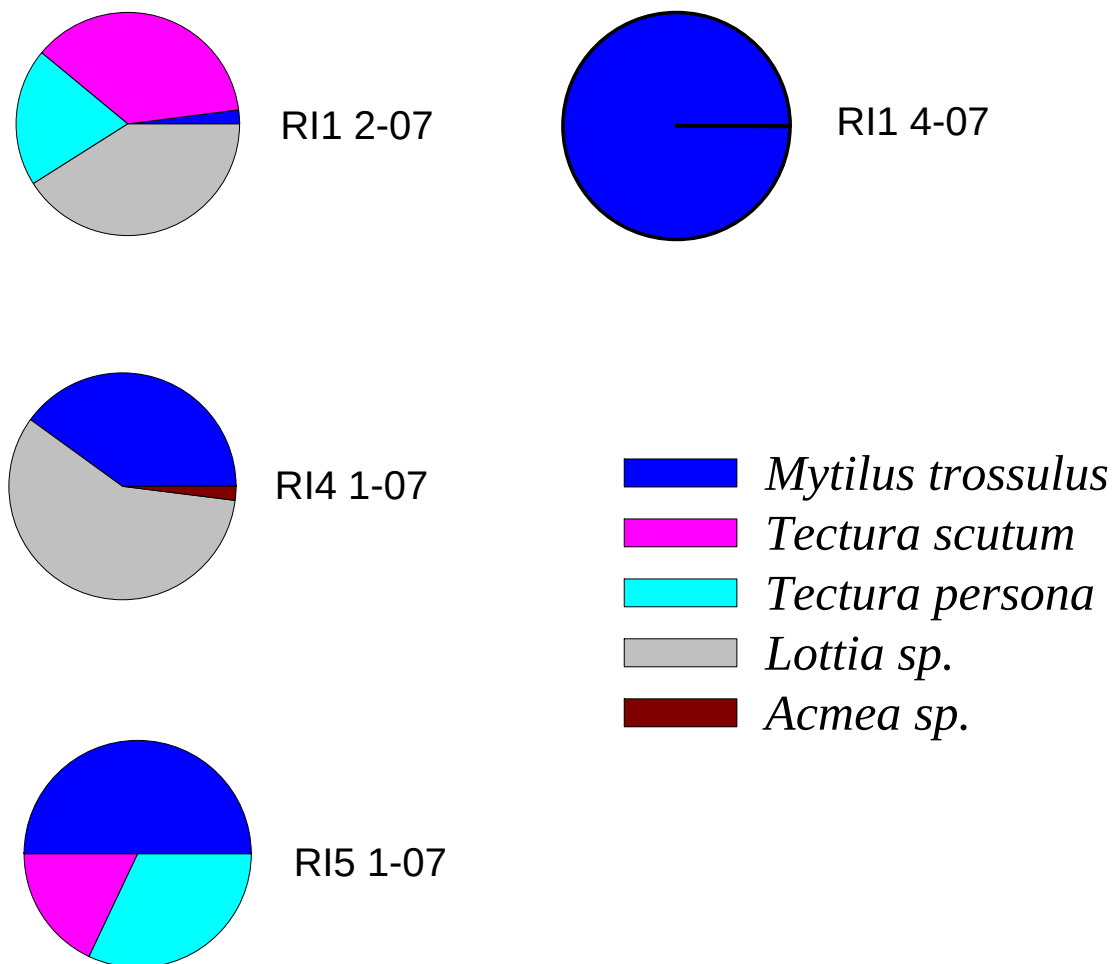


Figure 4.17. Species composition of prey collected from four black oystercatcher nests at KEFJ, June 2007. Each chart represents prey collected from one nest site and nest name and numbers correspond to individual nest identified in Tables 4.5 and 4.7.

Table 4.5. Black oystercatcher nest site numbers, nest status, number of adults, number of eggs, number of chicks and the sum of eggs and chicks per nest at KEFJ 2007. A = active nest; F= failed nest, IA= inactive nest. U = unknown number.

Site	Length	Nest site #	Status	# Adults	# Eggs	# Chicks	Prey collected
KP B5 RI1	20 km	1-07	A	2	3	0	N
		2-07	A	2	0	2	Y
		3-07	F	1	0	0	N
		4-07	A	2	2	0	Y ^a
KP B5 RI2	20 km						
KP B5 RI3	20 km	1-07	A	2	3	0	N
KP B5 RI4	20 km	1-07	A	2	0	2	Y ^a
KP B5 RI5	20 km	1-07	A	2	2	0	Y ^a

^a Prey remains from prior year

Table 4.6. Black oystercatcher nest density and numbers of eggs and chicks per active nest summarized by transect, KEFJ 2007. Nests with unknown chick numbers were not used in chick per nest calculations. Means include nest density and number of eggs and chicks per nest and are inclusive of all transects.

Site	Nest density (#/km)	# eggs	Eggs/nest	# chicks	Chicks/nest	Eggs + Chicks/nest
KP B5 RI1	0.20	5	1.25	2	0.5	1.4
KP B5 RI2	0	0	0	0	0	0
KP B5 RI3	0.05	3	3.0	0	0	3.0
KP B5 RI4	0.05	0	0	2	2.0	2.0
KP B5 RI5	0.05	2	2.0	0	0.0	2.0
Means (#/km)	0.07		1.25		0.50	1.68
Se	0.28		0.58		0.39	0.49

We recovered the shell remains of prey collected by black oystercatcher adults and brought back to the vicinity of their nests, presumably to provision their chicks. Prey remains were recovered from four nest sites, all of which were active in 2007. At three of the nest sites we presumed prey remains represented diet from a prior year as either eggs, or recently hatched chicks were at the nest (Table 4.5). Of the two nests where chicks were present, both provided shell collections.

We collected and measured 348 shell remains from four nests representing six prey species (Table 4.7). More than 99% of the diet consisted of mussels (36.8%) and four species of limpets (62.3%) (Figure 4.16, Table 4.7). The species composition of prey items returned to provision chicks varied among nests (Figure 4.17), but mussels occurred in all collections, ranging from 2-100%, while limpets ranged from zero to 98% of the diet by nest. Over all nests combined *Mytilus* comprised 37%, *Tectura* sp. 30%, *Lottia* sp. 32%, and *Acmea* <1% of the diet. Although relatively few species characterized the diet of black oystercatchers as a whole, we found substantial variation in the proportion of prey species among nests (Table 4.7, Figure 4.17).

Table 4.7. Species composition, mean sizes, standard errors and total number of prey of each species by nest collected in 2007 in KEFJ. No prey were collected on transects RI-2 or RI-3. Mean sizes and standard deviations are in millimeters.

Site	Nest	Species	Mean Size (mm)	SE of size (mm)	Total Measured
KP B5 RI1	2-07	<i>Mytilus trossulus</i>	34.5	3.5	2
		<i>Tectura persona</i>	19.3	0.9	20
		<i>Tectura scutum</i>	27.4	1.5	36
		<i>Lottia pelta</i>	21.3	0.6	40
	4-07	<i>Mytilus trossulus</i>	35.0	1.3	26
KP B 5 RI 4	1-07	<i>Mytilus trossulus</i>	27.4	1.0	49
		<i>Lottia pelta</i>	21.7	0.5	61
		<i>Lottia digitalis</i>	17.0	0.6	10
		<i>Acamea</i> sp.	24.3	1.2	3
KP B 5 RI 5	1-07	<i>Mytilus trossulus</i>	29.5	0.7	51
		<i>Tectura persona</i>	22.4	0.6	33
		<i>Tectura scutum</i>	28.6	1.0	18

Table 4.8. Mean sizes, standard errors and total number of prey of four common prey species collected within three of the intensive sites at KEFJ in 2007. No prey were collected at RI2 or RI3.

Species	Site	Mean Size (mm)	SE of size (mm)	Total Collected
<i>Lottia pelta</i>	KP B 5 RI1	21.3	0.6	40
	KP B 5 RI4	21.7	0.5	62
	KP B 5 RI5	NA	NA	NA
<i>Tectura scutum</i>	KP B 5 RI1	27.4	0.8	37
	KP B 5 RI4	NA	NA	NA
	KP B 5 RI5	28.6	1.0	18
<i>Tectura persona</i>	KP B 5 RI1	19.3	0.9	20
	KP B 5 RI4	NA	NA	NA
	KP B 5 RI5	22.4	0.6	33
<i>Mytilus trossulus</i>	KP B 5 RI1	40.0	1.2	33
	KP B 5 RI4	27.4	1.0	49
	KP B 5 RI5	29.5	0.6	51

Mean sizes (se) of shell remains by nest are presented in Table 4.7 and for the dominant prey within each oystercatcher transect in Table 4.8. *Mytilus trossulus* were the largest prey species

in each of the three transects where prey were collected, ranging from 27.4-40.0 in mean size. In general, mussels collected from transect RI1 were larger than mussels collected from RI4 and RI5 (Table 4.8). Other prey were generally similar in size among transects. Among all nests in 2007 *Lottia pelta* averaged 21.6 mm (range 13-37 mm; se = 0.4, $n=102$, Figure 4.18), *T. scutum* averaged 27.8 (range 17-38 mm; se = 0.6, $n=54$, Fig 4.19), and *Tectura persona* averaged 21.2 mm (range 10-41 mm; se = 0.6, $n=53$, Fig 4.20). *Mytilus trossulus* averaged 29.9 mm (range 10-51 mm; se = 0.6, $n=128$) (Figure 4.21).

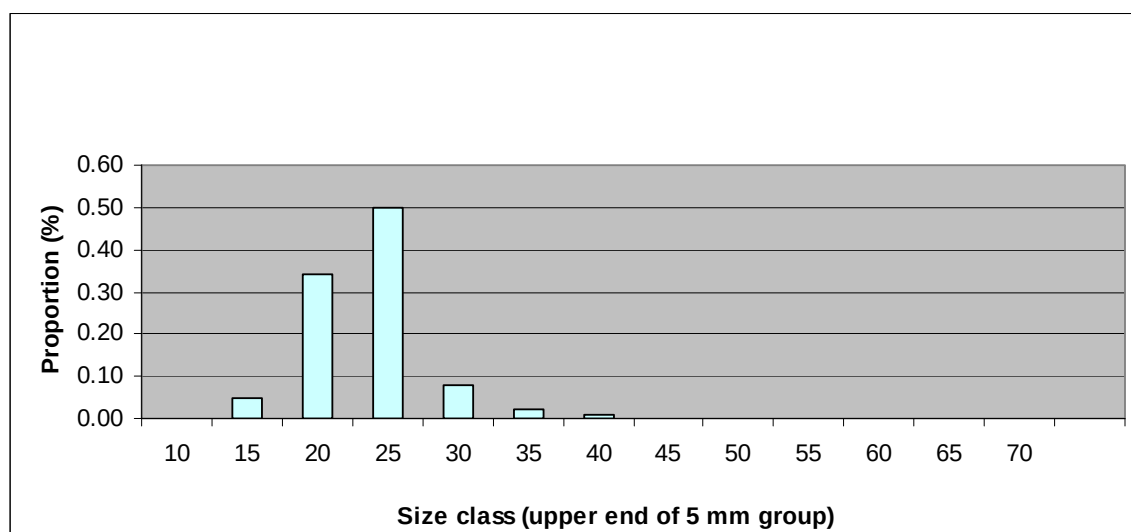


Figure 4.18. Size distribution of *Lottia pelta* collected from all black oystercatcher nest sites at KEFJ, June 2007 ($n=100$).



Figure 4.19. Size distribution of *Tectura persona* collected from all black oystercatcher nest sites at KEFJ, June 2007 ($n=53$).

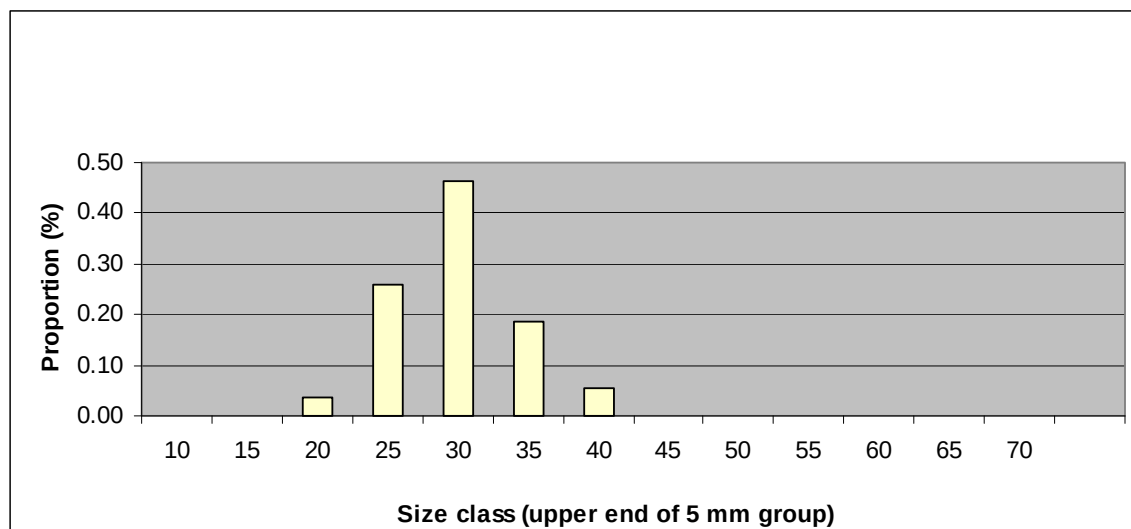


Figure 4.20. Size distribution of *Tectura scutum* collected from all black oystercatcher nest sites at KEFJ, June 2007 ($n=54$).

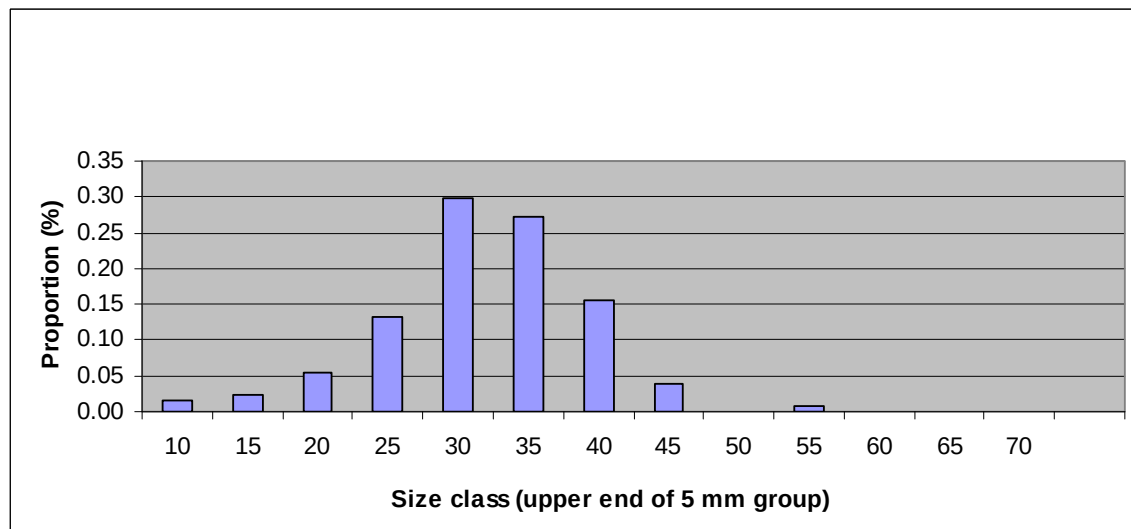


Figure 4.21. Size distribution of *Mytilus trossulus* collected from all black oystercatcher nest sites at KEFJ, June 2007 ($n=128$).

