# Chapter 1 VARIABILITY WITHIN NEARSHORE ECOSYSTEMS OF THE GULF OF ALASKA

B. Ballachey[1], J. Bodkin[1], H. Coletti[2], T. Dean[3], D.Esler[1], G. Esslinger[1], K. Iken[4], K. Kloecker[1], B. Konar[4], M. Lindeberg[5], D. Monson[1], M. Shephard[2], and B. Weitzman[1]
[1]U.S. Geological Survey, Alaska Science Center, Anchorage, Alaska
[2]National Park Service, Southwest Alaska Network, Anchorage, Alaska
[3]Coastal Resources Associates, Carlsbad, California
[4]School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, Fairbanks, Alaska
[5]NOAA Auke Bay Laboratory, Juneau, Alaska

## Introduction and Background

Nearshore marine habitats, which represent the interface among air, land and sea, form a critical component of the Gulf of Alaska (GOA) ecosystem. As an interface, the nearshore facilitates transfer of water, nutrients and biota between terrestrial and oceanic systems, creating zones of high productivity. The nearshore provides a variety of ecosystem services, including (1) nursery grounds for a wide variety of marine invertebrates and fishes (e.g., crabs, salmon, and herring), (2) nesting and pupping habitats for many pelagic marine predators (e.g., sea bird nesting colonies and pinniped rookeries), (3) important feeding habitats for high trophic level pelagic predators (e.g., killer whales), (4) habitat for resident nearshore species (including sea otters, harbor seals, shorebirds, sea ducks, nearshore fishes, and marine invertebrates), many of which are important sources of commercial and subsistence harvests, and (5) recreational, commercial and subsistence opportunities for human populations (Figure 1-1). The canopy forming kelps and eel grass beds found in the nearshore provide primary production and structure to nursery habitats, and also can dissipate wave energy thus reducing coastal erosion, and serve as a carbon "sink" capable of storing substantial amounts of atmospheric $CO_2$ (Wilmers et al. 2012).

