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PREDATION BY MARINE BIRDS AND MAMMALS IN THE SUBARCTIC NORTH PACIFIC OCEAN

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1 EXECUTIVE SUMMARY

Marine birds and marine mammals are important components of the North Pacific ecosystem. The amount of food consumed by marine birds and mammals can be considerable. In some areas, the prey of marine birds and mammals are important commercial species or are important prey for harvested species, so there can be conflicts between human and bird/mammal use of resources. Declines in some mammal and bird populations have raised concerns about possible competition with commercial fisheries. Because of the importance that marine birds and mammals have in the North Pacific, it is important to bring together and summarize available information on the food habits and consumption by these important predators in order to understand their role in the ecosystem.

To make comparisons and summarizations easier and more comprehensible, the PICES region (30°N to the Bering Strait) was subdivided into regions based on oceanographic domains (Fig. 1). These regions varied in size from about 7 million km^2 to over 100 million km^2. The quality and quantity of information was not uniform across the regions, making comparisons difficult.

At least 47 marine mammal species and 135 sea bird species inhabit the PICES region. Estimates of abundance exceed 10,000,000 marine mammals and 200,000,000 marine birds. Seabirds and marine mammals are widely distributed throughout the PICES region. The mean size of individuals ranges from 28 kg to over 100,000 kg for marine mammals and from 20 g to 8,000+g for marine birds.

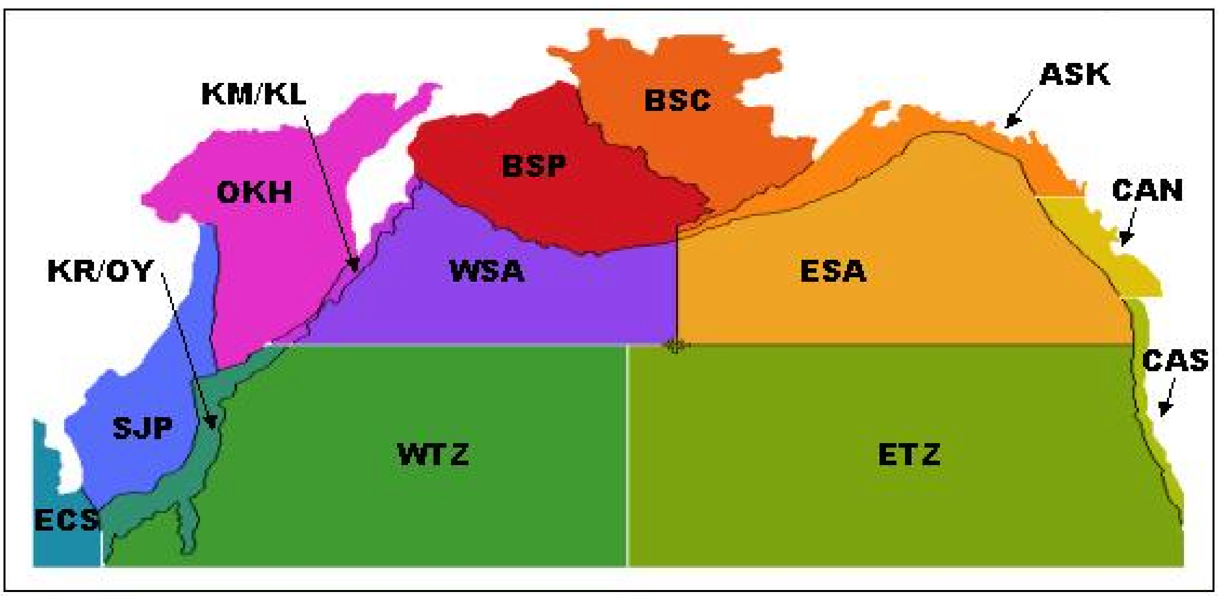

Fig. 1. Sub-regions in the PICES region (north of 30°N and including the marginal seas) of the North Pacific Ocean. ASK - Gulf of Alaska Continental Shelf; BSC - Bering Sea Continental Shelf; BSP - Bering Sea Pelagic; CAN - California Current North; CAS - California Current South; ECS - East China Sea; ESA - Eastern Subarctic; ETZ - Eastern Tropical Zone; KM/KL - Kurile Islands Region; KR/OY - Kuroshio/Oyashio Region; OKH - Sea of Okhotsk; SJP - Sea of Japan; WSA - Western Subarctic; WTZ - Western Tropical Zone.

1.1 Marine Birds

Marine birds occur throughout the PICES region, throughout the year. Many species that breed in the South Pacific migrate to the North Pacific to forage in summer. This is in contrast to marine mammals that do not make seasonal migrations across the equator. Because of these migrations, estimates of abundance and food consumption were limited to the summer months (June-August/September).

As with marine mammals, most marine birds are opportunistic feeders rather than prey specialists. The principal foods are small schooling fishes, squids and crustaceans that occur in large swarms. Many species feed across two or three trophic levels, including scavengers.

The birds included in this paper include albatrosses, shearwaters and their allies, pelicans and their allies, and phalaropes, skuas, gulls, terns and auks, all of which forage in the water column rather than on the benthos. Estimates of abundance in the sub-regions were derived from a combination of shipboard and aerial surveys and colony counts, depending on the available information and behavior of the species (see Appendix 6). Adjustments were made by region to fit the limitations of the available data. Species densities varied from 1 - 38 birds•km^{-2} in the Eastern Transition Zone and coastal Gulf of Alaska, respectively.

Appendix 7 is a compilation of the available information on the diets of marine birds in the PICES region. The data are from a variety of sources (e.g. stomach samples, regurgitations at roosts), all of which have certain limitations. Indices of the relative importance of prey types were developed to take account of the relative rate of occurrence in individuals, the percent presence in terms of biomass and in terms of relative number of items in stomachs. Within the zooplankton, euphausiids are the most important prey in most areas. Small cephalopods are generally more important than large cephalopods. The variation in type of fish eaten appears greater on the N-S axis than between E-W regions of the Pacific.

Metabolic rates in birds vary with body mass to a power between 0.6 and 0.8 since metabolic activity per gram is greater in small than large birds. Therefore, to estimate energy require-ments of a community of birds, the energetic requirements of each species must be determined individually. Daily energy requirements of individual birds were estimated using the allometric equation of Birt-Friesen. This calculates energy requirements as a function of body mass, which was derived from the literature. Energy demand for marine birds in a given area is a function of the biomass of birds present and can be estimated even when diets are not known.

Energy density of prey varies with taxon, within prey taxa and with condition of the individual prey item. The ability of marine birds to assimilate energy from the prey varies with nutritional state, food types and with the amount of lipid in the food. Assimilation efficiencies vary from about 70-80% in marine birds.

The number of species and predominant size class varies by sub-region. The fewest number of species (24) occurs in the Eastern Sub-Arctic, while the largest number is in the Kuroshio/ Oyashio Current sub-region (61 species). In general, the western Pacific sub-regions have a higher species richness than the eastern North Pacific but the difference is only about 10%. Birds of larger body mass (>1000 g) predominate in the Bering Sea and California Current sub-regions (murres, puffins and shearwaters). Most of these species forage in the upper water column for small fish or macrozooplankton. Small marine bird species (<125 g) predominate in the Eastern and Western Sub-Arctic, and Eastern and Western Transition sub-regions (storm petrels). These smaller birds forage at the water's surface, consuming mainly neuston and micronecton (see Appendix 7).

Reasonably complete estimates of summer prey consumption by marine birds during summer (June-August, 92 days) were developed for six of the PICES sub-regions (Table 6). Zooplankton were important in Bering Sea and coastal Gulf of Alaska; fish are important in most other areas and cephalopods were important in the Transition Zone.

1.2 Marine Mammals

Understanding marine mammal effects in the ecosystem are complicated by the nature of their life history: marine mammals generally are opportunistic feeders and consume a wide variety of prey within a specified size range. Because of the complex life history, different prey species and sizes are eaten by different life stages. For example in some cetacean species, young may continue to feed on milk for a year or more. Energetic demands also vary with life stage and with time of year: for example during their long migrations, large whales stop or greatly reduce their feeding. Finally, obtaining data on prey consumption and energetic demands is difficult due to restrictions in many areas from killing mammals for such studies and due to their underwater feeding. Some feed as deep as 3000 m.

Prey vary from plankton and benthic invertebrates to larger fish and squid and can include seabirds, other mammals and turtles. Small or juvenile fish and squid are frequent prey items. Even in the baleen whales (Mysticetes), prey varies from plankton to small schooling fish. Prey species are a function of the region and time of year and generally reflect the more abundant species.

There are few studies of the amount of food consumed by marine mammal species. Pinnipeds in the Gulf of Alaska were estimated to consume as much as 617,000 metric tons of prey annually. Similar data for other species are scarce.

There are large data gaps in information on abundance, seasonal distributions, migration patterns, regional prey selection, and energetic requirements for marine mammal species and life stages. Little is known on the energetic content of their prey. Therefore this report focuses on presenting the limited data available in tables, emphasizing the western Pacific area as an example of the difficulties in determining the total consumption and effects of marine mammals on prey resources. Summary tables describing marine mammal distribution, abundance, biomass, prey and energetic requirements (Tables 9-14) were developed from the detailed information, by region, that are reported in Appendices 9-11. Although both the marine mammal and the marine bird sections of the report dealt with the summer season, because of logistical problems with the data and calculations, there was some inconsistency between the two groups in determining the length of the summer seaon.

<u>Abundance</u>: Generally, abundance estimates are not for each specific PICES sub-region, as there are often seasonal or frequent movements between areas. In addition, the amount of data for estimating abundance is often low and therefore the estimates have wide confidence intervals. The difficulty of sighting marine mammals at sea also results in rather poor estimates of abundance.

<u>Diets</u>: Diets vary by sex, age, reproductive condition, time and foraging location. Therefore prey values used in estimating consumption were derived as generalized approximations of food habits. Finally, the energy requirements are difficult to measure directly and vary with age/size of the predator. Therefore we used a generalized formula to calculate energy requirement based on food consumption and body weight.

<u>Prey consumption</u>: We have developed quantitative estimates for the eight PICES sub-regions (Table 14) while no estimates are available in the other six sub-regions. With pooling available estimates of all 8 sub-regions (corresponding to approximately 49% of the total PICES region), total prey consumption is estimated to be 13,019,000 tonnes during summer (June-September, 122 days) per year. But obviously this figure is an extreme under-representation of total summer prey consumption by marine mammals in the PICES region due to lack of estimates in almost half of the PICES sub-regions and conservative population abundance estimates. Thus, it is still premature to give quantitative estimates of the total prey consumption by marine mammals.

1.3 General Remarks

For both marine birds and mammals, there are a number of confounding factors in estimating levels of prey consumption. The greatest sources of error are the lack of good estimates of population abundance and good information on diet composition over time and area. Thorough, well-designed surveys of at-sea distributions and abundances of marine birds and mammals are needed throughout the PICES region, and throughout all seasons if we are to understand the role these species play in the ecosystem. Survey coverage has been very low, for marine birds with generally less than two percent of the any sub-region covered. Most of the survey work has been in summer months, resulting in little information on abundance, distribution or food habits for other parts of the year.

The information summarized in this report indicates how PICES sub-regions vary in biomass/abundance of marine birds and mammals during summer months, and how the trophic pathways vary by sub-region. The estimates of total prey consumed are conservative because of the limited amount of information on abundance and/or diet. The data suggest a striking difference in productivity of waters in the eastern and western North Pacific and between the shelf and oceanic areas.

This report compiles available information on both marine bird and mammal distributions, abundance, food habits and prey consumption throughout the PICES region. It illustrates the large data gaps in our knowledge of these predators, particularly in quantitative estimates of abundance and food habits. Since the estimates of consumption are only for summer and are so data poor, the resulting estimates of total consumption and effects on the ecosystem are conservative. Hopefully, through the combined efforts of the PICES community, at least some of theses data gaps will be filled and we will develop a better understanding of the role of marine mammals and birds in the North Pacific ecosystem.

2 INTRODUCTION

2.1 Participation

The membership of Working Group 11 is listed in Appendix 1. The following members of the Working Group participated in the development of this report:

Norihisa Baba	John Bengtson
Alexander Boltnev	Patrick Gould
George Hunt	Chadwick Jay
Hidehiro Kato	Lloyd Lowry
Ken Morgan	Andrew Trites

2.2 Terms of Reference

The Terms of Reference for PICES Working Group 11 (Anon., 1996) were:

To evaluate the effects of predation by marine birds and mammals on intermediate and lower trophic levels of subarctic Pacific marine ecosystems, Working Group 11 will:

1. Obtain and tabulate available data on population sizes and prey consumption by marine birds and mammals;
2. Calculate seasonal and annual consumption, expressed as numbers and biomass, of particular marine resource species by particular bird and mammal populations;
3. Where possible, stratify the calculation as to age classes of prey and locality (local stock impacted);
4. Prepare a report for PICES describing data sources and methods of calculation, and the results, and identifying major lacunae in knowledge.

2.3 Overview

Marine mammals and birds are highly visible components of marine ecosystems. In many cases, the principal prey of marine mammals and marine birds consists of species of fish or zooplankton which are harvested in commercial fisheries, or which are the prey of harvested species. The interactions between marine mammals or marine birds and fisheries can be negative when the fisheries remove potential prey, particularly in the case of industrial fisheries that target small, oil-rich fish species (Schaefer, 1970; Furness, 1984b, 1987; Burger & Cooper, 1984; Monaghan, 1992) or positive, when offal and discards are made available to scavenging animals (Camphuysen *et al.*, 1993; Furness *et al.*, 1992; Gould *et al.*, 1997a) or when the removal of large, predatory fish species results in an increased abundance of forage fish (Springer, 1992). Thus, in recent years some multi-species models of fisheries interactions have attempted to account for consumption by marine birds and mammals (Croxall, 1989; Anon., 1991; Rice, 1992). In the North Pacific Ocean, recent declines in the abundance of certain species of marine mammals and marine birds have raised concern about the possibility that competition with commercial fisheries may be in part responsible for these declines (Bailey, 1989; Anon., 1993; NRC, 1996; Trites *et al.*, 1997, 1999), although other work suggests a major role for climate change (Springer, 1998).

2.4 Division of North Pacific into Sub-regions

As a first step in developing this report, the members of Working Group 11 divided the PICES region of interest (the North Pacific Ocean from 30° N to the Bering Strait), into manageable sub-regions that corresponded roughly to oceanographic domains (Fig. 1, Table 1). This task was essential not only because it facilitated comparisons between different sub-regions, but also because the amount of survey coverage and diet information varied greatly between sub-regions. The sub-regions were chosen so that they had physical and biological cohesion. The seaward extent of coastal sub-regions was defined as 100 km seaward of the 2000 m depth contour. Exceptions are the western Bering Sea and basin sub-region (BSP), the Sea of Okhotsk (OKH), the Sea of Japan (SJP), and the East China Sea (ECS), all of which include both continental shelf and deep basin areas. The size of sub-regions varies from 111,570 km^2 in the Kamchatka Current and Kurile Islands (KM/KL) to 7,808,530 km^2 in the Eastern Transition Zone (ETZ) (Table 1).

2.5 Limitations on temporal coverage

Because of a lack of data obtained from fall, winter and spring, the Working Group decided that its analyses would be restricted to the summer months of June, July and August (and September for marine mammals) when most species of marine mammals and birds have completed their migrations into the study area and are resident there. Thus we tried to calculate prey consumption and energy requirements on a "by summer" basis, but it was necessary to use different durations for each group: June-August (92 days) for marine birds and June-September (122 days) for marine mammals. We recognize that this treatment does not capture the seasonal fluxes of marine mammals and marine birds into or out of the study area, or the very different prey consumption rates of these predators in winter, when many individuals shift from northerly regions to more temperate waters in the North Pacific Ocean, or are absent from the North Pacific altogether. The normal, periodic foraging movements across the boundaries of the sub-regions are also not captured.

3 FOOD CONSUMPTION BY MARINE BIRDS IN THE NORTH PACIFIC OCEAN

3.1 Introduction

More than 135 species of marine birds (>195 if loons, grebes and waterfowl are included) occupy marine habitats throughout the North Pacific Ocean (Appendix 2). Their total numbers may well exceed 200,000,000. They range in weight from the 20 g least storm-petrel (*Oceanodroma microsoma*) to the >8,000 g short-tailed albatross (*Phoebastria albatrus*). Marine birds occur throughout the area and throughout the year. Most breed during the boreal summer, although some of the warmer-water species breed during the boreal winter. Many species that breed in the South Pacific during the austral summer migrate into the North Pacific to forage during the boreal summer.

Although many marine bird species show preferences for one or a few specific prey items, most species have a tendency toward opportunism. Almost any prey that can be seen, caught and swallowed is eaten (Appendix 3). Prey as small as 1 mm and as large as can fit within the bill and be swallowed are taken whole. Larger prey are shredded before consumption. Principal foods tend to be small schooling fishes, squids and crustaceans that congregate in large swarms (*e.g.*, capelin (*Mallotus villosus*), market squid (*Loligo opalescens*), and euphausiids (*e.g.*, *Thysanoessa* spp.). Marine birds employ a wide variety of foraging and food capture techniques (Ashmole, 1971). Ogi (1984) added a foraging category he called "grazing" to describe the behavior of sooty shearwaters (*Puffinus griseus*) when they are feeding on muscles and barnacles attached to floating debris. Prey are captured above, on, and below the water's surface. Marine birds have been recorded diving to depths greater than 100 m (Piatt & Nettleship, 1985; Burger & Powell, 1990). Foraging and capture techniques (influenced by morphological characters) may be the principal determinants in diet composition, and variations in them allow for high species richness within marine bird communities.

Marine birds are primarily secondary and tertiary carnivores as well as scavengers within marine ecosystems. Trophic structures for the North Pacific (Appendix 4) have been described by several authors. Parrin (1968) and Pearcy (1991) did not include marine birds and mammals in their models of North Pacific marine food webs. In contrast, Brodeur (1988) included birds and mammals but lumped them all together at a single trophic level (level 7). Others have focused on the trophic relations of marine birds (*e.g.*, Ainley & Sanger, 1979; Schneider & Shuntov, 1993; Hobson *et al.*, 1994; Sydeman *et al.*, 1997). Recent studies (Sanger, 1987a; Gould *et al.*, 1997a,b,c,d, 1998b) indicate that many marine bird species feed across two or three trophic levels. For example, Gould *et al.* (1997a) found that Laysan albatross (*Phoebastria immutabilis*) primarily eat small fish and squid, but will occasionally capture small invertebrates and scavenge large birds and mammals, thus feeding across three trophic levels. Likewise, short-tailed shearwaters (*Puffinus tenuirostris*) take a wide variety of prey from zooplankton to small fish and squid, thus spanning several trophic levels (Ogi *et al.*, 1980; Vermeer, 1992). In other cases, superficially similar species of marine birds forage at different trophic levels. Thus, Sanger (1987a) found that in the Gulf of Alaska, short-tailed shearwaters feed one trophic level below the closely related and morphologically similar sooty shearwaters.

The amount of food consumed by marine birds, and thus their trophic impact on marine ecosystems, can be considerable (Furness 1984a, 1987; Furness & Cooper, 1982; Duffy *et al.*, 1987; Bailey *et al.*, 1991). A recent summary of research on the prey demands of marine birds in the North Sea provided a useful overview of methods of modeling the trophic impact of marine birds (Anon., 1994). In the North Pacific, there are studies of marine bird trophic demand from southern California (Briggs & Chu, 1987), the Oregon coast (Wiens & Scott, 1975), the Gulf of Alaska (Degange & Sanger, 1987), the Bering Sea (Hunt *et al.*, 1981; Schneider & Hunt, 1982; Schneider *et al.*, 1986), and the Chukchi Sea (Swartz, 1966). Wiens and Scott (1975) estimated the annual consumption of prey by four species of marine birds along the coast of Oregon: sooty shearwater (30,717 mt), Leach's storm-petrel (*Oceanodroma leucorhoa*) (9,412 mt), Brandt's cormorant (*Phalacrocorax penicillatus*) (1,291 mt), and common murre (*Uria aalge*) (21,142 mt) for a total of 62,562 mt of which about 35,800 mt is consumed during the breeding season. Vermeer and Devito (1986) calculated that the nesting population of rhinoceros auklet (*Cerorhinca monocerata*) in the eastern North Pacific would receive 326 mt of food over a single breeding season. Degange and Sanger (1986) estimated that the biomass of prey consumed by marine birds in the Gulf of Alaska (excluding waterfowl, loons, grebes and shorebirds) was ~18 $kg \bullet km^{-2} \bullet day^{-1}$ over the continental shelf and ~2.4 $kg \bullet km^{-2} \bullet day^{-1}$ over oceanic waters. Swartz (1966) estimated that 13 breeding species (421,000 individuals) consumed 13,100 mt of food during four months at Cape Thompson, Alaska.

3.2 Methods

3.2.1 Defining marine bird stocks and populations

At present, it is difficult to define populations and stocks for the species of marine birds that frequent the North Pacific Ocean. For the transequatorial migrants, we know the region where they nest, but have no information on whether the birds from different parts of the nesting range or from different colonies co-mingle when on migration or when in the Northern Hemisphere. When considering species that nest in the North Pacific, we have almost no information on the extent to which individuals from different colonies mingle on the foraging grounds. Likewise, the extent of exchange of breeding adults between colonies from one year to the next remains unstudied, and we do not know whether the birds associated with a particular colony should be considered as a discrete stock. Evidence is accumulating that parameters of reproductive effort may vary synchronously on an interannual basis, very possibly because the birds share a common prey stock (Hatch *et al.*, 1993; Furness *et al.*, 1996; Hunt & Byrd, 1999). However, the population sizes of marine bird species nesting on different colonies usually do not show synchronous changes over time, and we often assume that the population dynamics of different colonies are not coupled. Thus the birds within a colony appear to be acting as if they are a separate stock.

To focus on marine birds that forage primarily in the water column, rather than on benthos, we consider here only the albatrosses, shearwaters and their allies, (Procellariiformes), pelicans and their allies (Pelecaniformes), and phalaropes, skuas, gulls, terns and auks (Charadriiformes). Other birds are important predators in marine habitats, especially nearshore, but are beyond the scope of our report. These include loons (Gaviiformes), grebes (Podicipediformes), shorebirds (Charadriiformes) and waterfowl (Anseriformes). For example, Vermeer and Ydenberg (1989) estimated that from September through May, Barrow's goldeneye (*Bucephala islandica*) and surf scoter (*Melanitta perspicillata*) together consumed >164,000 kg of blue mussels *(Mytilus edulis*) in Jervis Inlet (area of about 177 km^2), Canada.

3.2.2 Marine bird abundance

Few marine bird population sizes have been estimated on a world-wide or even ocean-wide basis (Croxall *et al.,* 1984). We derived estimates of abundance for marine birds in the PICES sub-regions from a combination of shipboard and aerial surveys and colony counts. Abundances based on shipboard or aerial surveys (birds km^{-2}) were used in preference to colony counts because they include sub-adult and non-breeding adult portions of the populations not present at the colonies. For wide ranging species that could be encountered at sea, the shipboard surveys sufficed. For species that are strongly attracted to ships, thereby artificially inflating their apparent abundance, and for species with highly clumped distributions that tend to bias population estimates, and for species which appear infrequently in surveyed waters, we depended on colony counts, or on estimates of the world population size, adjusted for the proportion present in each of the PICES sub-regions (Appendices 5 and 6).

Where available, we used the shipboard survey data stored in the ACCESS database by the U.S. Geological Survey, Alaska Biological Research Center, Anchorage, Alaska (Table 1). The coverage within this database is poor for both

CAN and CAS sub-regions; consequently we treated those two regions differently. In the CAN sub-region, we used data from shipboard surveys conducted by the Canadian Wildlife Service between 1988 and 1998 (K. Morgan, unpubl. data). The CWS surveys under-sampled coastal areas of CAN, and we used colony data for the three cormorant species found there (Rodway, 1991).

Deriving population estimates for CAS was somewhat more complex. As we did not have access to recent at-sea abundance estimates for the entire sub-region, we used the mean species density values from Washington and Oregon northern California and southern California presented in Tyler *et al.* (1993). Those density estimates were derived from a combination of aerial and vessel surveys. Thus, the CAS shipboard survey effort and extent of coverage are not clear. Where at-sea estimates were not reported for a species, we used colony data (Tyler *et al.*, 1993).

In the ETZ and Western Transition Zone (WTZ) we used unpublished surveys by P. Gould. Colony counts in the BSP, the eastern Bering Sea (BSC) and the coastal Gulf of Alaska (ASK) regions are from the colony catalog maintained by the U.S. Fish and Wildlife Service, Anchorage, Alaska (Sowls *et al.*, 1978).

For most marine bird species, shipboard surveys were used directly by multiplying the number of birds$\bullet$km^{-2} by the area (km^2) of the sub-region (Method "S" in Appendix 6, Tables 6.1 - 6.14). For two species of albatross, three species of shearwater and for northern fulmars, which are attracted to ships or contagiously distributed, we assumed that the ratios of the densities of each of these species across PICES sub-regions represented the proportion of the North Pacific population of each species in each sub-region. Therefore, to obtain the number of individuals of a species in each sub-region, we multiplied the proportions of each species seen in a sub-region by the estimated population for the entire PICES region (Method "D" in Appendix 6, Tables 6.1 - 6.14). This procedure was modified for sooty and short-tailed shearwaters because most of the data for these two species were reported as "dark shearwaters" as they are difficult to distinguish. The density of dark shearwaters in each PICES region was partitioned into sooty and short-tailed shearwaters using data from the literature to estimate the ratio of one species to the other in each area and then using that ratio to separate the estimates of shearwater densities into the numbers of each species. For the above calculations, we assumed the following total North Pacific abundances: Laysan albatross (2,500,000), black-footed albatross (*Phoebastria nigripes*) (200,000), northern fulmar (*Fulmarus glacialis*) (4,600,000), sooty shearwater (30,000,000), short-tailed shearwater (30,000,000), and Buller's shearwater (*Puffinus bulleri*) (2,500,000) (Appendix 5).

The data used for most sub-regions originated from either the database maintained by the U.S. Geological Survey, or from P. Gould (unpubl. data). Originally the USGS database was also used to estimate the proportions of the 6 ship-attracted/clumped species for CAN. However, as the coverage of CAN was so poor (only168 km^2), we recalculated the proportions of those species for CAN using recent data (1988-1998) (K. Morgan, unpubl. data). Thus, the population estimates for CAN for these 6 species presented in Appendix Tables 5.1-5.4 differ from those listed in Appendix Table 6.4. The values in Appendix Tables 5.1-5.4 (Black-footed Albatross - 3,056.64, Laysan Albatross - 144.59, Sooty Shearwater - 91,982.44, Short-tailed Shearwater - 10,540.31, Northern Fulmar - 436.59, Buller's Shearwater - 12,559.11) were derived from pre-1988 data. The estimates presented in Table 6.4 were the result of more recent data used in the proportion calculations (Black-footed Albatross - 2,523.01, Laysan Albatross - 194.58, Sooty Shearwater - 124,507.44, Short-tailed Shearwater - 14,258.09, Northern Fulmar - 6,547.11, Buller's Shearwater - 7,520.52). No attempt was made to recalculate the estimated populations of those species in the other sub-regions; consequently, summing the populations across all sub-regions will not sum to the assumed North Pacific populations given above.

3.2.3 Distribution and seasonal movements of marine birds

The principal breeding season for marine birds in the subarctic is May to September. In subtropical waters, many species (*e.g.*, albatrosses) breed between November and May. During the breeding season, many young birds either remain at-sea or visit the colonies only for short periods. After breeding, some species disperse within the region of the colony, while others move to other areas. Southward transequatorial migrations primarily occur in September-November and northward migrations occur primarily in March-May. Occupancy along the migration routes is difficult to assess. For areas at the northern terminus of a species' migration, we assumed occupancy for the entire June-August period (92 days). The 92-day occupancy period is also based on the fact that the densities of birds in PICES sub-regions are the average birds•km^{-2} for the entire June-August period.

