



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

2009

Natural Resource Data Series NPS/SWAN/NRDS—2010/055



ON THE COVER

Mussel bed sampling in Kenai Fjords National Park, 2009
Photograph by: Cuyler A. Smith, NPS

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Abstract

In 2009, we successfully completed a fourth year of protocol development and field sampling for the Southwest Alaska Network's (SWAN) Nearshore Vital Signs monitoring program in accordance with standard operating procedures set forth for each of six vital signs (marine intertidal invertebrates, kelp and seagrass, marine water chemistry and quality, marine birds, black oystercatcher, and sea otter). Soft sediment intertidal invertebrate sampling and skiff-based marine bird surveys were implemented for the first time in Lake Clark National Park and Preserve (LACL) in 2009. The current SOPs for soft sediment invertebrate sampling may not be appropriate for LACL. Site selection criteria may need to be based on observed shell litter as well as ability to access sites by plane. For this initial year the entire coastline of LACL was surveyed for marine birds. LACL had the highest densities of Scoters and black-legged kittiwake of all three parks during the summer surveys. LACL glaucous-winged gull density was comparable to Kenai Fjords National Park (KEFJ). Further analysis regarding marine bird surveys will be conducted to optimize sampling areas within LACL. We will return to sample LACL in 2011.

The first winter marine bird survey along the coast of Katmai National Park & Preserve (KATM) was completed in March, 2009. Winter surveys quantify the abundance of over-wintering, nearshore-reliant sea ducks and their reliance on winter nearshore food resources. Higher winter than summer densities occurred for the following four species: Barrow's goldeneye ($30.99/\text{km}^2$ vs. $0.0/\text{km}^2$), bufflehead ($15.22/\text{km}^2$ vs. $0.0/\text{km}^2$), long-tailed duck ($13.76/\text{km}^2$ vs. $0.0/\text{km}^2$), and harlequin duck ($69.19/\text{km}^2$ vs. $36.86/\text{km}^2$) than summer surveys. The next winter marine bird survey along the KATM coastline is scheduled for March, 2011.

Summer sampling in 2009 at Katmai National Park & Preserve (KATM) represented the fourth year of data collection and third year of data collection in Kenai Fjords National Park (KEFJ) for vital signs including intertidal invertebrates and algae; water chemistry and quality; marine bird surveys; black oystercatcher diet and productivity; and sea otter diet. Little modification was made to the rocky intertidal sampling protocol from previous years and we anticipate completion of a peer review of the SOP during the fall of 2010. Soft sediment invertebrates were sampled for the second time at both KATM and KEFJ. Based on previous results from the 2007 sampling season, in 2009 we extended transect lengths to 100 m instead of 50m to further distribute disturbance effects and to sample a larger area. We also sampled an additional 100 m transect at a lower tidal elevation than previously sampled. In several instances in 2007, very few or no clams were found at in some quadrats at the higher tidal heights. The next soft sediment invertebrate sampling event will occur in 2011. We recommend that continued soft sediment sampling at KATM and KEFJ occur solely at the lower tidal elevation due to the larger quantity of clams found at the lower tidal elevation in general in both KATM and KEFJ. We do not recommend sampling at both tidal elevations. The SOP will be revised to reflect modifications to the sampling scheme. At both KATM and KEFJ, we implemented a second year of mussel bed and eelgrass bed sampling. Draft SOPs are complete and will be reviewed during the fall of 2010. Five water temperature loggers are deployed at both KATM and KEFJ. One salinity logger is deployed at both KATM and KEFJ. Temperature and salinity data from 2009 are currently being analyzed and not reported here. Four additional salinity devices will be deployed at KATM and KEFJ during the 2010 field season at each rocky intertidal sampling site.

Blue mussel contaminant analysis was reported in the 2008 annual report. High levels of chlordane concentrations were found in Amalik Bay, KATM. Samples were collected from Amalik in 2009 to reanalyze the mussel tissue for chlordane levels. Results from that analysis are not yet available at the time of this report. At the other sites, we recommend that sampling of concentrations of metal and organic concentrations be measured at 5 year intervals, except in those instances when there is a reasonable cause for concern. Resampling of contaminants should occur in 2012.

Marine bird survey in both KATM and KEFJ will continue with little modification in 2010. We recommend that current survey effort continue until further analysis can be completed. Black oystercatcher abundance, nests density, productivity and diet data should continue to be collected with little revision. Sampling at the current intensity should allow us to detect trends in changes of nest density, productivity and diet (especially prey size) of the black oystercatcher. While sea otter data was collected at both parks, diet data are not reported here. Work is being completed on a sea otter forage database at this time. Database completion will ease data entry both in the field and office as well as optimize data analysis.

In 2010, we plan to finalize the sampling protocol through a peer review process and finalize data entry and data management procedures for the rocky intertidal and sea otter foraging sampling SOPs. We will continue sampling of vital signs at both KATM and KEFJ.

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Intertidal Invertebrates and Algae

Introduction

Intertidal invertebrate and algal communities provide an important source of 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; Lewis 1996, Keough and Quinn 1998, Jamieson et al. 1998; Shiel and Taylor 1999; Sagarin et al. 1999; Peterson et al. 2001, 2003).

Intertidal invertebrates and algae (including intertidal kelps) were sampled annually at KATM beginning in 2006, and at KEFJ beginning in 2008. Sampling of intertidal invertebrates and algae at these sites is designed to detect changes in these communities over time as part of the SWAN Vital Signs program. The specific objectives of this sampling on rocky shores are to assess changes in: 1) the relative abundance of algae, sessile invertebrates, and motile invertebrates in the intertidal zone, 2) the diversity of algae and invertebrates 3) the size distribution of limpets (*Lottia persona*) and mussels (*Mytilus trossulus*), and 4) the concentration of contaminants in mussel tissue, and 5) temperature (either sea or air depending on tidal stage). In this section, we present results of sampling conducted in 2009. The metrics to be examined are: 1) abundance estimates for dominant taxa of sessile invertebrates and algae, 2) densities of *Nucella* spp., *Katharina tunicata*, and sea stars and 3) size distributions of the limpet *Lottia persona*.

Methods

Sampling was conducted at five sites in sheltered rocky habitats within KATM and KEFJ in 2009. Descriptions of the study sites and methods used to sample intertidal algae and invertebrates are available in Dean and Bodkin 2009. The following is a general description of the methods employed. Sampling of abundance and species composition of algae and invertebrates was conducted along 50-m long transects at each site. The percent cover of algae and sessile invertebrates were estimated within 12 evenly spaced $\frac{1}{4}$ m² quadrats placed along transects that ran parallel to the shoreline and originated at permanent markers placed at 0.5 m and 1.5 m tidal elevations respectively. Quadrats were placed at a random start points and at equally spaced intervals thereafter. *Nucella* spp. and *Katharina tunicata* were counted within 12, 2 m² quadrats at each elevation. Sea stars were counted within a 50 m long by 4 m wide band with the lower extent of the transect positioned at MLLW (mean lower low water). In addition, a minimum of 119 individual limpets (*Lottia persona*) were measured at each site for estimation of size distributions.

The analyses presented here focus on estimates of abundance of dominant taxa at each tidal elevation, and on size distributions of limpets. Means and 90% confidence intervals are reported for each site. Mean sizes (shell length) and 90% confidence intervals are given for limpets.

Results

Mean percent cover (and 90% confidence intervals) are reported for each site at KATM and KEFJ in Figures 1 and 2. Relative abundance varied by site and tidal elevation, but barnacles and *Fucus gardneri* were generally the most abundant. The kelp *Alaria marginata* and mussels (*Mytilus trossulus*) were abundant at lower and upper elevations respectively at many sites. The exceptions were at Aialik Bay, McCarty Fjord, and Nuka Bay in KEFJ where these species were rare. The predatory snails (*Nucella* spp.) were observed at most sites, but were particularly abundant in the upper elevation (1.5 m MLLW) at Harris Bay (Figures 3 and 4). The chiton *Katharina tunicata* was found in relatively high densities (greater than 4 per sq. m) in the upper intertidal at Kaflia, Amalik, and Takli and were generally rare at all sites in KEFJ (Figures 3 and 4). *Pisaster ochraseus* and *Evasterias trochelii* were generally the most abundant sea stars (Figures 5 and 6). The highest densities of both species were found at McCarty Fjord in KEFJ. Median sizes of limpets (*Lottia persona*) generally ranged from 12 to 16 mm at KATM and 10 to 14 mm at KEFJ (Figures 7 and 8). The largest limpets observed were at Kukak Bay in KATM.

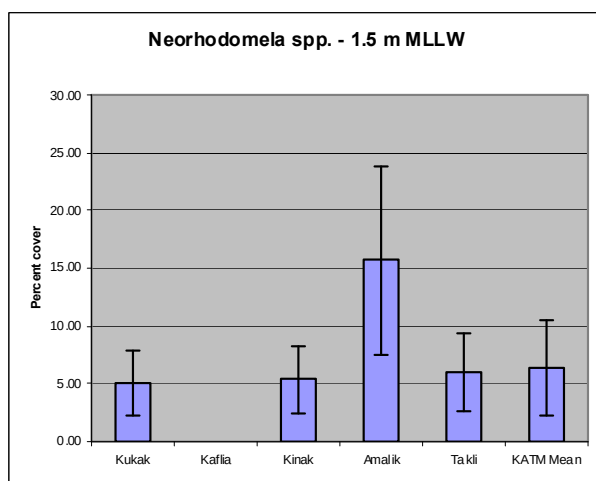
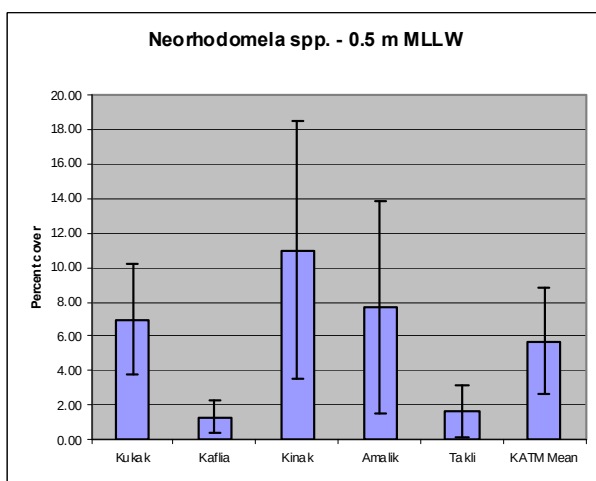
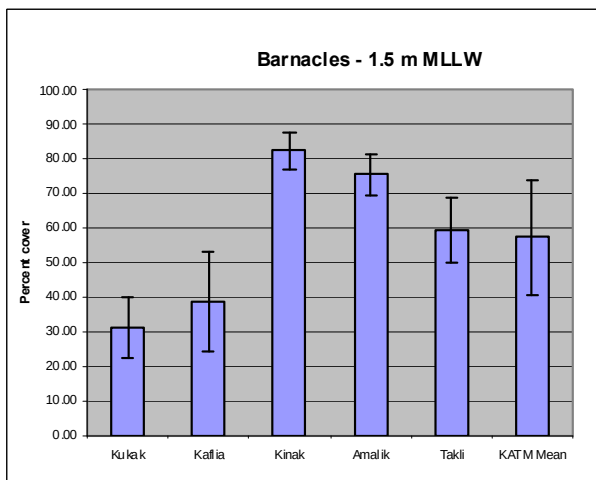
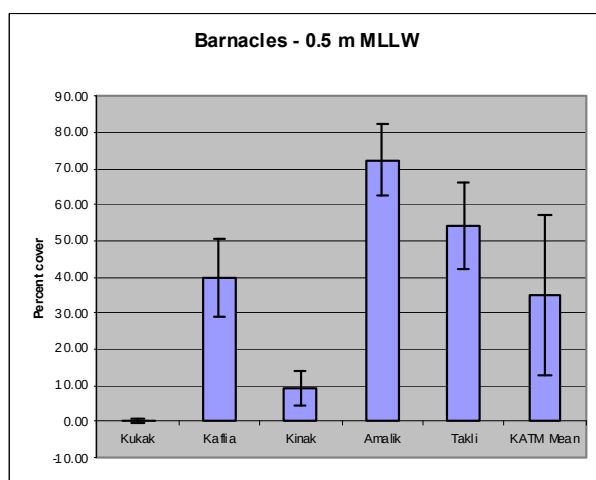
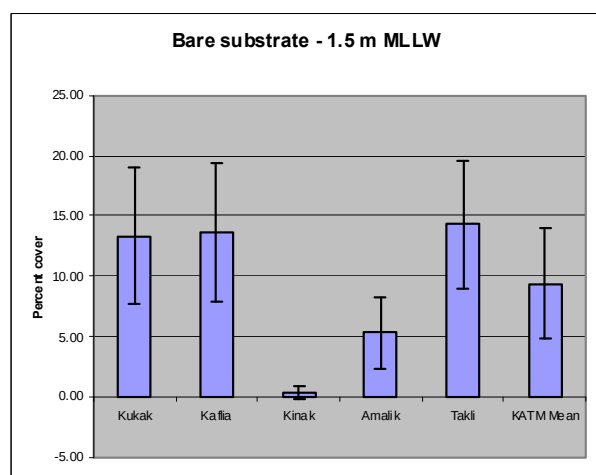
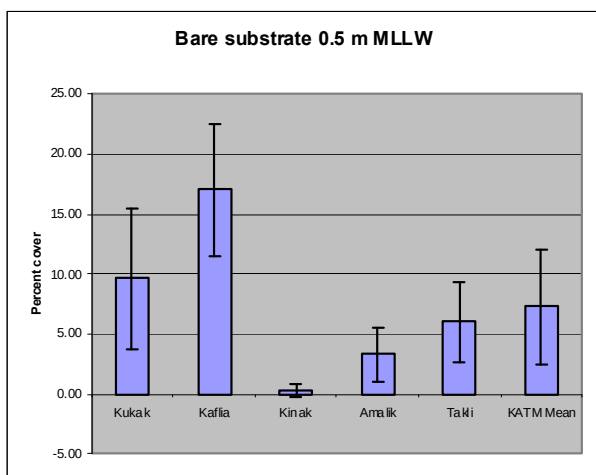


Figure 1. Percent cover (mean and 90% confidence intervals) of dominant sessile species at KATM in 2009.

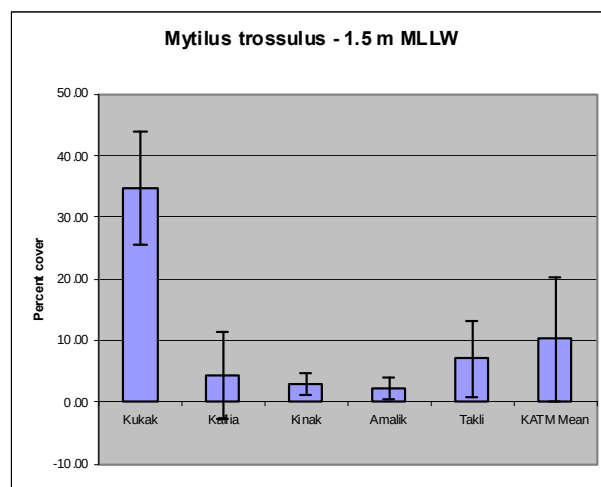
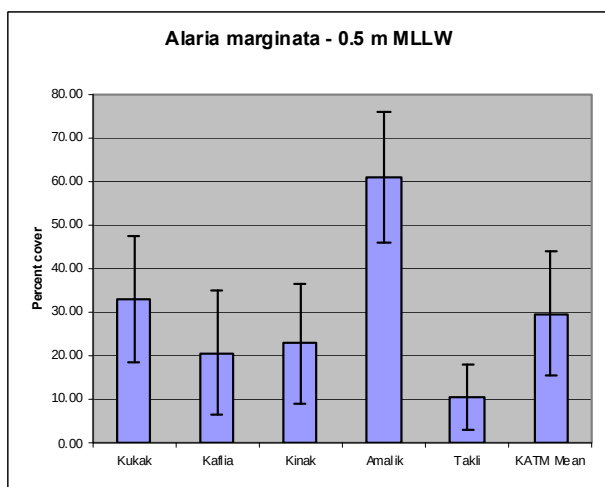
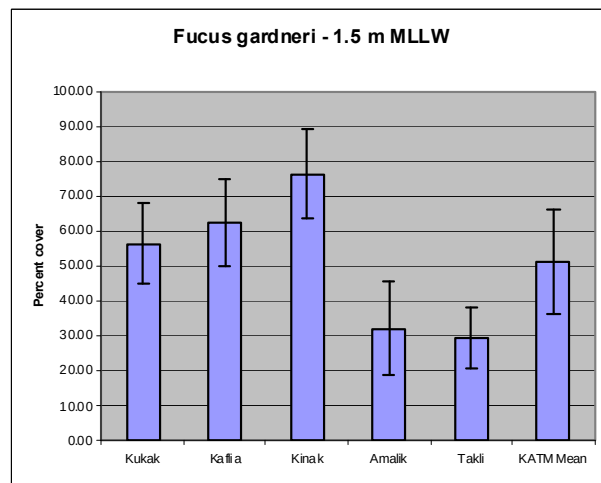
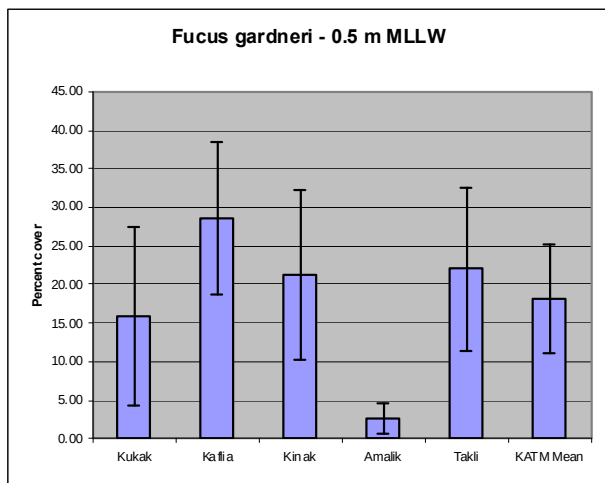


Figure 1 (continued). Percent cover (mean and 90% confidence intervals) of dominant sessile species at KATM in 2009.

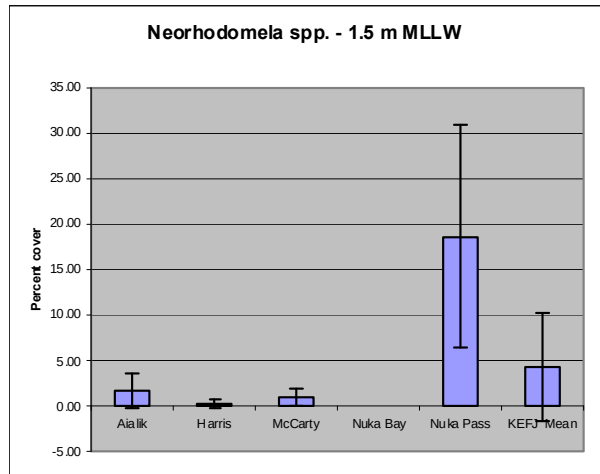
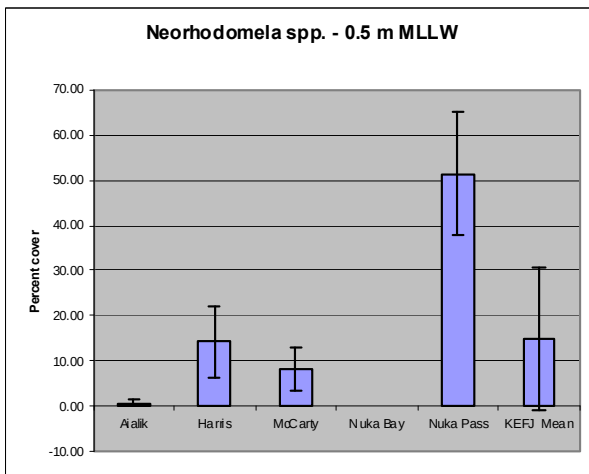
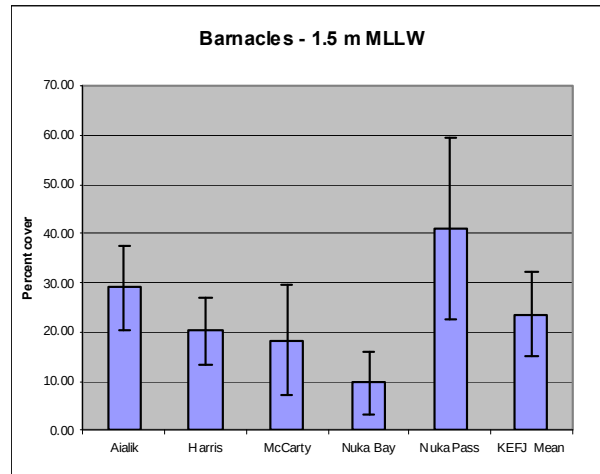
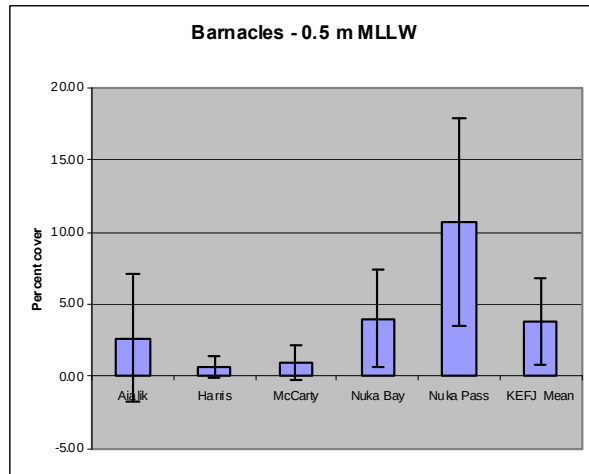
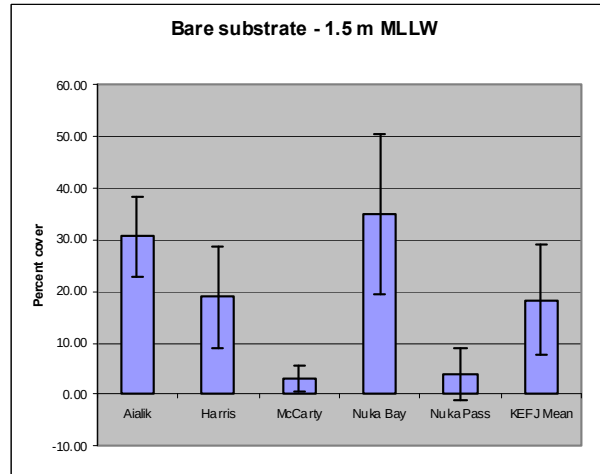
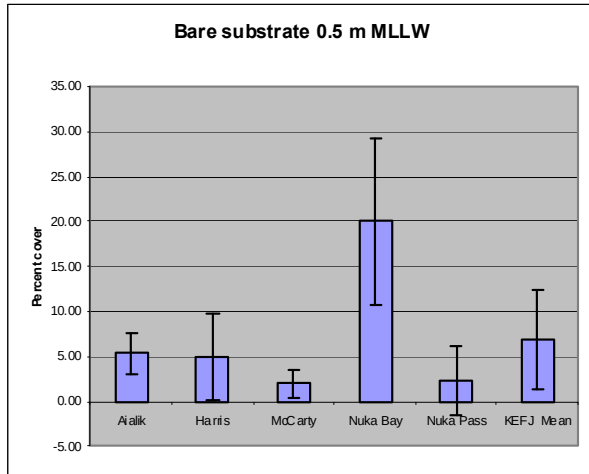


Figure 2. Percent cover (mean and 90% confidence intervals) of dominant sessile species at KEFJ in 2009.

