Section 9

SYNTHESIS

by

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9.1 INTRODUCTION

This synthesis presents an analysis of important aspects of the structure and function of the North Aleutian Shelf (NAS) ecosystem. It is based on existing data and on new data collected in this study. The structure of the synthesis reflects the primary objectives of the project: (1) to describe how the dominant fish, birds, and mammals use the NAS nearshore zone, (2) to clarify the important ecological components and processes on which these vertebrates depend, and (3) to evaluate the vulnerabilities of these vertebrates (and the factors on which they depend) to increased OCS-related activity in the area.

The synthesis has four main sections. Section 9.2 is a brief characterization of the NAS ecosystem from physical processes and lower trophic levels to top consumers. Section 9.3 focuses on Objective 1 (above), showing how the vertebrates are distributed in time and space and suggesting causes for the observed distributions. Section 9.4 addresses Objective 2, attempting to show how the important ecosystem processes and components regulate vertebrate use of the area in time and space. Section 9.5 evaluates the vulnerabilities of the important biota to OCS-related activities (Objective 3).

9.2 ECOSYSTEM CHARACTERIZATION

A general overview of important eoosystem processes and components on the NAS and how the biota depend on them is provided in point-form below.

1. In general, water appears to enter the NAS study area by advection from the west end (Schumacher and Moen 1983; Section 2.0, this report) and by dispersive exchange with shelf waters to the north (Section 2.0, this report). Minimal amounts are injected by stream discharge. Waters exit to the east by advection and to the north by dispersive exchange (Section 2 .O , this report).

2. The spatial juxtaposition of the NAS study area relative to Unimak Pass, the shelf edge, and the outer and middle shelf domains, in combination with the circulation patterns, strongly influences the sources (and thus the quality) of its water. Water at the west end of the study area apparently contains substantial proportions of both (a) Alaska Coastal Current water that has come through Unimak Pass from the Gulf of Alaska shelf (Schumacher and Moen 1983), and (b) water that has recently upwelled from either the deep Pacific (through eastern Aleutian passes--Hood 1986) or the Bering Sea (Section 3.0, this report). By the time waters exit the east end of the study area, they probably come to resemble to some extent adjacent central domain waters because of the appreciable dispersive exchange that typically occurs between the NAS and the central domain during transit of water through the study area.

3. Most of the nutrients that fuel the NAS ecosystem appear to come from the deep Pacific/Bering basins, based on the radiocarbon abundances of NAS biota (Section 3.0, this report). These nutrients presumably come onto the Bering Sea shelf west or northwest of the NAS study area, as evidenced by the prevailing circulation patterns (see Kinder and Schumacher 1981, Whitledge et al. 1986). They may come into our study area either directly, by advection at the study area's western end, or indirectly, via dispersive exchange with the adjacent shelf waters to the north (which also receive nutrient-rich waters from off the shelf to the west--Kinder and Schumacher 1981, Whitledge et al. 1986). NOAA-sponsored studies now in progress near the eastern Aleutian Islands have obtained preliminary new evidence suggesting that large proportions of the nutrients for the NAS area may come from the Bering Sea basin (S. Saupe, Univ. of Alaska, pers. comm.).

4. The temperature of the NAS waters is more seasonally variable than that of either the shelf break waters to the westorthe shelf waterstothe north. NAS waters are up to several degrees warmer in summer than either shelf break or deeper shelf waters. In winter they are cooler than the shelf break waters but similar in temperature to other shelf waters (Kinder and Schumacher 1981; Schumacher and Moen 1983; Section 2.0, this report). These seasonal temperature patterns, especially when viewed in the context of temperature patterns of adjacent water bodies, imply much about the seasonal utility of the NAS to the fauna. This point will be discussed later in this section.

5. In summer a front normally exists between the coastal domain and the adjacent middle/outer shelf domains to the north. The location of this front is typically about the 50-m depth contour (the approximate outer boundary of the NAS study area) (Kinder and Schumacher 1981, Coachman 1986), but appears to be temporally variable, sometimes encroaching shoreward to about the 30-m contour and sometimes moving to beyond the 50-m contour (Section 2.0, this report). Regardless of its location, it is considerably wider than the water is deep (Coachman 1986), so any effect it has on concentrating zooplankton might be spread over a fairly broad band where the domains meet. Whether this front exists at all in winter is unclear (Schumacher et al. 1979, Coachman 19861.

6. Phytoplankton production accounts for the great preponderance of carbon that enters the vertebrate food web; eelgrass carbon provides a very small proportion (Section 3.0, this report). During winter, when phytoplankton production is reduced, nutrients move onto the shelf and tend to build up all along the NAS (and elsewhere on the shelf--Whitledge et al. 1986). When light and water-column conditions become optimum in spring, an

intense plankton bloom occurs, then declines as nutrients are stripped from the water column. But all through summer and into fall, blooms (usually much smaller than the initial spring bloom) may recur with weather events (storms) that inject nutrients into the system from the west or north (Section 3.0, this report).

7. Because of the large spatial and temporal variations in primary productivity and the uncertainties in measurement techniques , no clear differences in primary production levels with distance either parallel or perpendicular to the coast were observed in this study. But differences undoubtedly exist; total primary productivity and annual carbon fixation is probably considerably higher at the west end, near the main source of the nutrients (Section 3.0, this report).

8. Annual carbon fixation by primary production in the NAS is about 220 to 240 g C/m^2-yr, averaged over the study area (Section 3.0, this report). This is about the same as reported for deeper shelf waters by other studies in the southeastern Bering Sea (Le., PROBES studies).

9. Phytoplankton produced in the NAS study area is very inefficiently grazed by water-column herbivores (copepods, euphausiids) (Section 8.0, this report); this same phenomenon has been reported to occur in deeper waters of the adjacent middle shelf. The excess production is presumably exported (primarily to the middle shelf, if the circulation model of Section 2.0 is any indication) or sinks and is consumed by the benthos. The relatively low standing stocks of benthic ‘herbivores suggest that most of the excess is exported, unless most of that which sinks is consumed by meiofauna before it enters the other benthic consumers.

10. Presumably, the phytoplankton in the NAS study area is underutilized for the same reason that it is underused In the central domain--copepods (the principal grazers) are species that overwinter on the shelf in small numbers and cannot reproductively respond in spring to take advantage of the sudden plankton abundance. (Conversely, on the outer shelf, oceanic species of copepods, that overwinter at depth in large numbers, graze the phytoplankton very efficiently--Cooney 1981.) Our studies show that the NAS copepod community is a mixture of middle shelf and outer shelf (oceanic) copepod species; the relative abundances of the two groups vary in time and space, and apparently depend on the circulation patterns that bring water masses (and therefore copepods) into the area from various deep ocean and shelf sources (Section 4.0, this report). At no time do the copepods appear to normally be present in sufficient abundance to effectively crop the phytoplankton (Section 8.0, this report).

11. Excluding jellyfish, the major components of the zooplankton biomass on the NAS are grazers (copepods, euphausiids) and predators on other zooplankton (chaetognaths) (Section 4.0, this report). The zooplankton standing stock biomass per unit area in the study area, and in other nearshore Bristol Bay waters, is much lower than that reported to occur in middle and outer shelf domains of the southeastern Bering Sea (Section 8.0, this report). The relatively high consumption of zooplankton by vertebrate consumers in these nearshore waters could contribute to this low observed biomass.

12. Cur sampling suggests that zooplankton groups have seasonal changes in relative abundance. Euphausilds seem to be the biomass dominant in late spring and early summer. Euphausiids decline in mid-summer, to be dominated thereafter by copepods and (in late summer and early fall)

by large jellyfish. Jellyfish comprised a very large proportion of the September zooplankton biomass in this study. By winter, chaetognaths are the dominant group (Section 4.0, this report). Seasonal changes in diets of zooplanktivorous birds and fish reflect this change in zooplankton abundance (Sections 5.0 and 6.0, this report). Second-year sampling suggested that this relative dominance pattern of zooplankton (and diets of birds and fish) might change somewhat from year to year--in May 1985 copepods were more abundant in relation to euphausiids (in samples and in bird and fish diets) than they were in May 1984 (Sections 4.0, 5.0, and 6.0, this report).