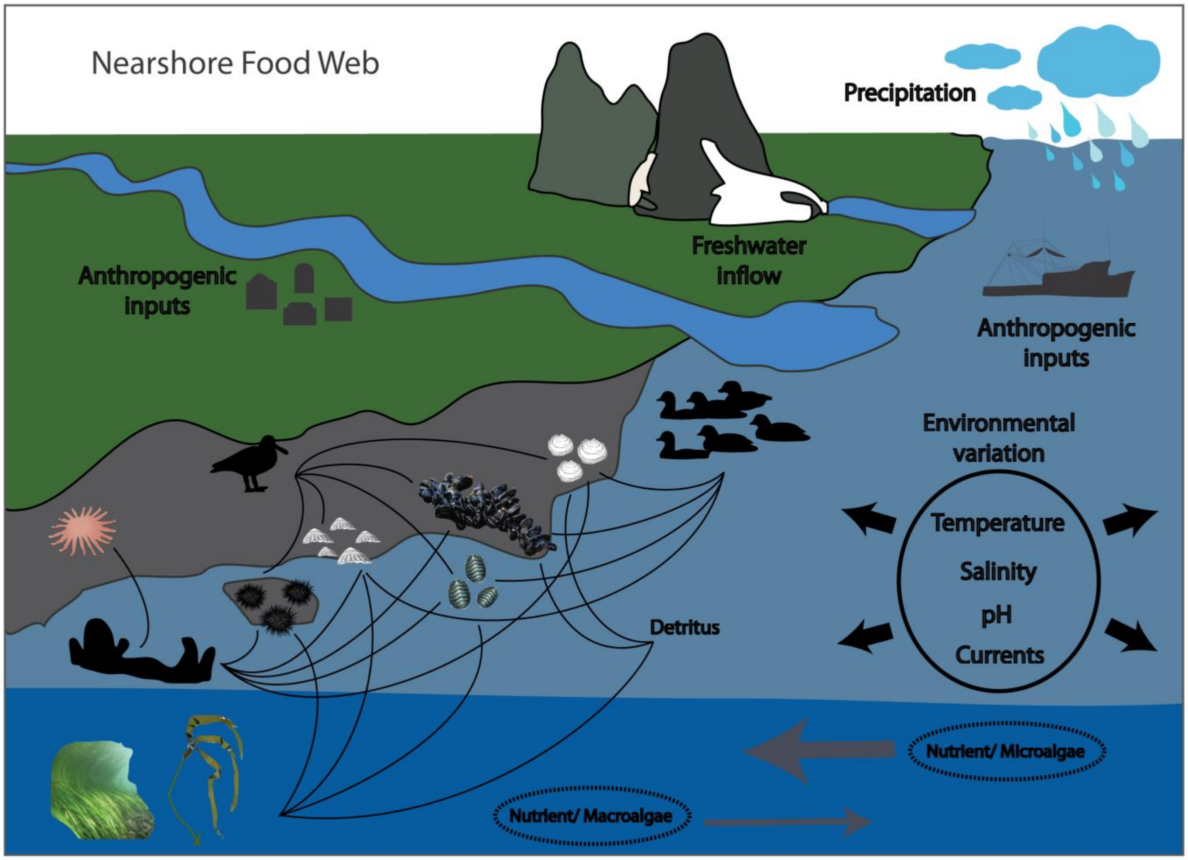


**Figure 1-1. Conceptual model illustrating ecological connections within the nearshore food web.**

Nearshore ecosystems are sensitive to natural and human disturbances on a variety of temporal and spatial scales, originating from any of the three major interfacing systems (e.g., pelagic toxic algal blooms and leaching of contaminants from watersheds). As with all marine systems, they face tremendous challenges associated with increased human impacts, including climate change (Crain et al. 2009, Hoegh-Guldberg and Bruno 2010) for which some consequences (e.g., ocean acidification) are anticipated to be far reaching and more severe at higher latitudes (Fabry et al. 2009).

Because many organisms in the nearshore are sessile or have limited home ranges, they are good candidates as indicators linked to sources of change. As a result of long-term experimental and monitoring work, we have a comparatively thorough understanding of mechanistic links between many nearshore consumers and their prey that facilitates understanding causes of change. Thus, monitoring of nearshore resources at appropriate spatial scales and over longer term periods affords opportunities to detect both regional and relatively localized causes of change and distinguish human-induced from natural changes, providing a basis for development of policies to reduce human impacts. In the GOA, monitoring of nearshore resources has been of particular importance in the past several decades, because it was the habitat most impacted by the 1989 *Exxon Valdez* oil spill (EVOS), and has been a repository for lingering oil linked to protracted injury to resident species (see Chapter 5 of this report). As a result of support for EVOS studies over the past 25 years, there are now a substantial number of long-term data sets on nearshore resources that form a valuable foundation for continued monitoring efforts to help us understand how large-scale perturbations, including EVOS, affect recovery and function of these ecosystems (Esler 2013, Ballachey et al. 2014, Bodkin et al. 2014).

## Historical and Ongoing Nearshore Monitoring in the Gulf of Alaska

In the early 2000s, a comprehensive monitoring plan for the nearshore marine ecosystem in the GOA was developed (Dean and Bodkin 2006). The framework for monitoring in the nearshore included sampling of a variety of specified biological and physical parameters (e.g. abundance and growth of intertidal organisms, abundance of selected birds and marine mammals, water quality) within specified areas across the GOA, selected to enhance our ability to detect change from a variety of sources. The monitoring plan was adopted by the National Park Service Southwest Alaska Network for their Vital Signs Long-term Monitoring Program (Bennett et al. 2006), and implemented in Katmai National Park and Preserve (KATM) in 2006 and Kenai Fjords National Park (KEFJ) in 2007. The plan also was implemented in western Prince William Sound (WPWS) in 2007, and again starting in 2010. In 2012, when the Gulf Watch Alaska (GWA) project was established, these ongoing nearshore monitoring efforts in WPWS, KATM, and KEFJ were assembled under the Nearshore component of the GWA program. At that time, additional monitoring areas in northern and eastern PWS (NPWS and EPWS) and in Kachemak Bay (KBAY, already the site of long-term nearshore studies by UAF) were incorporated into the overall Nearshore monitoring component of GWA, forming a total of 6 study areas. This distribution of monitoring areas across the GOA provides a broad geographical scale which, when combined with the acquisition of historic data sets, greatly increases our ability to detect and assign cause to differences among areas and over time. A list of metrics that are currently being monitored on an annual basis is provided in Table 1, below (note: EPWS and NPWS are being monitored only in alternate years). Detail on methods for data collection are presented in the protocols of marine nearshore ecosystem monitoring in the Gulf of Alaska (Dean et al. 2014).

### *Complexities Contributing to Variability of Nearshore Ecosystems in the Gulf of Alaska*

Ecological processes and physical conditions are widely recognized to affect the structure, composition and function of nearshore communities. As part of GWA, we are working to assess influences at multiple scales of various physical and biological drivers potentially capable of causing change in nearshore ecosystems. At the local scale, we are examining static factors such as exposure, fetch, freshwater input, tidewater glacial presence, and substrate (see Konar et al., this report). At broader scales of space and time, longer term monitoring and data have increased awareness of drivers such as the Pacific Decadal Oscillation (PDO), El Niño/Southern Oscillation (ENSO), and North Pacific Gyre Oscillation (NPGO), and we are just starting to consider whether impacts of these drivers can be detected on nearshore populations and communities in the GOA (see Monson et al., this report). Additional forces with even greater unknowns are those associated with climate change (e.g., warming waters and ocean acidification).

