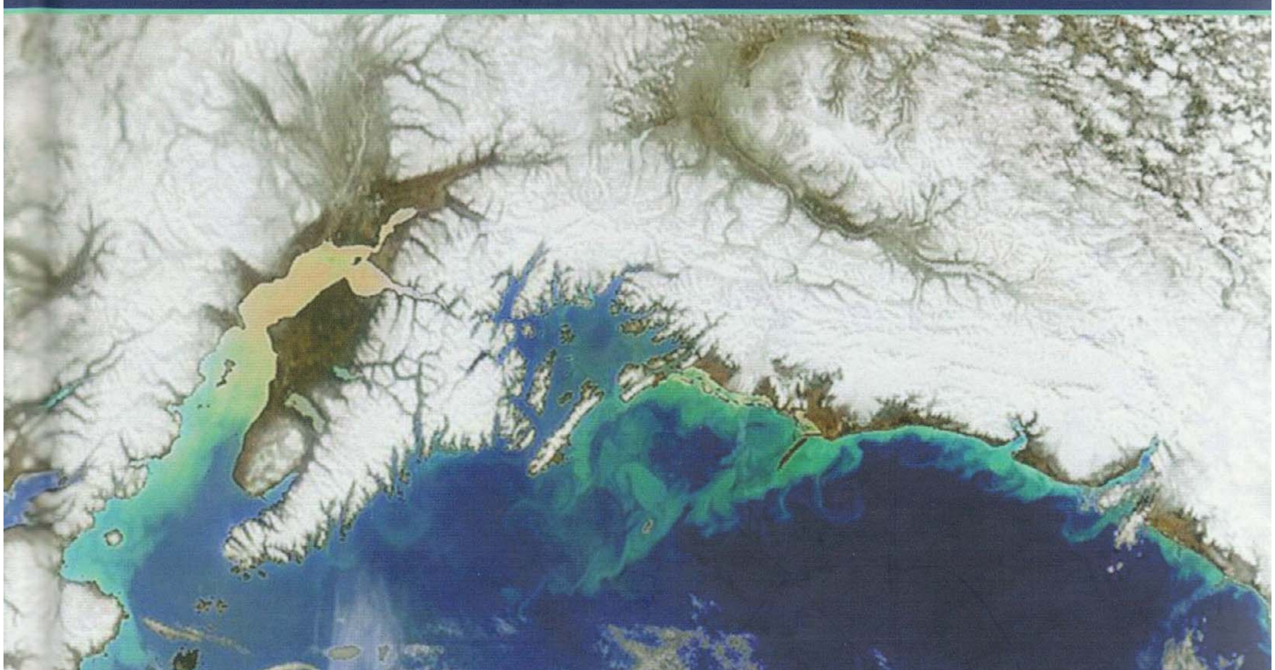
Long-Term Ecological Change in the Northern Gulf of Alaska



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BOX 6.1: MARINE ECOREGIONS OF ALASKA

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Any attempt to understand why marine organisms fluctuate in abundance is confounded by spatial scale. At larger scales, we are not surprised to observe seabird populations increasing rapidly at one colony in the Gulf of Alaska (GOA) while plummeting at a colony 1500 km away in the Eastern Bering Sea (EBS) – after all, these bodies of water are discrete "Large Marine Ecosystems" (LMEs, Sherman et al., 1990) and march to the beat of different climatic drummers (Hare and Mantua, 2000). But at smaller scales, we are often perplexed to find contrasting population dynamics in nearby colonies (Section 4.5). This mesoscale spatial heterogeneity probably reflects oceanographic processes occurring at the same scale (Speckman et al., 2005), or differential predator–prey dynamics (Kildaw et al., 2005), but in any case it complicates our efforts to understand how marine fish, bird, and mammal populations respond to, or are altered by, changes in their environment. To further cloud interpretation, many species operate over a wide range of spatial and temporal scales in a lifetime. For example, seabirds forage over tens of kilometers daily, but capture and consume prey in a matter of meters and seconds. Populations fluctuate over basin and decadal scales, but migrate and aggregate to breed over scales of hundreds of kilometers and months.

Therefore, it would be useful to characterize spatial heterogeneity in marine systems at scales smaller than those of LMEs. One approach is to adopt methods used to characterize terrestrial ecosystems (Bailey, 1980; Demarchi, 1996). Alaska has at least 20–30 terrestrial "ecosystem provinces" that are defined by topography, vegetation, climate, and other measurable features (Bailey, 1998; Nowacki et al., 2001). We know that there is similar spatial heterogeneity in marine systems, and we can use characteristics such as bathymetry, currents, temperature, and primary production to define marine regions (Bailey, 1998).