13. Distribution patterns of the benthos showed clear trends with depth (i.e., distance perpendicular from shore), and sometimes with alongshore locations. Benthic infaunal biomass was very low in waters less than 10 m deep (as would be expected because sea ice invades the area in some years); epifauna (principally shrimps and mysids) reached its highest biomass in these shallow areas. Total infaunal biomass was highest in western parts of the study area. Both infauna and epifauna tended to be abundant off the major inlets--1zembek Lagoon and Port Moller (Section 4.0, this report).

14. Some of these distributions of benthos could have been related to food availability. High infaunal biomass and high carbon fixation (by both phytoplankton and eelgrass) both appear in western parts of the study area (Sections 3.0 and 4.0, this report). Epifauna is most abundant where infauna (a probable competitor for food) is scarce (Section 4.0, this report).

15. Benthic infaunal biomasses between 20- end 50-m depths were similar to those reported for deeper parts of the southeastern Bering Sea shelf (Section 4.0, this report).

(Recall that primary productivity rates and the tendency **for** water-column grazers to be inefficient *were* also similar between the deeper parts of the NAS area and the middle shelf.)

16. The fish, bird, and mammal communities beyond about the 20-30-m depth contours appeared in large part similar to those in the **deeper** shelf waters beyond (Sections 5.0, 6.0, and 7.0, this report). Frequently the same species dominated, and **were** present in somewhat similar abundances. But there are a few obvious differences between the deep NAS and areas farther seaward. Pollook are probably much more abundant beyond the 50-m contour than inside; sea otters are the reverse.

17. The zone shoreward of the **20-30 m** depth contour appeared to contain somewhat different assemblages of species than did waters beyond. Numerous species of resident inshore fishes, plus seasonally-spawning **forage** fishes, are largely absent beyond 20 **m** (Section 5.0, this report). Ducks, cormorants, and gulls were common within 30-m depths, but **scarce** beyond; the reverse was true for shearwaters, **auklets,** murres, and phalaropes (Section 6.0, this report). Gray whales, sea otters, harbor seals, and sea lions were relatively common within 20 m, but scarce beyond (Section 7.0, this report).

18. As is apparent from the previous several paragraphs, an ecosystem "boundary" in terms of distributions of many invertebrates and vertebrates, appeared to occur at the **20-** 30-m depth **contour,** or even nearer to shore, and not at the 50-m contour as initially postulated. Inside this rather nebulous boundary, the biological community was in many ways different from that farther offshore in the study area. And in the deeper, farther offshore parts of the

study area, the biological community was similar to that in the middle domain beyond 50 m.

lg. Physical habitat constraints appeared responsible for making the biological community within the 20-30 m depth contour different from that farther offshore. Inshore fishes and spawning forage fishes were found only short distances away from bays, lagoons, sand substrates, benthic algal communities, and other shallow coastal habitats on which they depended (Section 5.0, this report). Shore1 ine nest sites combined with short foraging distances kept many birds (cormorants, gulls) nearshore in summer; preferences for shallow depths by benthic feeders (ducks) kept others near shore in winter (Section 6.0, this report). The benthic-feeding sea otter apparently prefers feeding in these shallow waters (Schneider 1981), and gray whales typically migrate and feed near shores throughout their range (Braham 1984). The nearshore infaunal community was, in comparison with that beyond 20 m, depauperate in terms of biomass and diversity, probably because of ice scour (Section 4.0, this report).

20. Use of the NAS study area by vertebrates appears to be highly seasonal partly because of the seasonality of food supplies in the water column. The spring bloom of phytoplankton occurs in May (Section 3.0, this report), followed by blooms of herbivorous zooplankton (copepods, euphausiids) in June/July (Section 4.0, this report). This, in turn, is followed by large-scale immigrations of plantivorous vertebrate consumers into the study area (Sections 5.0 and 6.0, this report), and they are abundant from spring through mid-summer. By August/September, the heavy grazing of zooplankton by vertebrates (and jellyfish) apparently depletes the supply, whereupon many birds, marine mammals, and forage fishes that feed in the water column move elsewhere, and levels of biological activity

remain relatively low until the next spring (Sections 4.0, 5.0, 6.0, and 7.0, this report). Animals that are abundant over winter (small flatfishes, sea ducks, sea otters, auklets) feed either on a seasonally stable infaunal food supply or near the shelf edge where planktonic food may be brought up from depth (Sections 5.0, 6.0, and 7.0, this report) .

21. It is likely that many fishes use the NAS nearshore zone in summer in preference to adjacent areas because the water temperature is higher there. Species possibly influenced in their use of the area by the warm water include the forage fishes, the flatfishes, and juvenile salmon (Section 5.0, this report). The presence of some of these fishes (e.g., sand lance) may in turn attract piscivorous birds and mammals to the nearshore zone in summer.

9.3 DISTRIBUTION AND ABUNDANCE OF HIGHER TROPHIC LEVELS

In this section we summarize the distribution and abundance patterns that have been observed, and identify the physical and biological factors that appear to be responsible for these patterns. Section 9.4, to come later, will discuss in greater detail these causative factors.

9.3 .1 Spatial Distribution

The NAS study area extends from the coast to the 50-m depth contour (and beyond in some cases), and from Cape Mordvinof on the west to Cape Seniavin on the east. Data from this study and others show that animal species composition and abundance often change with distance perpendicular to the coast (i.e., depth) and/or with location east-west along the coast.

Very few of the vertebrates sampled were distributed uniformly from the coast seaward to the deepest areas sampled. Fish, sampled mainly from late spring to early fall, showed depth preferences as follows: (1) sand lance, rainbow smelt, and yellowfin sole were most abundant at 20-m depths and shallower; (2) pollock, salmon, and rock sole were most abundant near the 50-m depth zone and beyond; and (3) herring and capelin (few of which were caught in this study) are known from other studies to be typically more abundant in the deeper waters except very briefly in late spring or summer when they come near shore to spawn (Section 5.0, this report). Among the birds, shearwaters, murres, auklets, and phalaropes concentrated in waters more than 30 m deep; cormorants, gulls, and sea ducks showed preferences for waters shallower than 30 m. Within these broad limits, some birds (shearwaters, murres) showed seasonal or annual differences in their depth zones of concentration (Section 6.0, this report). Among mammals, gray whales, Steller sea lions, walruses, and harbor seals were almost entirely restricted to shallow depths (<20 m) very near shore; northern fur seals were most common farthest from shore. Sea otters, generally most common near shore, became in winter more common in deeper water out to 50 m (Section 7.0, this report).

Reasons for the depth distributions observed appear to vary among species. Based on the present study and other investigations, the animals are probably responding to (1) the presence of the inner front (some birds), (2) the presence of specific shoreline or substrate types (fish, birds, and mammals), water temperature (fish), or prey availability (fish, birds, mammals).

Distributional abundances of some animals varied with east-west (coastwise) location in the study area. No clear pattern of coastwise abundances of fish emerged from the data in this study, but it is known that some fish are more abundant at the eastern end toward inner Bristol Bay (e.g., salmon, capelin) or near embayments such as Port Moller where spawning is concentrated (see Section 5.0, this report). Among birds, Crested Auklets (in winter) and shearwaters (in fall) were concentrated at the western end of the study area near Unimak Pass, and some others (e.g., Red-faced Cormorant, Glaucous-winged Gull) were concentrated in summer near known nesting colonies (Section 6.0, this report). Mammals showing marked coastwise concentrations included Steller sea lion and harbor seal (more abundant near haulout areas) and sea otters and fur seals (more abundant near the western end) (Section 7.0, this report).

Reasons for variability in coastwise abundances of animals include (1) the presence of coastal embayments attractive as feeding or spawning sites (birds, fish), (2) the presence of emergent coastal features unique as nesting or hauling-out sites (birds, mammals), and (3) the proximity of east or west ends of the study area to migration routes (i.e., Unimak Pass) or food concentrations (fish, birds, mammals).