DISCUSSION

Densities of black oystercatchers on marine bird and mammal transects was about four times greater at KATM (2.3/km) than at KEFJ (0.74/km), while densities of nesting pairs of black oystercatchers were about twice as great within the five randomly located transects at KATM (0.13/km), compared 0.07/km at KEFJ. Productivity of nests, estimated as eggs or chicks per nest was similar between the two Parks (1.8 at KATM and 1.7 at KEFJ). Nest densities on

randomly located transects of about 0.1/km were on the lower range of expected densities of 0.1-0.3/km found in Prince William Sound, AK (Meyers 2002). At KATM we also sampled a selected transect at Ninagiak Island where we encountered 1.8 nests/km, higher than on systematic transects and resulted in an overall average nest density of 0.41/km of shoreline at KATM. At this point it is unclear what factors may be contributing to the relatively high density of nest sites at Ninagiak Island, or if similarly high density areas may be found at KEFJ.

Of the 18 nests identified at KATM in 2006 nine were active in 2007, four had attempted, but failed to nest, and five were inactive. Of the 14 new nests identified in 2007, 13 were active and one was inactive. It appeared that some of the nesting pairs and their nest sites identified as new in 2007 were animals that had relocated to either new or alternative nest sites near their 2006 nest, as multiple nest sites, only one of which was active in a given year, were evident at some nesting locations. It will be important to identify and recognize these multiple nest sites as a single nesting location.

The recovery of prey shell remains from fourteen nest sites confirms the feasibility of this technique to obtain a sample of the species composition and sizes of prey used to provision chicks as well as a comparative measure of the sizes of some of the dominant intertidal mollusks measured directly (see intertidal community section). Limpets (two species of *Tectura* and one of *Lottia*) and the mussel (*Mytilus trossulus*) were the dominant prey item represented in the shell remains. At KEFJ, mussels comprised 48%, and limpets 52% of the prey remains collected, compared to 18% mussels and 77% limpets at KATM (Figures 4.9 and 4.16). The greater proportion of mussels in the diet of black oystercatchers at KEFJ is consistent with greater proportions of mussels observed in the sea otter diet and suggestive of a greater reliance of the higher trophic levels on mussels at KEFJ, compared to KATM. These differences may reflect a greater proportion of rocky intertidal at KEFJ and greater soft-sediment nearshore habitats at KATM. We also found that mussel sizes averaged about 11 mm more at KATM, compared to KEFJ, a highly significant difference (Mann Whitney Rank Sum test, $P < 0.001$). This difference may reflect greater predation pressure at KEFJ, or greater growth rates of mussels at KATM.

Strong dietary diversity was evident at the level of the individual nest (Figures 4.10 and 4.17) and may represent prey availability or dietary specialization. *Mytilus* and *Tectura persona* brought to nests by oystercatchers were near the largest sizes measured under the intertidal invertebrate sampling (Figures 2.8) suggesting size selective predation by the adult oystercatchers.

We obtained sample sizes of >17 prey at three KATM nest sites in 2007 and 2006. Comparison of the species composition at each of these nests reveals striking similarity in prey brought to provision chicks over at least two years. At nest RI1 3-06 diet was dominated by limpets in both years (Figure 4.22). At nest RI4 1-06 diet was almost exclusively mussels in both (Figure 4.23). At nest 4-06 at Ninagiak diet was diverse, with limpets and mussels important in both years, but with snails evident in 2006, being replaced with clams in 2007 (Figure 4.24). These consistencies in diet over years provide added evidence for dietary specialization at the level of the breeding pair, and that pairs return to the same nest in consecutive years.

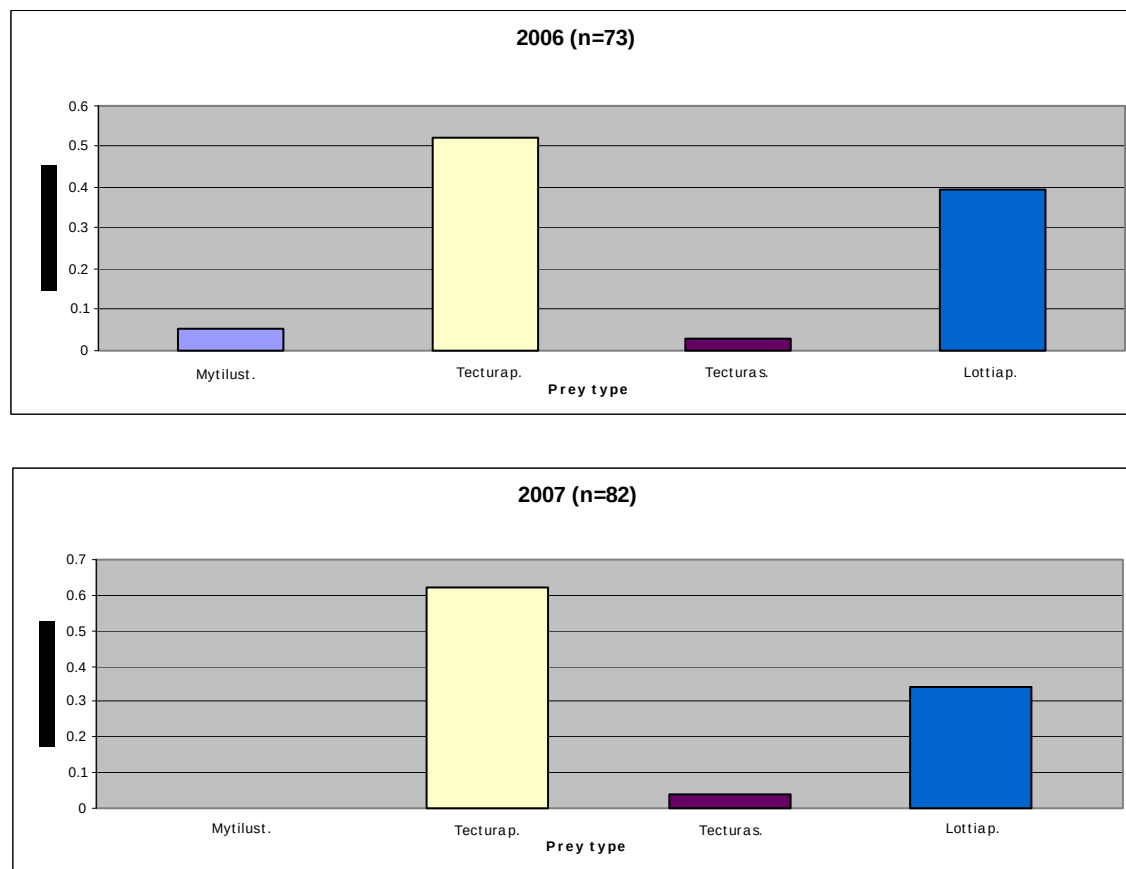


Figure 4.22. Comparison of the species composition of prey remains collected at nest RI1 3-06 in 2006 and 2007.

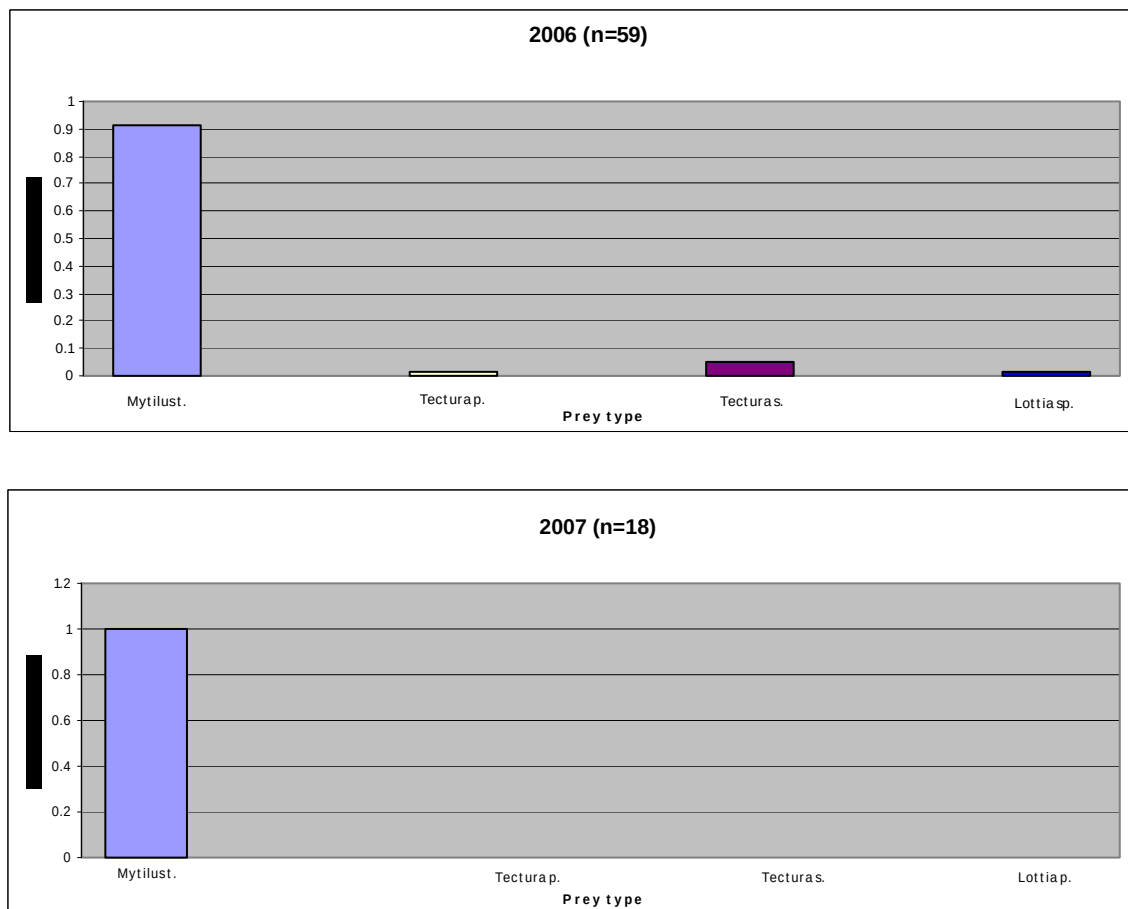


Figure 4.23. Comparison of the species composition of prey remains collected at nest RI4 1-06 in 2006 and 2007.

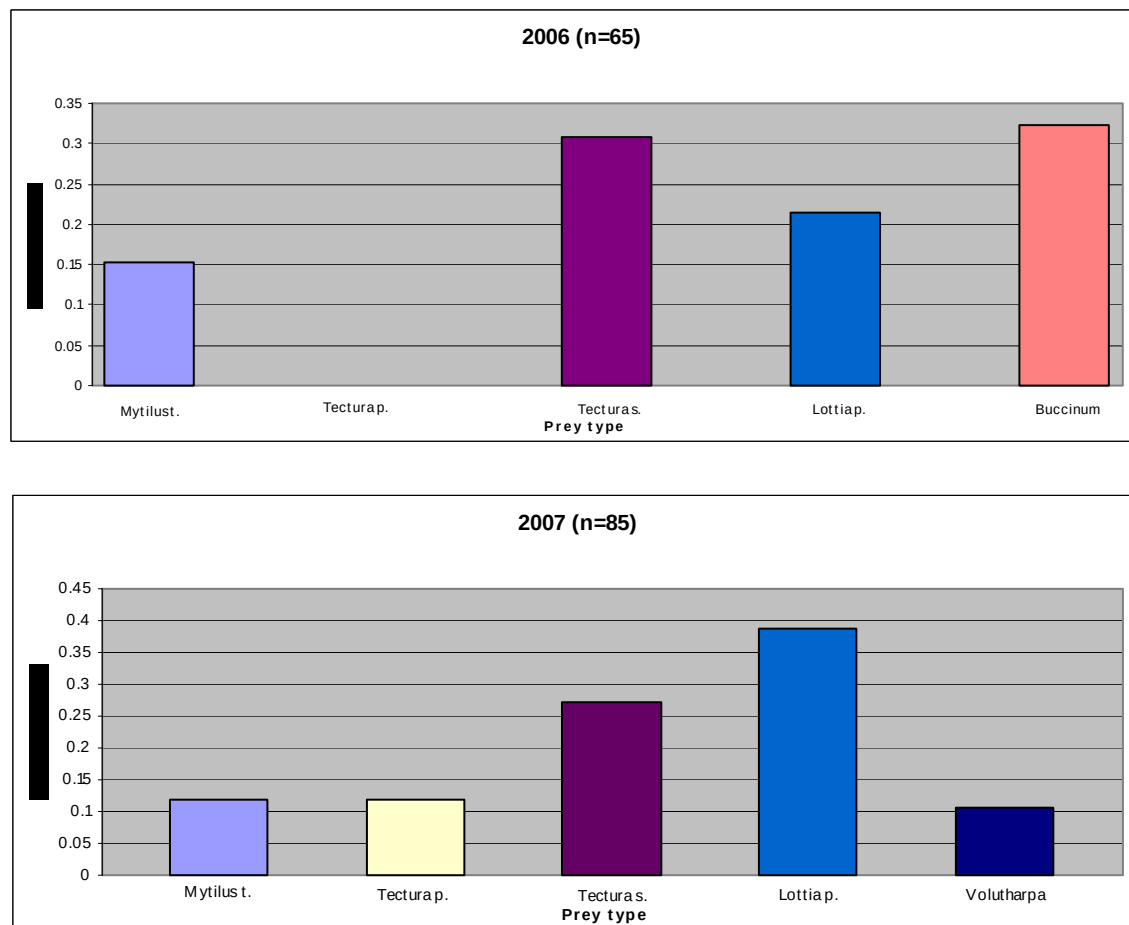


Figure 4.24. Comparison of the species composition of prey remains collected at Ninagiak nest 4-06 in 2006 and 2007.

RECOMMENDATIONS

Surveys of black oystercatcher abundance, nest density, and diet as reflected through prey remains brought to provision chicks were successfully implemented. Repeated sampling of those same transects and nests in 2007 provided evidence of the feasibility of the sampling design. We recommend continued sampling with little revision. It appears as though breeding pairs may have multiple nests at a nest site and care should be taken to recognize these as comprising the same nest site. It will be important to conduct future surveys as close as possible in time to these initial surveys (22 June-1 July), and care must be taken to minimize the disturbance to nests during sampling. Consideration should be given to utilizing remote sensing techniques to monitor a few active nest sites to validate the provisioning of chicks and provide evidence of possible sources of chick mortality and egg depredation at the nest site.

Given the importance of mussels and limpets to oystercatchers, particularly the larger size classes, revising the intertidal sampling with added emphasis in sampling the larger size classes may be warranted. Given the apparent high degree of dietary specialization among nests and the presumed limited foraging area of nesting pairs, more intensive sampling of prey populations in

close proximity to nests (e.g. within 10's-100's of m) could serve as a foundation for more detailed study related to the role of oystercatcher predation in structuring intertidal communities.