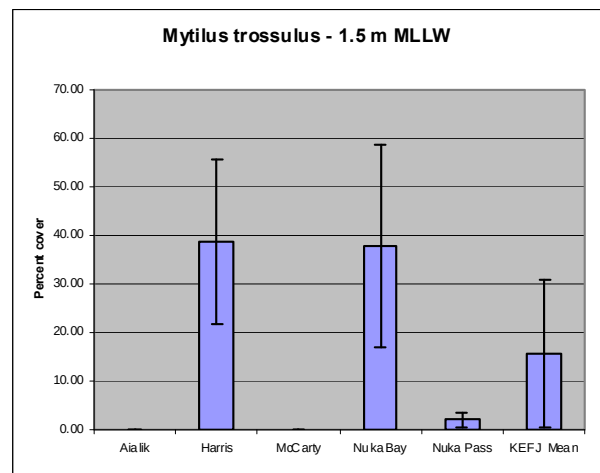
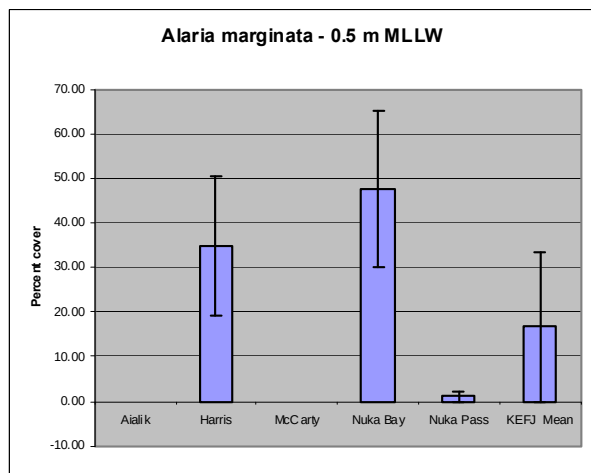
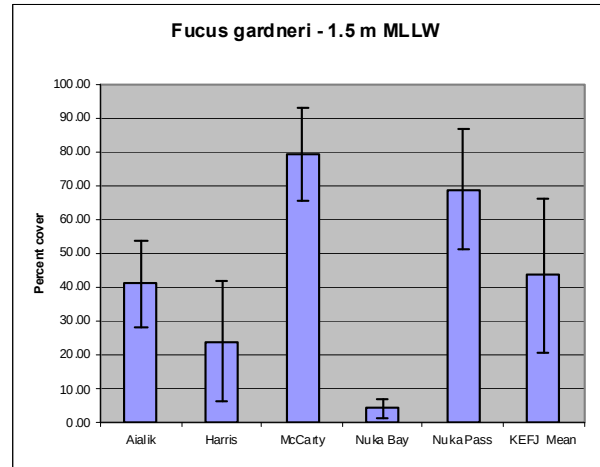
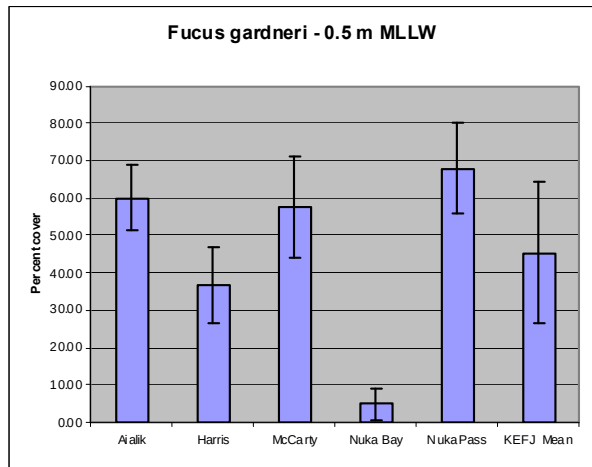


Figure 2 (continued). Percent cover (mean and 90% confidence intervals) of dominant sessile species at KEFJ in 2009.

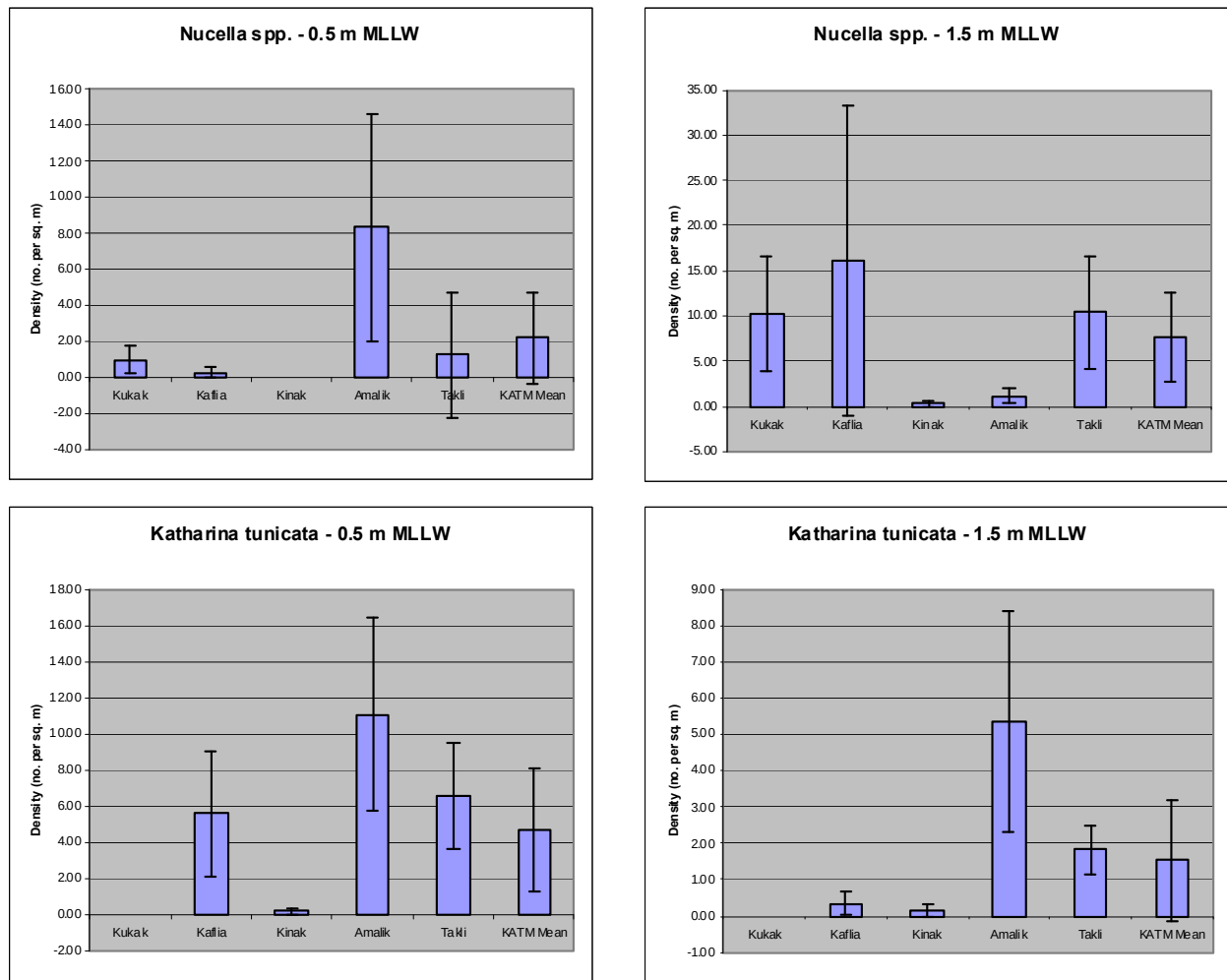


Figure 3. Density (mean and 90% confidence intervals) of *Nucella* spp. and *Katharina tunicata* at KATM in 2009.

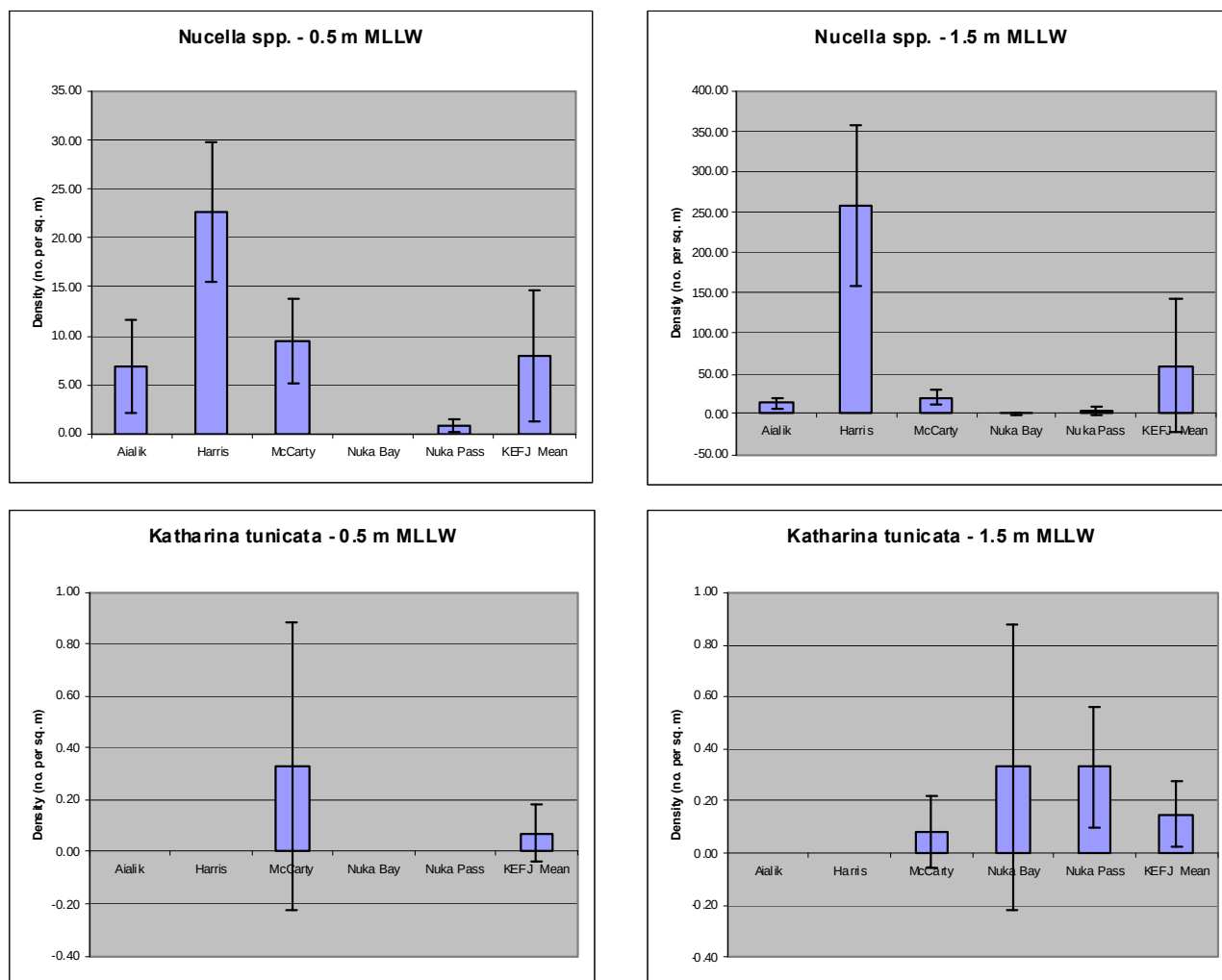


Figure 4. Density (mean and 90% confidence intervals) of *Nucella* spp. and *Katharina tunicata* at KEFJ in 2009.

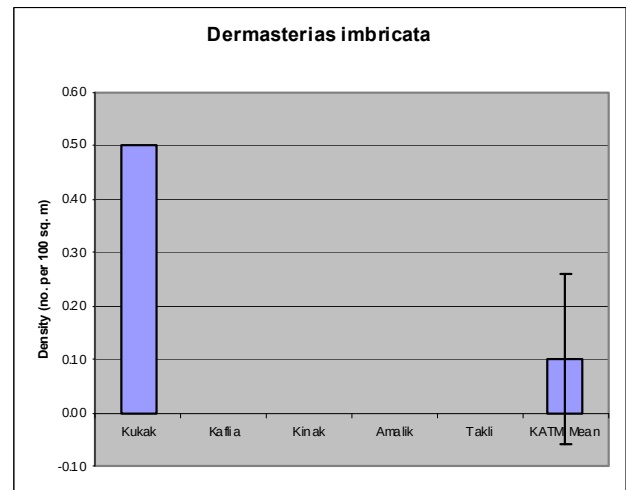
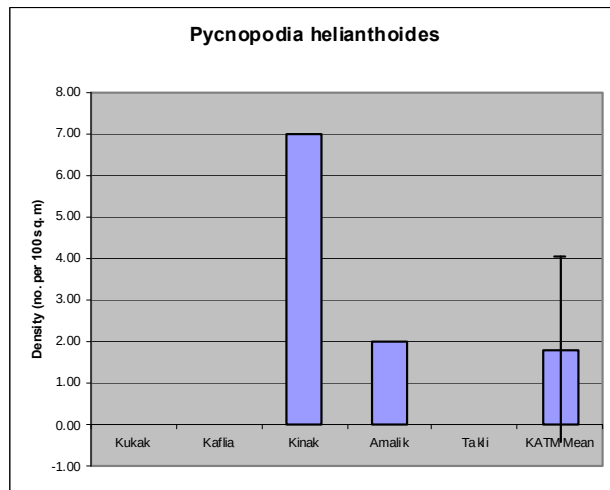
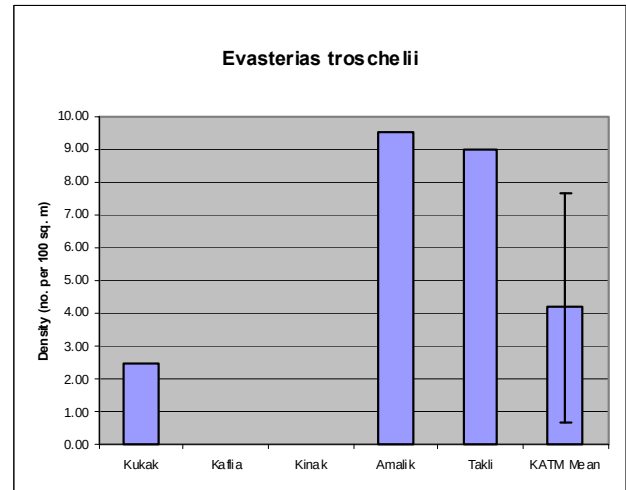
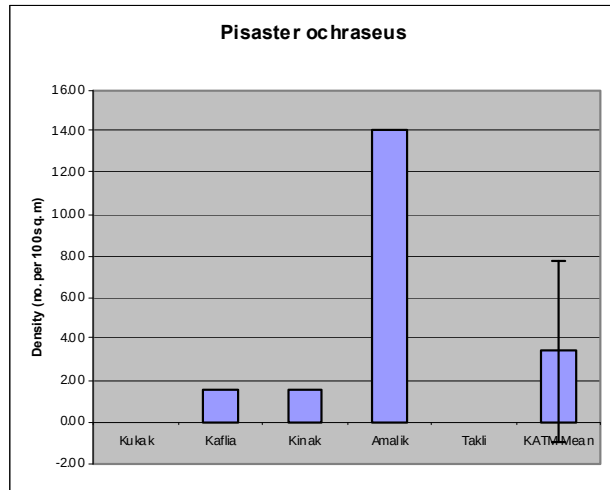


Figure 5. Density (mean and 90% confidence intervals) for dominant sea star species at KATM in 2009.

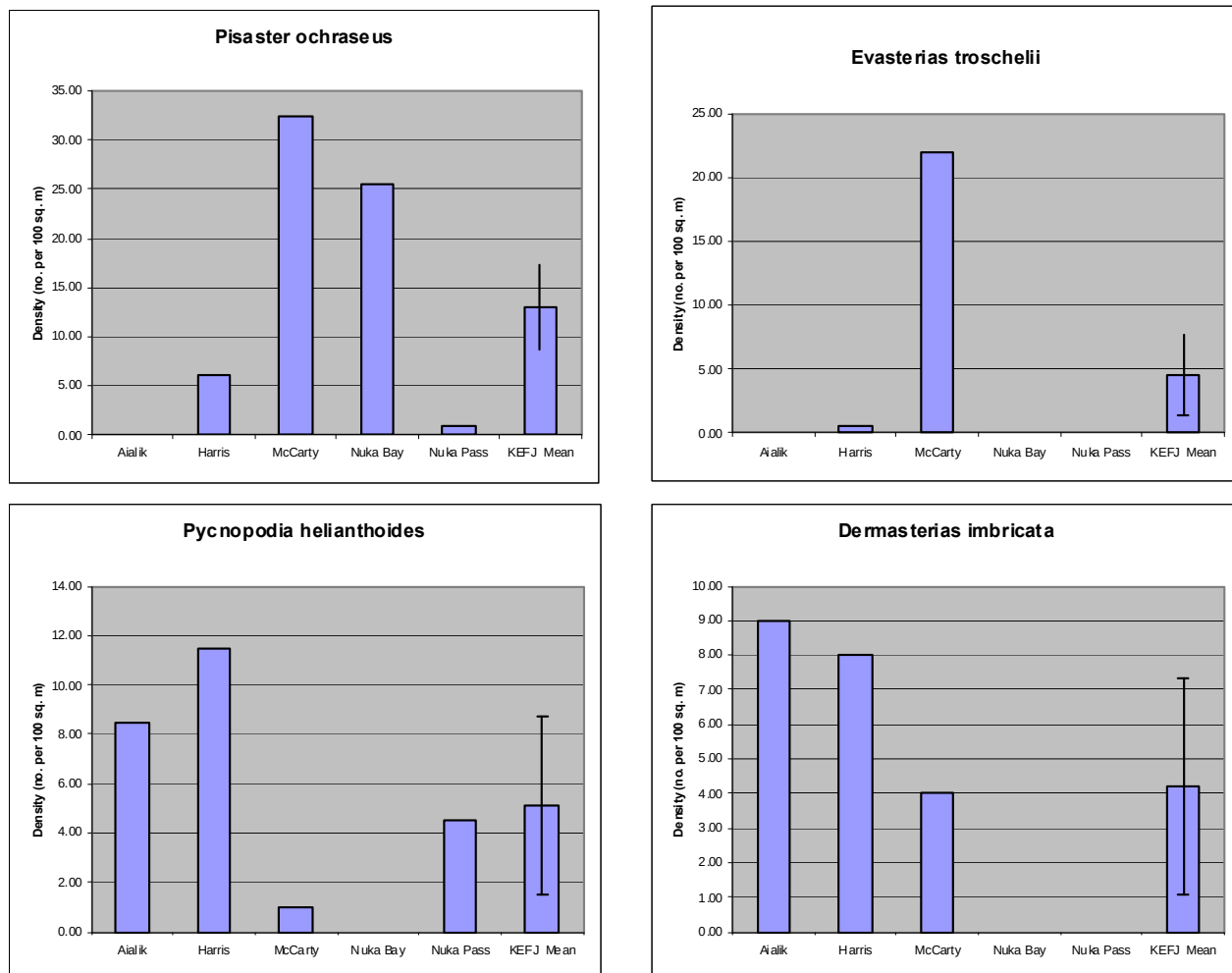


Figure 6. Density (mean and 90% confidence intervals) for dominant sea star species at KEFJ in 2009.

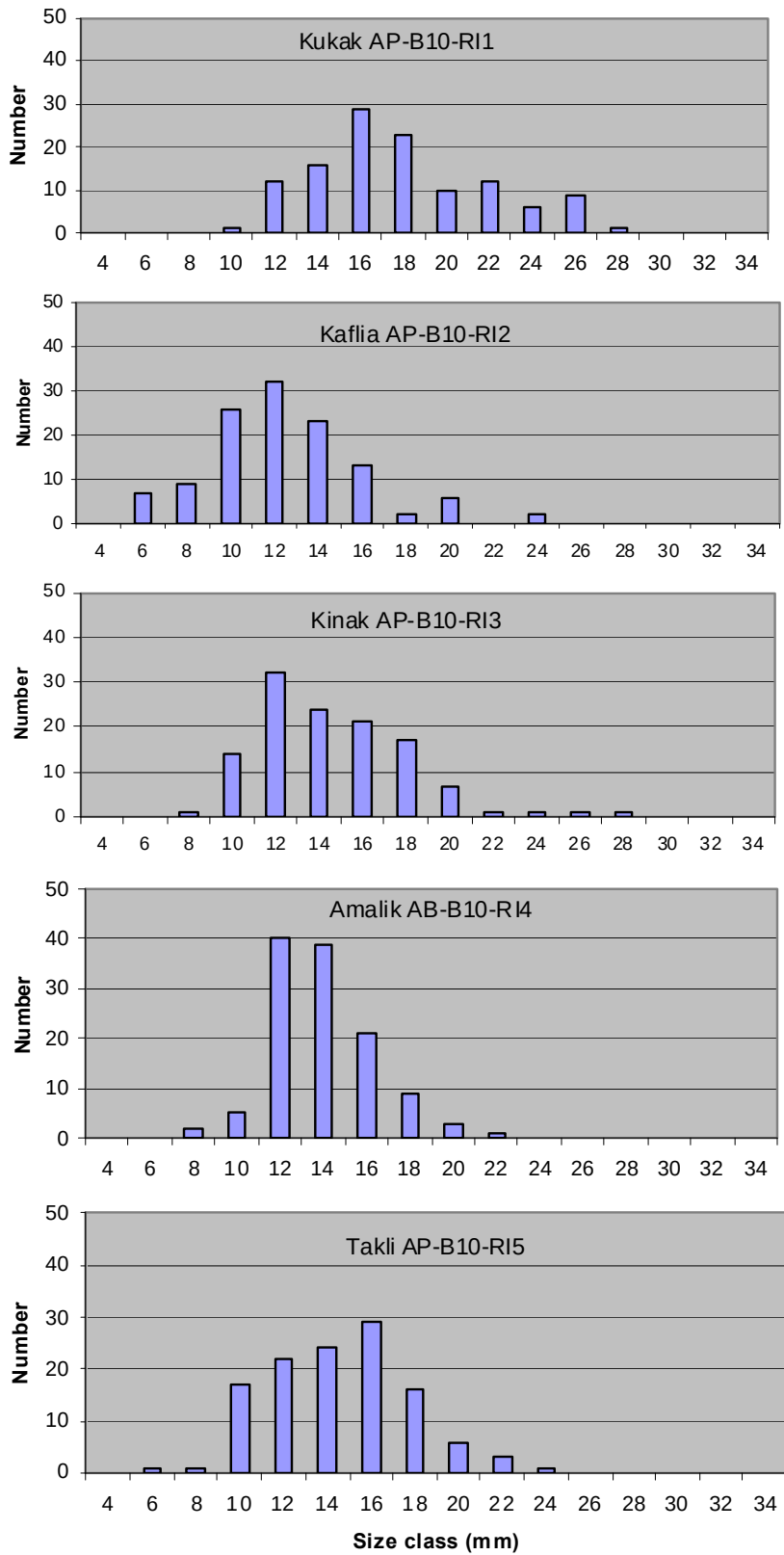


Figure 7. Size frequency distribution of *Lottia persona* at KATM in 2009.