9.3.2 Seasonal Patterns

All the important species varied seasonally in total abundance in the study area, and some showed seasonal shifts in distributions within the area. The best data on seasonal abundance exist for the spring, summer, and fall periods; winter data are sparse. The following information is taken from previous sections of this report.

Fish are, in general, much more abundant *in* the study area in late spring and summer than during other seasons (Section 5.0, this report). Forage fishes (herring, capelin, sand lance) began moving into the area in large numbers in late spring to spawn and/or feed; most were gone by late summer. Salmon juveniles leaving their natal streams in Bristol Bay traditionally move seaward (westward) through the area, and returning adults pass through eastward on their way to spawning areas in inner Bristol Bay streams. Most of these salmon movements take place in late spring and early summer, and most are concentrated mainly in deeper waters of the study area. Demersal fishes are most abundant in the area in summer; most (particularly large individuals) vacate the area in winter, though juvenile yellowfin and rock sole winter there. Water temperatures and perhaps food availability appear to promote this seasonal difference in fish distributional patterns.

Bird abundance overall, like that of fish, is greatest in summer (Section 6.0, this report). The main reason for the overwhelming summer abundance is the presence of several million Short-tailed Shearwaters, which nest in the southern hemisphere and spend their non-breeding period in the Bering Sea. Other species more abundant in summer than in winter are Black-legged Kittiwake and Glaucous-winged Gull; both species nest on nearby coasts. Birds more abundant in winter than in summer are Crested Auklets, scoters, eiders, murres, and cormorants. Note that, if shearwaters are excluded, winter bird densities are higher than summer densities. Seasonal differences in total bird abundance in the area, and distribution patterns within the area, are caused to some extent by the availability of nesting sites and migration passes nearby (e.g., for murres, gulls , cormorants, shearwaters), but also probably by food availability (e.g., for shearwaters, auklets, waterfowl, murres).

Mammals vary among species in their *seasonal* abundance and local distribution in the study area (Section 7.0, this report). Sea otters, consistently the most numerous mammals, shifted their distribution to deeper waters in winter but showed no marked seasonal difference in overall abundance in the study area. Steller sea lions and harbor and Dall porpoises showed no marked seasonal differences in abundance or in distribution within the study area (although would likely do so in years when sea ice invaded the study area). Harbor seals were most abundant in summer, and gray whales during spring and fall migrations. Most other mammals, though expected to be more common in summer, were seen too infrequently in this study to demonstrate any seasonal differences. Factors that account for seasonal differences in abundance include periodic intrusions of ice in winter (sea otters, harbor seals) and species migration patterns that bring mammals into or through the area from elsewhere (most whales).

9.3.3 Interannual Variabilitv

Abundances of many vertebrates are known to vary among *years* in the southeastern Bering Sea (Wooster 1983). Because this study included only two years of field sampling, end for many vertebrate groups the sampling efforts were not made in the same months in each of the two years, few data to evaluate interannual variability were collected. Only for fish and birds could populations be reasonably compared among years.

Inter-annual variability in fish populations were inferred by viewing this study's data (Section 5.0, this report) in isolation as well as in the context of data from other studies. Capelin and herring, reported by others (Warner and Shafford 1981, Barton et al. 1977) to be abundant in late spring/early summer in some years in the NAS nearshore zone, were not caught in abundance in either 1984 or 1985 during this study. (Scarcity of these fishes in our catches was probably due, in part, to our failure to sample at optimum times.) Catches per unit effort (both numbers and biomass) of yellowfin and rock sole in this study were considerably higher in May 1985 than they were in May 1984. Large annual differences in salmon populations are known to occur, but were not measurable in the present study because sampling was not designed to catch salmon. Annual observed differences can be caused by several factors--(l) differences among years in sampling effort (e.g., for capelin and herring), (2) annual differences in regional distributions of fish as a consequence of water temperature or prey distribution differences (for yellowfin and rock sole), (3) real differences in regional population numbers, caused by one or more factors operating over much larger areas than the study area or (4) a combination of all these (and perhaps other) factors.

Among birds, interannual comparisons are based largely on data collected in the present study (Section 6.0, this report). Annual differences in both total numbers and distributional patterns within the study area were observed. For example, in May 1985 overall density estimates (of all species) were higher than in May 1984. Short-tailed Shearwaters appeared to occur at highest densities (based on shipboard surveys) in deeper water in 1985 than they did in 1984; conversely, Northern Fulmars peaked in density in shallower areas in 1985 than they did in 1984.

Reasons for these observed interannual differences are not clear. Because seabirds are long-lived, it is unlikely that large changes in total numbers occur between years. Higher shipboard estimates of total densities in May 1985 than in May 1984 may be partly a consequence of an Inadequate survey technique. Shifts in depth preferences of shearwaters and fulmars among years could have been caused by shifts in hydrographic structure and, thereby, in prey distribution (e.g., horizontal changes in the location of the inner front), though this is not readily apparent from the oceanographic data. Because seabirds are highly mobile and can rapidly locate new prey sources and change their feeding locations accordingly, it is possible that distributional changes occur rapidly in response to short-term shifts in oceanographic conditions and prey availability. If this is so, observed annual differences in bird distribution cannot be interpreted as a between-year phenomenon.

9.4 FACTORS REGULATING DISTRIBUTION AND ABUNDANCE

The above discussion [Section 9.3) noted apparent causes for the observed distributions and abundances of biota. There seem to be two major causal **factors--trophic** and physical--involved in regulating these distributions and abundanoes.

9.4.1 Trophic Factors

Trophic dependencies and energy flow within NAS food webs have been depicted in a quantitative, conceptual model in the preceding chapter (Section 8.0, this report); a summary of the major points will help to introduce the following discussions. Pelagic primary production by phytoplankton provides nearly all the *energy* that supports the important vertebrates; **eelgrass** provides a relatively minor source of energy. The primary production supports both pelagic and benthic herbivores; vertebrates (in total) get approximately half their sustenance from the pelagic food web and half from the benthic. Primary production appears to be in excess of the needs of the herbivores. The excess carbon fixed by primary production is presumably exported, or used up in benthic meiof aunal food webs. The herbivorous zooplankton, and possibly the benthos, appear to be in short supply as food for the vertebrates that eat them. Predation by vertebrates may limit standing stocks and productivity of zooplankton and benthos.

The following sections expand upon these trophic factors (food supply, predation) as potential regulators of vertebrates **on** the NAS. Discussions proceed from lowest to highest trophic levels.

9.4.1.1 Primary Production, Nutrients, and Transport

Two sources of **carbon--eelgrass** transported from coastal lagoons and in situ phytoplankton production --are available to consumers in the NAS study area. It appears that **eelgrass** production contributes a very small part of the total, and that its greatest contribution is to the local benthic food web. Phytoplankton production is the major carbon source; it is apparently supported largely by deep-ocean nutrients (Section 3.0, this report). These nutrients may enter the NAS directly at its western end, or indirectly via water exchange with the middle shelf domain. The following paragraphs explain the apparent timing and manner of this nutrient supply to the NAS area and its use by the phytoplankton.

The general. circulation and water exchange patterns that prevail in the southeastern Bering Sea and in the NAS study area (Kinder and Schumacher 1981; Schumacher and Moen 1983; Section 2.0, this report) suggest that materials are transported into the NAS area from the west (by advection) and from the north (by dispersive exchange). Part of the water and transported materials that come from the west appears to be derived from the Alaska Coastal Current that has moved into the area from the shelf south of the Alaska Peninsula (Schumacher and Moen 1983). Part could also be derived from deep Bering and/or Pacific water that has upwelled on the north side of the eastern Aleutians and moved eastward onto the shelf along the north side of Unimak Island (see Hood 1986). Radio-carbon signatures of organisms collected from the NAS study area reflect a deep-ocean based food-web (Section 3.0, this report), lending support to this possibility. Waters that enter the NAS from the north undoubtedly come from the middle domain (see map in Fig. 2.2), though the ultimate source of the middle domain water is the deeper Bering Sea, as we discuss further below.