5 Sea Otters

INTRODUCTION

The sea otter (*Enhydra lutris*) may be the most common and conspicuous mammal in nearshore marine habitats in the north Pacific. It also may be the best understood marine mammal, in ecological terms, because of its well described role as a “keystone” predator in nearshore marine benthic ecosystems (Estes and Palmisano 1974, Estes and Duggins 1995). The sea otter is limited in distribution to shallow coastal waters by a diet that consists largely of benthic marine invertebrates (crabs, clams, urchins, snails) and a foraging depth range from the intertidal to about 100 m (Bodkin et al. 2004a). The species aggregates to rest, typically in nearshore areas, has relatively small home ranges (tens of kilometers of coastline), usually forages alone, has dive times that average < 2 minutes, and brings their prey to the surface for consumption. These characteristics support direct visual observation and provide for accurate and precise estimates of abundance.

Because sea otter foraging is limited to relatively shallow waters (Bodkin et al. 2004a and b), shore based observers equipped with high power and high resolution telescopes can accurately identify the type, number, and sizes of prey consumed. Observations of sea otter foraging success and intensity are measured using focal animal foraging observations (Altmann, 1974) adapted for sea otter work in past studies (Calkins 1978, Estes et al. 1986, Doroff and Bodkin 1994).

Observations of foraging sea otters provide information on food habits, foraging success, (mean proportion of feeding dives that are successful) and efficiency (mean kcal per dive) based on prey numbers, types and sizes obtained by feeding animals. Because sea otter populations are often prey limited, data on foraging behavior is useful in evaluating reasons for differences in sea otter densities or trends among regions or years (Estes et al. 1982, Gelatt et al. 2002, Dean et al. 2002, Bodkin et al. 2002).

Due to high spatial variability in marine invertebrate populations (e.g. extreme patchiness) and difficulty in sampling underwater prey populations, observations of foraging sea otters provide an alternative method to direct sampling of subtidal invertebrates. Following a successful foraging dive, sea otters return to the surface to consume their prey. This provides the opportunity to identify, enumerate, and determine the size of the benthic organisms they consume. Therefore, sea otter foraging data provides data on species composition and sizes of subtidal invertebrate prey populations that are difficult to obtain directly. Observations collected over time may allow inference to changes in the species composition and sizes of the nearshore benthic invertebrate communities.

Data on sea otter food habits, foraging efficiency, and prey sizes should prove useful when examining differences (if any) obtained through direct measures of densities, and size-class distributions of the invertebrates obtained through the intertidal invertebrate and algal data collection (Section 2 above, Dean and Bodkin 2006). Data collected on species composition and sizes of invertebrates recovered by sea otters will allow evaluation of changes in intertidal and subtidal benthic communities in different regions and over time. Sea otter foraging data,

including diet composition, foraging efficiency, and prey sizes will be useful in evaluating the role of food limitation as a factor in changing sea otter population sizes over time.

Because sea otters reside close to shore, can occur in relatively high densities (several per km²), and may haul out prior to death, collections of beach cast sea otter carcasses provide a powerful tool to evaluate patterns of mortality at the population level that likely reflect environmental and ecological conditions in the nearshore ecosystem (Kenyon 1969, Monson et al. 2000). Ages of individual sea otters at the time of death can be obtained by counting depositions in tooth sections (Bodkin et al. 1997). Overtime, changes in the age structure of dying sea otters can be used to model survival and provide inference about causes for change in mortality (Monson et al. 2000).

In this section we report on results from three data collection SOPs that include, estimates of sea otter distribution and density from the marine bird and mammal surveys, estimates of sea otter abundance from aerial surveys and estimates of sea otter diet from visual observations of foraging sea otters and examination of spraint remains deposited on haul out sites, and estimates of the age class distribution of sea otters found dead on the beach. Data on sea otter distribution and abundance is acquired through the skiff based surveys employed to estimate distribution and abundance of seabirds and marine mammals (see Section 3 above Marine Birds and Mammals, Dean and Bodkin 2006). Although these skiff surveys do not provide accurate estimates of sea otter abundance due to detection bias, the skiff survey results will provide an independent means to evaluate trends in sea otter population size over time. More accurate estimates of sea otter abundance are be obtained using aerial survey methods that were initiated in KEFJ during 2007 and will be initiated in KATM in 2008 .

METHODS

Distribution and density of sea otters was estimated from marine bird and mammal survey data. A detailed description of the survey methods and materials is given in the Marine Birds section (3) of this report. These surveys were conducted along systematically located transects approximately 5 km in length, which cover approximately 16-27% of the total shoreline within the study area. Two observers counted the number of sea otters within a strip 200 m wide parallel to and extending out from the shoreline. Most transects were centered 100 m offshore from the shoreline and included sampling offshore islands. Offshore or pelagic transects were added to the KATM survey in 2007 to decrease the bias associated with sampling only nearshore transects. Pelagic transects will be added to KEFJ in 2008. All data were entered directly into dLog2 software for biological sampling as described in the standard operating protocol. Each transect required about 40 minutes to sample, resulting in an average survey speed of about 10 knots.

Because sea otters commonly occur outside the dimensions of the shoreline marine bird and mammal surveys, and because detection is not estimated during the skiff surveys we conduct sea otter specific aerial surveys to estimate sea otter abundance within each Park. The survey follows protocols described in detail in Bodkin and Udevitz (1999). The survey is conducted from a small, single engine, float equipped aircraft with the pilot and observer able to observe out each side of the aircraft. The survey is flown at a speed of 100 kph (60 mph) and at an elevation of 91 m (300') The survey design consists of systematic sampling of 400 m wide transects that are

uniformly placed throughout the survey area. Selection and sampling of transects is proportion to expected sea otter abundance with most effort taking place in high density transects over waters from 0-40m in depth with the remainder placed in low density habitat further offshore in deeper water. Intensive searches are periodically conducted within transects to estimate the proportion of sea otters not detected on strips. Strip counts are adjusted for the area not surveyed and by a correction factor to obtain an adjusted population size estimate. Aerial surveys were planned for KATM and KEFJ in 2007 but completed only in KEFJ due to limited aircraft availability.

Food habits, foraging success and efficiency were derived from shore based observations of randomly selected foraging otters. Shore based observations were limited to sea otters feeding within approximately 1 km of shore. High power telescopes (Questar Corp., New Hope, PA.) and 10X binoculars were used to observe prey type, number, and size during foraging bouts of focal animals. A bout consisted of observations of repeated dives for a focal animal while it remained in view and continued to forage (Calkins 1978). Assuming each foraging bout records the feeding activity of a unique individual, bouts were considered independent while dives within bouts are not. Thus the length of any one foraging bout was limited to 20 dives, or one hour, after which a new focal animal was chosen.

Sea otter foraging observations were collected within a 10 km radius of three of the five rocky intensive sites for intertidal invertebrates and algae sampling (section 2). For each bout the otters estimated age (juvenile or adult, based on total length, extent of grizzle on head, and behavior) sex (presence/absence of penile bulge, pup or mammary glands, or undetermined), and reproductive status (independent or with pup) was recorded. Estimated distance from shore was recorded and foraging locations recorded by GPS position and mapped (decimal degrees, NAD 83). The foraging depth and habitat type was later estimated by overlaying coordinates onto GIS maps of bathymetry or bottom type (if available).

For each feeding dive, observers recorded dive times (time underwater searching for and retrieving prey) and surface intervals (time on the surface between dives) along with dive success (prey captured or not). In addition, prey identification (lowest possible taxa), prey number, and prey size (Dean and Bodkin 2006) was recorded. Prey size was estimated using the otter's fore paw width as a reference with an average width of 52 mm. The mean success rate, mean prey number, mean prey size, and most common prey type were determined. Metrics analyzed include the frequency distribution of prey types consumed, and the mean size of prey recovered.

Additional dietary information was obtained by examining sea otter spraint. Discrete deposits of spraint were examined and the relative abundance of various prey was estimated and categorized as either predominant (comprising >50% of spraint volume) or present (<50% of spraint volume). All other prey were classified as absent. Because prey can rarely be identified to species, prey were categorized by prey type as clams, crabs, mussels, sea urchins, or other prey.

In 2007 sections of open coastline as well as sea otter haul out sites were surveyed to recover sea otter carcasses. Skulls of sea otters were collected to provide data on age-at-death. All teeth were removed from skulls and have been submitted to a commercial laboratory (Matson's, Laboratory, Milltown MT) for analysis. These data are used in demographic models that

examine changes in the age distribution of dead otters over time. The general methods used to obtain sea otter skulls can be found in the coastline survey section of this report and detailed methods can be found in the coastline survey SOP (Dean and Bodkin 2006). Age results for the carcasses collected at KATM in 2006 are given in this report. Age estimates for 2007 have not been received at the time of completing this report.

RESULTS

KATM

Sea otter distribution and density estimated from the marine bird and mammal surveys

Sea otters were encountered on 15 of the 30 coastline transects and 4 of the 10 pelagic transects. A total of 130 adults and 24 pups were observed on the coastline transects (Figure 3.14), resulting in a mean density of 4.48 adult sea otters per km² and a mean density of 0.74 sea otter pups per km² (Table 5.1). A total of 25 adults and 7 pups were observed on the pelagic transects (Figure 3.20), resulting in a mean density of 2.91 adult sea otters per km² and a mean density of 0.81 sea otter pups per km² (Table 5.2). While sea otters were observed throughout the survey region, they were relatively more abundant on the outer coast compared to the inner portions of bays.

Table 5.1. Marine bird and mammal coastline survey results for sea otters and sea otter pups. Min and Max refer to the minimum and maximum number of sea otters observed within each group.

Species	# of groups	Min	Max	Sum	Mean Densities (km ²)	SE of density
Sea otter (adult) (<i>Enhydra lutris</i>)	49	1	64	135	4.48	2.68
Sea otter (pup) (<i>Enhydra lutris</i>)	7	1	11	24	0.74	0.56

Table 5.2. Marine bird and mammal pelagic survey results for sea otters and sea otter pups. Min and Max refer to the minimum and maximum number of sea otters observed within each group.

Species	# of groups observed	Min	Max	Sum	Average density (#/km ²)	SE
Sea otter (adult) (<i>Enhydra lutris</i>)	14	1	7	25	2.91	2.40
Sea otter (pup) (<i>Enhydra lutris</i>)	5	1	2	7	0.81	0.81

Sea otter abundance estimated from aerial surveys

Due to logistical constraints, aerial surveys of sea otters were not conducted in KATM in 2007. Aerial surveys will be conducted in 2008.

Estimates of sea otter diet from visual observations of foraging sea otters

From observations based at Amalik, Kaflia, Takli, Mink Is, Gull Cape, Kukak Bay, and Devil's Cove, we observed 65 sea otter forage bouts, consisting of 498 dives in block 10 KATM in June 2007 (Figure 5.1). To date, the data set is too small to perform analyses on a per site basis; therefore we present the results of foraging observations for all sites combined. The prey recovery success rate was 87% for dives with known results.

Sea otter diet composition was dominated by clams that comprised 71% of the prey items identified. Chitons, crabs, mussels, octopus, snails, sea stars, sea urchins, and other prey each comprised less than 10% of the of prey recovered (Figure 5.2).

The mean number of prey recovered by foraging sea otters was dependent on prey type (Figure 5.3). For all sites combined, when foraging on clams, chitons, or urchins an average of just under two prey per dive were captured. When preying on crabs, stars, or octopus an average of one prey per dive was captured. Snails and mussels were retrieved in higher numbers per dive, (8.2 and 4.1, respectively).

Sizes of prey captured by foraging sea otters varied by species (Figure 5.4). The predominant prey, clams, averaged 58 mm over all sites combined. Snails and mussels (and unidentified prey items) were generally the smallest prey, averaging about 33 mm. Crabs and urchins averaged 48 mm. Chitons averaged 56 mm, and stars 126 mm. It is difficult to determine a mean size for the octopus we observed the otters eating. All were larger than our size class estimations (based on paw width of an 'average' sea otter). Conservatively, the mean size for octopus was 156mm.

Estimates of energy recovery from prey captured by foraging sea otters varied by species, with smaller items having lower energy recovery estimates. On a 'per dive per prey type bout' basis, the mean energy for clams was 26 kcal. Other small prey such as snails and urchins averaged 0.42 kcal and 0.77 kcal, respectively. Chitons averaged 0.34 kcal and sea stars 0.83 kcal. Crab energy recovery was estimated at 0.45 kcal per dive and octopus at 2.72 kcal (again, conservatively). The average energy recovery rate was estimated at 1074 kcal hr⁻¹.

Mean dive times across areas and dive outcome ranged from 26 – 68s. There was some indication of variation in dive times dependent on prey type (Figure 5.5) although sample sizes for some prey are small.

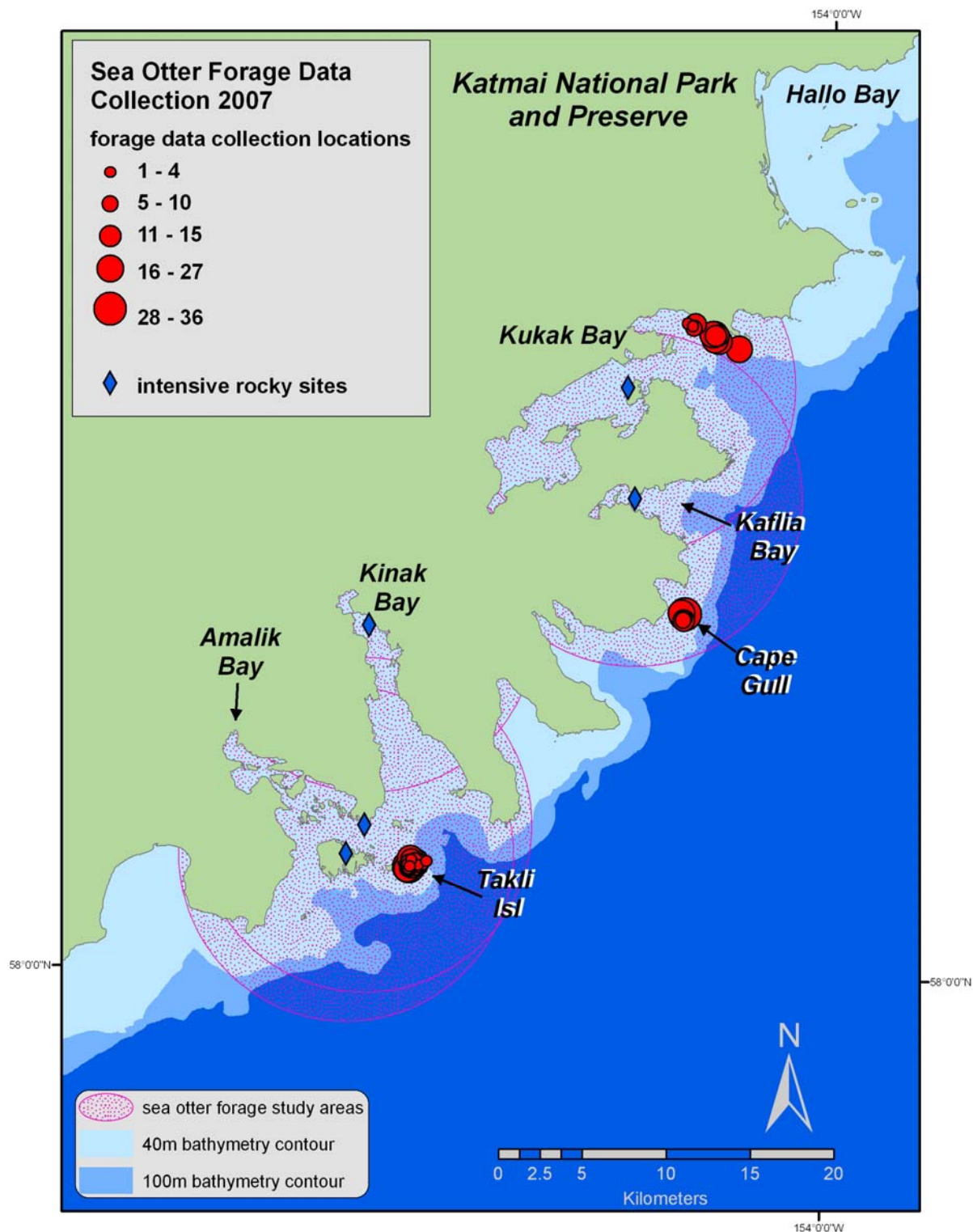


Figure 5.1. Locations of sea otters where dietary and behavioral data was collected from and the 10 km buffer zones established for each rocky intertidal sampling site. The dots in red indicate the location of the sea otter during forage data collection process and the size represents the number of dives observed per bout.

