

**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
USGS	US Geological Survey

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Abstract:

In 2006 we field tested a protocol for monitoring nearshore ecosystems in the Katmai National Park and Preserve (KATM) unit of the Southwest Alaska Network (SWAN) of National Parks. The protocol includes six draft standard operating procedures that correspond to NPS “vital signs”. These include: 1) water chemistry/temperature, 2) marine algae, 3) intertidal invertebrates, 4) marine birds, 5) black oystercatchers (*Haematopus bachmani*), and 6) sea otters (*Enhydra lutris*). We established five permanent rocky intertidal transects that provide focal points for vital sign sampling. A temperature recording device was placed at each transect origin. Algae and invertebrates were sampled along these 100 m (328.08 ft) transects. Dominant algae included *Fucus gardneri*, *Neorhodomela oregonia*, *Ulva* and *Palmaria* sp. Dominant invertebrates included barnacles (*Balanus* and *Semibalanus* sp.), snails (*Littorina sitkana*), and small limpets (*Lottia* and *Tectura* sp.). Samples of mussels and limpets at each site were used to estimate size distributions. We surveyed marine birds and mammals along 25 systematic transects, each approximately 5 km (3.12 miles) in length. The most abundant seabirds (number per square kilometer) were glaucous-winged gulls (*Larus hyperboreus*) (87.2/km²), cormorants (*Phalacrocorax* sp.) (68.3/km²), black legged kittiwakes (*Rissa tridactyla*) (58.4/km²), scoters (*Melanitta* sp.) (21.4/km²), and harlequin ducks (*Histrionicus histrionicus*) (16.9/km²). Steller sea lions (*Eumetopias jubatus*) (6.2/km²) were the most abundant marine mammal. An average of 3.2 black oystercatchers / km² were observed. Twelve black oystercatcher nests were observed along 100 km (62.14 miles) of coastline. Ten of these nests were active. These contained a total of eight eggs and 10 chicks. Sea otter densities were 4.9/km². Sea otter diet consisted predominantly of clams (76%), octopus (2%), snails (10%), sea stars (2%), chitons (5%), crabs (3%), urchins (2%), and other prey items (<1%). We recovered 37 sea otter carcasses from beaches along the KATM coast, most of those associated with offshore islands where sea otters commonly haul out. In addition to field testing of the nearshore monitoring protocol, we are revising the monitoring protocol and SOPs and began development of a database structure and a data management plan for nearshore.

Executive Summary:

In 2006 we field tested a protocol and standard operating procedures (SOPs) for long term monitoring of nearshore marine habitats in the Gulf of Alaska and National Park Service nearshore marine “vital signs” within the Southwest Alaska Network (SWAN) of National Parks (Dean and Bodkin 2006). Six vital signs were examined: 1) Kelps and seagrasses, 2) marine water quality, 3) marine intertidal invertebrates, 4) marine birds, 5) black oystercatcher (*Haematopus bachmani*), and 6) sea otter (*Enhydra lutris*). All work was conducted in the Katmai National Park and preserve (KATM).

We visited several kelp and eelgrass beds identified in prior aerial video shoreline surveys and assessed these as potential future monitoring sights. In general, bull kelp (*Nereocystis luetkana*) was widely distributed on exposed rocky headlands between Kukak Bay and Amalik Bay and the distribution was similar to that previously described. In some cases *Nereocystis* was mixed with canopy forming *Alaria*. Eelgrass beds were less widely distributed, and visits to many sites previously identified as eelgrass habitats had little or no eelgrass. However, we were able to identify eelgrass beds in relatively close proximity to sheltered rocky sites used for invertebrate sampling. In 2007 we will surveyed five eelgrass and five kelp beds that are located in close proximity to sheltered rocky intertidal sites established in 2006.

Water quality and intertidal invertebrates were examined at permanent intertidal sampling sites that were established in 2006. These five sites are located in Kukak Bay, Kafil Bay, Kinak Bay, Amalik Bay, and on Takli Island. A temperature recording devise (Hobo, Bourne, MA) was installed, profiles of elevation determined, and digital photographs were taken at each site to enable relocation. Large motile invertebrates (primarily sea stars) were counted along a 4 m (13.12 ft) wide band extending upslope from mean low-low water (MLLW) and stretching the 100 m (328.08 ft) length of the sampling site. The percent cover of algae and sessile invertebrates, and the abundance of smaller invertebrates (primarily littorine snails and limpets) were determined in 12 quadrats placed along each of the two transects. A digital photo was taken of each quadrat and substrate composition was estimated. Dominant algae included *Fucus gardneri*, *Neorhodomela oregonia*, *Ulva* sp., and *Palmaria* sp. Dominant invertebrates included barnacles (primarily *Balanus* and *Semibalanus* sp.), snails (*Littorina sitkana*), and small limpets (*Lottia* and *Tectura* sp). Mussels were collected from each site and are being analyzed to determine levels of contaminants.

We surveyed all marine birds and mammals along 25 transects, approximately 5 km (3.12 miles) in length. These surveys provide estimates of the species composition, abundance and distribution of marine birds and mammals occupying shoreline habitats in summer. Numerically dominant birds, in declining order, were: glaucous-winged gulls (*Larus hyperboreus*), cormorants (pelagic cormorants (*Phalacrocorax pelagicus*), red-faced cormorants (*Phalacrocorax urile*) and double-crested cormorants (*Phalacrocorax auritus*)), black-legged kittiwakes (*Rissa tridactyla*), scoters (white-winged scoters (*Melanitta fusca*) and surf scoters (*Melanitta perspicillata*)), horned puffins (*Fratercula corniculata*) and harlequin ducks (*Histrionicus histrionicus*). Steller sea lions

(*Eumetopias jubatus*) had the highest density of the marine mammals, followed by sea otters (*Enhydra lutris*) and harbor seals (*Phoca vitulina*). Because we only sampled a 200 m (656.17 ft) strip contiguous with the shoreline, some species that occupy shallow nearshore habitats > 200 m (656.17 ft) offshore are likely underrepresented. Densities calculated were unweighted averages. Establishment of a set of marine bird and mammal transects that sample > 200 m (656.17 ft) offshore should be considered in future monitoring. Additionally, 5 km (3.12 mile) transects centered at each of the intensive intertidal sites should be established.

We sampled five black oystercatcher transects corresponding to each of the five rocky intertidal sampling locations. An additional black oystercatcher transect was established around the perimeter of Ninagiak Island in Hallo Bay where large numbers of black oystercatchers were observed. A total of 17 black oystercatcher nests were found, 15 of which were active. The number of nests ranged from one to five per transect. Two of the active nests had no eggs or chicks. On the 13 other nests, we found 11 eggs and 13 chicks. The chicks ranged in developmental stage from newly hatched to mature (nearly black). The fact that we observed both eggs and mature chicks suggests that there may have been initial nest failures and that nests with eggs present represented a second brooding attempt. We recovered dietary prey remains from 10 of 12 nests where chicks were present. More than 500 prey items were identified to species and measured. Limpets (*Tectura* sp. and *Lottia* sp) and mussels (*Mytilus trossulus*) dominated the dietary remains.

For sea otters, we estimated abundance, examined diets, and collected sea otter carcass specimens found along the shorelines for later determination of age at death. Abundance was estimated using boat-based surveys. A total of 130 adult sea otters and 24 sea otter pups were observed. Aerial surveys of sea otter abundance that provide broader coverage and more accurate estimates of abundance are planned for 2007. We collected foraging data on sea otters associated with 3 of the 5 rocky intertidal sites and observed 65 forage bouts that included 451 forage dives. Sea otters were successful in obtaining prey on 91% of their forage dives. Sea otter diet was numerically dominated by clams followed by snails, chitons, crabs, sea stars, sea urchins, and octopus. A total of 37 sea otter carcasses (including partial remains and a tooth for aging) were collected to estimate age at death. Thirty three carcasses were associated with sea otter haul out sites, and four were located on beach segments selected for coastline surveys for sea otter carcasses. Teeth were removed from these carcasses and are being analyzed to determine the age at death. The age at death will be used in demographic models to evaluate trends in survival.

Surveys of shorelines for beach cast birds and mammals, wrack (kelps and algae), and debris of human origin were conducted in April, June and July of 2006. The primary purpose of these surveys was to collect sea otter carcasses, but ancillary data were obtained on other dead mammals and birds as well as live birds present along the shorelines during the survey. Data pertaining to the type and extent of debris along the beaches was also collected. Only 3 sea otter carcasses were collected in these surveys. A great deal of effort was allocated to conducting these coastline surveys and relatively

little data applicable to vital signs was obtained. Therefore, we are recommending that these surveys be discontinued or done on a very infrequent (once per decade) basis.

In addition to field testing of the nearshore monitoring protocol, we completed several additional tasks that were identified under the Inter-Agency Agreement between the NPS, SWAN and USGS, ASC. These included writing and revising the monitoring protocol and SOPs and developing a database structure and a management plan for nearshore data. In 2006 a draft monitoring protocol was submitted to the SWAN manager. Based on reviewer comments and results of preliminary implementation in 2006, the nearshore monitoring protocol is now undergoing revision. It is anticipated that an updated protocol will be completed in early 2007. The SOPs associated with each vital sign that were field tested in 2006 are also undergoing additional review and revision. The revisions will incorporate the recommendations identified at the end of each vital sign chapter in this report. Reconnaissance of eelgrass and kelp beds along the Katmai coast in 2006 provided information for developing vessel based monitoring designs that will be incorporated into draft SOPs' in 2007. Design and development of data management plans specific to each SOP requires SOP testing and validation. In 2006 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. Development of a data management plan will continue in 2007.

In 2007 we will repeat the preliminary sampling of SWAN vital signs completed in 2006 in the KATM and conduct an aerial survey of sea otter abundance. In addition, standard operating procedures to monitor seagrasses and kelps will be drafted and field tested and five sheltered soft sediment sites will be sampled. In winter 2008 we will initiate sampling of marine bird and mammal transects to estimate species composition, abundance, and distributions for over wintering birds and mammals. Several modifications to the sampling procedures implemented in 2006 will be considered. These include: 1) *In situ* measurement of limpets to reduce impacts of removal of limpets, 2) recording data electronically to enhance efficiency, 3) targeting of sea otter haul outs for sea otter carcass recovery, 4) expanding sampling efforts for marine birds and mammals to increase spatial relevance and reduce bias, and 5) elimination of coastline surveys that proved inefficient for collecting sea otter carcasses). Also, in 2007 we will implement the revised nearshore sampling protocol in the Kenai Fjords National Park (KEFJ) region in a manner consistent with data collection in the KATM region.

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, today 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 effects 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 and separation 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*). 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, are 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 initial sampling and testing of nearshore vital sign protocols conducted in 2006. All of the work was done in KATM (Figure 1.1). This is the initial phase of a program that will incorporate sampling in Kenai Fjords National Park (KEFJ) and 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.

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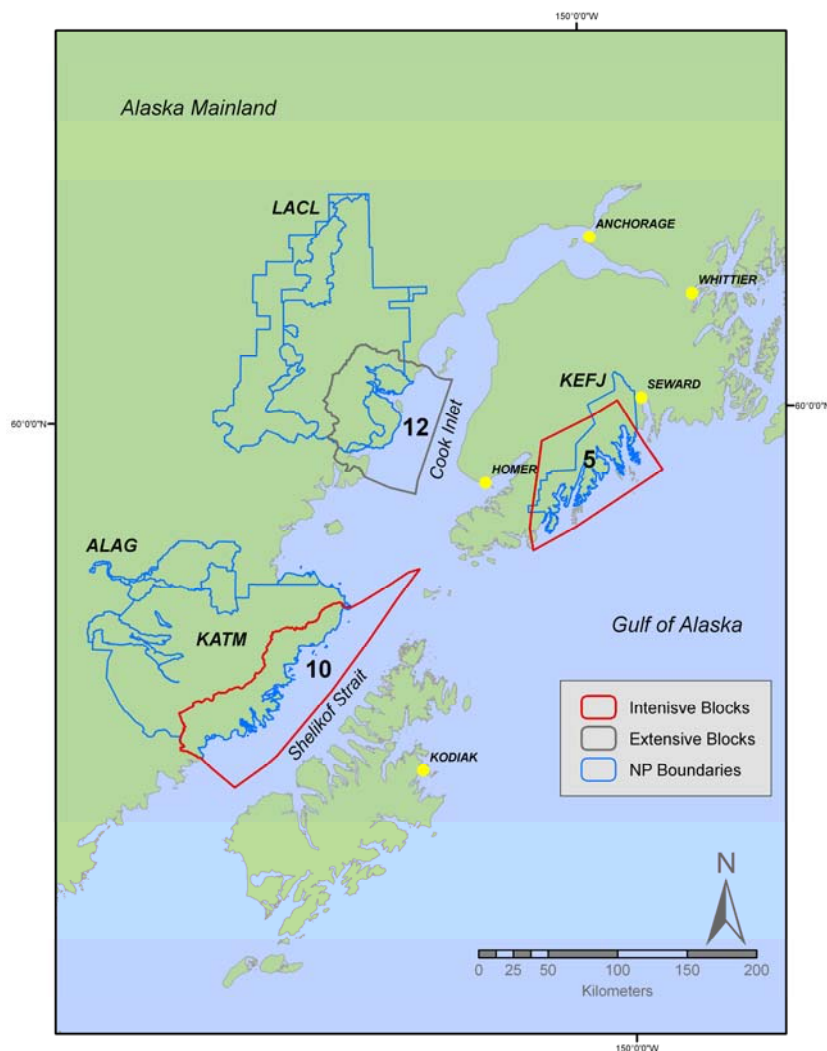


Figure 1.1. Sampling locations for the SWAN nearshore vital signs monitoring. Intensive sampling blocks (indicated in red) are locations for monitoring of all vital signs. Less frequent monitoring of a limited number of vital signs is to be conducted in the extensive block at LACL (indicated in grey). 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.
- 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.

Several sampling protocols, including evaluation of kelps and seagrasses, sampling of invertebrates in soft sediments, and aerial surveys of sea otter abundance were not initiated in 2006, but are planned for 2007.

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. Following we summarize 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 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 2007.

In 2006 draft SOPs' were completed providing a background and rational 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 HOBO SOP 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 2007. 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 will explore 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 2007, 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 will be completed prior to field testing in 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 2007 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 2007.

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. 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 that sea otter carcasses in KATM may be more efficiently acquired through collections of carcasses at haul-out sites. 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 2007, 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 June 2006 at five intertidal sampling sites in sheltered rocky habitats in the KATM. This is the first annual sampling of intertidal invertebrates and algae at these sites designed to detect changes in these communities over time as part of the SWAN Vital Signs program. The specific objectives of this sampling 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). In this report, we will focus on a general description of sampling activities conducted in 2006 and give a description of the communities at each of the sites sampled. Because water temperature data loggers are still deployed, intertidal temperature data will be reported in 2007. Results of chemical analysis of mussel tissues collected in 2006 are not available as of this reporting.

METHODS

Sampling was conducted at five sites in sheltered rocky habitats within KATM (Figure 2.1). 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. Detailed description of the methods used to sample water temperature, intertidal algae and invertebrates are available in Dean and Bodkin 2006. The following is a general description of the methods employed.

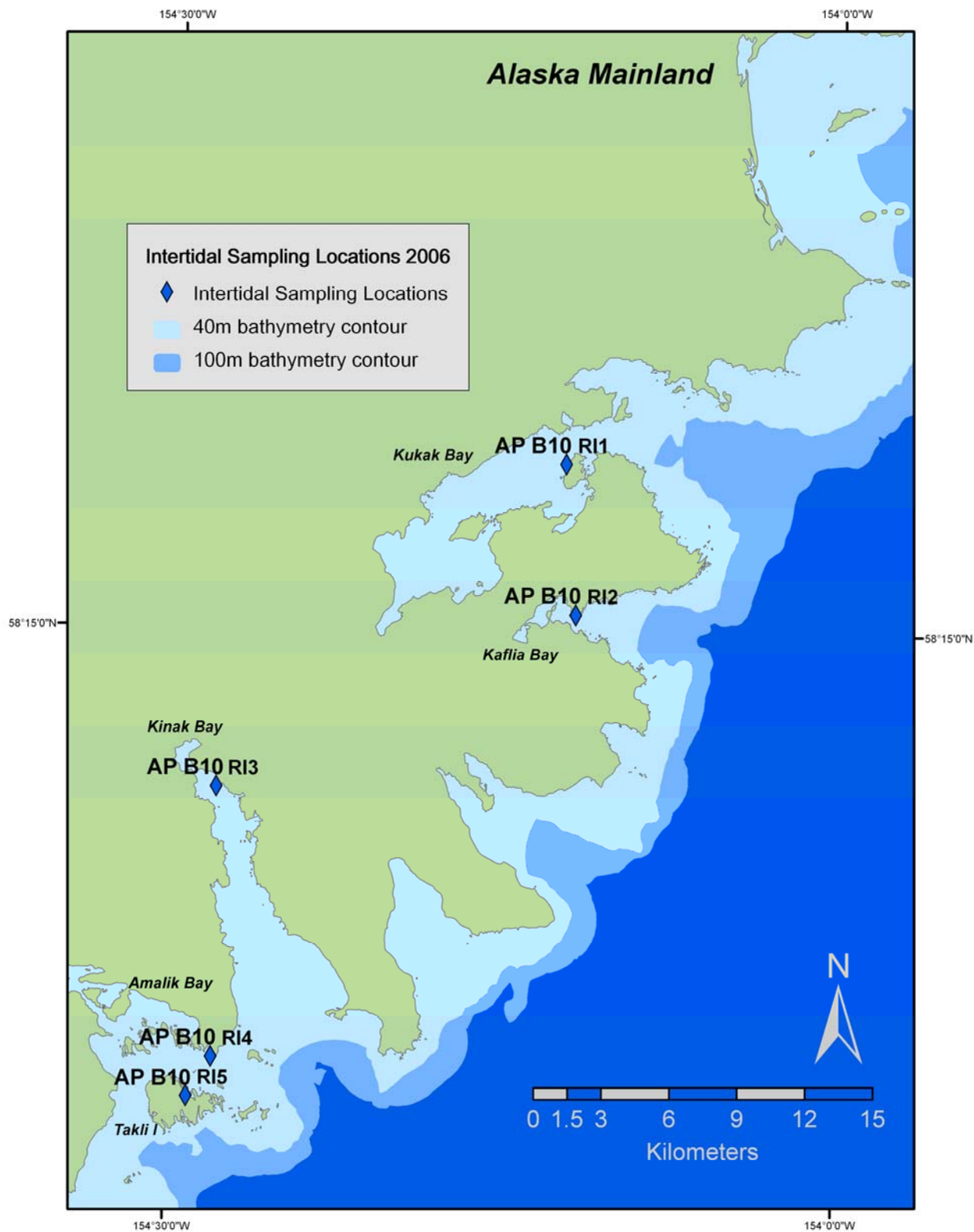


Figure 2.1. Locations of rocky intertidal sites (AP B10 RI1 through AP B10 RI5) established and sampled in Katmai National Park in 2006.

Permanent markers were installed at the 0.5 m and 1.5 m tidal elevations at each site. (Figure 2.2) Marker locations were determined by consulting tide tables to determine the time of MLLW, marking the waters edge at that time, and determining elevations above MLLW using a stadia rod and a site level. The markers were metal tags affixed to the rock using stainless steel screws and anchors. Also, two steel bars or markers were placed at the high water mark above the markers (Figure 2.3). Positions and distances from these markers to intertidal site tags were noted to aid in relocating transect positions in the event that tags are lost. A “Hobo” temperature recording device was placed at the 0.5 m marker at each site.

A 100 m long tape was stretched from each marker along the shoreline parallel to the waters edge (Figure 2.4). We then determined the slope profile at 25 m intervals along the tape by measuring distances between MLLW and positions of 1, 2, and 3 m elevations. Digital images were taken from the start point of each transect and pointing toward the end of the transect, from the end of each transect pointing back toward the start, and from approximately 200 m offshore (far enough offshore to be able to see both ends of the tape) facing the beach.



Figure 2.2. Stainless steel marker bolted to substrate at zero end and +0.5 m tidal elevation of 100 m transect at site AP B10 RI1, with HOBO temperature recorder and GPS used to obtain coordinates.

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.

The percent cover of substrate types, percent cover of algae, percent cover of sessile invertebrates, and counts of motile invertebrates were determined within 12 evenly spaced $\frac{1}{4}$ m² quadrats placed along transects placed parallel to the shoreline at the 0.5 m and 1.5 m tidal elevations respectively (Figure 2.5). Quadrats were placed at a random start point between 0- and 7.33 m along the tape and at 8.33 m intervals thereafter. Percent cover estimates and counts of small motile invertebrates were made within 0.25 m² quadrats. Intermediate size motile invertebrates (primarily larger snails and limpets) were counted within one square meter quadrats. Percent cover was estimated visually (for substrate type) or by determining the percentage occurrence under 49 systematically placed points within each quadrat (Figure 2.5).



Figure 2.3. Steel rebar and aluminum cap with site number (AP B10 RI2) stamped on top imbedded in the supratidal zone above the zero end markers at Kafia Bay.



Figure 2.4. Rocky intertidal transect on Takli Island (AP B10 RI5). Sampling is being conducted along tapes stretched along +0.5 and +1.5 m tidal elevations.



Figure 2.5. Sampling of algae and invertebrates in $\frac{1}{4} \text{ m}^2$ point contact quadrat in Kinak Bay (AP B10 RI3).

A minimum of 213 individual mussels (*Mytilus trossulus*) and limpets (*Tectura persona*) were sampled from 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).

RESULTS

The geomorphology at intertidal sampling sites was typical of sheltered rocky shorelines in the region, with gently to moderately sloping intertidal regions and substratum comprised primarily of bedrock and cobble/boulder. Average slopes over a 3 m rise in vertical elevation (starting at MLLW) ranged from 13° to 35° (Table 2.1). At the Amalik Bay site (AP B10 RI4) the intertidal zone was more gently sloped (13°) than at other sites (ranging from 28 to 35°). The substratum was predominantly bedrock at most sites, with the exception of the Takli Island site (AP B10 RI5) that was approximately half bedrock and half cobble/boulder (Table 2.2).

Table 2.1. Average slope (degrees) at intertidal sampling sites in KATM in 2006.

Site name	Site number	Slope (degrees)			Mean
		0 to 1 m	1 to 2 m	2 to 3 m	
Kukak	AP B10 RI1	26	26	31	28
KafLIA	AP B10 RI2	44	22	26	31
Kinak	AP B10 RI3	49	35	20	35
Amalik	AP B10 RI4	8	13	7	13
Takli	AP B10 RI5	35	25	33	31

Table 2.2. Substratum type at intertidal sampling sites in KATM in 2006.

Name	Site number	Elevation			
		0.5 m		1.5 m	
		%Bedrock	%Cobble/Boulder	%Bedrock	%Cobble/Boulder
Kukak	AP B10 RI1	90	10	83	17
KafLIA	AP B10 RI2	100	0	74	26
Kinak	AP B10 RI3	92	8	75	25
Amalik	AP B10 RI4	100	0	87	13
Takli	AP B10 RI5	45	55	50	50

Large motile invertebrates identified included 5 species of sea stars (Table 2.3). The most abundant were *Evasterias troschelii* and *Pisaster ochraceus*, and *Pycnopodia helianthoides*. Notably, there were no sea stars observed at the Kukak Bay site.

Table 2.3. Density (number per 400 m²) of large motile invertebrates (all are sea stars) at intertidal sampling sites at KATM, June 2006.

	Site				
	Kukak AP B10 RI1	Kaflia AP B10 RI2	Kinak AP B10 RI3	Amalik AP B10 RI4	Takli AP B10 RI5
<i>Dermasterias imbricata</i>	0	0	6	0	0
<i>Evasterias troschelii</i>	0	77	26	9	10
<i>Pisaster ochraceus</i>	0	3	0	13	0
<i>Pycnopodia helianthoides</i>	0	3	14	1	0
<i>Solaster stimpsoni</i>	0	1	0	0	0
Grand Total	0	84	46	23	10

The number of algal and sessile invertebrates species observed at each of the two tidal elevations at each site ranged from 15 to 24 (Table 2.4). 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. and barnacles (*Balanus* and *Semibalanus* sp. and unidentified barnacle spat) (Figure 2.6). Sites differed in that the site at Kukak (AP B10 RI1) had very few barnacles and the site at Kaflia (AP B10 RI2) had relatively little *Fucus* and much more *Porphyra*. 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 margianta*) algae (Figure 2.7). Sites differed greatly with respect to the relative abundance of these species.