Primary productivity is low in winter throughout the shelf, mainly because light is limited, but also because storms cause rapid mixing in the water column (even in the middle domain, which is stratified in most other seasons). This mixing dampens primary productivity by reducing the time that phytoplankton cells are in the euphotic zone (Sambrotto et al. 1986). During this period of low productivity, nutrients (nitrate) diffuse onto the Bering Sea shelf from the deeper waters to the west. This on-shelf flux of nutrients occurs not only in areas north of the NAS area, as reported by Whitledge et al. (1986), but also probably directly into the NAS from the west, as noted above.

As winter ends and spring progresses, the amount of daylight increases. At the same time, beginning in the eastern parts of Bristol Bay, the water column (at least in the middle domain) becomes stratified to some extent because the winter storm season terminates, fresh water is supplied to the surface by melting sea ice and river discharge, and surface waters warm (Sambrotto and Goering 1983). The longer days and (in the middle domain) the stratified water column expose phytoplankton cells longer to light, causing plankton blooms to commence (Sambrotto and Goering 1983). As nutrients (nitrate) that built up over the winter *are* assimilated from the euphotic zone by the phytoplankton, the loom diminishes. This pattern occurs both in the middle domain (Sambrotto and Goering 1983) and in the coastal domain (i.e., the NAS study area) (Section 3.0 , this report). In both the coastal and middle domains, the bloom may periodically be rejuvenated during the summmer if the normally stratified middle domain is mixed by strong winds such that nutrients from its bottom waters are brought into the euphotic zone of both domains (Section *3.0,* this *report).*

The timing of the phytoplankton bloom has strong implications for zooplankton abundance. During spring, particularly in eastern parts of the study area that are removed from the shelf edge, only small numbers of copepods are available from overwintered populations to take advantage of the bloom, and not until mid-summer do they reach near maximum numbers (see Section 4.0, this report). However, relatively large numbers of euphausiids may have overwintered on the shelf (Section 4.0, this report); thus, they may be the primary water-column grazers in the study area in spring. Apparently neither copepods nor euphausiids are ever sufficiently abundant in the NAS nearshore zone to crop a large percentage of the bloom before it settles to the bottom or is exported (Section 8.0, this report).

9.4.1 .2 First-level Consumers

As noted above, the major zooplanktonic *grazers are* euphausiids and copepods. The euphausiids are typically dominant in late spring and early summer and the copepods typically dominate in late summer and fall (Section 4.0, this report). A brief look at some aspects of euphausiid and copepod seasonal abundance and behavior will help explain their seasonal abundances in samples (and in predator diets) on the NAS.

Among the euphausiids, it is probable that Thysanoessa raschii and T. inermis form the major portions of samples and predator diets (see also Ponomareva 1966, Dagg 1982). Both these species are abundant on Bering Sea oontinental shelves. In spring, coinciding in time more or less with the phytoplankton bloom, they collect in large swarms at the surface to breed (Ponomereva 1966), where they are easy prey to both birds and fish. Their swarms may be found from late April to June in the Bering Sea. By late summer, Thvsanoessa becomes much less abundant to predators (and to sampling gear) because (1) they have dispersed from surface breeding swarms and are benthic in habit more of the time and (2) the numbers of adults have probably been cropped drastically by predators since early summer (see Ponomareva 1966).

In contrast to this pattern of seasonal abundance of euphausiids, the copepods in the coastal domain (similar to those in the adjacent middle domain) are at lowest abundance in winter and spring and increase to their highest abundance only by mid- to late summer (Lasker and Clarke 1982; Section 4.0, this report). Most of the time, the NAS is dominated by the small copepods that overwinter on the shelf and not by the large ones on the outer shelf that overwinter in the deep ocean environment, though the large copepods become more numerous when outer domain water intrudes into the NAS study area (Section 4.0, this report).

9.4.1 .3 Top Consumers

Top consumers, as defined in this section, are second- and third-level consumers in the NAS food webs. With a few minor exceptions (e.g., the surf clam, Spisula), the species important to man are exclusively in these second and third consumer levels. Several food-web factors in relation to the distributions and abundances of these consumers are important, as follows:

(1) Many of these ton consumers are more abundant in the study area in late spring and early summer than they are in late summer, fall, or winter. Included in this category are mainly birds (murres, shearwaters, kittiwakes, gulls), and fish (salmon, herring, capelin) that feed extensively on water-column invertebrates and to some extent on pelagic fish (Sections 6.0 and 5.0, this report). Nearly all these consumers feed heavily on euphausiids, or on fish that eat euphausiids (Section 8.0, this report). Most

species that are equally or more abundant in late summer, fall, or winter are mostly either year-round residents (harbor seal, cormorants, crabs, surf clam), and/or benthic feeders (sea otter, yellowfin and rock sole, crabs) (Sections 4.0, 5.0, 6.0, and 7.0, this report).

(2) Populations of most of the species that are seasonally abundant on the NAS in spring and early summer (excepting shearwaters) reauire large energy supplies preparatory to or during breeding, or for their young, at this time of year. This need means that each individual must acquire more food per day than at other times of the year; this may be particularly true for the fishes, which probably also require less food in winter because of low temperatures. This point and (1) above emphasize the need for water-column and surface feeders to find large quantities of readily available food at this time of year. The following point shows why food may be more available earlier in the year than later.

(3) Biomass of prey available to consumers that feed in the water column is much greater in late spring and early summer than it is in other seasons. Two main factors probably influence this greater availability. First, the lower the prey *occurs* in the food chain, the more abundant it tends to be (because each step up the food chain typically reduces the biomass about ten-fold). Euphausiids, the main spring/early summer prey base of pelagic top consumers (Section 8.0, this report) are primarily herbivorous (first-level consumer); sand lance, the main pelagic prey species for the same consumers later in the year, are second-level consumers, Second, primary productivity rates decline after the spring bloom, precipitating an eventual decline in herbivores, and finally in consumers of the herbivores. In combination, these differences between early-season and late-season prey on the NAS may have much to do with the seasonal abundances of their predators.

(4) The biomass of benthic-feeding vertebrates is more seasonally stable than that of pelagic species, probably reflecting the seasonal stability of the prey base. As noted earlier (Section 9.3), benthic feeders (as a group) are abundant in both summer and winter (e.g., demersal fishes and sea otters in summer; demersal fishes, sea otters, ducks in winter) in contrast to the scarcity of water-column feeders in fall and winter.

9.4.2 Physical Factors

Physical environmental factors that appear most effective in directly regulating animal abundance and distribution are three--(l) characteristics of shorelines or substrates, (2) extent of sea ice in winter, and (3) water temperatures. The first is a more or less fixed geological variable; the second and third are direct consequences of weather patterns and show great seasonal and annual variability.

9.4.2 .1 Shorelines and Substrates

Figure 9.1 illustrates sites where some animal populations congregate on North Aleutian Shelf coasts and islands, based on information presented in previous sections of this report. Some of these concentrations are at oceanside cliffs (not discernible from the map), some are on islands, and some are associated with bay and lagoon systems. Very few occur along relatively featureless coasts. Other animal aggregations associated with physical features include juvenile crabs associated with rocky or cobble benthic environments off Port Moller and Cape Seniavin (McMurray et al. 1984) and surf clam concentrations between Port Moller and Ugaskik Bay where depths and salinities are optimum (Hughes and Bourne 1981) (these are not shown on the map). Perhaps some of these sites of aggregation are favored because of some trophic advantage offered (e.g., relatively abundant food in waters nearby); this cannot be evaluated from the data.