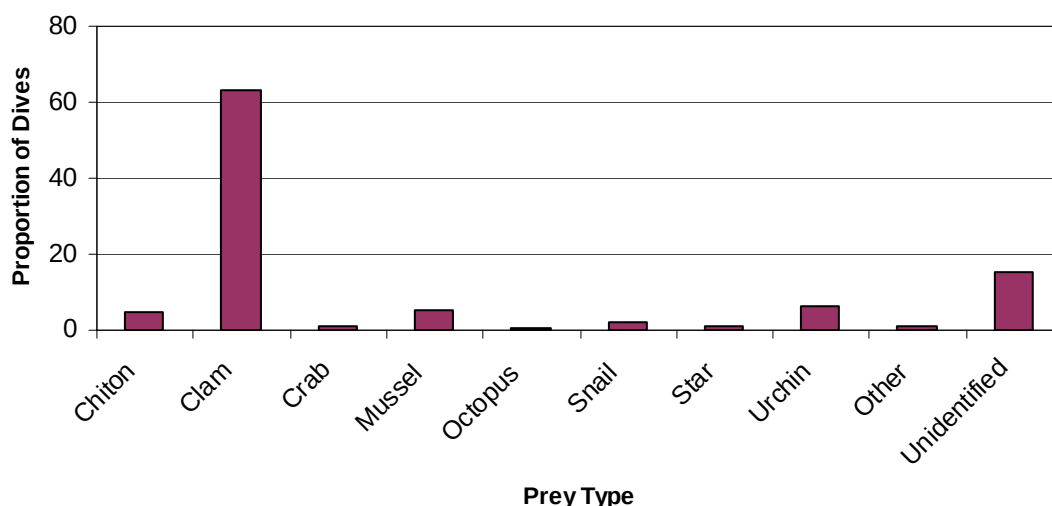


Figure 5.2. Sea otter diet composition of 477 prey items retrieved (multiples of same item per dive only counted once), KATM, June, 2007. Clams include species of *Saxidomus*, *Mya*, and *Tresus*. Chitons include species of *Katharina*, crabs include *Telmessus cheiragonus*, snails include species of *Nucella*, urchins are *Strongylocentrotus droebachiensis* and *purpuratus*, stars were unidentified, and other included species of sand-dollar.

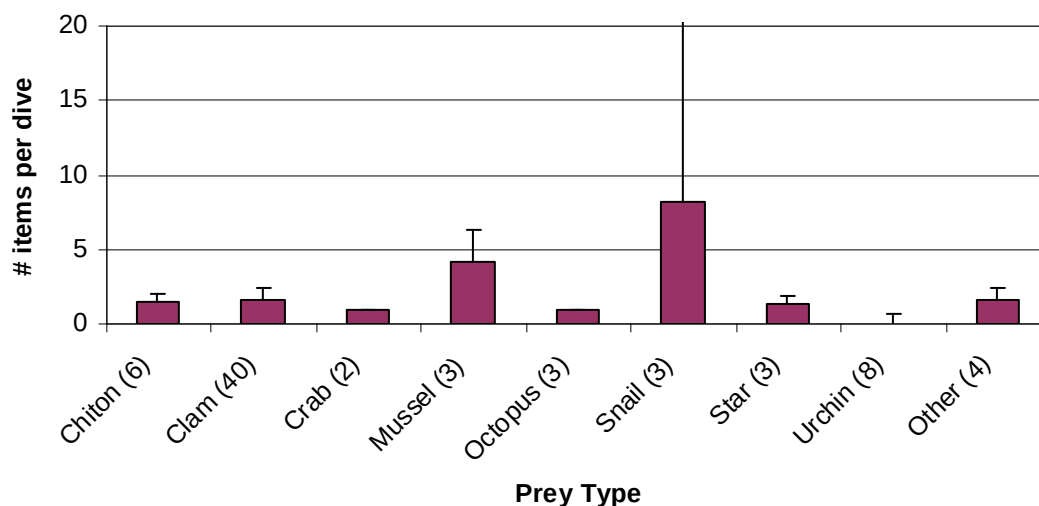


Figure 5.3. Mean number of prey items retrieved per dive by prey type for sea otters foraging at Block 10 KATM, June 2007. Numbers in parentheses indicate the number of foraging bouts with that prey type retrieved. Bars represent 1 standard error.

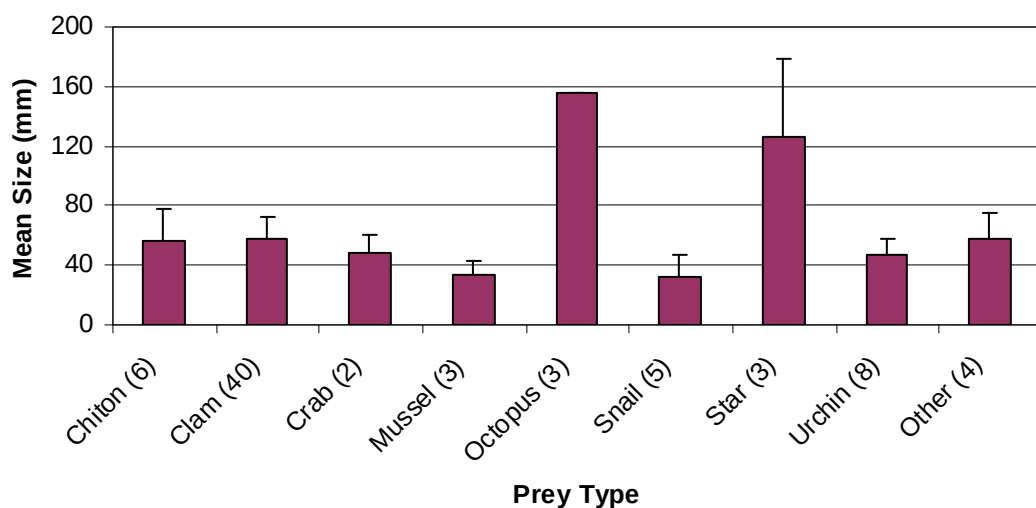


Figure 5.4. Mean size of prey items recovered by prey type for sea otters foraging in Block10, KATM, June 2007. Numbers in parentheses indicate the number of foraging bouts with that prey type retrieved. Bars represent 1 standard error.

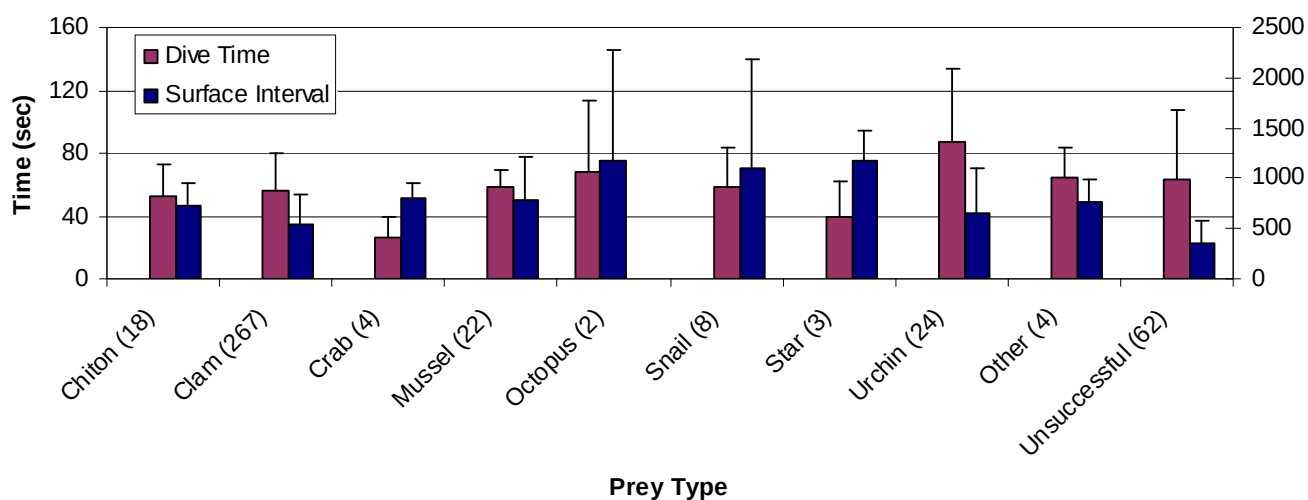


Figure 5.5. Mean dive times and surface interval times by prey type for sea otters foraging in Block10, KATM, June 2007. Time values for surface interval for octopus is on the secondary Y-axis. Numbers in parentheses indicate the number of dives with that prey type retrieved. Bars represent 1 standard error.

Examination of spraint remains deposited on haul out sites

The relative abundance of four prey types was categorized from 135 spraint deposits. Clams were the most commonly observed prey occurring in 87% of the samples. Crab occurred in 11% and mussels in 19% of the samples. Other identified prey included limpets, sand dollars (*Dendraster*), rock jingles, sea urchins, and barnacles.

Table 5.3. Prey types and relative frequency of occurrence in sea otter spraint examined from KATM, June 2007.

Prey Type	Mean % occurrence		Absent
	>50%	<50%	
Clam	79	7	13
Mussel	13	6	81
Crab	2	9	89
Urchin	0	<1	99
Other	3	4	93

Estimates of the age class distribution of sea otters found dead on the beach

In 2007, we recovered 44 sea otter carcasses, 11 on Shakun Island, 24 at Ninagiak, 5 at Hallo Beach, 2 in Kukak Bay and 2 on Kiukpilik Island (Figure 5.6). Teeth were collected from 40 of the 44 skulls for age analysis and have been submitted to a commercial laboratory (Matson's, Laboratory, Milltown MT) for analysis. Age estimates have not been received at the time of completing this report.

In 2006, a total of 37 sea otter carcasses were collected, most at the haul-out sites found in 2006. Of those 37 carcasses, 36 tooth samples were collected and sent to a commercial laboratory for analysis (Matson's, Laboratory, Milltown MT). The predominant age class at death was juvenile (0 – 3 years of age). Prime aged adults (4 – 8 years of age) and aged adults (>8 years of age) were found in equal proportions (Figure 5.7). Table 5.4 illustrates the age estimate results for each individual collected in 2006.

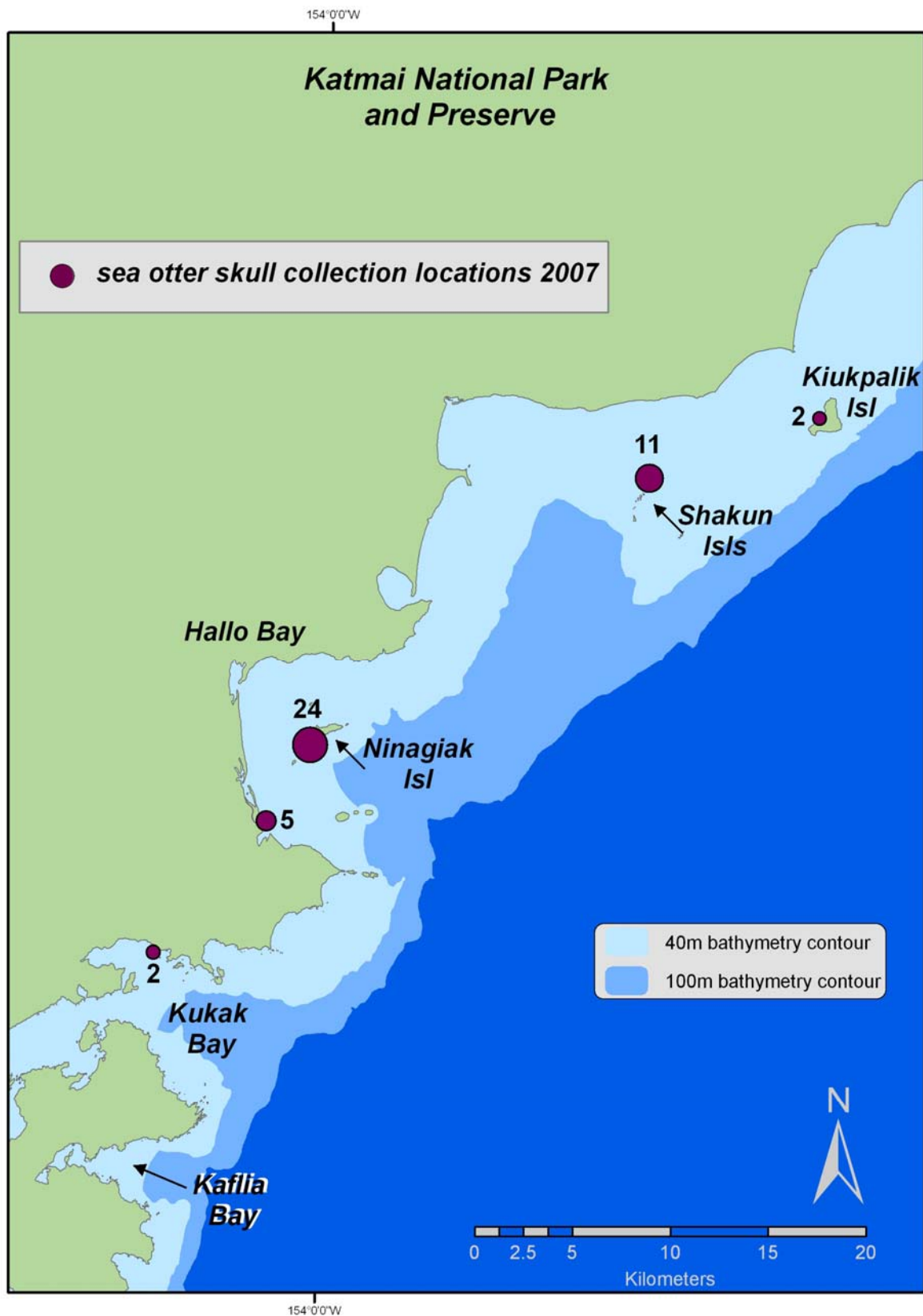


Figure 5.6. Locations and numbers of sea otter carcasses recovered from KATM in 2007.