3.2.4 Marine bird diets used in the model

We assembled the information available on the diets of marine birds in the PICES region (Appendix 7). Information on marine bird diets is obtained from sampling the food brought to chicks at colonies, by examining the hard-to-digest parts of prey that birds regurgitate at roosts, by examining stomachs of birds caught as bycatch in fishing gear, and by shooting birds at sea to obtain samples of food from their stomachs. The information available on diets carries a number of known biases. Foods brought to chicks at colonies may differ from that taken by adults for their own consumption (*e.g.* Decker *et al.*, 1995), hard parts found at roosts or in stomachs may be identifiable long after soft-bodied prey have been digested (Imber, 1973; Duffy & Laurenson, 1983; Furness *et al.*, 1984), and birds caught in fishing gear or collected at sea may reflect local feeding opportunities rather than the broader spectrum of prey taken in the region as a whole (*e.g.*, Gould *et al.*, 1997a). Indices of the relative importance of prey types (IRI) have been developed to consider the relative rate of occurrence in individuals, the percent presence in terms of biomass, and in terms of the relative numbers of items in stomachs (*e.g.,* Pinkas *et al.*, 1971; Duffy & Jackson, 1986; Day & Byrd, 1989; Gould *et al.*, 1997a). Percent mass or percent IRI was used to quantify diets whenever available. In a few cases where this information was not available, we used percent numbers of individual prey items.

3.2.5 Marine bird energy requirements

Marine birds require high rates of energy consumption because they are endothermic and active. Because heat loss in a small bird is proportionally greater than in a large-bodied bird, metabolic rates in birds scale with body mass to a power of between 0.6 and 0.8, such that metabolic activity per gram is larger in a small bird than in a large one. Thus, when estimating the energy requirements of a community of birds, it is essential to determine the energetic requirements of each species individually (Furness, 1984a).

Furness and Tasker (1996) have evaluated the methods available for estimating the energy requirements of a free-living marine bird community. There are two approaches. One approach involves the use of allometric equations to estimate the energy consumption of species whose energy requirements may never have been measured directly. This method depends upon the extrapolation of values obtained in the laboratory, adjusted for activity levels. This method requires estimates of the costs of various activities, and detailed, time-consuming field estimates of the amount of time devoted to each of these activities. The data necessary to apply this approach to the marine birds of the North Pacific are not available.

Alternatively, one can measure the turnover of isotopes of hydrogen and oxygen in free-living birds to assess energy expenditure over the period between release and recapture of an individual (Nagy, 1980, 1987). However, the application of this method is expensive and often difficult if nesting birds are not readily available. There are few species of North Pacific marine birds for which isotopic determination of energy requirements are available.

A third approach is to use allometric equations, developed from laboratory and field studies of a limited number of species, to estimate the likely energy requirements of birds of a given size (Birt-Friesen *et al.,* 1989). In this report, we estimated the daily energy requirements of individual birds by using the allometric equation of Birt-Friesen *et al.* (1989) that predicts energy requirements as a function of body mass:

$$\log Y = 3.24 + 0.727 \log M$$

where Y= daily energy requirements is in kj, and M= mass in kg (Birt-Friesen *et al.,* 1989). Data on the mean body mass of marine bird species that occur in the North Pacific were obtained from the literature (Dunning, 1993). Where separate values for each sex were given, we used the mean value to represent the species.

3.2.6 Energy content of marine bird prey

The energy density of marine bird prey varies with prey taxon, within prey taxa, and with the condition of the individual prey item (*e.g.*, Harris & Hislop, 1978; Hudson, 1986; Croxall *et al.*, 1991; Camphuysen *et al.*, 1993). There is no single source of data for the energy density of the multitude of prey types taken by marine birds in the North Pacific, or even for any one sub-region of the PICES region (see Furness & Tasker, 1996). For this report, we obtained or adapted values of prey energy density from: Hunt (1972), Dunn (1973, 1979), Sidwell (1981), Vermeer and Cullen (1982), Ford *et al*. (1982), Montevecchi and Piatt (1984), Wacasey and Atkinson (1987), Vermeer and Devito (1986), Furness and Tasker (1996), and Van Pelt *et al*. (1997). We used the following values for this exercise: miscellaneous invertebrate, 4 kj•g^{-1}; gelatinous zooplankton, 3 kj•g^{-1}; crustacean zooplankton, 4 kj•g^{-1}; small cephalopod, 3.5 kj•g^{-1}; large cephalopod 4 kj•g^{-1}; fish (low energy density, *e.g.*, cod [*Gaddus* spp.], rockfish, pollock), 3 kj•g^{-1}; fish (medium energy density, *e.g.*, capelin, sandlance [*Ammodytes hexapterus*]), 5 kj•g^{-1}; fish (high energy density, *e.g.*, myctophids, herring [*Clupea* spp.], saury [*Cololabis saira*]), 7 kj•g^{-1}; birds and mammals, 7 kj•g^{-1}; carrion, offal and discards, 5 kj•g^{-1}. The values for energy density of prey will require revision as information on more North Pacific species becomes available.

3.2.7 Food utilization efficiency of marine birds

The ability of marine birds to assimilate energy from their prey varies with nutritional state, food type, and with the amount of lipid in the food, such that energy from fish with higher lipid content is assimilated more efficiently than energy from fish with lower lipid concentrations (Furness & Tasker, 1996). Measured assimilation efficiencies of marine birds vary from 75 to 80% for fish, to about 70% for most other marine prey (Nagy *et al.*, 1984; Jackson, 1986; Gabrielsen *et al.*, 1987; Brown, 1989; Crawford *et al.*, 1991). Similar to Furness and Tasker (1996), we have assumed an assimilation efficiency of 75% for the conversion of daily energy requirements to the amount of prey needed to meet those requirements. The decision reflects the relatively narrow range of variation in assimilation efficiencies, and the much greater sources of error in other inputs to the model.

3.3 Model output

In Appendix 6 we present data on the abundance of marine birds, by sub-region, for the summer months of June through August. We also provide an estimate of bird-occupancy days for each marine bird species occurring in a sub-region, and the calculated daily energy requirements of an individual of each species. Information was not available that would allow estimates of the annual energy requirements of marine birds in the subarctic North Pacific. For most sub-regions, there were few data on the abundance of birds in spring or autumn, and virtually no information on the distribution and abundance of marine birds in winter.

The number of marine bird species reported from a sub-region varies from as few as 24 species in the Eastern Sub-Arctic (ESA), to a maximum of 61 species in the Kuroshio/Oyashio Current (KR/OY) sub-region (Table 2). The uncertainty in the number of species frequenting an area is the result of insufficient coverage of vast areas of ocean, and the propensity of seabirds to wander widely over the ocean. On average, sub-regions in the western Pacific Ocean support a greater richness of species than those in the eastern North Pacific, but the difference is only about 10 percent.

The predominant size-class of marine bird varies among regions (Table 3), and this variation is reflected in the dominant groups of marine birds present in the western and eastern North Pacific (Table 4). Marine birds larger than 1000 g are rare in all regions, but birds with body masses between 401 and 1000 g predominate in the BSC, BSP, ASK, CAN and CAS. Common species in this grouping include the murres (*Uria* spp.), puffins (*Fratercula* spp), and the shearwaters (*Puffinus* spp.). Most of these species forage in the upper water column for small fish or macrozooplankton. Species less than 125 g dominate the ESA, Western Sub-Arctic (WSA), ETZ and WTZ. In the eastern and western subarctic gyres and in the transition zones, storm-petrels (*Oceanodroma* spp.) are the most abundant species of marine birds (Appendix Tables 6.5, 6.6, 6.10, 6.11), with many more found in the western Pacific than in the East (Table 4). Storm-petrels, and phalaropes (*Phalaropus* spp.), which are particularly abundant in the ETZ (Table 4), forage at the water's surface. Both species groups consume neuston or micro-necton attracted to the neuston, and storm-petrels also feed on small fish and squid up to 74 mm in length (see Appendix Tables 7.1, 7.3, and 7.4). Many of the largest species of marine birds (*e.g.*, cormorants, pelicans and gulls) occupy shelf and inshore habitats, whereas many of the smallest species are found primarily over deep, oceanic waters (*e.g.*, storm-petrels and phalaropes). However, because several of the sub-regions contain both shelf and deepwater habitats, it is difficult to determine the relationship of bird size and habitat depth from Table 4.

The density of marine birds in the sub-regions varies from 38 birds•km^{-2} in the ASK sub-region to 1.0 birds•km^{-2} in the ETZ (Table 2). In the Bering Sea, densities are higher in the east than in the west (BSC= 34 birds•km^{-2} vs. BSP = 16 birds•km^{-2}). Although coverage of the western Bering Sea, in particular the shelf portions, is relatively poor and may not reflect the true abundance of marine birds in this region, the difference in density of marine birds between the BSC and the BSP most likely reflects the large proportion of shelf area in the BSC when compared to the BSP. South of the Bering Sea, the coastal ASK sub-region supports in excess of 10 birds•km^{-2}. The coastal sub-regions (KM/KL, KR/OY) in the western Pacific appear to support lower densities of marine birds, however, few surveys of these regions have been published, and the density of marine birds may be underestimated. In the more central sub-regions south of the Bering Sea, the density of marine birds appears greater in the western Pacific Ocean than in the east (WSA = 7 birds•km^{-2} vs. ESA = 2•birds km^{-2}, and WTZ = 9 birds•km^{-2} vs. ETZ = 1.0 birds•km^{-2}).

Energy consumption by marine birds in a given area is a function of the biomass of birds present, and can be estimated even when diets are not known. Among the sub-regions, energy consumption by marine birds varies from 0.8×10^3 kJ•km^{-2}•d^{-1} in the ETZ sub-region to 56.2×10^3 kJ•km^{-2}•d^{-1} in the ASK sub-region (Table 2). South of the Bering Sea, energy consumption by marine birds is greatest in the ASK, and CAS. In the Bering Sea, energy consumption by marine birds is twice as great in the eastern sub-region as it is in the west. In contrast, south of the Bering Sea, energy consumption by marine birds is three times greater in the western subarctic gyre than in the eastern subarctic, and more than 10 times greater in the WTZ than in the ETZ.

In Appendix 7 we present data on the diets of marine birds within the PICES region, by sub-region, during the summer months. These values reflect the data available in the major reviews that have covered a broad range of species. Many of these were completed in the late 1970s or early 1980s. In some cases new information suggests that diets have changed, at least locally (*e.g.*, Pribilof Islands: Decker *et al.*, 1995; Hunt *et al.*, 1996b,c; Gulf of Alaska: Piatt & Anderson 1996), but in general, we do not have sufficient recent data to allow presentation of up-dated dietary information.

The marine bird prey species or species groups of particular importance in each of the sub-regions are summarized in Table 5. Within the zooplankton, euphausiids are likely the most important component of marine bird diets except in the ETZ and WTZ, where the goose barnacle, *Lepus fascicularis*, predominates in shearwater diets. Likewise, in all areas other than the ETZ and WTZ, small cephalopods are more important than large species. However, in the ETZ and WTZ, albatrosses make use of neon flying squid, *Ommastrephes bartrami*, at least some of the time taking squid caught in drift nets. In the North Pacific Ocean, marine birds include in their diets a wide variety of fish, most of which are of medium to high energy density. An exception is the use of walleye pollock (*Theragra chalcogramma*), a fish of low energy density, in the eastern Bering Sea. Although the data are too sparse to make the generalization with confidence, the variation in the type of fish taken appears greater on the north-south axis than between the east and west sides of the North Pacific.

We were able to develop reasonably complete estimates for marine bird summertime (June-August, 92 days) prey consumption in six sub-regions of the PICES region for which we could account for much of the prey consumed (Table 6). Zooplankton were important in the BSC and ASK, fish were important in all areas other than the ETZ, and cephalopods were important in the ETZ and WTZ. Data on prey types eaten in other regions were insufficient to develop meaningful estimates of total prey consumption.

To provide a rough estimate of upper and lower bounds on the amounts of prey consumed by marine birds in each sub-region, we estimated prey consumption based on the seasonal energy demands of the marine bird communities assuming either that all prey were of the lowest energy density (3 $kj \bullet g^{-1}$) or of the highest energy density (7 $kj \bullet g^{-1}$) (Table 7). The eastern Bering Sea and the Gulf of Alaska stand out as areas with high fluxes per unit area of marine life to marine birds. In contrast, the ESA and the ETZ have considerably lower fluxes per unit area to marine birds than most other sub-regions.

3.4 Discussion of prey consumption by marine birds

3.4.1 Reliability of estimates of prey consumption by marine birds

A number of sources of error potentially affect the estimates of prey consumption by marine birds. These include the estimation of energy demand, diet composition, energy density of prey, and estimates of the distribution and abundances of marine bird populations. Of these, the greatest sources of error almost certainly are in the estimates of the sizes of populations in the various sub-regions and in the estimates of diet composition. Many of the data on diet composition and abundance of birds were gathered in the mid to late 1970s, when the possibility of offshore oil development spurred studies along the west coast of the United States, in Alaska, and along potential tanker routes from North America to Asia. Since then, fewer large-scale studies have occurred, despite major changes in the marine ecosystems of the North Pacific Ocean (Venrick *et al.*, 1987; Anon., 1993; Francis & Hare 1994; NRC, 1996; Brodeur *et al.*, 1996; Mantua *et al.*, 1997; Springer, 1998). These ecosystem shifts have resulted in changes in the populations of breeding birds (*e.g.*, Hunt & Byrd, 1999), their diets (*e.g.*, Decker *et al.*, 1995; Hunt *et al.*, 1996b,c; Piatt & Anderson, 1996), and in the distribution and abundance of marine birds at sea (*e.g.*, Viet *et al*., 1996). Because recent survey data are generally lacking, in this report we have relied primarily on data from the 1970s and early 1980s, except in CAN and CAS, where more recent surveys were available.

The estimates of individual daily metabolic demand are the most robust of the parameters used to model marine bird prey demand. These figures are based on well-accepted and tested allometric equations for energy requirements, and are unlikely to require major revision. We have chosen to use equations from Brit-Friesen *et al.* (1989) that relies on regressions based on Daily Energy Expenditures, rather than on Basal Metabolic Rates multiplied by 4, as used by Anon. (1994). Both methods have strengths and weaknesses (Anon. 1994), and we chose the use of allometric estimates of Daily Energy Expenditures as the most direct relationship with the fewest assumptions about the appropriate multiplier to be applied to basal metabolic rate estimates. Estimates from the two approaches vary only marginally, and whichever method was applied, it would not materially affect the estimates of prey consumption.

Estimates of diet composition are based on several sources of data: collections of food samples made at colonies, investigations of the stomach contents of birds caught in drift nets, and samples from birds shot at sea. Each method of sampling is subject to biases inherent in the foraging behavior and requirements of the birds sampled, and all methods reflect the composition of only the last few meals rather than a broad overview of the diet. These problems become particularly acute when sample sizes are small and collection sites and dates are limited in range. Prey provided to chicks at a colony may differ from prey taken by breeding birds for their own consumption, or by non-breeding portions of the population. Birds caught in drift nets may have been attracted to the nets by the opportunity to scavenge prey types not usually available to them, and may not represent the normal spectrum of prey taken by the population. Finally, when birds are shot at sea while foraging, the prey contained may represent what was in a particular prey patch, rather that the full breadth of the diet.

Estimates of the energy density or content of many of the species of prey taken by marine birds are unavailable. For prey types that have been analyzed, evidence suggests considerable seasonal and spatial variation in energy density within a prey species (*e.g.*, capelin, Montevecchi & Piatt, 1984; sandlance, Hislop *et al.*, 1991). Inaccuracies in the values of energy density assigned to prey types used in our model could have a direct and marked effect on the estimates of the amount of a particular prey required to meet a bird's energy requirements. We provide the values of all parameters used in our model so that as better estimates of prey energy density become available, prey consumption estimates can be recalculated.

Estimates of the sizes of populations of marine birds within the sub-regions are the most error-prone parameters in the model. Although for some species and in some regions, estimates of the numbers of adult birds attending colonies are fairly robust (particularly for surface- and cliff-nesting species in the smaller colonies), for many species (particularly nocturnal, burrow-nesting species) and regions, estimates are weak or non-existent. Likewise, the percentages of populations that are subadult or non-breeding adults not attending colonies are almost universally poorly known.

Population estimates based on at-sea surveys of birds are biased by a number of factors. Only a minute fraction of the vast areas over which extrapolations must be made have been surveyed, the coverage in some regions is concentrated in commercial shipping lanes or zones of active fishing, and many aspects of the marine environment that may result in predictable concentrations of foraging birds have not been sampled in a way that would minimize bias. There remains a great need for thorough, well-designed surveys of the at-sea distributions and abundances of marine birds throughout the PICES region.

Only three PICES sub-regions (BSC, ASK, CAN) had >2% of the total area surveyed. In all other sub-regions, the area covered was <0.5% of the sub-region. Since many of the surveys involved repeated coverage of commercial shipping routes or surveys from vessels working in a restricted area, the geographic coverage of sub-regions was generally less than the number of square kilometers of survey coverage.

The spatial distribution of coverage has a profound effect on the densities of birds encountered. Particularly in shelf regions and around islands and seamounts, evidence is accumulating that marine birds aggregate predictably at oceanographic features where prey concentrate (Hunt & Schneider, 1987; Hunt *et al.*, 1993, 1999). Thus, if surveys are concentrated in these areas, or if they are under-sampled, bias will result. In the database used for parameterizing the model, survey data are aggregated, and the coverage of coarse-scale features cannot be ascertained.

The aggregation of survey data in the database also precludes determination of the effects of autocorrelation between subsequent transects along a survey line. Spatial autocorrelation between samples is almost certain to be strong (Schneider, 1990), and results in a decrease in the effective sample size available for statistical evaluation of pattern. Thus, our analyses in this report are presented without statistical evaluation of significance.

Despite these difficulties in developing estimates of the model parameters, our results suggest some large-scale, robust patterns in the types and amounts of prey consumed in the PICES region of the North Pacific Ocean. Our findings are in agreement with earlier, more qualitative studies, and give an indication of how sub-regions of the North Pacific differ in the biomass of marine birds supported and in the trophic pathways of importance. For most sub-regions, our estimates of the total prey consumed are conservative because either the total number of birds present or their diets were unknown, and so those species were not represented in the estimates of consumption of particular prey types.

3.4.2 Regional variation in numbers and biomass of marine birds supported

Gould (1983) and Gould & Piatt (1993) suggested that there was a marked decline in the density of marine birds between the Subarctic Area (hundreds of birds•km^{-2}) and the Transitional Zone (tens of birds•km^{-2}). In the present analysis, we found a marked decline in marine bird densities between the Bering Sea (16 – 34 birds•km^{-2}) and the Subarctic Area (2 – 7 birds•km^{-2}), but little change in the density between the Subarctic Area and the Transition Zone (1 – 9 birds•km^{-2}). The difference between the Bering Sea and the Subarctic Area most likely reflects both the greater productivity of the Bering Sea, particularly of its shelf areas, and also the importance of the availability of suitable nesting areas to support near-shore foraging alcids during the breeding season. We do not know why we found little difference between the Subarctic Areas and Transition Zone compared to what Gould (1983) and Gould and Piatt (1993) found.

There were also striking differences in the densities of birds between the western and eastern sides of the North Pacific. The densities of marine birds in the western North Pacific subarctic were 3 times greater than those in the Eastern Subarctic and 9 times greater in the Western Transition than in the Eastern Transition Zone (Tables 2, 4). The ratio of biomass supported in the Western compared to the Eastern Subarctic Zone (~5 ×) and the Western versus Eastern Transition Zones (8 ×) were similar to the ratios of avian densities and reflected the contributions to biomass per unit area of large-bodied species such as albatrosses in the west. These data suggest a striking difference in the productivity of waters in the eastern and western North Pacific (Sugimoto & Tadokoro, 1997; Springer *et al.*, 1999).

The ratios of marine bird densities between the Western and Eastern Subarctic developed in this report are similar to those calculated by Springer *et al.* (1999) (3.3), who used the same database, but without modification (see Methods). However, the absolute values differ strikingly from those reported by Springer *et al.* (1999) because we adjusted overall numbers of ship-attracted birds and those with highly clumped distributions to known maximum world or North Pacific population size. Thus where Springer *et al.* (1999) estimated the mean density of birds•km^{-2} in the Western Subarctic to be 24, we estimated the average density to be 7. The ratios we found between west and east differ from those of Sanger and Ainley (1988), who divided the subarctic zone into western, central and Gulf of Alaska sections, with the Gulf of Alaska having the highest avian densities. Wahl *et al.* (1989) compared bird densities in the western and eastern subarctic gyres and found marine bird densities 5.8 × greater in the west.

Both resident nesting species and transequatorial migrants that spend the boreal summer in the Northern Hemisphere contribute to the higher avian biomass in the western North Pacific Ocean (Table 4)(Springer *et al.*, 1999). Most importantly, sooty shearwaters, which spend the austral winter in the Northern Hemisphere and which are the dominant component of marine bird biomass in both the Subarctic and Transition Zones, are far more abundant in the western North Pacific (Table 8). It is their abundance in the Western Transition Zone rather than in the Western Subarctic that makes sooty shearwaters the dominant presence in the western North Pacific. In contrast, short-tailed shearwaters, though abundant in the Western Transition Zone, continue their migration eastward, with the bulk of their population spending the Summer in the eastern Bering Sea and Gulf of Alaska (Appendix 5B).

Springer *et al.* (1999) point out that northern fulmars, fork-tailed storm-petrels (*Oceanodroma furcata*), least auklets (*Aethia pusilla*) and crested auklets (*A. cristatella*) nest in far greater numbers in the Western Subarctic, whereas common murres, ancient murrelets (*Synthliboramphus antiquum*), Cassin's auklets (*Ptychoramphus aleutica*), rhinoceros auklets and horned puffins (*Fratercula corniculata*) have larger breeding populations in the Eastern Subarctic. Our analyses do not show particularly high numbers of least and crested auklets in the Western Subarctic Area. The difference between the two analyses results from our inclusion of the marine bird colonies of the Aleutian Islands within the Bering Sea sub-regions. Many, if not most, of the auklets from these colonies forage to the north of the Aleutians in Bering Sea waters (Hunt *et al.*, unpubl. data) and rarely, if ever, visit the Subarctic in summer.

Throughout the North Pacific, it is the shelf regions that support the greatest densities of marine birds. The eastern Bering Sea Shelf, and the Gulf of Alaska are both areas of exceptionally high densities of marine birds. Thus, although the areas involved are not necessarily very large, it is these sub-regions that support the highest rates of energy flux to marine birds. Gould (1983) found the highest densities of marine birds along the edge of the continental shelf in the vicinity of 54° to 55° N. Similarly, Sanger and Ainley (1988) pointed out that the density and biomass of marine birds in the oceanic portion of the Gulf of Alaska was only about one eighth those of the neighboring continental shelf. To the southeast, Morgan *et al.* (1991) observed that the CAN shelf waters supported not only the highest density of marine birds, but the highest diversity as well. As Springer *et al.* (1999) suggest, this concentration of marine birds along shelf edges and over shelf waters reflects the high rates of productivity in these regions (Parsons, 1986; Springer *et al.*, 1996).

3.5 Regional variation in consumption by marine birds

The greatest energy demand and prey consumption by marine birds occurs in the Western Transition Zone with a summer consumption of between 712,341 mt and 1,662,130 mt. However, the greatest flux to birds per unit area occurs in the shelf waters of the Gulf of Alaska where between 0.74 and 1.72 mt•km^{-2} is consumed each summer (Table 7).

3.5.1 Regional variation in marine bird diets

The type of prey used by marine birds varied considerably between the sub-regions. In the shelf waters of the eastern North Pacific Ocean, there is a suggestion of an increasing importance of fish and decreasing use of zooplankton as one goes from the Bering Sea in the north to the California Current South in the south. In the eastern Bering Sea, prey consumption was almost evenly divided between crustacean zooplankters and fishes, with euphausiids (primarily taken by short-tailed shearwaters) and copepods (least auklets) being the most important zooplankton types; walleye pollock (murres and kittiwakes [*Rissa* spp.]) was the most important fish. In the Gulf of Alaska, euphausiids (short-tailed shearwaters), and to a lesser extent copepods (Cassin's auklets), were the most important zooplankton consumed. However, overall, fish were the most important prey type for marine birds (sooty shearwaters, short-tailed shearwaters and tufted puffins [*Fratercula cirrhata*]), with capelin and sandlance being the most important prey species in the Gulf. In the California Current North, off the west coast of Vancouver Island, the importance of fish to marine birds, listed as 70% in Table 6, may be under-represented, as the contributions to fish consumption by sooty shearwaters and California Gulls (*Larus californicus*) there were not accounted for. These two species represent approximately 20% of the marine bird population of CAN in summer. In the California Current South, off California, Oregon and Washington, fish were the most important prey of marine birds, with common murres, sooty shearwaters and cormorants being the most important consumers. Surface-foraging western gulls (*Larus occidentalis*) were also important fish consumers in this region. The most important fish species was northern anchovy (*Engraulis mordax*), followed by rockfish (*Sebastes* spp.) of various species. Zooplankton were, overall, a minor component of marine bird prey consumption.

In the North Pacific Ocean, least and crested auklets specialize on copepods and euphausiids, respectively (Hunt et al., 1996c, 1998). The nesting distributions of these marine birds are almost entirely restricted to the Bering Sea and the

Sea of Okhotsk, and few individuals of these species nest south or east of the Aleutian Islands. In the Gulf of Alaska and south to Baja California, the dominant planktivorous alcid is the Cassin's auklet, which takes large amounts of larval and juvenile fish in addition to euphausiids and copepods. Cassin's auklets, while often locally abundant, do not attain the vast numbers present in least and crested auklet colonies in the Bering Sea and the Sea of Okhotsk. Populations of Cassin's auklets have been shown to be sensitive to variations in the abundance of zooplankton (Ainley *et al.*, 1990). Off the west coast of Vancouver Island, Cassin's auklets feed mostly on *Neocalanus cristatus* over the outer shelf in summer. However, as this zooplankter becomes scarce in surface waters in fall, Cassin's auklets forage more in nearshore waters (Vermeer *et al.* 1989). The higher densities of zooplankton in the Bering Sea and Sea of Okhotsk than in the Gulf of Alaska and southward along the California coast suggest that the distribution patterns of these marine birds reflects the abundance of planktonic prey (Motoda & Minoda, 1974; Coyle *et al.*, 1998; Roemmich & McGowan, 1995).

The North Pacific Subarctic and Transition Zone regions pose particular difficulties for assessing marine bird diets. There are no data on marine bird diets from the oceanic Eastern Subarctic, and all data from the Western Subarctic and the Transition Zones are from birds caught in gill nets. Thus, the sample of prey used is potentially biased because of the association with fishing activity and the subset of prey present in the fishing grounds. In their review, Springer *et al.* (1999) augmented the rather limited set of data from the gill net-caught birds with information derived from colony studies in the Gulf of Alaska, Japan and Russia, and included material from Sanger and Ainley (1988) based on collections made in shelf waters of the Gulf of Alaska, primarily off Kodiak Island. We are hesitant to extrapolate from coastal and shelf waters to the subarctic gyre, as the prey base and the diets of the birds may differ significantly from the shelf region.