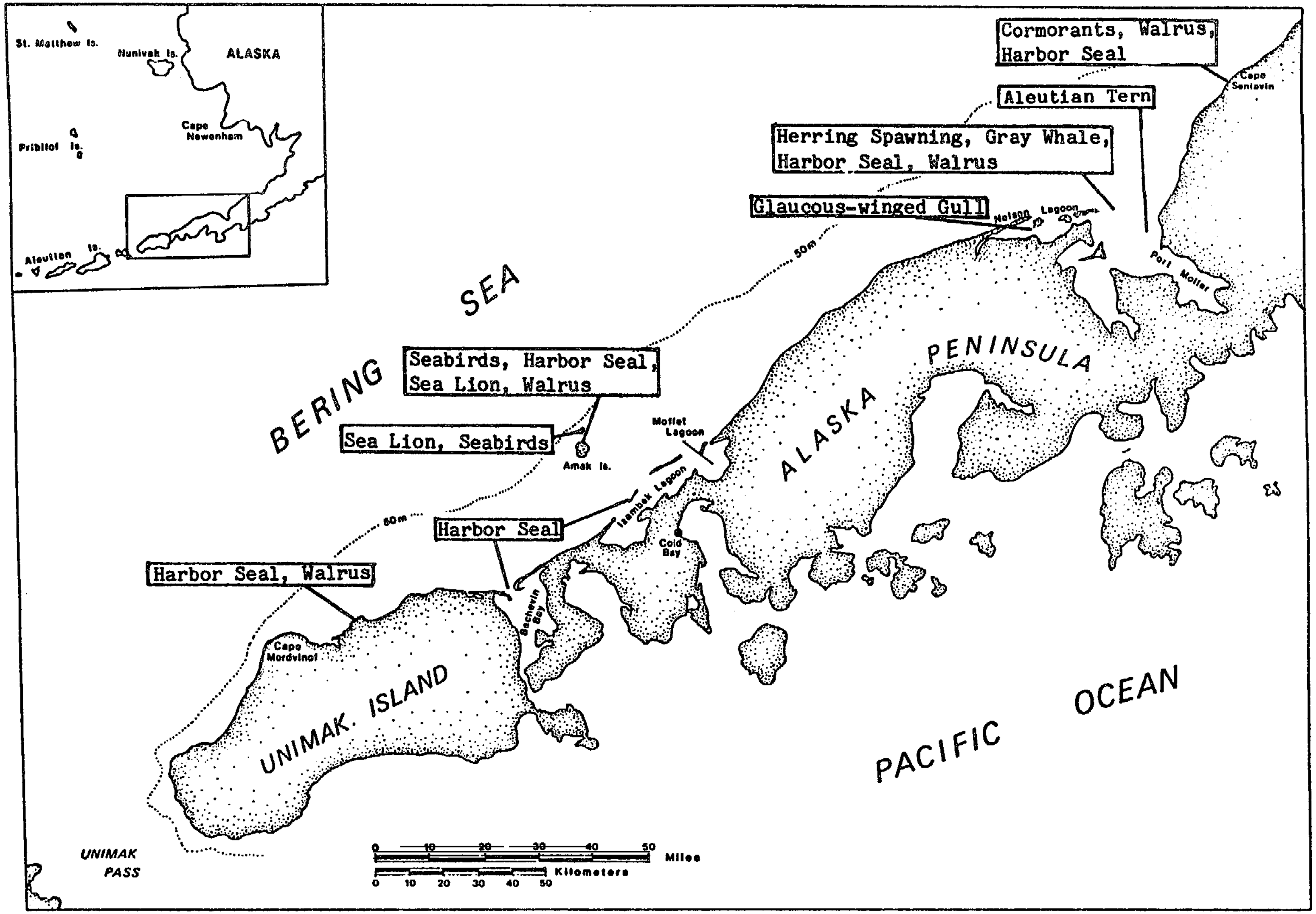

Figure 9.1. Areas where some of the animal populations in the NAS study area are concentrated.

9.4.2.2 Ice

Winter ice has positive effects on some species and negative effects on others. In most years, sea ice at its maximum extent approaches, but does not invade, the NAS study area from the northeast; in unusually cold years much of the area may be ioe-covered in late winter and early spring (Niebauer 1981). Thus, walruses, which typically are associated with ice year-round, are near the southern limits of their distribution on the NAS. Conversely, sea otters, harbor seals, waterfowl and seabirds may be displaced to the south by encroaching ice, and are near their northern limits of winter distribution on the NAS (Sections 6.0 and 7.0, this report).

9.4.2.3 Water Temperature

Water temperature strongly affects the distribution and abundance of many, perhaps all, poikilothermic (cold-blooded) species (fishes and invertebrates) in medium to high latitudes (Laevastu 1984, Schumacher and Reed 1983). It is conceded to be one of the most important regulating factors for populations of fishes and invertebrates in the southeastern Bering Sea. It may also affect the homoeotherms (birds and mammals), because fishes and invertebrates are key components in the food webs of all of them.

It is well known that large annual variations in water temperature occur over the continental shelf of the southeastern Bering Sea. The differences are evidenced by such phenomena as differences in the extent of sea ice cover in winter, warming in spring or cooling in fall that are earlier or later than normal, and variations in seasonal maximum and minimum temperatures. Within the 100-m isobath, these variations seem to be caused mainly by annual differences in weather patterns, as has been discussed by Schumacher and Reed (1983). Less well known are the annual variations in temperature differences between the NAS nearshore zone and deeper shelf areas, which in some years (e.g., in summers when deeper waters are colder than normal) could create in the nearshore zone an important thermal sanctuary for fishes and inverterates (see Section 5.0, this report). The following paragraphs discuss how water temperature (and variability therein) affects fishes and invertebrates that use the NAS area, and what that implies about the seasonal distribution and abundance of these animals in the area.

Temperatures are known or suspected to affect the distributional abundances of salmon, forage fishes (sand lance, capelin, herring), demersal fishes (pollock, yellowfin sole, rock sole), and crabs. In addition, temperature has been shown to be an especially important factor in all aspects of fish energy budgets-=-it influences the amount of food ingested, the rate at which food is digested, and the general metabolic rate of the organism (e.g., Kinne 1960, Beamish 1964, Brett and Higgs 1970, Jobling et al. 1977, and many others).

Water temperature significantly affects the distribution of juvenile salmon as they migrate seaward into the Bering Sea (Straty 1981). Annual temperature differences can be expected to result in variations in the time juveniles reach the North Aleutian Shelf and the length of time they remain in this region. Sea temperatures may also influence the width of the seaward migration route of juveniles (Straty 1974), and thus influence what proportion of the migrants pass through the NAS area.

For forage fishes such as herring, oapelin and sand lance, there are three general activities directly influenced by water temperatures: (1) reproduction, (2) rates of egg and larval development, and (3) population movements. Herring spawning, for example, is related to winter and spring water temperatures, Le., it is early in warm years and late in cold years (Wespestad and Barton 1981). Herring, capelin, and sand lance have demersal eggs that generally require two or more weeks to hatch, with water temperature being the determining variable. The rate of larval development for these species is probably also related to temperature, but other environmental factors such as food supply for larval herring (Wespestad and Barton 1981) may be more consequential. Temperature may influence the seasonal distribution and movements of juvenile and adult herring morethananyotherenvironmentalfactor (Wespestad and Barton 1981). Temperature influences where herring overwinterinthe central Bering Sea, when they migrate from offshore overwintering sites to coastal spawning grounds, when they spawn, and perhaps the length of time they remain in coastal waters before returning to offshore waters.

Temperature is also a key factor influencing the distribution and seasonal movements of demersal fishes such as pollock and yellow fin sole (Bakkala 1981, Smith 1981, Favorite and Laevastu 1981). In spring these fish tend to migrate from offshore overwintering areas to shallower portions of the continental shelf to feed and, in some cases, spawn, and in fall they retreat to deeper overwintering areas on the outer shelf and upper slope. The latter migration is thought to be an avoidance response to the cold bottom temperatures (0 to -1.8°C) existing over the eastern Bering Sea shelf in winter. The fish overwinter near the shelf break where water temperatures are about 5-6°C warmer. Movements in spring back into shallower water are probably influenced by increasing temperatures as well as other factors. Similarly, temperature may affect the year class strength of yellowfin sole, with above-average abundances occurring in warmer years (Maeda 1977, cited by Bakkala 1981).

Temperature affects both the distribution of adult red king crabs and the development and survival of their larvae (Armstrong et al. 1983). In late winter and early spring adult males apparently migrate from deeper, offshore areas to join females in shallow water for breeding; the nearshore, shallow water habitat is apparently selected in part for warmer water temperatures (and perhaps greater food supplies). Temperature is considered one of the most crucial physical factors affecting survival and growth of larvae (McMurray et al. 1984). Severe climatological changes could account for large fluctuations in survival of a year-class and later recruitment to the fishery. For example, both 1975 and 1976 were severely cold years and poor survival of larvae and juveniles then oould account for low abundance of sublegal males f ive to six years later in 1981-82 (McMurray et al. 1984) and nine to ten years later in 1984-85 (this study).