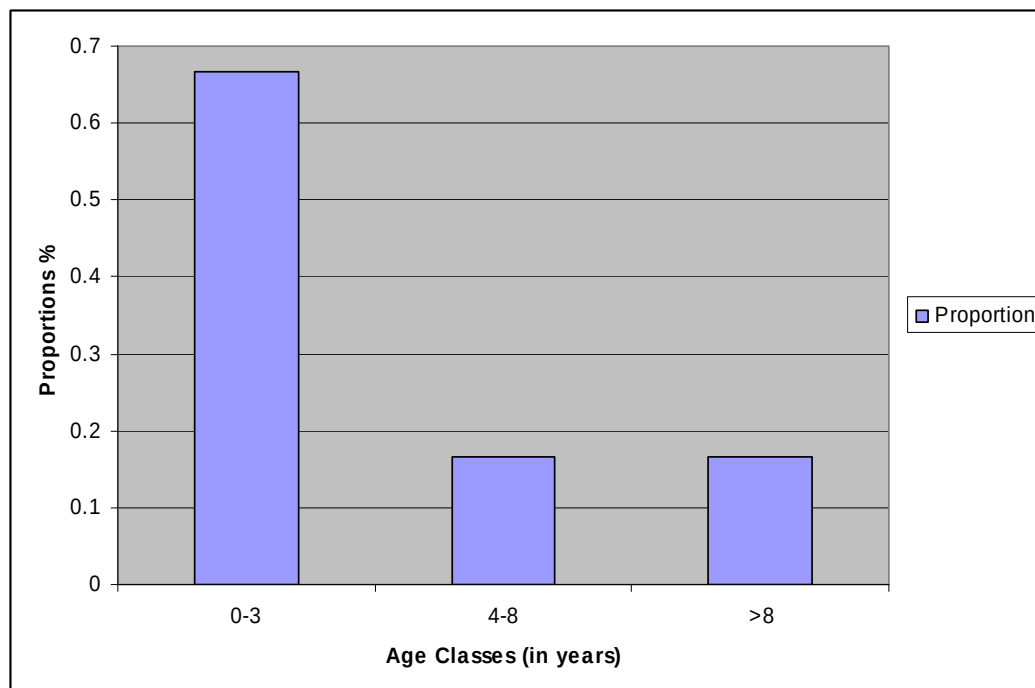


Figure 5.7. Age classes of sea otter carcasses found dead on beaches and haulout sites in 2006, KATM

Table 5.4. Age estimate results from sea otter carcasses collected in 2006, KATM. Results from Matson's Laboratory (Milltown, MT).

Date	Tooth ID	Age	Age Range	Tooth ID	Age	Age Range
Jun-Jul 2006	APD-0602	1	.	APD-0622	0	.
Jun-Jul 2006	APD-0603	1	.	APD-0623	11	10-12
Jun-Jul 2006	APD-0604	3	.	APD-0624	3	.
Jun-Jul 2006	APD-0605	5	4-6	APD-0625	2	.
Jun-Jul 2006	APD-0606	3	.	APD-0626	2	.
Jun-Jul 2006	APD-0607	8	7-8	APD-0627	8	7-8
Jun-Jul 2006	APD-0608	3	.	APD-0628	9	8-10
Jun-Jul 2006	APD-0609	1	.	APD-0629	3	.
Jun-Jul 2006	APD-0610	5	5-6	APD-0630	1	.
Jun-Jul 2006	APD-0611	3	.	APD-0631	2	.
Jun-Jul 2006	APD-0612	8	7-9	APD-0632	2	1-2
Jun-Jul 2006	APD-0613	11	11-12	APD-0633	1	.
Jun-Jul 2006	APD-0614	9	8-10	APD-0634	0	.
Jun-Jul 2006	APD-0615	1	.	APD-0635	3	2-4
Jun-Jul 2006	APD-0616	1	.	APD-0636	1	.
Jun-Jul 2006	APD-0617	1	1-2	APD-0637	15	.
Jun-Jul 2006	APD-0618	2	.			
Jun-Jul 2006	APD-0619	2	1-2			
Jun-Jul 2006	APD-0620	13	13-14			
Jun-Jul 2006	APD-0621	4	3-4			

KEFJ

Sea otter distribution and density estimated from the marine bird and mammal surveys

Sea otters were encountered on 9 of the 38 coastal transects (Figure 3.33). A total of 114 adults and 39 pups were counted resulting in a mean density of 3.6 adult sea otters per km² and 1.36 sea otter pups per km² (Table 5.1).

Table 5.5. Marine bird and mammal survey results for sea otter adults and pups. Min and Max refer to the minimum and maximum number of sea otters observed within each group.

Species	# of groups observed	Min	Max	Sum	Average density (#/km ²)	SE
Sea otter (adult) (<i>Enhydra lutris</i>)	72	1	9	114	3.60	1.36
Sea otter (pup) (<i>Enhydra lutris</i>)	26	1	6	39	1.36	0.77

Sea otter abundance estimated from aerial surveys

Between 18 and 28 June, 2007, 123 transects in the high and low density stratum were surveyed in KEFJ to estimate sea otter abundance (Table 5.6). The high density stratum consisted of 832.3 km² and the low density 653.5 km². One hundred and six transects representing 280 km of high density transect length, and 17 transects representing 42 km of low density transect were surveyed. Ninety seven percent of all sea otters were observed on high density transects (Table 5.6, Figure 5.8). The estimated detection probability was 0.54 resulting in a correction factor of 1.84 and a total estimated population size of 1511 sea otters residing in KEFJ.

Table 5.6. Summary of information on KEFJ sea otter aerial survey in June 2007.

Region	Stratum	Counts	Correction Factor	Population size	SE	Proportional SE	Density #/km ²
Kenai Fjords NP	High	95	1.84	1298	603	0.46	1.56
	Low	3	1.84	213	165	0.78	0.33
	Total	98		1511	625	0.41	1.02

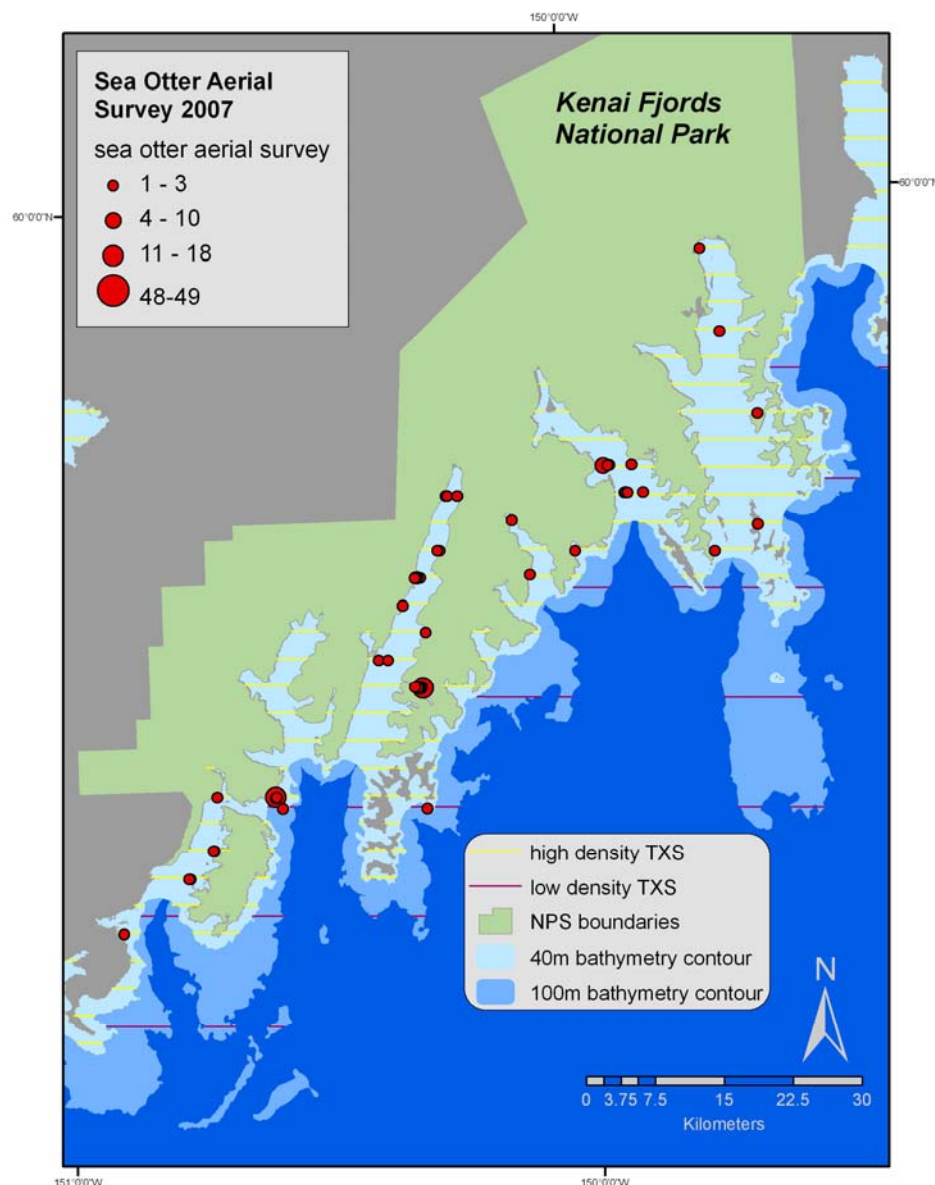


Figure 5.8 Distribution and abundance of sea otters observed on high and low density transects in KEFJ, June 2007.

Estimates of sea otter diet from visual observations of foraging sea otters

From observations based at Aialik Bay, Beautiful Is., McCarty Fjord, Pederson Lagoon, Otter Cove, and Tonsina Bay, we observed 44 sea otter forage bouts, consisting of >450 dives in block 5 KEFJ in June 2007 (Figure 5.9). These observations are associated with monitoring sites RI2, RI3, and RI4. To date the data set is too small to perform analyses on a per site basis; therefore we present the results of foraging observations for all sites combined. The prey recovery success rate was 91% for dives with known results.

Sea otter diet composition was dominated by mussels that comprised 53% of the prey items identified. Clams were the second most important prey item identified, comprising 36% of

identified prey items. Chitons and other prey each comprised less than 10% of the prey recovered (Figure 5.10).

The mean number of prey recovered by foraging sea otters was dependent on prey type (Figure 5.11). For all sites combined, when foraging on clams, chitons, or other items an average of just under two prey per dive were captured. When preying on mussels, higher numbers per dive were retrieved, 9.6 on average.

Sizes of prey captured by foraging sea otters varied by species (Figure 5.12). The predominant prey, mussels, averaged 22 mm over all sites combined. Clams averaged 56 mm. The chitons and stars observed were larger, 89 mm and 112 mm, respectively; while snails and other prey were smaller, 26 mm and 46 mm.

Estimates of energy recovery from prey captured by foraging sea otters varied by species, with smaller items having lower energy recovery estimates. On a 'per dive per prey type bout' basis, the mean energy for mussels was <1 kcal. Other small prey such as snails averaged <1 kcal. Clams averaged 4.2 kcal, chitons averaged 0.27 kcal, and sea stars 0.97 kcal. The average energy recovery rate was estimated at 182 kcal hr⁻¹. These calculations indicate that these otters would need to feed 38 hours/day to meet the daily energetic requirements. There may be several explanations for this obviously incorrect estimate. One may be the observers are underestimating the number and sizes of mussels being brought to the surface and consumed. This may be a likely explanation as typically mussels are brought to the surface in clumps and rapidly ingested. That mussel sizes were underestimated by observers is supported by the mean size of mussels we measured both directly (31 mm at random intertidal sites) and those that black oystercatchers brought to nest to provision chicks (30 mm), compared to the 22 mm average size estimated by observing otters forage. Another explanation may be a seasonal component to the sea otter diet. Mussels may be gravid during this time of year, offering higher caloric values than we incorporate into our energetic calculations, while at other times of the year rely on different prey species. Until further investigation, we cannot make any final conclusions.

Mean dive times across areas and dive outcome ranged from 22 – 88s. There was some indication of variation in dive times dependent on prey type (Figure 5.13) although sample sizes for some prey are small.

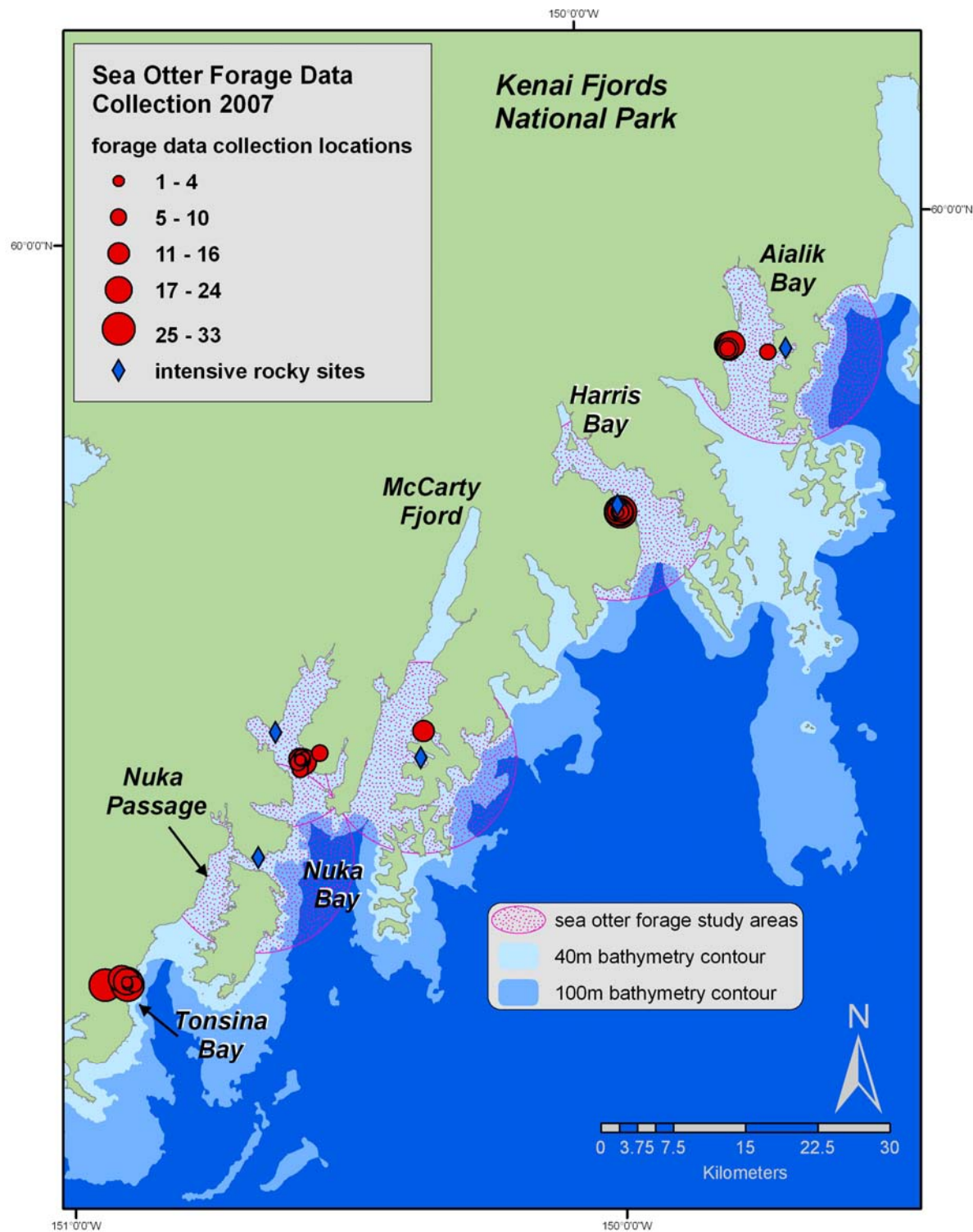


Figure 5.9. Locations of sea otters that we collected dietary and behavioral data from and the 10 km buffer zones established for each rocky intertidal sampling site. The dots in red indicate the location of the sea otter during forage data collection process and the size represents the number of dives observed per bout.