In the absence of comparable diet data from the Eastern and Western Subarctic gyres, we can still obtain some idea of the foods used by examining the foraging behaviors and size classes of the marine birds inhabiting these regions. Within the Western and Eastern Subarctic sub-regions, the mix of marine bird species is similar in the east and the west, with the exception that Laysan albatrosses are more abundant in the western subarctic and black-footed albatrosses are more abundant in the east. Likewise, sooty and short-tailed shearwaters were more abundant in the west, as were storm-petrels and phalaropes. Farther south, in the Transition Zone, both Laysan and black-footed albatrosses take neon flying squid and offal associated with the high seas gillnet fishery for squid; when not associated with the squid fishery, Laysan albatrosses take fish, whereas black-footed albatrosses take squid (Gould *et al.,* 1997a). Sooty shearwaters, in the Western Subarctic forage primarily on fish, in particular Japanese sardine (*Sardinops melanostica,* Shiomi & Ogi, 1992). These data, at best very sparse, suggest that fish may be more important in the Western Subarctic, and squid in the east. Both storm-petrels and phalaropes forage on neuston, and the abundance of these small marine birds in the Western Subarctic Area suggests that there, this layer of the ocean must support a great abundance of prey.

Contrasts between the eastern and western North Pacific are much more striking in the Transition Zone than in the Subarctic (Table 4). The Western Transition Zone is dominated by 20 million sooty shearwaters, 2.4 million Buller's shearwaters, 29 million Leach's storm-petrels, and 2.6 million fork-tailed storm-petrels. In contrast to the Subarctic, gulls and allies and phalaropes were more abundant in the Eastern Transition Zone than the west. The high numbers of storm-petrels in the Western Transition Zone again emphasizes the importance of neuston in this region.

Diet data are more abundant from the Transition Zones than from the Subarctic, and they indicate that marine birds in the Western Transition Zone depend primarily on fish, whereas, in the Eastern Transition Zone cephalopods are of primary importance. These data are, however, distorted by the sampling of birds caught in the high-seas driftnet fisheries. When the contributions of neon flying squid and Pacific pomfret (*Brama japonica*) were excluded from the analysis (because they were most likely scavenged from the fishery), small cephalopods and fish were of greater importance in the Western Transition Zone and barnacles and to a much lesser extent pelagic snails were of greater importance in the eastern Transition Zone. Barnacles were the single most important food of sooty and short-tailed shearwaters in the Transition Zone as a whole, and fishes were of secondary importance (Gould *et al.*, unpubl. ms). There was also a shift from the use of barnacles in the southern latitudes (38 to 41°N) to fish and cephalopods toward the north (42 to 45°N) (Gould unpubl. data). This spatial trend is somewhat confounded by the temporal shift in the gillnet fishery toward the north as the summer progresses. Thus, it is difficult to separate the spatial and seasonal aspects of the patterns observed. Of the fish consumed, lanternfishes (Myctophidae) were most important in short-tailed shearwater diets and Pacific saury was most important for sooty shearwaters. Although there was little east-west variation in the occurrence of myctophids in the stomachs of sooty shearwaters, Japanese sardines were taken almost exclusively in the westernmost portions of the North Pacific (Gould unpubl. data). Buller's shearwaters, which were far more abundant in the Western Transition Zone than in the east, had a diet composed of 71% by mass of Pacific saury (Gould *et al.*, 1998a).

4 FOOD CONSUMPTION BY MARINE MAMMALS IN THE NORTH PACIFIC OCEAN

4.1 Introduction

At least forty-seven species of marine mammals are known to inhabit the PICES region in the North Pacific Ocean. Although accurate estimates of population abundance for these species are notoriously difficult to obtain, the number of individuals may exceed 10,000,000. A major factor that makes this group of apex predators so important ecologically is their wide distribution, high abundance, and their relatively large body size. Average body weights of marine mammal species in the North Pacific (from cetaceans and pinnipeds to polar bears and sea otters) ranges from 28 kg (northern fur seal) to 102,736 kg (blue whale).

Marine mammals generally migrate annually between breeding and feeding areas. Pinnipeds use both land and ocean habitats, while whales stay in water throughout their life. Most pinnipeds are distributed among solitary islands or rocky beaches where humans cannot approach easily. Phocids that live near drift ice migrate with the ice (Naito, 1976), while those inhabiting beaches move nearer to their breeding places along coastal areas (Naito, 1982). Among the otariids, Steller sea lions migrate mainly in the coastal area but some of them go far to sea to forage (Kastelein & Weltz, 1991; Loughlin *et al.*, 1987, 1993). Northern fur seals migrate in the open sea (Bigg, 1982, 1990; Nagasaki, 1960; Wada, 1971a; Lander & Kajimura, 1982). The migration distances of northern fur seals are perhaps the longest of the pinnipeds in the North Pacific Ocean. Almost all immature fur seals remain distributed in the central North Pacific Ocean during the first few years of life (Baba *et al.*, 1993).

Most of the mysticetes migrate to higher latitudes to feed on prey in summer. They inhabit lower latitudes to breed in winter and feeding activity is not common there (Gaskin, 1982). An exception is the Bryde's whale, which stays in a lower latitudinal range throughout the year (Gaskin, 1982). Unlike the mysticetes, odontocetes do not have such clear seasonality in their feeding activity. Most of the smaller odontocetes migrate seasonally, but the range is rather local. Migration patterns are known in both north-south movements and also between coastal and pelagic areas. Dall's porpoise in the western side of the North Pacific migrate to the Sea of Okhotsk in summer, and migrate to the Japan/East Sea and the northwestern North Pacific in winter (Miyashita, 1991; Amano & Kuramochi, 1992). In contrast to the populations in the western side of the North Pacific, migrations of Dall's porpoise in the eastern North Pacific are described only as onshore-offshore movements (Kajimura & Loughlin, 1988). The migration patterns of sperm whales depend on their sex and body size. Smaller males and females migrate from middle to lower latitudes, while larger males migrate to higher latitudes in summer. In winter, they are distributed in middle to lower latitudes (Best, 1979; Kato, 1995).

There are some reports on the trophic structure of marine ecosystems (Laevasto & Larkins, 1981). Marine mammals are usually recognized as the top predators in marine ecosystems (e.g. Hobson *et al.*, 1997). The prey items of marine mammals vary by season and place. Seals inhabiting drifting sea ice take prey under the sea ice (Fisher & Mackenzie, 1954; Frost & Lowry, 1980). Seals and sea lions in coastal areas feed on bottom fishes, mesopelagic fishes, and cephalopods (Itoo *et al.*, 1983; Merrick *et al.*, 1997; Kato, 1982). Northern fur seals take epipelagic fishes and cephalopods in the open sea (Panina, 1966; Sinclair *et al.*, 1994; Wada, 1971b; Kajimura & Loughlin, 1988; Kajimura, 1984). Steller sea lions sometimes take northern fur seal pups (Gentry & Johnson, 1981). Seabird remains have been observed in the stomachs of sea otters, northern fur seals, and walrus (VanWagenen *et al.*, 1981; Gjertz, 1990; Yoshida *et al.*, 1978).

Mysticetes usually feed on zooplankton such as euphausiids and copepods. However, some species such as fin, Bryde's, minke and humpback whales also regularly feed on fishes as well

(Kawamura, 1980; Kasamstu & Tanaka, 1991; Tamura *et al*., 1998). The prey fishes are usually abundant shoaling fishes including sardines, herrings, anchovies, sauries and mackerels (Kawamura, 1980; Gaskin, 1982; Kasamstu & Tanaka 1991; Tamura *et al*., 1998). Grey whales feed on benthic organisms living in mud on the continental shelf (Gaskin, 1982). Larger odontocetes including sperm and Baird's beaked whales prefer cephalopods, but sometimes fishes are important prey in specific areas (Nishiwaki & Oguro, 1971; Clarke, 1980; Kawakami, 1980). Smaller odontocetes including dolphins and porpoises feed on small fishes and squids, but false killer and pygmy killer whales sometimes attack other whales and dolphins (Perryman & Foster, 1980; Walker & Jones, 1994; Palacios & Mate, 1996; Walker, 1996; Ohizumi *et al*., 1998). Killer whales feed on large prey including fishes, squids, sea birds, sea turtles and marine mammals (Caldwell & Caldwell, 1969; Gaskin, 1982; Estes *et al*., 1998).

The kinds of food consumed change with seasonal migrations of marine mammals (Perez & Bigg, 1986). Though some marine mammals have strong preferences for certain types of prey (Lindstrom *et al.*, 1998; Cox *et al*., 1996), almost all marine mammals are opportunistic feeders (Kajimura, 1984). Marine mammals usually feed nocturnally and foraging behavior is often related to the daily movement of fish or squid (Kajimura, 1984). Some marine mammals (e.g., Steller sea lions and humpback whales) take food by schooling the prey into a ball (Riedman, 1990). Marine mammals dive deeply; for instance, northern elephant seals dive up to about 1,250m (Le Boeuf *et al*., 1985, 1986), and sperm whales can dive to about 3,000m. This means that prey items of marine mammals comprise a wide variety from bottom dwellers to surface fauna.

There have been several studies of food consumption by marine mammals (e.g. Perez & McAlister, 1993; Hammill & Stenson, 1997). For example, Antonelis *et al*. (1984) examined the annual food consumption by northern fur seals off California. Steller sea lions, harbor seals, and northern fur seals in the Gulf of Alaska have been estimated to be taking as much as 617,000 mt of prey (ASG report 93-01, 1993). Interactions between marine mammals and fisheries have also been evaluated (Lowry & Forst, 1985; Swartzman & Harr, 1985; Trites *et al.*, 1997).

Tamura & Ohsumi (1999) estimated the annual food consumption by whales in the world is from 100,000,000 mt to 500,000,000 mt. However, there have been no specific attempts to estimate the total amount of prey consumed by all marine mammals in the North Pacific Ocean.

4.2 Methods

In evaluating food consumption by marine mammals throughout the PICES region, our working group was immediately faced with the reality that there are immense data gaps in our understanding of marine mammal population size, seasonal distribution, migration patterns, prey preferences in different geographic areas, and both the energetic requirements of the mammals as well as the energetic content of their various prey. Therefore, we quickly realized that the daunting task that we had been assigned had the danger of leading us to make unrealistic assumptions to fill those gaps. After considerable debate, we agreed that the bulk of our work would focus on developing three sets of tables designed to present a sample of what was known about this topic, and, perhaps more importantly, to highlight the large holes in knowledge that prevent a realistic assessment of the total amounts of prey consumed by marine mammals in the North Pacific. Appendix Tables 9, 10, and 11 present the results of our syntheses. The reader will note that many of the cells in the tables are blank. We deliberately chose blanks rather than overextending the limits of credibility in making weakly supported assumptions just for the sake of drafting tables that looked more complete. However, it will be appreciated that in developing tables with so many blanks, the extent to which we could draw conclusions was limited. Therefore, in those cases where we have attempted a more detailed interpretation of the results derived from these tables, we chose to focus on the western PICES sub-regions as examples of what might be learned from this type of synthesis.

4.2.1 Defining marine mammal stocks and populations

In ecology, a population is typically defined as a group of interbreeding or potentially interbreeding individuals of the same species. The word "stock" is often used in fisheries science to mean a congregation of populations for population analysis and management of the species. Populations and stocks of marine mammals are not fully understood, especially regarding large whales. Marine mammals migrate so widely that it is very difficult to estimate the population abundance or stock discreteness in each PICES sub-regions. Therefore, due to the nature of animal behavior and also the lack of information, we incorporated solely summer information (June – September, 122 days) in our analysis.

4.2.2 Marine mammal abundance

We attempted to incorporate marine mammal population abundance in each PICES sub-region as much as possible although we had considerable difficulties subdividing the data and abundance estimates to fit the PICES sub-regions. The populations are derived from sighting surveys, colony counts, tag recovery, CPUE (catch per unit effort), and distribution density based on the best information currently available. Population estimates of marine mammals are shown in Appendix 9, which is subdivided into thirteen separate sub-regions within the PICES region. In these tables, L is line transect, S is strip transect, M is mark recapture, C is colony count, E is catch per unit of effort, and D is density index of distribution. In the western sub-regions, populations of seals and sea lions were quoted from papers of NPFSC (1984) and Buckland et al. (1993) for northern fur seal, of Loughlin et al. (1992) for Steller sea lion, of Popov (1982) for phocids in the Okhotsk Sea, and of Hayama (1988) for Kurile seals.

For cetaceans in the western PICES sub-regions, we incorporated population estimates by sighting surveys mainly based on line-transect sampling theory (Gates *et al*., 1968), which is usually adopted by the Scientific Committee of International Whaling Commission (IWC) for abundance estimation purpose. Populations of whales and dolphins were quoted from papers of Kato *et al*. (1997) for sperm whales, Dall's porpoises, Pacific white-sided dolphins, and minke whales, Miyashita & Kato (1993) for Baird's beaked whales, Shimada & Miyashita (1997) for Bryde's whales, Miyashita (1993a) for Dall's porpoises, short-finned pilot whales, bottlenose dolphins, Risso's dolphins, spotted dolphins, and striped dolphins, Kato & Miyazaki (1986) for Dall's porpoise, Miyashita (1992) for northern right-whale dolphins, and Pacific white-sided dolphins, Brownell *et al*. (1999) for bowhead and gray whales.

However, the information is not sufficient for many sub-divisions, and in such cases we have kept cells blank for areas in which abundance estimates were unavailable or deemed unreliable. Furthermore, if a marine mammal is known to migrate among two or more PICES sub-regions, the same number of populations is assumed to extend into those sub-regions as a tentative measure. However, this approach did not allow us to accurately estimate the population sizes for certain species during the summer months.

4.2.3 Distribution and seasonal movements of marine mammals

The breeding season for marine mammals differs by species. For example, it is generally from June to September for otariid seals, and from April to June for phocid seals. The lactation period also differs by species. It varies in length from weeks for phocid seals (Riedman, 1990), to from 4 months to more than one year for otariid seals (Peterson, 1968; Gentry, 1981; Schusterman, 1981). Therefore, the prey species of both pup and mother seals is likely to be similar during lactation periods. The prey of juvenile seals is somewhat different because they are distributed far out to sea, away from the breeding sites on islands and along the mainland coasts (Hobbs & Jones, 1993).

Most pinnipeds in the PICES region move south after the breeding season. Many non-breeding individuals are never present near the breeding grounds. For some species, southward migration begins during October to January, and northward migrations begin during April through June. Migration speed is generally about 4 km•h^{-1} for northern fur seals (Kiyota *et al*., 1992) and about 18.8•km^{-1} for humpback whales (Mate *et al*., 1998). Their migration routes are not fully understood, but satellite tracking is helping to clarify these patterns. For instance, northern fur seals migrate to the central North Pacific from their breeding islands and then approach coastal areas (Kiyota *et al*., 1992). Northern elephant seals migrate to the vicinity of the Aleutian Islands from breeding islands off California (Stewart & DeLong, 1995).

Most species of cetaceans are highly migratory, especially Mysticetes, which are widely distributed at higher latitudes in summer for feeding and in lower latitudes in winter for breeding; some penetrate into areas well north or south of the PICES region. However, their migration corridors are not well known except for gray and bowhead whales which breed and feed in coastal regions. Although sperm whales have a seasonal migration similar to that of mysticetes, most odontocetes remain in particular water masses throughout the year with some north-south seasonal or inshore-offshore migration. Some types of local resident populations are thought to exist.

In conclusion, cetaceans are distributed widely throughout the PICES region, however both mysticete and ondontocete whales seasonally shift their habitats at least over the PICES sub-regions and it is rare for the same population to remain within the same PICES sub-region throughout year.

4.2.4 Marine mammal diets used in the model

Marine mammal diets vary widely. Furthermore, sex, age, reproductive condition, time and foraging locations of individual marine mammals alter their prey preferences. Although it is difficult to summarize, we attempted to select at least some general estimates of food consumption. Therefore, we used values reported by Pauly *et al*. (1998) and these are shown as the "default" prey preferences in Appendix Table 10. These values were derived as generalized approximations of food habits for particular species of marine mammals on a worldwide basis.

4.2.5 Marine mammal energy requirements

In general, the energy requirements of marine mammals in summer seem to be high due to breeding activities. It is difficult to measure the amount of energy required by wild marine mammals directly so we used a generalized formula relating the amount of food consumption (energy requirement) and to body weight (Perez *et al*., 1990). The formula is:

$$\log E = a + 0.75 \times \log M$$

where E = energy requirement per day (kcal•d^{-1}), a = coefficient, and M = mean body weight (kg). The value for "a" is 317 for toothed whales, 192 for baleen whales, 372 for otariid seals, and 200 for phocid seals. It was converted into kj as 1 kcal = 4.186 kj.

The average body weight of each species was quoted from Trites & Pauly (1998). If average body weights of males and females were reported separately, we calculated the mean of them and used it as the representative value of the species. The marine mammals' daily energy requirements are shown in Appendix Table 9 by species.

4.2.6 Energy content of marine mammal prey

The energy value of prey varied among prey species and location. Energy values of some fish in winter are higher than in summer (Jangagard, 1974; Bigg *et al*., 1978). Although a wide variety of reports concerning the energy value of marine mammal prey have been published, we used the following general values: benthic invertebrates 4 kj•g^{-1}; crustacean zooplankton, 4 kj•g^{-1}; small cephalopods 3.5 kj•g^{-1}; large cephalopods 4 kj•g^{-1}, epipelagic fishes (in the surface layers, for example, pollock, mackerel), 7 kj•g^{-1} mesopelagic fishes (in the middle layers, for example, myctophids, herring), 7 kj•g^{-1} miscellaneous 5 kj•g^{-1}, seabird and marine mammals 7 kj•g^{-1}.

4.2.7 Food utilization efficiency of marine mammals

There is, of course, some loss of energy when prey are consumed and digested by marine mammals. This loss of energetic transfer follows from lost food during eating (i.e., food scraps lost), inefficient absorption (i.e., energy excreted as feces), and a general loss due to the metabolic cost of digestion. Prey items also vary in the nutritional condition. For example, fish with high fat quality is absorbed better than the fish with low fat quality. Although marine mammal prey items are represented by several different taxonomic groups: plankton, squid, octopus, fishes, seabirds to marine mammals, we have assumed an assimilation efficiency of 75% for the conversion of daily energy requirements to the amount of prey needed to meet those requirements.

4.3 Model Output

The total number of marine mammal species recognized in the western part of the PICES region was 41 (Table 9). The maximum number of species of marine mammals was 33 in the KR/OY sub-regions and the minimum number was 14 in the ECS sub-region. The fact that the number of species is high in the KR/OY sub-regions is related to the Kuroshio and Oyashio currents. The average percentage of the number of species whose population is known is about 27% (range; 7% in the WSA sub-regions - 58% in the OKH sub-regions) (Table 10).

The range of marine mammal population sizes in the western PICES region varied from about 4,620,000 animals in the WTZ sub-region to about 2,300 animals in the WSA sub-region (Table 11). The total population of marine mammals in the western PICES region is about 10,410,000 animals (including duplicated population within neighboring sub-regions). The total population of marine mammals (excluding the duplicated populations) was about 6,500,000 animals. This value was derived under the condition of 27% of the marine mammal species inhabiting in the western part of the PICES region (Table 9).

The total biomass of marine mammals in the western parts of the PICES region during summer was approximately 209,700,000 mt as a minimum estimate. The biomass of marine mammals in each PICES sub-region ranged from approximately 2,000,000 mt in the SJP sub-region to approximately 121,400,000 mt in the WTZ sub-region (Table 11). On the other hand, the total energy requirement of marine mammals in the western PICES sub-regions during summer was about $5,372\times10^{10}$ kj. The energy requirement of marine mammals in each of these sub-regions ranged from about 25×10^{10} kj in the SJP sub-region to about $2,904\times10^{10}$ kj in the WTZ sub-region (Table 11). The estimated values of daily energy requirements of marine mammals in all sub-regions in summer (June-September) is also summarized in Appendix 9.

The estimated prey composition of each marine mammal in the western sub-region is shown in Appendix 10. The prey composition was 36-46% fish and 13-36% squid (Table 12). Apart from fish and squid, the prey composition was high for benthic invertebrates (20.4%) in the OKH sub-regions and for crustacean zooplankton (36.9%) in the WSA sub-regions (Table 12). The presumed percentage of marine mammal prey items during summer in all sub-regions is shown in Appendix 10.

The total amount of food consumed by marine mammals in the western North Pacific Ocean during summer was about 13,020,000 mt (Table 13a,b). Again, it should be noted that the estimated value is a conservative one because the estimate is based on minimum predator abundance due to a lack of high-quality quantitative information for both the abundance and food consumption of many predators and in many sub-regions. Among these sub-regions, the highest value of consumption was about 6,395,000 mt (49% of total) in the WTZ sub-region, and the lowest was 70,000 tons (0.5%) in the SJP sub-region. The amount of food consumed, by PICES sub-region, is shown in Appendix 11.

4.4 Discussion

4.4.1 Reliability of estimates of prey consumption by marine mammals

Many potential errors, i.e. the change of energy requirement, prey species, feeding behavior, energy value of prey, population abundance etc., influence our estimate of the amount of food consumed by marine mammals. Errors in the estimates are introduced by changes of observers, instruments, sea condition, and sighting counts, etc. Of these, the population and food habits are considered to be important factors affecting the accuracy of the estimates of food consumption. Especially lacking are population abundance estimates for many species and in many strata (PICES sub-regions), which obviously leads to a serious downward bias in our estimates of total food consumption by marine mammals. Thus, our present estimate of food consumption is necessarily a great under-representation and should be understood as a minimum value of the total food consumption.

For our calculations, we used the energy method of consumption estimation of Perez and McAlister (1993). Their formula uses daily energy expenditures (DEE) derived from average body weight of animals and the food weight consumed through the year in captivity. Metabolic energy is in proportion to 3/4 square of body weight. Generally BMR (Basal Metabolic Rate) is known as the formula of $M = 70 \times W^{0.75}$ (Kleiber, 1961), where M is BMR (Kcal/day) and W is body weight (kg). The BMR is an absolute measurement taken when the animal is not using muscle, digestion, and adjustment of body temperature at all. DEE of mammals was 2.1- 2.7 times of BMR (Farlow, 1976; Feldkamp, 1985). Innes *et al*. (1987) reported that active metabolic rates of marine mammals ranged from about twice the value of Kleiber BMR for phocid seals to over four times the value for otariid seals. Costa *et al*. (1985), Nagy (1987), and Gentry and Kooyman (1986) suggested that active pinnipeds may have active metabolic rates about three times that of their resting metabolic rates. The formula in used this report was not so different from their values. The error introduced by these differences is smaller than the large errors associated with other parameters (e.g., abundance estimates). Energy values of prey species varied by season and location. It must be examined more precisely, and all values of prey species' energy used in the model should be verified in future.

The prey species preferences were derived from various data sources, i.e., stomach contents, scat, etc. The food consumption is influenced greatly by the physiology of animals. Results of feeding habits are affected by sampling time (Markussen, 1993), digestion (Helm, 1984), prey preference (Sinclair *et al*., 1994), feeding behavior, and body condition of animal. These parameters affect the resulting food consumption estimates. More information concerning food habits and population abundance of marine mammals are needed to understand the role of marine mammals in marine ecosystems.

4.4.2 Regional variation in numbers of marine mammals

The density of marine mammals in the western PICES sub-regions (BSP, OKH, KM/KL, WSA, WTZ, KR/OY, and SJP) ranged from 0.002 individuals per km^2 in the SJP sub-region to 0.6 individuals per km^2 in the OKH sub-region. The overall density in the western sub-regions was 0.36 individuals per km^2. The density in the WTZ sub-region alone (41% species coverage) was also 0.36 individuals per km^2 (Table 14).

Although the amount of information varies by species and sub-region, it is possible to summarize the general tendency as follows. The average body weight of all marine mammals in the WTZ (215 kg per individual=121,417,000mt / 4,619,545 individuals / 122 days) was smaller than that of KR/OY (671 kg per individual) during summer (June-September). The reason for this is that there are many dolphins in the WTZ and many whales in the KR/OY. In addition, the KR/OY has the upwelling of Kuroshio and Oyashio Currents, though the continental shelves in KR/OY sub-region are narrow. Although the WTZ sub-region does not have a continental shelf, there are transition zones consisting of fronts formed by the confluence of the Kuroshio and Oyashio Currents. Many plankton, *Diaphus* sp., saury, pomfret, and flying squid, etc. exist in WTZ.

Both OKH and BSP are covered with drifting ice in winter and the productivity of the ocean therefore increases in summer. But the average body weight for all marine mammals was small (194 kg per individual in OKH and 96 kg per individual in BSP) compared to WTZ (215 kg per individual) and KR/OY (671 kg per individual). This was due to an abundance of seals. Furthermore, the biomass of marine mammals in BSP was smaller than that of OKH. This may be due to a smaller continental shelf in BSP compared to the OKH. The mean weight of marine mammals in KM/KL was 84 kg per individual. This is due to the narrow continental shelf and poor nutrient condition of the sea. The Sea of Japan becomes warm in summer owing to the Tsushima warm current. Dall's porpoises, pacific white-sided dolphins, minke whales etc. are distributed here mainly during summer, but the population estimates were available for only two whales (minke and Baird's beaked whales).

4.4.3 Regional variation in consumption by marine mammals

The total food consumption of marine mammals in the western PICES sub-regions during summer (June-September, 122 days) was estimated to be about 13,000,000 mt in this study. This is about 6% (range 3-10%) of the daily energy consumption per body mass of marine mammals. This value is within the feeding rate (4-15%) of marine mammals as reported before (Spottee & Adams, 1981) (Table 11).

Fish represented about 60% of total prey in both WTZ and KM/KL. Squid represented 56% of total in KR/OY and about 70% in WSA (Table 13b). On the other hand, a sum of benthic invertebrate's (23%) and crustacean zooplankton (27%) accounts for 50% of total food consumption in OKH. The percentage of benthic invertebrates was about 45% in BSP. The percentage of crustacean zooplankton represents about 34% in SJP. Thus, the main food of marine mammals varies among the PICES sub-regions. This result may reflect the important prey for dominant marine mammals in the North Pacific Ocean.

Food consumption of marine mammals in the North Pacific Ocean is comprised of 52% for fish and 36% for squid during summer. It should be noted that some of the food consumption data of marine mammals used in this report were derived from studies of the feeding habits of marine mammals in the Southern Hemisphere. Feeding habits are known to be different between Northern Hemisphere and Southern Hemisphere. Updated information on the actual feeding habits of specific marine mammals should be incorporated into future analysis.

4.4.4 Data gaps

Although we tried to incorporate as much information as was possible, we only incorporated data from about 11 (27%) of the 41 species of marine mammals that are known to inhabit the western PICES sub-regions. If the marine mammals in the eastern sector are considered, this percentage would grow even smaller. Moreover, even when information was available, its quality was not necessarily sufficient to satisfy the standards needed to accurately assess feeding intensity of top predators in marine ecosystems. Obviously, a great deal of additional information is needed before the types of assessments and synthesis initiated in this exercise can be undertaken with success. Data gaps that require attention include population abundance estimates, seasonal movements, feeding rates, region-specific food preferences, and the energetic content of prey items.

4.4.5 General remarks

In this report, we estimated the total food consumption by marine mammals as 13,020,000 mt. However, this estimate is obviously a minimum estimate of the consumption due to reasons such as using minimum estimate of predator abundance, as explained in the previous section. Thus, the value should be re-examined in the future with incorporation of further information that will be obtained through new research.

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7 TABLES

Table 1. Surface areas and marine bird survey effort for sub-regions of the PICES region.

PICES Sub-region	Code	Area (km^2)	Survey effort (km^2)	Area covered (%)
Eastern Bering Sea Shelf	BSC	1,022,000	35,485	3.5
Western Bering Sea and Basin	BSP	1,358,000	8,755	0.1
Gulf of Alaska	ASK	429,000	15,735	3.7
California Current, North	CAN	166,000	3,446	2.1
Eastern Sub-Arctic	ESA	3,622,000	2,490	0.0
Western Sub-Arctic	WSA	2,168,000	4,340	0.2
Kamchatka and Kurile Islands	KM/KL	112,000	12	0.0
Sea of Okhotsk	OKH	1,600,000	0	0
California Current, South	CAS	129,000		?
Eastern Transition Zone	ETZ	7,809,000	6,065	0.1
Western Transition Zone	WTZ	6,338,000	11,805	0.2
Kuroshio/Oyashio Currents Zone	KR/OY	348,000	700	0.2
Sea of Japan	SJP	1,006,000	0	0
East China Sea	ECS	435,000	0	0

Table 2. Summary of seabird species richness, density and biomass of marine birds and marine bird energy demand within PICES sub-regions.