Temperature undoubtedly also affects the recruitment, growth rates, and distributional patterns of invertebrates important in food webs. Timing of occurrence, and perhaps the distributions, of surfaoe swarms of euphausiids may be temperature-related. The relative abundances of oopepods and euphausiids in seasonal diets of vertebrates, as observed in this study, are perhaps temperature-related, though little is known of this subject .

9.5 VULNERABILITIES OF BIOTA TO OCS ACTIVITIES

This section discusses the vulnerabilities of the important fish, bird, and mammal populations to activities (herein called OCS activities) that might occur should oil exploration and development escalate in or near the NAS area. Emphasis will be on the potential effects of oil spills, but other activities such as those associated with oil well drilling and increased boat traffic will be considered in cases where they seem important. Impacts of OCS activities on the processes and components supporting the important vertebrates will be addressed in cases where these impacts may appreciably affect the vertebrates themselves.

In this discussion, "vulnerability" and "sensitivity" are two words used to describe the susceptibilities of animal populations to adverse impact from OCS activities. Vulnerability is defined as the likelihood that significant portions of regional populations will interact with OCS activities. Sensitivity is the level of response of individual animals to the activities with which they come in contact. Thus, a population that is highly concentrated in space might be highly vulnerable to an activity, particularly if that activity is likely to occur in the same places-as the concentration; a population that is widely dispersed would not be particularly vulnerable to any localized activity. Populations whose members are highly sensitive to activities may suffer considerable adverse effects if the populations are vulnerable, but not if the populations are relatively invulnerable. Relatively invulnerable populations comprised of individuals not sensitive are secure from adverse effects.

Extensive reviews already exist of the known levels of sensitivity of Bering Sea fish, birds, and mammals to oil and other OCS activities, as follows: (1) fish and shellfish (Curl and Manen 1982; Thorsteinson and Thorsteinson 1982, 1984; Laevastu et al. 1985), (2) mammals (Braham et al. 1982, Davis and Thomson 1984, Armstrong et al. 1984, Pace 1984), and (3) birds (Strauch and Hunt 1982, Roseneau and Herter 1984, Armstrong et al. 1984, Pace 1984). All the species with which we are concerned have been included in one or more of these reviews, and the data collected in the present study do not provide significant new data on sensitivity. Thus our discussions will depend on existing information about species sensitivities, and will provide new information mainly on vulnerabilities of populations.

9.5.1 Relative Sensitivities of Important Species

Consensus in the literature about relative sensitivities of invertebrates, fish, birds, and mammals is generally as follows:

(1) Fish and Invertebrates--Eggs and larval stages of fish and invertebrates are relatively sensitive to oil in comparison with adults. Further, it is difficult or Impossible for these early life stages to actively avoid oil with which they come in contact, which further enhances their sensitivity.

(2) Birds--Birds in general are the most highly sensitive group of vertebrates to being oiled. Oil may drastically impair the insulative and buoyancy values of feathers, frequently causing mortality if birds remain in water. Because marine birds are especially dependent on their use of the aquatic environment and the water surface, they are likely to come into direct contact with spilled oil. Birds also occasionally collide with ships, suffering dramatic mortalities on a very local scale. Nesting seabfrds are very sensitive to some types of human activity, most obviously the taking of eggs or young from nests.

(3) Mammals--Sensitivity varies greatly among the mammal species. Mammals insulated largely with fur (fur seal, sea otter) respond more adversely to being oiled than do the other species, which are insulated with subcutaneous blubber. The literature also suggests that very young mammals, whether furred or otherwise, are generally more sensitive than older ones of the same species.

9.5.2 Vulnerabilities of Populations

General vulnerabilities of important vertebrate species and their food webs in the NAS and vicinity have been discussed by Pace (1984), Laevastu et al. (1985) and Truett and Craig (1986), based on existing literature. Conclusions of these authors, modified and supplemented as appropriate by findings of the present study, lead to the conclusions that follow.

9.5.2.1 Fish

Oil spills are assumed by most people to be the OCS activity of most concern with respect to fish. Laevastu et al. (1985) concluded that the largest oil spills conceivable would have only minor effects at most on the eastern Bering Sea populations of fish and shellfish, despite the sensitivity of larval stages. They point out that populations of all species are so widely dispersed, and potential oil spills so restricted in space, that only insignificant portions of the Bering Sea populations would even come into contact with the oil.

Several points about Laevastu et al.'s (1985) oil effects model should be noted in order to assess its applicability to fish populations in the NAS study area. Three hypothetical oil spill scenarios in the southeastern Bering Sea were considered, all spills at depths of less than 50 m. One was near the east end of the NAS study area (at a 45-m depth near Port Moller) and all were assumed to be very large spills. In general, the model assumed maximum adverse behavior of the spilled oil with respect to the various life stages of the species considered. Fishes and crabs important to the commercial fishery (demersal species, salmon, and pelagic species) were included in the evaluation, but evaluations of the effects of oil spills on beaches and on coastal spawning of herring and capelin were excluded. Thus it appears that the model is applicable to areas beyond the immediate subtidal zone of the NAS study area but not to bays, lagoons, intertidal, *or very* shallow subtidal areas.

On a local scale, some fish populations are vulnerable. The most vulnerable species are probably the littoral spawners such as capelin and Pacific herring. The next most vulnerable are probably the freshwater spawners such as boreal smelt and salmon, the juveniles of which spend some time in the shallow nearshore environment. Species that live year-round in shallow waters might be next most vulnerable. Most demersal and pelagic species are relatively invulnerable. On a very local basis, capelin could be highly vulnerable because they spawn in intertidal or shallow subtidal areas, where spilled oil might likely be deposited. Newly-hatched larvae tend to accumulate in surface water. But in the final analysis, capelin populations are so regionally dispersed and mobile that the effects of the worst imaginable oil spill could probably not be measured.

Herring would probably be the most vulnerable of the commercially-important species to an oil spill because their spawning, incubation and nursery stages all occur in shallow shoreline environments where oil might collect and persist for relatively long periods. But spawning stocks of herring in the NAS area are small compared with other stocks in the eastern Bering Sea. As summer progresses, juvenile herring move offshore where they are less vulnerable. Post-spawning adult herring from Bristol Bay stocks migrate Into the study area to feed in summer and fall, but they are expected to be relatively secure from large-scale population losses (see Laevastu et al. 1985).

The most vulnerable stage in the life cycle of salmon occurs in late spring and early summer when smolts migrate downstream and inhabit coastal waters. Smolts are dependent on estuarine habitats for feeding and adjustment to new salinity regimes as they leave fresh water and enter the ooe an. As summer progresses, these juveniles disperse farther offshore where they are less vulnerable to in the nearshore zone disturbances.

Bax (1985) and Laevastu et al. (1985) examined the vulnerabilities of Bristol Bay sockeye salmon juveniles and adults to oil spills. Their worst-case estimates of mortality from a large spill in Bristol Bay were 13% of Bristol Bay juveniles and 5% of the adults. Six percent of the juveniles and 2% of the adults could be tainted. At no time does the NAS study area harbor a very large proportion of Bristol Bay salmon juveniles or adults.

Resident Inshore fishes of the NAS, especially those restricted to lagoons and bays, are relatively vulnerable in the sense that their populations are concentrated in habitats where spilled oil may accumulate and/or persist for relatively long periods. Included are species such as rockfish, greenling, and sculpins. (Note that these bays and lagoons are largely outside the NAS area as it was defined in this study.)

Groundfish are probably less vulnerable to OCS effects than are other fishes because they inhabit subtidal benthic environments, where oil is unlikely to accumulate. It is possible that an oil spill could damage the pelagic eggs, larvae, and/or Juvenile stages of these species in surface waters, particularly in the case of pollock. But pollock populations are small within the study area in comparison with their populations farther offshore. For both pollock and other demersal fish, the widespread abundance of the early life stages suggest that population-level effects would be small on any except a very local basis.