Table 2.4. Species of dominant intertidal algae and sessile invertebrates at lower (0.5m MLLW) and mid (1.5m MLLW) intertidal sites at KATM, June 2006. x = present, 0 = absent.

		Site				
Species	Common Name	Kukak	Kinak	Kaflia	Amalik	Takli
		AP B10 RI1	AP B10 RI2	AP B10 RI3	AP B10 RI4	AP B10 RI5
Lower Intertidal (0.5 m MLLW)						
<i>Acrosiphonia</i> sp.	Red alga	0	x	x	x	x
<i>Alaria marginata</i>	Brown alga	x	x	x	x	x
<i>Analipus japonicus</i>	Brown alga	0	x	0	x	x
<i>Balanophyllia elegans</i>	Cup coral	0	x	0	x	0
<i>Balanus</i> / <i>Semibalanus</i> sp.	Barnacle	0	x	x	x	x
<i>Balanus glandula</i>	Barnacle	x	0	0	0	0
<i>Chthamalus dalli</i>	Barnacle	x	x	0	x	x
<i>Clodophora</i> / <i>Rhizoclonium</i> sp.	Green alga	0	0	x	0	x
<i>Corallina</i> sp.	Red alga	0	0	x	0	0
<i>Cryptosiphonia woodii</i>	Red alga	0	0	x	0	0
<i>Elachista fucicola</i>	Brown alga	0	0	0	0	x
<i>Endocladia muricata</i>	Red alga	0	0	0	0	x
<i>Fucus gardneri</i>	Brown alga	x	x	x	x	x
<i>Gloiopeltis furcata</i>	Red alga	0	0	0	x	x
<i>Halosaccion glandiforme</i>	Red alga	x	0	x	0	0
<i>Laminaria saccharina</i>	Brown alga	0	x	0	0	0
<i>Lithothamnion</i> sp.	Red alga	0	x	0	x	0
<i>Mastocarpus papillatus</i>	Red alga	x	x	x	0	0
<i>Melanosiphon intestinalis</i>	Brown alga	x	x	x	0	x
<i>Microcladia borealis</i>	Red alga	0	0	x	0	0
<i>Mytilus trossulus</i>	Mussel	0	x	0	x	x
<i>Neorhodomela larix</i>	Red alga	0	0	x	x	0
<i>Neorhodomela oregona</i>	Red alga	x	0	x	x	x
<i>Odonthalia floccosa</i>	Red alga	0	0	x	0	0
<i>Palmaria collophylloides</i>	Red alga	x	x	x	0	0
<i>Palmaria hecatensis</i>	Red alga	x	x	x	x	0
<i>Palmaria</i> sp.	Red alga	0	0	x	0	0
<i>Pilayella littoralis</i>	Brown alga	x	0	x	0	x
<i>Polysiphonia</i> sp.	Red alga	0	0	x	0	x
<i>Porphyra</i> sp.	Red alga	0	x	0	x	0
<i>Pterosiphonia bipinnata</i>	Red alga	x	x	x	x	x
<i>Ralfsia</i> sp.	Brown alga	0	0	x	0	0
<i>Scytosiphon simplicissimus</i>	Brown alga	0	0	x	x	x
<i>Semibalanus balanoides</i>	Barnacle	x	0	0	0	0
<i>Stomachetosella cruenta</i>	Bryozoan	0	x	0	0	0
<i>Tokidadendron kurilensis</i>	Red alga	x	0	0	0	0
<i>Ulothrix flacca</i>	Green alga	0	0	0	x	0
<i>Ulva</i> sp.	Green alga	x	x	x	x	x
Unidentified green algae	Green alga	0	0	x	0	0
Total No. Species		15	18	24	18	18

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Table 2.4. cont.

		Site				
Species	Common Name	Kukak AP B10 RI1	Kinak AP B10 RI2	Kaflia AP B10 RI3	Amalik AP B10 RI4	Takli AP B10 RI5
Mid Intertidal (1.5 m MLLW)						
<i>Acrosiphonia</i> sp.	Green alga	x	x	x	x	x
<i>Alaria marginata</i>	Brown alga	x	x	0	x	x
<i>Analipus japonicus</i>	Brown alga	0	0	x	0	x
<i>Anthopleura elegantissima</i>	Sea anemone	0	0	0	x	0
<i>Balanus</i> / <i>Semibalanus</i> sp.	Barnacle	x	x	x	x	x
<i>Balanus glandula</i>	Barnacle	x	0	0	0	0
<i>Chthamalus dalli</i>	Barnacle	x	x	x	x	x
<i>Clodophora/Rhizoclonium</i> sp.	Green alga	0	0	x	x	0
<i>Corallina</i> sp.	Red alga	0	0	0	x	0
<i>Cryptosiphonia woodii</i>	Red alga	x	0	0	0	0
<i>Elachista fucicola</i>	Brown alga	0	0	0	0	x
<i>Endocladia muricata</i>	Red alga	0	x	x	x	x
<i>Fucus gardneri</i>	Brown alga	x	x	x	x	x
<i>Gloiopeltis furcata</i>	Red alga	x	x	x	x	x
<i>Halosaccion glandiforme</i>	Red alga	x	0	x	0	0
<i>Lithothamnion</i> sp.	Red alga	0	0	0	x	0
<i>Mastocarpus papillatus</i>	Red alga	x	0	x	x	0
<i>Melanosiphon intestinalis</i>	Brown alga	x	0	x	x	x
<i>Mytilus trossulus</i>	Mussel	x	x	x	x	x
<i>Neorhodomela oregona</i>	Red alga	x	0	x	x	x
<i>Odonthalia floccosa</i>	Red alga	0	x	0	0	0
<i>Palmaria collophyloides</i>	Red alga	x	0	x	x	0
<i>Pilayella littoralis</i>	Brown alga	x	0	x	0	x
<i>Polysiphonia</i> sp.	Red alga	x	0	0	x	x
<i>Porphyra</i> sp.	Red alga	x	x	x	x	x
<i>Pterosiphonia bipinnata</i>	Red alga	x	x	x	x	x
<i>Ralfsia</i> sp.	Red alga	0	0	x	0	0
<i>Scytosiphon simplicissimus</i>	Brown alga	0	x	0	x	0
<i>Semibalanus cariosus</i>	Barnacle	0	0	0	x	0
<i>Ulva</i> sp.	Green alga	x	x	x	x	x
unidentified brown algae	Brown alga	0	x	0	x	0
unidentified filamentous red algae	Red alga	x	x	0	0	0
Total No. Species		20	15	19	23	17

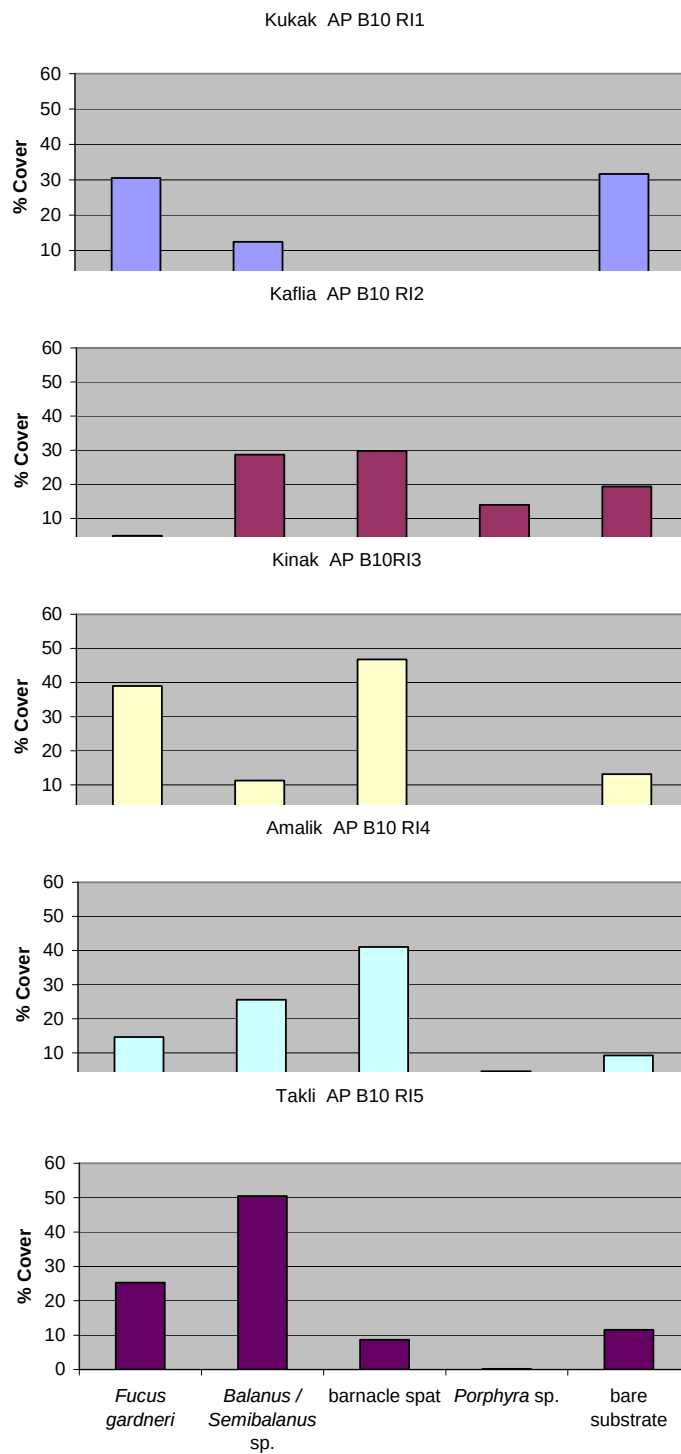


Figure 2.6. Mean percent cover of dominant intertidal algae and invertebrates at mid (1.5m MLLW) intertidal sites at KATM, June 2006.

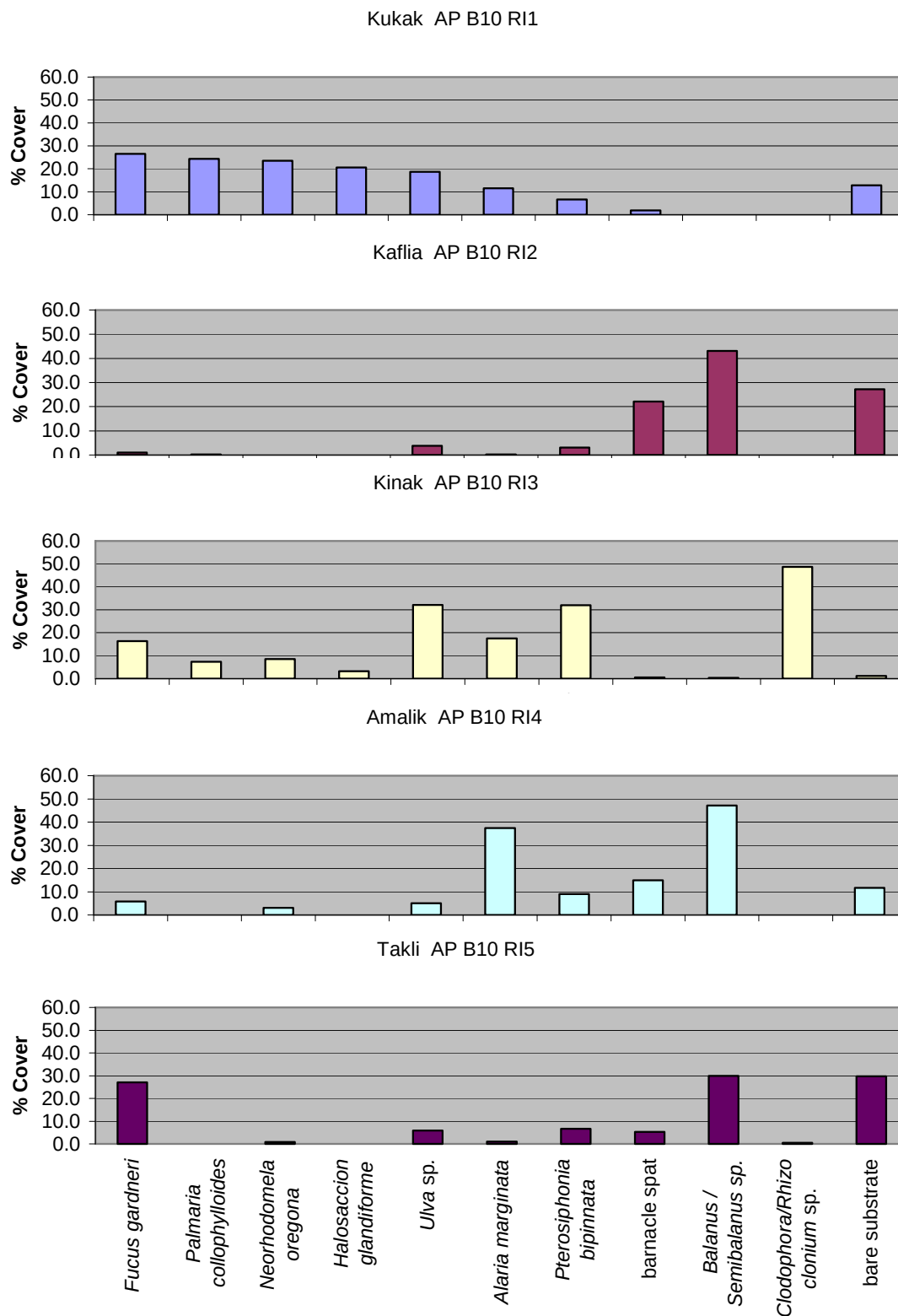


Figure 2.7. Mean percent cover of dominant algae and sessile invertebrates at lower (0.5m MLLW) intertidal sites in KATM, June 2006.

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From two to five intermediate-size invertebrates were observed at each tidal elevation and site (Table 2.5). The numerically dominant species were the predatory snail, *Nucella lamellosa* and the chiton, *Katherina tunicata*. Sites differed in species composition and abundance (Fig. 2.8). Notably there were no *Katherina* at Kukak Bay (AP B10 RI1) and no *Nucella lamellosa* at Kinak Bay (AP B10 RI3).

Table 2.5. Species of intermediate size invertebrates at lower (0.5 m MLLW) and mid (1.5 m MLLW) intertidal sites at KATM, June 2006. X = present, 0 = absent.

Species	Common Name	Site				
		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	0	X	0	0	0
<i>Buccinum baeri</i>	Snail	X	0	0	0	0
<i>Katharina tunicata</i>	Chiton	0	X	X	X	X
<i>Leptasterias epichlora</i>	Sea star	0	0	0	X	0
<i>Nucella lamellosa</i>	Snail	X	X	0	X	X
<i>Strongylocentrotus droebachiensis</i>	Sea urchin	0	0	0	X	X
<i>Tonicella lineata</i>	Chiton	0	0	0	X	0
unknown anemone	Sea anmeone	0	0	X	0	0
<i>Utricina crassicornis</i>	Sea anemone	0	X	0	0	0
	Total Number of Species	2	4	2	5	4
Mid Intertidal (1.5 m MLLW)						
<i>Anthopleura elegantissima</i>	Sea anmeone	X	0	X	X	X
<i>Anthopleura xanthogrammica</i>	Sea anmeone	X	0	0	0	0
<i>Buccinum baeri</i>	Snail	0	0	0	X	0
<i>Katharina tunicata</i>	Chiton	0	X	X	X	X
<i>Leptasterias epichlora</i>	Sea star	0	0	0	X	X
<i>Metridium senile</i>	Sea anemone	0	X	0	0	0
<i>Nucella lamellosa</i>	Snail	X	X	0	X	X
<i>Utricina crassicornis</i>	Sea anmeone	0	X	X	0	0
	Total Number of Species	3	4	3	5	4

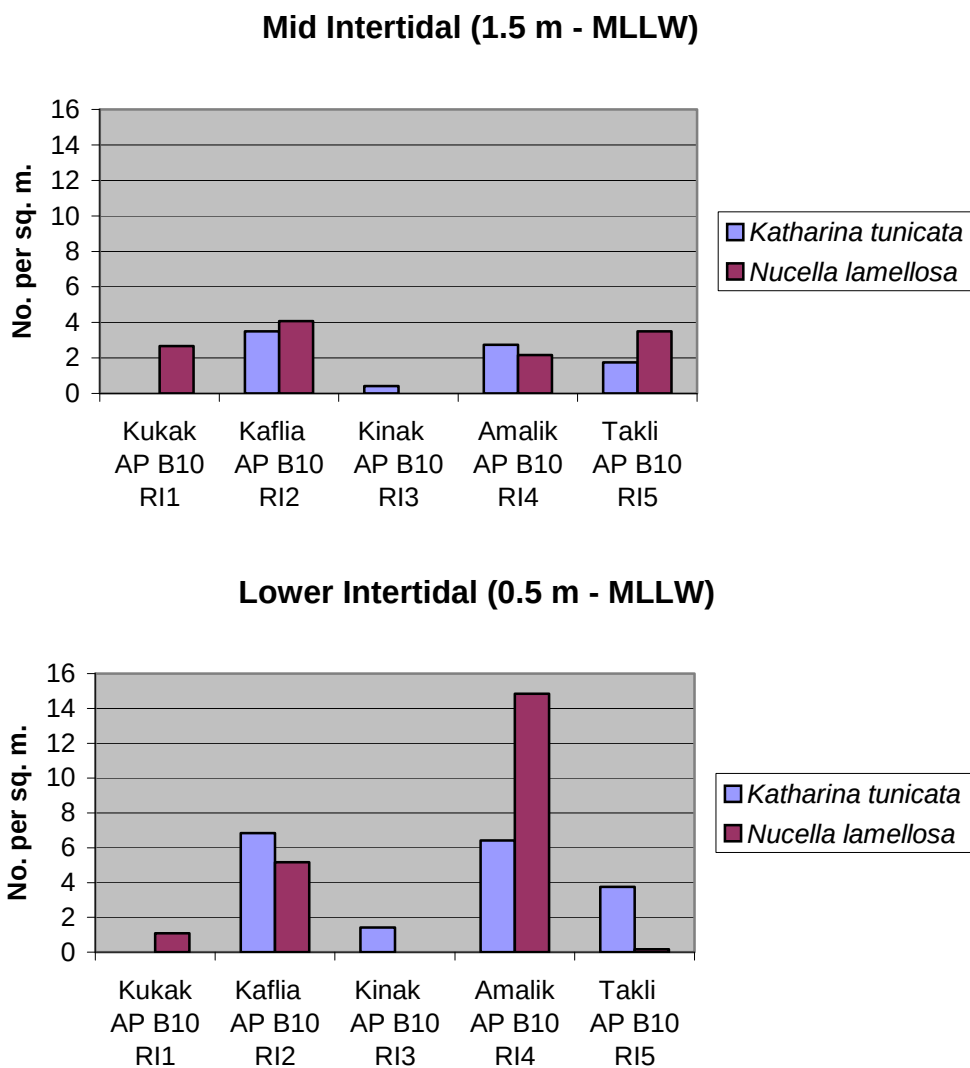


Figure 2.8. Density (number per m²) of dominant intermediate-size intertidal species at KATM, June 2006.

The number of smaller motile invertebrates at each elevation and site ranged from 5 to 17 (Table 2.6). The largest number of species (16 or 17 species at each elevation) was observed at Amalik Bay (AP B10 RI4) and the fewest (5 to 8 species per elevation) at Kukak (AP B10 RI1) and Kinak (AP B10 RI3) Bays. Numerically dominant species included littorine snails (*Littorina sitkana*) and limpets (both *Lottia pelta* and small unidentified limpets classified as *Lottiidae*) (Figure 2.9).

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Table 2.6. Species of small motile invertebrates at lower (0.5 m MLLW) and mid (1.5 m MLLW) intertidal sites at KATM in 2006. x = present, 0 = absent.

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>Amphiporus formidabilis</i>	Ribbon worm	x	0	x	x	0
<i>Buccinum baeri</i>	Snail	x	0	0	0	0
<i>Cancer oregonensis</i>	Crab	0	0	0	x	0
<i>Cucumaria vegae</i>	Sea cucumber	x	0	0	x	0
<i>Emplectonema gracile</i>	Ribbon worm	0	x	0	x	0
<i>Haplogaster mertensii</i>	Crab	0	0	0	x	0
<i>Katharina tunicata</i>	Chiton	0	0	x	0	0
<i>Lepasterius epichlora</i>	Sea star	x	0	0	x	0
<i>Littorina scutulata</i>	Snail	0	0	0	x	x
<i>Littorina sitkana</i>	Snail	x	x	x	x	x
<i>Lottia digitalis</i>	Limpet	0	x	0	0	0
<i>Lottia pelta</i>	Limpet	x	x	x	x	x
<i>Margarites pupillus</i>	Snail	0	x	x	x	x
<i>Margurites helicinus</i>	Snail	0	x	0	x	0
<i>Mopalia sp.</i>	Chiton	0	0	x	0	0
<i>Neomolgus littoralis</i>	Mite	0	0	x	0	0
<i>Onchidella borealis</i>	Unsheeled snail	0	0	0	x	0
<i>Pagurus sp.</i>	Crab	x	x	x	x	x
<i>Paranemertes perigrina</i>	Ribbon worm	0	x	0	x	0
<i>Pentidotea wosnesenskii</i>	Isopod	0	0	0	x	x
<i>Phidiana crassicornis</i>	Sea slug	0	x	0	0	0
<i>Siphonaria thersites</i>	Unsheeled snail	0	x	0	0	0
<i>Tectura scutum</i>	Limpet	x	x	0	x	x
<i>Tonicella lineata</i>	Chiton	0	0	0	x	0
Total number of species		8	11	8	17	7
Mid Intertidal (1.5 m MLLW)						
<i>Amphiporus formidabilis</i>		0	0	0	x	0
<i>Anthopluera elagantissima</i>	Sea Anemone	0	0	0	x	0
<i>Buccinum baeri</i>	Snail	0	x	0	0	0
<i>Emplectonema gracile</i>	Snail	0	0	0	x	x
<i>Lepasterius epichlora</i>	Sea star	0	0	0	x	0
<i>Littorina scutulata</i>	Snail	x	x	x	x	x
<i>Littorina sitkana</i>	Snail	x	x	x	x	x
<i>Lottia digitalis</i>	Limpet	0	0	0	0	x
<i>Lottia pelta</i>	Limpet	x	x	x	x	x
<i>Margarites pupillus</i>	Snail	0	0	0	x	0
<i>Margurites helicinus</i>	Snail	0	x	0	x	x
<i>Neomolgus littoralis</i>	Mite	0	0	x	0	x
<i>Onchidella borealis</i>	Unsheeled snail	0	x	0	x	x
<i>Pagurus sp.</i>	Crab	x	x	x	x	x
<i>Paranemertes perigrina</i>	Ribbon worm	0	0	0	x	0
<i>Pentidotea wosnesenskii</i>	Isopod	0	0	0	x	0
<i>Siphonaria thersites</i>	Unsheeled snail	0	x	0	x	0
<i>Tectura persona</i>	Limpet	x	x	0	0	0
<i>Tectura scutum</i>	Limpet	x	x	0	x	x
<i>Tonicella lineata</i>	Chiton	0	0	0	x	0
Total number of species		6	10	5	16	10

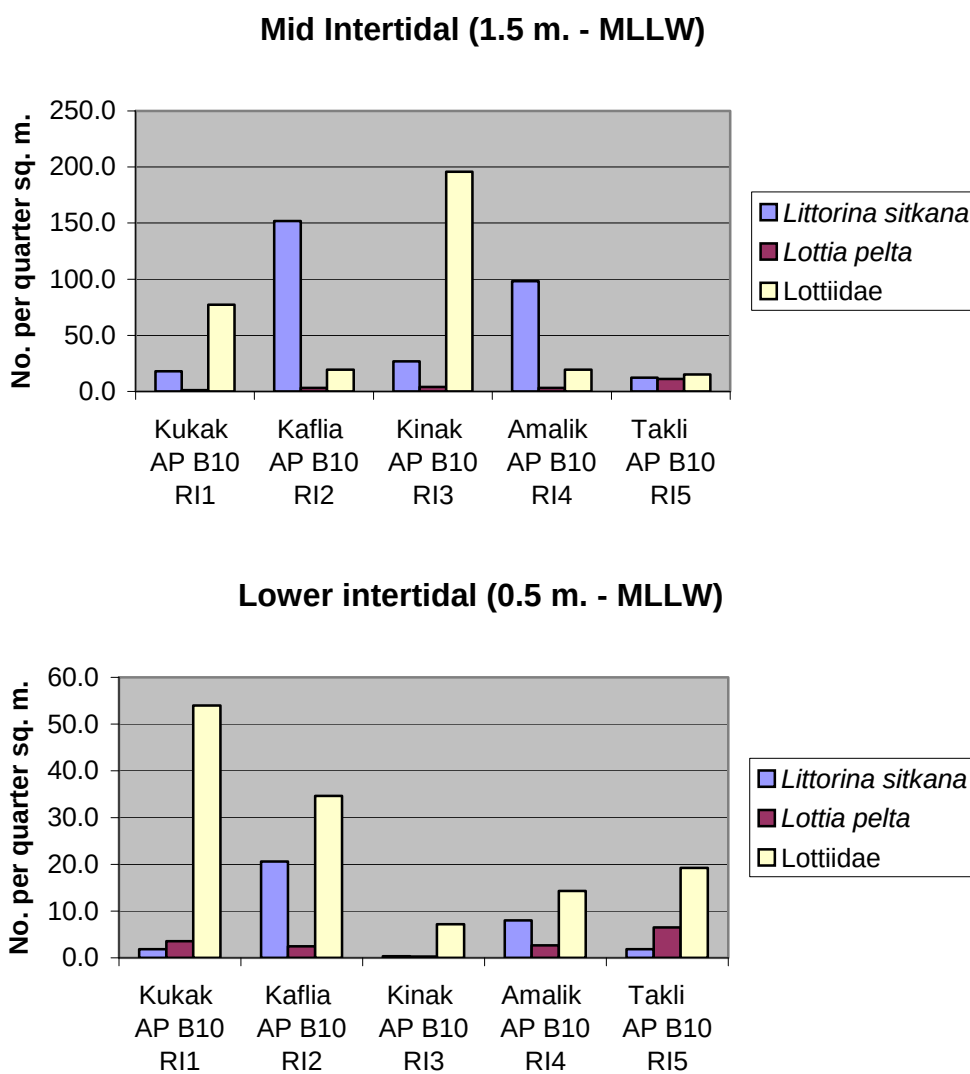


Figure 2.9. Density (number per 0.25 m²) of dominant smaller motile intertidal species at KATM in 2006.