The degree to which habitats can be subdivided – and the classification system for naming each division – are somewhat arbitrary. For convenience, we followed Demarchi (1996) who developed an hierarchical system for classifying terrestrial and marine ecosystems of British Columbia, and who used the term "ecoregion" to describe a marine ecoregion unit as an area with major physiographic and minor oceanographic variation at a regional spatial scale. For example, slope, shelf, and coastal areas would be segregated because of "major physiographic variation." Within a shelf area, we might further segregate waters with major oceanographic boundaries, such as fronts associated with the 50-m and 100-m isobaths on the EBS shelf (Coachman, 1986); topographic irregularities, e.g., islands such as Kodiak I. that creates persistent oceanographic differences upstream and downstream of the island; or currents that significantly alter shelf production regimes, such as the Anadyr Current in the northern Bering Sea (Springer et al., 1989; Springer and McRoy, 1993). For this analysis, we considered only features present during the summer months in Alaska. Presumably, mesoscale features could be quite different in winter – they are probably significant to species that do not migrate south, but are beyond detailed description here due to the paucity of winter-time data on habitat characteristics.

There are many sub-regions within the LMEs that can be identified by their similarities in oceanography and biology, and these mesoscale ecoregions often cross LME boundaries (Favorite et al., 1976; Piatt and Springer, 2003; Batten et al., 2005). One may also find regional patterns in geochemistry between and within LMEs (Longhurst 1998; Schell et al., 1998). After examining such mesoscale patterns in the distribution of biological indicators and considering topographic, bathymetric, and oceanographic features (such as persistent fronts, e.g., Belkin and Cornillon, 2003), we have tentatively identified 30 marine ecoregions in Alaska (see Fig. 6.1, Table 6.1). For example, cross-shelf differences in bottom depth and oceanography in the GOA and EBS create well-described heterogeneity in plankton, fish, and bird communities across these shelves, reflected in discrete coastal, inner shelf, outer shelf, slope, and oceanic species assemblages (e.g., Cooney, 1981; Doyle et al., 2002; Piatt and Springer, 2003; Lanksbury et al., 2005; see also Section 2.3). Within the enclosed waters of southeastern Alaska and Cook Inlet, gradients in oceanographic conditions create discrete distributional boundaries for some plankton and fish species (Johnson et al., 2005; Speckman et al., 2005). Open ocean areas may be defined by large-scale oceanographic processes, such as the Alaska Gyre in the GOA (Favorite et al., 1976), which appears to spatially structure plankton, fish, bird, and mammal populations (Brodeur and Ware, 1992; Springer et al., 1999). Strong along-slope currents carrying nutrient-rich waters create productive habitats along the edges of continental shelves in the GOA, EBS and Beaufort Sea, creating narrow bands of high primary productivity (e.g., the Bering Sea "Green Belt," Springer et al., 1996). These support a high abundance of organisms, some of which are tightly associated with those shelf-edge ecoregions (e.g., sablefish and Pacific ocean perch, Fritz et al., 1998; myctophids and squid, Sinclair and Stabeno, 2002; albatross, Piatt et al., 2006). A remarkable synthesis of papers on the Aleutians (Schumacher et al., 2005) reveals how spatial variation in topography and oceanography (Ladd et al., 2005) results in marked segregation of some fish (Logerwell et al., 2005), bird (Jahncke et al., 2005) and mammal (Call and Loughlin, 2005; Sinclair et al., 2005) populations into three distinct ecoregions along the Aleutian Archipelago.

Table 6.1: Names of Alaska marine ecoregions.