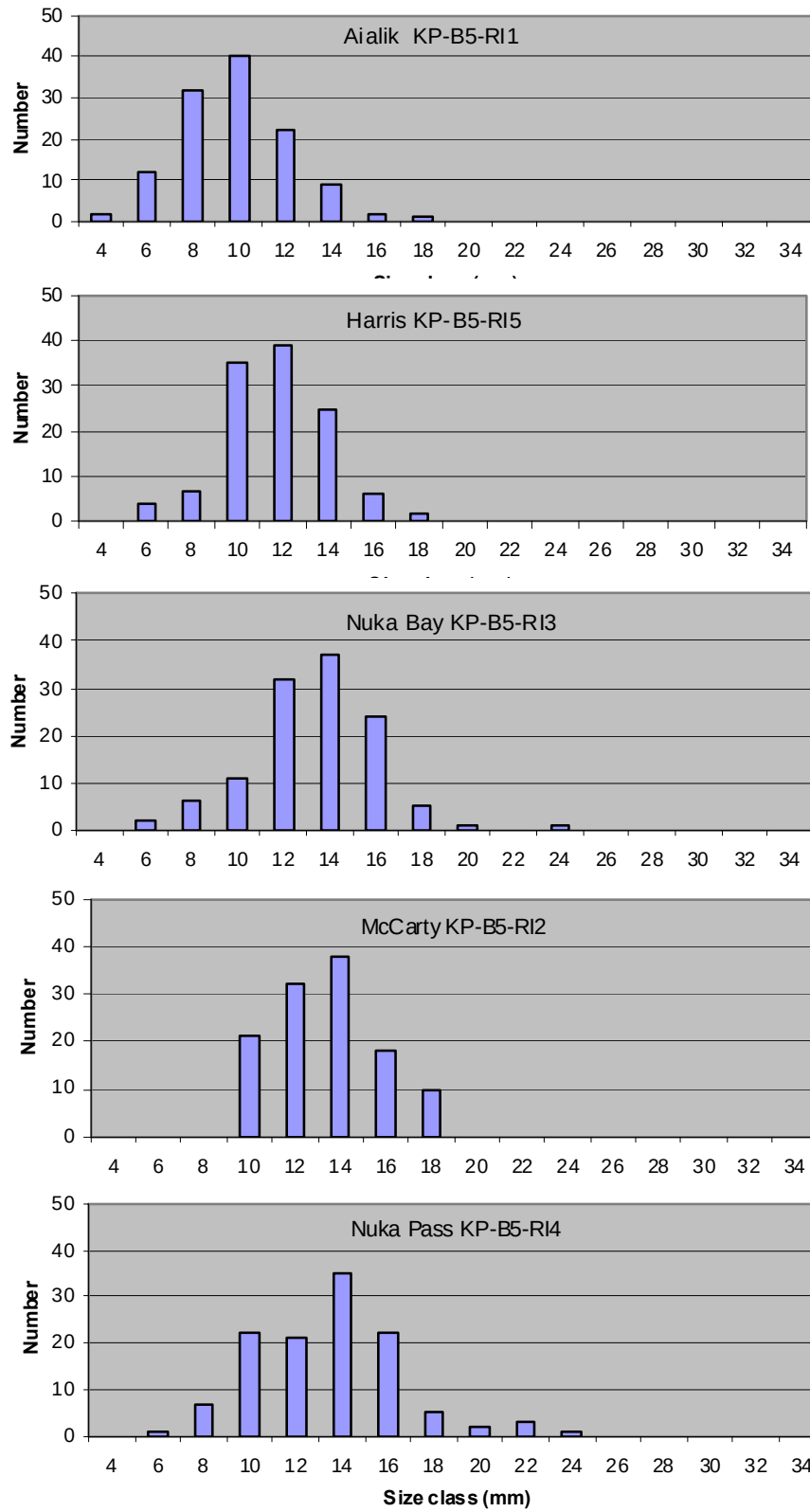


Figure 8. Size frequency distribution of *Lottia persona* at KEFJ in 2009.

Discussion

The sampling described provided reasonable estimates of the abundance of intertidal invertebrates and algae (including intertidal kelps) at sites within each park. While we do not provide analysis of past years results here, it appears that there was considerable inter-annual variation in relative abundance of sessile species between 2006 and 2009 at KATM, but few clear trends in intertidal communities over the four year period. We anticipate that the methods employed will detect ecologically meaningful levels of change in the future.

We attempted to repeat sampling of fixed photo quadrats at each site to provide an additional, perhaps more cost effective, means of estimating relative abundance of sessile species. However, we were unable to consistently relocate fixed photo quadrats. Quadrat locations were marked with stainless steel bolts in 2008, but we were unable to locate these in 2009 in spite of considerable effort. Occasionally bolts were found under large boulders, suggesting that wave action had moved boulders, perhaps covering or shearing anchor bolts, especially in the lower intertidal zone. Because of the high degree of disturbance, it is unlikely that we will be able to repeatedly photograph fixed quadrats unless they are marked in some other manner.

Recommendations

Based on these results, we recommend continued estimation of percent cover by sessile invertebrates and algae using random point counts and counting snails, chitons and sea stars on fixed quadrats and transects. However, based on our inability to successfully relocate fixed quadrats for photo analysis, we recommend eliminating or modifying this sampling in future years.

Soft Sediment Invertebrate Sampling

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 soft sediment intertidal sampling conducted in 2009 in LACL, KATM and KFFJ. For soft sediment shorelines, we focus on results from sampling at five sites at LACL, five sites at KATM and five sites at KEFJ. KATM was initially established and sampled in 2006 and KEFJ was initially established and sampled in 2007. Specific objectives are to assess changes in: 1) the relative abundance of clams in the intertidal zone, 2) the diversity of clams, and 3) the size distribution of numerically abundant clam species (*Macoma* sp.).

Methods

The sampling protocol was similar to that detailed in Bodkin and Kloecker, (1999, and Bodkin et al. 2008) and was adapted from an intertidal clam sampling protocol originally used in Prince William Sound, Alaska (Bodkin et al. 2008). These sites were selected using a GRTS sampling protocol (Stevens and Olsen 2004) designed to provide a random, spatially balanced sample. Once all the potential soft sediment sites were identified, due to logistics, only the soft sediment sites that were located in proximity to the rocky sites were examined as potential permanent soft sediment sites. LACL was the exception because no rocky sites were identified and established because the coastline is predominately soft sediment based on existing environmental sensitivity index data. Selection of soft sediment sites to sample in LACL were based solely on GRTS sampling. Presence of shell litter was the indicator used to decide on a sampling location. If there was no shell litter present or some other aspect of the GRTS segment was not conducive to invertebrate recruitment, alternate nearby sites from the ordered GRTS list were substituted. A handheld GPS was used to navigate to the segment. The following modifications to the 2007 sampling protocol were made for the 2009 sampling. Transect lengths were extended to 100 m instead of 50m to further distribute disturbance effects and to sample a larger area. An additional 100 m transect was added to sample at the 0.0 m MLLW tidal elevation. In several instances in 2007, very few or no clams were found in some quadrats at the 0.5 m tidal height. If time allowed during the sampling season in 2007, test quads were dug at lower tidal elevations to search for the presence of clams. In many cases, clams were found at tidal elevations lower than the specified 0.5 m. Our specific objectives in this SOP are to detect and assess changes in: 1) the relative abundance of clams in the intertidal zone, 2) the diversity of clams, and 3) the mean size and size distribution of abundant clam species. Therefore, in 2009 we implemented the sampling at both tidal elevations in KATM and KEFJ. In LACL sampling at only the 0.0 m tidal elevation

was implemented. No sampling at the 0.5 m tidal elevation was completed. At each site a 100 m transect was positioned horizontally along the beach at the +0.5 m and 0.0 m MLLW tide levels. A random starting meter was chosen and six (12 along transects in LACL) 0.25 m² quadrats were excavated to a depth of 25 cm at each tidal elevation. On site, all sediments were sieved through a 10 mm mesh screen and all clams (as well as crabs, mussels, and urchins at most sites) were identified to the lowest possible taxa, counted, and measured to the nearest millimeter using dial calipers. Sediments were returned to the quadrat during the sieving process, whereas biota was returned following measurements.

At each site, we measured the abundance (number of individuals per unit area) of larger bivalve species (e.g. *Protothaca staminea*, *Clinocardium* sp., *Macoma* sp., *Mya arenaria*, *Mytilus trossulus*, and *Saxidomus gigantea*) and the size distributions of any species observed in large enough numbers.

For each site sampled we calculated the mean density of clams / 0.25 m² by species by site at each tidal elevation by park and the size class distributions of the predominant clam, *Macoma* spp., as well as mean size of clams collected by site at each tidal elevation by park. Because the data set collected to date is intended to be compared against identical data collected from the same sites in the future, we do not perform or report statistical tests of significance in this report.

Results

Density

Sampling clams using the described method is not appropriate for LACL. Four of the sites (SI1, SI2, SI4 and SI5) had no clams observed. At SI3, only 12 clams (primarily *Macoma* spp.) were observed. Therefore, no analysis was done for LACL. Potential methods for refinement for LACL are in the Discussion and Recommendation sections.

In general more clams were found at the 0.0 m tidal elevation by site in KATM and KEFJ than at the 0.5 m tidal elevation, the exceptions being SI2 in KATM and SI4 and SI5 in KEFJ. SI3 was not sampled at the 0.5 m tidal elevation in KATM in 2009 due to logistical constraints. *Macoma* spp. were the dominant clam at three sites at the 0.0 m and three sites at the 0.5 m tidal elevations in KATM, except sites SI3 and SI4 at which *Saxidomas* was predominant (Figure 9 and 10). *Macoma* spp. were the dominant clam at both the 0.5 m and 0.0 m tidal elevation at all sites in KEFJ (Figure 11 and 12). The density of *Macoma* spp. per quadrat per site ranged from 0 to 46.17 clams per 0.25 m² at the 0.0 m tidal elevation and from 0 to 52.67 at the 0.5 m tidal elevation in KATM in 2009. The density of *Macoma* spp. per quadrat per site ranged from 16.67 to 25.83 clams per 0.25 m² at the 0.0 m tidal elevation and from 5.83 to 37.83 at the 0.5 m tidal elevation in KEFJ in 2009. The number of clams per quadrat varied extensively within sites as well as among sites, tidal elevations and parks.

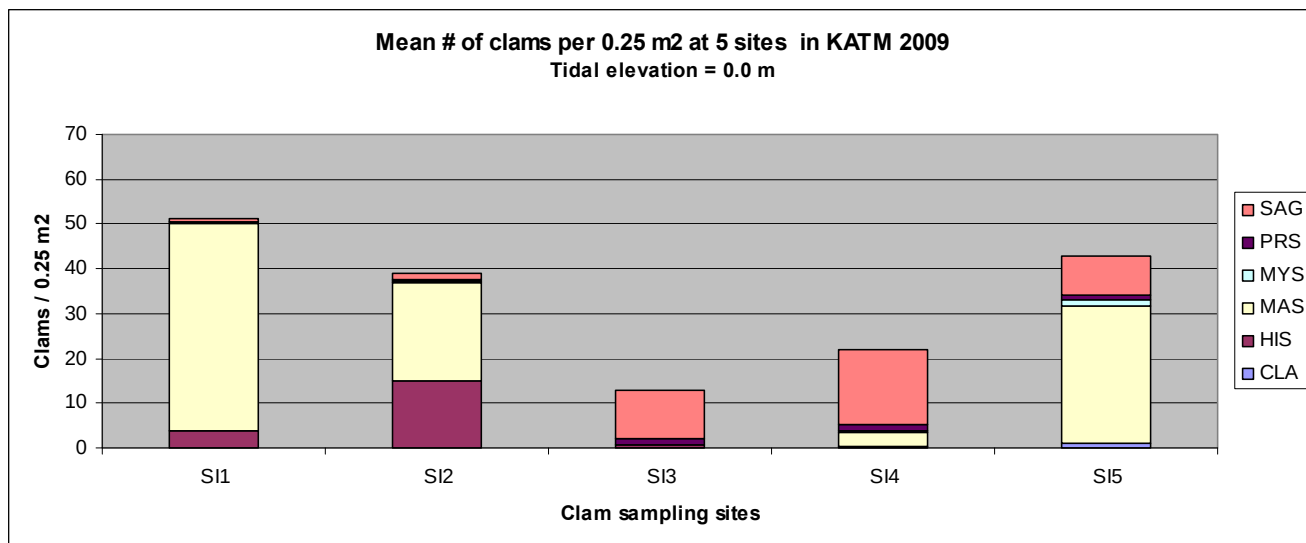


Figure 9. Mean numbers of clams per quadrat at 5 soft intensive (SI) sites in KATM, 2009 at the 0.0 m tidal elevation. Clam species abbreviations are: *Saxidomus gigantea* (SAG), *Protothaca staminea* (PRS), *Mya* spp. (MYS), *Macoma* spp. (MAS), *Hiatella* spp. (HIS), and species occurring in low frequencies and pooled in the category other clam (CLA).

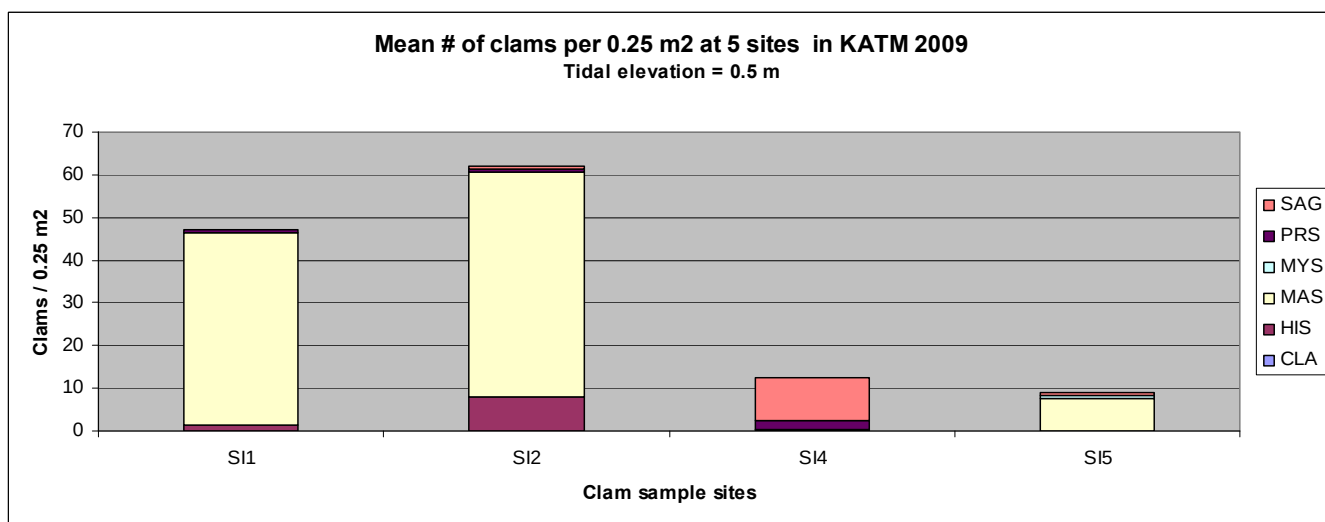


Figure 10. Mean numbers of clams per quadrat at 5 soft intensive (SI) sites in KATM, 2009 at the 0.5 m tidal elevation. Clam species abbreviations are: *Saxidomus gigantea* (SAG), *Protothaca staminea* (PRS), *Mya* spp. (MYS), *Macoma* spp. (MAS), *Hiatella* spp. (HIS), and species occurring in low frequencies and pooled in the category other clam (CLA). SI3 at the 0.5 m tidal elevation was not sampled.

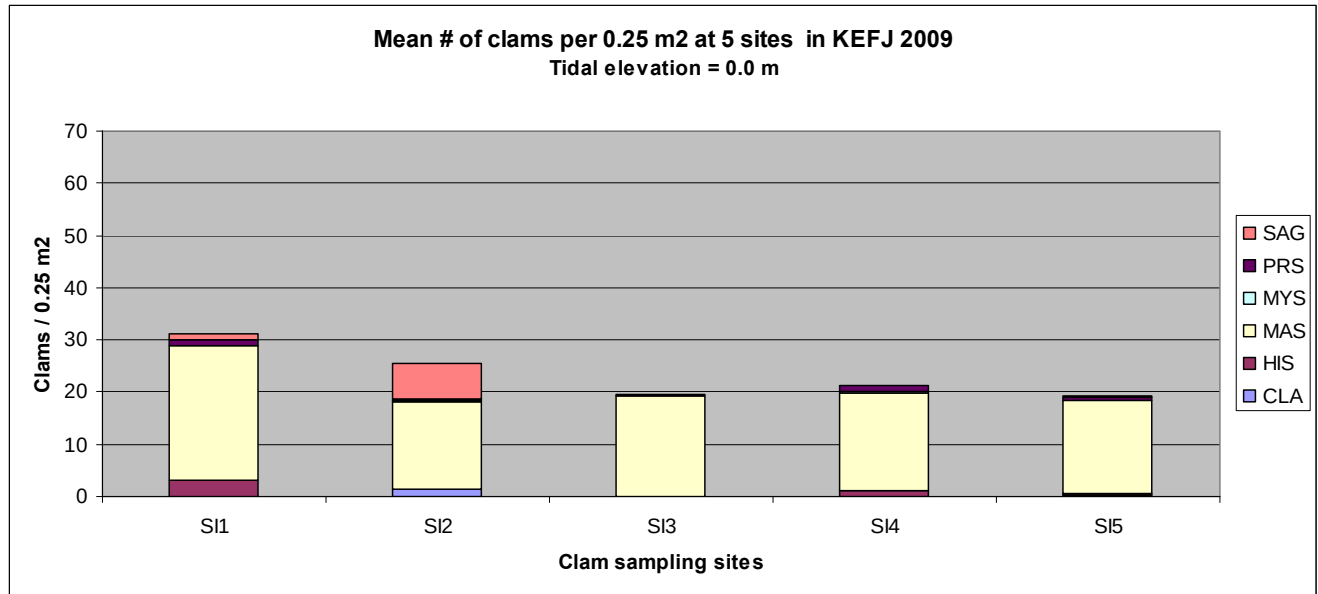


Figure 11. Mean numbers of clams per quadrat at 5 soft intensive (SI) sites in KEFJ, 2009 at the 0.0 m tidal elevation. Clam species abbreviations are: *Saxidomus gigantea* (SAG), *Protothaca staminea* (PRS), *Mya* spp. (MYS), *Macoma* spp. (MAS), *Hiatella* spp. (HIS), and species occurring in low frequencies and pooled in the category other clam (CLA).

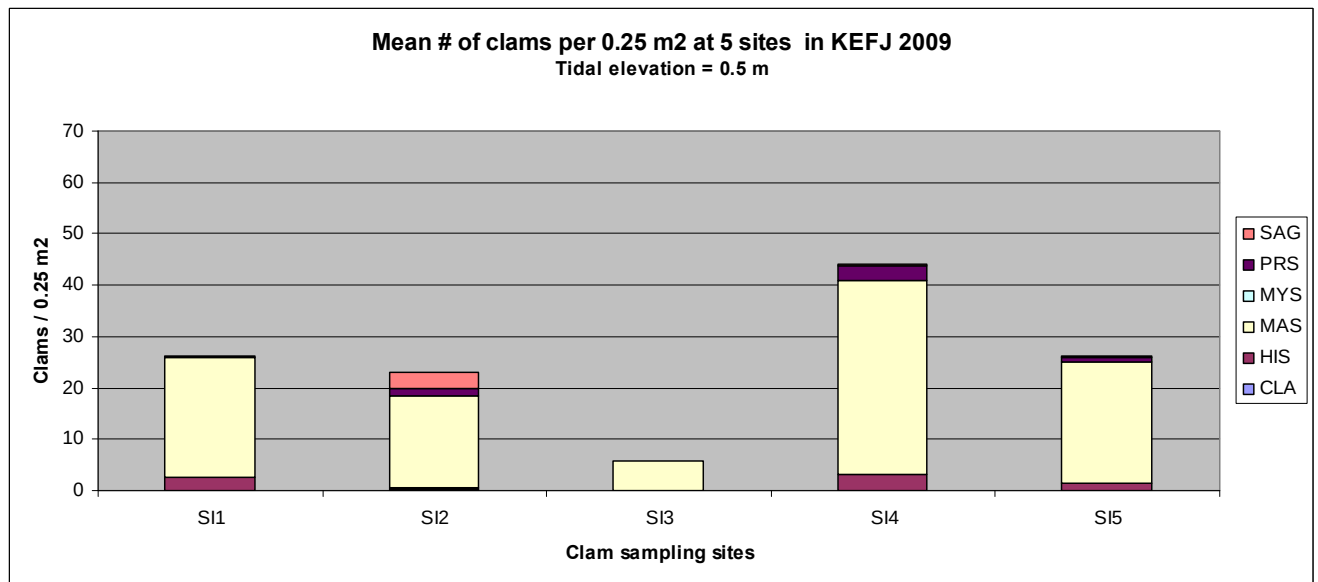


Figure 12. Mean numbers of clams per quadrat at 5 soft intensive (SI) sites in KEFJ, 2009 at the 0.5 m tidal elevation. Clam species abbreviations are: *Saxidomus gigantea* (SAG), *Protothaca staminea* (PRS), *Mya* spp. (MYS), *Macoma* spp. (MAS), *Hiatella* spp. (HIS), and species occurring in low frequencies and pooled in the category other clam (CLA).