Size distributions of mussels (*Mytilus trossulus*) and limpets (*Tectura persona*) are given in Figures 2.10 and 2.11. At all sites but Kukak Bay (AP B10 RI1), size distributions of both species were unimodal and had the largest number of individuals were in the 12 to 14 mm (for *Tectura*) or 12 to 16 mm (for *Mytilus*) size classes. At Kukak, size distributions of both species were skewed toward larger sizes. Size distributions had two (or perhaps more) modes, and had a relatively large proportion of individuals in the 28 and 20 mm size categories for *Mytilus* and *Tectura* respectively.

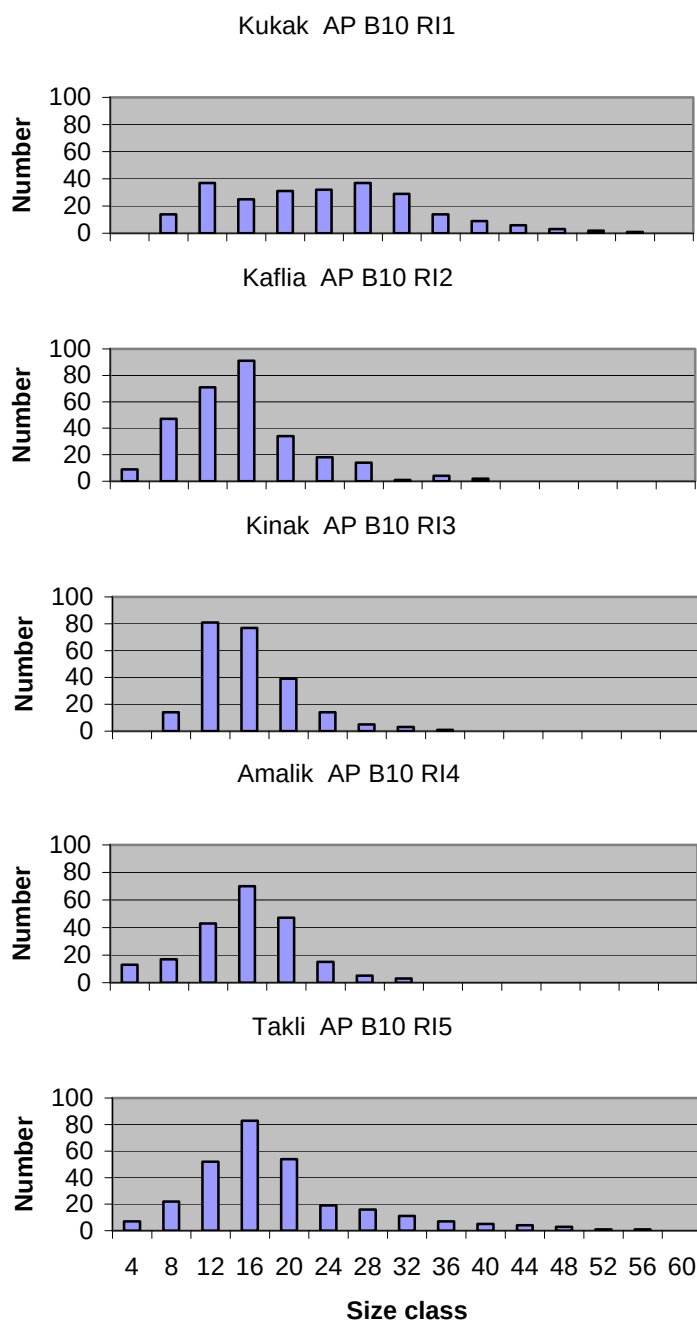


Figure 2.10. Size frequency distribution of *Mytilus trossulus* at KATM in 2006. Size classes are in mm shell length.

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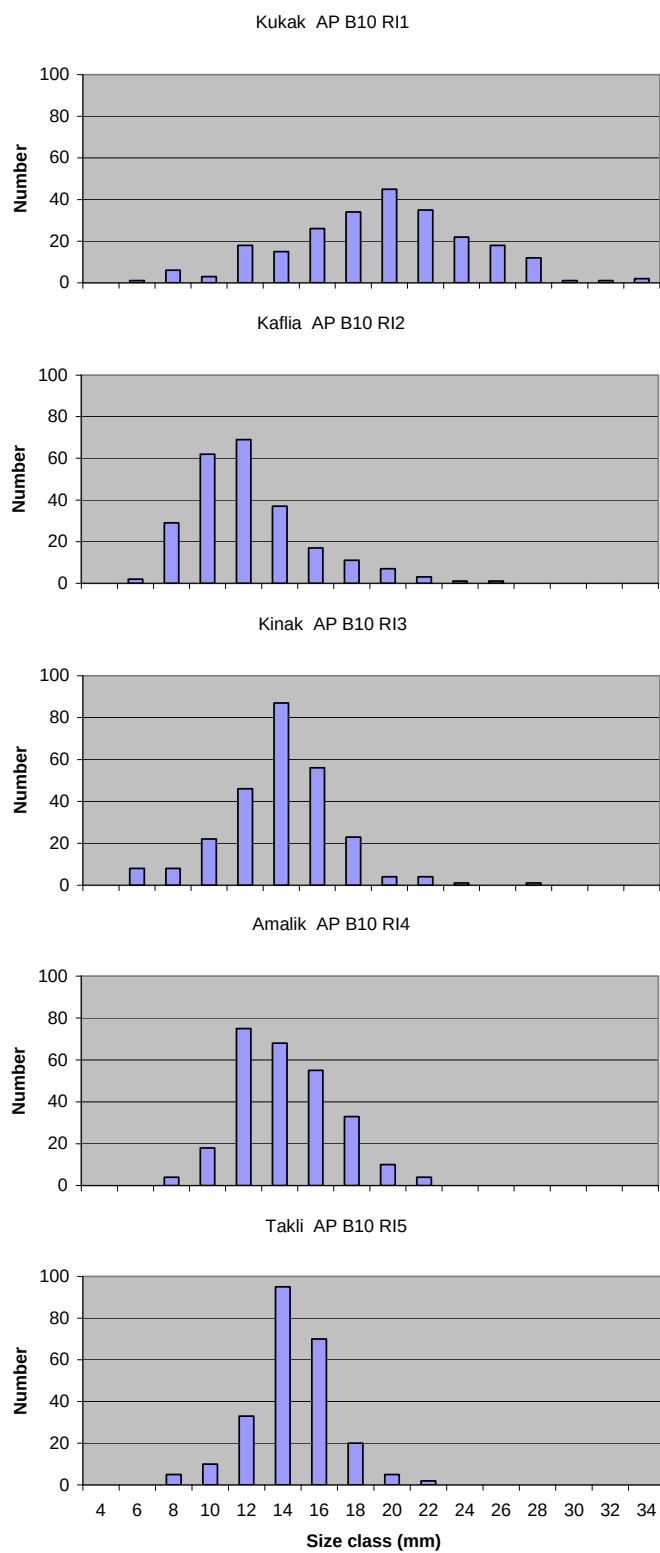


Figure 2.11. Size frequency distribution of *Tectura persona* at KATM sites in 2006. Size classes are in mm shell length.

DISCUSSION

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 site 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. Differences could not be attributed to slope or substrate characteristics which were similar at Kukak and other sites. In the current context of long-term monitoring, inter-site variation is of less interest than changes that occur within a site or sites over time. Temporal variation will be determined following additional sampling conducted in the coming years.

RECOMMENDATIONS

Several modifications to the standard operating procedure would enhance the sampling process. These include refinement of data sheets and refinement of procedures for collection of “unidentified” species. Also, *in situ* measurement of limpets (to avoid depletion of these populations over time) and the use of data logging computers should be explored. Measurements of slope for each individual quadrat should also be included. Slope of the quadrat (e.g. vertical vs. horizontal) appeared to have an influence on species composition and relative abundance and may be a valuable covariate in the analysis of change over time. It is also suggested that selected extensive sites be established at Ninagiak Island where other sampling protocols were instituted. This site appears to be important breeding and feeding grounds for a variety of birds and mammals and harbor rich intertidal communities.

3 Marine Birds

INTRODUCTION

Marine birds and mammals are important constituents of marine ecosystems and 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, Barrows (*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, Barrows 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 in June and July, 2006. 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 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 (Figure 3.1).

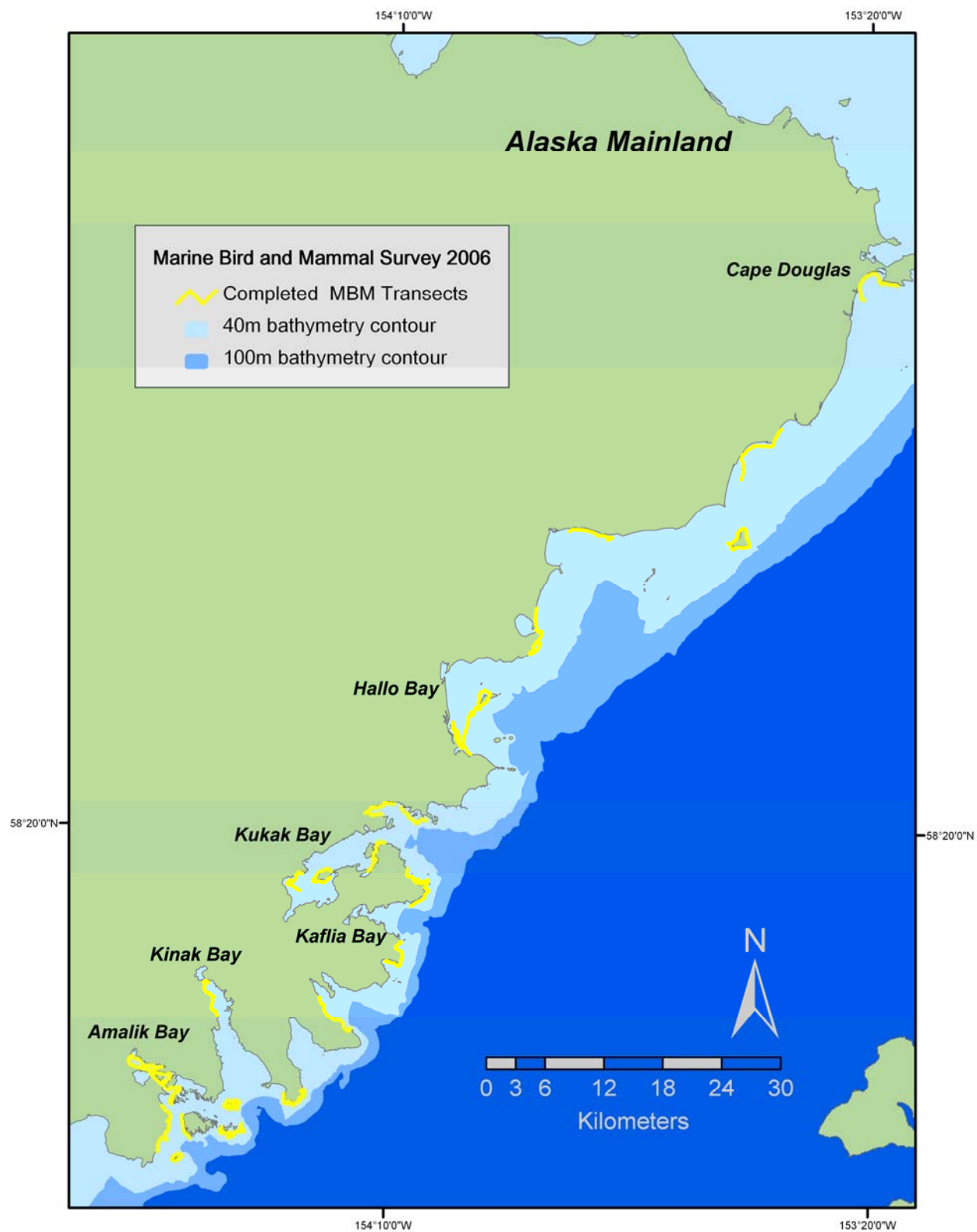


Figure 3.1 Locations of marine bird and mammal transects sampled in KATM, June 2006.

RESULTS

Between June 23 and June 30, 2006 we surveyed 25 shoreline transects in KATM. Transect lengths ranged from 1.2 km to 16.4 km and averaged 6.4 km. We sampled approximately 159 km, or about 24.5% of the shoreline in the KATM sampling block. The most common birds observed were the glaucous-winged gull ($87.2/\text{km}^2$), and the black-legged kittiwake ($58.4/\text{km}^2$). Species considered reliant on nearshore habitats included the harlequin duck ($16.9/\text{km}^2$, $\text{se}=3.4$); the surf scoter ($20.9/\text{km}^2$, $\text{se}=19.3$), the common merganser ($5.1/\text{km}^2$, $\text{se}=3.5$), and the red-breasted merganser ($0.3/\text{km}^2$, $\text{se}=0.2$). Densities of other marine birds and mammals detected on shoreline transects can be found in Table 3.1.

Sea otters were the most widely distributed marine mammal and were observed on 10 of 24 transects. Steller sea lions had the highest density of the marine mammals at $6.2/\text{km}^2$ ($\text{se}=6.2$) followed by sea otters with a density of $5.7/\text{km}^2$ (including pups) ($\text{se}=0.5$). Densities were calculated using unweighted averages.

Distribution maps for marine bird and mammals that were relatively abundant or of special interest (e.g. loons and murrelets) are given in Figures 3.2 through 3.14. Harlequin ducks, black oystercatchers, glaucous-winged gulls, black-legged kittiwakes, sea otters, and harbor seals were relatively abundant and uniformly distributed along the shore. Other species, including the scoters, cormorants, mew gulls, puffins, common mergansers, and Steller sea lions were relatively abundant but had highly aggregated distributions. Red-breasted mergansers, Pacific loons, and murrelets were rare.

Table 3.1. Species and densities (se) of marine birds and mammals in the nearshore marine zone in KATM, June 2006. Approximately 25% 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
Arctic tern (<i>Sterna paradisaea</i>)	4	1	3	7	0.3	0.2
Auklets (<i>Alcidae</i> sp.)	1	24	24	24	0.5	0.5
Bald eagle (<i>Haliaeetus leucocephalus</i>)	60	1	2	68	2.2	0.3
Black-legged kittiwake (<i>Rissa tridactyla</i>)	46	1	275	1616	58.4	28.6
Black oystercatcher (<i>Haematopus bachmani</i>)	43	1	11	93	3.2	1.2
Unid. Murrelet (<i>Brachyramphus</i> sp.)	1	2	2	2	0.1	0.1
Cassin's Auklet (<i>Ptychoramphus aleuticus</i>)	4	2	15	28	0.8	0.8
Common eider (<i>Somateria mollissima</i>)	3	1	7	9	1.5	1.5
Common merganser (<i>Mergus merganser</i>)	14	1	124	179	5.1	3.5
Common Murre (<i>Uria aalge</i>)	2	1	5	6	0.2	0.2
Crested auklet (<i>Aethia cristatella</i>)	1	4	4	4	0.1	0.1
Double-crested cormorant (<i>Phalacrocorax auritus</i>)	10	1	9	29	1.1	0.8
Glaucous gull (<i>Larus hyperboreus</i>)	1	2	2	2	0.0	0.0
Glaucous-winged gull (<i>Larus glaucescens</i>)	172	1	280	2337	87.2	23.3
Harlequin duck (<i>Histrionicus histrionicus</i>)	81	1	40	502	16.9	3.4
Horned puffin (<i>Fratercula corniculata</i>)	24	1	75	203	20.0	17.3
Kittlitz's murrelet (<i>Brachyramphus brevirostris</i>)	1	2	2	2	0.1	0.1
Mallard (<i>Anas platyrhynchos</i>)	3	1	5	7	0.3	0.3
Marbled murrelet (<i>Brachyramphus marmoratus</i>)	4	1	2	7	0.3	0.2
Mew gull (<i>Larus canus</i>)	6	1	32	58	1.5	1.0
Northern crow (<i>Corvus caurinus</i>)	28	1	3	36	1.2	0.4
Pacific loon (<i>Gavia pacifica</i>)	2	1	3	4	0.1	0.1
Pelagic cormorant (<i>Phalacrocorax pelagicus</i>)	14	1	800	1014	31.0	27.8
Pigeon guillemot (<i>Cephus columba</i>)	107	1	12	277	8.6	2.3
Red-breasted merganser (<i>Mergus serrator</i>)	3	1	4	9	0.3	0.2
Red-faced cormorant (<i>Phalacrocorax urile</i>)	26	1	121	581	18.2	11.5
Surf scoter (<i>Melanitta perspicillata</i>)	3	2	18	22	0.3	0.2
Tufted puffin (<i>Fratercula cirrhata</i>)	18	1	210	246	6.7	4.9
Unid. Cormorant (<i>Phalacrocoracidae</i> sp.)	5	1	240	324	19.1	14.9
Unid. Goldeneye (<i>Bucephala</i> sp.)	1	1	1	1	0.0	0.0
Unid. Gull (<i>Laridae</i> sp.)	22	1	9	35	1.3	0.5
Unid. Loon (<i>Gavia</i> sp.)	2	1	2	3	0.1	0.1
Unid. Scoter (<i>Melanitta</i> sp.)	2	1	4	5	0.2	0.2
White-winged scoter (<i>Melanitta fusca</i>)	7	1	108	176	20.9	19.3

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Table 3.1 con't.

Species	# of groups observed	Min	Max	Sum	Average density (#/km ²)	SE
Marine Mammals						
Harbor seal (<i>Phoca vitulina</i>)	40	1	19	100	2.8	1.2
Sea otter (adult) (<i>Enhydra lutris</i>)	54	1	39	130	4.9	0.5
Sea otter (pup) (<i>Enhydra lutris</i>)	15	1	8	24	0.8	0.4
Steller sea lion (<i>Eumetopias jubatus</i>)	7	1	74	103	6.2	6.2
River otter (<i>Lutra canadensis</i>)	1	1	1	1	0.0	0.0

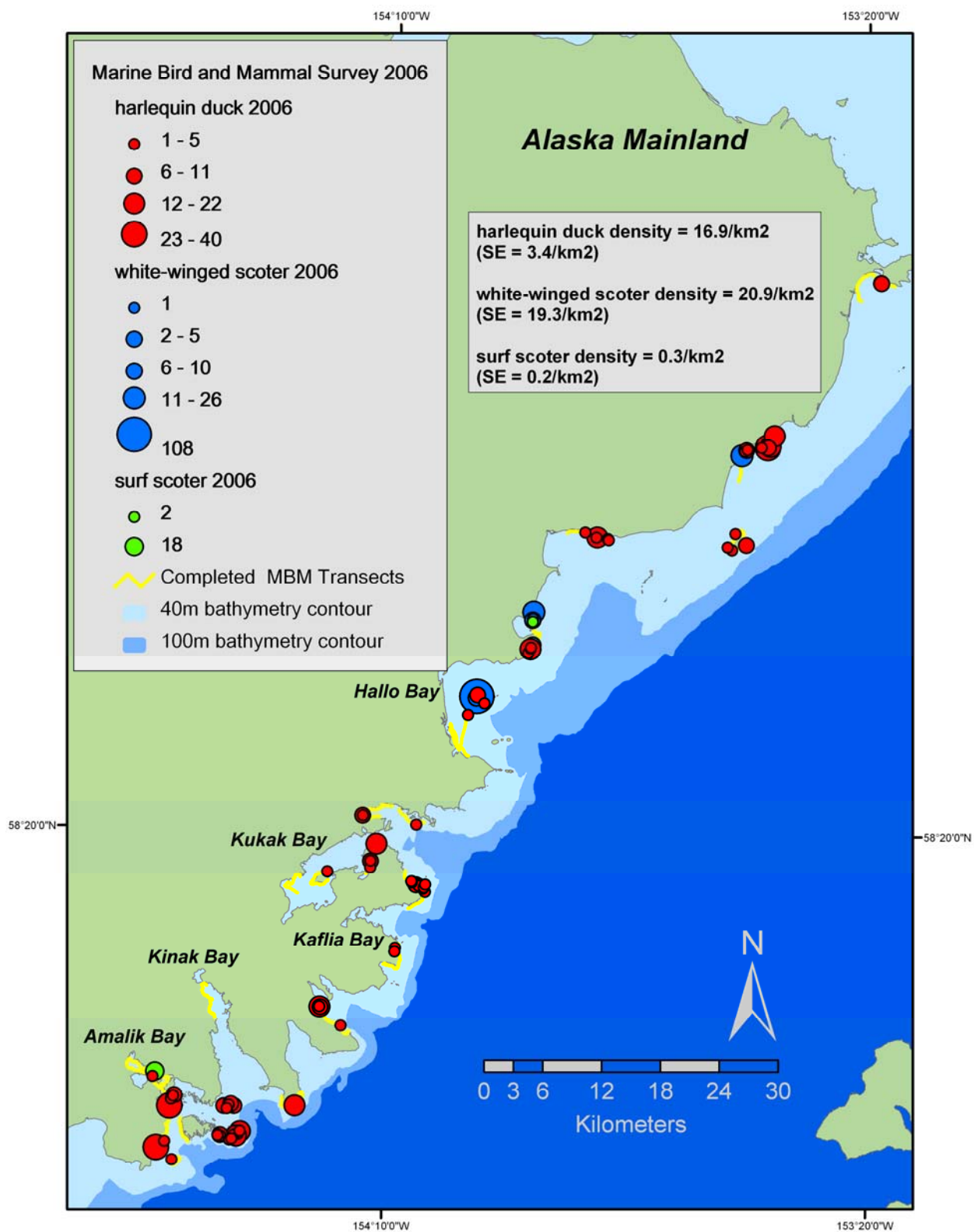


Figure 3.2. Distribution, abundance, and density of sea ducks (harlequin duck, white wing scoter and surf scoter) in block 10 KATM, June 2006.