Sub-region	Number of Species	Individuals (No.)	Density (individuals km^{-2})	Biomass ($kg \cdot km^{-2}$)	Daily Energy Consumption ($kj \cdot km^{-2} \cdot d^{-1}$) x 10^3
BSC	37	34,690,000	34	18.6	48.8
BSP	45	22,325,000	16	7.0	18.7
ASK	38	16,140,000	38	21.5	56.2
CAN	52	1,405,000	8	3.7	9.9
ESA	24-30	7,905,000	2	0.8	2.1
WSA	30-31	14,945,000	7	3.8	8.8
KM/KL	47-54	Insufficient Data			
OKH	41-43	Insufficient Data			
CAS	49	1,809,000	14	9.7	22.9
ETZ	35-40	5,850,000	1	0.4	0.8
WTZ	35-40	56,620,000	9	3.2	8.6
KR/OY	54-61	Insufficient Data			
SJP	30	Insufficient Data			
ECS	25-36	Insufficient Data			

Table 3. Number of marine bird species and percent of all marine birds by size-class and PICES sub-region.

Sub-region	1-125 g		126-400 g		401-1000 g		> 1000 g	
	# spp	% individ	# spp	% individ	# spp	% individ	# spp	% individ
BSC	7	15	8	8	13	76	9	0.3
BSP	9	33	12	26	14	37	10	4
ASK	8	12	8	4	13	83	9	1
CAN*	7	23	14	28	18	41	13	7
ESA	4	52	8	6	11	39	7	3
WSA	5	49	8	3	11	40	7	8
KM/KL*	12	-	13	-	18	-	11	-
OKH	10	-	7	-	16	-	10	-
CAS	9	18	13	10	16	58	11	14
ETZ	8	66	14	12	11	9	7	13
WTZ	8	56	14	4	11	39	7	1
KR/OY	14	-	16	-	19	-	12	-
SJP	8	-	5	-	10	-	7	-
ECS	-	-	-	-	-	-	-	-
Overall	24%	40%	32%	9%	24%	49%	20%	5%

Table 4. Comparison of populations of dominant bird groups in Western and Eastern North Pacific.

Western N. Pacific	Albatrosses	Fulmars & Shearwaters	Storm-Petrels	Gulls & allies	Phalaropes	Alcids	Total	Surface Area
Western Subarctic	1,105,000	4,135,000	7,100,000	1,064,000	87,000	145,000	13,636,000	2,168,315
Western Transition Zone	386,000	23,503,000	31,600,000	174,000	120,000	2,000	55,785,000	6,337,700
Total	1,491,000	27,638,000	38,700,000	1,238,000	207,000	147,000	69,421,000	8,506,015
Density (number/km^2)	0.18	3.25	4.55	0.15	0.02	0.02	8.16	

Eastern N. Pacific	Albatrosses	Fulmars & Shearwaters	Storm-Petrels	Gulls & allies	Phalaropes	Alcids	Total	Surface Area
Eastern Subarctic	44,000	2,301,000	4,100,000	1,088,000	12,000	284,000	7,545,000	3,621,580
Gulf of Alaska	9,000	9,360,000	1,240,000	1,415,000	410,000	3,691,000	12,435,000	428,520
California Current North	3,000	275,000	230,000	268,000	97,000	612,000	872,000	166,456
Eastern Transition Zone	665,000	435,000	2,700,000	839,000	1,152,000	59,000	5,791,000	7,808,530
California Current South	3,000	245,000	175,000	244,300	240,000	489,000	907,000	128,620
Total	724,000	12,615,000	8,445,000	3,854,000	1,911,000	5,135,000	27,550,000	12,153,706
Density (number/km^2)	0.06	1.04	0.69	0.32	0.16	0.42	2.27	

Table 5. Summary of important prey species by PICES sub-region.

Sub-region	Zooplankton	Cephalopod	Small Fish
BSC	Euphausiid	Sm. Cephalopod	Walleye pollock
BSP	Copepods	Sm. Cephalopod	Sandlance, Capelin
ASK	Euphausiids	Sm. Cephalopod	Capelin, Sandlance
CAN	Copepods Euphausiids	Loligo opalescens	Sandlance, Sebastes spp., Myctophids
ESA	No Data	No Data	No Data
WSA	?	Sm. cephalopod	*Sardinopes melanostica* *Pleurogrammus monopterigius*
KM/KL	Euphausiids	?	*Pleurogrammus*
OKH	Euphausiids	?	?
CAS	Euphausiids	*Loligo opalescens*	*Engraulis mordax*
ETZ	*Lepus fascicularis*	*Ommastrephes bartrami*	*Cololabis saira*
WTZ	*Lepus fascicularis*	*Ommastrephes bartrami*	*Cololabis saira*
KR/OY	?	?	*Pleurogrammus monopterigius*
SJP	No Data	No Data	No Data
ECS	No Data	No Data	No Data

Table 6. Percent consumption by prey class, amounts consumed, and percent of energy demand within the better studied sub-regions.

Region	Zooplankton	Cephalopods	Fishes	Total mt•km^{-2} •summer^{-1}	% Total Energy Demand Represented
Eastern Bering Sea	50	2	47	1.09	98
Gulf ofAlaska	36	12	51	1.15	99
N. California Current	18	5	70	0.09	48
S. California Current	7	11	78	0.36	83
Eastern Transition Zone	18	63	18	0.01	67
Western Transition Zone	15	29	51	0.14	85

Table 7. Estimated total prey consumption (per 92 day summer) by marine birds in PICES sub-regions.

Sub-region	Assuming all Prey with an Energy Density of 7 kj•g^{-1}		Assuming all Prey with an Energy density of 3 kj•g^{-1}	
	Total Prey Consumption (× 1,000 mt)	Prey Consumption mt•km^{-2}	Total Prey Consumption (× 1,000 mt)	Prey Consumption mt•km^{-2}
BSC	656	0.64	1,530	1.50
BSP	333	0.25	777	0.57
ASK	316	0.74	738	1.72
CAN	22	0.13	51	0.31
ESA	99	0.03	230	0.06
WSA	250	0.12	583	0.27
KM/KL	Insufficient Data			
OKH	Insufficient Data			
CAS	39	0.30	90	0.70
ETZ	84	0.01	195	0.03
WTZ	712	0.11	1,662	0.26
KR/OY	Insufficient Data			
SJP	Insufficient Data			
ECS	Insufficient Data			

Table 8. Comparison of sooty and short-tailed shearwater populations in the Subarctic and Transition Zones of the North Pacific Ocean (Data from Appendix VI, Tables 6.3, 6.5, 6.6, 6.9, 6.10, and 6.11).

Sub-region				
Species	Western Subarctic	Eastern Subarctic	Gulf of Alaska	Total
Sooty shearwater	3,100,000	1,600,000	2,900,000	7,600,000
Short-tailed shearwater	430,000	220,000	6,100,000	6,750,000
	Western Transition Zone	Eastern Transition Zone	California Current South	Total
Sooty shearwater	20,500,000	360,000	330,000	21,190,000
Short-tailed shearwater	930,000	67,000	15,000	1,012,000
Total	24,960,000	2,247,000	9,345,000	36,552,000

Table 9. Marine mammal species in the western PICES sub-regions during summer.

Species	BSP	WSA	KMKL	OKH	WTZ	KROY	SJP	ECS
Northern fur seal	*	*	*	*	*	*	*	
Steller sea lion	*	*	*	*		*	*	
Bearded seal	*			*				
Harbor seal	*		*			*		
Ribbon seal	*			*				
Ringed seal	*			*				
Spotted seal	*			*		*	*	
Sea otter	*		*					
Blue whale	*	*	*		*	*		
Bowhead whale	*			*				
Bryde's whale					*	*		*
Fin whale	*	*	*	*	*	*	*	*
Gray whale			*	*				
Humpback whale	*	*	*	*				
Minke whale	*	*	*	*	*	*	*	*
Northern right whale	*	*	*	*	*	*		
Sei whale	*	*	*		*	*		
Baird's beaked whale			*	*		*	*	
Bottlenose dolphin					*	*	*	*
Commom dolphin					*	*	*	*
Dall's porpoise	*	*	*	*	*	*		
Dwarf sperm whale					*	*	*	*
False killer whale					*	*	*	*
Finless porpoise						*	*	*
Fraser's dolphin					*	*		
Harbor porpoise	*		*	*		*		
Killer whale	*	*	*	*	*	*	*	*
Northern right whale dolphin	?	*	*		*	*		
Pacific white-sided dolphin	?	*	*	*	*	*	*	*
Pygmy killer whale					*	*		
Pygmy sperm whale					*	*	*	*
Risso's dolphin					*	*	*	*
Short-finned pilot whale-N					*	*		
Short-finned pilot whale-S					*	*		*
Sperm whale	*	*	*		*	*		
Spotted dolphin					*	*		
Striped dolphin					*	*		
White whale				*				?
Ziphiids	*	*	*	*	*	*	*	*

Table 10. Ocean surface area, number of marine mammal species, and numbers and percentage of species with abundance estimates by PICES sub-region in the North Pacific Ocean during summer.

PICES sub-region	Code	Area (km^2)	Number of marine mammal species	Number of marine mammal species with abundance estimates	% species covered
Eastern Bering Sea Shelf	BSC	1,021,950	22	7	32
Western Bering Sea and Basin	BSP	1,357,655	20	6	30
Gulf of Alaska	ASK	428,520	18	5	28
California Current, North	CAN	166,456	16	4	25
Eastern Sub-Arctic	ESA	3,621,580	13	0	0
Western Sub-Arctic	WSA	2,168,315	14	1	7
Kamchatka and Kurile Islands	KM/KL	111,570	19	7	37
Sea of Okhotsk	OKH	1,599,225	19	11	58
California Current, South	CAS	128,620	30	17	57
Eastern Transition Zone	ETZ	7,808,530	27	6	22
Western Transition Zone	WTZ	6,337,700	27	11	41
Kuroshio/Oyashio Current Zone	KR/OY	348,455	33	6	18
Sea of Japan	SJP	1,006,455	16	2	13
East China Sea	ECS	435,235	14	0	0

Table 11. Summary of marine mammal species richness, density, biomass, and energy demand of marine mammals in PICES sub-regions during summer.

PICES sub-region	Number of marine mammal species	Number of marine mammal species estimated	Estimated abundance of marine mammals (number)	Marine mammal biomass during summer ($\times 10^3$ mt)	Marine mammal energy demand during summer ($\times 10^{10}$ kj)	Total prey consumption during summer ($\times 10^3$ mt)
BSC	22	7	Insufficient data			
BSP	20	6	494,000	5,778	166	487
ASK	18	5	Insufficient data			
CAN	16	4	Insufficient data			
ESA	13	0	Insufficient data			
WSA	14	1	2,323	5,248	60	180
KM/KL	19	7	3,724,341	38,427	1,559	4,029
OKH	19	11	1,178,269	27,865	468	1,325
CAS	30	17	Insufficient data			
ETZ	27	6	Insufficient data			
WTZ	27	11	4,619,545	121,417	2,904	6,395
KR/OY	33	6	114,513	8,978	190	533
SJP	16	2	3,500	2,022	25	70
ECS	14	0	Insufficient data			
TOTAL	162	44	10,136,491	209,735	5,372	13,019

Table 12. Percentage of marine mammal prey items western PICES sub-regions during summer.

Sub-region	Benthic invertebrates	Crustacean zooplankton	Squid			Fish				Birds and mammals	Total
			Small	Large	All squid	Small epipelagic	Meso-pelagic	Misc.	All fish		
BSP	14.5	31.3	7.1	6.6	13.7	13.4	2.9	21.8	38.2	2.4	100.0
WSA	2.7	36.9	10.4	10.4	20.8	10.4	7.7	18.1	36.2	3.5	100.0
KMKL	12.8	26.9	10.6	9.7	20.3	11.7	6.4	19.4	37.5	2.5	100.0
OKH	20.4	24.6	10.4	2.9	13.2	15.0	4.6	26.1	45.7	2.9	100.0
WTZ	1.8	16.4	19.2	15.6	34.8	11.2	14.8	18.6	44.6	2.4	100.0
KROY	3.7	15.0	19.5	14.4	33.9	12.4	11.0	21.9	45.3	2.1	100.0
SJP	5.7	10.4	21.1	15.0	36.1	12.9	7.5	24.3	44.6	3.2	100.0

Table 13a. Food consumption (× 10^3 mt) by marine mammals in western PICES sub-regions during summer.

Sub-region	Benthic invertebrates	Crustacean zooplankton	Squid			Fish				Birds and mammals	Total prey	%
			Small	Large	All squid	Epi-pelagic fishes	Meso-pelagic fishes	Misc.	All fish			
WTZ	122.7	106.4	1217.8	1299.3	2517.1	783.7	1603.2	1261.6	3648.4	0.0	6394.6	49.1
KMKL	201.4	72.9	1001.0	495.3	1496.4	556.9	869.8	831.0	2257.7	0.7	4029.1	30.9
OKH	305.0	356.0	213.1	2.8	215.9	162.3	158.3	127.0	447.7	0.0	1324.5	10.2
KROY	10.2	0.8	135.8	164.2	300.0	62.9	58.9	100.2	222.0	0.0	533.0	4.1
BSP	216.9	55.1	34.7	17.9	52.6	38.7	18.9	104.5	162.1	0.2	486.9	3.7
WSA	9.0	0.0	18.0	108.2	126.3	9.0	9.0	27.1	45.1	0.0	180.4	1.4
SJP	3.4	23.7	10.2	8.5	18.7	14.3	3.4	6.9	24.6	0.0	70.4	0.5
Total	868.6	614.8	2630.6	2096.2	4726.9	1627.8	2721.5	2458.2	6807.5	1.0	13018.7	100.0
%	6.7	4.7	20.2	16.1	36.3	12.5	20.9	18.9	52.3	0.0	100.0	

Table 13b. Percentage of food composition by marine mammals in western PICES sub-regions during summer.

Sub-region	Benthic invertebrates	Crustacean zooplankton	Squid			Fish				Birds and mammals	Total prey
			Small	Large	All squid	Epipelagic fish	Meso-pelagic fish	Misc.	All fish		
WTZ	2	2	19	20	39	12	25	20	57	0	100
KMKL	5	2	25	12	37	14	22	21	56	0	100
OKH	23	27	16	0	16	12	12	10	34	0	100
KROY	2	0	25	31	56	12	11	19	42	0	100
BSP	45	11	7	4	11	8	4	21	33	0	100
WSA	5	0	10	60	70	5	5	15	25	0	100
SJP	5	34	14	12	27	20	5	10	35	0	100
Total	7	5	20	16	36	13	21	19	52	0	100

Table 14. Comparison of abundance and density of main marine mammals (number•km^{-2} in PICES western sub-regions) during summer.

Sub-region	Otariid	Phocid	Minke whale	Dall's porpoise	Pacific white-sided dolphin	Sperm whale	Total number	Surface area(km^2)	Density (no./km^2)
BSP	201,500	292,500	?	?	?	?	494,000	1,357,655	0.360
OKH	57,500	336,800	19,209	554,000	?	-	967,509	1,599,225	0.600
KMKL, WSA, KROY, WTZ	240,100	3,400	5,841	1,925,000	1,050,818	20,588	3,245,747	8,966,040	0.360
SJP	?	?	1,900	?	?	-	1,900	1,006,455	0.002
Total	499,100	632,700	26,950	2,479,000	1,050,818	20,588	4,709,156	12,929,375	0.360
Density (no./km^2)	0.04	0.05	0.002	0.2	0.09	0.002	0.39		

8 APPENDICES

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Appendix 2. Marine birds of the pelagic North Pacific Ocean

(Data on weights from Dunning, 1993)

Common Name	Scientific Name	Mean Weight (g)	Daily Energy Needs (kj)
Short-tailed Albatross	*Phoebastria albatrus*	8,400.0	8,164.90
Black-footed Albatross	*Phoebastria nigripes*	3,148.0	4,000.10
Laysan Albatross	*Phoebastria immutabilis*	3,041.5	3,901.26
Northern Fulmar	*Fulmarus glacialis*	544.0	1,116.30
Phoenix Petrel	*Pterodroma alba*	272.0	674.42
Mottled Petrel	*Pterodroma inexpectata*	316.0	752.09
Solander's Petrel	*Pterodroma solandri*	?	?
Murphy's Petrel	*Pterodroma ultima*	360.0	826.86
Kermadec Petrel	*Pterodroma neglecta*	?	?
Herald Petrel	*Pterodroma arminjoniana*	161.0	460.64
Tahiti Petrel	*Pterodroma rostrata*	?	?
Dark-rumped Petrel	*Pterodroma phaeopygia*	434.0	947.23
Juan Fernandez Petrel	*Pterodroma externa*	?	?
Cook's Petrel	*Pterodroma cookii*	178.5	496.52
Bonin Petrel	*Pterodroma hypoleuca*	176.0	491.46
Black-winged Petrel	*Pterodroma nigripennis*	?	?
Stejneger's Petrel	*Pterodroma longirostris*	?	?
Pycroft's Petrel	*Pterodroma longirostris pycrofti*	153.0	443.89
Bulwer's Petrel	*Bulweria bulwerii*	99.0	323.46
Streaked Shearwater	*Calonectris leucomelas*	?	?
Pink-footed Shearwater	*Puffinus creatopus*	721.0	1,369.99
Flesh-footed Shearwater	*Puffinus carneipes*	568.0	1,151.89
Wedge-tailed Shearwater	*Puffinus pacificus*	388.0	873.13
Buller's Shearwater	*Puffinus bulleri*	380.0	860.01
Sooty Shearwater	*Puffinus griseus*	787.0	1,460.07
Short-tailed Shearwater	*Puffinus tenuirostris*	543.0	1,114.81
Manx/Newell's Shearwater	*Puffinus puffinus*	?	?
Townsend's Shearwater	*Puffinus auricularis*	323.0	764.17
Black-vented Shearwater	*Puffinus opisthomelas*	276.0	681.62
Audubon's Shearwater	*Puffinus lherminieri*	168.0	475.12
Wilson's Storm-Petrel	*Oceanites oceanicus*	32.0	142.31
Band-rumped Storm-Petrel	*Oceanodroma castro*	41.8	172.82
Swinhoe's Storm-Petrel	*Oceanodroma monorhis*	35.8	154.41
Leach's Storm-Petrel	*Oceanodroma leucorhoa*	39.8	166.77
Tristram's Storm-Petrel	*Oceanodroma tristrami*	84.0	287.05
Matsudaira's Storm-Petrel	*Oceanodroma matsudairae*	?	?
Fork-tailed Storm-Petrel	*Oceanodroma furcata*	55.3	211.82
Black Storm-Petrel	*Oceanodroma melania*	59.0	222.03
Ashy Storm-Petrel	*Oceanodroma homochroa*	36.9	157.84
Least Storm-Petrel	*Oceanodroma microsoma*	20.5	102.95
Magnificent Frigatebird	*Fregata magnificens*	1,474.0	2,304.08
Great Frigatebird	*Fregata minor*	1,055.0	1,806.78
Lesser Frigatebird	*Fregata ariel*	806.0	1,485.61
Red-tailed Tropicbird	*Phaethon rubricauda*	624.0	1,233.39

Appendix 2 continued

Common Name	Scientific Name	Mean Weight (g)	Daily Energy Needs (kj)
Red-billed Tropicbird	*Phaethon aethereus*	750.0	1,409.84
White-tailed Tropicbird	*Phaethon lepturus*	334.0	783.00
American White Pelican	*Pelecanus erythrorhynchos*	7,000.0	7,151.32
Brown Pelican	*Pelecanus occidentalis*	3,438.0	4,264.76
Red-footed Booby	*Sula sula*	1,003.0	1,741.59
Masked Booby	*Sula dactylatra*	1,987.5	2,863.32
Brown Booby	*Sula leucogaster*	1,237.5	2,028.99
Great Cormorant	*Phalacrocorax carbo*	2,109.5	2,990.05
Temminck's Cormorant	*Phalacrocorax capillatus*	?	?
Javanese Cormorant	*Phalacrocorax niger*	?	?
Double-crested Cormorant	*Phalacrocorax auritus*	1,674.0	2,527.38
Red-faced Cormorant	*Phalacrocorax urile*	2,157.0	3,038.85
Pelagic Cormorant	*Phalacrocorax pelagicus*	1,868.0	2,737.10
Brandt's Cormorant	*Phalacrocorax penicillatus*	2,103.0	2,983.35
Red Phalarope	*Phalaropus fulicaria*	55.7	212.79
Red-necked Phalarope	*Phalaropus lobatus*	33.8	148.09
Wilson's Phalarope	*Phalaropus tricolor*	60.0	224.62
South Polar Skua	*Catharacta maccormicki*	1,156.0	1,930.95
Pomarine Jaeger	*Stercorarius pomarinus*	694.0	1,332.50
Parasitic Jaeger	*Stercorarius parasiticus*	464.5	995.17
Long-tailed Jaeger	*Stercorarius longicaudus*	296.5	718.06
Glaucous Gull	*Larus hyperboreus*	1,412.5	2,233.79
Herring Gull	*Larus argentatus*	1,135.0	1,905.38
Thayer's Gull	*Larus thayeri*	996.0	1,732.74
Glaucous-winged Gull	*Larus glaucescens*	1,010.0	1,750.42
Slaty-backed Gull	*Larus schistisagus*	1,327.0	2,134.65
Mew Gull	*Larus canus*	403.5	898.36
Western Gull	*Larus occidentalis*	1,011.0	1,751.68
Black-headed Gull	*Larus ridibundus*	284.0	695.92
Yellow-footed Gull	*Larus livens*	1,322.0	2,128.80
Franklin's Gull	*Larus pipixcan*	280.0	688.79
Ring-billed Gull	*Larus delawarensis*	518.5	1,078.01
Little Gull	*Larus minutus*	118.0	367.50
Indian Black-headed Gull	*Larus brunnicephalus*	?	?
Chinese Black-headed Gull	*Larus saundersi*	?	?
Black-tailed Gull	*Larus crassirostris*	533.5	1,100.59
California Gull	*Larus californicus*	606.5	1,208.14
Heerman's Gull	*Larus heermanni*	500.0	1,049.91
Bonaparte's Gull	*Larus philadelphia*	281.0	690.57
Black-legged Kittiwake	*Rissa tridactyla*	407.0	904.01
Red-legged Kittiwake	*Rissa brevirostris*	391.0	878.04
Ivory Gull	*Pagophila eburnea*	616.0	1,221.87
Sabine's Gull	*Xema sabini*	191.0	521.57
Ross's Gull	*Rhodostethia rosea*	187.0	513.60
Aleutian Tern	*Sterna aleutica*	120.0	372.02
Arctic Tern	*Sterna paradisaea*	110.0	349.21

Appendix 2 continued

Common Name	Scientific Name	Mean Weight (g)	Daily Energy Needs (kj)
Common Tern	*Sterna hirundo*	120.0	372.02
Forster's Tern	*Sterna forsteri*	158.0	454.38
Gray-backed Tern	*Sterna lunata*	146.0	429.03
Gull-billed Tern	*Sterna nilotica*	170.0	479.22
Black-napped Tern	*Sterna sumatrana*	100.0	325.84
Bridled Tern	*Sterna anaethetus*	95.6	315.35
Elegant Tern	*Sterna elegans*	257.0	647.17
Royal Tern	*Sterna maxima*	470.0	1,003.73
Caspian Tern	*Sterna caspia*	655.0	1,277.64
Roseate Tern	*Sterna dougallii*	110.0	349.21
Chinese Crested Tern	*Sterna bernsteini*	?	?
Lesser Crested Tern	*Sterna bengalensis*	204.0	547.14
Crested Tern	*Sterna bergii*	342.0	796.59
Sooty Tern	*Sterna fuscata*	180.0	499.55
Least Tern	*Sterna antillarum*	43.1	176.71
Little Tern	*Sterna albifrons*	57.0	216.53
Whiskered Tern	*Chlidonias hybridus*	88.2	297.41
White-winged Black Tern	*Chlidonias leucopterus*	54.2	208.75
White Tern	*Gygis alba*	111.0	351.52
Black Noddy	*Anous minutus*	119.0	369.76
Brown Noddy	*Anous stolidus*	198.0	535.40
Blue-gray Noddy	*Procelsterna cerulea*	53.0	205.38
Dovekie	*Alle alle*	163.0	464.79
Pigeon Guillemot	*Cepphus columba*	487.0	1,029.99
Spectacled Guillemot	*Cepphus carbo*	490.0	1,034.60
Thick-billed Murre	*Uria lomvia*	964.0	1,692.09
Common Murre	*Uria aalge*	992.5	1,728.32
Marbled Murrelet	*Brachyramphus marmoratus*	222.0	581.83
Kittlitz's Murrelet	*Brachyramphus brevirostris*	224.0	585.64
Long-billed Murrelet	*Brachyramphus perdix*	?	?
Ancient Murrelet	*Synthliboramphus antiquus*	206.0	551.04
Japanese Murrelet	*Synthliboramphus wumizusume*	?	?
Xantus' Murrelet	*Synthliboramphus hypoleucus*	167.0	473.06
Craveri's Murrelet	*Synthliboramphus craveri*	151.0	439.66
Cassin's Auklet	*Ptychoramphus aleuticus*	188.0	515.60
Parakeet Auklet	*Aethia psittacula*	258.0	649.00
Whiskered Auklet	*Aethia pygmaea*	121.0	374.27
Crested Auklet	*Aethia cristatella*	264.0	659.94
Least Auklet	*Aethia pusilla*	84.0	287.05
Rhinoceros Auklet	*Cerorhinca monocerata*	520.0	1,080.28
Horned Puffin	*Fratercula corniculata*	619.0	1,226.19
Tufted Puffin	*Fratercula cirrhata*	779.0	1,449.26

Appendix 2 continued

Common Name	Scientific Name	Mean Weight (g)	Daily Energy Needs (kj)
Common Loon	*Gavia immer*	4,134.0	4,876.42
Yellow-billed Loon	*Gavia adamsii*	5,500.0	6,001.28
Pacific Loon	*Gavia pacifica*	1,659.0	2,510.89
Arctic Loon	*Gavia arctica*	3,355.0	4,189.66
Red-throated Loon	*Gavia stellata*	1,551.0	2,390.97
Western Grebe	*Aechmophorus occidentalis*	1,477.0	2,307.49
Great-crested Grebe	*Podiceps cristatus*	738.0	1,393.40
Red-necked Grebe	*Podiceps grisegena*	1,023.0	1,766.77
Horned Grebe	*Podiceps auritus*	453.0	977.20
Eared Grebe	*Podiceps nigricollis*	292.0	710.12
Little Grebe	*Tachybaptus ruficollis*	201.0	541.28
Tundra Swan	*Cygnus columbianus*	6,650.0	6,889.56
Whooper Swan	*Cygnus cygnus*	9,350.0	8,826.33
Trumpeter Swan	*Cygnus buccinator*	10,850.0	9,834.62
Greater White-fronted Goose	*Anser albifrons*	2,579.5	3,460.88
Bean Goose	*Anser fabalis*	2,521.0	3,403.64
Snow Goose	*Chen caerulescens*	2,630.5	3,510.49
Ross' Goose	*Chen rossii*	1,589.5	2,433.98
Emperor Goose	*Chen canagica*	2,743.0	3,619.01
Brant	*Branta bernicla*	1,300.0	2,102.99
Canada Goose	*Branta canadensis*	?	?
Wood Duck	*Aix sponsa*	658.0	1,281.89
Mandarin Duck	*Aix galericulata*	570.0	1,154.84
Green-winged Teal	*Anas crecca*	341.0	794.90
American Black Duck	*Anas rubripes*	1,250.0	2,043.87
Mallard	*Anas platyrhynchos*	1,082.0	1,840.28
Spot-billed Duck	*Anas poecilorhyncha*	1,000.0	1,737.80
Northern Pintail	*Anas acuta*	1,010.5	1,751.05
Garganey	*Anas querquedula*	326.0	769.32
Baikal Teal	*Anas formosa*	550.0	1,125.24
Falcated Teal	*Anas falcata*	649.0	1,269.12
Blue-winged Teal	*Anas discors*	386.0	869.86
Cinnamon Teal	*Anas cyanoptera*	385.5	869.04
Northern Shoveler	*Anas clypeata*	613.0	1,217.54
Gadwall	*Anas strepera*	919.5	1,634.94
Eurasian Wigeon	*Anas penelope*	771.5	1,439.11
American Wigeon	*Anas americana*	755.5	1,417.35
Canvasback	*Aythya valisineria*	1,219.0	2,006.90
Redhead	*Aythya americana*	1,045.0	1,794.31
Common Pochard	*Aythya ferina*	823.0	1,508.33
Ring-necked Duck	*Aythya collaris*	705.0	1,347.82
Tufted Duck	*Aythya fuligula*	694.0	1,332.50
Greater Scaup	*Aythya marila*	944.5	1,667.14
Lesser Scaup	*Aythya affinis*	820.0	1,504.33
Common Eider	*Somateria mollissima*	2,063.5	2,942.51

Appendix 2 continued

Common Name	Scientific Name	Mean Weight (g)	Daily Energy Needs (kj)
King Eider	*Somateria spectabilis*	6,617.5	6,865.06
Spectacled Eider	*Somateria fischeri*	1,368.0	2,182.40
Steller's Eider	*Polysticta stelleri*	807.5	1,487.62
Harlequin Duck	*Histrionicus histrionicus*	622.5	1,231.23
Oldsquaw	*Clangula hyemalis*	873.0	1,574.41
Black Scoter	*Melanitta nigra*	950.0	1,674.19
Surf Scoter	*Melanitta perspicillata*	950.0	1,674.19
White-winged Scoter	*Melanitta fusca*	1,757.0	2,617.88
Common Goldeneye	*Bucephala clangula*	900.0	1,609.66
Barrow's Goldeneye	*Bucephala islandica*	910.0	1,622.64
Bufflehead	*Bucephala albeola*	403.5	898.36
Smew	*Mergellus albellus*	610.0	1,213.21
Hooded Merganser	*Lophodytes cucullatus*	610.0	1,213.21
Common Merganser	*Mergus merganser*	1,470.5	2,300.10
Red-breasted Merganser	*Mergus serrator*	1,021.5	1,764.88
Chinese Merganser	*Mergus squamatus*	?	?
Ruddy Duck	*Oxyura jamaicensis*	?	?