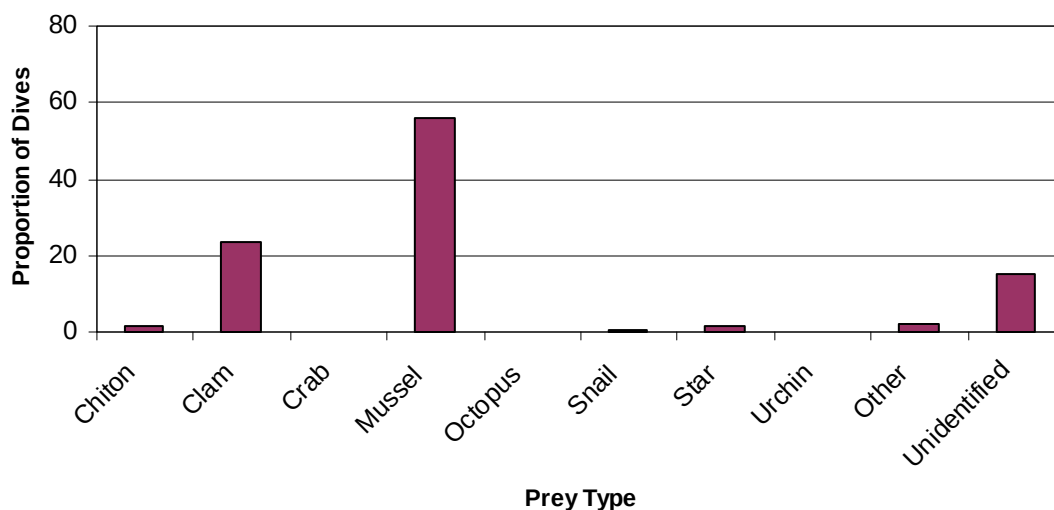


Figure 5.10. Sea otter diet composition of 432 prey items retrieved (multiples of same item per dive only counted once), KEFJ, June, 2007. Clams include species of *Saxidomus*, *Mya*, and *Macoma*. Chitons include species of *Cryptochiton*, stars include *Pisaster*, and other included unidentified bivalves, and worms.

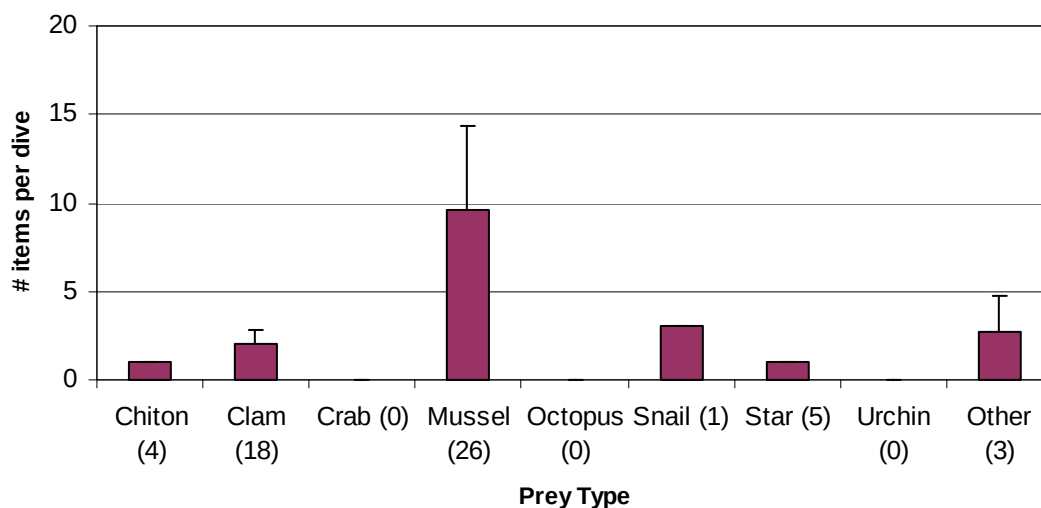


Figure 5.11. Mean number of prey items retrieved per dive by prey type for sea otters foraging in KEFJ, June 2007. Numbers in parentheses indicate the number of foraging bouts with that prey type retrieved. Bars represent 1 standard error.

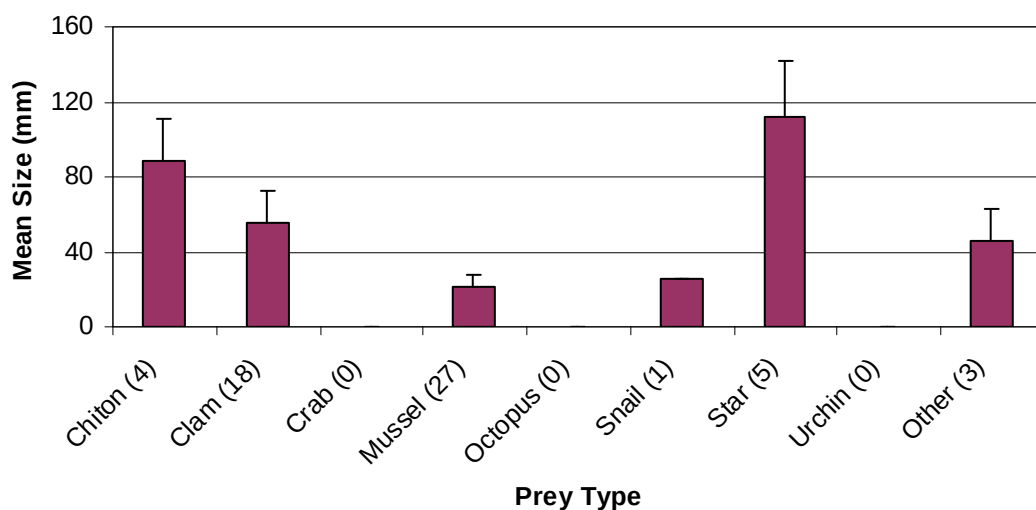


Figure 5.12. Mean size of prey items recovered by prey type for sea otters foraging in KEFJ, June 2007. Numbers in parentheses indicate the number of foraging bouts with that prey type retrieved. Bars represent 1 standard error.

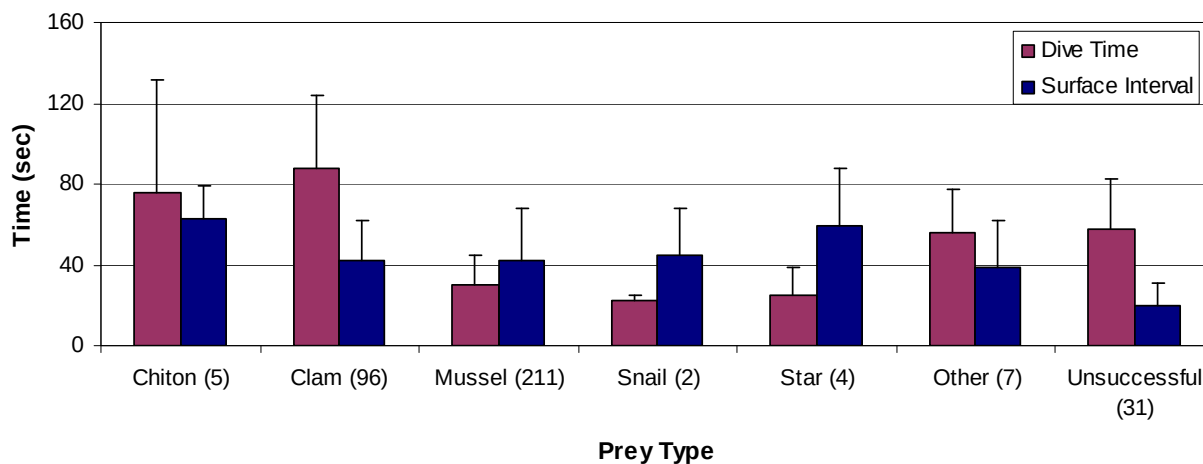


Figure 5.13. Mean dive times and surface interval times by prey type for sea otters foraging in KEFJ, June 2007. Time values for surface interval for octopus is on the secondary Y-axis. Numbers in parentheses indicate the number of dives with that prey type retrieved. Bars represent 1 standard error.

Examination of spraint remains deposited on haul out sites

The relative abundance of four prey types was categorized from 90 spraint deposits. Mussels were the most commonly observed prey occurring in 84% of the samples. Clam occurred in 14% and crab in 8% of the samples. Other identified prey included limpets, sand dollars (*Dendraster*), sea urchins, fish, isopods, and barnacles.

Table 5.7. Prey types and relative frequency of occurrence in sea otter spraint examined from KEFJ, June 2007.

Prey Type	Mean % occurrence		Absent
	>50%	<50%	
Clam	10	4	86
Mussel	74	10	16
Crab	6	2	92
Urchin	2	1	87
Other	9	9	82

Estimates of the age class distribution of sea otters found dead on the beach

The full coastline survey protocol was not completed in Kenai Fjords NP due to the lack of available appropriate habitat. One sea otter skull was collected by an NPS employee after the completion of the trip in Otter Cove. A tooth was extracted and sent to a lab for age analysis. Results should be available for the SWAN 2008 Nearshore Annual Report.

DISCUSSION

Marine bird and mammal surveys

Sea otters were distributed throughout the areas surveyed during the marine bird and mammal surveys in KATM and KEFJ but were comparatively less abundant inside bays compared to outer coast in KATM, but more abundant inside bays and protected waters in KEFJ. This could be due to the bathymetry contour differences (slope) between each Park. KATM has a relatively large shallow shelf extending outwards from the coastline, while KEFJ has relatively little shallow water habitat (<40 m) outside the bays. There may also be possible seasonal variations in distribution. During the March 2008 marine bird and mammal surveys, seasonal patterns in distribution may become evident. Sea otter pups were commonly observed with females suggesting most habitats supported reproductively mature females throughout KATM and KEFJ. Because we only surveyed within the nearshore zone in KEFJ, and only a small proportion of pelagic waters in KATM, the density we calculated for each park is not comparable with sea otter density estimates from elsewhere

Sea otter aerial surveys

We estimated sea otter abundance in KEFJ at 1,511 individuals at a density of 1.02/km². We were unable to complete the aerial survey at KATM due to limited aircraft availability.

Estimates of sea otter diet from visual observations of foraging sea otters

The sea otters we observed foraging were highly successful at both KATM and KEFJ (0.87 and 0.91 respectively) in obtaining prey. At KATM diet was dominated by clams (0.71) and at KEFJ by mussels and clams (0.53 and 0.36 respectively). Chitons, snails, crabs, stars, mussels, urchins, and octopus comprised the remainder of the diet at both locations. This success rate and dietary

composition at Katmai were similar to those for sea otters occupying other soft sediment habitats in the Gulf of Alaska such as Prince William Sound (Calkins 1978, Doroff and Bodkin 1994, Dean et al. 2002) and Kodiak Island (Kvitek et al. 1992, Doroff and DeGange. 1994). Based on the energy recovery rates calculated, an average Katmai otter would need to forage >12 hours per day to meet its daily energetic requirements. This is at the high end of the range reported for other areas (4.4 – 11.8 hours per day, Dean et al. 2002) but might be an artifact of the small sample size rather than a true need for exorbitant foraging. The energy recovery rate (1890 kJ hr^{-1}) is at the low end of the range for other populations studied ($1274 - 6134 \text{ kJ hr}^{-1}$, Dean et al. 2002). Although the proportion of octopus observed being consumed was relatively small overall (0.11), because they were relatively large (> 156mm) with estimated weights to several kg, we suspect they provided a relatively large contribution to the sea otters' energetic requirements.

The high proportion of mussels (*Mytilus trossulus*) we observed in the otters at KEFJ has not been previously reported. Generally, mussels are considered an energetically inferior prey (Garshelis et al. 1984, Doroff et al. 1994). And although they are a common but minor component of the otters' diet at many locations, generally constituting a few percent, they were observed to constitute up to 40% of the diet in Prince William Sound at one location (Estes et al. 1981). The relatively low energetic value assigned to mussels resulted in an estimated daily caloric intake rate that could not possibly sustain a sea otter. It is possible that numbers, sizes, and caloric values of mussels may have been underestimated in our calculations, and additional work is required to resolve this issue. The high proportion of mussels we observed in 2007 warrants perhaps additional effort in 2008 foraging observations, paying particular attention to observations of mussel foraging and perhaps mussel collections to estimate caloric content.

Estimates of the age class distribution of sea otters found dead on the beach

In KATM during the sampling season of 2007, we continued to have adequate carcass recovery rates (44 in 2007, 37 in 2006) that will provide reasonable sample sizes to describe the age distribution of dying sea otters if recovery rates remain similar for several years. The recovery of sea otter carcasses near winter haul out sites provided a relatively efficient approach to acquiring carcasses.

RECOMMENDATIONS

Sampling procedures designed to provide data related to the sea otter vital sign were successfully implemented in 2006 (KATM) and continued in 2007 (KATM and KEFJ). Marine bird and mammal surveys provided data on the summer distribution of sea otters in nearshore waters. The addition of transects in habitats further offshore will provide improved data on sea otter distribution. Although the skiff surveys contain recognized sources of detection bias, results over time should provide information on trends in abundance to supplement the aerial surveys designed specifically for sea otters, which are conducted less frequently.

We recommend that future foraging observations be obtained in proximity to the other rocky intertidal sampling sites as sea otter distribution allows as outlined in the SOP. Additional marine bird and mammal transects centered on each rocky intensive site should improve data on sea otter distribution in relation to the rocky intensive sites. Completion of sea otter aerial surveys and marine bird and mammal surveys provided useful information in identifying

concentrations of sea otters as well. These concentrations of sea otters should be utilized as areas for focus to acquire sea otter forage observations.

In 2006, we recommended that to gain efficiency in terms of sea otter carcass recovery rates, identifying and searching for sea otter haul outs on islands would provide an efficient means to recover a large sample of skulls suitable for analyzing and modeling age at death. In 2007, we recovered 44 sea otter carcasses from KATM; 11 on Shakun Island, 24 at Ninagiak, 5 at Hallo Beach, 2 in Kukak Bay and 2 on Kiukpilik Isl. Teeth were collected from 40 of the 44 skulls for age analysis. Results will be available in the 2008 SWAN Nearshore Annual Report.

The full coastline survey protocol was not completed in Kenai Fjords NP due to the lack of available appropriate habitat. One sea otter skull was collected by an NPS employee after the completion of the trip in Otter Cove. A tooth was extracted and sent to a lab for age analysis. Because sea otter densities are relatively low, collections of adequate numbers of sea otter carcasses may require additional effort and a longer period of time to obtain a meaningful sample size. Efforts to obtain sea otter carcasses should be coordinated with other ongoing biological sampling conducted by NPS biologists.

6 Kelps

INTRODUCTION

Kelps are large brown algae of the order Laminariales that occur in intertidal and shallow subtidal zone. In the Gulf of Alaska, bull kelp (*Nereocystis luetkeana*) and dragon kelp (*Alaria fistulosa*) often grow on rocky substrate in the nearshore zone and produce long fronds that can reach the surface from depths over 20 m and form visible surface canopies (O'Clair and Lindstrom 2000). These canopy forming kelp are important habitats that provide primary production as well as shelter for fish and a variety of invertebrates (Rosenthal et al 1977, Estes and Duggins 1995, Dean et al. 1999). Kelps are susceptible to both natural and human disturbances including large storms, changes in water quality due to volcanic eruptions, and oil spills (Rigg 1914, Dean et al 1989). Because of their ecological importance and their susceptibility to disturbance, kelps are an important vital sign being used to evaluate changes in the nearshore marine system at KATM and KEFJ.