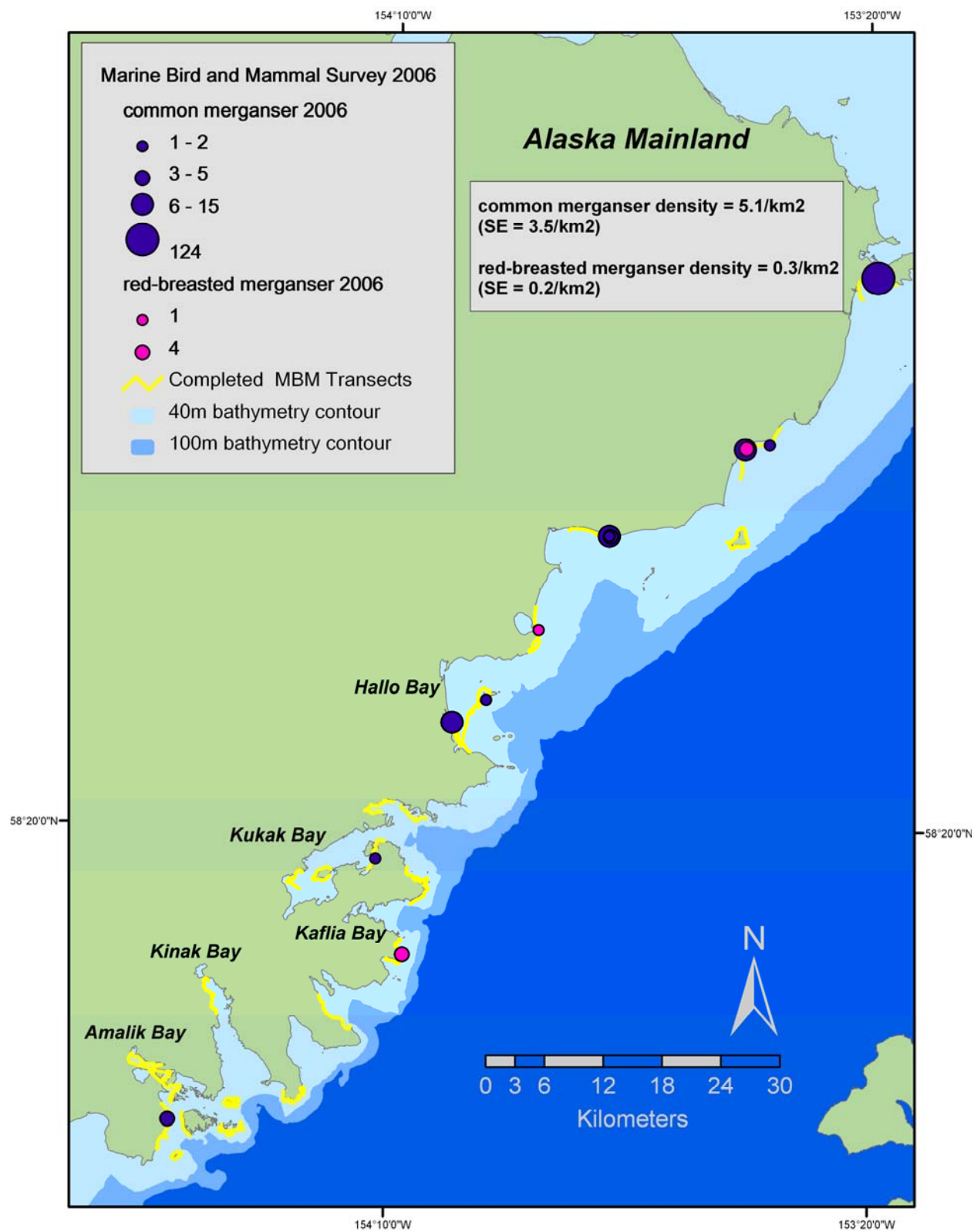


Figure 3.3. Distribution, abundance, and density of common and red-breasted mergansers in block 10 KATM, June 2006.

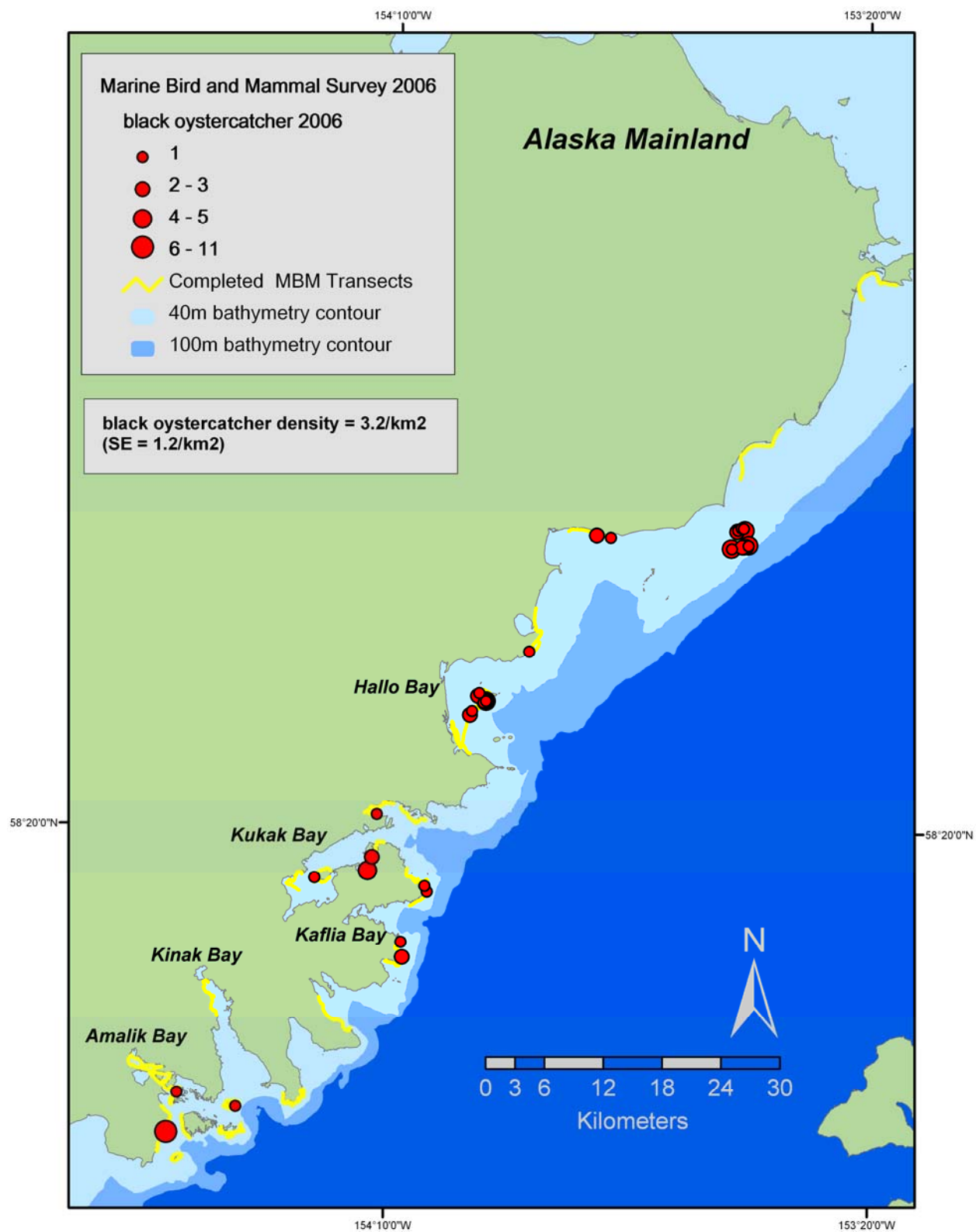


Figure 3.4. Distribution, abundance, and density of black oystercatchers in block 10 KATM, June 2006.

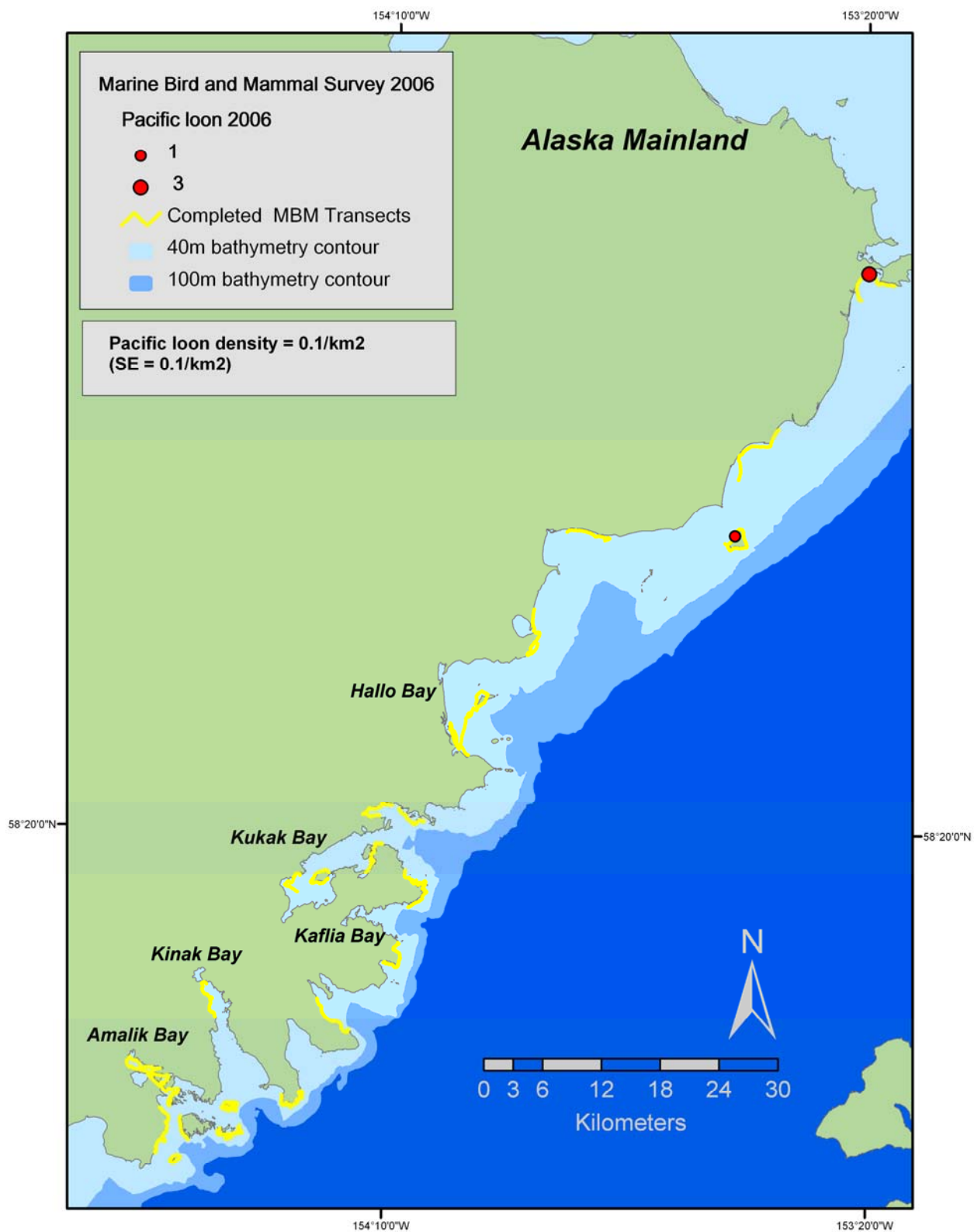


Figure 3.5. Distribution, abundance, and density of Pacific loons in block 10 KATM, June 2006.

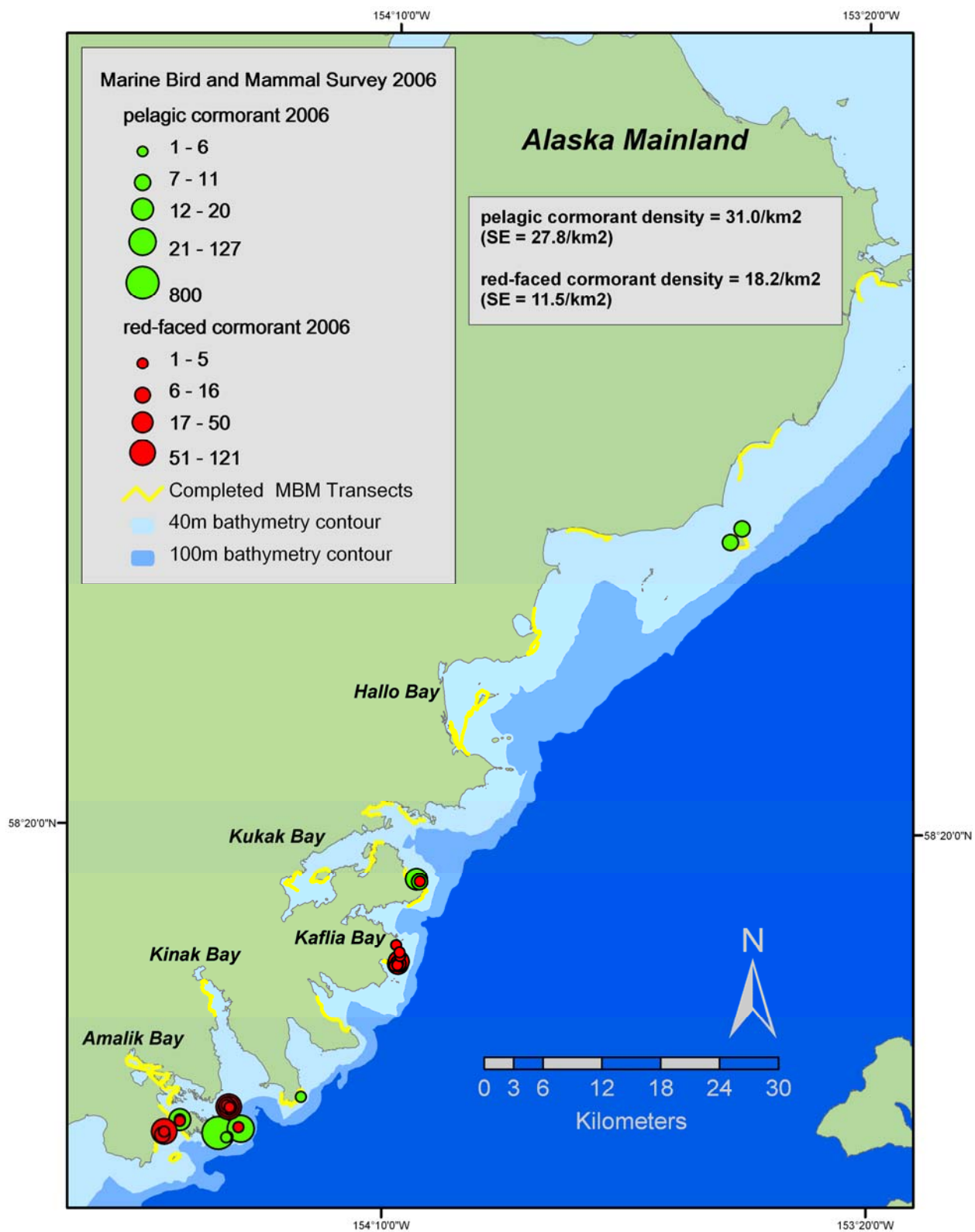


Figure 3.6. Distribution, abundance, and density of pelagic and red-faced cormorants in block 10 KATM, June 2006.

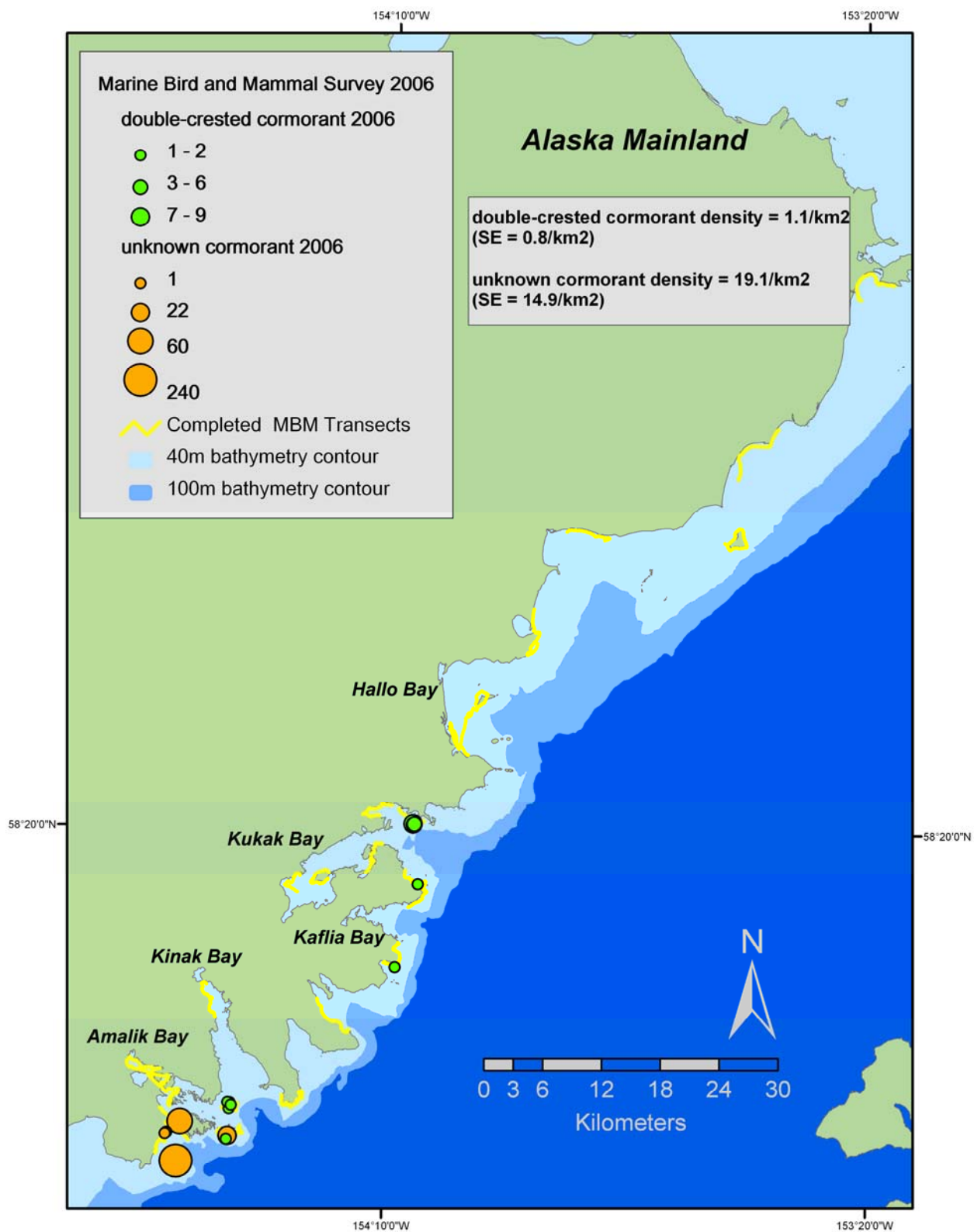


Figure 3.7. Distribution, abundance, and density of unidentified and double crested cormorants in block 10 KATM, June 2006.

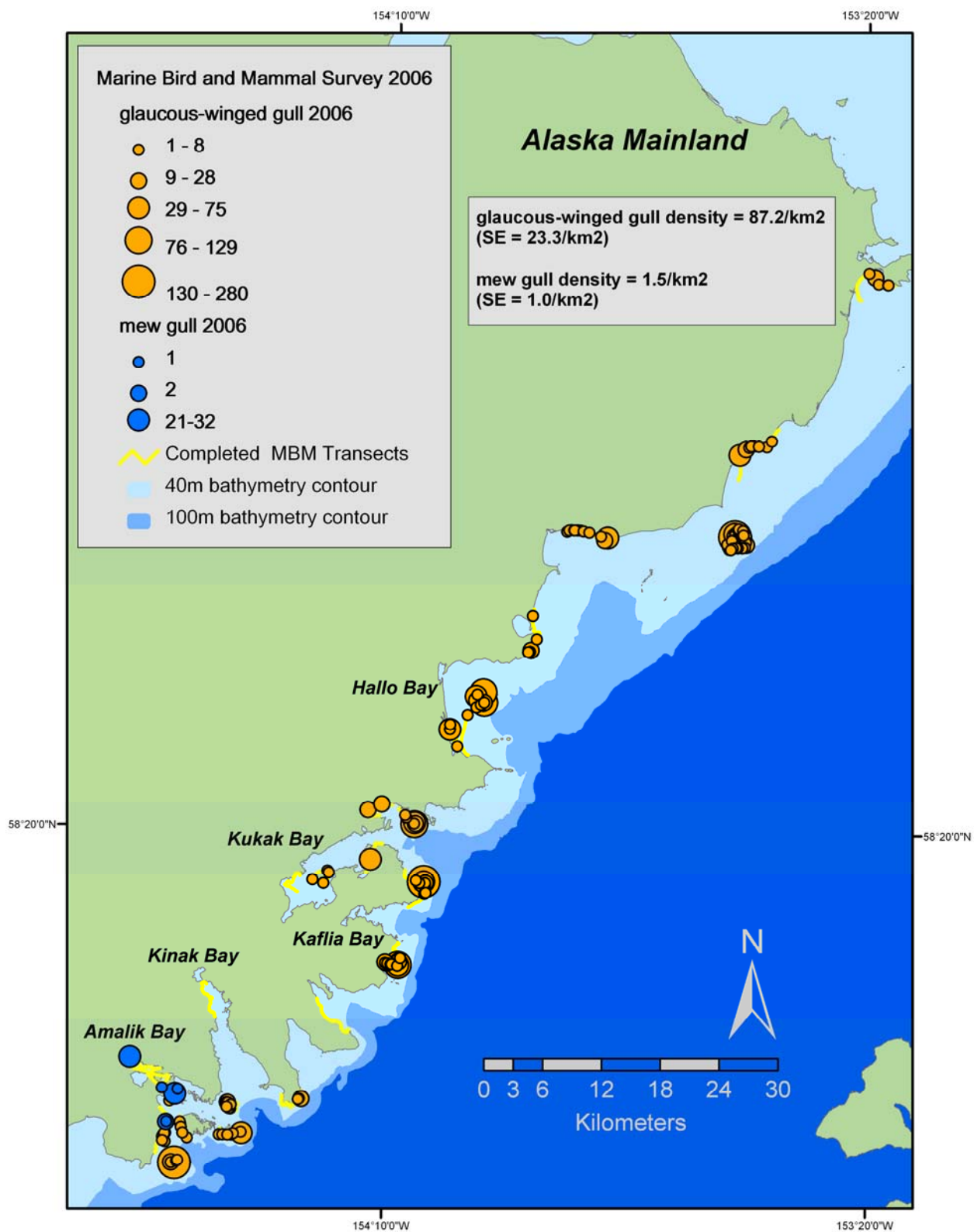


Figure 3.8. Distribution, abundance, and density of glaucous-winged and mew gulls in block 10 KATM, June 2006.