Appendix 3. Seabirds as predators of marine organisms: prey captured within PICES sub-regions. The following codes were used in the table: + = < 15% of diet, ++ = 15-33% of diet, +++ = >33% of diet, L = Loons only, C = Cormorants only, CL = Cormorants and Loons, W = Waterfowl only, 0 = offal from fishing boats only, MG = mew gull only, G = gull only, BG = Bonaparte's gull, only, MB = mew and Bonaparte's gulls.

PHYLUM CLASS FAMILY SPECIES	PICES SUB-REGION ECS	SJP	OKH	KR/OY	KM/KL	BSP	BSC	ASK	CAN	CAS	WSA	ESA	WTZ	ETZ
PLANTS														
Unidentified Plants	-	-	-	-	-	+	-	+	-	-	-	-	-	-
Unidentified Seeds	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Emptrum nigrum	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Algae														
Unidentified Algae	-	-	-	-	-	+	-	-	+MG	+	-	-	-	-
Calcareous Algae	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Unidentified Monostroma	-	-	-	-	-	-	-	-	+MG	-	-	-	-	-
Ulva spp.	-	-	-	-	-	-	-	-	+MG	-	-	-	-	-
Ectocarpus spp.	-	-	-	-	-	-	-	-	+MG	-	-	-	-	-
Porphyra spp.	-	-	-	-	-	-	-	-	+MG	-	-	-	-	-
CNIDARIA														
Hydrozoa														
Unidentified Hydrozoa	-	-	-	-	-	-	-	-	-	+	+	-	-	-
Velellidae														
Velella sp.	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Velella velella	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Velella lata	-	-	-	+	-	-	-	-	-	-	-	-	+	-
Thecate Hydrozoan	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Scyphozoa														
Unidentified Scyphomedusae	-	-	-	-	+	-	++	-	+	-	+	-	-	-
ANNELIDA														
Polychaeta														
Unidentified Polychaeta	-	-	-	-	-	-	+	-	-	+	-	-	-	-
Nereidae														
Unidentified Nereidae	-	-	-	-	-	-	+	+	-	+BG	-	-	-	-
MOLLUSCA														
Unidentified Mollusca	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Monoplacophora	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Neopolina sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polyplacophora	-	-	-	-	-	++	-	+	-	-	-	-	-	-

Unidentified Chiton	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Katherina tunicata	-	-	-	-	-	++	-	+	-	-	-	-	-	-
Mopalia spp.	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Gastropoda														
Unidentified Gastropod	-	-	-	-	-	+	-	+	-	+	-	-	-	-

PHYLUM CLASS FAMILY SPECIES	ECS	SJP	OKH	KR/OY	KM/KL	BSP	BSC	ASK	CAN	CAS	WSA	ESA	WTZ	ETZ
						PICES SUB-REGION								
Unidentified Veliger Larvae	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Archeogastropod														
Acmaea sp.	-	-	-	-	-	+	-	+	-	-	-	-	-	-
Mesogastropoda														
Littorina spp.	-	-	-	-	-	+	-	-	+MG	-	-	-	-	-
Carinaria sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Fusitriton sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Janthina sp.	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Janthina sp. eggs	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Janthina pallida	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Thecosomata														
Unidentified Thecosomata	-	-	-	-	-	+	+	-	-	-	+	-	-	-
Unidentified Pteropod	-	-	-	-	+	+	+	-	-	+	+?	-	-	-
Cavolinia globulosa	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Limacina sp.	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Limacina helicina	-	-	-	-	-	-	-	+	-	-	+	-	+?	-
Gymnosomata														
Clione sp.	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Clione limacina	-	-	-	-	+	-	-	-	-	-	-	-	-	-
Bassommatophora														
Unidentified Snails	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Collisella pelta	-	-	-	-	-	++	-	-	-	-	-	-	-	-
Notoacmaea scutum	-	-	-	-	-	++	-	-	-	-	-	-	-	-
Bivalvia														
Unidentified Bivalvia	-	+	-	-	-	+	-	+	-	-	-	-	-	-
Filibranchia														
Mytilus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mytilus edulis	-	-	-	-	-	++	-	+	+G	-	-	-	-	-
Mytilus californianus	-	-	-	-	-	-	-	-	+G	-	-	-	-	-
Cephalopoda														
Unidentified Cephalopoda	-	-	-	-	-	++	++	+++	+	+++	-	-	-	-
Unidentified Cephalopoda														

juveniles	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified Cephalopoda larvae	-	-	-	-	-	+	+	-	-	-	-	-	-	-
Coleoidea														
Unidentified Teuthoidea	-	-	-	++	-	+	+++	-	+	+	+++	-	-	+
Unidentified Teuthoidea juveniles	-	-	-	-	+++	-	-	+++	-	-	+	-	+	++
Unidentified Teuthoidea larvae	-	-	-	-	-	-	-	++	-	-	-	-	-	-

PHYLUM / CLASS / FAMILY / SPECIES	PICES SUB-REGION													
	ECS	SJP	OKH	KR/OY	KM/KL	BSP	BSC	ASK	CAN	CAS	WSA	ESA	WTZ	ETZ
Architeuthidae														
Architeuthis sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Ommastrephidae														
Unidentified Ommastrephidae	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Ommastrephes bartrami	-	-	-	-	-	-	-	-	-	-	-	-	+++	+++
Onychoteuthidae														
Unidentified Onychoteuthidae	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Onychoteuthis spp.	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Onychoteuthis borealijaponicus	-	-	-	-	-	-	-	+	-	+	-	-	+	+
Onychoteuthis banksii	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Gonatidae														
Unidentified Gonatidae	-	-	-	-	-	+	-	+	-	-	+	-	+	-
Unidentified Gonatidae Larvae	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Gonatopsis sp.	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Gonatopsis borealis	-	-	-	-	-	-	-	-	-	-	+	-	+	+
Berryteuthis anonychus	-	-	-	-	-	+	-	-	+	-	+	-	++	+
Berryteuthis magister	-	-	-	-	-	-	-	-	-	-	+	-	+	-
Gonatus spp.	-	-	-	-	-	+	-	-	-	++	+	-	+	+
Gonatus sp. c.f. G. berryi	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Gonatus sp. c.f. G. pyros	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Gonatus pyros	-	-	-	-	-	-	-	-	+?	-	-	-	-	-
Gonatus middendorfi	-	-	-	-	-	-	-	++	-	-	-	-	-	-
Enoploteuthidae														
Abraliopsis felis	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Octopoteuthidae														
Unidentified Octopoteuthidae	-	-	-	-	-	-	-	-	-	+	-	-	+	+

Octopoteuthis sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Octopoteuthis deletron	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Histioteuthidae														
Histioteuthis sp.	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Histioteuthis doffeini	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Histioteuthis heteropsis	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Mastigoteuthida														
Mastigoteuthis sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Chiroteuthidae														
Chiroteuthis calyx	-	-	-	-	-	-	-	-	+?	-	-	-	+	+
Chiroteuthis sp.	-	-	-	-	-	-	-	-	-	-	+	-	-	+
Cranchiidae														
Leachia dislocata	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Megalocranchia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Taonius sp.	-	-	-	-	-	-	-	-	-	-	-	-	+	+

PHYLUM CLASS FAMILY SPECIES	ECS	SJP	OKH	KR/OY	KM/KL	BSP	BSC	PICES SUB-REGION ASK	CAN	CAS	WSA	ESA	WTZ	ETZ
Taonius pavo	-	-	-	-	-	-	-	-	+?	-	-	-	+	+
Galiteuthis sp.	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Galiteuthis phyllura	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Loliginidae														
Loligo opalescens	-	-	-	-	-	-	-	-	+	+++	-	-	-	-
Vampyroteuthida														
Vampyroteuthis infernalis	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Octopodidae														
Unidentified Octopodidae	-	-	-	-	-	-	-	+	+	-	-	-	-	-
Octopus spp.	-	-	-	-	-	-	-	++	-	+	-	-	-	-
Octopus rubescens	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Ocythoidae														
Ocythoe tuberculata	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Alloposidae														
Allopsus mollis	-	-	-	-	-	-	-	-	-	-	-	-	-	+
ARTHROPODA														
Crustacea														
Unidentified Crustacea	-	-	-	-	-	-	+	+	-	+	-	-	-	-
Unidentified Crustacea Larvae	-	-	-	-	-	-	+	-	-	+	-	-	-	-
Copepoda														
Unidentified Copepoda	-	-	-	-	-	++	+	+++	-	-	+	-	-	-
Calanoid Copepods	-	-	-	-	-	-	-	+++	-	-	-	-	-	-

Epilabidocera longipedata	-	-	-	-	-	-	-	-	+BG	-	-	-	-	-
Neocalanus plumchrus	-	-	-	-	-	+++	+++	-	+	-	-	-	-	-
Neocalanus cristatus	-	-	-	-	-	+++	+	-	+++	-	-	-	-	-
Calanus cristatus	-	-	-	-	-	-	+	-	+++	-	+	-	-	-
Calanus sp.	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Calanus marshallae	-	-	-	-	-	-	+	-	+	-	-	-	-	-
Calanus pacificus	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Calanus finmarchicus	-	-	-	-	-	-	+++	-	-	-	-	-	-	-
Calanus plumchrus	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Eucalanus bungii	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Pseudocalanus elongatus	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Bathycalanus bradyi	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Metridia pacifica	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Metridia sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Cirripedea														
Unidentified Barnacle	-	-	-	-	-	-	-	+	+MG	-	+?	-	-	-
Cirriped cypris	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Lepas sp.	-	-	-	-	-	-	-	-	-	-	-	-	+++	++
Lepas sp. cyprids	-	-	-	-	-	-	-	-	-	-	-	-	+++	+++
Lepas fascicularis	-	-	-	-	-	-	-	-	-	-	-	-	+	+++

PHYLUM CLASS FAMILY SPECIES	PICES SUB-REGION ECS	SJP	OKH	KR/OY	KM/KL	BSP	BSC	ASK	CAN	CAS	WSA	ESA	WTZ	ETZ
Lepas anatifera	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Polliceps polymerus	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Balanus glandula	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Balanus cariosus	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Malacostraca														
Unidentified Nebaliidae	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Unidentified Mysidacea	-	-	-	+	-	-	+	+	+BG	-	+	-	+	-
Acanthomysis sp.	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Neomysis rayii	-	-	-	-	-	-	-	+++	-	-	-	-	-	-
Diastylis bidentata	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Lamprops sp.	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Unidentified Isopoda	-	-	-	-	-	-	+	+	+MG	-	-	-	-	-
Ligia Isopods	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Lironeca vulgaris	-	-	-	-	-	-	-	-	-	+C	-	-	-	-
Unidentified Cymothoidae	-	-	-	-	-	-	-	-	-	+C	-	-	-	-
Cirolana californiensis	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Anuropus bathypelagicus	-	-	-	-	-	-	-	-	-	-	-	-	-	+

PHYLUM CLASS FAMILY								PICES SUB-REGION						
SPECIES	ECS	SJP	OKH	KR/OY	KM/KL	BSP	BSC	ASK	CAN	CAS	WSA	ESA	WTZ	ETZ
Idotea metallica	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Unidentified Amphipoda	-	-	-	+	+	+	++	+	+	+BG	+	-	+	+
Euthemisto libellula	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Calliopius laeviusculus	-	-	-	-	-	-	-	-	+MB	-	-	-	-	-
Cyphocaris challengeri	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Amphitoe dalli	-	-	-	-	-	-	-	-	+MG	-	-	-	-	-
Unidentified Hyperiid Amphipods	-	-	-	-	-	-	++	+	+	+	-	-	-	-
Parathemisto spp.	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Parathemisto pacifica adults	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Parathemisto pacifica juveniles	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Parathemisto pacifica	-	-	-	-	-	+++	+	-	+	-	-	-	-	-
Parathemisto japonica	-	-	-	-	-	-	-	+	-	-	+	-	-	-
Parathemisto libellula	-	-	-	-	-	+	+++	-	-	-	-	-	-	-
Vibilia sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Vibilia propingua	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Primno macropa	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Paratylus sp.	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Hyperia sp.	-	-	-	-	+	-	-	-	+	-	-	-	-	-
Hyperia galba	-	-	-	-	+	+	+	-	-	-	+	-	-	-
Hyperia medusarum	-	-	-	-	-	-	+	-	+	-	-	-	-	-
Hyperoche sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Hyperoche medusarum	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Phronema sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Phronema sedentaria	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Paraphromina sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Calliopius sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Mephidippa sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Brachycelus sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Caligus sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Euprimno malcropa	-	-	-	-	-	-	-	-	+BG	-	-	-	-	-
Unidentified Lysianassidae	-	-	-	-	-	+	-	-	-	-	+	-	-	-
Unidentified Gammaridea	-	-	-	-	-	+	+	+	+?	-	+	-	-	+
Unidentified Atylus	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Unidentified Pontogeneia	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Unidentified Anonyx	-	-	-	-	-	-	+	-	-	-	-	-	-	-

PHYLUM CLASS FAMILY SPECIES	ECS	SJP	OKH	KR/OY	KM/KL	BSP	BSC	ASK	CAN	CAS	WSA	ESA	WTZ	ETZ
Unidentified Monoculodes	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Unidentified Orchomenella	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Paracallisoma alberti	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Paracallisoma coecus	-	-	-	-	-	-	-	-	+++	-	-	-	-	-
Cyphocaris challengeri	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Amphitoe dalli	-	-	-	-	-	-	-	-	+?	-	-	-	-	-
Unidentified Eucarida	-	-	-	-	-	-	+C	-	-	-	-	-	-	-
Unidentified Euphausiacea	-	-	+++	+	+++	++	+++	+++	+++	++	++	-	+	-
Thysanoessa spp.	-	-	-	-	-	-	-	-	++	-	-	-	-	-
Thysanoessa raschii	-	-	+	-	-	+++	++	++	++	-	-	-	-	-
Thysanoessa spinifera adults	-	-	-	-	-	-	-	-	+++	-	-	-	-	-
T. spinifera juveniles	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Thysanoessa spinifera	-	-	-	-	-	+	-	++	+++	+++	-	-	-	-
Thysanoessa inermis	-	-	-	-	++	+	++	++	-	-	-	-	-	-
Thysanoessa longipes adults	-	-	-	-	-	-	-	-	++	-	-	-	-	-
T. longipes juveniles	-	-	-	-	-	-	-	-	++	-	-	-	-	-
Thysanoessa longipes	-	-	-	-	+	+	+	+	+	+	++	-	-	-
Euphausia pacifica	-	-	-	-	-	-	-	-	+++	++	-	-	+	-
Euphausia sp.	-	-	-	-	-	-	-	-	-	+BG	-	-	-	-
Nematocelis difficilis	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Unidentified Decapoda	-	-	-	-	-	++	++C	+	+	-	-	-	-	-
Unidentified Decapoda Larvae	-	-	+	-	-	+	+	-	-	-	-	-	-	-
Unidentified Decapoda Megalops	-	-	-	-	-	-	-	-	-	++BG	-	-	-	-
Unidentified Crabs	-	-	-	-	-	+	++C	+	-	-	-	-	-	-
Balanus spp.	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Cancer sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Unidentified Paguridea	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Pagurus sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Unidentified Brachyura	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Unidentified Brachyura Larvae	-	-	-	-	-	-	+	-	+	+	-	-	-	-
Unidentified Brychyruan Zoea	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Tesmesus sp.	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Planes minmutus	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Blepharipoda occidentalis	-	-	-	-	-	-	-	-	-	+G	-	-	-	-
Erimacrus isenbeckii	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Unidentified Oplophoridae	-	-	-	-	-	-	-	-	-	-	-	-	+	+

PICES SUB-REGION

Unidentified Shrimp	-	-	-	-	-	+	++C	+	+	-	+?	-	+	+
Unidentified Eualid Shrimp	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Eualus sp.	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Crangon spp.	-	-	-	-	-	-	-	+	+	-	-	-	-	-
Crangon franciscorum	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Unidentified Caridea	-	-	-	-	-	+	+	-	++	-	-	-	-	-
Unidentified Caridea Larvae	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Unidentified Pandalidoidea	-	-	-	-	-	-	-	+	+	-	-	-	-	-
Pandalidae larvae	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Pandalus spp.	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Pandalus platyceros	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Pandalus borealis	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Pandalus goniuris	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Pandalopsis dispar	-	-	-	-	-	-	-	-	++	-	-	-	-	-
Pasiphaea pacifica	-	-	-	-	-	-	-	-	+	+	-	-	-	-
Pangurid Larvae	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Unidentified Crab Megalopae	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Telmesus chieragonus	-	-	-	-	-	+	-	+	-	-	-	-	-	-
Unidentified Lithodidae	-	-	-	-	-	+	-	-	-	-	-	-	-	+
Orchomere obtusa	-	-	-	-	-	-	-	-	+?	+G	-	-	-	-
Hayle sp.	-	-	-	-	-	-	-	-	+?	+BG	-	-	-	-
Idothea resecata	-	-	-	-	-	-	-	-	-	+BG	-	-	-	-
Idothea fewkesi	-	-	-	-	-	-	-	-	-	+BG	-	-	-	-
Insecta														
Unidentified Insects	-	-	-	-	-	+	+	+	-	+	+	-	-	-
Unidentified maggots	-	-	-	-	-	-	-	-	-	+BG	-	-	-	-
Unidentified Pupae	-	-	-	-	-	-	-	-	-	+BG	-	-	-	-
Unidentified Coleoptera	-	-	-	-	-	-	-	-	+MB	+	-	-	-	-
Unidentified Halipid Coleopteran	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Unidentified Diptera	-	-	-	-	-	-	-	-	+BG	-	-	-	-	-
Unidentified Diptera larvae	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Unidentified Hemiptera	-	-	-	-	-	-	-	-	+BG	-	-	-	-	-
Unidentified Hemoptera	-	-	-	-	-	-	-	-	+BG	-	-	-	-	-
Unidentified Hymenoptera	-	-	-	-	-	-	-	-	+BG	-	-	-	-	-

PHYLUM CLASS FAMILY SPECIES	ECS	SJP	OKH	KR/OY	KM/KL	BSP	BSC	ASK	CAN	CAS	WSA	ESA	WTZ	ETZ
	PICES SUB-REGION													
Unidentified Lepidoptera	-	-	-	-	-	-	-	-	+BG	-	-	-	-	-
Unidentified Neuroptera	-	-	-	-	-	-	-	-	+BG	-	-	-	-	-

Unidentified Mallophaga	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Unidentified Formicidae	-	-	-	-	-	-	-	-	-	-	-	-	-	+
ECHINODERMATA														
Stelleroidea														
Asteroidea														
Leptasterias hexactus	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Echinoidea														
Unidentified Echinoidea	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Strongylocentrotus spp.	-	-	-	-	-	-	-	+	-	-	-	-	-	-
S. polyacanthus	-	-	-	-	-	+++	-	-	-	-	-	-	-	-
Unidentified Sea Urchins	-	-	-	-	-	-	-	+	-	-	-	-	-	-
CHAETOGNATHA														
Unidentified Chaetognatha	-	-	-	-	-	+	+	-	-	-	-	-	-	-
CHORDATA														
Pices														
** Atherinops affinis	-	-	-	-	-	-	-	-	-	+	-	-	-	-
** Perciformes	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Unidentified Fish	-	-	+++	+++	+++	+++	+++	-	+++	+++	+++	-	++	-
Unidentified Fish Juvenile	-	-	-	-	+++	-	-	-	-	-	+?	-	-	-
Unidentified Fish Larvae	-	-	-	+	+	-	-	-	-	-	+	-	-	-
Unidentified Fish eggs	-	-	-	-	-	-	-	-	+	++	-	-	-	-
Petromyzontidae														
Unidentified Lamprey	-	-	-	-	-	-	-	-	+G	-	-	-	-	-
Lampetra japonica	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Chimeridae														
Hydrolagus colliei	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Carcharhinidae														
Prionace glauca	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Osteichthyes														
Clupeidae														
Unidentified Clupeidae	-	-	-	-	-	-	-	-	-	+++	-	-	-	-
Clupea harengus	-	-	-	-	-	-	+	++	+++	+	-	-	-	-
Herring eggs	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Sardinops melanosticta	-	-	-	++	-	-	-	-	-	-	++	-	+	-
Sardinops sagax	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Engraulidae														
Unidentified Engraulidae	-	-	-	-	-	-	-	-	++	+++	-	-	-	-
Engraulis mordax	-	-	-	-	-	-	-	-	++	+++	-	-	-	-
Engraulis larvae	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Engraulis japonica	-	+	-	-	-	-	-	-	-	-	-	-	++	-
PHYLUM														

CLASS FAMILY								PICES SUB-REGION						
SPECIES	ECS	SJP	OKH	KR/OY	KM/KL	BSP	BSC	ASK	CAN	CAS	WSA	ESA	WTZ	ETZ
Argentinidae														
Nansenia candida	-	-	-	-	-	-	-	-	+++	-	-	-	-	-
Bathylagidae														
Leuroglossus schmidti	-	-	-	-	-	-	-	-	-	-	+?	-	+	-
Leuroglossus stilbius	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Bathylagus sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	+
Osmeridae														
Unidentified Osmeridae	-	-	-	-	-	-	-	+	+	++	-	-	-	-
Unidentified Osmeridae Larvae	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Allosmerus elongatus	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Mallotus villosus	-	-	-	-	-	-	++	+++	++	-	-	-	-	-
Mallotus villosus post-larvae	-	-	-	-	-	-	-	+++	-	-	-	-	-	-
Mallotus villosus juvenile	-	-	-	-	-	-	-	+++	-	-	-	-	-	-
Hypomesus pretiosus	-	-	-	-	-	-	-	+	+	-	-	-	-	-
Thaleichthys pacificus	-	-	-	-	-	-	-	-	+	+	-	-	-	-
Spirinchus starski	-	-	-	-	-	-	-	-	++	-	-	-	-	-
Salmonidae														
Unidentified Salmonidae	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Unidentified Salmonidae eggs	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Oncorhynchus keta	-	-	-	-	-	-	-	+	++	-	-	-	-	-
Oncorhynchus kisutch	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Oncorhynchus nerka	-	-	-	-	-	-	-	+	+++	-	-	-	-	-
Paralepidae														
Lestidium sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-
?Lestidium ringens	-	-	-	-	-	-	-	-	+?	-	-	-	-	-
Paralepis atlantica	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Alepisauridae														
Alepisaurus ferox juvenile	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Myctophidae														
Unidentified Myctophidae	-	-	-	+	-	-	+++	+	+	-	+	-	+	+
Protomyctophum sp.	-	-	-	-	-	-	-	-	-	-	-	-	++	+
Protomyctophum thompsoni	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Lampanyctus jordani	-	-	-	-	-	-	-	-	-	-	-	-	++	++
Lampanyctus ritteri	-	-	-	-	-	-	-	-	-	+	-	-	+	-
Lampanyctus regalis	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Lampanyctus sp. c.f. L. achirus	-	-	-	-	-	-	-	-	-	-	-	-	+	-

PHYLUM CLASS FAMILY SPECIES	ECS	SJP	OKH	KR/OY	KM/KL	BSP	BSC	ASK	CAN	CAS	WSA	ESA	WTZ	ETZ
						PICES SUB-REGION								
Electrona risso	-	-	-	-	-	-	-	-	-	-	-	-	++	++
Symbolophorus californiense	-	-	-	-	-	-	-	-	+	-	-	-	+	+
Stenobrachius sp.	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Stenobrachius nannochir	-	-	-	-	-	-	-	+	-	-	+	-	-	-
Stenobrachius leucopsarus	-	-	-	-	-	+	-	-	+	-	+	-	-	-
Tarletonbeania sp.	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Tarletonbeania crenularis	-	-	-	-	-	-	-	-	+	+	+	-	-	-
Triphoturus mexicanus	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Notoscopelas japonicus	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Ceratoscopelas sp.	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Diaphus theta	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Diaphus gigas	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Lampadena urophaos	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Moridae														
Unidentified Moridae	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Gadidae														
Unidentified Gadidae	-	-	-	-	-	-	-	+	-	+	-	-	-	-
Eleginus gracilis	-	-	-	-	-	-	+++	-	-	-	-	-	-	-
Boreogadus saida	-	-	-	-	-	-	+++	-	-	-	-	-	-	-
Theragra chalcogramma	-	-	-	-	-	+	+++	+	+	-	-	-	-	-
T. chalcogramma juveniles	-	-	-	-	-	+	-	+++	-	-	-	-	-	-
Microgadus proximus	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Gadus macrocephalus	-	-	-	-	-	-	+	+	+	-	-	-	-	-
Gadus pacificus juveniles	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Merluccius productus	-	-	-	-	-	-	-	-	-	++	-	-	-	-
Macrouridae														
Coryphaenoides sp.	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Ophidiidae														
Unidentified Ophidiidae	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Otophidium scrippsi	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Chilara taylori	-	-	-	-	-	-	-	-	-	+BG	-	-	-	-
Bythitidae														
Brosmophycis marginata	-	-	-	-	-	-	-	-	-	+BG	-	-	-	-
Batrachoididae														
Porichthys notatus	-	-	-	-	-	-	-	-	-	++	-	-	-	-
Scomberesocidae														
Cololabis saira	-	-	-	++	-	-	-	+	+++	+++	+	-	++	+++