9.5.2.2 Birds

We have seen that birds are, in general, more sensitive to oil spills than are fish or mammals. In some instances they are also quite vulnerable.

Birds can be vulnerable for one or both of two reasons--(l) large proportions of populations occur as local concentrations and/or (2) their intrinsic behavior exposes them to OCS activities (e.g., oil on water, human activity at nesting sites). Populations exhibiting both these traits are highly vulnerable; those exhibiting neither are relatively secure from appreciable impact.

Four species or species groups--Short-tailed Shearwaters, Crested Auklets, Glaucous-winged Gulls, and seaducks-concentrate themselves in space and also have behaviors that make them vulnerable. Short-tailed Shearwaters frequently occur in large concentrations (flocks of over 100,000 are common> and spend much time swimming on the water's surface where spilled oil can readily reach them. Crested Auklets were found in large concentrations in this study near the west end of the study area; this species spends virtually all its time swimming or diving. The largest colony of Glaucous-winged Gulls in Alaska is located adjacent to the study area on a spit in Nelson Lagoon; this colony is exposed to egg-gathering and other human activity that might occur in the area, or to a local oil spill (adults forage largely in the vicinity of the colony).

Seaducks occur in fairly large concentrations and are readily susceptible to floating oil.

Of these four species, the Crested Auklets are probably most vulnerable as a population, with seaducks next in order. The swimming and diving behavior of auklets insures that oil spilled near them would pose a high risk to the birds, and perhaps one-eighth or more of the Alaska population has been counted in one concentration area on the NAS. Large proportions of wintering populations of eiders, scoters, and Harlequin Ducks likewise occur in the NAS area in winter, and ducks are highly likely to be oiled if oil is present. In contrast, shearwater behavior enables them to normally avoid spilled oil, and, even though single flocks can be large, each is a small proportion of the perhaps tens of millions of birds that occupy the Bering sea. Likewise, Glaucous-winged Gulls are less likely to be affected by spilled oil on the water, and regulatory action should be sufficient to protect eggs and young at nests.

The other bird species appear to be relatively invulnerable, when NAS populations are viewed in the context of Bering Sea populations. Populations that use the NAS are either small proportions of Bering Sea populations (e.g., fulmars, cormorants, murres) and/or have behaviors that would likely enable them to avoid oil on the sea (e.g., kittiwakes, terns, phalaropes) .

9.5.2.3 Mammals

Similarly to other vertebrates, the vulnerabilities of mammals depend on the proportions of regional populations harbored by the NAS, the tendency for the animals to congregate in areas where OCS activities might occur, and the probability that the animals could detect and avoid oil in the environment.

The most common marine mammals that occur in the NAS area appear to be sea otter, Steller sea lion, northern fur seal, harbor seal, and gray whale. Steller sea lion, northern fur seal, and gray whale populations migrate through the area in spring and fall; small proportions of the population of each spend the summer there. Sea otters and harbor seals are present year-round. Large proportions of the total population of gray whales use the area; significant proportions of sea lion and otter populations of the Bering Sea also occur in the NAS. Relative vulnerabilities of each of these populations to activities on the NAS are discussed below.

The NAS study area contains the highest densities of sea otters of any place in the Bering Sea (Schneider 1981). Frost et al. (1982) and the present study found highest densities in the west parts of the study area from Moffet Lagoon to Unimak Island. During most seasons, greatest densities occur near the coast within 10-20 m water depths (Section 7.0; this report). A haulout site near the southwest entrance to Izembek Lagoon attracted up to a hundred or more animals at various times during this study. But the majority are probaly dispersed over a broad area at all times and are thus relatively invulnerable as a population to localized effects of OCS activities.

The Steller sea lion probably exhibits the greatest tendency of any of these species to concentrate large proportions of its populations in restricted localities. Traditional haulout sites exist at Amak Island and on the north side of Unimak Island; there is a breeding rookery on Sea Lion Rock near Amak Island (Frost et al. 1982). During the present study, relatively high densities were observed near the Amak Island and Unimak Island haulout areas; densities tended to be low elsewhere. Because of this tendency to congregate near and on shores, sea lions are judged to be the most vulnerable of the mammals to potential effects of OCS activities.

Northern fur seal were seldom observed during this study, but they are known to concentrate in migratory passage in spring and fall in and near Unimak Pass near the west end of the study area (North Pacific Fur Seal Commission 1971). Based on the scarcity of observations during this study, and on the fact that most observations were of single animals, we judge that fur seal populations of the Bering Sea are highly invulnerable to OCS activities that occur within the study area.

Harbor seals occur in relatively high densities in coastal parts of the NAS study area, and the total number along the north side of the Alaska Peninsula is a significant portion of the Bering Sea population (Frost et al. 1982). Observations made during this study showed many to haul out on islands in the Port Moller vicinity. (Significant numbers probably hauled out also in Izembek Lagoon and farther inland reaches of Port Moller; these areas were not surveyed, since they were outside the study area.) Most animals observed were either hauled out or in very shallow waters near the coast, indicating a moderate level of vulnerability to oil spills or other localized activities that occur along coasts or in bays and lagoons.

The majority of the entire population of eastern Pacific gray whales is reported to migrate in spring in a very narrow coastal band through the NAS study area; a few of these apparently spend the summer in the Nelson Lagoon area near Port Moller (Braham et al. 1982). Some migrants apparently return through the area in fall (Leatherwood et al. 1983). Observations made during this study substantiate these reported observations. Because relatively small proportions of the migrants occupy the NAS at any one time, the vulnerability of the population to oil spills or other short-term activities is not as great as it might otherwise be. But the population would be extremely vulnerable to impacts from long-term activities in the shallow waters of the NAS.

9.5.3 Implications for Assessing the Effects of OCS Activities

The information presented above and in other parts of this report implies that certain animal groups are more likely to be adversely affected than are others. In general, we propose the following points.

(1) Seabirds, especially Crested Auklets, seaducks, Short-tailed Shearwaters, and Glaucous- winged Gulls (in approximately that order), are of greatest concern with respect to potential effects of OCS development in the NAS. Sea otters probably follow as a close second to this group of seabirds. The activity of major concern relative to impacts on these animals is oil spills.

(2) A secondary level of concern with respect to oil spills revolves around species that stand to exhibit less regionally Important effects but might suffer local impacts. Included in this group are some fishes (e.g., capelin, herring, salmon), some birds (e.g., fulmars, cormorant s, murres), and some mammals (e.g., northern fur seals, Steller sea lion).

(3) Other vertebrates in the study area appear relatively immune from even local adverse effects of OCS activities. Included are most pelagic and demersal fishes (excluding herring and capelin), birds that feed from the sea surface by dipping or seizing (kittiwakes, terns, phalaropes), and mammals that are widely dispersed and insulate themselves with blubber (e.g., porpoises, most whales).

(4) It seems unlikely that appreciable effects on the vertebrates will come mainly as a consequence of effects on their food webs. First, many of the important species, particularly the birds and mammals, are probably more susceptible to impact than are the prey species (largely fishes and invertebrates) they consume. Second, adverse impacts on food-web components are unlikely to be more than local, given the localized nature of most oil spills. With the rapid movement of zooplankton and other prey, and the high mobility of the consumers themselves, these local effects on food webs are not likely to substantially reduce food available to the consumers, much less to be measurable as changes in consumer populations. One possible exception might be severe reduction in infauna.

Information collected in this study also suggests something about the measurability, predictability, and consequences of impacts caused by OCS development. Important points follow.

(1) The deeper Darts (> 20 m) of the PAS appear to be in many ways similar in ecosystem structure and function to the middle shelf domain beyond the 50-m contour. This implies that the kinds of impacts that might occur with OCS development are similar between the areas. It further suggests that information gathered on the NAS might be usefully extrapolated in some cases to other areas of the southeastern Bering Sea, and vice versa.