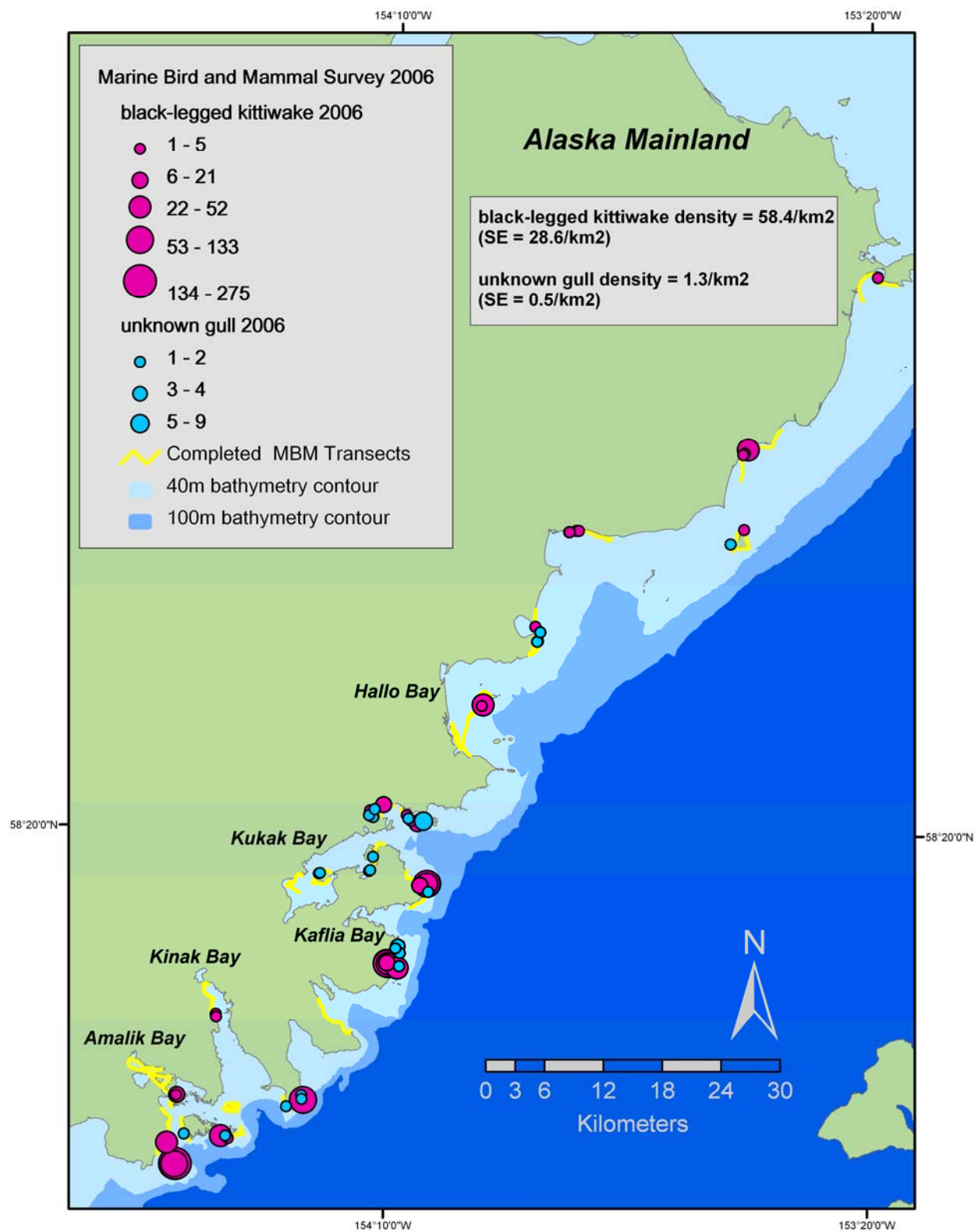


Figure 3.9. Distribution, abundance, and density of black-legged kittiwakes and unidentified gulls in block 10 KATM, June 2006.

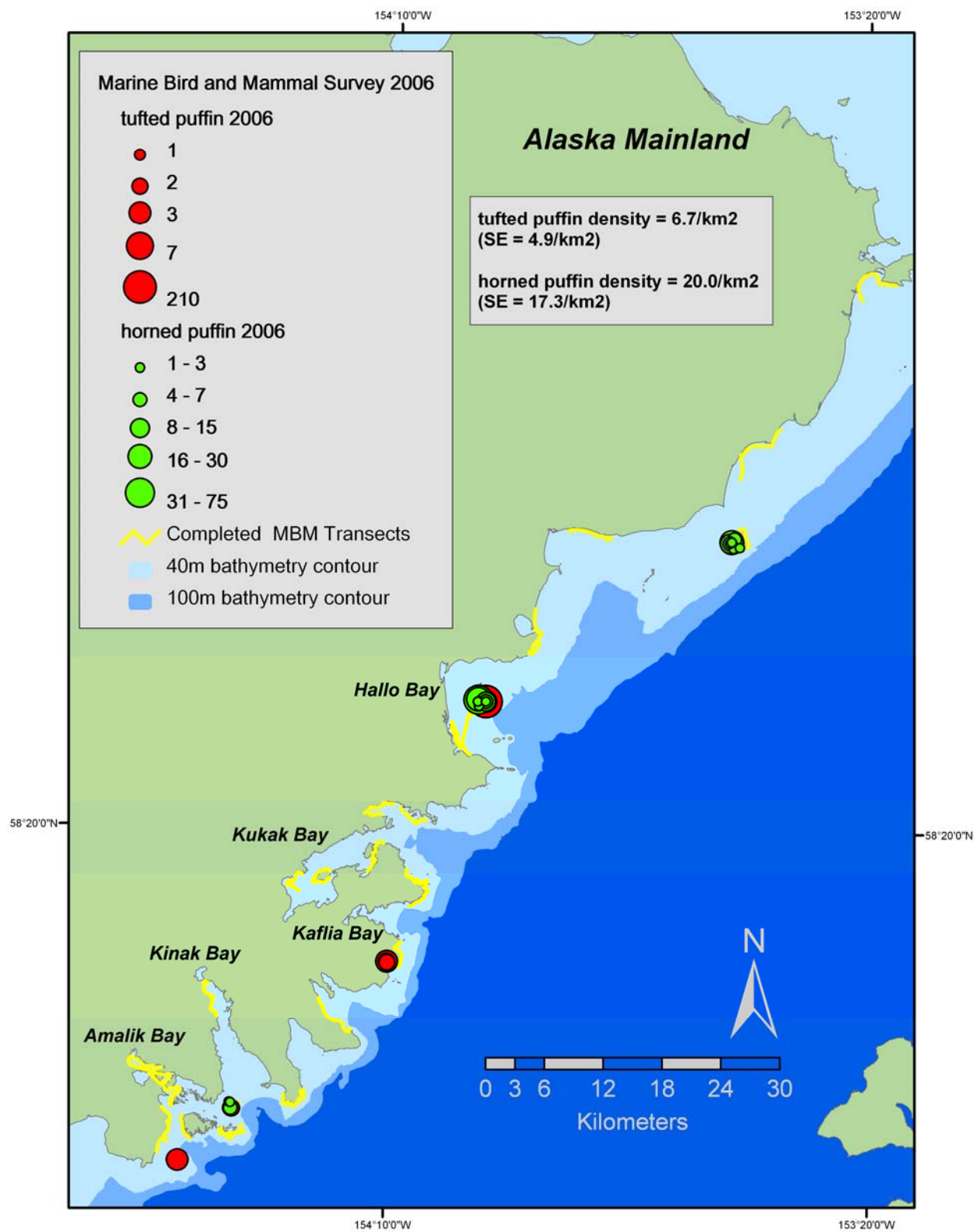


Figure 3.10. Distribution, abundance, and density of tufted and horned puffins in block 10 KATM, June 2006.

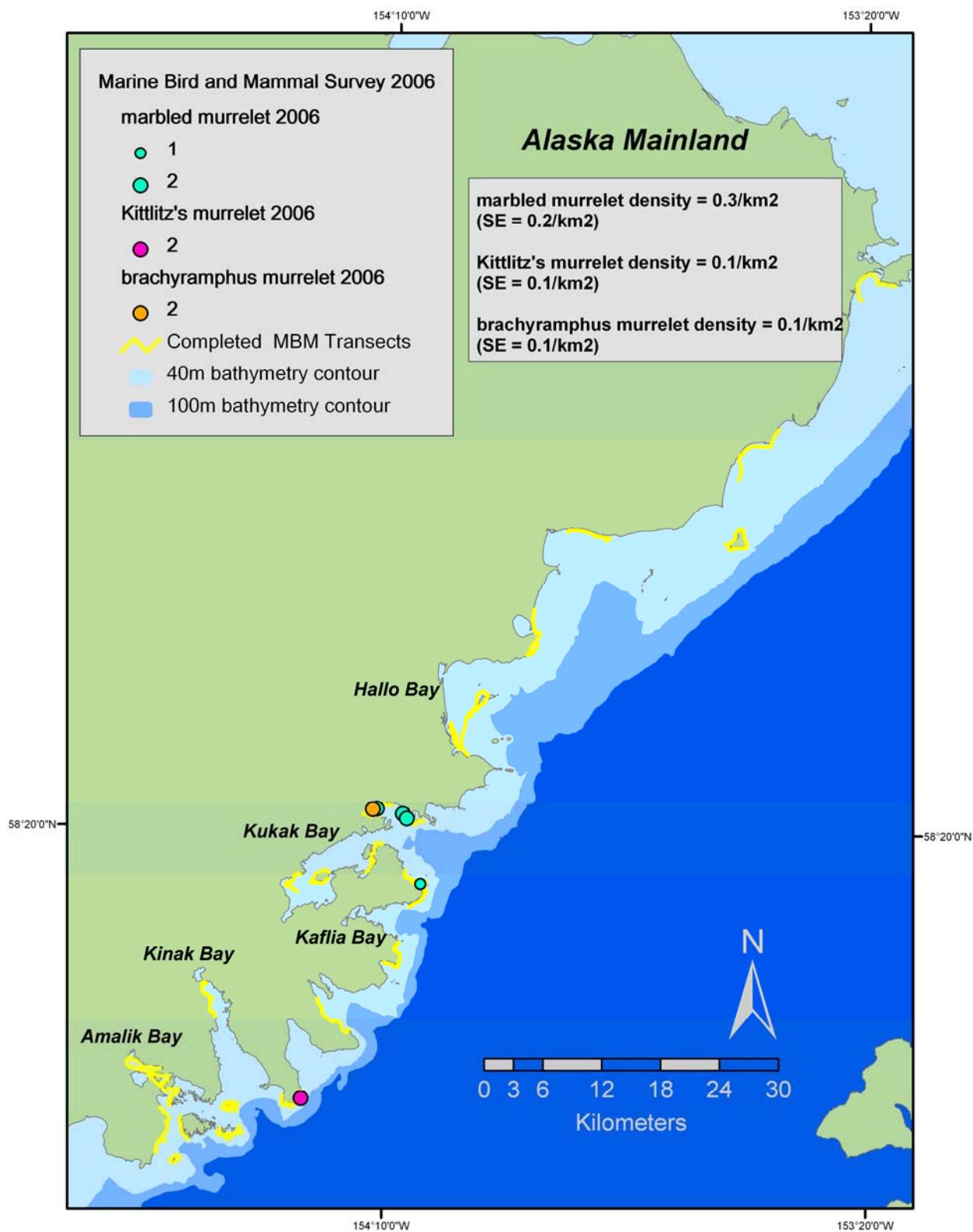


Figure 3.11. Distribution, abundance, and density of marbled, Kittlitz's, and unidentified branchyramphus murrelets in block 10 KATM, June 2006.

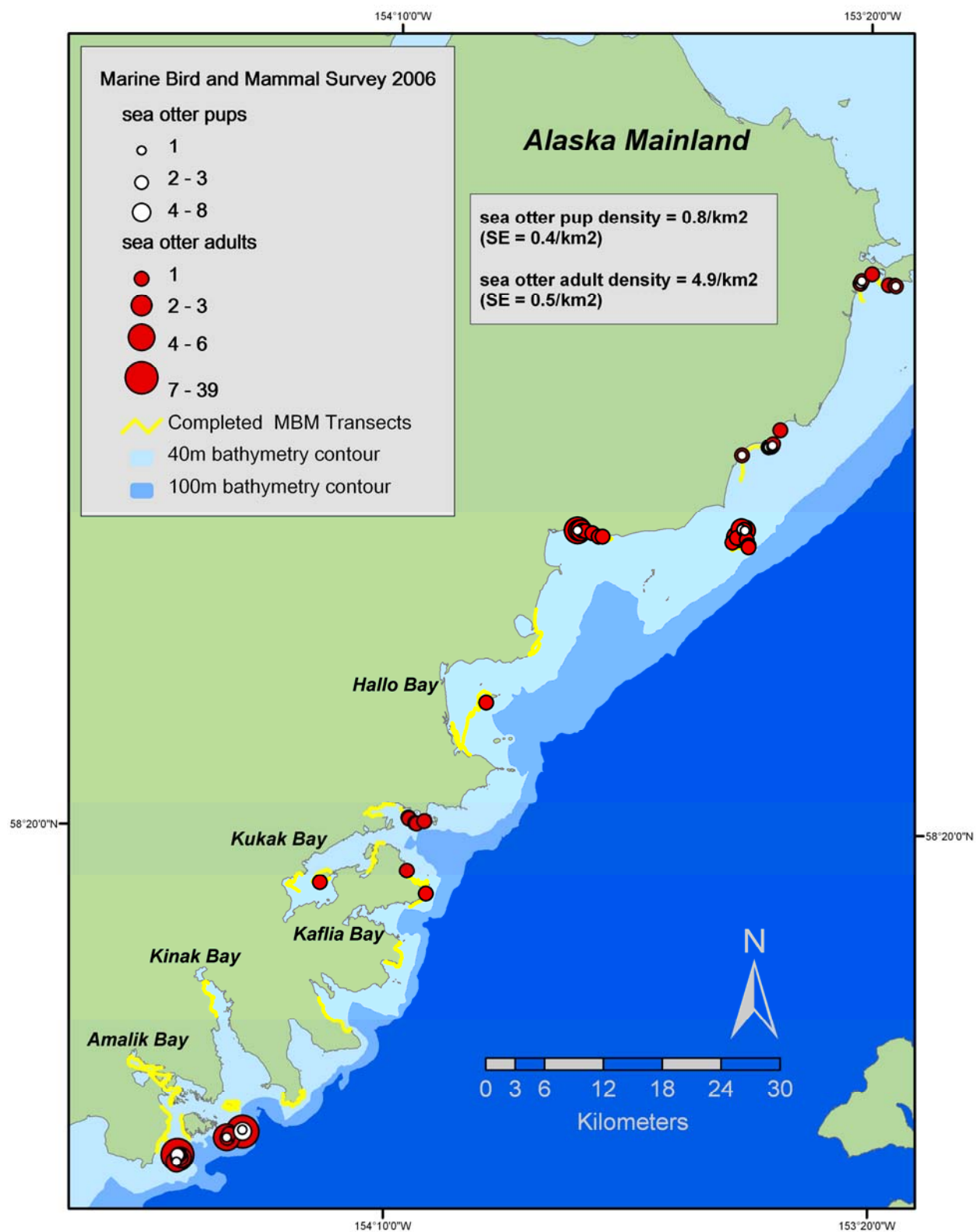


Figure 3.12. Distribution, abundance, and density of sea otters in block 10 KATM, June 2006.

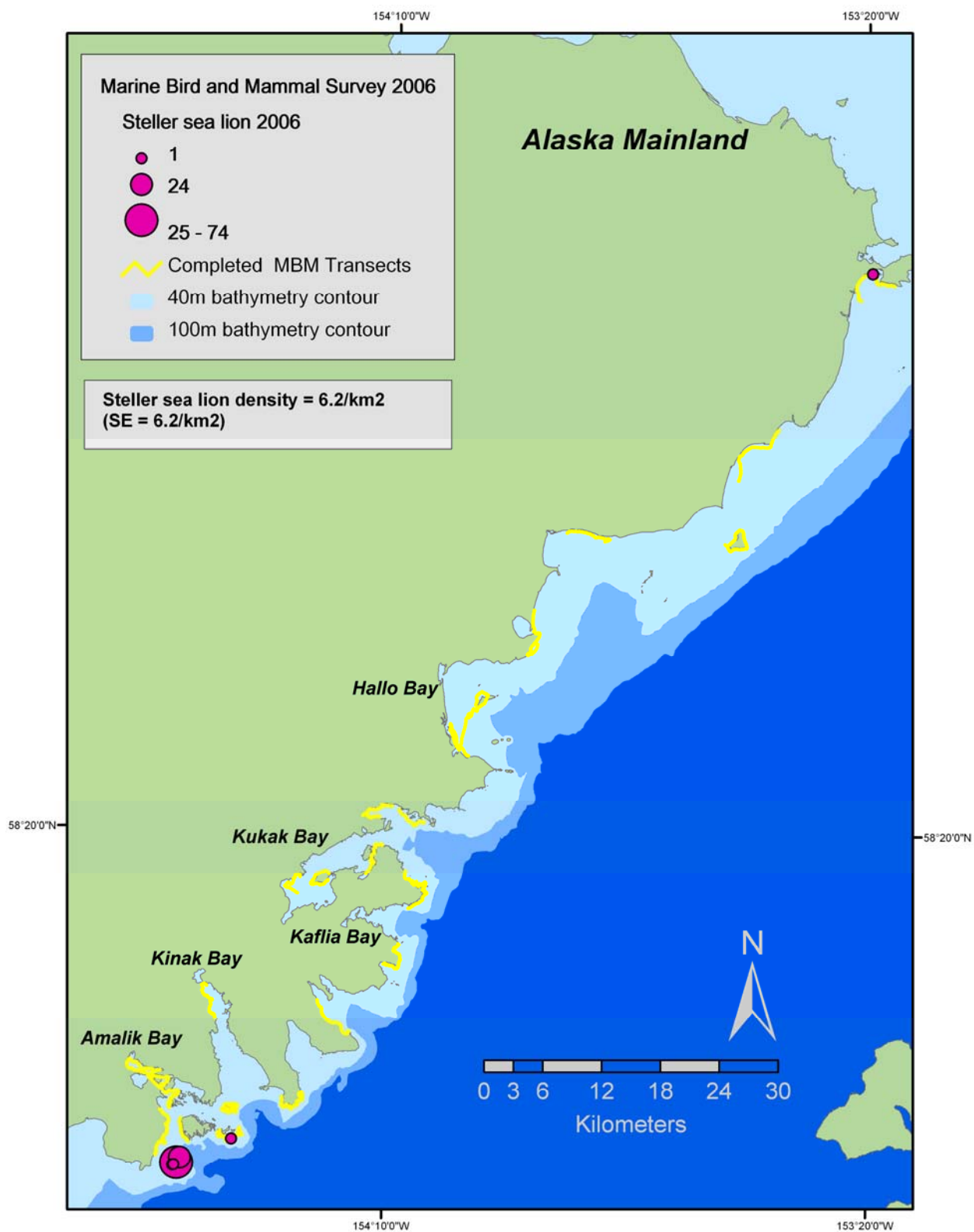


Figure 3.13. Distribution, abundance, and density of Steller sea lions in block 10 KATM, June 2006.

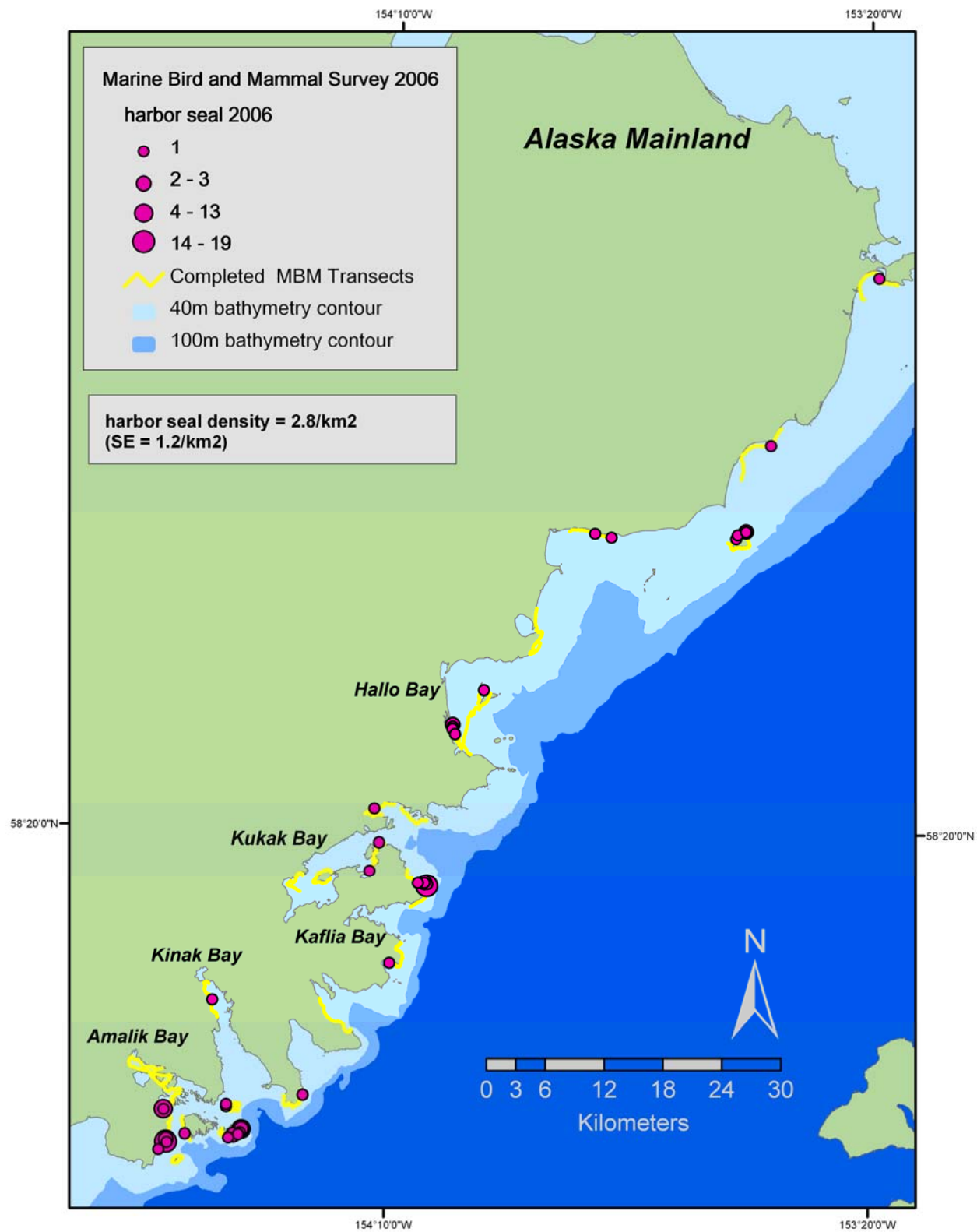


Figure 3.14. Distribution, abundance, and density of harbor seals in block 10 KATM, June 2006.

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. Because we only sampled 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, 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 (<20 m) habitats > 200 m offshore should be considered. Additionally, 5 km transects centered at each of the intensive intertidal sites should be established. Similar surveys should be conducted during the late winter period (March) 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 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 ecologically and socially 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 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 (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. 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 and breeding territory density and occupancy 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; 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 centered on each intertidal invertebrate and algal site (Figure 4.1). In addition, oystercatcher abundance, productivity, and diet data were collected from a selected site at Ninagiak Island and its surrounding islets in Hallo Bay (Figure 4.1).