Mean Size and Size Frequency Distributions

Sampling clams using the described method is not appropriate for LACL. Four of the sites (SI1, SI2, SI4 and SI5) had no clams observed. At SI3, only 12 clams (primarily *Macoma* spp.) were

observed. Therefore, no analysis was done for LACL. Potential methods for refinement for LACL are in the Discussion and Recommendation sections.

The overall means for clam size were 20.94, 22.83, 31.65, 32.27, and 42.94 mm for *Hiatella*, *Macoma*, *Mya*, *Protothaca*, and *Saxidomas*, respectively in KATM at the 0.0 m tidal elevation. The overall means for clam size were 25.40, 24.64, 34.44, 38.29, and 44.73 mm for *Hiatella*, *Macoma*, *Mya*, *Protothaca*, and *Saxidomas*, respectively in KATM at the 0.5 m tidal elevation (Figures 13 and 14). The overall means for clam size were 23.88, 21.33, 40.00, 27.44, and 34.94 mm for *Hiatella*, *Macoma*, *Mya*, *Protothaca*, and *Saxidomas*, respectively in KEFJ at the 0.0 m tidal elevation. The overall means for clam size were 17.83, 21.10, 21.00, 29.09, and 36.67 mm for *Hiatella*, *Macoma*, *Mya*, *Protothaca*, and *Saxidomas*, respectively in KEFJ at the 0.5 m tidal elevation (Figure 15 and 16).

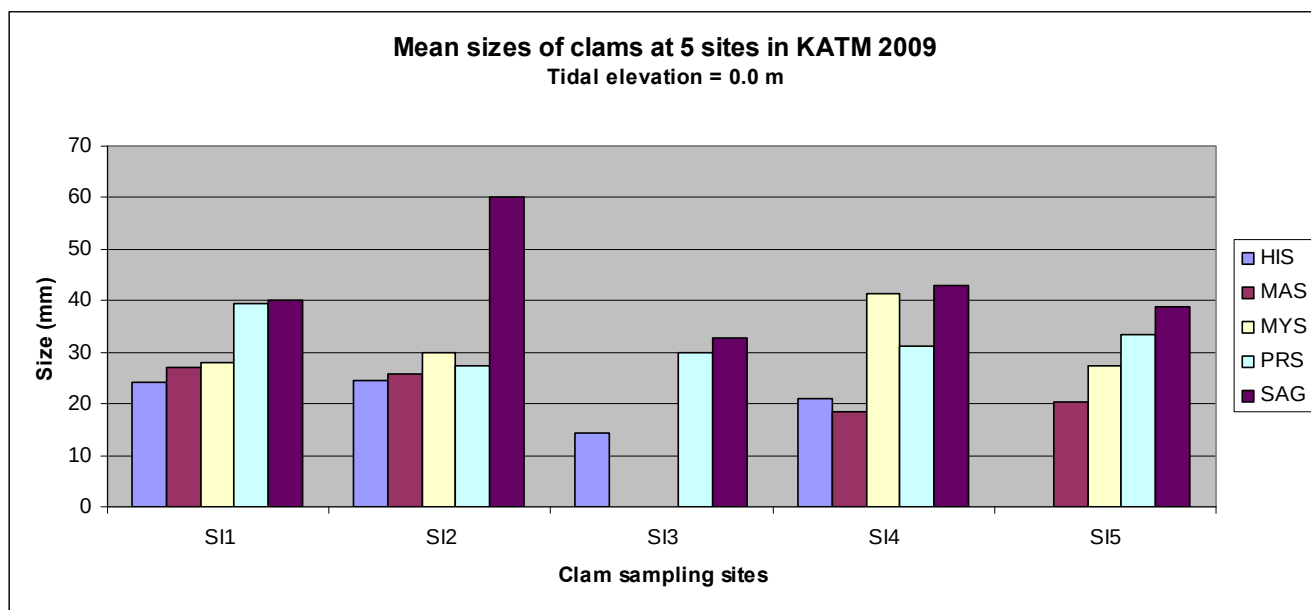


Figure 13. Mean sizes of clams at 5 soft intensive (SI) sites in KATM in 2009 at the 0.0 m tidal elevation. Clam species abbreviations are: *Saxidomus gigantea* (SAG), *Protothaca staminea* (PRS), *Mya* spp. (MYS), *Macoma* spp. (MAS), *Hiatella* spp. (HIS).

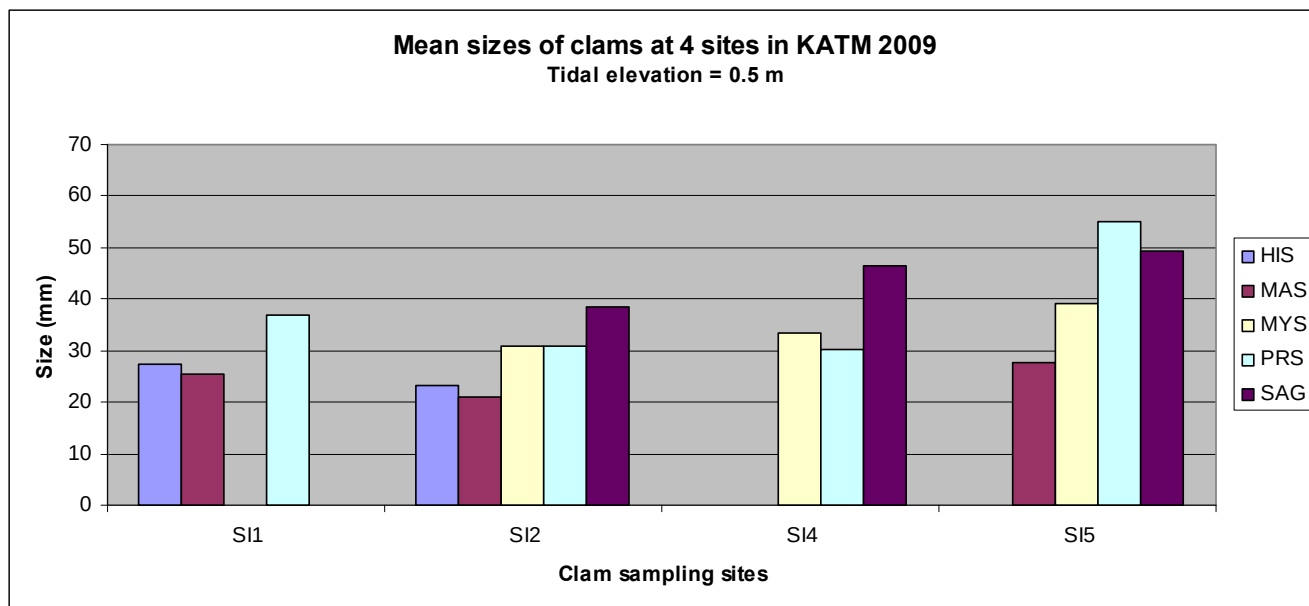


Figure 14. Mean sizes of clams at 4 soft intensive (SI) sites in KATM in 2009 at the 0.5 m tidal elevation. Clam species abbreviations are: *Saxidomus gigantea* (SAG), *Protothaca staminea* (PRS), *Mya* spp. (MYS), *Macoma* spp. (MAS), *Hiatella* spp. (HIS).

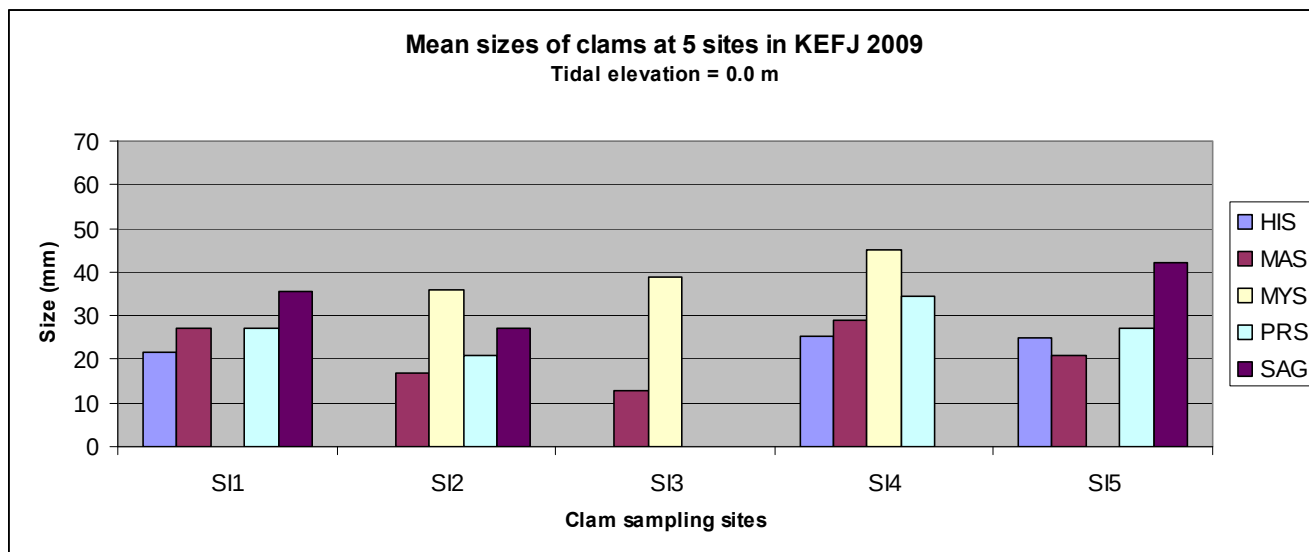


Figure 15. Mean sizes of clams at 5 soft intensive (SI) sites in KEFJ in 2009 at the 0.0 m tidal elevation. Clam species abbreviations are: *Saxidomus gigantea* (SAG), *Protothaca staminea* (PRS), *Mya* spp. (MYS), *Macoma* spp. (MAS), *Hiatella* spp. (HIS).

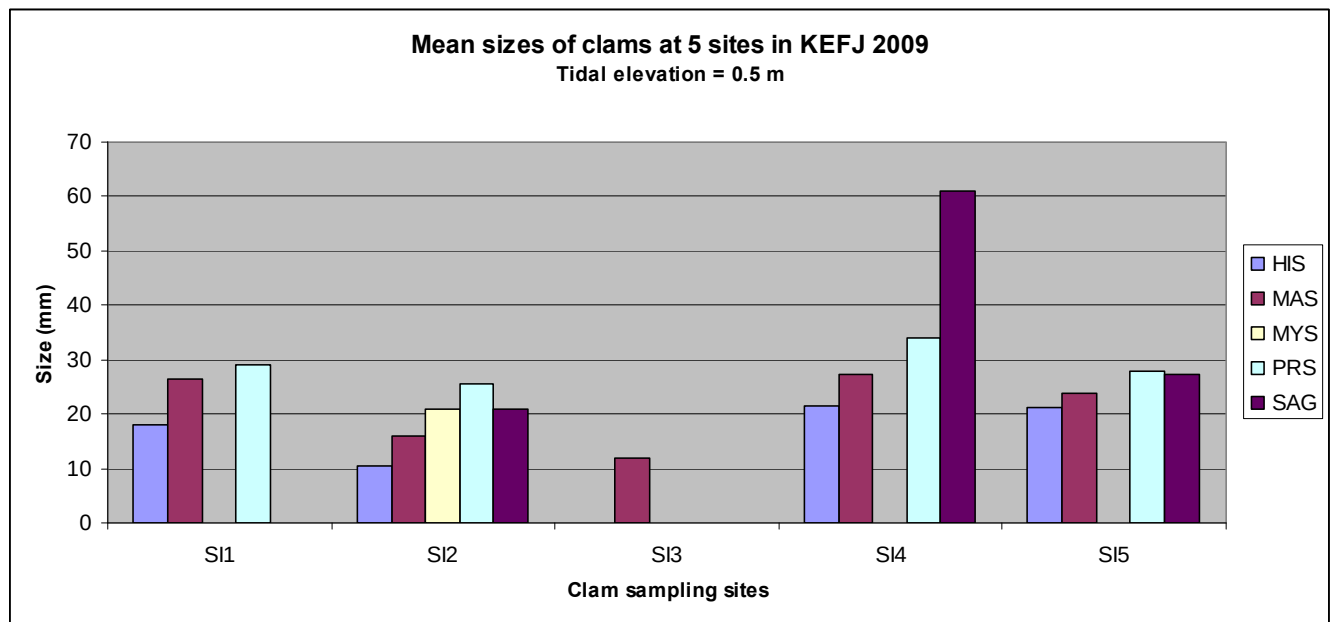


Figure 16. Mean sizes of clams at 5 soft intensive (SI) sites in KEFJ in 2009 at the 0.5 m tidal elevation. Clam species abbreviations are: *Saxidomus gigantea* (SAG), *Protothaca staminea* (PRS), *Mya* spp. (MYS), *Macoma* spp. (MAS), *Hiatella* spp. (HIS).

As stated earlier, *Macoma* spp. was the most abundant clam, overall in both KATM and KEFJ. The majority of *Macomas* were in the 16-20 mm class for both tidal elevations in KATM (Figure 17 and 18). The majority of *Macomas* were in the 11-15 mm class for both tidal elevations in KEFJ (Figure 19 and 20). However, KEFJ sites SI1 (Aialik Bay), SI4 (Nuka Pass) and SI5 (Harris Bay) exhibited higher proportions of distributions in the larger size classes (21-25 mm and 26-30 mm) at both tidal elevations.

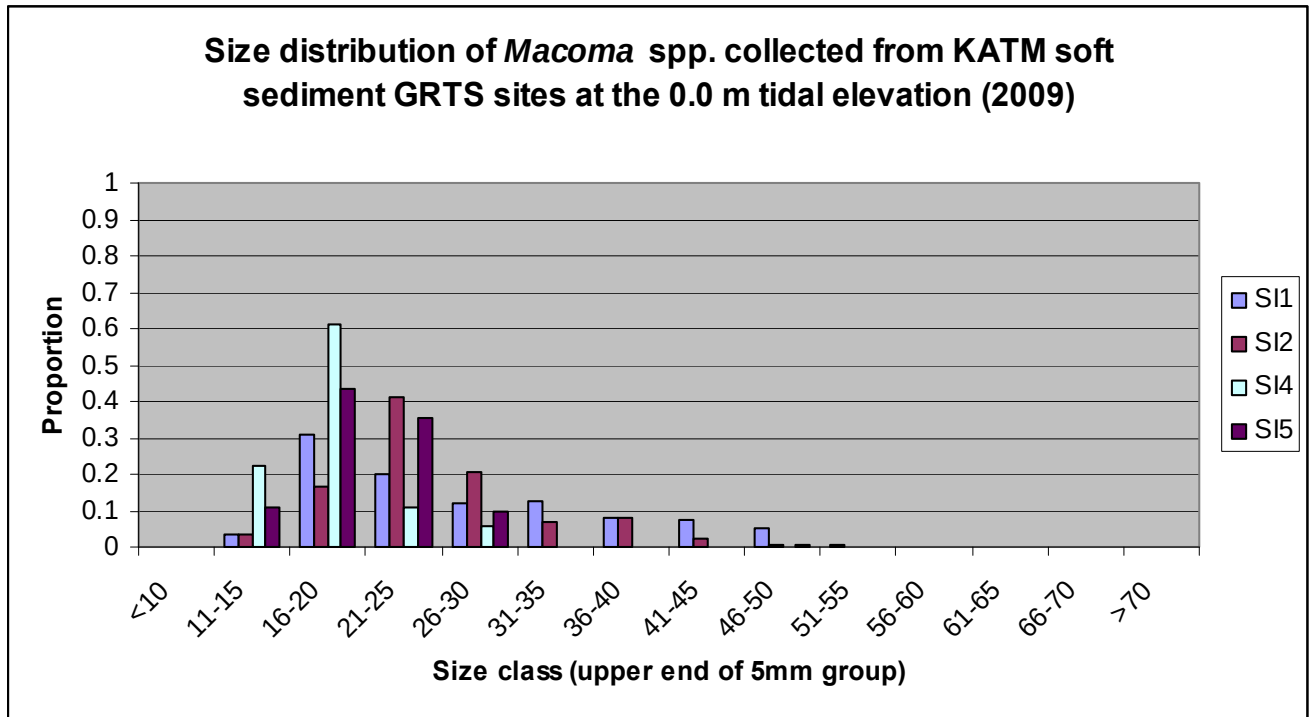


Figure 17. Comparison of size classes of *Macoma* in KATM by site in 2009 at the 0.0 m tidal elevation. No *Macoma* spp. were observed at site SI3.

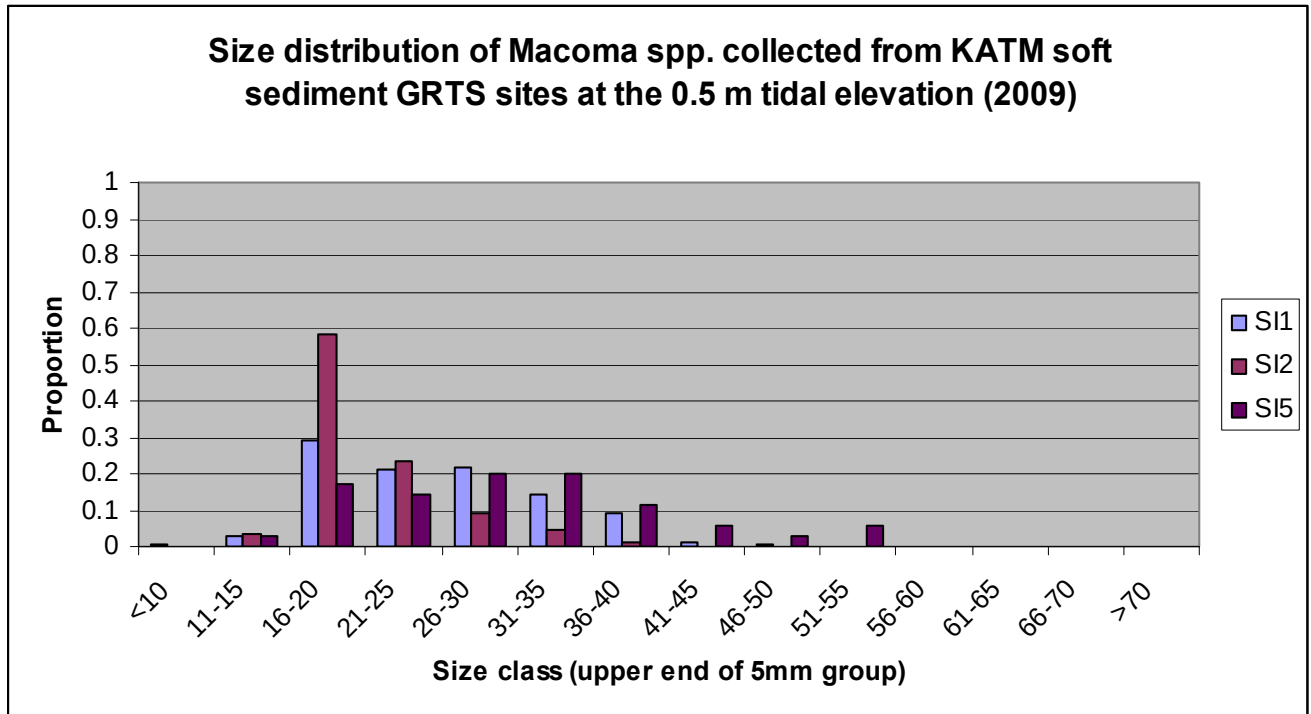


Figure 18. Comparison of size classes of *Macoma* in KATM by site in 2009 at the 0.5 m tidal elevation. No *Macoma* spp. were observed at site SI4 and SI3 was not sampled at the 0.5 m tidal elevation.

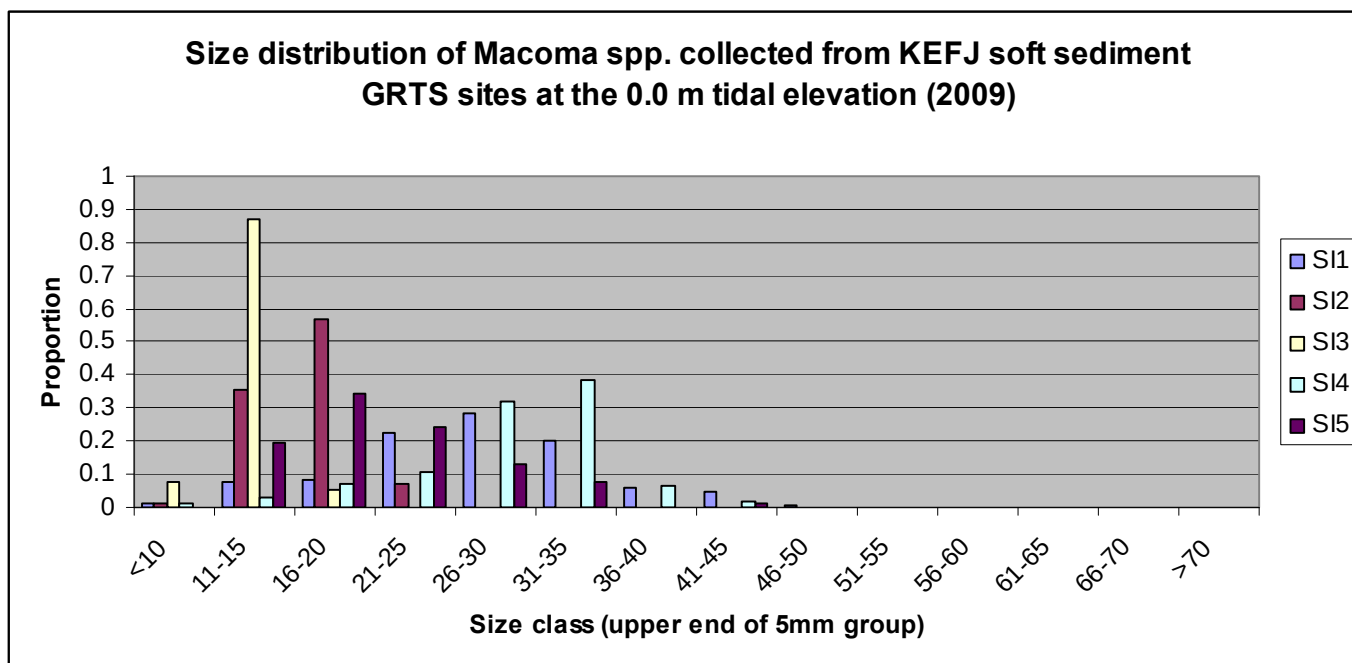


Figure 19. Comparison of size classes of *Macoma* in KEFJ by site in 2009 at the 0.0 m tidal elevation.