(2) Large annual variations occur in distributions and abundances of many species. Many of the important species

as well as the food-web components supporting them show large and sometimes unpredictable year-to-year variations in distribution and abundance of adults and/or recruitment of young. Such variability makes it very difficult to accurately prediot, for any one year, how many organisms or what proportion of a population would be affected by a given OCS activity, or what the long-term effect on the population would be. Further, such unpredictable natural variability makes it very difficult to sort man-caused from natural change once a development-related impact has occurred.

(3) Distributions of most of the directly important species and the important components of their food chains are spatially patchy. Distributional patchiness has the same consequences for predicting or measuring man-caused impact as does annual variability--it greatly increases the difficulty of developing programs that will accurately predict, or measure, the effects of development activities in the area.

(4) Important pelagic species and their food-web components tend to be more highly mobile than benthic species. This mobility makes it very difficult in the pelagic system to either predict effects of a site-specific activity (because the organisms may be able to readily avoid the activity) or to measure the effects once they have occurred (because the affected organisms may quickly disperse themselves among unaffected organisms, or vice versa). Reliable predictions or measures of impact on infauna, or possibly on their predators, would probably be, in contrast, much simpler. (This generality might not hold in cases where impacts occur at nesting, breeding, or haul-out sites to which otherwise mobile organisms are tied by tradition or need.)

(5) A greater diversity and abundance of important species populations, particularly breeding populations, occupy the area in spring and summer than in fall and winter. This

implies that the chances for important adverse impacts are greater earlier in the year, particularly because eggs and young are generally more vulnerable to human-related activities than are adults. Crested Auklets and seaducks may be notable exceptions (particularly because of their susceptibility to oil), for few occupy the area in early summer and many congregate there in fall and winter.

(6) Evidence suEnests that many of the species feeding on the pelagic food web may readily adapt to large changes in prey species availability. This implies that adverse impacts to only parts of the prey base may pose less of a problem to these consumers than it would if they were less versatile in dietary habits. Whether the benthic feeders are likewise adaptable is not clear.

(7) Because many of the animal populations on the NAS seem to exhibit meat variability among years in response to natural environmental factors, it is very likely that they are "pre-adapted" to survive (over the long-term) man-caused disasters. In the short-term of a few months or years, however, it may still be possible for OCS activities to have substantial effects on some populations.

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move into coastal waters where they are thought to be most abundant in water less than 50 m deep, at least in summer.

Sand lance have a wide range of toleranoe to many physical factors. They have been collected in nearshore waters at temperatures ranging 0-200C and over wide salinity and depth ranges. The most important physical factor in regard to their distribution may be the availability of suitable substrates for spawning and burrowing.

Most sand lance caught in the NANZ ranged In size from 70-160 mm (Fig. 5.12). Their sizes varied inconsistently between sampling periods, suggesting that we sampled different groups of fish passing through the region rather than following one population through time. Isakson et al. (1986) caught generally smaller sand lance (SO-1 00 mm) in their beach seine hauls along the north side of the Alaska Peninsula.

The abundance of sand lance in the NANZ was highly variable in time and space. They were abundant in all four coastal habitats sampled (Table 5.7) but were most frequently encountered in shallower waters (Fig. 5.13). Highest BPUE values were usually in waters 20 m or less in both midwater and bottom trawls (Fig. 5.14). Isakson et al. (1986) report that, as summer progressed, sand lance moved away from the beaches and farther offshore--the CPUE in their beach seines dropped steadily from 5107 sand lance in late June to 4 in late August.

Sand lance were most abundant in the study area from spring to late summer (Fig. 5.15). Their distribution at this time was very patchy as illustrated by highly variable catches. An example of sand lance schools is shown on an echo-sounder recording made offshore of Izembek Lagoon (Fig. 5.16)--over 30,000 sand lance were caught at this site during a single 10-min midwater trawl (equaling about 50% of all sand lance caught during this study). On a local scale, annual variablilty of sand lance 'is large, depending on the size and number of schools moving through a given area and their presumably erratic residency time at any one site.

There is little background information about the food habits of sand lance in the northeast Pacific Ocean. Harris and Hartt (1977) and Rogers et al. (1979) examined sand lance from Kodiak Island and Smith and Paulson (n.d.) recorded the stomach contents of 5 sand lance from Izembek Lagoon.

During the present study, the food habits of 288 sand lance were examined. They had consumed a variety of zooplankton, but euphausiids

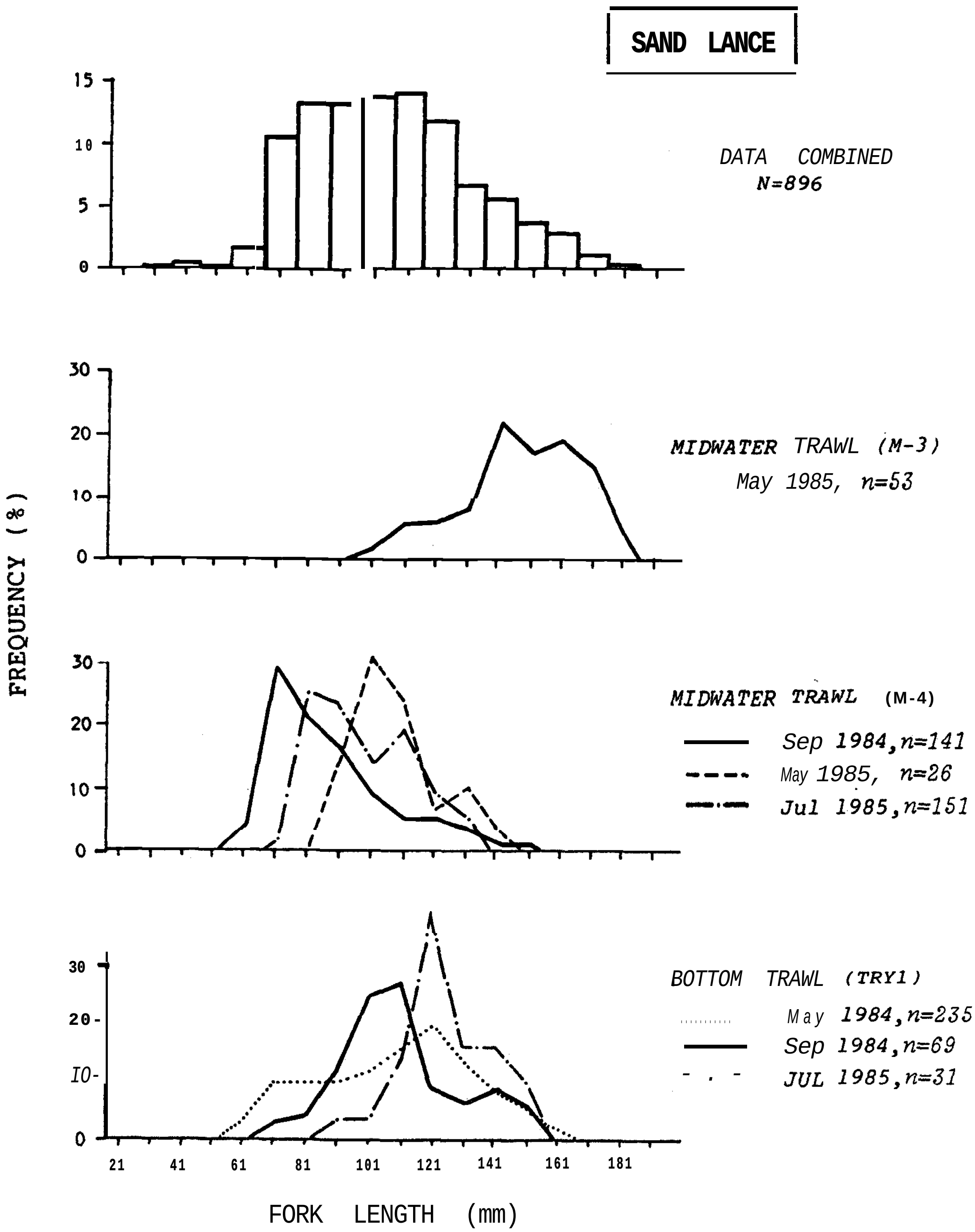

Figure 5.12. Length frequencies of sand lance in all catches and in catches separated by gear and date, NANZ study area, Alaska.