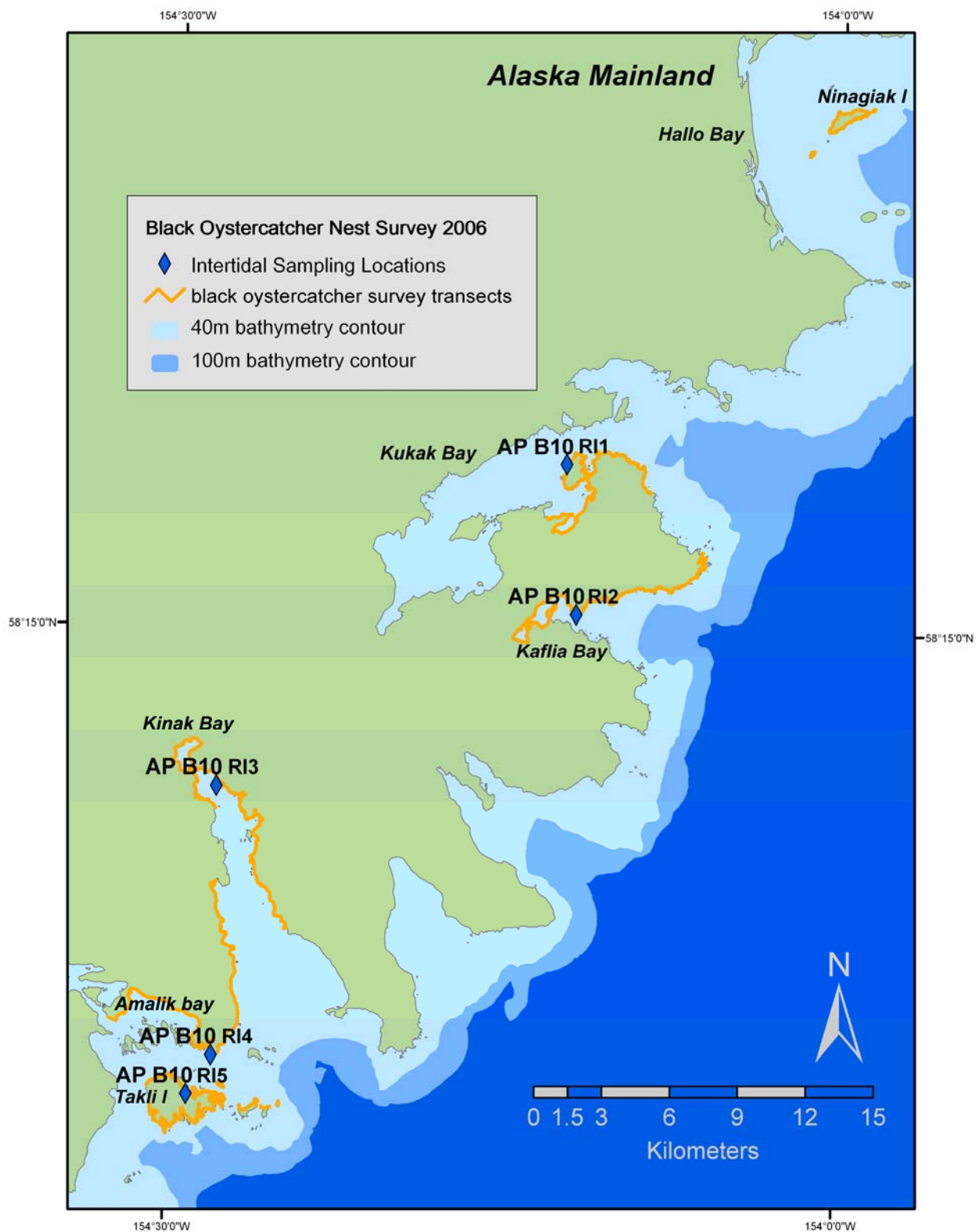


Figure 4.1. Location of transects for black oystercatcher nest surveys in KATM, June 2006.

Black oystercatcher breeding territories and nest sites were located and sampled by three observers traveling slowly and methodically along prescribed transects (Fig. 4.1) 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 4.2). Nests, eggs (Figure 4.3), and chicks (Figure 4.4) 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 4.5) was a conspicuous behavior used to determine if a nest was present. A GPS was employed to identify the track line of the survey skiff and identify the positions of all oystercatcher nests.



Figure 4.2. 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 4.3. 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 (not occupied, no eggs, chicks, or adults, only applies to nests active in previous years, not applicable to data collected in 2006), 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 4.4. Black oystercatcher chick (in center of photo).



Figure 4.5. 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 nests and 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 also searched for the presence of shell remains indicative of adult birds provisioning their chicks (Figure 4.6). Not all nest sites had prey remains. For example if eggs were not hatched or were depredated prior to hatching, shell prey remains are absent. 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 equaled or exceeded 20 individuals.



Figure 4.6. Shell remains of black oystercatcher prey collected from nest site 4, AP B10 RI1, block 10 KATM, June 2006.

RESULTS

The mean density of black oystercatchers was $3.2/\text{km}^2$ (Section 3, Table 3.1 and Figure 3.4). Individuals were relatively widely distributed along the KATM shoreline, with the highest densities observed at Ninagiak Island and in Kukak Bay. We located a total of 18 black oystercatcher nests on the 6 transects surveyed for nest density (Figure 4.7). 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.

Generally, a pair of adults was present at each nest, except three adults were seen at nest 3 at Kukak Bay (Table 4.2). Of the 18 nests found, 16 were active and two had failed. Chicks were most common at Kukak with nine chicks found at four nests (Table 4.3). At the other five transects only three chicks were found at 14 nests, but 13 eggs were located in 11 of those nests where chicks were absent. The two failed nests were found at Amalik Bay and Takli Island. Overall we encountered 0.25 nests/km and nest production was 1.4 eggs or chicks per nest (Table 4.2).

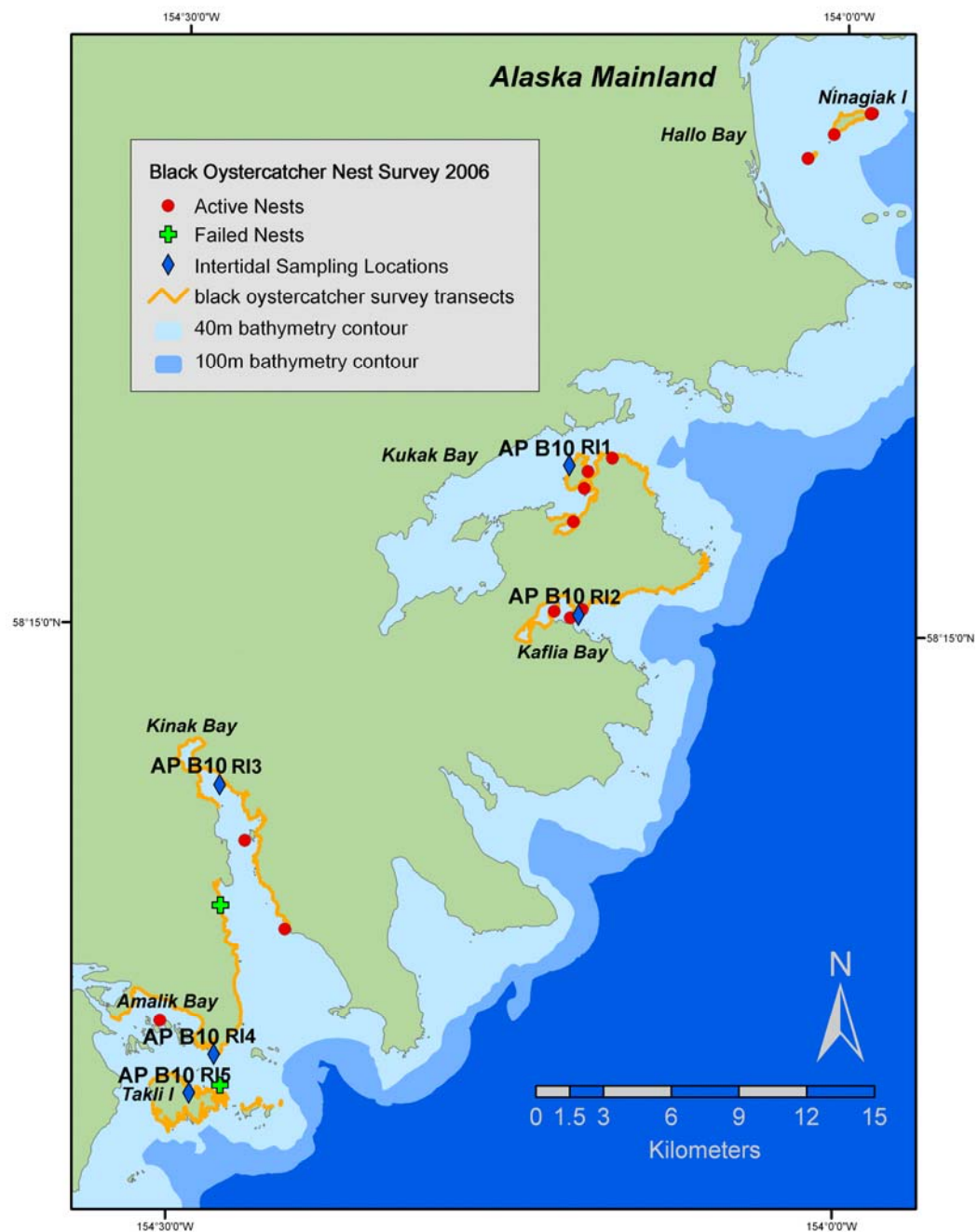


Figure 4.7. Locations of black oystercatcher transects and nest sites in KATM block 10, June 2006.

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. A = active nest; F= failed nest. UNK = unknown number of chicks, nest assumed active and chicks not detected.

Site	Length	Nest site #	Status	# Adults	# Eggs	# Chicks	Prey collected
Kukak AP B10 RI1	20 km	1	A	2	0	2	N
		2	A	2	0	2	Y
		3	A	3	0	2	Y
		4	A	2	0	3	Y
Kaflia AP B10 RI2	20 km	1	A	2	1	0	N
		2	A	2	1	1	Y
		3	A	2	1	0	N
Kinak AP B10 RI3	20 km	1	A	2	0	UNK	Y
		2	A	2	1	0	N
Amalik AP B10 RI4	20 km	1	F	2	0	0	Y
		2	A	2	3	0	N
Takli AP B10 RI5	22.5 km	1	F	2	1	0	N
Ninagiak Island	6.1 km	1	A	2	3	0	N
		2	A	2	0	1	Y
		3	A	2	0	UNK	Y
		4	A	2	0	1	Y
		5	A	2	0	UNK	Y
		6	A	2	3	0	N

Table 4.2. Black oystercatcher nest density and numbers of eggs and chicks per nest summarized by transect. 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	0.2	0	0	9	2.25	2.25
Kaflia AP B10 RI2	0.15	3	1	1	0.33	1.33
Kinak AP B10 RI3	0.1	1	0.5	0	0.00	0.50
Amalik AP B10 RI4	0.05	3	1.5	0	0.00	1.50
Takli AP B10 RI5	0.04	1	1	0	0.00	1.00
Ninagiak Island	1.0	6	1	2	0.50	1.50
Means (#/km)	0.25		0.83		0.51	1.35
Se	0.15		0.21		0.36	0.24

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 of the 18 nest sites (Table 4.2). Of the 10 nests where chicks were present, nine provided shell collections and one did not. Of the seven nests where eggs only were present, none provided shell remains.

We collected 519 shell remains from 10 nests represented by 13 species (Table 4.2). The mean number of shell remains per nest was 52 (se=12.9) and sample sizes ranged from 6-137. An average of five species of prey per nest (se=0.5) were identified from the collections and ranged from 3-8. Five prey species accounted for 89% of all prey items (Table 4.2). *Mytilus trossulus* and *Tectura persona* were the predominant prey (26% each), followed by *Tectura scutum* (20%) and *Lottia pelta* (17%). *Katharina tunicata* and *Buccinum baeri* contributed 4% and 5% to the total, respectively. 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 4.8). The mussel, *Mytilus trossulus*, was found at each nest site, contributing from 6-90% of the total. As a group, limpets were present at all nests and numerically dominant among all prey. *Tectura scutum*, found in 80% of the nest contributed from 0-37% of prey by nest. *Tectura persona*, found in 60% of the nests contributed from 0-86% of prey by nest. *Lottia pelta* was found in 70% of the nests and contributed from 0-38% of prey by nest (Figure 4.8).

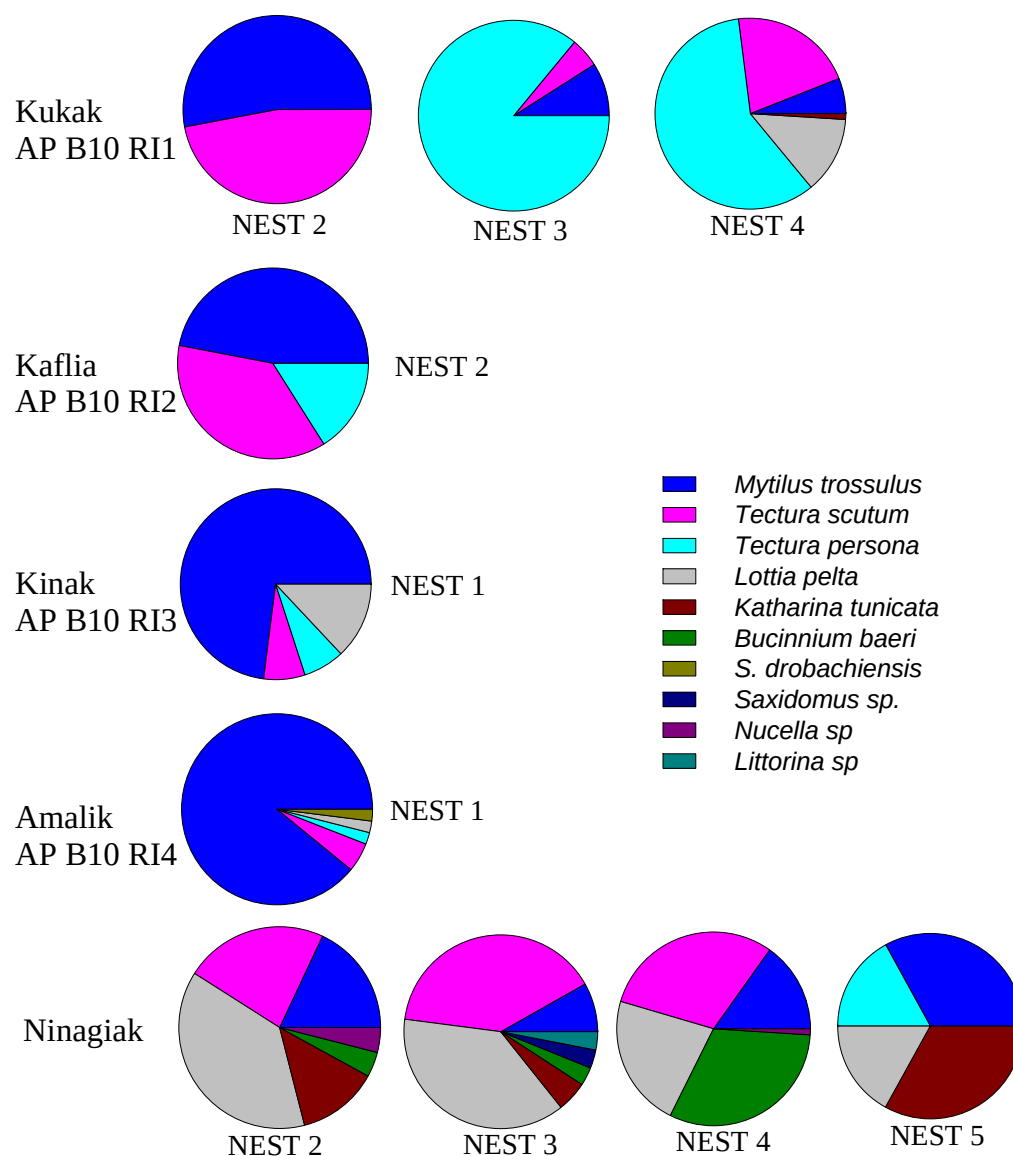


Figure 4.8. Species composition of prey collected from black oystercatcher nests KATM, June 2006. Each chart represents prey collected from one nest site and nest name and numbers correspond to individual nest identified in Table 4.2.

Table 4.2. Species composition, mean sizes, standard errors and total number of prey of each species by nest collected at four of the intensive sites and the selected intensive site. No prey were collected at Takli Island (AP B10 RI5) as the only nest found there was inactive. Mean sizes and standard errors are in millimeters. *S. droebachiensis* refers to the green urchin, *Strongylocentrotus droebachiensis*.

Site	Nest	Species	Mean Size (mm)	SE of size (mm)	Total Collected
AP B10 RI1	2	<i>Mytilus trossulus</i>	40.1	2.0	18
Kukak		<i>Tectura persona</i>	21.5	0.9	11
		<i>Tectura scutum</i>	26.3	3.2	3
	3	<i>Mytilus trossulus</i>	45.5	2.4	4
		<i>Tectura persona</i>	17.6	0.5	38
		<i>Tectura scutum</i>	22.0	1.0	2
	4	<i>Katharina tunicata</i>	34.0	NA	1
		<i>Lottia pelta</i>	21.9	1.1	18
		<i>Mytilus trossulus</i>	42.8	2.1	8
		<i>Tectura persona</i>	22.0	0.4	81
		<i>Tectura scutum</i>	26.7	1.0	29
AP B10 RI2	2	<i>Humilaria kennereyi</i>	31.0	NA	1
Kafila		<i>Mytilus trossulus</i>	41.1	2.1	9
		<i>Saxidomus gigantea</i>	36.5	3.5	2
		<i>Tectura persona</i>	17.0	NA	1
		<i>Tectura scutum</i>	35.2	4.3	6
AP B10 RI3	1	<i>Tectura scutum</i>	30.0	NA	1
Kinak		<i>Tectura persona</i>	22.0	NA	1
		<i>Lottia pelta</i>	27.0	1.0	2
		<i>Mytilus trossulus</i>	50.0	1.6	11
AP B10 RI4	1	<i>Lottidae sp.</i>	17.0	NA	1
Amalik		<i>Mytilus trossulus</i>	45.3	1.1	54
		<i>S. droebachiensis</i>	29.0	NA	1
		<i>Tectura persona</i>	26.0	NA	1
		<i>Tectura scutum</i>	16.0	1.7	3
Ninagiak	2	<i>Buccinum baeri</i>	23.3	2.8	4
		<i>Katherina tunicata</i>	37.2	1.9	13
		<i>Lottia digitalis</i>	14.0	NA	1
		<i>Lottia pelta</i>	22.9	0.8	38
		<i>Mytilus trossulus</i>	35.4	1.7	18
		<i>Nucella sp.</i>	23.5	1.3	4
		<i>Tectura scutum</i>	29.8	1.1	23
	3	<i>Buccinum baeri</i>	12.0	NA	1
		<i>Katherina tunicata</i>	30.0	3.0	2
		<i>Littorina sitkana</i>	13	NA	1
		<i>Lottia digitalis</i>	15	NA	1
		<i>Lottia pelta</i>	19.4	0.8	14
		<i>Mytilus trossulus</i>	35.3	0.9	3
		<i>Saxidomus gigantea</i>	29	NA	1
		<i>Tectura scutum</i>	23.1	2.0	15
	4	<i>Buccinum baeri</i>	23.5	0.5	21
		<i>Lottia digitalis</i>	12.0	NA	1
		<i>Lottia pelta</i>	19.7	0.6	14
		<i>Mytilus trossulus</i>	32.6	2.1	10
		<i>Nucella lamalossa</i>	32.0	NA	1
		<i>Tectura scutum</i>	26.1	1.0	20
	5	<i>Katherina tunicata</i>	29.5	10.5	2
		<i>Lottia pelta</i>	14.0	NA	1
		<i>Mytilus trossulus</i>	29.0	1.0	2
		<i>Tectura persona</i>	24.0	NA	1

Table 4.3. 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 Takli Island (AP B10 RI5) as the only nest found there was inactive..

Species	Site	Mean Size (mm)	SE of size (mm)	Total Collected
<i>Lottia pelta</i>	AP B10 RI1 Kukak	21.9	1.1	18
	AP B10 RI2 Kafliia			
	AP B10 RI3 Kinak	27.0	1.0	2
	AP B10 RI4 Amalik			
	Ninagiak	21.3	0.5	67
<i>Tectura scutum</i>	AP B10 RI1 Kukak	26.4	0.9	34
	AP B10 RI2 Kafliia	35.2	4.3	6
	AP B10 RI3 Kinak	30.0		1
	AP B10 RI4 Amalik	16.0	1.7	3
	Ninagiak	26.8	0.8	58
<i>Tectura persona</i>	AP B10 RI1 Kukak	20.6	0.3	130
	AP B10 RI2 Kafliia	17.0		1
	AP B10 RI3 Kinak	22.0		1
	AP B10 RI4 Amalik	26.0		1
	Ninagiak	24.0		1
<i>Mytilus trossulus</i>	AP B10 RI1 Kukak	41.5	1.4	30
	AP B10 RI2 Kafliia	41.1	2.1	9
	AP B10 RI3 Kinak	50	1.6	11
	AP B10 RI4 Amalik	45.3	1.1	54
	Ninagiak	34.2	1.2	33

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 8 of the 10 collections and *Katharina tunicata* the largest in the other two. In general, mussels collected from transects AP B10 RI1-RI4 were larger than mussels collected from Ninagiak Is. nests. Among all nests *Lottia pelta* averaged 26.7 mm and ranged from 13-34 mm (Fig. 4.9), *T. scutum* averaged 26.9 mm and ranged from 12-47 mm (Fig 4.10), and *Tectura persona* averaged 20.7 mm and ranged from 11-30 mm (Fig 4.11). *Mytilus trossulus* averaged 41.9 mm and ranged from 17-57 mm among all sites (Fig. 4.12).

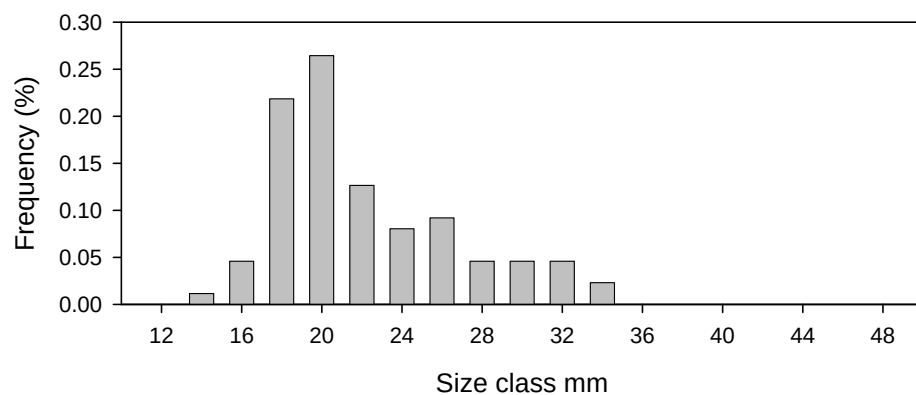


Fig. 4.9 . Size distribution of *Lottia pelta* collected from all black oystercatcher nest sites at block 10, KATM, June 2006 (n=87).

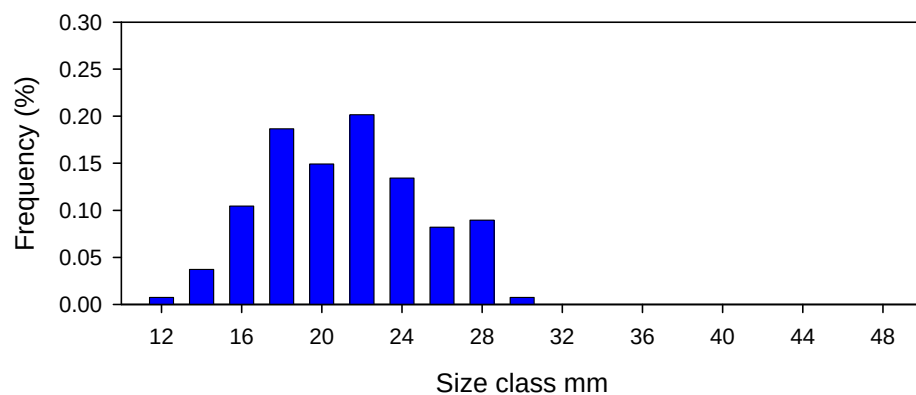


Fig. 4.10. Size distribution of *Tectura persona* collected from all black oystercatcher nest sites at block 10, KATM June 2006 (n=134).

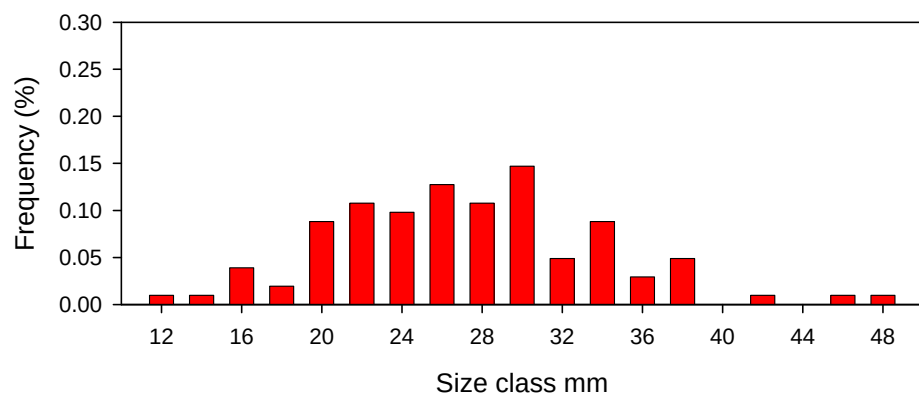


Fig. 4.11. Size distribution of *Tectura scutum* collected from all black oystercatcher nest sites at block 10, KATM June 2006 (n=102).