Kelps are widely distributed along the coasts of KATM and KEFJ (see coastal surveys of Harper and Morris, www.coastalaska.net). Data on the large scale distribution of kelps along shoreline are provided by aerial imagery (Harper and Morris 2004). The purpose of this task was to evaluate methods to estimate changes in kelp canopy cover on a smaller spatial scale (100s of sq. m).

METHODS

We tested several methods for measuring the relative abundance of bull kelp at three sites in KEFJ and one site in KATM in 2007. Techniques employed included a visual census of all visible surface floats within a given stretch of shoreline, visual counts of surface floats within specified transects, and counts of plants using a down-looking sonar.

RESULTS, DISCUSSION, AND RECOMMENDATIONS

All of the methods employed provided an estimate of the density of bull kelp within a several hundred meter stretch of coastline. However, we highly doubt the accuracy and precision of these estimates for any of the methods employed. Visual counts of kelp at the surface appeared to provide reasonable estimates of this parameter at the time of the survey, but we noted extreme dependency of the number counted on the tidal elevation, wave, and current conditions. Sonar counts can overcome problems associated examining just those plants at the surface, but we were unable to distinguish individual plants on sonar and were unable to distinguish bull kelp from other smaller kelps in the region. As a result, we do not recommend that either of these methods be used in assessing changes in kelp as a vital sign.

There are methods available that can be used to evaluate kelp density on a scale of 100s of sq. meters. These include more sophisticated sonar techniques, aerial mapping, towed underwater video methods, of diver transects (Zabloudil et al 1991, Stekoll et al. 2006, J. Harper unpublished data). However, these methods are costly to develop and to conduct on a routine basis. Given the current status of the SWAN monitoring program, we recommend that no further effort be spent on developing techniques for evaluation of smaller-scale distributions of kelp at this time. Instead, we think it prudent to rely on existing aerial imagery (Harper and Morris 2004) to

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provide large-scale data until more cost effective methods or additional sources of funding become available.

7 Eelgrass

INTRODUCTION

Eelgrass (*Zostera marina*) is the dominant seagrass in protected waters of the Gulf of Alaska and is broadly distributed in sheltered embayments, especially in habitats dominated by soft sediments. (McRoy 1968, 1970). It often forms “beds” or relatively monotypic stands that can cover much of the shallow (0 to 5 m depth) subtidal zone. Eelgrass is an important “living habitat” that serves as a nutrient filter, provides shelter for fish and a variety of invertebrates, and provides physical substrate for invertebrates and algae (Rosenthal et al. 1977; Phillips 1984, Dean et al. 1999, Jewett et al. 1999). Eelgrass is a major primary producer in the marine nearshore and because it is located in shallow water, is susceptible to oil spills and other human disturbances (Zieman et al 1884, Short and Wyllie-Echeverria 1996, Dean et al 1988). Eelgrass is especially susceptible to dredging, anchor scars, and events that reduce light penetration into the water column such as runoff (increased turbidity) or nutrient addition (Walker et al 1989, Short and Wyllie-Echeverria 1996).

In this section, we describe results of preliminary evaluations of methods for assessing the relative abundance of eelgrass in KATM and KEFJ in 2007. Eelgrass is an important “vital sign” and our goal is to develop an effective method that can be used to assess changes in the extent of eelgrass over time. Specifically, the objectives of this task are to: 1) assess changes in the cover and relative abundance of eelgrass, and 2) assess changes in the lower depth limit of eelgrass over time. The reduction of the lower depth limitation is a critical indicator of deteriorating environmental conditions for eelgrass, and especially those related to a reduction in light penetration. The surveys will provide data on the relative abundance of eelgrass associated with sampled shoreline segments approximately 200 m in length. The methods evaluated were selected to provide cost effective sampling of eelgrass beds at this scale (Precision Identification 2002, Robinson et al 1996). These data will be supplemented by less frequent, larger scale mapping of eelgrass beds in the region using aerial imaging (Harper and Morris 2004).

METHODS

In 2007, we evaluated methods to map and determined the relative extent (based on percent cover) of eelgrass at five locations in KATM and at four locations at KEFJ (Figure 7.1 and 7.2). Sites selected were eelgrass beds closest to the intensive sampling site for invertebrates on sand and gravel beaches in each bay. Locations of eelgrass beds were preliminarily identified based on aerial shorezone mapping surveys (Harper and Morris 2004, data from www.coastalaska.net) and confirmed by direct observation. The shorezone surveys found no areas of extensive eelgrass in McCarty Fjord, but identified several locations with “patchy” eelgrass. Our searches of these locations in 2007 found no eelgrass. As a result, no sampling was conducted at McCarty Fjord.

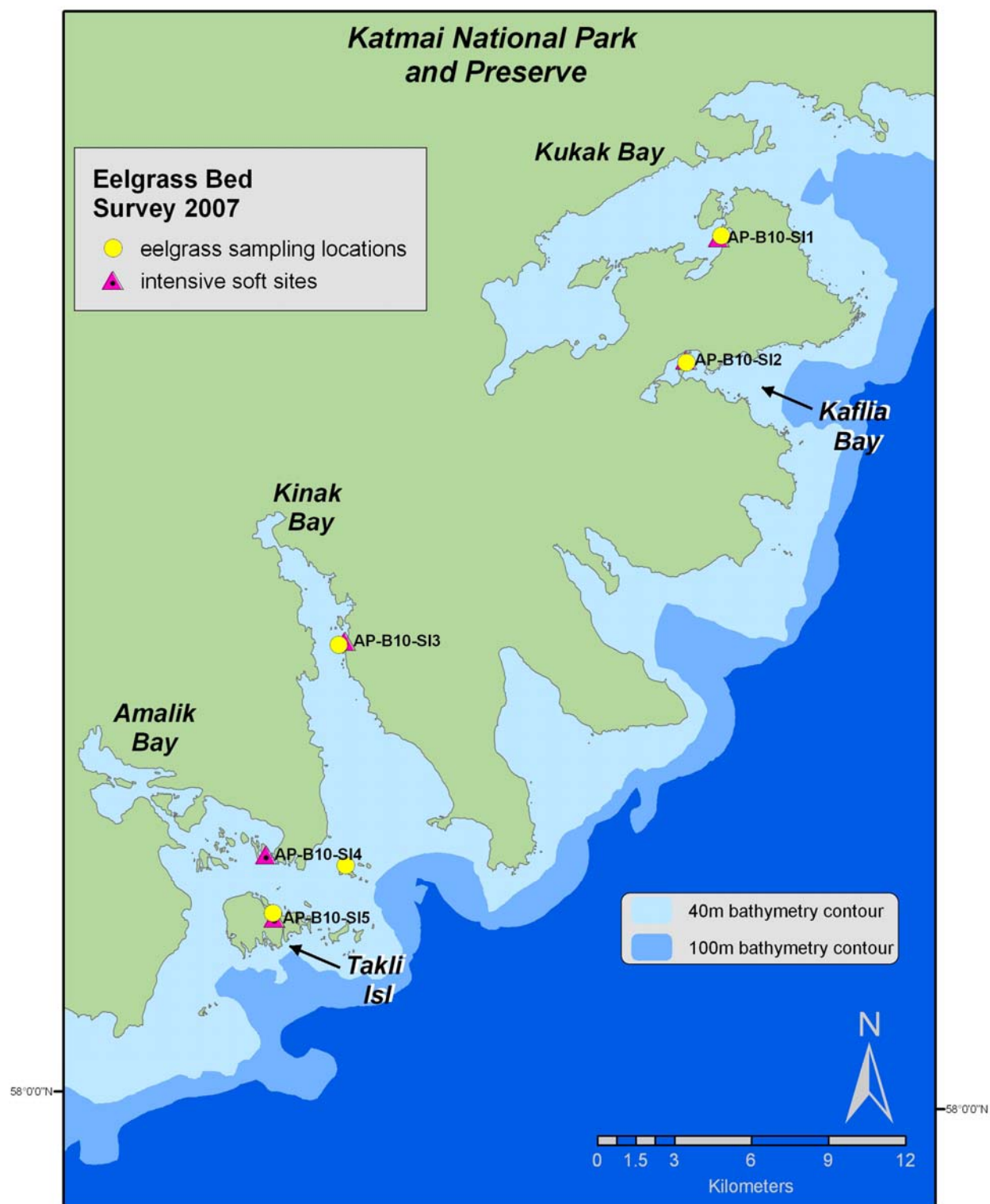


Figure 7.1. Location of eelgrass beds sampled in KATM in 2007.

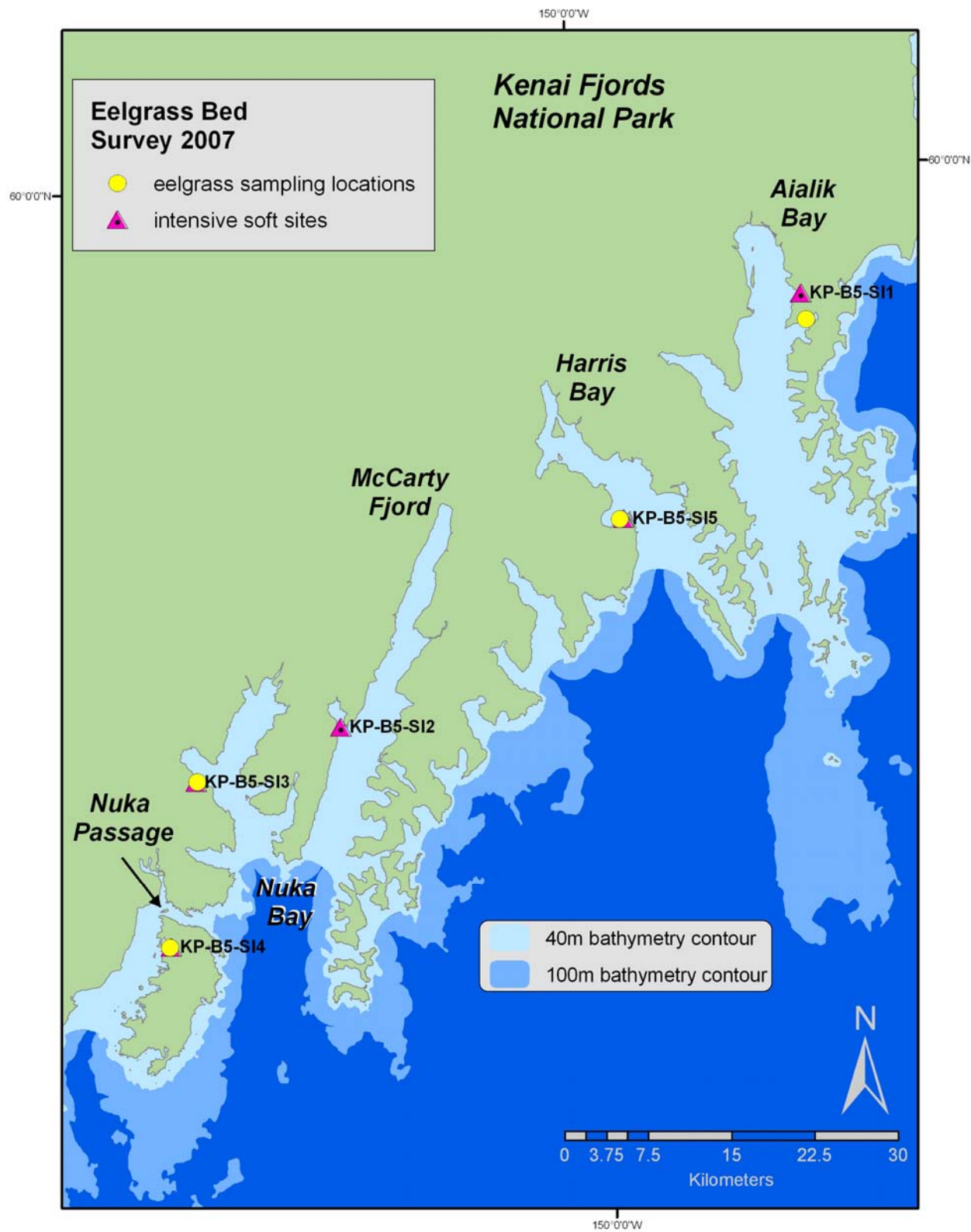


Figure 7.2. Location of eelgrass beds sampled in KEFJ in 2007.

At each site we sampled eelgrass within a polygon bounded by a shoreline of approximately 200 to 250 m in length and extending to depths at which eelgrass was no longer observed. The distance between the inshore and offshore boundaries of the area sampled varied depending on the slope of the bottom at a particular site, but was generally 200 m or less. At sites that were in smaller bays, this represented the entire eelgrass bed at the site. In other cases where eelgrass occurred over much larger expanses of shoreline (e.g. Shelter Cove in Nuka Bay), this represented a fraction of the bed at that site.

Several methods were evaluated in mapping eelgrass beds. Locations of eelgrass boundaries were estimated by direct observation when possible. In general, inshore boundaries could be delineated on foot when sites were sampled during low tides, or from a small boat when sampled during periods of high tides. Boundary positions were recorded using a GPS. We employed a towed underwater video system (Delta Vision, Ocean Systems, Inc.) to determine the presence or absence of eelgrass in deeper waters in which eelgrass could not be directly observed from the surface. Figure 7.3 illustrates an image captured by the underwater camera system.



Figure 7.3. Underwater image of eelgrass

At most locations, we attempted to map the beds by running a small inflatable boat with a towed video over a series of transects (generally 20) running perpendicular to shore at each site. The transects were spaced at equal intervals and extended from as close to the shoreline as possible to approximately 20 m beyond the outer boundary of eelgrass. On each transect, we either noted the positions of the beginning and ends of segments with eelgrass present (at sites where the distribution of eelgrass was more or less continuous), or noted presence or absence of eelgrass at equally timed intervals. At one site in KATM, boundaries of the entire bed were visible at low tide and the perimeter was mapped using a GPS.

RESULTS

At all sites but one (McCarty Fjord), we were able to locate eelgrass beds that can serve as long-term monitoring sites. An example map of the eelgrass bed at Kukak Bay, KATM is provided in Figure 7.4.