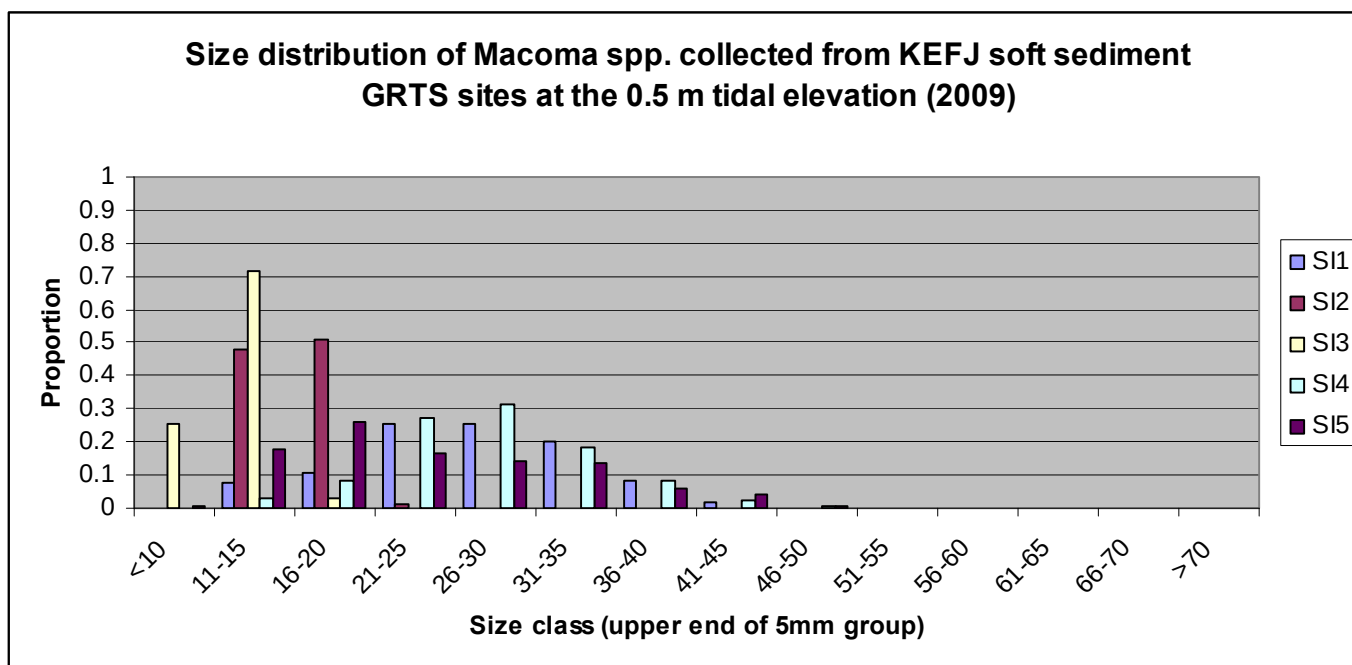


Figure 20. Comparison of size classes of *Macoma* in KEFJ by site in 2009 at the 0.5 m tidal elevation.

Discussion

In both KATM and KEFJ the number of clams per quadrat varied extensively within sites as well as among sites and parks. Lab results have not yet been received for sediment grain size analysis

so we have not yet been able to determine the relationship between substrate and clam populations. Once additional data has been collected and lab results received, it is anticipated that a spatial analysis could be conducted to examine the role of variables such as substrate qualities, aspect, slope, distance from freshwater influx, and the presence of predators (sea otters, black oystercatchers, seaducks) on intertidal clam communities in KATM and KEFJ.

Macoma spp. mean sizes were similar at both parks. However, size distribution varied by site in KEFJ. This variation in size distribution may be effected by predation pressure. Mean clam sizes and the distribution of clam sizes by species will provide some of the best evidence of a possible predator effect at our sampling sites. For example, in Glacier Bay, at random and preferred clam habitat sites sampled prior to sea otter foraging pressures, respective mean sizes of *Protothaca* and *Saxidomus* are about 40 and 70 mm (Bodkin and Kloecker 1999). *Saxidomus* and *Protothaca* are preferred clam prey of sea otters in Alaska (Kvitek et al. 1992, JLB unpub. data) and larger clams are preferentially selected by foraging sea otters (Kvitek et al. 1992, Kvitek et al. 1993). The clam populations that persist in areas with prolonged sea otter foraging are characterized by reduced densities and size distributions that are truncated near the minimum size clams that are regularly consumed. However, this study has not yet determined the impact of predation pressure on prey communities in KATM or KEFJ. We expect that as marine predators continue to exert foraging pressure on intertidal communities that the overall abundance of preferred clams will decrease and that the size distributions of those clams will shift toward higher proportions of smaller individuals.

Recommendations

Recommendations for LACL include refining the sampling to focus on areas that exhibit high densities of clams and are accessible by plane. Utilizing a plane may allow us to sample many areas to find appropriate habitat for establishing long-term monitoring sites. *Macoma* spp. may be a significant prey item for several species of shorebirds and ducks (Bennett 1996). However, our current sampling methods in LACL do not adequately sample *Macoma* spp. Another important commercially and recreationally harvested intertidal invertebrate species along the LACL coastline is the razor clam (*Siliqua patula*). Alaska Department of Fish and Game currently monitors razor clam density along the east side of Cook Inlet, but not along the west side. An established protocol for specifically sampling razor clams is available through ADF&G. This protocol differs from current SWAN soft sediment intertidal sampling and would exclude sampling of all other soft sediment invertebrates. Discussions with SWAN and LACL staff will continue to establish monitoring priorities and determine the monitoring protocol best suited for the LACL coast.

We recommend that continued soft sediment sampling at KATM and KEFJ occur solely at the 0.0 m tidal elevation instead of the 0.5 m tidal elevation due to the larger quantity of clams found at the 0.0 m tidal elevation in general in both KATM and KEFJ. We do not recommend sampling at both tidal elevations. The SOP should be revised to reflect sampling that occurs within twelve quadrats along one tidal elevation.

Mussel Bed Sampling

Introduction

Pacific blue mussels (*Mytilus trossulus*) are a dominant invertebrate in the intertidal zone and are critically important prey for a variety of organisms including sea otters, black oystercatchers, harlequin ducks, Barrows goldeneye, and several species of sea stars (O'Clair and Rice 1985, O'Clair and O'Clair 1988, VanBlaricom 1988, Andres and Flaxa 1995, Esler et al. 2002, Bodkin et al. 2002). Mussels are widely distributed in many intertidal habitats, but also form relatively monotypic stands of larger individuals that are termed mussel beds. The goal of mussel bed sampling is to assess changes in the size of beds and in the size of mussels within those beds over time. These data are primarily to be used as an indicator of mussel abundance as prey for various vertebrate predators (sea stars, sea ducks and sea otters). Specifically, the objectives are to estimate: 1) the density of mussels within these beds, 2) the density of large mussels within these beds, and 3) the size distribution of larger mussels within the beds (those generally consumed by black oystercatchers, sea ducks and sea otters). Sampling is conducted in sheltered rocky habitats within KATM and KEFJ. We define mussel beds as sites with relatively high densities of Pacific blue mussels. Specifically, mussel beds are defined as areas with greater than approximately 10% cover by mussels within contiguous 0.25 m² quadrats over areas of 100 m² or greater. Metrics used to evaluate change over time will include the area of individual mussel beds (in m²), average density of large mussels (greater than 20 mm in length), and the mean size of mussels > 20 mm.

Methods

Sampling sites are defined as 50 m of coastline with contiguous mussel beds. These sites were selected following intensive searches in 2008 for the presence of mussel beds adjacent to the randomly selected rocky intertidal sites (see intertidal invertebrates and algae section). The closest mussel bed to the randomly selected rocky intertidal site was selected for sampling.

A transect 50 m in length was established through the mid point of the bed, relative to tidal elevation, and at the left end of the bed, as observed from the water. A permanent bolt was placed at this location and at 5 m intervals along the 50 m length of the horizontal transect to establish the site for future sampling. Ten vertical transects were then established at systematic intervals based on a random start point along the horizontal transect length, and the distance from the upper most margin of the bed to the lower margin (or the zero tidal elevation) were measured.

Estimates of mussel density are made within quadrats that are randomly located along each vertical transect. Quadrat dimensions are dependent on the density of mussels ≥ 20 mm within 1 m of the predetermined random point along the vertical transect, and determined at the time of sampling. The quadrat size can range from .0025 m² to 1.00 m² (5 cm to 100 cm on a side) with the size dependent on obtaining a collection of at least 20 mussels ≥ 20 mm in length. This results in approximately 200 mussels to estimate size distributions. All mussels ≥ 20 mm are collected from within the quadrat and later counted and measured, and densities of large mussels are calculated. Densities of all mussels (of a size that is visually detectable, approximately 5 mm and greater) are estimated from a 2.54 cm radius (20.27 cm²) core located at the same random

number that defined the vertical quadrat, but on the opposite side of the tape from the origin of the quadrat.

Results

In 2009 we estimated the abundance and sizes of mussels at five mussel bed sites in KATM and at five sites in KEFJ. The mean density of mussels obtained from all cores at KATM was 8,061 / m² (se=4,597), and at KEFJ was 21,439 / m² (se=11,051). At KATM, mean densities of mussels ranged from 4,242/ m² (se=2,049) at Kinak Bay (MI-3) to 14,603 (se=2,694) at Takli Island (MI-5) (Figure 21). At KEFJ, the range in mean densities was from 1,973/ m² (se=1,289) at Aialik Bay (MI-1) to 6,315/ m² (se=1698) at Harris Bay (MI-5) (Figure 22).

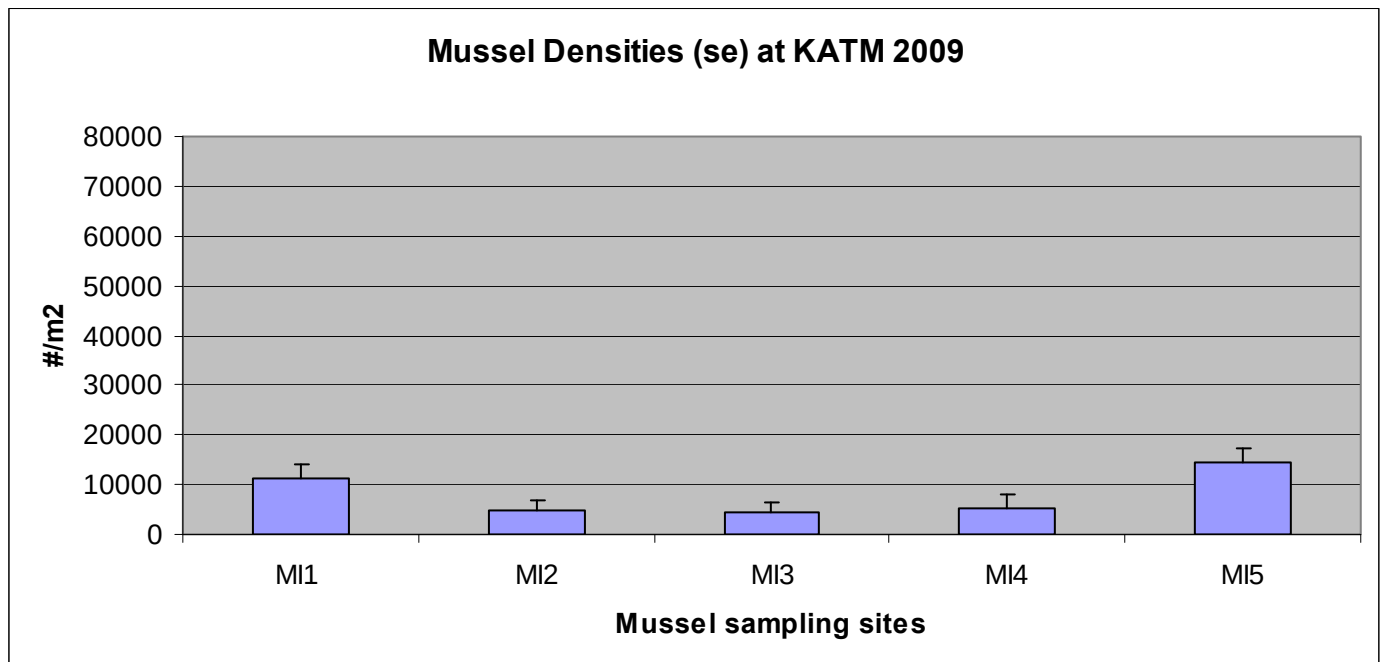


Figure 21. Mean densities (se) of mussels visible to the unaided eye obtained from 25.4 mm radius cores obtained from each of five mussel beds at KATM in 2009.

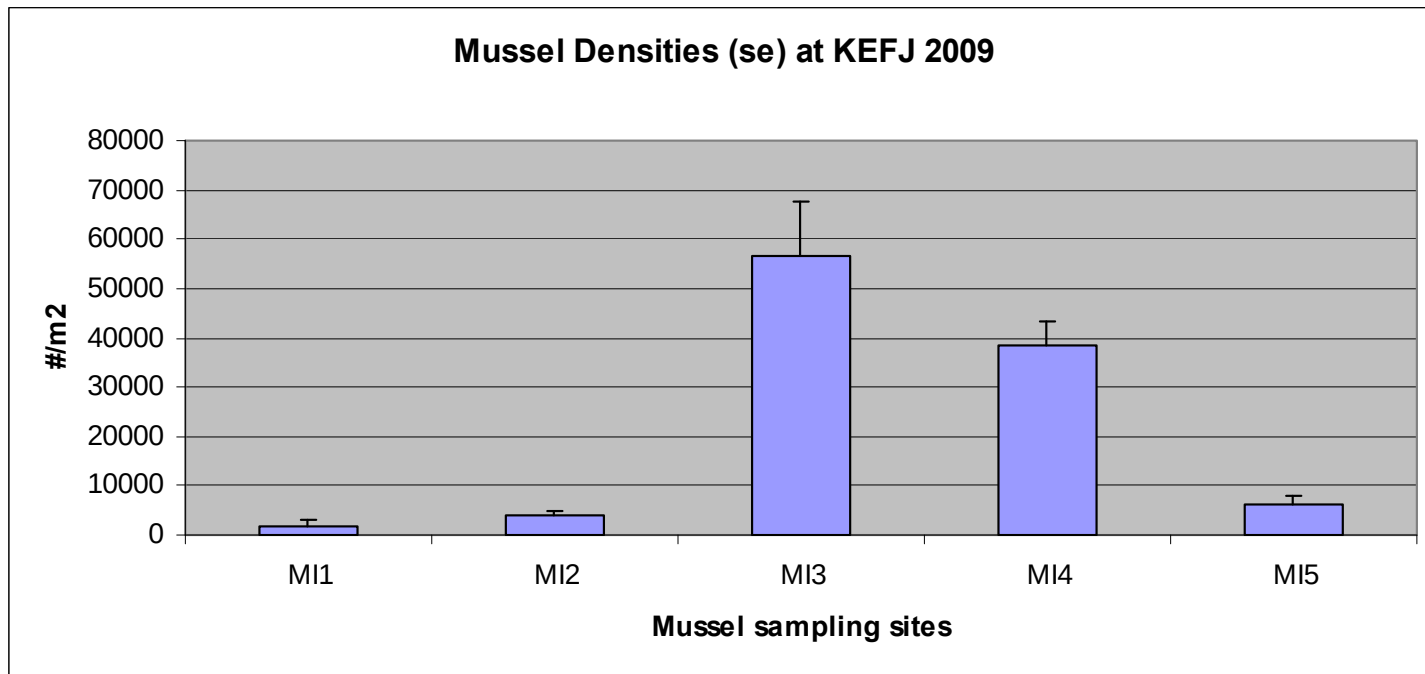


Figure 22. Mean densities (se) of mussels visible to the unaided eye obtained from 25.4 mm radius cores obtained from each of five mussel beds sites at KEFJ in 2009.

The mean density of mussels $\geq 20\text{mm}$ obtained KATM was $1,500/\text{m}^2$ ($\text{se}=476$), and at KEFJ was $2,488/\text{m}^2$ ($\text{se}=1113$). At KATM, mean densities ranged from $384/\text{m}^2$ ($\text{se}=240$) at Takli Island (MI-5) to $2,954$ ($\text{se}=926$) at Kukak Bay (MI-1) (Figure 23). At KEFJ, mean densities ranged from $216/\text{m}^2$ ($\text{se}=124$) at Aialik Bay (MI-1) to $6,630$ ($\text{se}=5536$) at Nuka Passage (MI-4) (Figure 24).

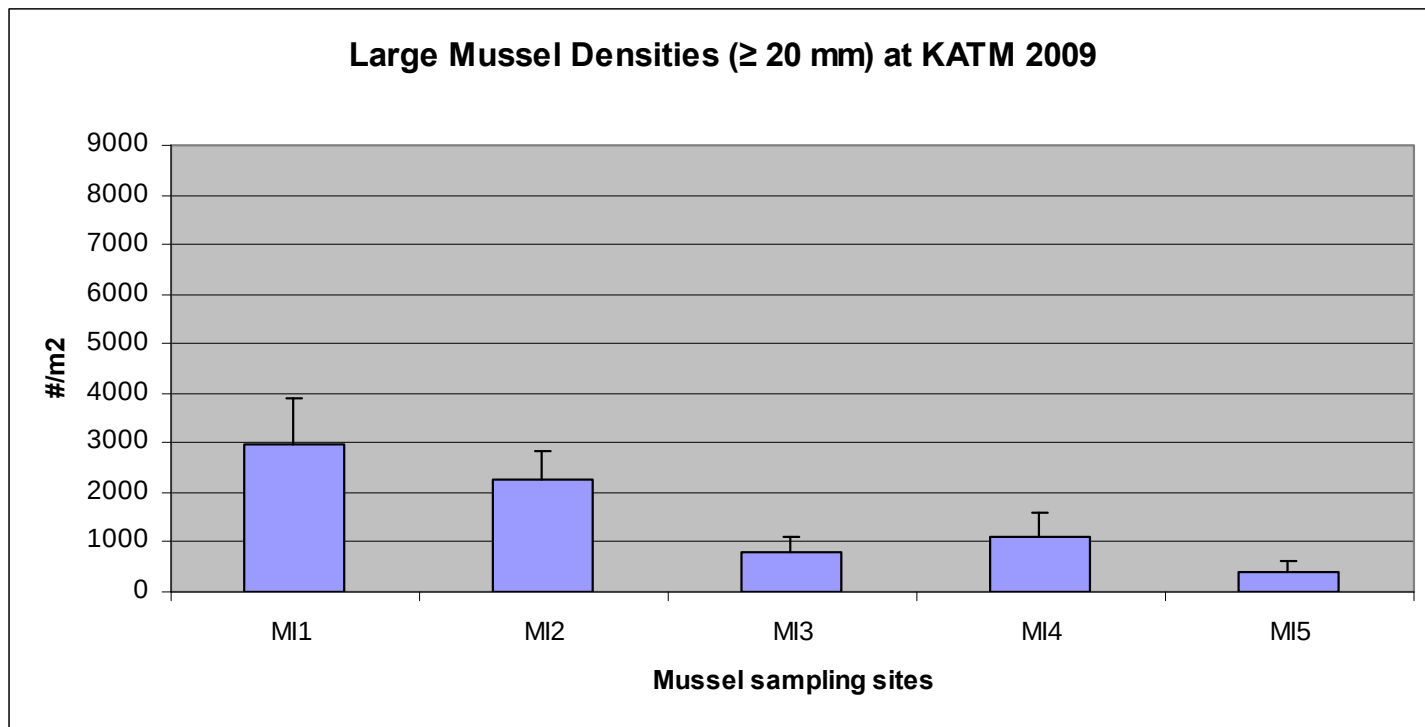


Figure 23. Mean densities (se) of mussels ≥ 20 mm at each of five mussel beds from variable sized plots in KATM in 2009.

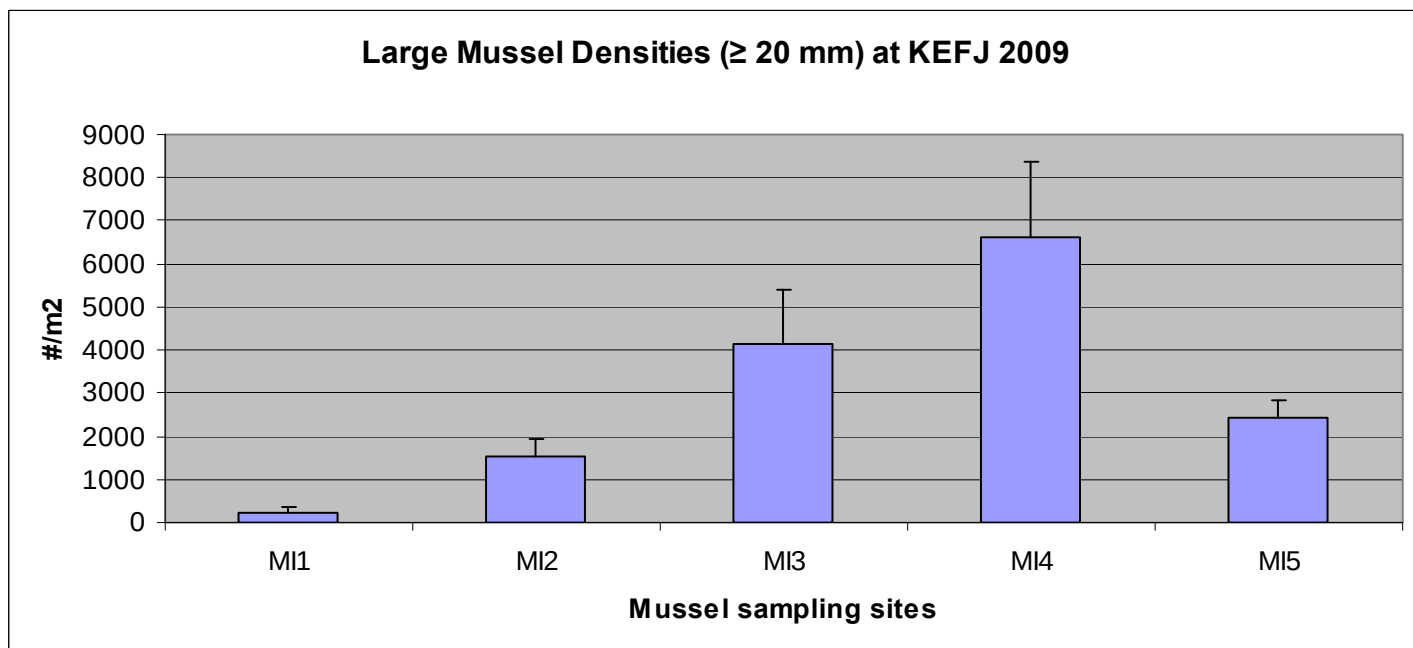


Figure 24. Mean densities (se) of mussels ≥ 20 mm at each of five mussel beds from variable sized plots in KEFJ in 2009.