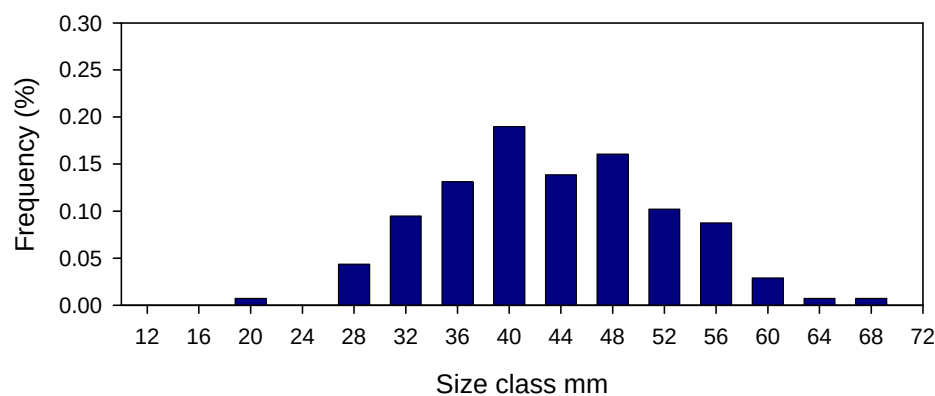


Fig. 4.12. Size distribution of *Mytilus trossulus* collected from all black oystercatcher nest sites block 10 KATM, June 2006 (n=137).

DISCUSSION

We encountered black oystercatcher nests on each of the systematic 20 km transects we sampled and the mean nest density of 0.10/km (or 2/20km) we estimated was at the lower range of anticipated within an expected range of 2-6 per 20 km in Prince William Sound, AK (Meyers 2002). The nest density on the selected transect at Ninagiak Island was higher (1.0/km) than on systematic transects and resulted in an overall average nest density of 0.25/km of shoreline. Perhaps noteworthy was the finding of a high number of chicks per nest, compared to eggs, at site AP B10 RI1 (Kukak Bay). It was also at the AP B10 RI1 intertidal site in Kukak Bay that predatory sea stars were absent and that both mussels and limpets were larger than at the other intertidal sites.

The recovery of prey shell remains from nine of ten nest sites where chicks were present 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*) were the dominant prey item represented in the shell remains (63%) followed, by the mussel *Mytilus trossulus* (20%). Strong dietary diversity was evident at the level of the individual nest 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 (Fig. 2.10 and 2.11) suggesting size selective predation by the adult oystercatchers.

RECOMMENDATIONS

Surveys of black oystercatcher abundance, nest density, and diet as reflected through prey remains brought to provision chicks were successfully implemented. We recommend continued sampling with little revision. 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.

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 abundance from the marine bird and mammal surveys, 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 will be obtained using aerial survey methods to be initiated in 2007.

METHODS

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 (range 1.2-16.4 km) in length, which cover approximately 24.5% 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. One pre-selected transect in Hallo Bay was largely an unexposed reef and was replaced by one around the perimeter of Ninagiak Island. Two transects near the southern limit of the study area were originally selected for sampling were not sampled due to time and travel logistics. All transects were centered 100 m offshore from the shoreline and included sampling offshore islands. 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.

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 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 otters 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, the mean size of prey recovered, and the mean energy obtained per hour of foraging. The latter is derived from prey type, prey size, number of prey, and reported caloric values and weight/length relationships of each prey along with forage dive success rates and mean dive and prey handling times (see Kvitek et al. 1992, Doroff and DeGange 1994, Dean et al. 2002).

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 2006 we surveyed sections of open coastline as well as sea otter haul out sites to recover sea otter carcasses. Skulls of sea otters were collected to provide data on age-at-death. 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).

RESULTS

Sea otters were encountered on 10 of the 24 coastline transects. A total of 130 adults and 24 pups were observed, resulting in a mean density of 5.7 sea otters per km² (Table 5.1). 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 (Figure 5.1).

Table 5.1. Marine bird and mammal 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 adults (<i>Enhydra lutris</i>)	54	1	39	130	4.9	0.5
Sea otter pups (<i>Enhydra lutris</i>)	15	1	8	24	0.8	0.4

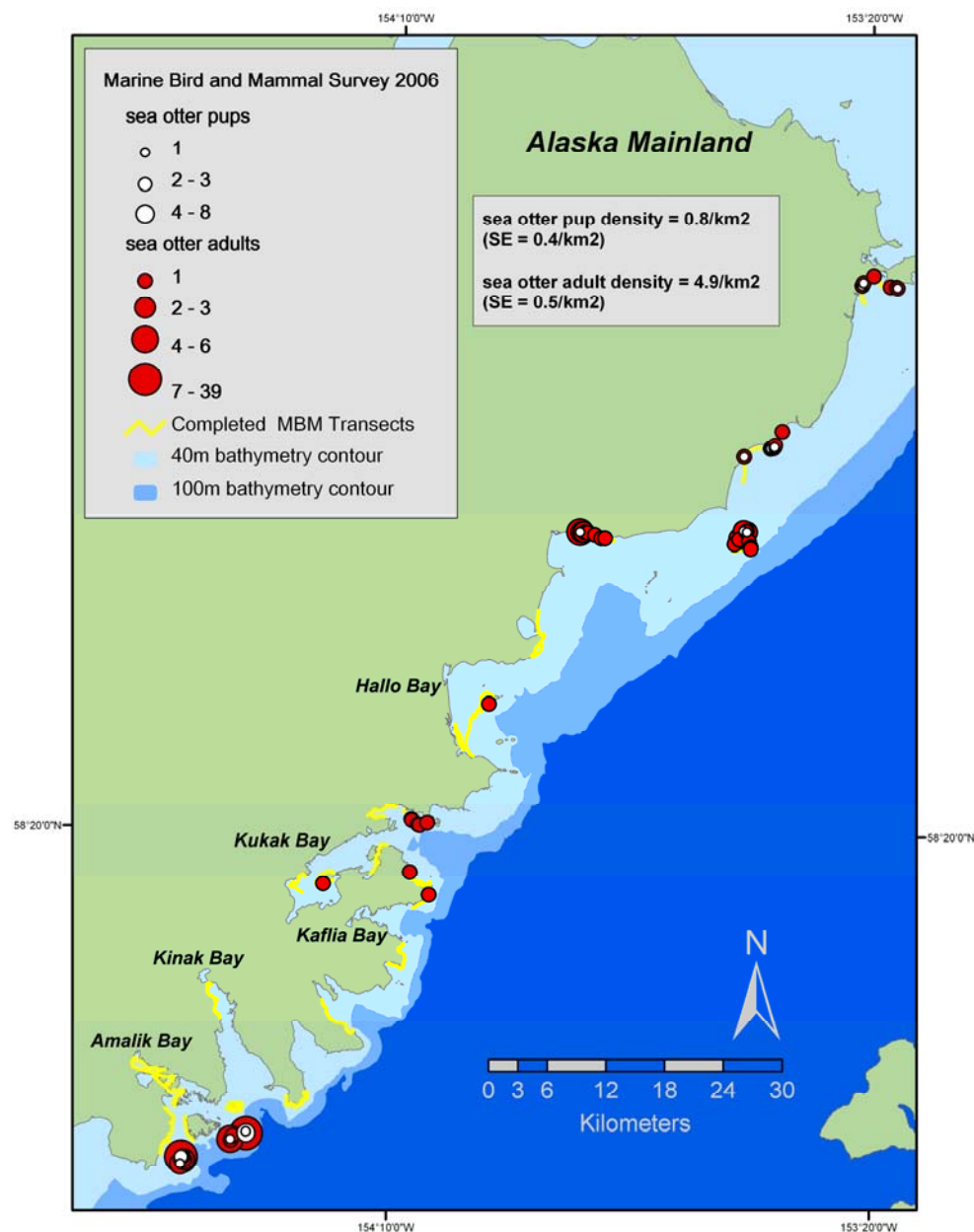


Figure 5.1. Distribution and relative abundance of sea otters detected along coastline transect surveys of marine birds and mammals June 2006, KATM.

We observed 65 sea otter forage bouts, consisting of 451 dives in block 10 KATM in June 2006 (Fig. 5.2). Associated with the intertidal sampling site AP B10 RI1, in Kukak Bay we observed 126 dives with a mean success rate of 0.98. Associated with AP B10 RI4 and AP B10 RI5, from observations based on Mink Is. we observed 325 forage dives with a mean success rate of 0.88. Because sea otters were relatively rare in the vicinity of Kafia and Kinak Bays, no sea otter foraging data were collected from these sites. We present the results of foraging observations for all three sites combined.

Sea otter diet composition was dominated by clams that comprised 76% of the prey items identified. Chitons, crabs, mussels, snails, sea stars, sea urchins, and other prey each comprised less than 5% of the total number of prey items (Figure 5.3).

The mean number of prey recovered by foraging sea otters was dependent on prey type (Fig. 5.4). For all sites combined, when foraging on clams, snails, or urchins, an average of two prey per dive were captured. When preying on chitons, crabs, mussels, or stars, an average of one prey per dive was captured.

Sizes of prey captured by foraging sea otters varied by species (Fig. 5.5). Snails, sea urchins, and mussels were generally the smallest prey, averaging about 40 mm. The predominant prey, clams, averaged 52 mm over all sites combined. Chitons averaged 90 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 145mm.

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 10 kJ. Other small prey such as snails and urchins averaged 0.65 kJ and 0.36 kJ, respectively. Chitons averaged 1.17 kJ and sea stars 0.14 kJ. Crab energy recovery was estimated at 6.41 kJ per dive and octopus at 15.42 kJ (again, conservatively). The average energy recovery rate was estimated at 1890 kJ hr⁻¹ (range 1480 – 2240 kJ hr⁻¹; Dean et al. 2002).

Forage dive times across areas and dive outcome averaged 58s. Successful dives were slightly longer (62s) than unsuccessful dives (51s). There was some indication of variation in dive times dependent on prey type (Fig. 5.6) although sample sizes for some prey are small.

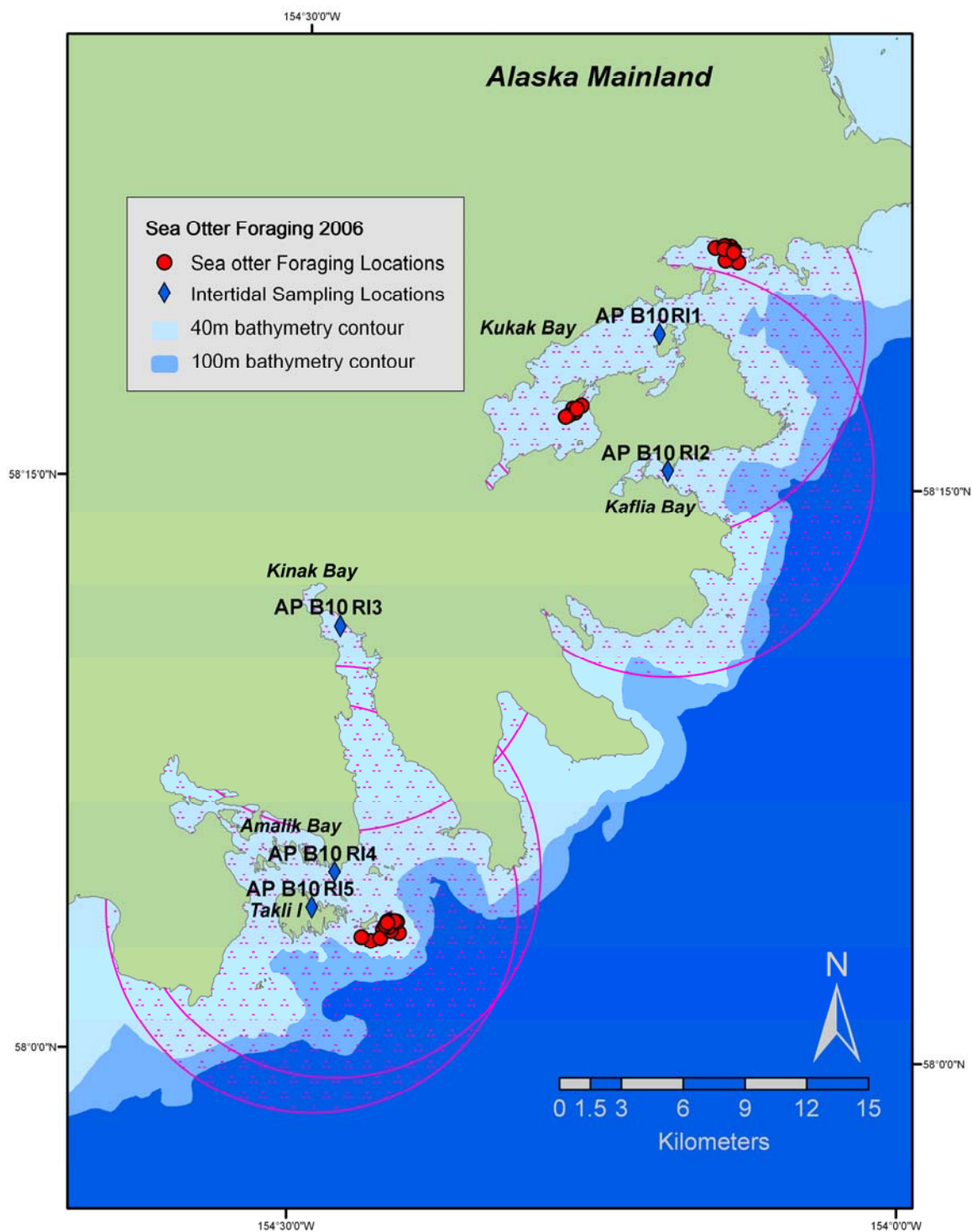


Figure 5.2. Locations of sea otters that we collected dietary and behavioral data from and the 10 km buffer zones established for each rocky intertidal sampling site. The dots in red indicate the location of the sea otter during forage data collection process.

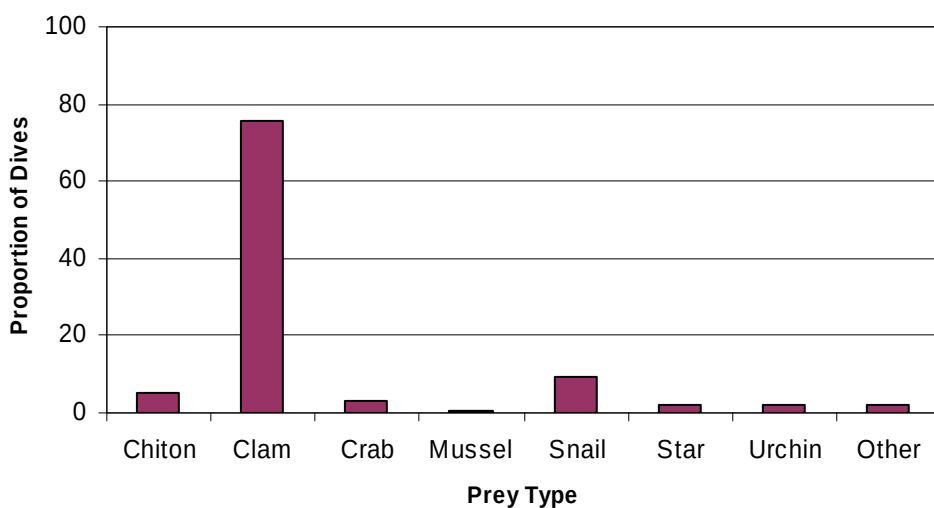


Figure 5.3. Sea otter diet composition, KATM, June, 2006. Clams include species of *Saxidomus*, chitons include species of *Katharina* and *Cryptochiton*, crabs include *Telmessus cheiragonus*, snails include species of *Nucella*, urchins are *Strongylocentrotus droebachiensis*, stars were unidentified, and other included species of Octopus.

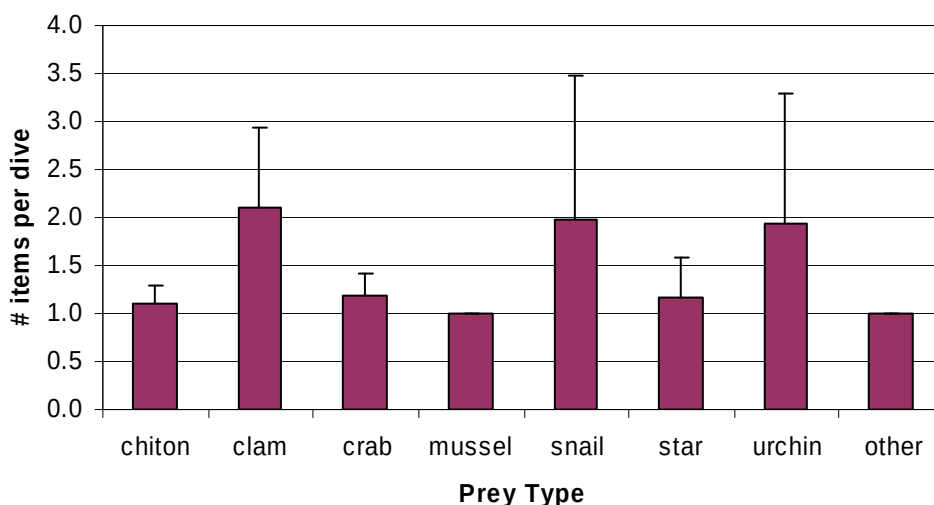


Figure 5.4. Mean number of prey items retrieved per dive by prey type for sea otters foraging at Block 10 KATM, Jun2006. Chitons include species of *Katharina* and *Cryptochiton*, clams include species of *Saxidomus*, crabs include *Telmessus cheiragonus*, snails include species of *Nucella*, urchins are *Strongylocentrotus droebachiensis*, stars were unidentified, and other included species of octopus. Bars represent 1 standard error.

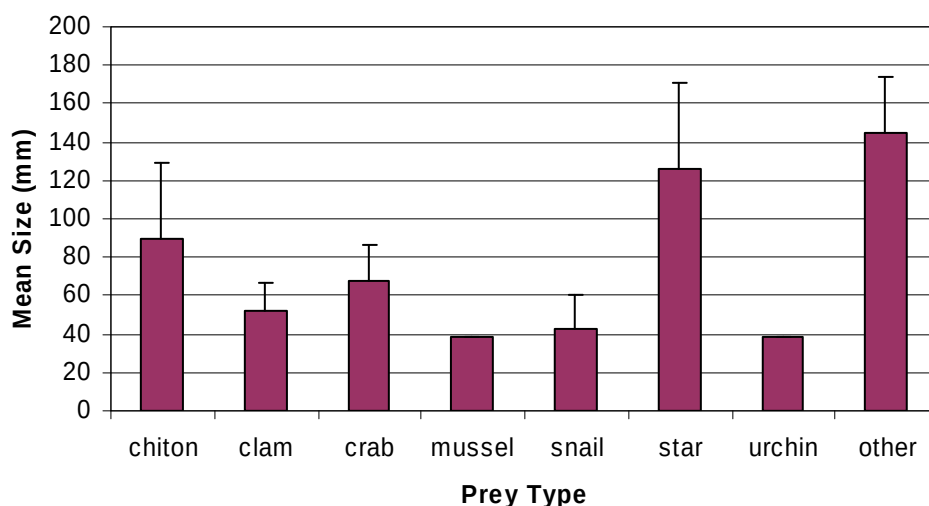


Figure 5.5. Mean size of prey items recovered by prey type for sea otters foraging in Block10, KATM, June, 2006. Chitons include species of *Katharina* and *Cryptochiton*, clams include species of *Saxidomus*, crabs include *Telmessus cherrigonus*, snails include species of *Nucella*, urchins are *Strongylocentrotus droebachiensis*, stars were unidentified, and other included species of *Octopus*. Bars represent 1 standard error.

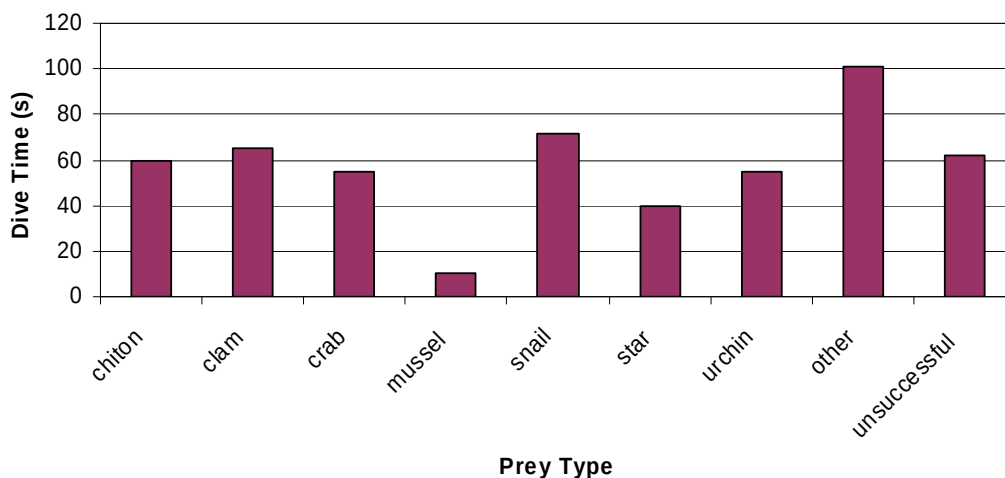


Figure. 5.6. Mean dive times by prey type for sea otters foraging in Block10, KATM, June and July 2006. Chitons include species of *Katharina* and *Cryptochiton*, clams include species of *Saxidomus*, crabs include *Telmessus cherrigonus*, snails include species of *Nucella*, urchins are *Strongylocentrotus droebachiensis*, stars were unidentified, and other included species of *Octopus*.

The relative abundance of four prey types was categorized from 100 spraint deposits, seventy five of which were on Ninagiak Island and the other 25 were on Shakun Island. Clams were the

most commonly observed prey occurring in 92% of the samples. Crab occurred in 30% and mussels in 29% of the samples. Other identified prey included sand dollars (*Dendraster*), sea urchins, and snail operculum.

Table 5.2. Prey types and relative frequency of occurrence in sea otter spraint examined from Ninagiak and Shakun Is. in June and July 2006.

Prey Type	Mean % occurrence		
	>50%	<50%	Absent
Clam	79	13	8
Mussel	13	16	71
Crab	7	23	70
Other	0	5	95

A total of 37 sea otter carcasses (including partial remains and a tooth for aging, Figure 5.7) were collected (Table 5.3, Figure 5.8). Four carcasses were recovered from 26.7 km of shoreline identified a priori as potential depositional beaches. Thirty-three carcasses were recovered from about 5 km of shoreline associated with sea otter haul out sites identified by large depositions of fecal material (spraint). Teeth were removed from skulls 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.



Figure 5.7. Sea otter skeleton found near Cape Douglas on 27 April 2006, KATM.