PHYLUM CLASS FAMILY SPECIES	ECS	SJP	OKH	KR/OY	KM/KL	BSP	BSC	ASK	CAN	CAS	WSA	ESA	WTZ	ETZ
	PICES SUB-REGION													
Gasterosteidae														
Gasterosteus aculeatus	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Syngnathidae														
Unidentified Scorpaeniformes	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Scorpaenidae														
Unidentified Scorpaenidae	-	-	-	-	-	-	+	-	+	+	-	-	-	-
Sebastes spp.	-	-	-	-	-	-	-	+	+++	++	+	-	-	-
Sebastes spp. post-larvae	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Sebastes spp. larvae	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Sebastes alutus	-	-	-	-	-	-	-	-	+++	-	-	-	-	-
Sebastes crameri	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Sebastes flavides	-	-	-	-	-	-	-	-	+++	-	-	-	-	-
Sebastes entomelas	-	-	-	-	-	-	-	-	+++	-	-	-	-	-
Sebastes proriger	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Sebastes melanops	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Anoplopomatidae														
Anoplopoma fimbria	-	-	-	-	-	-	-	+	++	+	-	-	-	-
Hexagrammidae														
Unidentified Hexagrammidae	-	-	-	-	-	-	-	+	+	-	-	-	-	-
Hexagrammos spp.	-	-	-	-	-	-	-	+	+	-	-	-	-	-
Hexagrammos stelleri	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Hexagrammos decagrammus	-	-	-	-	-	+	-	+	++	-	-	-	-	-
Hexagrammos lagocephalus	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Ophiodon sp.	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Ophiodon elongatus	-	-	-	-	-	-	-	+	+	-	-	-	-	-
Pleurogrammus sp. juvenile	-	-	+	-	-	-	-	-	-	-	++	-	-	-
Pleurogrammus monopterigius	-	-	-	+	-	-	-	+	-	-	-	-	-	-
P. monopterigius juvenile	-	-	-	-	++	-	-	-	-	-	+++	-	-	-
Cottidae														
Unidentified Cottidae	-	-	-	-	+	+	+	+	-	+	-	-	-	-
Triglops pingeli	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Blepsias cirrhosus	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Myoxecephalus quadricornis	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Scorpaenichthys marmoratus	-	-	-	-	-	-	-	-	+	+	-	-	-	-
Hemilepidotus sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Hemilepidotus hemilepidotus	-	-	-	-	-	-	-	+	+	-	-	-	-	-
Hemilepidotus sinosus	-	-	-	-	-	-	-	-	+	-	-	-	-	-

Hemilepidotus jordani	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Psychrolutes paradoxus	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Nautichthys oculofasciatus	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Leptocottus armatus	-	-	-	-	-	-	-	-	+C	-	-	-	-	-
Agonidae														
Unidentified Agonidae	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Bathyagonus alascanus	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Cyclopteriddae														
Eumicrotremus orbis	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Carangidae														
Trachurus symmetricus	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Stichaeidae														
Unidentified Stichaeidae	-	-	-	-	-	-	+	+	+	-	-	-	-	-
Stichaeus punctatus	-	-	-	-	-	-	+	-	-	-	-	-	-	-

PHYLUM CLASS FAMILY SPECIES						PICES SUB-REGION								
	ECS	SJP	OKH	KR/OY	KM/KL	BSP	BSC	ASK	CAN	CAS	WSA	ESA	WTZ	ETZ
Chirolophis polyactocephalus	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Lumpenus spp.	-	-	-	-	-	+	+	-	-	-	-	-	-	-
Lumpenus maculatus	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Lumpenus sagitta	-	-	-	-	-	-	-	-	+C	-	-	-	-	-
Pholidae														
Unidentified Pholidae	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Pholis sp.	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Pholis laeta	-	-	-	-	-	-	-	-	+C	-	-	-	-	-
Apodichthys flavidus	-	-	-	-	-	-	-	-	+C	-	-	-	-	-
Ptilichthyidae														
Ptilichthys goodei	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Zaproridae														
Zaprora silenus	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Trichodontidae														
Trichodon trichodon	-	-	-	-	-	-	+	+	++	-	-	-	-	-
Blenniidae														
Unidentified Blennies	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Ammodytidae														
Ammodytes hexapterus	-	-	-	-	-	+	+++	+++	+++	-	-	-	-	-
Ammodytes personatus	-	+++	-	-	-	-	-	-	-	-	-	-	-	-
Gempylus serpens	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Scombridae														
Scomber japonicus	-	-	-	-	-	-	-	-	-	-	-	-	+	-

Stromateidae														
Icichthys lockingtoni	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Peprilus simmillimus	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Bothidae														
Citharichthys sp.	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Citharichthys spp. larvae	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Citharichthys sordidus	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Citharichthys stigmaeus	-	-	-	-	-	-	-	-	-	+C	-	-	-	-
Bramidae														
Brama japonica	-	-	-	-	-	-	-	-	-	-	-	-	++	++
Kyphosidae														
Medialuna californiensis	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Embiotocidae														
Phaneordon furcatus	-	-	-	-	-	-	-	-	-	+MG	-	-	-	-
Zalembius roseaceus	-	-	-	-	-	-	-	-	-	+G	-	-	-	-
Cymatogaster aggregata	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Bathymasteridae														
Ronquilus jordani	-	-	-	-	-	+	-	+	-	-	-	-	-	-
Bathymaster signatus	-	-	-	-	-	+	-	-	-	-	-	-	-	-

PHYLUM
CLASS
FAMILY

SPECIES	ECS	SJP	OKH	KR/OY	KM/KL	BSP	BSC	ASK	CAN	CAS	WSA	ESA	WTZ	ETZ
						PICES SUB-REGION								
Zoarcidae														
Lycodes sp.	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Pleuronectidae														
Unidentified Pleuronectidae	-	-	-	-	-	-	+	+	+	-	-	-	-	-
Unidentified Pleuronectidae Larvae	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Unidentified Pleuronectidae juvenile	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Hippoglossoides elassodon	-	-	-	-	-	-	-	+	+	-	-	-	-	-
Microstomus pacificus	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Glyptocephalus zachirus	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Atrheresthes stomias	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Soleidae														
Symphurus atricauda	-	-	-	-	-	-	-	-	-	+C	-	-	-	-
Photichtyidae														
Ichthyococcus sp.	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Diretmidae														
Diretmus sp. c.f. D. argenteus	-	-	-	-	-	-	-	-	-	-	-	-	+	-

PHYLUM / CLASS / FAMILY / SPECIES	PICES SUB-REGION													
	ECS	SJP	OKH	KR/OY	KM/KL	BSP	BSC	ASK	CAN	CAS	WSA	ESA	WTZ	ETZ
Searsiidae														
Sagamichthys abei	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Melamphaeidae														
Melamphaes sp.	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Melamphaes lugubris	-	-	-	-	-	-	-	-	+	-	-	-	+	+
Poromitra crassiceps	-	-	-	-	-	-	-	-	-	-	-	-	+	+
Notosudidae														
Scopelosaurus harryi	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Aves														
Unidentified eggs	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Procellariidae														
Oceanodroma sp.	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Oceanodroma leuchorhoa	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Oceanodroma furcata	-	-	-	-	-	++	-	+	-	-	-	-	-	-
Phalacrocoracidae														
Phalacrocorax spp.	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Phalacrocorax urile	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Laridae														
Rissa tridactyla	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Alcidae														
Synthliboramphus antiquum	-	-	-	-	-	+	-	+G	-	-	-	-	-	-
Aethia cristatella	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Aethia pusilla	-	-	-	-	-	+++	-	-	-	-	-	-	-	-
Ptychoramphus aleuticus	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Lunda cirrhata	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Mammalia														
Unidentified Cetacean	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Unidentified Pinniped	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Eumetopias jubata (hair)	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Phoca hispida	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Zalophus californicus	-	-	-	-	-	-	-	-	-	++	-	-	-	-
Eschrichtius robustus	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Alopex lagopus (hair)	-	-	-	-	-	+	-	-	-	-	-	-	-	-

Appendix 4. Proposed trophic structure for marine communities in the North Pacific with special reference to marine birds and mammals

Trophic Level	Representative Organisms
1	Phytoplankton
2	Microzooplankton
3	Crustaceans
	Pteropods
	Salps
4	Hyperiids
	Heteropods
	Juvenile bony fishes
	Juvenile squids
	Pacific saury
	Lanternfish
	Small Marine Birds
	Fork-tailed Storm-Petrel
	Least Auklet
	Crested Auklet
	Red Phalarope
5	Small Sharks
	Adult bony fishes
	Pacific Pomfret
	Albacore
	Salmon
	Adult squids
	Neon Flying Squid
	Dolphins
	Northern Right Whale Dolphin
	Medium to Large Marine Birds
	Laysan Albatross
	Sooty Shearwater
	Red-faced Cormorant
	Glaucous-winged Gull
	Black-legged Kittiwake
	Common Murre
	Tufted Puffin
6	Large Sharks
	Billfish
	Large Marine Bird Scavengers
	Black-footed Albatross
7	White Shark
	Killer Whale

Appendix 5. Assumptions, baseline data and calculations for deriving estimates of seabird populations in the North Pacific

Appendix Table 5.1. Data used to derive populations of black-footed and Laysan albatrosses in PICES sub-regions of the North Pacific Ocean.

Assumptions:
N. Pacific Population of Black-footed Albatross = 200,000
N. Pacific Population of Laysan Albatross = 2,500,000
Density Adjustment Factor = N. Pacific Population/Apparent Density

Black-footed Albatross:

PICES Areas	Area (km^2)	Density (B/km^2)	Apparent Density (No. of Birds)	Density Adjustment Factor	Adjusted Density (No. of Birds)
BSP	1,357,653.00	0.01	13,522.22	0.061132822	826.65
BSC	1,021,952.00	0.00	112.41	0.061132822	6.87
ASK	428,521.10	0.33	140,520.64	0.061132822	8,590.42
ESA	3,621,581.00	0.10	375,304.44	0.061132822	22,943.42
CAN	166,456.30	0.30	50,000.00	0.061132822	3,056.64
CAS	128,620.20	0.43	55,000.00	0.061132822	3,362.31
ETZ	7,808,530.00	0.20	1,551,711.08	0.061132822	94,860.48
WTZ	6,337,697.00	0.14	917,001.38	0.061132822	56,058.88
KR/OY	348,452.00	0.23	81,551.71	0.061132822	4,985.49
WSA	2,168,317.00	0.04	86,841.10	0.061132822	5,308.84
KM/KL	111,569.80	?	?	0.061132822	?
SJP	1,006,455.00	0.00	0.00	0.061132822	0.00
ECS	435,236.00	0.00	0.00	0.061132822	0.00
OKH	1,599,223.00	?	?	0.061132822	?
TOTAL	26,540,263.40		3,271,564.98	0.061132822	200,000.00

Laysan Albatross:

PICES Areas	Area (km^2)	Density (B/km^2)	Apparent Density (No. of Birds)	Density Adjustment Factor	Adjusted Density (No. of Birds)
BSP	1,357,653.00	0.13	173,616.67	0.722938859	125,514.23
BSC	1,021,952.00	0.00	1,144.59	0.722938859	827.47
ASK	428,521.10	0.00	569.93	0.722938859	412.03
ESA	3,621,581.00	0.01	28,356.98	0.722938859	20,500.36
CAN	166,456.30	0.00	200.00	0.722938859	144.59
CAS	128,620.20	0.00	50.03	0.722938859	36.17
ETZ	7,808,530.00	0.10	789,832.81	0.722938859	571,000.83
WTZ	6,337,697.00	0.07	457,708.48	0.722938859	330,895.24
KR/OY	348,452.00	0.54	187,275.53	0.722938859	135,388.76
WSA	2,168,317.00	0.71	1,541,543.29	0.722938859	1,114,441.55
KM/KL	111,569.80	2.49	277,808.80	0.722938859	200,838.78
SJP	1,006,455.00	0.00	0.00	0.722938859	0.00
ECS	435,236.00	0.00	0.00	0.722938859	0.00
OKH	1,599,223.00	?	?	0.722938859	?
TOTAL	26,540,263.40		3,458,107.10	0.722938859	2,500,000.00

Appendix Table 5.2. Data used to derive populations of sooty and short-tailed shearwaters in PICES sub-regions of the North Pacific Ocean (June-August).

Assumptions:
N. Pacific population of dark shearwaters (sooty plus short-tailed) = 60,000,000
N. Pacific population of sooty shearwater = 30,000,000; short-tailed shearwater = 30,000,000
Dark Shearwater Density Adjustment Factor = N. Pacific population of dark shearwaters/Apparent Density of dark shearwaters in the N. Pacific
Sooty Shearwater Adjustment Factor = 0.5/(N. Pacific dark shearwater population/Apparent sooty shearwater density)
Short-tailed Shearwater Adjustment Factor = 0.5/(N. Pacific dark shearwater population/Apparent short-tailed shearwa density)

Dark Shearwaters:

PICES Areas	Area (km^2)	Density (B/km^2)	Apparent Density (No. of Birds)	Density Adjustment Factor	Adjusted density (No. of Birds)
BSP	1357653.0	5.15	6,991,912.95	0.153863824	1,075,802.47
BSC	1021952.0	35.82	36,606,320.64	0.153863824	5,632,388.49
ASK	428521.1	106.44	45,611,785.88	0.153863824	7,018,003.82
ESA	3621581.0	4.73	17,130,078.13	0.153863824	2,635,699.33
CAN	166456.3	6.02	1,002,066.93	0.153863824	154,181.85
CAS	128620.2	27.22	3,501,041.84	0.153863824	538,683.69
ETZ	7808530.0	0.51	3,982,350.30	0.153863824	612,739.65
WTZ	6337697.0	34.69	219,854,708.93	0.153863824	33,827,686.35
KR/OY	348452.0	60.00	20,907,120.00	0.153863824	3,216,849.44
WSA	2168317.0	15.85	34,367,824.45	0.153863824	5,287,964.91
KM/KL	111569.8	?	?	0.153863824	?
SJP	1006455.0	0.00	0.00	0.153863824	0.00
ECS	435236.0	0.00	0.00	0.153863824	0.00
OKH	1599223.0	?	?	0.153863824	?
TOTAL	26540263.4		389,955,210.05	0.153863824	60,000,000.00

Sooty Shearwater:

Areas	Adjusted density (No. of Birds)	Estimated (%)	Apparent Density (No. of Birds)	Density Adjustment Factor	Adjusted Density (No. of Birds)
BSP	1,075,802.47	0.03	32,274.07	0.611881128	19,747.90
BSC	5,632,388.49	0.03	168,971.65	0.611881128	103,390.57
ASK	7,018,003.82	0.68	4,772,242.60	0.611881128	2,920,045.18
ESA	2,635,699.33	0.97	2,556,628.35	0.611881128	1,564,352.64
CAN	154,181.85	0.97	150,327.30	0.611881128	91,982.44
CAS	538,683.69	0.99	533,296.85	0.611881128	326,314.28
ETZ	612,739.65	0.96	588,230.06	0.611881128	359,926.87
WTZ	33,827,686.35	0.99	33,489,409.49	0.611881128	20,491,537.64
KR/OY	3,216,849.44	0.50	1,608,424.72	0.611881128	984,164.73
WSA	5,287,964.91	0.97	5,129,325.96	0.611881128	3,138,537.75
KM/KL	?		?	0.611881128	?
SJP	0.00		0.00	0.611881128	0
ECS	0.00		0.00	0.611881128	0
OKH	?		?	0.611881128	?
TOTAL	60,000,000.00		49,029,131.06		30,000,000.00

Appendix Table 5.2 continued

Short-tailed Shearwater:

Areas	Adjusted density (No. of Birds)	Estimated (%)	Apparent Density (No. of Birds)	Density Adjustment Factor	Adjusted Density (No. of Birds)
BSP	1,075,802.47	0.97	1,043,528.39	2.734514482	2,853,543.50
BSC	5,632,388.49	0.97	5,463,416.84	2.734514482	14,939,792.47
ASK	7,018,003.82	0.32	2,245,761.22	2.734514482	6,141,066.58
ESA	2,635,699.33	0.03	79,070.98	2.734514482	216,220.74
CAN	154,181.85	0.025	3,854.55	2.734514482	10,540.31
CAS	538,683.69	0.01	5,386.84	2.734514482	14,730.38
ETZ	612,739.65	0.04	24,509.59	2.734514482	67,021.82
WTZ	33,827,686.35	0.01	338,276.86	2.734514482	925,022.98
KR/OY	3,216,849.44	0.50	1,608,424.72	2.734514482	4,398,260.69
WSA	5,287,964.91	0.03	158,638.95	2.734514482	433,800.50
KM/KL	?		?	2.734514482	?
SJP	0.00		0.00	2.734514482	0.00
ECS	0.00		0.00	2.734514482	0.00
OKH	?		?	2.734514482	?
TOTAL	60,000,000.00		10,970,868.94		29,999,999.99

** Note: Sooty Shearwater Adjusted Density plus Short-tailed Shearwater Adjusted Density should not equal the value for Dark Shearwater Adjusted Density. To obtain total dark shearwaters in area you should add Sooty Shearwater Adjusted Density to Short-tailed Shearwater Adjusted Density.

Appendix Table 5.3. Data used to derive populations of northern fulmar in PICES sub-regions of the North Pacific Ocean.

Assumptions:
North Pacific Population of Northern Fulmar = 4,600,000
Northern Fulmar Density Adjustment Factor = North Pacific Population/Apparent Density.

PICES Areas	Area (km^2)	Density (B/ km^2)	Apparent Density (No. of Birds)	Density Adjustment Factor	Adjusted Density (No. of Birds)
BSP	1,357,653.00	6.44	8,740,502.13	0.178789015	1,562,705.77
BSC	1,021,952.00	4.43	4,527,063.41	0.178789015	809,389.21
ASK	428,521.10	4.72	2,021,685.42	0.178789015	361,455.14
ESA	3,621,581.00	0.72	2,603,011.34	0.178789015	465,389.83
CAN	166,456.30	0.01	2,441.91	0.178789015	436.59
CAS	128,620.20	0.02	2,455.36	0.178789015	438.99
ETZ	7,808,530.00	0.00	11,556.62	0.178789015	2,066.20
WTZ	6,337,697.00	0.45	2,861,343.44	0.178789015	511,576.78
KR/OY	348,452.00	3.48	1,212,982.32	0.178789015	216,867.91
WSA	2,168,317.00	1.54	3,343,956.79	0.178789015	597,862.74
KM/KL	111,569.80	3.60	401,651.28	0.178789015	71,810.84
SJP	1,006,455.00	0.00	0.00	0.178789015	0.00
ECS	435,236.00	0.00	0.00	0.178789015	0.00
OKH	1,599,223.00	?	?	0.178789015	?
TOTAL	26,540,263.40		25,728,650.03	0.178789015	4,600,000.00

Appendix Table 5.4. Data used to derive populations of Buller's shearwater in PICES sub-regions of the North Pacific Ocean.

Assumptions:
North Pacific Population of Buller's Shearwater = 2,500,000

Buller's Shearwater Density Adjustment Factor = North Pacific Population/Apparent Density

PICES Areas	Area (km^2)	Density (B/km^2)	Apparent Density (No. of Birds)	Density Adjustment Factor	Adjusted Density (No. of Birds)
BSP	1,357,653.00	0.000	0.00	1.674547388	0.00
BSC	1,021,952.00	0.000	0.00	1.674547388	0.00
ASK	428,521.10	0.000	0.00	1.674547388	0.00
ESA	3,621,581.00	0.002	6,446.41	1.674547388	10,794.83
CAN	166,456.30	0.045	7,500.00	1.674547388	12,559.11
CAS	128,620.20	0.117	15,000.00	1.674547388	25,118.21
ETZ	7,808,530.00	0.001	3,591.92	1.674547388	6,014.85
WTZ	6,337,697.00	0.230	1,457,670.31	1.674547388	2,440,938.01
KR/OY	348,452.00	?	?	1.674547388	?
WSA	2,168,317.00	0.001	2,732.08	1.674547388	4,575.00
KM/KL	111,569.80	?	?	1.674547388	?
SJP	1,006,455.00	0.000	0.00	1.674547388	0.00
ECS	435,236.00	0.000	0.00	1.674547388	0.00
OKH	1,599,223.00	0.000	0.00	1.674547388	0.00
TOTAL	26,540,263.40		1,492,940.73	1.674547388	2,500,000.00

Appendix 6. Abundance, occupancy and daily energy requirements of marine birds

Appendix Table 6.1. Abundance, occupancy and energy requirements for marine birds: Bering Sea Continental Shelf (PICES sub-region BSC) in summer (June-August).

Species	Abundance	Method	Residency (days)	Occupancy	Body Mass (kg)	Allometric Daily Energy Needs (kj)
Short-tailed Albatross	+	-	-	+	8.4000	8,164.9
Black-footed Albatross	10	D	92	920	3.1480	4,000.1
Laysan Albatross	800	D	92	73,600	3.0420	3,901.3
Northern Fulmar	810,000	D	92	74,520,000	0.5440	1,116.3
Sooty Shearwater	100,000	D	92	9,200,000	0.7870	1460.1
Short-tailed Shearwater	14,900,000	D	92	1,370,800,000	0.5430	1,114.8
Leach's Storm-Petrel	3,000	S	92	276,000	0.0398	166.8
Fork-tailed Storm-Petrel	2,000,000	S	92	184,000,000	0.0553	211.8
Red-faced Cormorant	14,000	S	92	1,288,000	2.1570	3,038.8
Pelagic Cormorant	21,000	S	92	1,932,000	1.8680	2,737.1
Double-crested Cormorant	1,000	S	92	92,000	1.6740	2,527.4
Pomarine Jaeger	+	-	-	+	0.6940	1,332.5
Parasitic Jaeger	+	-	-	+	0.4645	995.2
Long-tailed Jaeger	+	-	-	+	0.2965	718.1
Jaegers	37,000	S	92	3,404,000	0.7275	?
Red Phalarope	604,700	S	92	55,632,400	0.0557	212.8
Red-necked Phalarope	75,000	S	92	6,900,000	0.0338	148.1
Glaucous Gull	4,000	C	92	368,000	1.4125	2,233.8
Glaucous-winged Gull	31,000	C	92	2,852,000	1.0100	1,750.4
Herring Gull	100	C	92	9,200	1.1350	1,905.4
Mew Gull	200	C	92	18,400	0.4035	898.4
Black-legged Kittiwake	1,900,000	S	92	174,800,000	0.4070	904.0
Red-legged Kittiwake	500,000	S	92	46,000,000	0.3910	878.0
Arctic Tern	87,000	S	92	8,004,000	0.1100	349.2
Aleutian Tern	93,000	S	92	8,556,000	0.1200	372.0
Dovekie	50	C	92	4,600	0.1630	464.8
Common Murre	3,200,000	S	92	294,400,000	0.9925	1,728.3
Thick-billed Murre	4,900,000	S	92	450,800,000	0.9640	1,692.1
Pigeon Guillemot	9,000	C	92	828,000	0.4870	1,030.0
Marbled Murrelet	+	-	-	+	0.2220	581.8
Kittlitz's Murrelet	+	-	-	+	0.2240	585.6
Long-billed Murrelet	+	-	-	+	?	?
Ancient Murrelet	3,000	C	92	276,000	0.2060	551.0
Parakeet Auklet	290,000	C	92	26,680,000	0.2580	649.0
Crested Auklet	2,000,000	S	92	184,000,000	0.2640	659.9
Least Auklet	2,500,000	S	92	230,000,000	0.0840	287.0
Horned Puffin	143,600	S	92	13,211,200	0.6190	1,226.2
Tufted Puffin	458,600	S	92	42,191,200	0.7790	1,449.3

Appendix Table 6.2. Abundance, occupancy and energy requirements for marine birds: Bering Sea Pelagic/Russia/Aleutian Islands (PICES sub-region BSP) in summer (June-August).

Species	Abundance	Method	Residency (Days)	Occupancy	Body Mass (kg)	Allometric Daily Energy Need (kj)
Short-tailed Albatross	+	-	-	+	8.4000	8,164.9
Black-footed Albatross	800	D	92	73,600	3.1480	4,000.1
Laysan Albatross	130,000	D	92	11,960,000	3.0420	3,901.3
Northern Fulmar	1,600,000	D	92	147,200,000	0.5440	1,116.3
Mottled Petrel	+	-	-	+	0.3160	752.1
Sooty Shearwater	20,000	D	92	1,840,000	0.7870	1,460.1
Short-tailed Shearwater	2,900,000	D	92	266,800,000	0.5430	1,114.8
Leach's Storm-Petrel	120,000	S	92	11,040,000	0.0398	166.8
Fork-tailed Storm-Petrel	4,500,000	S	92	414,000,000	0.0553	211.8
Red-faced Cormorant	560,000	S	92	51,520,000	2.1570	3,038.8
Pelagic Cormorant	180,000	S	92	16,560,000	1.8680	2,737.1
Double-crested Cormorant	2,000	S	92	184,000	1.6740	2,527.4
Pomarine Jaeger	+	-	-	+	0.6940	1,332.5
Parasitic Jaeger	+	-	-	+	0.4645	995.2
Long-tailed Jaeger	+	-	-	+	0.2965	718.1
Jaegers	270,000	S	92	24,840,000	0.4817	1,026.9
Red Phalarope	318,300	S	92	29,283,600	0.0557	212.8
Red-necked Phalarope	55,700	S	92	5,124,400	0.0338	148.1
Glaucous Gull	2,000	C	92	184,000	1.4125	2,233.8
Glaucous-winged Gull	33,000	C	92	3,036,000	1.0100	1,750.4
Herring Gull	2,000	C	92	184,000	1.1350	1,905.4
Slaty-backed Gull	20,000	C	92	1,840,000	1.3270	2,134.7
Mew Gull	+	-	-	+	0.4035	898.4
Black-headed Gull	+	-	-	+	0.2840	695.9
Sabine's Gull	1,000	C	92	92,000	0.1910	521.6
Black-legged Kittiwake	420,000	S	92	38,640,000	0.4070	904.0
Red-legged Kittiwake	1,200,000	S	92	110,400,000	0.3910	878.0
Arctic Tern	1,300	C	92	119,600	0.1100	349.2
Common Tern	1,000	C	92	92,000	0.1200	372.0
Aleutian Tern	400	C	92	36,800	0.1200	372.0
Pigeon Guillemot	31,000	C	92	2,852,000	0.4870	1,030.0
Spectacled Guillemot	+	C	92	+	0.4900	1,034.6
Common Murre	190,000	S	92	17,480,000	0.9925	1,728.3
Thick-billed Murre	890,000	S	92	81,880,000	0.9640	1,692.1
Marbled Murrelet	+	-	-	+	0.2220	581.8
Kittlitz's Murrelet	+	-	-	+	0.2240	585.6
Long-billed Murrelet	+	-	-	+	?	?
Ancient Murrelet	29,000	C	92	2,668,000	0.2060	551.0
Cassin's Auklet	105,000	C	92	9,660,000	0.1880	515.6
Parakeet Auklet	90,000	C	92	8,280,000	0.2580	649.0
Crested Auklet	4,300,000	S	92	395,600,000	0.2640	659.9
Least Auklet	2,300,000	S	92	211,600,000	0.0840	287.0
Whiskered Auklet	6,000	C	92	552,000	0.1210	374.3
Rhinoceros Auklet	30	C	92	2,760	0.5200	1,080.3
Horned Puffin	145,000	S	92	13,340,000	0.6190	1,226.2
Tufted Puffin	1,900,000	S	92	174,800,000	0.7790	1,449.3

Appendix Table 6.3. Abundance, occupancy and energy requirements for marine birds: Gulf of Alaska (PICES sub-region ASK) in summer (June-August).