The mean size of mussels ≥ 20 mm was 27.7 mm (se=0.6) at KATM and 27.2 mm (se=1.1) at KEFJ. At KATM, the mean size of mussels ≥ 20 mm ranged from 24.4 mm (se=1.5) at Takli

Island (MI-5) to 32.3 (se=2.4) at Kafia (MI-2) (Figure 25). At KEFJ, mean sizes of mussels ≥ 20 mm ranged from 23.6 mm (se=1.1) at Harris Bay (MI-5) to 29.3 (se=1.9) at McCarty Fjord (MI-2) (Figure 26).

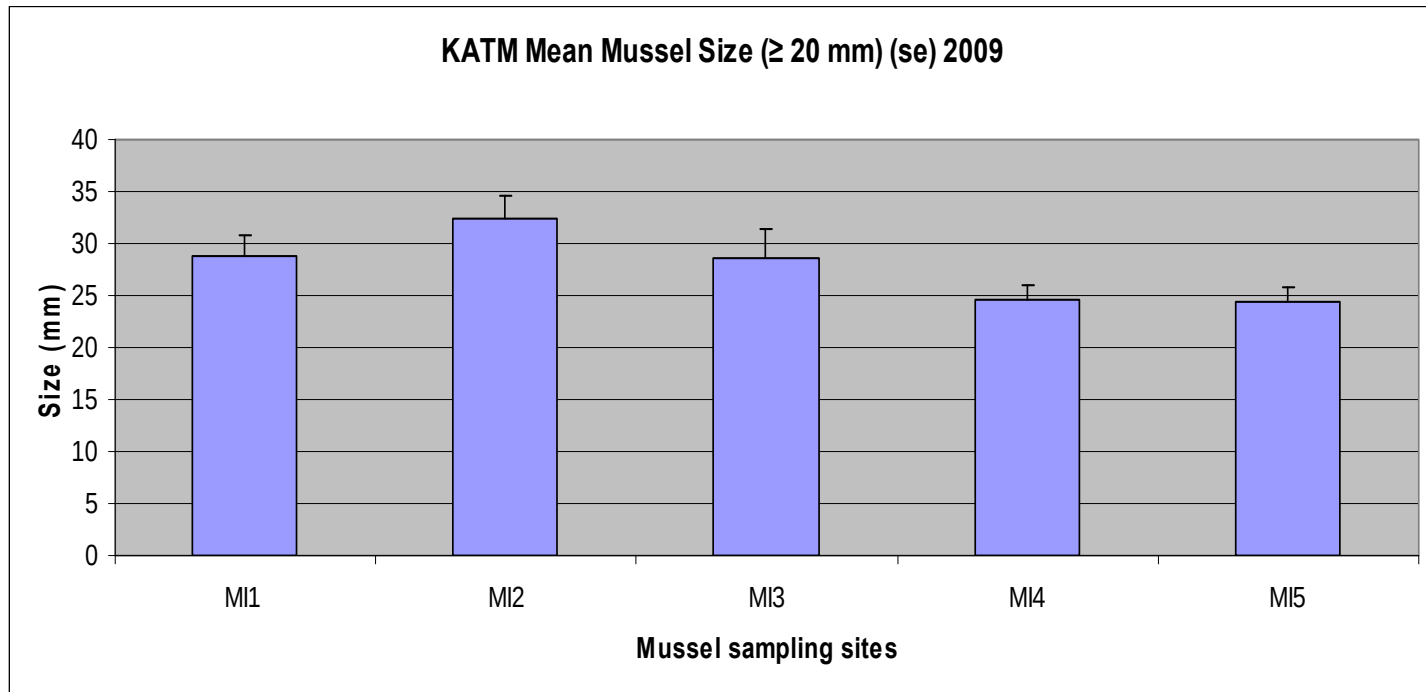


Figure 25. Mean sizes (se) of mussels ≥ 20 mm at each of five mussel beds in KATM in 2009.

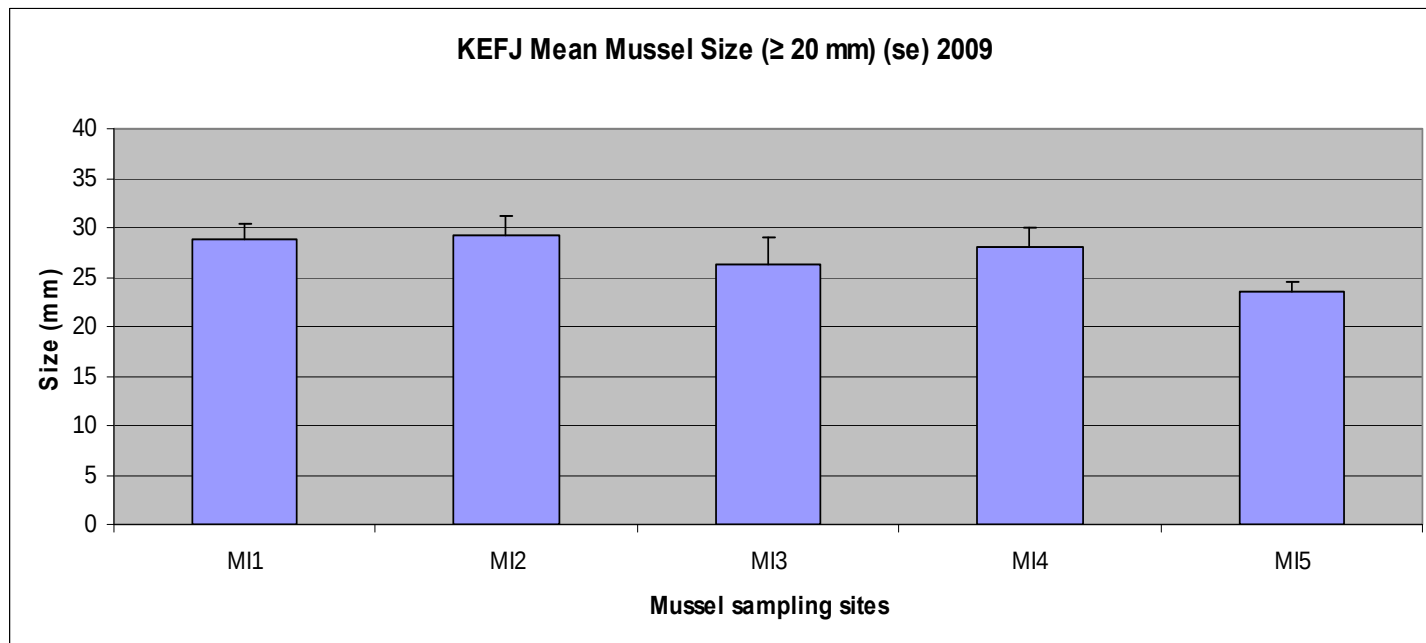


Figure 26. Mean sizes (se) of mussels ≥ 20 mm at each of five mussel beds in KEFJ in 2009.

The mean proportion of mussels ≥ 20 mm was 0.23 (se=0.06) at KATM and 0.23 (se=0.06) at KEFJ. At KATM the proportion of mussels ≥ 20 mm ranged from 0.03 at Takli Island (MI-5) to 0.46 at Kafliia Bay (MI-2) (Figure 27). At KEFJ the proportion of mussels ≥ 20 mm ranged from 0.07 at Nuka Bay (MI-3) to 0.39 at McCarty (MI-2) (Figure 28).

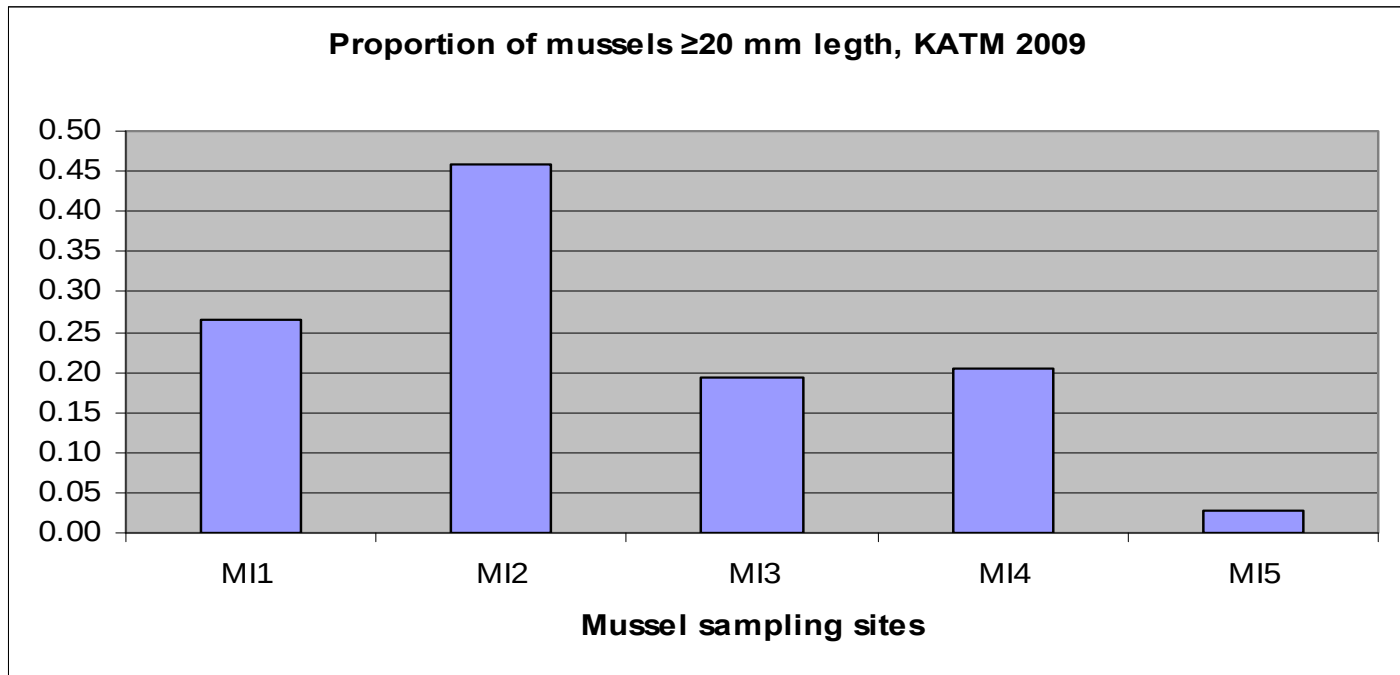


Figure 27. Mean proportion of mussels ≥ 20 mm at each of five mussel beds in KATM in 2009.

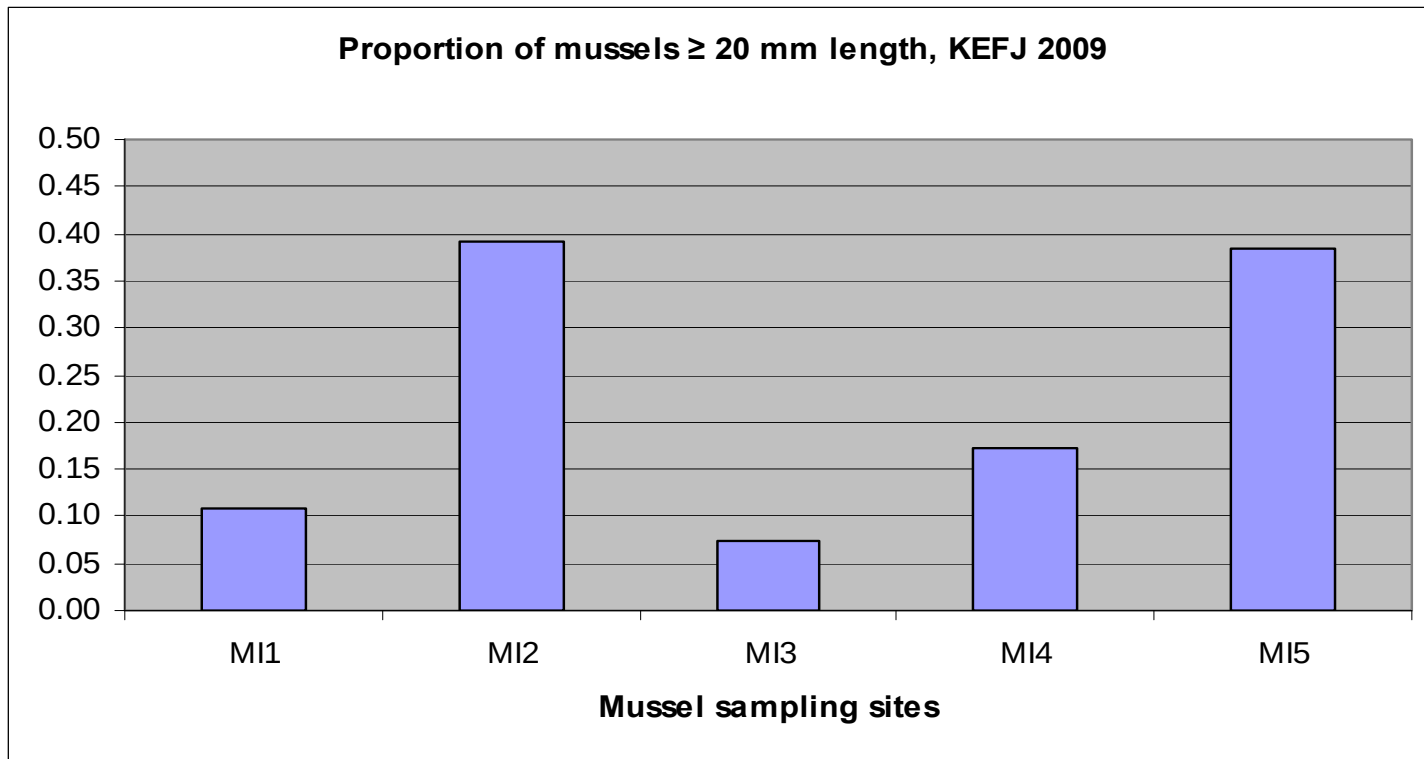


Figure 28. Mean proportion of mussels ≥ 20 mm at each of five mussel beds in KEFJ in 2009.

Discussion

Using the methods briefly described above, we were able to estimate densities of mussels, the sizes of mussels ≥ 20 mm, and the proportion of mussels ≥ 20 mm. Mussel densities varied greatly among sites, both in terms of all mussels and those ≥ 20 mm. Mean sizes of mussels ≥ 20 mm were relatively uniform among all sites. The high uniformity in mean sizes and low variance among sites, suggest perhaps a common mechanism structuring the sizes of mussels in the parks. While evaluating variance estimates of mussel densities and sizes for sensitivity to detect change will require additional years of data, the relatively low variation in mean sizes of large mussels across sites continues to suggest that mussel size may provide a statistically powerful metric to detect change over time

Recommendations

Our second year of descriptive analysis indicates that the method produces relatively precise estimates of abundance, within sites, and that sizes of mussels may provide a metric sensitive to change both among and within sites. We recommend the continuation of annual mussel bed sampling.

Eelgrass Bed Sampling

Introduction

Eelgrass (*Zostera marina*) is the dominant seagrass in protected waters of the Gulf of Alaska and is broadly distributed in sheltered embayments, especially in habitats dominated by soft sediments where they often form “beds” or relatively monotypic stands that can cover much of the shallow (0 to 5 m depth) subtidal zone (McRoy 1968, 1970). Eelgrass is an important “living habitat” that serves as a nutrient filter, provides shelter for fish and a variety of invertebrates, and provides physical substrate for invertebrates and algae (Thayer and Phillips 1977, Jewett et al. 1999, Dean et al. 2000, Bostrom et al. 2006). Eelgrass is a major primary producer in the marine nearshore (McConnaughey and McRoy 1979) and because it is located in shallow water, is susceptible to oil spills and other human disturbances (Short and Wiley-Eschevaria 1996, Dean et al. 1998, Duarte 2002, Larkum et al. 2006, Short et al. 2006). Eelgrass is especially susceptible to dredging, anchor scars, and events that reduce light penetration into the water column such as runoff (increased turbidity) or nutrient addition (Walker et al. 1989, Oleson 1996, Hauxwell et al. 2003, Neckles et al. 2005, Terrados et al. 2006).

The purpose of this sampling is to assess changes in the extent of eelgrass over time. In this report, we examine results from sampling eelgrass cover in KATM and KEFJ in 2009. The sampling is designed to examine smaller spatial (within beds of approximately 1 km²) and temporal scale (several year) changes within eelgrass beds

Methods

We sampled the percent cover of eelgrass at five sites in KATM and five sites in KEFJ in 2009. All were in sheltered bays and were at eelgrass beds in closest proximity to sites selected for sampling of invertebrates on sand/gravel beaches that were chosen using a GRTS procedure (Stevens and Olsen, 2004) that provided a spatially balanced yet random selection of sites. At each site we sampled eelgrass within a prescribed area along shoreline of approximately 200 m in length. The width of each bed examined depended on the depth contour at each site, but was generally on the order of 50 to 100 m. The areas sampled were bounded by an approximately 200 m long segment of shoreline over which eelgrass was observed and extended offshore to a distance approximately 15 m beyond the last observed eelgrass. The percent cover of eelgrass within this area was estimated by determining the presence or absence of eelgrass at approximately evenly spaced intervals along a series of transects running perpendicular to shore that were spaced approximately 20 m apart. Presence absence was determined using a dropped underwater video camera lowered from a small inflatable boat and a single-beam sonar. At each observation point we recorded whether eelgrass was present or not.

Results

The percent of observations with eelgrass present ranged from 17 to 60%. The highest percent covers were observed at Harris Bay and Nuka Bay in KEFJ.

Table 1. Percent of observations with eelgrass at sites in KATM and KEFJ in 2009. Means and 90% confidence intervals (mean plus or minus CI) are given.

Park Name	Site Name	Site Number	Percent of observations with eelgrass present
KATM	Kukak	AP-B10-RI1	53
	Kaflia	AP-B10-RI2	26
	Kinak	AP-B10-RI3	19
	Amalik	AP-B10-RI4	38
	Takli	AP-B10-RI5	50
	Mean		37
	CI		11
KEFJ	Aialik	KP-B5-RI1	17
	Harris	KP-B5-RI5	58
	McCarty	KP-B5-RI2	24
	Nuka Bay	KP-B5-RI3	60
	Nuka Passage	KP-B5-RI4	49
	Mean		42
	CI		15

Discussion

Using the methods briefly described above, we were able to estimate percent cover by eelgrass in prescribed areas. Determination of our ability to detect change in eelgrass cover over time will require additional years of sampling.

Recommendations

Based on replicate sampling completed in 2008, our analysis indicated that the method produces relatively precise estimates of the relative abundance of eelgrass. We recommend the continuation of annual eelgrass bed sampling.

Marine Bird Surveys

Introduction

Marine birds and mammals are important constituents of marine ecosystems and are sensitive to variation in marine conditions. Our focus on nearshore marine bird monitoring will be on species that are relatively abundant and trophically linked to the nearshore food web where the kelps and seagrasses contribute substantially to primary productivity and benthic invertebrates such as clams, mussels and snails, transmit that energy to higher level trophic level fishes, birds and mammals. Species of focus in the nearshore food web include black oystercatchers, cormorants, glaucous-winged gulls, black-legged kittiwakes, goldeneyes (winter density and distribution), harlequin ducks, pigeon guillemots, and scoters. Because other birds and mammals will be encountered in the course of monitoring nearshore species, observations of all marine birds and mammals are recorded and reported.

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. 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. pigeon guillemots, black-legged kittiwakes, 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 pigeon guillemots that forage on small fish, may suggest a common cause of change, one that may be independent of food. Such an approach may provide insights related to competing hypotheses relative to cause of change within or among populations (Petersen et al. 2003). In addition many of these species, including the harlequin duck, Barrow's goldeneye, and black oystercatcher were impacted by the Exxon Valdez oil spill, and exhibited protracted recovery periods as a consequence of lingering oil in nearshore habitats in Prince William Sound (Andres 1999, Trust et al. 2000, Esler et al. 2000, Esler et al. 2002). Long-term monitoring of these species at different locations will likely provide increased confidence in assessment of the status of these populations relative to restoration and recovery from the 1989 spill. Additionally, existing data collected using comparable methods are available from other nearshore habitats in the Gulf of Alaska for periods up to 20 years (Irons et al. 1988, Irons et al. 2000). 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.

Methods

Standardized surveys of marine birds were conducted in KATM from 2006-2009 and KEFJ from 2007-2009 through late June and into early July and in LACL for the first time in 2009. 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 are

conducted from small vessels (5-8 m length) that are navigated along selected sections of coastline that represent independent transects at speeds of 8-12 knots. Transect width is 200 m and two observers searched each side of the vessel out 100 m. All marine birds and mammals within the 200 m transect width that includes 100 m ahead of, behind, and over the vessel are identified and counted. One observer navigates the skiff, and generally surveys the offshore portion of the transect. The second observer counts birds and mammals on the shore side of the survey transect, and a third member of the team is responsible for entering observations into a computer program (dLOG2) designed specifically for these surveys (Dean and Bodkin 2006), and assists in observations. All transects considered in this analysis are run 100 m offshore and parallel to the shoreline.

The survey design consists of a series of transects along shorelines such that a minimum of 20% of the shoreline is surveyed. Transects are systematically selected beginning at a random starting point from the pool of contiguous 2.5-5 km transects that are 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.

Summer survey data analysis focuses on seven taxa while winter survey data analysis focuses on those same seven, plus an additional three sea ducks (Barrow's goldeneye, bufflehead and long-tailed duck). Each is identified as important to nearshore food webs and as important indicators of change (Dean and Bodkin 2009). Several species were grouped into higher order taxa (e.g., cormorants and scoters) because identification to species within these groups was not always possible. Cormorant species included pelagic, red-faced, and double crested cormorants. Scoters included surf, black, and white-winged scoters.