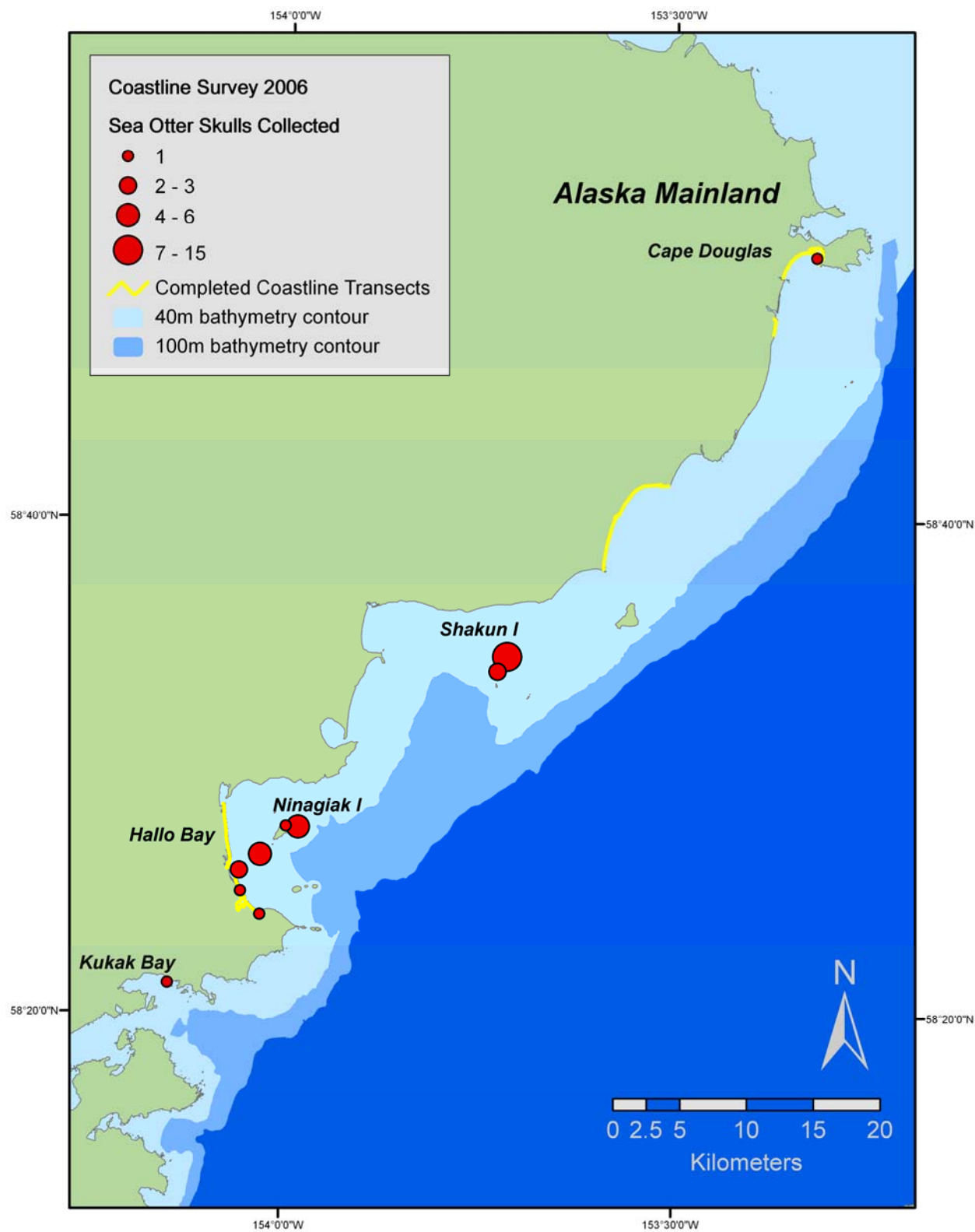


Figure 5.8. Locations of sea otter carcasses recovered from KATM in 2006.

Table 5.3. General location and number of sea otter carcasses recovered from KATM in 2006.

Area	Number
C. Douglas	1
Hallo Bay	3
Kukak Bay	1
Ninagiak	14
Shakun Is	18

DISCUSSION

Sea otters were distributed throughout the areas we surveyed in KATM but were comparatively less abundant inside bays compared to outer coast. This may reflect possible seasonal variation in distribution. Sea otter pups were commonly observed with females suggesting most habitats supported reproductively mature females. Because we only surveyed within the nearshore zone, the density ($5.7/\text{km}^2$) we calculated is not comparable with sea otter density estimates from elsewhere. However, our observations of the distribution and abundance of sea otters are consistent with a sea otter population that has occupied this area for at least several generations. Further evaluation of the status of the sea otter population in this region relative to available habitat will be possible following completion of an aerial survey designed specifically to provide unbiased estimates of sea otter distribution and abundance scheduled for completion in KATM in 2007.

The sea otters we observed foraging were highly successful (>0.90) at obtaining prey and had a diet dominated by clams. Chitons, snails, crabs, stars, mussels, urchins, and octopus comprised the remainder of the diet. This success rate and dietary composition are 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 ($> 156\text{mm}$) with estimated weights to several kg, we suspect they provided a relatively large contribution to the sea otters' energetic requirements.

The sample of 37 sea otter carcasses recovered will provide a reasonable sample size to describe the age distribution of dying sea otters if recovery rates remain similar for several years. Recovery of sea otter carcasses from designated coastline survey segments ($n=4$) was small compared to collections made at haul outs ($n=33$). 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. 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. However, if sea otters remain rare near sites AP B10 RI2 and AP B10 RI3 we suggest allocating effort to similar areas sampled in 2006. Completion of marine bird and mammal surveys provided useful information in identifying concentrations of sea otters required for forage observations.

We recommend that systematic coastline surveys for sea otter carcass recovery be discontinued. We found sea otter carcass recovery was efficient at haul out sites and recommend that sea otter carcass collections at Ninagiak and Shakun Islands be continued. Discovery of additional sea otter haul out sites could increase the number of carcasses recovered.

6 Coastline surveys of birds and mammals, animal carcasses, debris and other resources.

INTRODUCTION

The systematic collection of observational data and biological specimens along shorelines has proven useful in monitoring marine environments. Beach surveys have been used to document patterns in the distribution and relative abundance of birds and mammals closely associated with marine shorelines, carcasses of marine birds and mammals, and debris on beaches. The utility of shoreline survey data is exemplified by collections of sea otter carcasses from beaches in Prince William Sound that have been made for several decades (Monson et al. 2000). Teeth extracted from the skulls of sea otters have been used to provide age estimates for sea otters, and the age-at-death data have been modeled to provide histories of sea otter survival rates (see section 5). Other coastline survey observations include the documentation of die offs of marine birds or other marine life (Bodkin and Jameson 1991) and have been conducted worldwide to examine the impacts of oil spills (e.g. Dahlmann et al. 1994, Camphuysen 1997, Camphuysen and Heubeck 2001) and other pollution events. Other uses of shoreline survey data include documentation of changes in human use patterns and potential threats to marine life and beach esthetics from beached debris, documentation of spawning by marine animals, assessment of changes in beach geomorphology, and documentation of unusual events that may occur.

Although not a SWAN vital sign, the routine monitoring of shorelines in the Gulf of Alaska may contribute to the acquisition of data relevant to vital signs, such as marine bird abundance and sea otter carcasses (sections 3 and 5 above). In 2006 we initiated an exploratory effort to evaluate the feasibility and efficiency of surveying shorelines along the KATM coast. The specific objectives of these shoreline surveys included:

- Document the relative species composition and relative abundance of marine birds and mammals closely associated with the shoreline.
- Document large-scale die offs of birds, mammals, and invertebrates.
- Document patterns of human-use based on observations of the amount and type of debris on beaches.
- Document the location and extent of herring spawn on beaches.
- Describe and document beach geomorphology.

METHODS

Coastline surveys were conducted by observers walking designated segments of the coastline in the Gulf of Alaska in spring and summer; recording the relative abundance of birds and mammal species that are closely associated with the shoreline; documenting the location and types of dead organisms, human activities, beached debris, and herring spawn; collecting sea otter skulls for laboratory analysis of age-at-death; and noting changes in coastline geomorphology. Several designated segments of coastline were identified as potentially suitable beaches (Figure 6.1) prior to the 2006 sampling season.

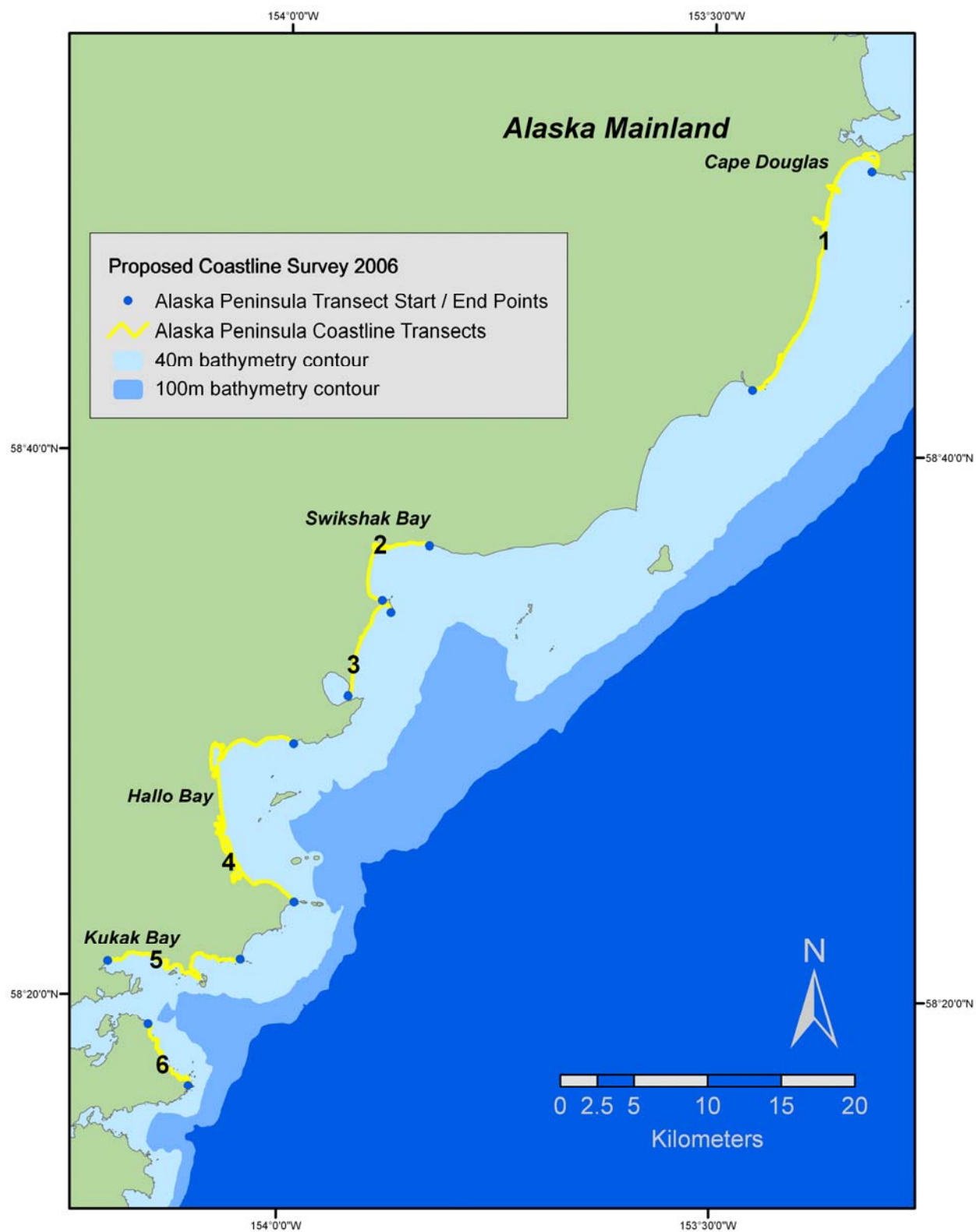


Figure 6.1. Location of coastline segments selected for exploratory implementation of the coastline survey SOP (Dean and Bodkin 2006).

The coastlines to be surveyed within each region were divided into segments of approximately 1 to 30 km that are easily distinguished by geomorphologic features (e.g. point to point, see Figure 6.1). The start and endpoints of each shoreline segment were identified by latitude and longitude (decimal degrees, NAD 83) and recorded using a GPS. Each segment was identified by a predetermined numbering system indicating the AP region and segment number (1...Z).

Surveys were conducted by crews of two or more people walking along the selected coastline segments and searching between the water line and the storm tide line. Generally, the search effort focused on the high tide line and the storm tide line where there is a wrack line and where skeletal remains and beached debris are often found, while the lower beach was scanned for live birds and marine mammals and freshly deposited carcasses.

Within each beach segment, 100 m sub-segments of shoreline were randomly selected to estimate beach cast debris, algae, and stranded invertebrates. Beach cast debris of human origin was classified as: fishing/boat gear; glass, plastic, metal, or other containers; or other debris. Volume of each type of debris was estimated as the number of 33 gallon bags that would be filled by each type of debris that is observed on the beach. Beach wrack is categorized as: *Nereocystis luetkeana* (bull kelp); *Alaria fistulosa* (ribbon kelp); *Zostera sp.* (eelgrass); *Macrocystis sp* (giant kelp); other brown kelps; red/green algae; *Fucus* (rockweed) *Phylospadix* (surfgrass); or other. The volume of beach wrack was estimated categorically as <1, <10, <100, <1000, or >1000 gallons of observable wrack. Species composition was estimated categorically as absent; <1%; 1-75%; or >75% of the total estimated volume. Endpoints of these 100 m segments were identified by GPS coordinates and photos from each end point taken toward the opposing endpoint were taken.

We implemented the coastline survey protocol during field trips in April and June 2006. Only a small subset of the segments originally chosen were surveyed. Two of the segments surveyed (1 and 4) were subsets of the segments originally identified and one segment (Z) was a segment that was identified during the June 2006 field work as a potential shoreline suitable for testing the coastline survey protocol (Figure 6.2). Segment 1 consisted of two disjunct sub segments, one 0.76 km and another 4.5 km in length (Figure 6.2).

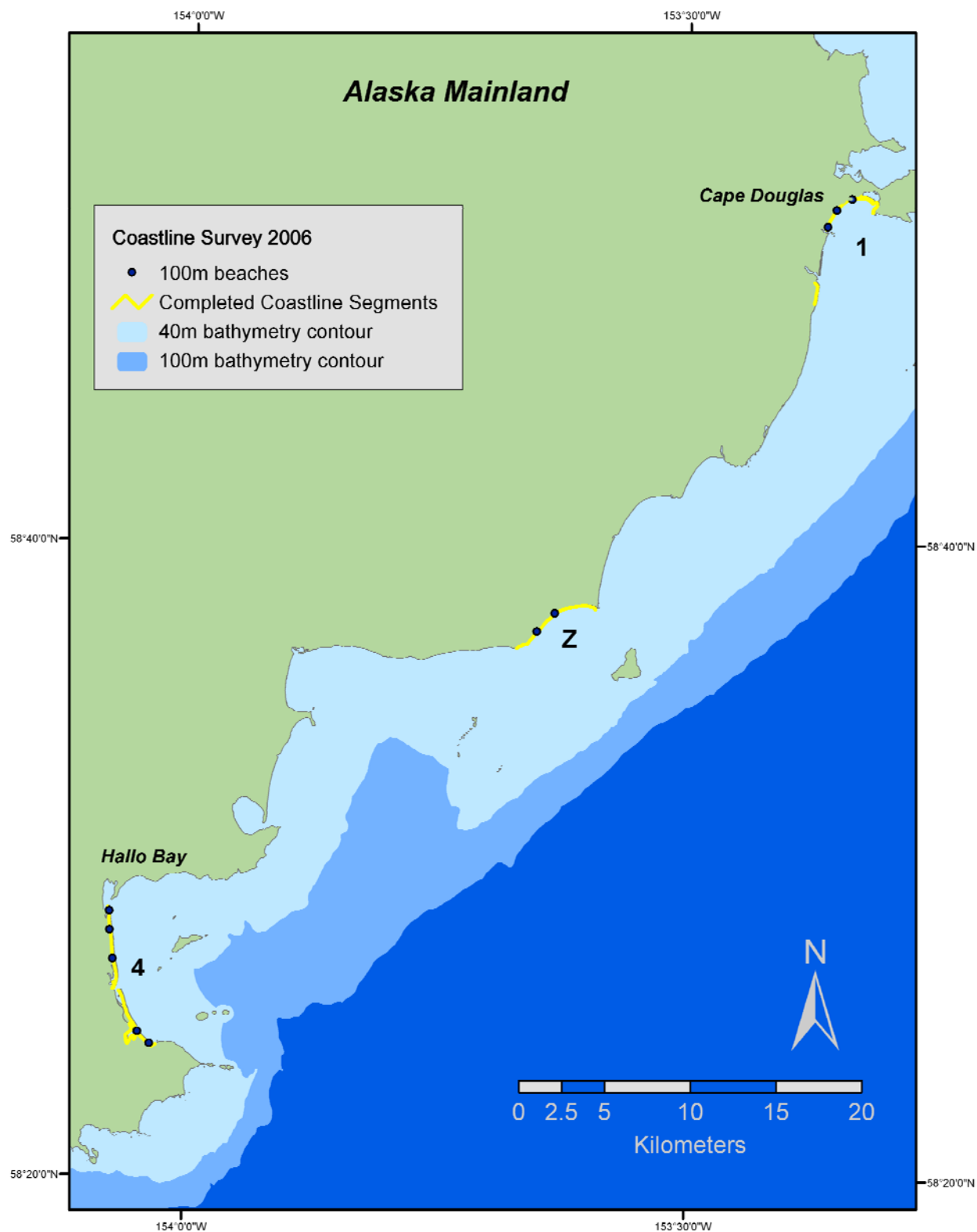


Figure 6.2. Coastal segments 1, 4, and Z surveyed for marine birds and mammals, and 100 m beach sections surveyed for beach cast debris and wrack in block 10 KATM, April, June, and July 2006.

RESULTS

A total of four sea otter carcasses and one bald eagle carcass (Figure 6.3) were observed on the coastlines surveyed. Observations of marine birds and mammals observed while conducting coastline surveys are presented in Table 6.1. Five species of shore birds and four species of waterfowl were detected.

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Figure 6.3. Bald eagle carcass located on coastline survey segment 4 at upper tidal level. Carcass was in relatively fresh condition, estimated days old.

Table 6.1. Presence and numbers of marine birds and mammals observed while surveying coastline segments in block 10 KATM, April, June and July, 2006.

Segment 1 was surveyed only in April, Segment 4 in April and June, and Segment Z only in July 2006. X indicates presence if number observed is unknown and numbers indicate number observed. See Fig. 6.2 for locations of segments.

Species	Segment 1	Segment 4	Segment Z
Bald eagle (<i>Haliaeetus leucocephalus</i>)	1	1	
Black brant (<i>Branta bernicla</i>)	X		
Black bellied plover (<i>Pluvialis squatarola</i>)			100
Black oystercatcher (<i>Haematopus bachmani</i>)	3		
Black turnstone (<i>Arenaria melanocephala</i>)	X		5
Black legged kittiwake (<i>Rissa tridactyla</i>)			5
Common merganser (<i>Mergus merganser</i>)			1
Glaucous-winged gull (<i>Larus glaucescens</i>)	X	125	
Harlequin duck (<i>Histrionicus histrionicus</i>)		X	
Herring gull (<i>Larus argentatus</i>)			21
Horned grebe (<i>Podiceps auritus</i>)	X		
Red-breasted merganser (<i>Mergus serrator</i>)			2
Pacific golden plover (<i>Pluvialis fulva</i>)			8
Pintail (<i>Anas acuta</i>)			5
Semi-palmated plover (<i>Charadrius semipalmatus</i>)	X		
Unid goldeneye (<i>Bucephala sp.</i>)	X		
Unid merganser (<i>Mergus sp.</i>)	28		
Widgeon (<i>Anas americana</i>)			2
White fronted goose (<i>Anser albifrons</i>)	X		15
Sea otter (<i>Enhydra lutris</i>)	4		72/3
Harbor seal (<i>Phoca vitulina</i>)	2	1	

Data on the volume of beach debris was collected from 10 randomly selected 100 m beaches, three in segment 1, five in segment 4 and two in segment Z (Table 6.2). Debris originating from fishing or other boating activities dominated beach cast debris in terms of volume. The number of 33 gallon trash bag equivalents of fishing/boat debris ranged from 0-26 and averaged about 4 bags per 100 m length of beach. Plastic containers dominated the beach cast debris in terms of frequency of occurrence. Nine of 10 beaches had plastic containers deposited. Metal containers were slightly more common and abundant than glass containers and most of the metal container volume consisted of metal drums. Other common debris of human origin was dimensional lumber, with one or more bags found on three beaches (Table 6.2). An example of fishing/boat beach cast debris is presented in Figure 6.4.



Figure 6.4. Beach cast fishing gear on coastline survey segment 4 (see Fig. 6.2).

Table 6.2. Estimated abundance of beach cast debris of human origin on ten randomly selected 100 m long beaches in block 10, KATM, surveyed in April (Segment 1, and Segment 4 beaches 1,2, and 3), or June and July (Segment 4 beaches 4 and 5, and Segment Z). Numbers refer to the estimated number of 33 gallon trash bags that the visible debris would fill.

	Segment 1				Segment 4				Segment Z			
# of 33 gal. bags	#1	#2	# 3		# 1	# 2	# 3	# 4	# 5		# 1	# 2
Fishing/boat gear	<1	1	2		5	8	26	2	1			
Glass containers						<1	1	<1	1			
Plastic containers	<1	<1	1		<1	<1	1	1	<1		<1	
Metal containers		<1	<1		2			2			1	
Misc. containers								<1	<1			
Other			1 wood		<1			3 wood	2 wood		<1 plastic/ rubber	

The volume and species composition of beach wrack (beach cast kelps and seagrasses) was estimated from nine of the 10 beaches where debris of human origin was estimated (Table 6.3).

Table 6.3. Estimated volumes and proportions of kelps, seagrasses and algae in beach wrack in block 10, KATM in April, June, and July 2006. A=absent.

	Segment 1				Segment 4					Segment Z	
	#1	#2	#3		#1	#2	#3	#4		#1	#2
est. wrack volume (gal)	<1gal	<10 gal	<10 gal		<1000 gal	<1000 gal	<10 gal	<100 gal		<10gal	<100 gal
<i>Nereocystis</i>	1-75%	1-75%	1-75%		A	A	A	1-75%		A	
<i>Alaria</i>	1-75%	>75%	1-75%		A	A	A	A		1-75%	>75%
<i>Zostera</i>	A	A	A		1-75%	A	A	1-75%		A	A
<i>Macrocystis</i>	A	A	A		A	A	A	A		A	A
Other browns	1-75%	1-75%	1-75%		<1%	<1%	<1%	A		1-75%	1-75%
Red/green algae	A	<1%	A		A	A	A	<1%		1-75%	<1%
<i>Fucus</i>	1-75%	1-75%	1-75%		>75%	>75%	>75%	1-75%		1-75%	<1%

One instance of large debris was observed on coastline segment 1. A fishing vessel, approximately 20 m in length and 5 m in beam was located at NAD83 coordinates 58.84305 by 153.35130. (Figure 6.5). The vessel was severely deteriorated and has likely been present for several years.



Figure 6.5. Beach cast large debris of human origin located in coastline segment 1 (Figure 6.1).

DISCUSSION

Approximately 60 km of coastline was identified a priori for implementing the coastline survey SOP in block 10 KATM in 2006. In April 2006 a crew of three scientists and pilot spent one week based out of King Salmon in an effort to survey those 60 km of coastline. During that week the crew was able to fly to the coast on two days due to weather restrictions, and on both days the amount of coastline that could be surveyed was limited by weather. The length of coastline surveyed was 9.3 km and one sea otter carcass was recovered. In June and July 2006 an additional 14 km of mainland coast was surveyed and three sea otter carcasses were recovered. In June 2006 four small islands were surveyed where sea otters had routinely hauled out and 33 sea otter carcasses were recovered in about 4 km of coastline. Thus recovery of sea otter carcasses was comparatively efficient when searching offshore islands where sea otter regularly haul out and relatively inefficient when searching mainland shorelines during the spring when access was by aircraft. Recovery of animal carcasses other than sea otters was rare on both mainland and offshore islands.

Data on species composition and numbers of marine birds and mammals was collected during surveys of coastline segments. The presence of shore birds was relatively high during beach surveys compared to skiff surveys. This difference may be a result of detection differences by survey method due to the small size and cryptic coloration of most shore birds, but may also reflect differences in timing of the surveys.

Information on the type and quantity of beach cast debris and beach wrack was collected in ten 100 m section of beach. The volume and composition of debris and wrack differed between

beaches and likely varies over time as a result of oceanographic and atmospheric processes. We found no evidence of herring spawn in either April or June and July, although beaches surveyed in April may not have been conducive to spawning. There was little evidence of recent human activities on the coastline segments we surveyed. Photographs of coastline segments and debris beach endpoints provide a record of shoreline geomorphology.

RECOMMENDATIONS

Overall, beach access was difficult and expensive in spring and one of the primary objectives in the coastline survey SOP, the collection of sea otter carcasses, was poorly met. For the acquisition of dead sea otters we recommend focusing efforts on identifying haul out sites on offshore islands and surveying those for sea otter carcasses during the summer sampling period.

Surveys of mainland coastlines in the summer can provide information on the volume and types of beach cast debris and wrack that may prove useful over time. However, the costs in terms of personnel and vessel time are high and we recommend that the effort expended in continuing the coastline surveys for these purposes be minimized, perhaps at a reduced sampling density of once every 10 years.

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