Our ability to monitor the nearshore ecosystem, and detect short to long-term and local to regional scale change in biological resources and their productivity, is based on several key aspects of the GWA program. First, we are evaluating metrics on a relatively large number of species, including vertebrates and invertebrates at different trophic levels, as well as marine plants and algae, all of which are important components of nearshore communities. Second, we are monitoring this suite of metrics at study areas selected to represent a large spatial scale across the GOA, allowing for differentiation of local versus regional change and providing insight into the role of environmental drivers in structuring communities. Third, we are accumulating long-term data sets on these nearshore species (in some cases, representing decades of information), which is essential if an ecosystem monitoring program is to be effective at identifying causes of change. Fourth, the Nearshore component of GWA is a truly integrated effort, not an assemblage of related and somewhat independent projects; this allows for consistency in overarching concepts, as well as in the performance of the monitoring and delivery of findings. In addition, we are working on the development of conceptual models related to the nearshore ecosystem, which will provide important insight into food webs and other factors influencing community structure as we continue with the monitoring program. We expect over time to integrate data from the “Environmental Drivers” and “Pelagic” GWA components to increase our understanding of the role that ocean and atmospheric derived factors influence nearshore ecosystems.

### *Nearshore Component Synthesis Products*

For the Nearshore component, we present two synthesis products in this chapter: (a) Influence of static habitat attributes on local and regional biological variability in rocky intertidal communities of the northern Gulf of Alaska, and (b) Inter-annual and spatial variation in Pacific blue mussels (*Mytilus trossulus*) in the Gulf of Alaska. In the first analysis, Konar et al. (this chapter) found that overall, in the central Gulf of Alaska, local static habitat attributes of rocky intertidal study sites appeared to be of similar or slightly greater importance in structuring and characterizing biological communities than regional drivers. Understanding the importance of static attributes is important to distinguish them from influences of temporal drivers in these regions, particularly in the context of long-term monitoring of these communities and climate variables, and also is applicable for management purposes in terms of damage assessment. In the second analysis, Monson et al. (this chapter) identified a decline in the abundance, size and caloric content of mussels across the GOA over a six year period beginning in 2008. The decline in mussel abundance was reflected in reduced mussel consumption by both sea otters and black oystercatchers during this period. Integrating biological and physical information from the adjacent ocean will allow understanding of the factors and scales contributing to the dynamics of future mussel populations as well as those of their consumers.

These are two examples, using subsets of data collected as part of the Nearshore component of GWA, that illustrate the value of having broad-scale and long-term datasets when evaluating change in marine ecosystems. We have many additional data streams for other metrics that will further contribute to our understanding of nearshore ecosystems in the Gulf of Alaska. Continuation of the Nearshore component will extend the timeline of data collection and hence increase the power to answer questions about sources and mechanisms of change.

**List 4-1. List of metrics measured as part of the Nearshore monitoring program.**

Metrics* are collected at 5 sites at each of 6 study areas: KATM, KBAY, KEFJ, WPWS, EPWS and NPWS. All sites are monitored on an annual basis except NPWS and EPWS, which are monitored every other year.

1. Rocky intertidal shoreline:
    - % cover of various species (algae and sessile invertebrates) at tidal elevations of 0.5 and 1.5 MLLW
    - *Lottia* persona (limpets) – mean size and density, at the upper tidal elevation
    - *Nucella* spp. (sea snails) and *Katharina tunicata* (chiton) – densities, at 0.5 m and 1.5 m MLLW
    - Sea star densities along a 100 m transect at the 0 tidal elevation
    - Temperature
2. Mussel beds:
    - Density of larger mussels ≥ 20 mm
    - Overall density of mussels
    - Area ($m^2$) of mussel beds
3. Bivalves in soft sediments:
    - Species composition
    - Density
    - Size distribution
4. Eelgrass beds:
    - Proportion of area with eelgrass present
5. Marine bird and mammals surveys:
    - Density and distribution of birds and mammals
6. Black oystercatchers:
    - Density of active nests
    - Number of eggs and chicks / active nest
    - Species composition and size distribution of prey (shell remains) at nest sites
7. Sea otter foraging observations:

- Visual observations of foraging sea otters to quantify energy recovery rates through:
  -prey type
  -prey size
  -dive and surface times
  -proportion of successful dives
  -caloric recovery rates

8. Sea otter abundance:
   - Aerial surveys to estimate abundance of sea otters

9. Sea otter mortality patterns:
   - Annual collection of carcasses from shorelines to assess patterns of mortality, based on ages at death

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*Metrics 5-9 are not collected at the extensive sites; and metric 8 is not collected annually. Bivalves in soft sediment sites in all areas are only sampled every other year to minimize effects from destructive sampling.

### *Nearshore Component: Considerations for Future Directions*

- Continue broad-scale, long-term monitoring, largely as currently conducted; revise metrics and protocols based on the first 5-10 years of monitoring (although any changes must be highly justified, to avoid breakage of data streams).
- Enhance local-scale monitoring of key physical variables, considering the strong local structure of biological communities.
- Initiate directed research on important relationships and processes revealed in the first 5 years of monitoring, such as growth, recruitment, and population dynamics of benthic invertebrates and algae and performance of vertebrate consumers.
- Institute winter marine bird surveys directed at Gulf Watch Alaska Nearshore component study areas, including WPWS, Kenai Fjords, and Katmai National Parks.
- Support continuation of Resurrection Bay monthly marine bird surveys led by the Alaska SeaLife Center.
- Develop outreach products indicating the “State of the Nearshore” to be updated on an annual basis.

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