Species	Abundance	Method	Residency (Days)	Occupancy	Body Mass (kg)	Allometric Daily Energy Needs (kj)
Short-tailed Albatross	+	-	-	+	8.4000	8164.9
Black-footed Albatross	9,000	D	92	828,000	3.1480	4000.1
Laysan Albatross	400	D	92	36,800	3.0420	3901.3
Northern Fulmar	360,000	D	92	33,120,000	0.5440	1116.3
Sooty Shearwater	2,900,000	D	92	266,800,000	0.7870	1460.1
Short-tailed Shearwater	6,100,000	D	92	561,200,000	0.5430	1114.8
Leach's Storm-Petrel	40,000	S	92	3,680,000	0.0398	166.8
Fork-tailed Storm-Petrel	1,200,000	S	92	110,400,000	0.0553	211.8
Brandt's Cormorant	25	S	92	2,300	2.1030	2983.3
Red-faced Cormorant	7,000	S	92	644,000	2.1570	3038.8
Pelagic Cormorant	6,000	S	92	552,000	1.8680	2737.1
Double-crested Cormorant	1,000	S	92	92,000	1.6740	2527.4
Pomarine Jaeger	+	-	-	+	0.6940	1332.5
Parasitic Jaeger	+	-	-	+	0.4645	995.2
Long-tailed Jaeger	+	-	-	+	0.2965	718.1
Jaegers	140,000	S	92	12,880,000	0.7275	1026.9
Red Phalarope	49,200	S	92	4,526,400	0.0557	212.8
Red-necked Phalarope	361,000	S	92	33,212,000	0.0338	148.1
Herring Gull	1,000	C	92	92,000	1.1350	1905.4
Glaucous-winged Gull	210,000	C	92	19,320,000	1.0100	1750.4
Mew Gull	15,000	C	92	1,380,000	0.4035	898.4
Black-legged Kittiwake	870,000	S	92	80,040,000	0.4070	904.0
Arctic Tern	87,000	S	92	8,004,000	0.1100	349.2
Aleutian Tern	92,000	S	92	8,464,000	0.1200	372.0
Common Murre	720,000	S	92	66,240,000	0.9925	1728.3
Thick-billed Murre	73,000	S	92	6,716,000	0.9640	1692.1
Pigeon Guillemot	28,000	C	92	2,576,000	0.4870	1030.0
Ancient Murrelet	190,000	C	92	17,480,000	0.2060	551.0
Marbled Murrelet	+	-	-	+	0.2220	581.8
Kittlitz's Murrelet	+	-	-	+	0.2240	585.6
Long-billed Murrelet	+	-	-	+	?	?
Cassin's Auklet	370,000	C	92	34,040,000	0.1880	515.6
Parakeet Auklet	59,000	C	92	5,428,000	0.2580	649.0
Crested Auklet	6,000	S	92	552,000	0.2640	659.9
Whiskered Auklet	200	C	92	18,400	0.1210	374.3
Least Auklet	3,000	S	92	276,000	0.0840	287.0
Rhinoceros Auklet	170,000	C	92	15,640,000	0.5200	1080.3
Horned Puffin	172,000	S	92	15,824,000	0.6190	1226.2
Tufted Puffin	1,900,000	S	92	174,800,000	0.7790	1449.3

Appendix Table 6.4. Abundance, occupancy and energy requirements for marine birds: California Current North (PICES sub-region CAN) in summer (June-August).

Species	Abundance	Method	Residency (Days)	Occupancy	Body Mass (kg)	Allometric Daily Energy Needs (kj)
Short-tailed Albatross	+	S	-	-	8.4000	8164.9
Black-footed Albatross	2,500	D	92	230,000	3.1480	4000.1
Laysan Albatross	200	D	92	18,400	3.0420	3901.3
Northern Fulmar	6,500	D	92	598,000	0.5440	1116.3
Mottled Petrel	+	S	-	-	0.3160	752.1
Murphy's Petrel	60	S	92	5,520	0.3600	826.9
Sooty Shearwater	125,000	D	92	11,500,000	0.7870	1460.1
Short-tailed Shearwater	14,000	D	92	1,288,000	0.5430	1114.8
Buller's Shearwater	7,500	D	92	690,000	0.3800	860.0
Flesh-footed Shearwater	100	S	92	9,200	0.5680	1151.9
Pink-footed Shearwater	27,000	S	92	2,484,000	0.7210	1370.0
Manx Shearwater	+	S	-	-	?	?
Black-vented Shearwater	+	S	-	-	0.2760	681.6
Leach's Storm-Petrel	96,000	S	92	8,832,000	0.0398	166.8
Fork-tailed Storm-Petrel	134,000	S	92	12,328,000	0.0553	211.8
Magnificent Frigatebird	+	S	-	-	1.4740	1806.8
Brown Pelican	+	S	-	-	3.4380	4264.8
Brandt's Cormorant	100	C	92	9,200	2.1030	2983.3
Pelagic Cormorant	10,000	C	92	920,000	1.8680	2737.1
Double-crested Cormorant	5,000	C	92	460,000	1.6740	2527.4
Pomarine Jaeger	300	S	92	27,600	0.6940	1332.5
Parasitic Jaeger	500	S	92	46,000	0.4645	995.2
Long-tailed Jaeger	600	S	92	55,200	0.2965	718.1
South Polar Skua	600	S	92	55,200	1.1560	1930.9
Red Phalarope	+	S	-	-	0.0557	212.8
Red-necked Phalarope	+	S	-	-	0.0338	148.1
Phalaropes	97,000	S	92	8,924,000	0.0447	196.3
Mew Gull	100	S	92	9,200	0.4035	898.4
Herring Gull	2,400	S	92	220,800	1.1350	1905.4
Thayer's Gull	100	S	92	9,200	0.9960	1732.7
California Gull	155,000	S	92	14,260,000	0.6065	1208.1
Western Gull	1,500	S	92	138,000	1.0110	1751.7
Glaucous-winged Gull	78,000	S	92	7,176,000	1.0100	1750.4
Glaucous Gull	50	S	92	4,600	1.4125	2233.8
Bonaparte's Gull	200	S	92	18,400	0.2810	690.6
Sabine's Gull	27,000	S	92	2,484,000	0.1910	521.6
Black-legged Kittiwake	+	S	-	-	0.4070	904.0
Caspian Tern	+	S	-	-	0.6550	1277.6
Arctic/Common Tern	1,700	S	92	156,400	0.1150	360.7
Aleutian Tern	+	S	-	-	0.1200	372.0
Common Murre	87,000	S	92	8,004,000	0.9925	1728.3
Thick-billed Murre	+	S	-	-	0.9640	1692.1
Pigeon Guillemot	2,200	S	92	202,400	0.4870	1030.0
Marbled Murrelet	36,000	S	92	3,312,000	0.2220	581.8
Long-billed Murrelet	+	S	-	-	?	?
Xantus' Murrelet	30	S	92	2,760	0.2240	473.1
Ancient Murrelet	124,000	S	92	11,408,000	0.2060	551.0
Cassin's Auklet	200,000	S	92	18,400,000	0.1880	515.6
Parakeet Auklet	+	S	-	-	0.2580	649.0
Rhinoceros Auklet	132,000	S	92	12,144,000	0.5200	1080.3
Horned Puffin	100	S	92	9,200	0.6190	1226.2
Tufted Puffin	31,000	S	92	2,852,000	0.7790	1449.3

Appendix Table 6.5. Abundance, occupancy and energy requirements for marine birds: Eastern Subarctic (PICES sub-region ESA) in summer (June-August).

Species	Abundance	Method	Residency (Days)	Occupancy	Body Mass (kg)	Allometric Daily Energy Needs (kj)
Short-tailed Albatross	+	-	-	+	8.4000	9164.9
Black-footed Albatross	23,000	D	92	2,116,000	3.1480	4000.1
Laysan Albatross	21,000	D	92	1,932,000	3.0420	3901.3
Northern Fulmar	470,000	D	92	43,240,000	0.5440	1116.3
Cook's Petrel	?	-	-	?	0.1785	496.5
Mottled Petrel	+	-	-	+	0.3160	752.1
Murphy's Petrel	?	-	-	?	0.3600	826.9
Sooty Shearwater	1,600,000	D	92	147,200,000	0.7870	1460.1
Short-tailed Shearwater	220,000	D	92	20,240,000	0.5430	1114.8
Buller's Shearwater	11,000	D	92	1,012,000	0.3800	860.0
Flesh-footed Shearwater	+	-	-	+	0.5680	1151.9
Pink-footed Shearwater	+	-	-	+	0.7210	1370.0
Leach's Storm-Petrel	2,200,000	S	92	202,400,000	0.0398	166.8
Fork-tailed Storm-Petrel	1,900,000	S	92	174,800,000	0.0553	211.8
Cormorant	2,000	S	92	184,000	2.8217	3694.2
South Polar Skua	160,000	S	92	14,720,000	1.1560	1930.9
Pomarine Jaeger	40,000	S	92	3,680,000	0.6940	1332.5
Parasitic Jaeger	80,000	S	92	7,360,000	0.4645	995.2
Long-tailed Jaeger	440,000	S	92	40,480,000	0.2965	718.1
Red Phalarope	5,000	S	92	460,000	0.0557	212.8
Red-necked Phalarope	7,000	S	92	644,000	0.0338	148.1
Glaucous-winged Gull	+	-	-	+	1.0100	1750.4
Herring Gull	?	-	-	?	1.1350	1905.4
Black-legged Kittiwake	440,000	S	92	40,480,000	0.4070	904.0
Red-legged Kittiwake	?	-	-	?	0.3910	878.0
Thick-billed Murre	15,000	S	92	1,380,000	0.9640	1692.1
Ancient Murrelet	?	-	-	?	0.2060	551.0
Parakeet Auklet	?	-	-	?	0.2580	649.0
Horned Puffin	13,800	S	92	1,269,600	0.6190	1226.2
Tufted Puffin	255,000	S	92	23,460,000	0.7790	1449.3

Appendix Table 6.6. Abundance, occupancy and energy requirements for marine birds: Western Subarctic (PICES sub-region WSA) in summer (June-August).

Species	Abundance	Method	Residency (Days)	Occupancy	Body Mass (kg)	Allometric Daily Energy Needs (kj)
Short-tailed Albatross	+	-	-	+	8.4000	8164.9
Black-footed Albatross	5,000	D	92	460,000	3.1480	4000.1
Laysan Albatross	1,100,000	D	92	101,200,000	3.0420	3901.3
Northern Fulmar	600,000	D	92	55,200,000	0.5440	1116.3
Cook's Petrel	+	-	-	+	0.1785	496.5
Mottled Petrel	+	-	-	+	0.3160	752.1
Sooty Shearwater	3,100,000	D	92	285,200,000	0.7870	1460.1
Short-tailed Shearwater	430,000	D	92	39,560,000	0.5430	1114.8
Buller's Shearwater	5,000	D	92	460,000	0.3800	323.5
Flesh-footed Shearwater	+	-	-	+	0.5680	1151.9
Pink-footed Shearwater	+	-	-	+	0.7210	1370.0
Leach's Storm-Petrel	3,500,000	S	92	322,000,000	0.0398	166.8
Fork-tailed Storm-Petrel	3,600,000	S	92	331,200,000	0.0553	211.8
Cormorant	1,000	S	92	92,000	2.8217	3694.2
South Polar Skua	150,000	S	92	13,800,000	1.1560	1930.9
Pomarine Jaeger	190,000	S	92	17,480,000	0.6940	1332.5
Parasitic Jaeger	76,000	S	92	6,992,000	0.4645	995.2
Long-tailed Jaeger	38,000	S	92	3,496,000	0.2965	718.1
Red Phalarope	87,000	S	92	8,004,000	0.0557	212.8
Red-necked Phalarope	+	-	-	+	0.0338	148.1
Glaucous-winged Gull	+	-	-	+	1.0100	1750.4
Herring Gull	?	-	-	?	1.1350	1905.4
Black-legged Kittiwake	610,000	S	92	56,120,000	0.4070	904.0
Red-legged Kittiwake	+	-	-	+	0.3910	878.0
Thick-billed Murre	47,000	S	92	4,324,000	0.9640	1692.1
Ancient Murrelet	+	-	-	+	0.2060	551.0
Crested Auklet	380,000	S	92	34,960,000	0.2640	660.0
Parakeet Auklet	+	-	-	+	0.2580	649.0
Least Auklet	47,000	S	92	4,324,000	0.0840	287.0
Horned Puffin	85,000	S	92	7,820,000	0.6190	1226.2
Tufted Puffin	892,000	S	92	82,064,000	0.7790	1449.3

Appendix Table 6.7. Abundance, occupancy and energy requirements for marine birds: Kamchatka and Kurile Islands (PICES sub-region KM/KL) in summer (June-August).

Species	Abundance	Method	Residency	Occupancy	Body Mass (kg)	Allometric Daily
Short-tailed Albatross	+	-	-	+	8.4000	8164.9
Black-footed Albatross	+	-	-	+	3.1480	4000.1
Laysan Albatross	200,000	D	92	18,400,000	3.0420	3901.3
Northern Fulmar	70,000	D	92	6,440,000	0.5440	1116.3
Mottled Petrel	?	-	-	?	0.3160	752.1
Cook's Petrel	+	-	-	+	0.1785	496.5
Bonin Petrel	+	-	-	+	0.1760	491.5
Sooty Shearwater	+	-	-	+	0.7870	1460.1
Short-tailed Shearwater	+	-	-	+	0.5430	1114.8
Flesh-footed Shearwater	+	-	-	+	0.5680	1151.9
Streaked Shearwater	+	-	-	+	?	?
Buller's Shearwater	?	-	-	?	0.3800	860.0
Leach's Storm-Petrel	350,000	C	92	32,200,000	0.0398	166.8
Fork-tailed Storm-Petrel	200,000	C	92	18,400,000	0.0553	211.8
Band-rumped Storm-Petrel	?	-	-	?	0.0418	172.8
Swinhoe's Storm-Petrel	?	-	-	?	0.0358	154.4
Red-faced Cormorant	25,000	C	92	2,300,000	2.1570	3038.8
Pelagic Cormorant	55,000	C	92	5,060,000	1.8680	2737.1
Temminck's Cormorant	7,000	C	92	644,000	?	?
South Polar Skua	+	-	-	+	1.1560	1930.9
Pomarine Jaeger	+	-	-	+	0.6940	1332.5
Parasitic Jaeger	+	-	-	+	0.4645	995.2
Long-tailed Jaeger	+	-	-	+	0.2965	718.1
Red Phalarope	+	-	-	+	0.0557	212.8
Red-necked Phalarope	+	-	-	+	0.0338	148.1
Glaucous Gull	+	-	-	+	1.4125	2233.8
Glaucous-winged Gull	+	-	-	+	1.0100	1750.4
Herring Gull	+	-	-	+	1.1350	1905.4
Slaty-backed Gull	90,000	C	92	8,280,000	1.3270	2134.7
Mew Gull	+	-	-	+	0.4035	898.4
Black-tailed Gull	1,000	C	92	92,000	0.5335	1100.6
Black-headed Gull	+	-	-	+	0.2840	695.9
Little Gull	+	-	-	+	0.1180	367.5
Sabine's Gull	+	-	-	+	0.1910	521.7
Black-legged Kittiwake	90,000	C	92	8,280,000	0.4070	904.0
Red-legged Kittiwake	+	-	-	+	0.3910	878.0
Caspian Tern	?	-	-	?	0.6550	1277.6
Arctic Tern	+	-	-	+	0.1100	349.2
Common Tern	+	-	-	+	0.1200	372.0
Aleutian Tern	+	-	-	+	0.1200	372.0
Pigeon Guillemot	5,000	C	92	460,000	0.4870	1030.0
Spectacled Guillemot	5,000	C	92	460,000	0.4900	1034.6
Common Murre	300,000	C	92	27,600,000	0.9925	1728.3
Thick-billed Murre	43,000	C	92	3,956,000	0.9640	1692.1
Long-billed Murrelet	?	-	-	?	?	?
Ancient Murrelet	3,000	C	92	276,000	0.2060	551.0
Japanese Murrelet	?	-	-	?	?	?
Parakeet Auklet	1,000	C	92	92,000	0.2580	649.0
Crested Auklet	1,000,000	C	92	92,000,000	0.2640	659.9
Least Auklet	1,000	C	92	92,000	0.0840	287.0
Whiskered Auklet	+	-	-	+	0.1210	374.3
Rhinoceros Auklet	10,000	C	92	920,000	0.5200	1080.3
Horned Puffin	4,000	C	92	368,000	0.6190	1226.2
Tufted Puffin	175,000	C	92	16,100,000	0.7790	1449.3

Appendix Table 6.8. Energy requirements for marine birds: Sea of Okhotsk (PICES sub-region OKH) in summer (June-August).

Species	Abundance	Method	Residency (Days)	Occupancy	Body Mass (kg)	Allometric Daily Energy Needs (kj)
Black-footed Albatross	?	-	-	?	3.1480	4000.1
Laysan Albatross	?	-	-	?	3.0420	3901.3
Northern Fulmar	380,000	C	92	34,960,000	0.5440	1116.3
Bonin Petrel	+	-	-	+	0.1760	491.5
Sooty Shearwater	+	-	-	+	0.7870	1460.1
Short-tailed Shearwater	+	-	-	+	0.5430	1114.8
Streaked Shearwater	+	-	-	+	?	?
Leach's Storm-Petrel	+	-	-	+	0.0398	166.8
Fork-tailed Storm-Petrel	+	-	-	+	0.0553	211.8
Great Cormorant	+	-	-	+	2.1095	2990.1
Red-faced Cormorant	+	-	-	+	2.1570	3038.8
Pelagic Cormorant	10,000	C	92	920,000	1.8680	2737.1
Temminck's Cormorant	100	C	92	9,200	?	?
Pomarine Jaeger	+	-	-	+	0.6940	1332.5
Parasitic Jaeger	+	-	-	+	0.4645	995.2
Long-tailed Jaeger	+	-	-	+	0.2965	718.1
Red Phalarope	+	-	-	+	0.0557	212.8
Red-necked Phalarope	+	-	-	+	0.0338	148.1
Herring Gull	+	-	-	+	1.1350	1905.4
Glaucous Gull	+	-	-	+	1.4125	2233.8
Glaucous-winged Gull	+	-	-	+	1.0100	1750.4
Slaty-backed Gull	80,000	C	92	7,360,000	1.3270	2134.7
Black-tailed Gull	2,000	C	92	184,000	0.5335	1100.6
Black-headed Gull	1,000	C	92	92,000	0.2840	695.9
Mew Gull	1,000	C	92	92,000	0.4035	898.4
Black-legged Kittiwake	500,000	C	92	46,000,000	0.4070	904.0
Little Gull	+	-	-	+	0.1180	367.5
Common Tern	3,000	C	92	276,000	0.1200	372.0
Arctic Tern	+	-	-	+	0.1100	349.2
Aleutian Tern	1,000	C	92	92,000	0.1200	372.0
Common Murre	600,000	C	92	55,200,000	0.9925	1728.3
Thick-billed Murre	300,000	C	92	27,600,000	0.9640	1692.1
Pigeon Guillemot	+	-	-	+	0.4870	1030.0
Spectacled Guillemot	10,000	C	92	920,000	0.4900	1034.6
Long-billed Murrelet	+	-	-	+	?	?
Ancient Murrelet	25,000	C	92	2,300,000	0.2060	551.0
Parakeet Auklet	300,000	C	92	27,600,000	0.2580	649.0
Crested Auklet	1,590,000	C	92	146,280,000	0.2640	659.9
Least Auklet	5,500,000	C	92	506,000,000	0.0840	287.0
Whiskered Auklet	1,000	C	92	92,000	0.1210	374.3
Rhinoceros Auklet	3,000	C	92	276,000	0.5200	1080.3
Horned Puffin	200,000	C	92	18,400,000	0.6190	1226.2
Tufted Puffin	500,000	C	92	46,000,000	0.7790	1449.3

Appendix Table 6.9. Energy requirements for marine birds: California Current South (PICES sub-region CAS) in summer (June-August).

Species	Abundance	Method	Residency	Occupancy	Body Mass	Allometric Daily
Short-tailed Albatross	+	S	-	+	8.4000	8164.9
Black-footed Albatross	3,000	D	92	276,000	3.1480	4000.1
Laysan Albatross	50	D	92	4,600	3.0420	3901.3
Northern Fulmar	400	D	92	36,800	0.5440	1116.3
Mottled Petrel	+	S	-	+	0.3160	752.1
Cook's Petrel	+	S	-	+	0.1785	496.5
Sooty Shearwater	330,000	D	92	30,360,000	0.7870	1460.1
Short-tailed Shearwater	15,000	D	92	1,380,000	0.5430	1114.8
Buller's Shearwater	25,000	D	92	2,300,000	0.3800	860.0
Flesh-footed Shearwater	+	S	-	+	0.5680	1151.9
Pink-footed Shearwater	110,000	S	92	10,120,000	0.7210	1370.0
Black-vented Shearwater	14,000	C	92	1,288,000	0.2760	681.6
Leach's Storm-Petrel	100,000	S	92	9,200,000	0.0398	166.8
Fork-tailed Storm-Petrel	75,000	S	92	6,900,000	0.0553	211.8
Least Storm-Petrel	15,000	C	92	1,380,000	0.0205	103.0
Black Storm-Petrel	10,000	C	92	920,000	0.0590	222.0
Ashy Storm-Petrel	6,000	S	92	552,000	0.0369	157.8
Brown Pelican	12,000	S	92	1,104,000	3.4380	4264.8
Brandt's Cormorant	75,000	S	92	6,900,000	2.1030	2983.3
Pelagic Cormorant	29,000	C	92	2,668,000	1.8680	2737.1
Double-crested Cormorant	17,000	C	92	1,564,000	1.6740	2527.4
Pomarine Jaeger	1,300	S	92	119,600	0.6940	1332.5
Parasitic Jaeger	1,500	S	92	138,000	0.4645	995.2
Long-tailed Jaeger	+	S	-	+	0.2965	718.1
South Polar Skua	+	S	-	+	1.1560	1930.9
Red Phalarope	+	S	-	+	0.0557	212.8
Red-necked Phalarope	+	S	-	+	0.0338	148.1
Phalaropes	240,000	S	92	22,080,000	0.0447	196.3
Herring Gull	500	S	92	46,000	1.1350	1905.4
Heerman's Gull	5,000	S	92	460,000	0.5000	1049.9
California Gull	5,000	S	92	460,000	0.6065	1208.1
Western Gull	195,000	S	92	17,940,000	1.0110	1751.7
Glaucous-winged Gull	15,000	S	92	1,380,000	1.0100	1750.4
Bonaparte's Gull	1,000	S	92	92,000	0.2810	690.6
Sabine's Gull	10,000	S	92	920,000	0.1910	521.6
Black-legged Kittiwake	1,000	S	92	92,000	0.4070	904.0
Caspian Tern	+	S	-	+	0.6550	1277.6
Arctic/Common Tern	9,000	S	92	828,000	0.5310	360.7
Forster's Tern	+	S	-	+	0.1580	454.4
Common Murre	300,000	C	92	27,600,000	0.9925	1728.3
Pigeon Guillemot	19,000	C	92	1,748,000	0.4870	1030.0
Marbled Murrelet	6,000	C	92	552,000	0.2220	581.8
Long-billed Murrelet	+	S	-	+	?	?
Xantus' Murrelet	1,700	S	92	156,400	0.2240	473.1
Ancient Murrelet	1,300	S	92	119,600	0.2060	551.0
Cassin's Auklet	140,000	S	92	12,880,000	0.1880	515.6
Rhinoceros Auklet	6,500	S	92	598,000	0.5200	1080.3
Horned Puffin	+	S	-	+	0.6190	1226.2
Tufted Puffin	14,000	S	92	1,288,000	0.7790	1449.3

Appendix Table 6.10. Energy requirements for marine birds: Eastern Transition Zone (PICES sub-region ETZ) in summer (June-August).

Species	Abundance	Method	Residency (Days)	Occupancy	Body Mass (kg)	Allometric Daily Energy Needs (kj)
Short-tailed Albatross	+	-	-	+	8.4000	8164.9
Black-footed Albatross	95,000	D	92	8,740,000	3.1480	4000.1
Laysan Albatross	570,000	D	92	52,440,000	3.0420	3901.3
Northern Fulmar	2,000	D	92	184,000	0.5440	1116.3
Phoenix Petrel	+	-	-	+	0.2720	674.4
Solander's Petrel	+	-	-	+	?	?
Murphy's Petrel	+	-	-	+	0.3600	826.9
Kermadec Petrel	+	-	-	+	?	?
Herald Petrel	+	-	-	+	0.1610	460.6
Dark-rumped Petrel	+	-	-	+	0.4340	947.2
White-necked Petrel	+	-	-	+	?	?
Cook's Petrel	?	-	-	?	0.1785	496.5
Bonin Petrel	+	-	-	+	0.1760	491.5
Black-winged Petrel	+	-	-	+	?	?
Stejneger's Petrel	+	-	-	+	?	?
Pycroft's Petrel	?	-	-	?	0.1153	443.9
Bulwer's Petrel	+	-	-	+	0.0990	323.5
Sooty Shearwater	360,000	D	92	33,120,000	0.7870	1460.1
Short-tailed Shearwater	67,000	D	92	6,164,000	0.5430	1114.8
Buller's Shearwater	6,000	D	92	552,000	0.3800	860.0
Flesh-footed Shearwater	+	-	-	+	0.5680	1151.9
Pink-footed Shearwater	+	-	-	+	0.7210	1370.0
Leach's Storm-Petrel	1,200,000	S	92	110,400,000	0.0398	166.8
Fork-tailed Storm-Petrel	1,500,000	S	92	138,000,000	0.0553	211.8
Band-rumped Storm-Petrel	+	-	-	+	0.0418	172.8
Tristram's Storm-Petrel	+	-	-	+	0.0840	287.0
Wilson's Storm-Petrel	+	-	-	+	0.0320	142.3
South Polar Skua	70,000	S	92	6,440,000	1.1560	1930.9
Pomarine Jaeger	52,000	S	92	4,784,000	0.6940	1332.5
Parasitic Jaeger	17,000	S	92	1,564,000	0.4645	995.2
Long-tailed Jaeger	700,000	S	92	64,400,000	0.2965	718.1
Red Phalarope	1,152,000	S	92	105,984,000	0.0557	212.8
Red-necked Phalarope	?	-	-	?	0.0338	148.1
Glaucous Gull	?	-	-	?	1.4125	2233.8
Glaucous-winged Gull	+	-	-	+	1.0100	1750.4
Herring Gull	?	-	-	?	1.1350	1905.4
Thick-billed Murre	23,000	S	92	2,116,000	0.9640	1692.1
Parakeet Auklet	+	-	-	+	0.2580	649.0
Horned Puffin	+	-	-	+	0.6190	1226.2
Tufted Puffin	36,000	S	92	3,312,000	0.7790	1449.3

Appendix Table 6.11. Energy requirements for marine birds: Western Transition Zone (PICES sub-region WTZ) in summer (June-August).