Number	Ecoregion name
1	Alaska Gyre Center
2	North Pacific Current – Alaska Stream Loop
3	Eastern Gulf of Alaska Transitional
4	Eastern Gulf of Alaska Slope
5	Prince of Wales Shelf and Inside Waters
6	Chichagof Shelf and Inside Waters
7	Northern Gulf of Alaska Slope
8	Northern Gulf of Alaska Shelf
9	Prince William Sound Inside Waters
10	Western Cook Inlet – Shelikof Strait
11	Southeastern Cook Inlet – Kodiak Upwelling
12	Alaska Peninsula Coastal and Shelf
13	Western Gulf of Alaska – Alaska Stream
14	Eastern Aleutians
15	Central Aleutians
16	Western Aleutians
17	Aleutian Arc – Alaska Stream
18	Bering Sea – Bowers Basin
19	Bering Sea – Aleutian Basin
20	Bering Sea Shelf Edge – Green Belt
21	Eastern Bering Sea – Outer Domain
22	Eastern Bering Sea – Middle Domain
23	Eastern Bering Sea – Inner Domain
24	Eastern Bering Sea – Alaska Coastal
25	Northern Bering – Chukchi Sea – Anadyr Stream
26	Western Bering Sea – Shelf
27	Beaufort–Chukchi Coastal – Shelf
28	Beaufort–Chukchi Sea – Barrier Island-Lagoon System
29	Beaufort–Chukchi Sea – Shelf Edge
30	Arctic Ocean – Basin

In these examples, some indicator species were found to occupy only one or a few ecoregions (and thereby helped define them), whereas many more species showed no apparent affinity for any one ecoregion or its boundaries. This highlights the subtlety of ecoregional structuring: it is important enough to explain the distribution patterns of some taxa, but may only serve as a source of background variability to species that are adapted for living in a broader range of habitats. Either way, it may be useful to consider the population ecology of marine animals in Alaska in light of ecoregion patterns (Fig. 6.1). If boundaries are stable, perhaps these patterns can help explain the distribution of some taxa. If ecoregions have different production regimes and patterns of variability, perhaps we can better explain spatial and temporal variability in status and trends of widely distributed taxa (e.g., Dragoo et al., 2003), and even the contrasting population dynamics of adjacent colonies that are actually situated in different ecoregions (e.g., see Piatt and Harding, Section 4.8).

This is an initial effort; the boundaries, shapes, and number of ecoregions will no doubt be refined. For the present, we can draw a few conclusions: (1) The size and shape of marine ecoregions differ one from another, but usually extend along one axis that is determined mostly by bottom topography and current flow; (2) There is much greater heterogeneity in coastal-shelf environments than in the open ocean; (3) Across-shelf boundaries between ecoregions are fairly conspicuous, being defined by persistent fronts or strong topographic gradients between

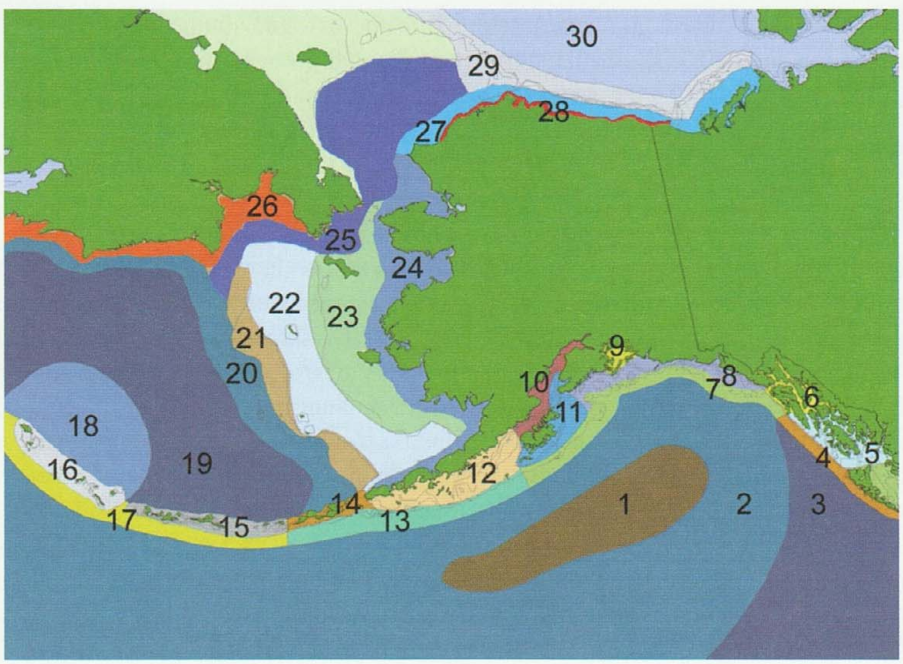

Figure 6.1: Marine ecoregions of Alaska.

shelf, slope, and oceanic habitats; (4) Along-shelf boundaries are more subtle, and are often resolved by patterns in animal distribution more so than by physical characteristics; (5) More analyses are needed to better resolve marine ecoregions in Alaska using both physical and biological datasets.

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