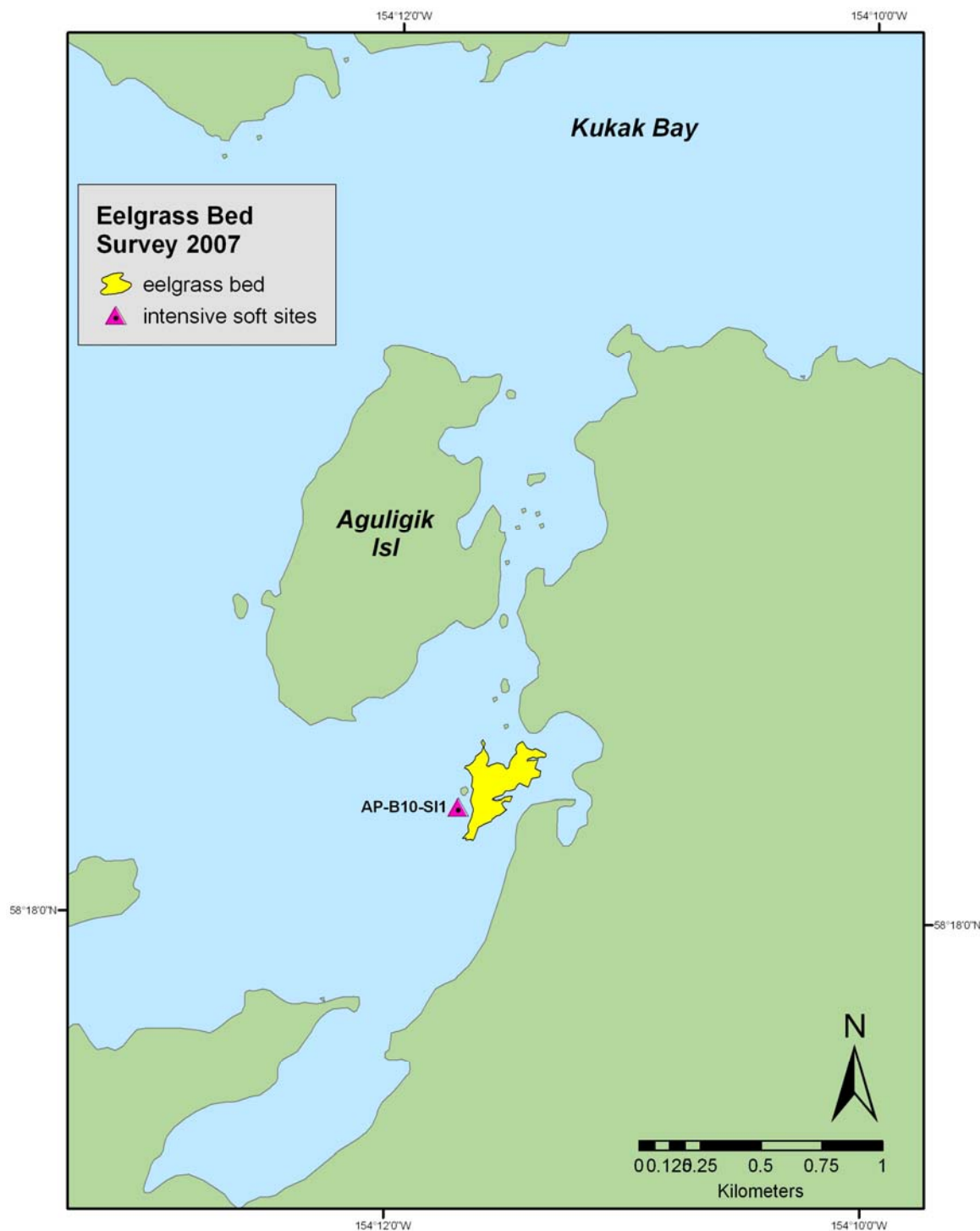


Figure 7.4. Map of eelgrass at Kukak Bay, AP-B10-EI1.

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The towed video worked well in revealing presence or absence of eelgrass. However, we were unable to automatically link our GPS to the video and relied on keeping track of waypoints manually and recording positions of waypoints in the GPS. In many cases, this proved inadequate and errors in recording positions made mapping and making reasonable estimates of relative abundance difficult in most cases.

DISCUSSION AND RECOMMENDATIONS

Our recommendations for methods to be used to map eelgrass beds in 2008 are as follows. First, based on preliminary surveys conducted at each site in 2007, pre-select shoreline segments of 250 m at each site for mapping. Map the shoreward boundary of eelgrass at each site by walking the boundary and recording the positions in a computer using Dlog (a system we have used to continually track positions during bird and mammal surveys). Mark the ends of the shoreline segment walked with temporary markers. Mark offshore boundaries of a polygon to be measured using small floats and record positions of these. Use the towed video and computer with Dlog and map eelgrass within the defined sampling polygon at each site. Run a series of transects perpendicular to shore spaced 10m apart. Record locations of boundaries of patches of eelgrass on each transect using the Dlog software. Map the eelgrass bed at each site and compute the area covered by eelgrass. Sample these same polygons yearly.

8 Acknowledgements

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10 Appendix A.

Protocol for estimating intertidal clam species, density and sizes (adapted from Prince William Sound, Exxon Valdez oil spill restoration project 96025-00025)

SOP IC-1-2

Estimation of the Abundance and Size Structure of Intertidal Littleneck Clams as Food for Sea Otters

4/24/97

1.0 Introduction

Among the intertidal clams, littleneck clams (*Protothaca staminea*) are the dominant ones taken by sea otters. The purpose of this sampling effort is to determine the relative abundance and size distribution of intertidal littleneck clams in each of two regions in western Prince William Sound (PWS): along 50 km of unoiled coastline off western Montague Island between Mooselips Bay and Stockdale Harbor, and 50 km of oiled coastline around Knight Island, in Herring Bay (25 km) and Bay of Isles (25 km). This information is required to determine the availability of this clam as food for sea otters.

2.0 Background

Sampling was conducted in summer 1996 to estimate the abundance and size distribution of intertidal clams. We sampled at a series of systematically selected sites and at sites that were systematically selected from preferred clam habitat. Results indicate that littleneck clams (*Protothaca*) were more abundant and larger at Knight Island sites. The data for *Macoma* were less conclusive. Clams appeared larger at Knight, but *Macoma* were more abundant at Montague. This year, we will concentrate on sampling *Protothaca* and *Macoma* at new random (systematically selected with a random start point) sites, and resampling some preferred habitats where there were high densities of clams in 1996.

3.0 Methods

3.1 Initial stage stratified random sampling

Thirty sampling sites were selected from within each of two areas (Montague and Knight Island). The sites were 200 m long stretches of coastline. The following steps were used in selecting sampling sites that are systematically placed along the shoreline, with a randomly selected start point.

Divide the coastline within each area (Montague or Knight) into segments of 200 m in length. Include the shorelines of major island which are included within existing GIS shoreline coverages.

Note that a segment may include shorelines from several adjacent islands.

Label each 200-m long segment with a number.

Divide the total number of segments (xx) by the number of segments to be surveyed (30). Multiply a random proportion by the product (x) to indicate the first segment to be sampled. Select the remaining sampling segments by selecting every xth segment from the first.

Note that these are the same segments that are being sampled for sea urchins, and are a subset of those sampled for mussels.

We will sample along a randomly placed 50-m long transect at each site between + 0.5 and - 0.5 m. Transects will run roughly parallel to shore, along a selected depth contour (Fig. 5). The starting points for transects will be selected as follows:

Start at a randomly selected location along the shore. Find the site using differential (or P-code) GPS. We know that the coordinates selected are not particularly accurate, and that some may be as much as 50 to 100 inshore of the waters' edge, or offshore of land. Do not get hung up on finding the "exact" location. Get to the location as best as possible and select the start point with as little bias as possible. Actual GPS locations of the beginnings and endings of all clam beaches will be recorded.

Drop buoys at randomly selected depths within each depth stratum. Determine the tidally adjusted depths by noting the tidal height at a specific time and location using TIDE1 software. (ALT F2 allows one to obtain a specific tidal height for a given time and location.) Use Stockdale Harbor as the software location for determining tides at Montague sites, Knight Island Passage as the location for determining tidal heights in Herring Bay, and Snug Harbor for determining tidal heights in Bay of Isles.

In some cases it may be necessary to set the intertidal station on foot. In these cases, place a 2 m stick (marked in 10 cm increments) at the waters edge and hold vertically. Place a hand site level at the appropriate height above the water. For example, if the tidal height is -0.4 m, and the desired station location is +0.4 m, hold the site level at the 0.8 m mark on the meter stick. Point at the site perpendicular to shore. Have a second person place a buoy at the place where the line-of-site meets the substrate.

Distances between the +0.5, 0, -0.5, -5 and -10 m depths will be noted in urchin surveys.

At each buoy, a 50 m tape will be stretched from the buoy along a given depth contour. The tape will be connected to the buoy and stretched to the right of the buoy, while facing shore. On each transect, we collect a sediment sample from 5 randomly selected 0.25 m² quadrats. The quadrat position will be at a random point between 0 and 0.95 m along the tape, and at 10 m intervals thereafter. The quadrats will be placed on the offshore side of the tape, and will be placed so that the right hand leg of the quadrat, while facing offshore, is to the randomly selected distance on the tape. In cases where the substrate is too coarse to collect a sample, no sample will be collected and we will note that the quadrat was unsuitable clam habitat.

All sediment samples collected from transects will be returned to the boat and sieved through a series of 3 nested screens. Mesh size for these screens are 2.5, 1.25 and 1.0 cm. Remove and measure all clams to the nearest mm using a vernier caliper. After being measured, clams will be frozen in labeled bags for further analysis.

This sampling will be conducted during the period May 19 through June 26, 1997, using 3 teams of two to three persons. On each day, each team will mark out 3 to 4 sites to be sampled during that or the following day. During the low tide, the team will sample over a 50-m stretch of intertidal area and collect sediments.

3.2 Sampling of preferred habitat

Sampling will be conducted at 12 sites (6 at Montague and 6 at Knight Island) where we observed relatively high densities of clams in 1996. These are ICMI006, ICMI007, ICMI008, ICMI011, ICMI012, ICMI013, ICBI002, ICBI003, ICBI005, ICBI007, ICHB001, and ICHB002.

Sampling will occur during a low-tide series between May 19 and June 26. Sampling will be conducted by two, two-person crews.

The starting points for transects will be the same as used in 1996. Find the site using differential (or P-code) GPS. We know that the coordinates selected are not particularly accurate, and that some may be as much as 50 to 100 m inshore or offshore. Do not get hung up on finding the exact location. Get to the location as best as possible and select the start point with as little bias as possible. Record on Intertidal Clam Sampling Sites Preferred Habitats form IC-97-FD-01.

At each site measure a random distance (the same as used in 1996) from the left hand site boundary. Find the 0 m tide level (MLLW) at this location. This is the left or the beginning end (facing shore) of the 100 m site transect at 0 m MLLW. A surveyors measuring stick, pop level, local tide table and watch will be needed to obtain the 0 m tidal height. Stretch a 100-m tape along the 0 m contour to the right of the start point. Randomly select the first quadrat between 0 and 13.8 m and place a 0.25 m² sampling frame down there. (These are different random numbers than used in 1996). Quadrats 2-7 are sequentially and equally spaced at 14.3 m intervals to the right along the transect line at 0 m tidal height.

The quadrat should be positioned so that the prescribed random distance is at the lower left corner of the frame. Excavate the substrate within the frame to a depth of 10 cm and place in a labeled 19 L bucket. Collect a core for sediment grain size analysis one meter to the left of the quadrat. Insert a core with a 5 cm inside diameter 10 cm deep into the substrate. Place the contents into a labeled 1 gallon zip-loc bag. Fill out the Intertidal Clam Sediment/HC Collection form (IC-97-FD-02). Repeat the sampling procedures from quadrat 1 for quadrats 2-7.

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Later in the day, after all samples have been collected the samples are to be sieved to remove clams. Wash sediment through a series of three nested screens and measure all clams. Record data on a lab data form IC-97-LD-01.

In the laboratory, select 60 clams from the two study areas (Montague vs. Knight) for analysis. Measure shell length to the nearest 0.1 mm using vernier calipers. Blot each clam dry with a paper towel. Open the clam and remove tissue from the shell using forceps or a scalpel. Place tissue in a preweighed aluminum weigh boat and weigh to the nearest 0.001 g on a Mettler PM200 balance. Determinant wet weights of both the tissue and shell and record these on the laboratory data sheet (IC-97-LD-02). Place the clams in an 800 C oven for 48 hours, cool in a dessicator and weigh to determine dry weight. Ash the clams in a 500o C muffle furnace for 4 hours, cool in a dessicator and weigh to determine ash weight. Ash-free dry weight is calculated by subtracting the ash weight from dry weight.

4.0 Equipment and supplies

The sampling equipment and supplies needed by each field crew for each sampling site are as follows:

- 1 Differential GPS
- 1 Intertidal Clam Sampling Sites - Preferred Habitats form (IC-97-FD-01)
- 1 Intertidal Clam Sediment/HC Collection form (IC-97-FD-02)
- 1 meter stick, pop level, tide table, watch
- 7 0.25 m² PVC frames
- 2 shovels
- 8 19 L (5 gal) plastic buckets
- 1 set of nested screens and washstand
- 1 portable water pump w/2 hoses & nozzles
- 10 1 gal zip-loc bags w/plastic labels
- 2 sediment corers

5.0 Data analysis

6.1 The average density of intertidal littleneck and Macoma clams on random transects

We will compute the average density of each clam species within each site and area, as sampled from randomly selected site transects. We will test for differences between areas using a 1-way ANOVA.

6.2 The extent of habitat within each area

The extent of area within each area will be determined by multiplying the average distances between boundaries (measures by tape between -0.5 to +0.5 m) within an area, times the extent of shoreline with the area. We will test for differences between areas using a 1-way ANOVA.

6.3 The total abundance of intertidal littleneck clams within each area based on random sampling

The total abundance of littleneck clams within each area will be determined as the sum of the quantities (average densities x extent of area) within each area. We may also want to consider computing this value for specified size classes (e.g., 5-10 mm long). We will test for differences between areas using a 1-way ANOVA.

6.0 Training

The training for those conducting the field sampling is as follows:

Read and comprehend the SOP prior to the time of the field cruise.

Attend a briefing and review session to discuss the SOP just after mobilization for the cruise.

Take part in the initial sampling of one designated site.

7.0 Quality Assurance

The cruise leader, or his/her designee, will conduct all training sessions, and will approve or disapprove a person for use of this SOP.

It is imperative that all data sheets are completed in full the day the work is done. All data sheets will be reviewed by the cruise leader, or his/her designee, daily.

The cruise leader will complete a log of all activities daily.

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Intertidal Clam Sampling Sites - Preferred Habitats
IC-97-FD-01

Samplers: _____ Date: _____

Area: _____ Site Number: _____ 0 m Tidal Height: _____

Time: _____

Tide: _____

Target UTME: _____ UTMN: _____

Start Pt. UTME: _____ UTMN: _____

Quadrat Positions: (RN) _____ * 13.8m = _____ Q1

Q1 _____ + 14.3m = _____ Q2

Q2 _____ + 14.3m = _____ Q3

Q3 _____ + 14.3m = _____ Q4

Q4 _____ + 14.3m = _____ Q5

Q5 _____ + 14.3m = _____ Q6

Q6 _____ + 14.3m = _____ Q7

Comments: _____

Distance between -0.5 m to +0.5 m	Method
Q1	
Q2	
Q3	
Q4	
Q5	
Q6	
Q7	

Comments: _____

INTERTIDAL CLAM SEDIMENT/HYDROCARBON COLLECTION SHEET
Form IC-97-FD-02

Samplers : _____ Date: _____

Area.:_____Start: UTME:_____

UTMN:_____

Positioning Method:_____

Site #	Transect #	Quad #	Sample ID #	Actual Depth	Sed Gsz Collected	HC Tissue Collected
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[illegible]

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INTERTIDAL CLAM DENSITIES ON TRANSECTS LAB SHEET
Form IC-97-LD-01

Observer:_____

Date:_____

[illegible]

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INTERTIDAL CLAM WEIGHTS LAB SHEET
Form IC-97-LD-02

Observer: _____ Date: _____

[illegible]

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INTERTIDAL CLAM SEDIMENT GRAIN SIZE LAB SHEET
Form IC-97-LD-03

Observer: _____ Date: _____

[illegible]

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