Results

Four surveys were conducted in 2009. Three summer surveys that included LACL, KEFJ and KATM and a winter survey in KATM were completed in 2009. Only focal species densities and standard errors observed on nearshore transects are reported here. Because only one continuous transect along the LACL coastline was completed, no SE's are reported for LACL.

Table 2. Average density of focal species observed during a summer survey of the LACL coast, 2009.

Species	Average density (#/km ²)
Black-legged kittiwake (<i>Rissa tridactyla</i>)	210.80
Black scoter (<i>Melanitta nigra</i>)	0.87
Double-crested cormorant (<i>Phalacrocorax auritus</i>)	2.94
Glaucous-winged gull (<i>Larus glaucescens</i>)	35.40
Harlequin duck (<i>Histrionicus histrionicus</i>)	7.09
Pigeon guillemot (<i>Cepphus columba</i>)	0.27
Surf scoter (<i>Melanitta perspicillata</i>)	12.38
Unid. Scoter (<i>Melanitta sp.</i>)	70.34
White-winged scoter (<i>Melanitta fusca</i>)	3.55

Table 3. Average density and standard error of focal species observed during a winter survey of the KATM coast, 2009.

Species	Average density (#/km ²)	SE
Barrow's goldeneye (<i>Bucephala islandica</i>)	30.99	9.01
Black-legged kittiwake (<i>Rissa tridactyla</i>)	27.05	15.32
Black oystercatcher (<i>Haematopus bachmani</i>)	1.42	0.48
Black scoter (<i>Melanitta nigra</i>)	33.40	10.88
Bufflehead (<i>Bucephala albeola</i>)	15.22	7.10
Double-crested cormorant (<i>Phalacrocorax auritus</i>)	0.52	0.32
Glaucous-winged gull (<i>Larus glaucescens</i>)	38.35	10.85
Harlequin duck (<i>Histrionicus histrionicus</i>)	69.19	9.75
Long-tailed duck (<i>Clangula hyemalis</i>)	13.76	2.63
Pelagic cormorant (<i>Phalacrocorax pelagicus</i>)	12.38	2.61
Pigeon guillemot (<i>Cephus columba</i>)	2.46	0.91
Red-faced cormorant (<i>Phalacrocorax urile</i>)	0.70	0.46
Surf scoter (<i>Melanitta perspicillata</i>)	11.40	2.92
Unid. Scoter (<i>Melanitta sp.</i>)	33.21	12.57
White-winged scoter (<i>Melanitta fusca</i>)	17.81	5.21

Table 4. Average density and standard error of focal species observed during a summer survey of the KATM coast, 2009.

Species	Average density (#/km ²)	SE
Black-legged kittiwake (<i>Rissa tridactyla</i>)	59.93	19.05
Black oystercatcher (<i>Haematopus bachmani</i>)	1.37	0.48
Black scoter (<i>Melanitta nigra</i>)	9.85	9.85
Double-crested cormorant (<i>Phalacrocorax auritus</i>)	1.43	1.28
Glaucous-winged gull (<i>Larus glaucescens</i>)	110.68	38.45
Harlequin duck (<i>Histrionicus histrionicus</i>)	36.86	13.28
Pelagic cormorant (<i>Phalacrocorax pelagicus</i>)	34.32	22.48
Pigeon guillemot (<i>Cephus columba</i>)	16.35	4.74
Red-faced cormorant (<i>Phalacrocorax urile</i>)	10.64	9.52
Surf scoter (<i>Melanitta perspicillata</i>)	16.84	10.95
Unid. Cormorant (<i>Phalacrocoracidae sp.</i>)	0.32	0.15
Unid. Scoter (<i>Melanitta sp.</i>)	0.38	0.34
White-winged scoter (<i>Melanitta fusca</i>)	23.32	12.43

Table 5. Average density and standard error of focal species observed during a summer survey of the KEFJ coast, 2009.

Species	Average density (#/km ²)	SE
Black-legged kittiwake (<i>Rissa tridactyla</i>)	81.82	76.05
Black oystercatcher (<i>Haematopus bachmani</i>)	1.29	0.07
Double-crested cormorant (<i>Phalacrocorax auritus</i>)	1.68	0.76
Glaucous-winged gull (<i>Larus glaucescens</i>)	119.19	40.06
Harlequin duck (<i>Histrionicus histrionicus</i>)	15.92	8.26
Pelagic cormorant (<i>Phalacrocorax pelagicus</i>)	13.48	6.66
Pigeon guillemot (<i>Cepphus columba</i>)	4.63	1.31
Red-faced cormorant (<i>Phalacrocorax urile</i>)	7.33	3.31
Surf scoter (<i>Melanitta perspicillata</i>)	0.07	0.07
Unid. Cormorant (<i>Phalacrocoracidae sp.</i>)	6.69	2.67
Unid. scoter (<i>Melanitta spp.</i>)	0.04	0.04

Discussion

LACL had the highest black-legged kittiwake density of all three parks during the summer surveys. Two large colonies in Tuxedni Channel were observed during the survey that contributed to the high density of black-legged kittiwakes. LACL glaucous-winged gull density was comparable to KEFJ. Scoter density was the highest of all three parks as well. The KATM winter survey was completed for the first time in 2009. We observed higher densities of Barrow's goldeneye (30.99/km² vs. 0.0/km²), bufflehead (15.22/km² vs. 0.0/km²), long-tailed duck (13.76/km² vs. 0.0/km²), and harlequin duck (69.19/km² vs. 36.86/km²) than summer surveys. This is not unexpected but what these observations illustrate is the continued use of nearshore environment as a food source throughout the year. KATM and KEFJ continue to be sampled annually during the summer. In 2009, KATM exhibited higher densities of harlequin ducks, scoters and cormorants than KEFJ. Black oystercatcher density was similar across both parks. KEFJ exhibited higher densities of gulls.

Recommendations

We recommend that survey effort continue until further analysis can be completed. After the 2010 field season, we will have an additional year of survey data from KATM and KEFJ and will examine these data to suggest what levels of change we can reasonably expect to detect. We will return to LACL in 2011. Winter surveys should continue for both KATM and KEFJ to quantify over-wintering sea ducks, utilizing the nearshore. We will also explore the possibility of re-allocating sampling efforts to specific habitat types that may enhance our ability calculate detection and to detect trends for species of interest.

Black Oystercatcher Sampling

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*, *Acmea*, and *Colisella* sp.) (Andres and Falxa 1995), which are ecologically and culturally important constituents of the intertidal community. The species is considered a Management Indicator Species by the Chugach National Forest and a species of concern nationally (Brown et al. 2001), and regionally (Alaska Shorebird Working Group 2000) and is widely recognized as a species representative of nearshore habitats. Because of their complete reliance on intertidal habitats, their reproductive biology, and foraging ecology, black oystercatchers are particularly amenable to long-term monitoring (Lentfer and Maier 1995, Andres 1998).

As a “keystone” species (Power et al. 1996), the black oystercatcher has a large influence on the structure of intertidal communities that is disproportionate to its abundance. The black oystercatcher receives its recognition as a keystone species through a three-trophic-level cascade initiated by the oystercatcher as a top level consumer in the nearshore (Marsh 1986a and b, Hahan and Denny 1989, Falxa 1992) whose diet consists largely of gastropod (limpets) and bivalve (mussels) mollusks that are ecologically important in the intertidal community. As a consequence of oystercatcher foraging, large numbers of herbivorous limpets can be removed (Frank 1982, Lindberg et al. 1987), resulting in shifts in limpet species composition and reduced size distribution (Marsh 1986a, Lindberg et al. 1987). As a consequence of reduced limpet densities and the diminished grazing intensity that results, algal populations respond through increased production and survival, resulting in enhanced algal populations (Marsh 1986a, Meese 1990, Wootton 1992, Lindberg et al. 1998). Additionally, like other invertebrate, avian and mammalian predators in the nearshore, a large fraction of the oystercatcher’s diet consists of mussels, an important filter feeding bivalve (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 (Intertidal Invertebrates and Algae section of this report). 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 density, breeding territory density and occupancy, and prey will provide a potentially powerful tool in identifying the magnitude and causes of inevitable change in Gulf of Alaska nearshore habitats and communities, particularly in response to the anticipated increased use and influence of those habitats by humans.

Methods

There are three components to the sampling related to black oystercatchers: estimation of breeding pair density and nest occupancy through oystercatcher-specific surveys; estimation of species composition and size distributions of prey returned to provision chicks; and estimation of density of breeding and non-breeding black oystercatchers observed during the marine bird and mammal surveys. Results regarding the black oystercatcher density estimates are given in the marine bird survey section of this report. Detailed survey methods for estimation of nest occupancy and diet can be found in the black oystercatcher breeding territory occupancy and chick diet SOP (Dean and Bodkin 2006). The detailed methods used to obtain marine bird densities can be found in the marine bird SOP (Dean and Bodkin 2006) and in Bodkin et al. (2007b and 2008).

Black oystercatcher breeding territory density, nest occupancy, and prey data were collected along five 20 km transects each centered on the randomly (GRTS) rocky intertidal algal and invertebrate sites at KATM since 2006 and KEFJ since 2007. Nest sites were located by surveying the shoreline in a small boat. All accessible nest sites were visited to determine the number of chicks and or eggs present and all prey items (e.g. mussel or limpet shells) present at a nest site were collected. All prey were measured. Here, we present size data for most abundant prey species, Pacific blue mussels (*Mytilus trossulus*) and the limpets (*Lottia pelta*, *Lottia persona* and *Lottia scutum*).

Results

Density and Productivity

All five GRTS selected black oystercatcher transects were analyzed at the park level for nest density (nest/km) and productivity (chicks + eggs/nest). The mean density of active black oystercatcher nest sites at KATM ranged from 0.05 to 0.10 per km of shoreline in 2009 (Table 6). The mean productivity (eggs + chicks / nest) ranged from 0 to 1.5 eggs + chicks / nest for KATM in 2009 (Table 6). The mean density of active black oystercatcher nest sites at KEFJ ranged from 0.05 to 0.10 per km of shoreline in 2009 (Table 7). The mean productivity (eggs + chicks / nest) ranged from 1.0 to 3.0 eggs + chicks / nest for KEFJ in 2009 (Table 7).

Table 6. Average density of active or occupied nests as well as productivity per nests and standard error from GRTS transects on the KATM coast, 2009.

Site	Active or occupied nest density (#/km)	#Eggs	Eggs/nest	#Chicks	Chicks/nest	Eggs + Chicks/nest
AP B10 RI1	0.10	2	1	1	0.5	1.5
AP B10 RI2	0.15	3	1	6	2	3
AP B10 RI3	0.10	2	1	2	1	2
AP B10 RI4	0.05	0	0	0	0	0
AP B10 RI5	0.10	3	1.5	1	0.5	2
Means (#/km)	0.10		0.9		0.8	1.7
Se	0.02		0.24		0.34	0.49

Table 7. Average density of active or occupied nests as well as productivity per nests and standard error from GRTS transects on the KEFJ coast, 2009.

Site	Active or occupied nest density (#/km)	#Eggs	Eggs/nest	#Chicks	Chicks/nest	Eggs + Chicks/nest
KP B5 RI1	0.10	2	1.00	0	0.00	1.00
KP B5 RI3	0.05	2	2.00	0	0.00	2.00
KP B5 RI4	0.15	0	0.00	5	1.67	1.67
KP B5 RI5	0.10	6	3.00	0	0.00	3.00
Means (#/km)	0.10		1.50		0.42	1.92
Se	0.02		0.65		0.42	0.42

Diet

Three species of limpets (*Lottia pelta*, *Lottia persona*, and *Lottia scutum*) and the Pacific blue mussel (*Mytilus trossulus*) were the predominant prey items found at black oystercatcher nest

sites in both KATM and KEFJ (Figures 29 and 30). Together these species represented 89% of prey items found at KATM nest sites and 90% in KEFJ in 2009.

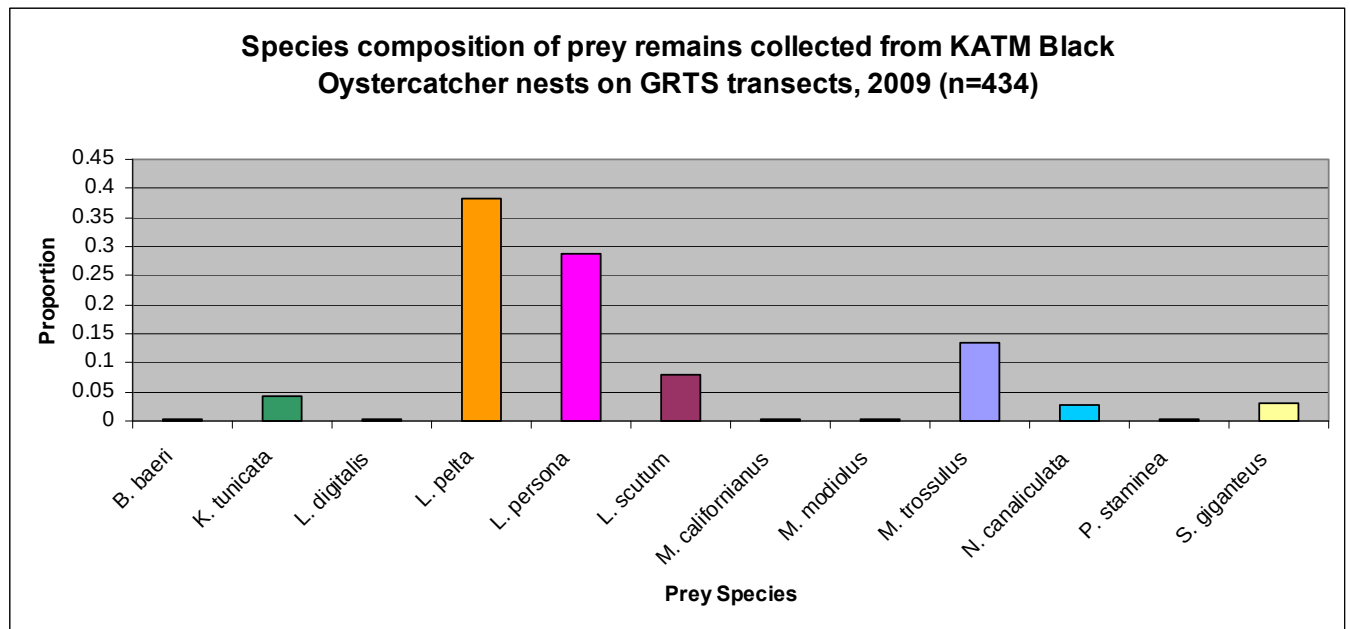


Figure 29. Proportion of prey collected at active black oystercatcher nests in KATM in 2009.

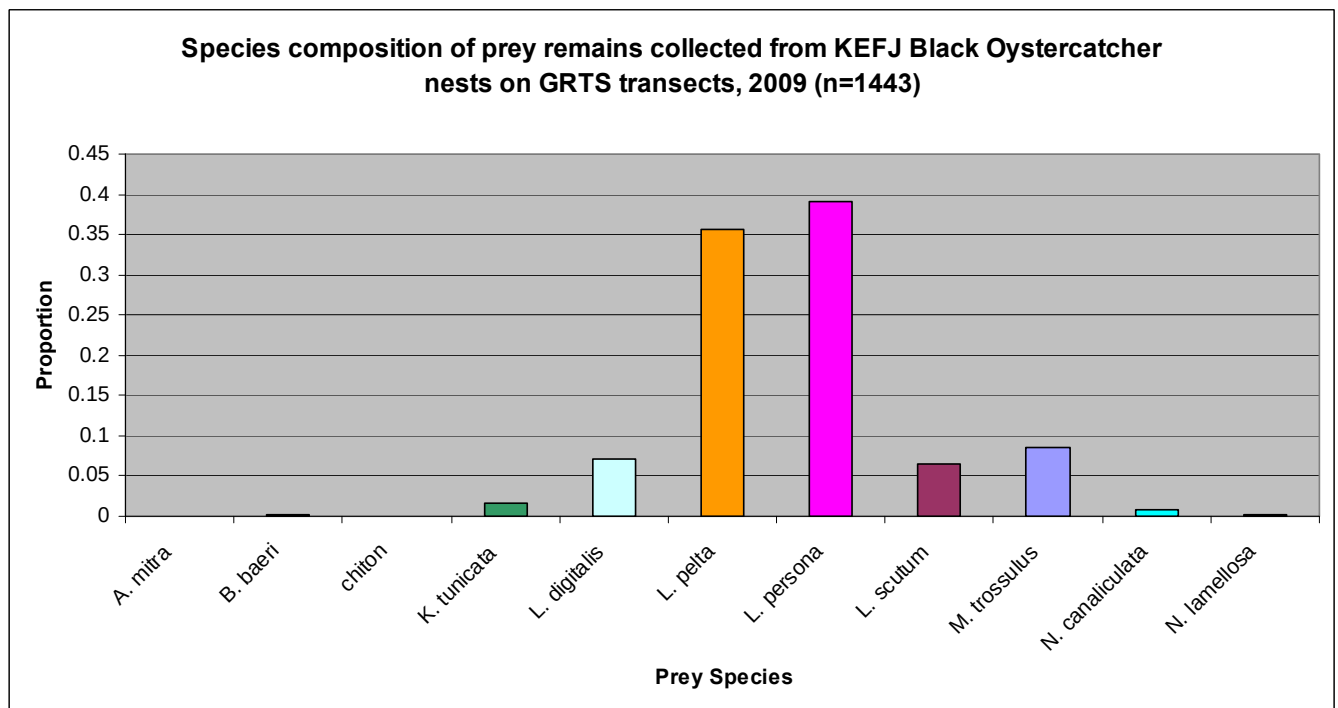


Figure 30. Proportion of prey collected at active black oystercatcher nests in KEFJ in 2009.

Prey size is measured for all species. However, we report only on the size distribution of the four most predominate prey species found in the black oystercatcher nests, *Lottia pelta*, *Lottia persona*, *Lottia scutum* and *Mytilus trossulus*. Mean sizes for the four predominate prey in KATM and KEFJ are given in tables 8 and 9. Mean *L. pelta* size ranged from 18.55 to 22.60 mm, *L. persona* size ranged from 17.99 to 24.15 mm, *L. scutum* size ranged from 24.00 to 31.33 mm and mussel size ranged from 23.75 to 40.00 mm in KATM. Mean *L. pelta* size ranged from 22.03 to 22.79 mm, *L. persona* size ranged from 19.08 to 23.54 mm, *L. scutum* size ranged from 23.88 to 25.90 mm and mussel size ranged from 21.70 to 26.7 mm in KEFJ (Figures 31 to 38).

Table 8. Average size of the 4 predominate prey species collected from active or occupied nests and standard errors from GRTS transects on the KATM coast, 2009. No prey items were collected on GRTS transects AP B10 RI4 or AP B10 RI5.

Species	Site	Mean Size (mm)	SE (mm)	Total Collected
<i>L. pelta</i>	AP B10 RI1	18.55	0.56	31
<i>L. pelta</i>	AP B10 RI2	22.60	1.21	10
<i>L. pelta</i>	AP B10 RI3	19.60	0.34	107
<i>L. persona</i>	AP B10 RI1	17.99	0.38	85
<i>L. persona</i>	AP B10 RI2	19.06	0.83	17
<i>L. persona</i>	AP B10 RI3	24.15	1.00	13
<i>L. scutum</i>	AP B10 RI1	24.00	3.00	2
<i>L. scutum</i>	AP B10 RI2	31.33	3.76	3
<i>L. scutum</i>	AP B10 RI3	26.43	0.62	28
<i>M. trossulus</i>	AP B10 RI1	40.00	11.00	2
<i>M. trossulus</i>	AP B10 RI2	27.24	1.39	51
<i>M. trossulus</i>	AP B10 RI3	23.75	1.11	4

Table 9. Average size of the 4 predominate prey species collected from active or occupied nests and standard errors from GRTS transects on the KEFJ coast, 2009. No prey items were collected on GRTS transects KP B5 RI2, KP B5 RI3 or KP B5 RI5.

Species	Site	Mean Size (mm)	SE (mm)	Total Collected
<i>L. pelta</i>	KP B5 RI1	22.03	0.55	32
<i>L. pelta</i>	KP B5 RI4	22.79	0.21	409
<i>L. persona</i>	KP B5 RI1	19.08	0.39	72
<i>L. persona</i>	KP B5 RI4	23.54	0.20	482
<i>L. scutum</i>	KP B5 RI1	25.90	0.86	39
<i>L. scutum</i>	KP B5 RI4	23.88	0.76	50
<i>M. trossulus</i>	KP B5 RI1	26.17	0.51	75
<i>M. trossulus</i>	KP B5 RI4	21.70	1.00	47

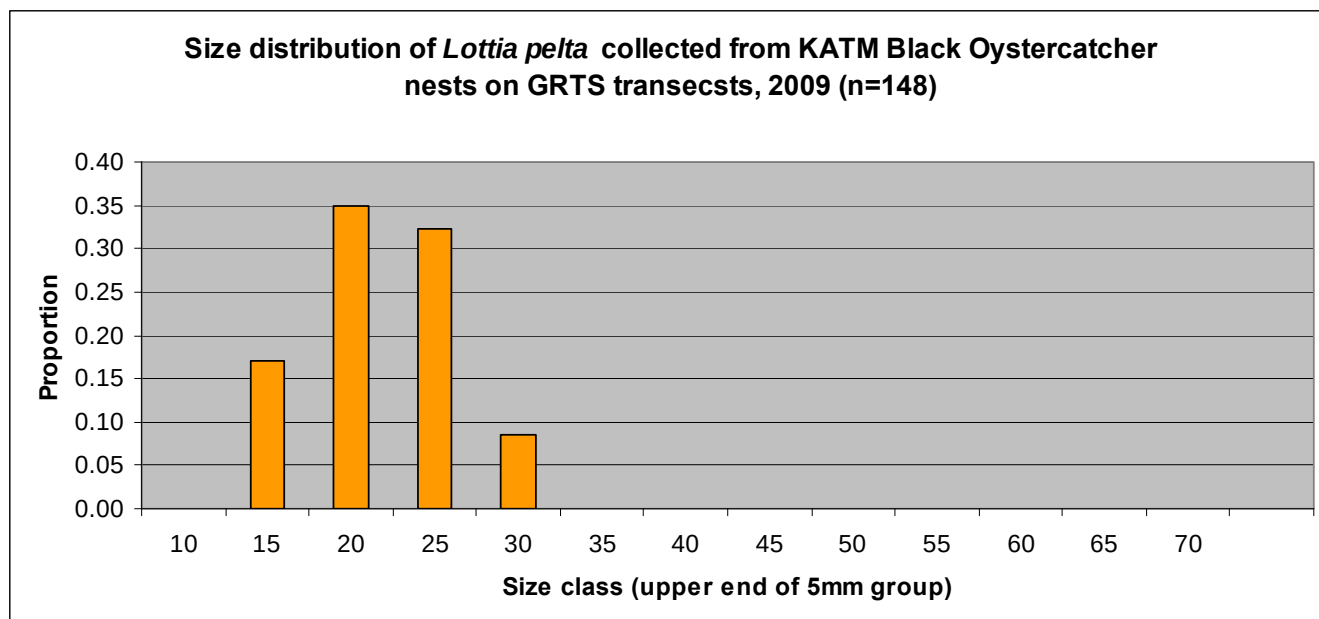


Figure 31. Size distribution of *Lottia pelta* collected from black oystercatcher nest sites on GRTS transects at KATM, 2009.

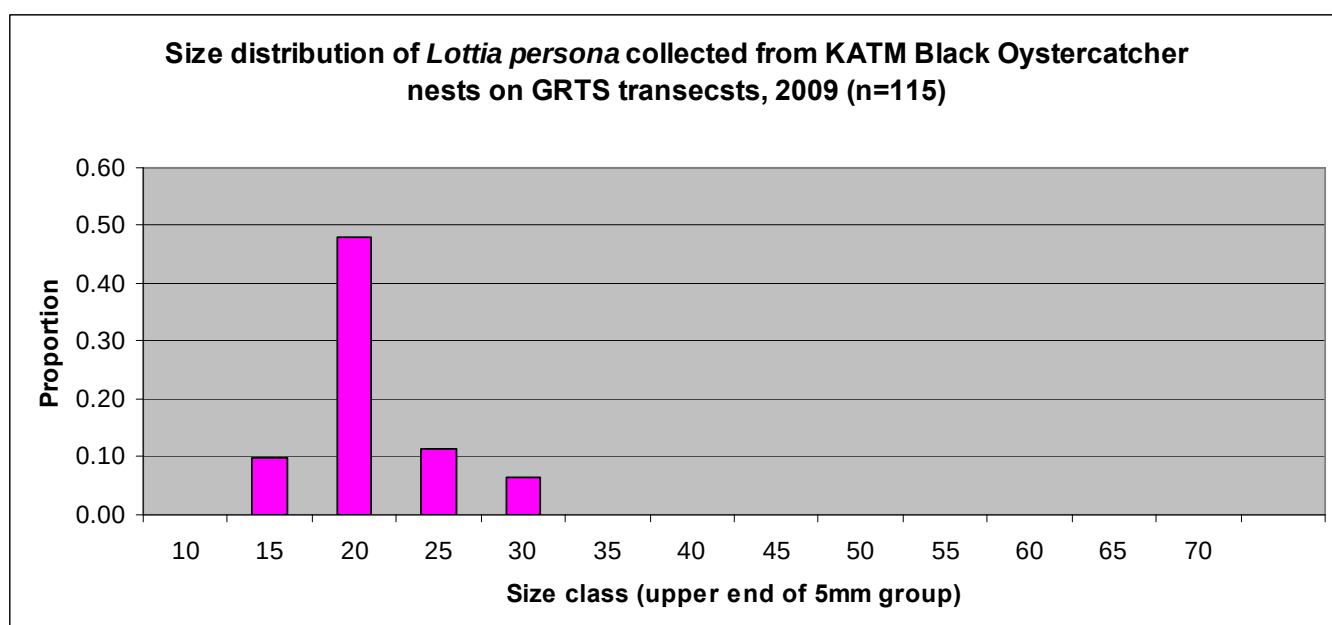


Figure 32. Size distribution of *Lottia persona* collected from black oystercatcher nest sites on GRTS transects at KATM, 2009.

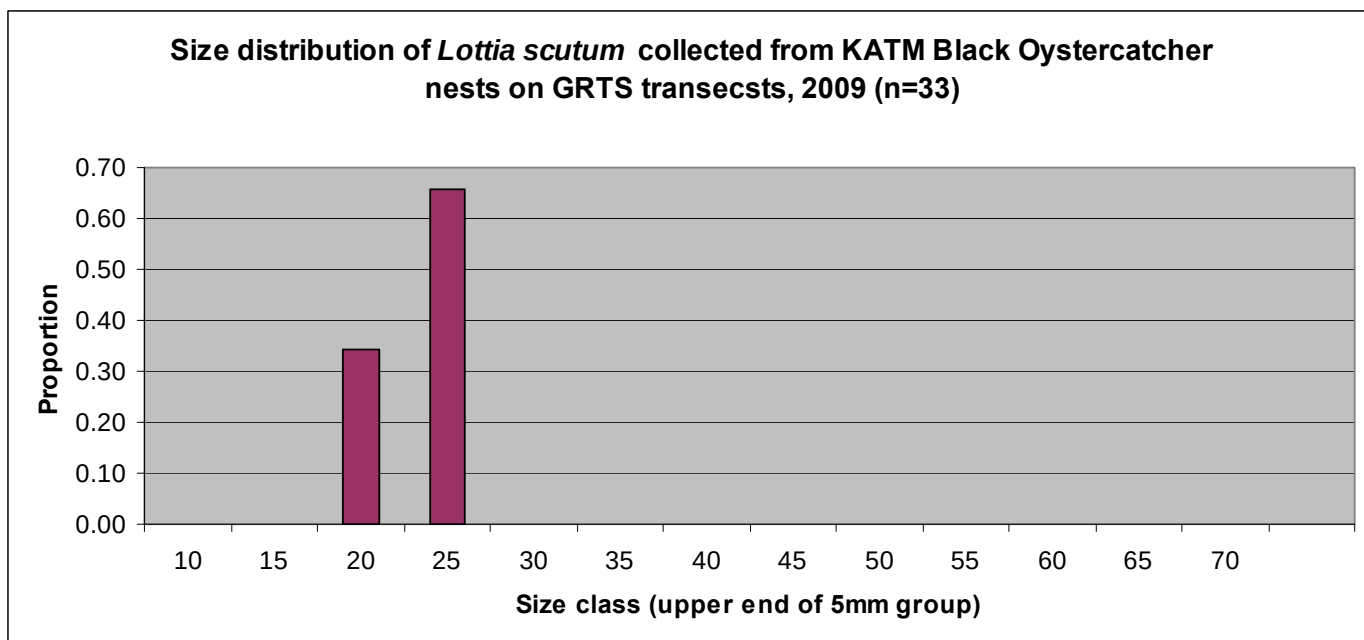


Figure 33. Size distribution of *Lottia scutum* collected from black oystercatcher nest sites on GRTS transects at KATM, 2009.

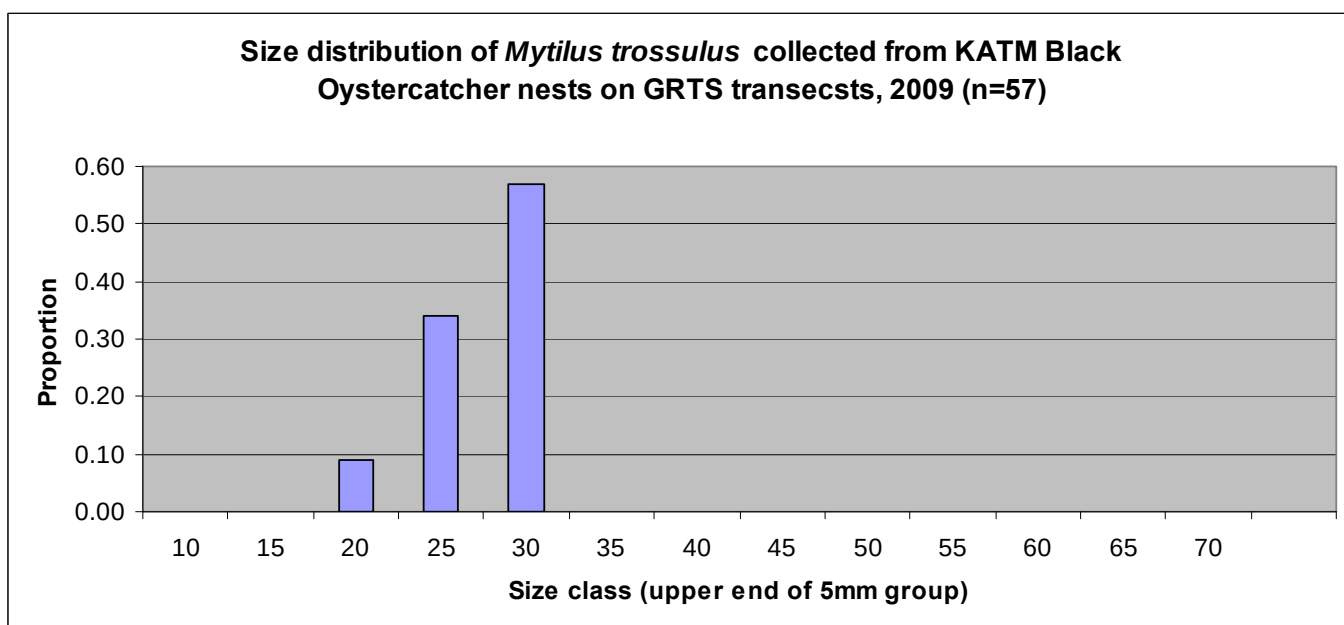


Figure 34. Size distribution of *Mytilus trossulus* collected from black oystercatcher nest sites on GRTS transects at KATM, 2009.

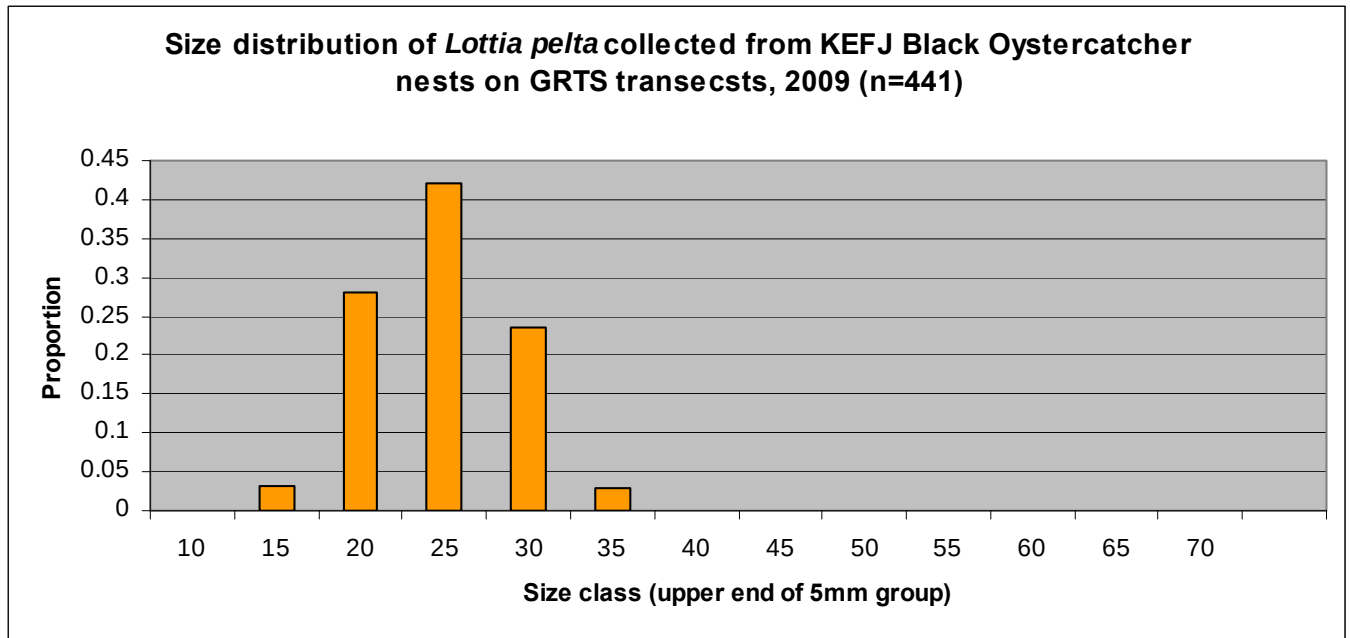


Figure 35. Size distribution of *Lottia pelta* collected from black oystercatcher nest sites on GRTS transects at KEFJ, 2009.

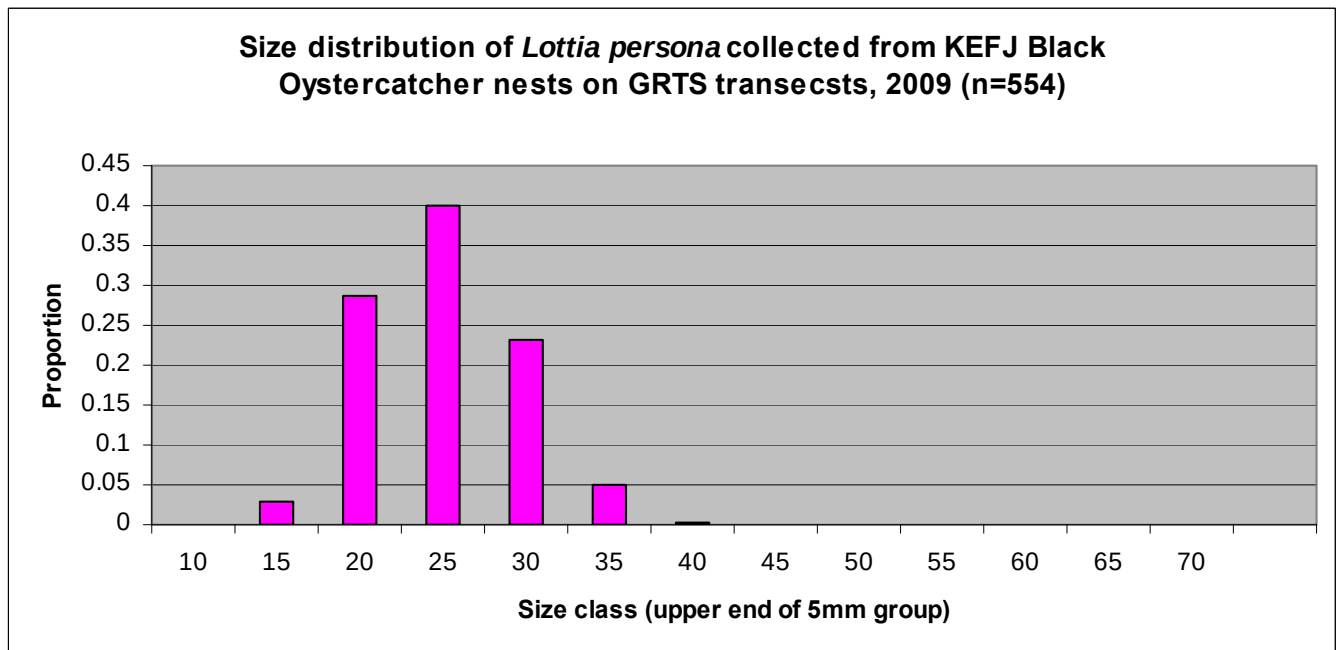


Figure 36. Size distribution of *Lottia persona* collected from black oystercatcher nest sites on GRTS transects at KEFJ, 2009.

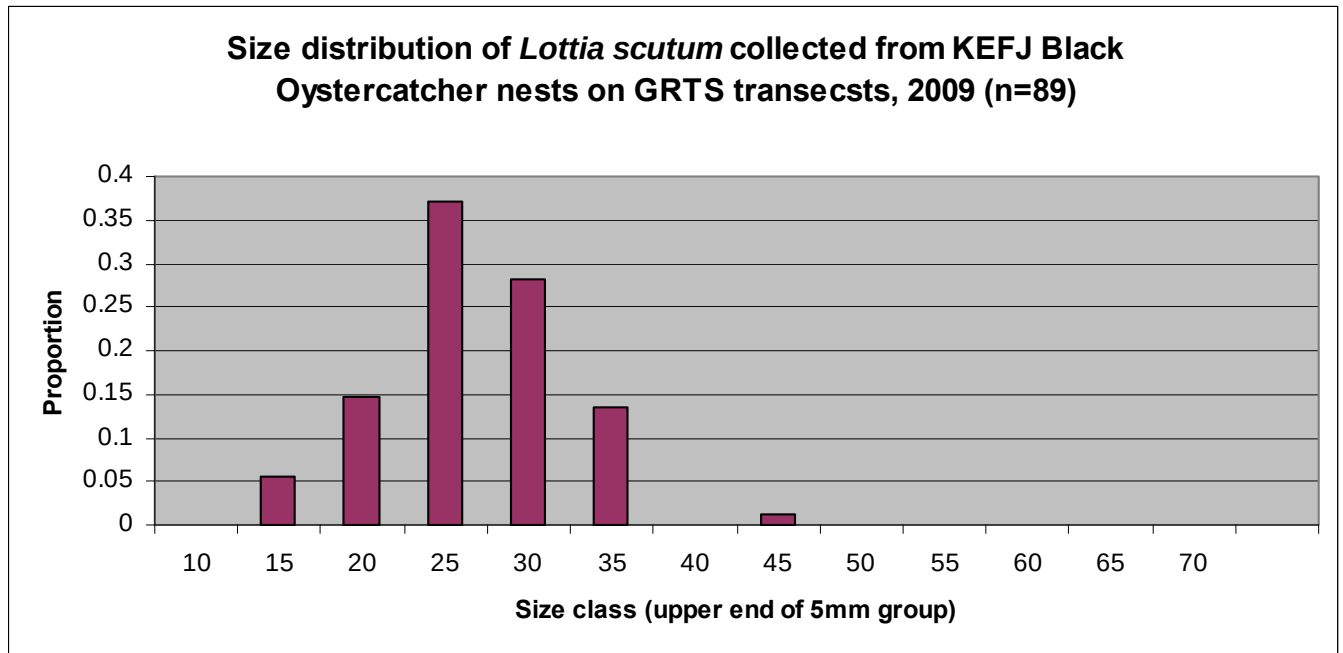


Figure 37. Size distribution of *Lottia scutum* collected from black oystercatcher nest sites on GRTS transects at KEFJ, 2009.

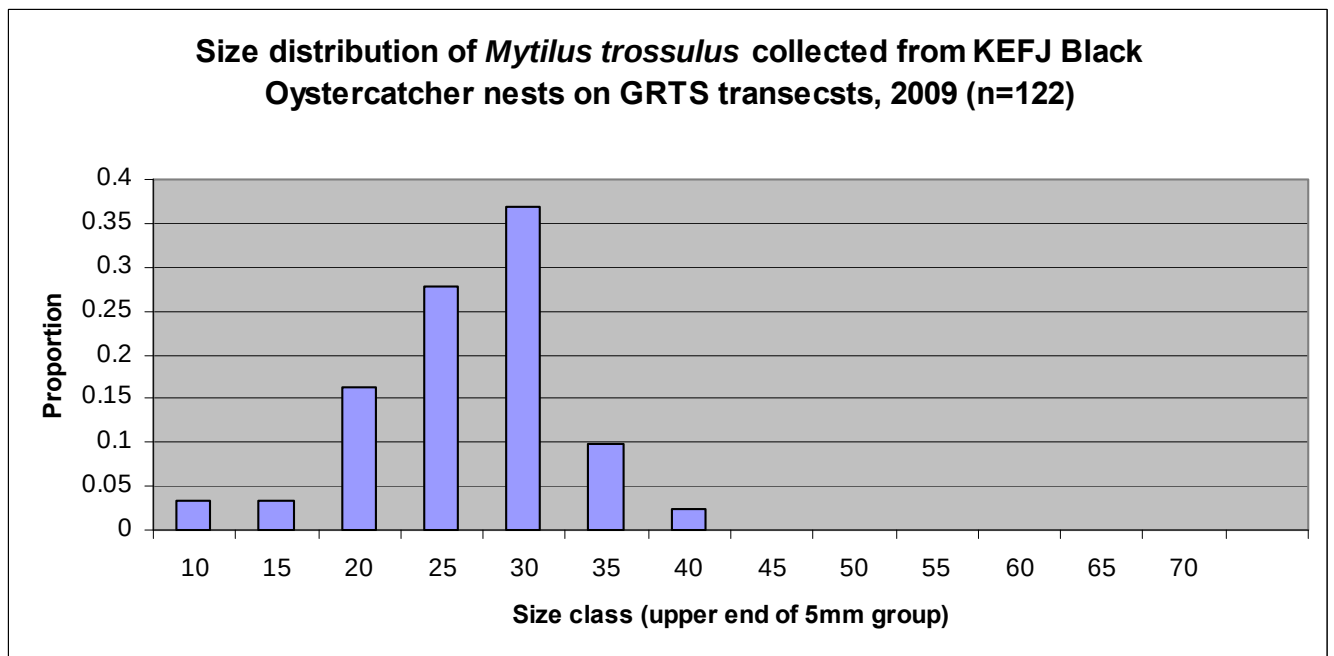


Figure 38. Size distribution of *Mytilus trossulus* collected from black oystercatcher nest sites on GRTS transects at KEFJ, 2009.

Discussion

Measures of active nest density were similar in KATM and KEFJ in 2009. Productivity was higher in KEFJ than KATM. *L. pelta* was the dominant prey item in KATM while *L. persona*

was the dominant prey item in KEFJ. In general *L. pelta* and *L. persona* were larger in KEFJ than in KATM, while *L. scutum* and *M. trossulus* were larger in KATM than KEFJ. Variation in sizes was generally low. This is not surprising, but may be a key metric for monitoring purposes. Measurements of sea otter prey, pre- and post arrival of sea otters in Glacier Bay, AK, have indicated a decline in prey sizes correlated with the increased occupation of Glacier Bay proper with sea otters (Bodkin et al. 2007a and c). A similar result may possibly occur as densities in nesting black oystercatchers changes. Lower densities of black oystercatchers may lead to increased densities of larger size classes of mussels and limpets sampled at the rocky intertidal sites and mussel beds or nest sites. The reverse may also be possible. Increased black oystercatcher densities may decrease the densities of the larger size classes of prey.

Recommendations

Surveys of black oystercatcher abundance, nest density, and diet as reflected through prey remains brought to provision chicks has been successfully implemented in KATM and KEFJ and has shown that at appropriate spatial scales of analysis, our data should continue to be collected with little revision. Sampling at the current intensity should allow us to detect trends in changes of nest density, productivity and diet (especially prey size) of the black oystercatcher. It appears as though breeding pairs may have multiple nests at a nest site and care should continue to be taken to recognize these as comprising the same nest site. It will be important to conduct future surveys as close as possible in time to these initial surveys and care must continue to be taken to minimize the disturbance to nests during sampling.

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