Species	Abundance	Method	Residency (Days)	Occupancy	Body Mass (kg)	Allometric Daily Energy Needs (kj)
Short-tailed Albatross	+	-	-	+	8.4000	8164.9
Black-footed Albatross	56,000	D	92	5,152,000	3.1480	4000.1
Laysan Albatross	330,000	D	92	30,360,000	3.0420	3901.3
Northern Fulmar	510,000	D	92	46,920,000	0.5440	1116.3
Phoenix Petrel	+	-	-	+	0.2720	674.4
Solander's Petrel	+	-	-	+	?	?
Murphy's Petrel	+	-	-	+	0.3600	826.9
Kermadec Petrel	+	-	-	+	?	?
Herald Petrel	+	-	-	+	0.1610	460.6
Dark-rumped Petrel	+	-	-	+	0.4340	947.2
White-necked Petrel	+	-	-	+	?	?
Cook's Petrel	?	-	-	?	0.1785	496.5
Bonin Petrel	+	-	-	+	0.1760	491.5
Black-winged Petrel	+	-	-	+	?	?
Stejneger's Petrel	+	-	-	+	?	?
Pycroft's Petrel	?	-	-	?	0.1153	443.9
Bulwer's Petrel	+	-	-	+	0.0990	323.5
Sooty Shearwater	20,500,000	D	92	1,886,000,000	0.7870	1460.1
Short-tailed Shearwater	930,000	D	92	85,560,000	0.5430	1114.8
Buller's Shearwater	2,400,000	D	92	220,800,000	0.3800	860.0
Flesh-footed Shearwater	+	-	-	+	0.5680	1151.9
Pink-footed Shearwater	+	-	-	+	0.7210	1370.0
Leach's Storm-Petrel	29,000,000	S	92	2,668,000,000	0.0398	166.8
Fork-tailed Storm-Petrel	2,600,000	S	92	239,200,000	0.0553	211.8
Band-rumped Storm-Petrel	+	-	-	+	0.0418	172.8
Tristram's Storm-Petrel	+	-	-	+	0.0840	287.0
Wilson's Storm-Petrel	+	-	-	+	0.0320	142.3
South Polar Skua	50,000	S	92	4,600,000	1.1560	1930.9
Pomarine Jaeger	25,000	S	92	2,300,000	0.6940	1332.5
Parasitic Jaeger	74,000	S	92	6,808,000	0.4645	995.2
Long-tailed Jaeger	25,000	S	92	2,300,000	0.2965	718.1
Red Phalarope	120,000	S	92	11,040,000	0.0557	212.8
Red-necked Phalarope	?	-	-	?	0.0338	148.1
Glaucous Gull	?	-	-	?	1.4125	2233.8
Glaucous-winged Gull	+	-	-	+	1.0100	1750.4
Herring Gull	?	-	-	?	1.1350	1905.4
Thick-billed Murre	2,000	S	92	184,000	0.9640	1692.1
Parakeet Auklet	+	-	-	+	0.2580	649.0
Horned Puffin	+	-	-	+	0.6190	1226.2
Tufted Puffin	+	-	-	+	0.7790	1449.3

Appendix Table 6.12. Energy requirements for marine birds: Kuroshio/Oyashio Currents (PICES sub-region KR/0Y) in summer (June-August).

Species	Abundance	Method	Residency (Days)	Occupancy	Body Mass (kg)	Allometric Daily Energy Needs (kj)
Short-tailed Albatross	+	-	-	+	8.4000	8164.9
Black-footed Albatross	5,000	D	92	460,000	3.1480	4000.1
Laysan Albatross	140,000	D	92	12,880,000	3.0420	3901.3
Northern Fulmar	220,000	D	92	20,240,000	0.5440	1116.3
Solander's Petrel	+	-	-	+	?	?
White-necked Petrel	+	-	-	+	?	?
Cook's Petrel	?	-	-	?	0.1785	496.5
Bonin Petrel	+	-	-	+	0.1760	491.5
Stejneger's Petrel	+	-	-	+	?	?
Bulwer's Petrel	+	-	-	+	0.0990	323.5
Sooty Shearwater	980,000	S	92	90,160,000	0.7870	1460.1
Short-tailed Shearwater	4,400,000	S	92	404,800,000	0.5430	1114.8
Flesh-footed Shearwater	+	-	-	+	0.5680	1151.9
Streaked Shearwater	2,500,000	C	92	230,000,000	?	?
Buller's Shearwater	+	-	-	+	0.3800	860.0
Wedge-tailed Shearwater	+	-	-	+	0.3880	873.1
Audubon's Shearwater	+	-	-	+	0.1680	475.1
Leach's Storm-Petrel	3,500,000	S	92	322,000,000	0.0398	166.8
Fork-tailed Storm-Petrel	3,600,000	S	92	331,200,000	0.0553	211.8
Tristram's Storm-Petrel	+	-	-	+	0.0840	287.0
Band-rumped Storm-Petrel	+	-	-	+	0.0418	172.8
Swinhoe's Storm-Petrel	1,000	C	92	92,000	0.0358	154.4
Matsudaira's Storm-Petrel	?	-	-	?	?	?
White-tailed Tropicbird	?	-	-	?	0.3340	783.0
Red-tailed Tropicbird	?	-	-	?	0.7500	1409.8
Brown Booby	2,000	C	92	184,000	1.2375	2029.0
Lesser Frigatebird	?	-	-	?	0.8060	1485.6
Great Cormorant	10,500	C	92	966,000	2.1095	2990.1
Red-faced Cormorant	+	-	-	+	2.1570	3038.8
Pelagic Cormorant	+	-	-	+	1.8680	2737.1
Temminck's Cormorant	+	-	-	+	?	?
South Polar Skua	+	-	-	+	1.1560	1930.9
Pomarine Jaeger	+	-	-	+	0.6940	1332.5
Parasitic Jaeger	+	-	-	+	0.4645	995.2
Long-tailed Jaeger	?	-	-	?	0.2965	718.1
Unidentified Jaegers	42,000	S	92	3,864,000	0.4850	1026.9
Red Phalarope	+	-	-	+	0.0557	212.8
Red-necked Phalarope	149,000	S	92	13,708,000	0.0338	148.1

Appendix Table 6.12 (continued). Energy requirements for marine birds: Kuroshio/Oyashio Currents (PICES sub-region KR/0Y) in summer (June-August).

Species	Abundance	Method	Residency (Days)	Occupancy	Body Mass (kg)	Allometric Daily Energy Needs (kj)
Glaucous Gull	+	-	-	+	1.4125	2233.8
Herring Gull	+	-	-	+	1.1350	1905.4
Slaty-backed Gull	+	-	-	+	1.3270	2134.7
Mew Gull	+	-	-	+	0.4035	898.4
Black-tailed Gull	+	-	-	+	0.5335	1100.6
Black-headed Gull	+	-	-	+	0.2840	695.9
Little Gull	+	-	-	+	0.1180	367.5
Black-legged Kittiwake	+	-	-	+	0.4070	904.0
Caspian Tern	?	-	-	?	0.6550	1277.6
Common Tern	+	-	-	+	0.1200	372.0
Little Tern	+	-	-	+	0.0570	216.5
Sooty Tern	+	-	-	+	0.1800	499.6
Spectacled Guillemot	+	-	-	+	0.4900	1034.6
Common Murre	+	-	-	+	0.9925	1728.3
Thick-billed Murre	+	-	-	+	0.9640	1692.1
Unidentified Murre	2,000	S	92	184,000	0.9783	1710.2
Long-billed Murrelet	+	-	-	+	?	?
Ancient Murrelet	+	-	-	+	0.2060	551.0
Japanese Murrelet	1,700	C	92	156,400	?	?
Crested Auklet	+	-	-	+	0.2640	659.9
Least Auklet	+	-	-	+	0.0840	287.0
Whiskered Auklet	+	-	-	+	0.1210	374.3
Rhinoceros Auklet	+	-	-	+	0.5200	1080.3
Horned Puffin	+	-	-	+	0.6190	1226.2
Tufted Puffin	2,000	S	92	184,000	0.7790	1449.3

Appendix Table 6.13. Energy requirements for marine birds: Sea of Japan (PICES sub-region SJP) in summer (June-August).

Species	Abundance	Method	Residency (Days)	Occupancy	Body Mass (kg)	Allometric Daily Energy Needs (kj)
Streaked Shearwater	200,000	C	92	18,400,000	?	?
Leach's Storm-Petrel	100	C	92	9,200	0.0398	166.8
Swinhoe's Storm-Petrel	15,000	C	92	1,380,000	0.0358	154.4
Band-rumped Storm-Petrel	8,000	C	92	736,000	0.0418	172.8
Great Cormorant	1,000	C	92	92,000	2.1095	2,990.1
Red-faced Cormorant	+	-	-	+	2.1570	3,038.8
Pelagic Cormorant	2,000	C	92	184,000	1.8680	2,737.1
Temminck's Cormorant	8,000	C	92	736,000	?	?
Jaegers	+	-	-	+	0.4850	1,026.9
Phalaropes	+	-	-	+	0.0447	196.3
Herring Gull	+	-	-	+	1.1350	1,905.4
Slaty-backed Gull	2,000	C	92	184,000	1.3270	2,134.7
Glaucous Gull	+	-	-	+	1.4125	2,233.8
Mew Gull	+	-	-	+	0.4035	898.4
Black-headed Gull	+	-	-	+	0.2840	695.9
Black-tailed Gull	110,000	C	92	10,120,000	0.5335	1,100.6
Little Gull	+	-	-	+	0.1180	367.5
Black-legged Kittiwake	+	-	-	+	0.4070	904.0
Caspian Tern	+	-	-	+	0.6550	1,277.6
Common Tern	1,000	C	92	92,000	0.1200	372.0
Whiskered Tern	+	-	-	+	0.0882	297.4
Common Murre	1,000	C	92	92,000	0.9925	1,728.3
Spectacled Guillemot	12,000	C	92	1,104,000	0.4900	1,034.6
Ancient Murrelet	1,000	C	92	92,000	0.2060	551.0
Japanese Murrelet	+	-	-	+	?	?
Long-billed Murrelet	?	-	-	?	?	?
Crested Auklet	+	-	-	+	0.2640	659.9
Least Auklet	+	-	-	+	0.0840	287.0
Rhinoceros Auklet	2,000	C	92	184,000	0.5200	1,080.3
Horned Puffin	+	-	-	+	0.6190	1,226.2
Tufted Puffin	+	-	-	+	0.7790	1,449.3

Appendix Table 6.14. Energy requirements for marine birds: East China Sea (PICES sub-region ECS) in summer (June-August).

Species	Abundance	Method	Residency (Days)	Occupancy	Body Mass (kg)	Allometric Daily Energy Needs (kj)
Short-tailed Albatross	+	?	?	+	8.4000	81164.9
Black-footed Albatross	+	?	?	+	3.1480	4000.1
Northern Fulmar	+	?	?	+	0.5440	1116.3
Bonin Petrel	?	?	?	?	0.1760	491.5
Bulwer's Petrel	?	?	?	?	0.0990	323.5
Streaked Shearwater	+	?	?	+	?	?
Wedge-tailed Shearwater	?	?	?	?	0.3880	873.1
Swinhoe's Storm-Petrel	+	?	?	+	0.0358	154.4
Great Cormorant	+	?	?	+	2.1095	2990.1
Temminck's Cormorant	+	?	?	+	?	?
Red-necked Phalarope	+	?	?	+	0.0338	148.1
Pomarine Jaeger	?	?	?	?	0.6940	1332.5
Parasitic Jaeger	+	?	?	+	0.4645	995.2
Long-tailed Jaeger	?	?	?	?	0.2965	718.1
Herring Gull	+	?	?	+	1.1350	1905.4
Slaty-backed Gull	+	?	?	+	1.3270	2134.7
Common Gull	+	?	?	+	0.4035	898.4
Black-headed Gull	+	?	?	+	0.2840	695.9
Indian Black-headed Gull	+	?	?	+	?	?
Little Gull	+	?	?	+	0.1180	367.5
Chinese Black-headed Gull	+	?	?	+	?	?
Black-tailed Gull	+	?	?	+	0.5335	1100.6
Common Tern	+	?	?	+	0.1200	372.0
Roseate Tern	+	?	?	+	0.1100	349.2
Chinese Crested Tern	+	?	?	+	?	?
Caspian Tern	+	?	?	+	0.8550	1277.6
Crested Tern	?	?	?	?	0.3420	796.6
Gull-billed Tern	+	?	?	+	0.1700	479.2
Sooty Tern	?	?	?	?	0.1800	499.6
Little Tern	+	?	?	+	0.0570	216.5
Whiskered Tern	+	?	?	+	0.0882	297.4
Common Murre	?	?	?	?	0.9925	1728.3
Spectacled Guillemot	?	?	?	?	0.4900	1034.6
Ancient Murrelet	?	?	?	?	0.2060	551.0
Japanese Murrelet	+	?	?	+	?	?
Rhinoceros Auklet	?	?	?	?	0.5200	1080.3

Appendix 7. Marine bird prey preferences

Appendix Table 7.1. Marine Bird prey preferences: Bering Sea Continental Shelf and Shelfbreak (PICES sub-region BSC) in summer (June-August). Approximate percent composition of diet is given for each prey category. Unidentified Fish were assumed to be of medium energy density.

Species	Miscellaneous Invertebrates ~4kj/g	Gelatinous Zooplankters ~3kj/g	Crustacean Zooplankters ~4kj/g	Small Cephalopods ~3.5kj/g	Fish (Low Energy Density) ~3kj/g*	Fish (Med.Energ y Density) ~5kj/g*	Fish (High Energy Density) ~7kj/g*	Carrion, Offal & Discards ~5kj/g	Unknown ~5kj/g	Major Prey Species (also see footnotes)	References (also see footnotes)
Northern Fulmar[1]	0	+	0.06	0.212	0.606	0.121	0	+	0.001	*Theragra chalcogramma*	Hunt et al. 1981
Short-tailed Shearwater[1, 2]	0	+	0.872	0.001	0	0.126	0	0	0.001	*Parathemisto libellula*	Ogi et al. 1980
Fork-tailed Storm-Petrel	+	+	+++	++	0	+	+	0	0		Harrison 1984
Red-faced Cormorant	0.001	0	0.152	0	0.154	0.689	0	0	0.004	Miscellaneous fish	Hunt et al. 1981
Black-legged Kittiwake[1,3,4]	0	+	0.073	0.01	0.453	0.325	0.113	0	0.026	*Theragra chalcogramma*	Hunt et al. 1981
Red-legged Kittiwake[1,5]	+	+	0.01	0.019	0.238	0.145	0.572	0	0.016	*Myctophidae*	Hunt et al. 1981
Common Murre[3,4,6,7]	+	0	0.037	0.012	0.562	0.39	0	0	0	*Theragra chalcogramma*	Hunt et al. 1981
Thick-billed Murre[3,4,5,6,7,8]	0.001	+	0.176	0.053	0.396	0.36	0.004	0	0.01	*Theragra chalcogramma*	Hunt et al. 1981
Parakeet Auklet [9,10]	0.235	+	0.485	0.004	0.045	0.221	0	0	0.01	*Euphausiidae*	Hunt et al. 1981
Crested Auklet [9,10,11]	+	+	0.983	0	0	0.008	0	0	0.009	*Euphausiidae*	Hunt et al. 1981
Least Auklet [10,11,12,13,14,15]	+	+	0.927	0	0.003	0.004	0	0	0.066	*Cal. marshallae glacialis*	Hunt et al. 1981
Horned Puffin	0.039	0	0.111	0.007	0.407	0.39	0	0	0.046	*Hexagrammos stelleri*	Hunt et al. 1981
Tufted Puffin	0.119	0	0.034	0.017	0.17	0.644	0	0	0.016	*Theragra chalcogramma*	Hunt et al. 1981

* FISH: Low density (~3kj/g) = Cod, Rockfish, Pollock, etc.; Medium density (~5kj/g) = Capelin, Sandlance, etc.; High density (~7kj/g) = Lanternfish, Herring, Saury, Sardine, etc.

1/ Harrison (1984) found high frequencies of occurrence of scyphomedusae in the diets of these species.

2/ Hunt et al. (1996a) found that *Thysanoessa rashii* was the almost exclusive prey of short-tailed shearwaters around the Pribilof Islands.

3/ Springer et al. (1987) found *Eleginus gracilis* and *Ammodytes hexapterus* overall to be the most important prey of Common Murres and Black-legged Kittiwakes at Bluff, They found that *Boreogadus saida* were the most important diet component of Common and Thick-billed murres at St. Lawrence Island, and that *Ammodytes hexapterus* dominated the diets of Black-legged Kittiwakes at St. Lawrence Island.

4/ Springer et al. (1986) found *Theragra chalcogramma* to be the most important food of thick-billed murres, common murres, and black-legged kittiwakes on St. Matthew Island. They also found a variety of invertebrates in the diets of the three species including crabs, pteropods, polychaetes, and miscellaneous crustaceans. The exception to this was in 1982 when Pleuronectidae were tentatively identified as being of major importance in the diet of black-legged kittiwakes.

5/ Decker et al. (1995) used same data to show same diets.

6/ Ogi et al. (1985) found the major prey of Common Murres in the northwest Bering Sea to *be Parathemisto libellula* but, unlike Thick-billed Murres Common murres ate substantial amounts of euphausiids and fish (see Ogi and Hamanaka 1982).

7/ Decker and Hunt (1996) found *Theragra chalcogramma* and *Thysanoessa raschii* to be the primary prey of thick-billed and common murres around the Pribilof Islands. They also found squid to be important in common murre diets, but their sample sizes were small.

8/ Ogi and Hamanaka (1982) found Amphipods (especially *Parathemisto libellula*) to be the most important prey of thick-billed murres in the Gulf of Anadyr and adjacent waters of the northwestern Bering Sea. They found jellyfish only in thick-billed murres from the Gulf of Anadyr (0.2%) . The only species of fish found in the diet was Mallotus villosus.

9/ Bédard (1969) found that *Calanus finmarchicus*, probably a misidentification of *Neocalanus plumchrus*, to dominate diets of least auklets at St. Lawrence Island. He found that *Thysanoessa* spp. and Gammaridea dominated the diet of crested auklets and that *Calanus cristatus*, *Parathemisto libellula* and *Limacina* were of major importance in the diet of parakeet auklets

10/ Harrison (1990) found that: euphausiids dominated the diet of crested auklets on St. Matthew and St. Lawrence Islands and were important in the Chirikov Basin; Ctenophores and scyphomedusae dominated the diet of parakeet auklets in the Chirikov Basin; and Decapods in the diets of least and crested auklets.

11/ Piatt et al. (1990) found *Thysanoessa* spp. to comprise 97.8% of mass in diet of Crested Auklets, and that *Neocalanus plumchrus* composed 87% of diet of Least Auklets. They also found trace amounts of fish and squid in Least Auklet diets.

12/ Roby & Brink (1986) reviewed the literature and determined that the major prey of least auklets was consistently calanoid copepods.

13/ Springer & Roseneau (1985) found *Calanus marshallae* to comprise 84-89% of diet on St. Matthew Island, 3-65% on St. Lawrence Island, and 30% on Pribilof Islands. They found that *C. plumchrus* and *C. cristatus* were important on St. Lawrence Island and on the Pribilof Islands.

14/ Hunt and Harrison (1990) identified *Neocalanus plumchtrus* as the major prey of least auklets on King Island

15/ Hunt et al. (1990) identified *N. plumchurs and N. cristatus* as the major prey species of least auklets near St. Lawrence Island. They also found a few crab larvae and zoea, and *Limacina in a few stomachs.*

Appendix Table 7.2. Marine bird prey preferences: Russian/Aleutian Island/Pelagic Bering Sea (PICES sub-region BSP) in summer (June-August). Approximate percent composition of diet is given for each prey category. Unidentified Fish were assumed to be of medium energy density.

Species	Miscellaneous Invertebrates ~4kj/g	Gelatinous Zooplankters ~3kj/g	Crustacean Zooplankters ~4kj/g	Small Cephalopods ~3.5kj/g	Fish (Low Energy Density) ~3kj/g*	Fish (Medium Energy Density) ~5kj/g*	Fish (High Energy Density) ~7kj/g*	Birds & Mammals ~7kj/g	Carrion, Offal & Discards ~5kj/g	Unknown ~5kj/g	Major Prey Species	References
Short-tailed Shearwater	0	0	0.082	0.857	0	0.06	0	0	0	0.001	*Berryteuthis anonychus*	Ogi et al. 1980
Glaucous-winged Gull[1]	++	0	0	0	++	0	0	++	+	0	Sea Urchins, Birds, Fish	Trapp 1979
Parakeet Auklet[2]	0.175	0.292	0.31	0.122	0.058	0.038	0.006	0	0	0	Gelatinous organisms, *Limacina spp., Neocalanus cristatus, Thysanoessa inermis*	Hunt et al. 1998
Crested Auklet[2]	0.002	0	0.873	0.121	0.004	0	0	0	0	0	*Thysanoessa inermis*	Hunt et al. 1998
Least Auklet[2]	0.011	0	0.987	+	0	0	0	0	0	0.002	*Neocalanus plumchrus/ flemengeri*	Hunt et al. 1998
Whiskered Auklet	+	0	0.998	+	0	+	0	0	0	0.002	*Neocalanus plumchrus*	Day & Byrd 1989
Horned Puffin	0	0	0	++	+	+++	0	0	0	0	*Ammodytes hexapterus & Mallotus villosus*	Wehle 1983
Tufted Puffin	0	0	0	0	+	+++	0	0	0	0	*Ammodytes hexapterus*	Wehle 1983

* FISH: Low density (~3kj/g) = Cod, Rockfish, Pollock, etc.; Medium density (~5kj/g) = Capelin, Sandlance, etc.; High density (~7kj/g) = Lanternfish, Herring, Saury, Sardine, etc.

1/ Trapp (1979) found that sea urchins dominated diets of glaucous-winged gulls at Agattu and Alaid-Nitzki Islands, and that birds dominated the diet at Buldir and Semisopochnoi Islands, and that fish dominated the diets at Little Kiska Island.

2/ Day and Byrd (1989) found that *Neocalanus cristatus* made up 100% of Parakeet Auklet diets, *Neocalanus cristatus* made up 100% of Crested Auklet diets, and *Neocalanus plumchrus* made up 99.9 % of Least Auklet diets at Buldir Island.

Appendix Table 7.3. Marine bird prey preferences: Gulf of Alaska (PICES sub-region ASK) in summer (June-August). Approximate percent composition of diet is given for each prey category. Unidentified Fish were assumed to be of medium energy density

Species	Miscellaneous Invertebrates ~4kj/g	Gelatinous Zooplankters ~3kj/g	Crustacean Zooplankters ~4kj/g	Small Cephalopods ~3.5kj/g	Fish (Low Energy Density) ~3kj/g*	Fish (Medium Energy Density) ~5kj/g*	Fish (High Energy Density) ~7kj/g*	Birds & Mammals ~7kj/g	Carrion, Offal & Discards ~5kj/g	Unknown ~ 5kj/g	Major Prey Species	References
Northern Fulmar	0.002	+	0.009	0.96	0.006	0.022	0	0.001	+	0	Gondatidae	DeGange & Sanger 1987
Sooty Shearwater	0.001	0	0.017	0.266	0	0.716	0	0	0	0	*Mallotus villosus*	DeGange & Sanger 1987
Short-tailed Shearwater	0.018	0	0.725	0.02	0.001	0.236	0	0	0	0	*Euphausiidae*	DeGange & Sanger 1987
Fork-tailed Storm-Petrel	0.013	0	0.32	0.607	0.017	0.042	0	0	0	0.001	*Euphausiidae*	DeGange & Sanger 1987
Red-faced Cormorant	0	0	0	0	0.04	0.93	0.02	0	0	0.01	*Ammodytes hexapterus*	Sanger 1986
Pelagic Cormorant	0.002	0	0.006	0	0.006	0.986	0	0	0	0	*Ammodytes hexapterus*	DeGange & Sanger 1987
Double-crested Cormorant	0	0	+	0	0	+++	0	0	0	0	Unidentified Fish	Sanger 1986
Pomarine Jaeger	0	0	0	0	0	+	0	0	0	0	*Mallotus & Ammodytes*	Sanger 1986
Parasitic Jaeger	0	0	0	0	0	+	0	0	0	0	*Mallotus villosus*	Sanger 1986
Red-necked Phalarope	0.47	0	0.2	0.13	0	0.2	0	0	0	0	Nereid Polychaetes	Sanger 1986
Glaucous-winged Gull	0.016	0	0.009	0	0.002	0.962	0	+	+	0.011	Miscellaneous Fishes	DeGange & Sanger 1987
Common Gull	0.026	0	0.922	0	0	0.052	0	0	0	0	*Mallotus villosus*	DeGange & Sanger 1987
Black-legged Kittiwake	0.022	0	0.112	0.001	0.012	0.799	0	0	0	0.054	*Gammarid amphipods*	DeGange & Sanger 1987
Arctic Tern	0.001	0	0.958	0	0	0.029	0	0	0	0.012	*Thysanoessa inermis*	DeGange & Sanger 1987
Aleutian Tern	0.015	0	0.786	0	0	0.198	0	0	0	0.001	*Thysanoessa inermis*	DeGange & Sanger 1987
Common Murre	0.002	0	0.106	0.001	0.117	0.744	0	0	0	0.03	*Mallotus villosus*	DeGange & Sanger 1987
Thick-billed Murre	0.001	0	0.1	0.736	0.023	0.14	0	0	0	0	*Cephalopods*	DeGange & Sanger 1987
Pigeon Guillemot	0.013	0	0.391	0	0.048	0.548	0	0	0	0	Miscellaneous fishes	DeGange & Sanger 1987
Ancient Murrelet	0	0	0.776	0.002	0.012	0.205	0	0	0	0.005	*Thysanoessa inermis*	DeGange & Sanger 1987
Marbled Murrelet	0.002	0	0.162	0	0.04	0.796	0	0	0	0	*Mallotus*	DeGange & Sanger

Species	Miscellaneous Invertebrates ~4kj/g	Gelatinous Zooplankters ~3kj/g	Crustacean Zooplankters ~4kj/g	Small Cephalopods ~3.5kj/g	Fish (Low Energy Density) ~3kj/g*	Fish (Medium Energy Density) ~5kj/g*	Fish (High Energy Density) ~7kj/g*	Birds & Mammals ~7kj/g	Carrion, Offal & Discards ~5kj/g	Unknown ~ 5kj/g	Major Prey Species	References
											villosus	1987
Kittlitz's Murrelet	0	0	0.243	0	0.04	0.702	0.015	0	0	0	Miscellaneous fishes	DeGange & Sanger 1987
Cassin's Auklet	0.001	0	0.942	0.011	0	0.046	0	0	0	0	Calanoid copepods	DeGange & Sanger 1987
Parakeet Auklet	0	0	0.586	0	0	0.414	0	0	0	0	*Euphausiidae*	DeGange & Sanger 1987
Crested Auklet	0	0	0.999	0	0	0	0	0	0	0	*Acanthomysis spp.*	DeGange & Sanger 1987
Rhinoceros Auklet	0	0	0	0.012	0	0.945	0.015	0	0	0.028	Miscellaneous fishes	DeGange & Sanger 1987
Horned Puffin [1]	0.001	0	0.007	0.012	0.001	0.975	0	0	0	0.004	*Mallotus villosus*	DeGange & Sanger 1987
Tufted Puffin [2,3]	0.002	0	0.112	0.078	0.006	0.802	0	0	0	0	*Mallotus villosus*	DeGange & Sanger 1987

* FISH: Low density (~3kj/g) = Cod, Rockfish, Pollock, etc.; Medium density (~5kj/g) = Capelin, Sandlance, etc.; High density (~7kj/g) = Lanternfish, Herring, Saury, Sardine, etc.

1/ Wehle (1983) found that *Ammodytes hexapterus* was the most numerous prey with greatest frequency of occurrence at the Shumagin Islands in 1976 and at the Barren Islands in 1977, and that *A. hexapterus* and *Mallotus villosus* were of nearly equal numbers and frequency at the Barren Islands in 1977.

2/ Wehle (1983) found that *Ammodytes hexapterus* was the most numerous prey with greatest frequency of occurrence at Ugaiushak and Middleton Islands while Mallotus villosus was the most numerous prey number with greatest frequency of occurrence at Cathedral and the Barren Islands.

3/ Sanger & Hatch (1987) found that *Theragra chalcogramma* was the most important prey fed to young at Tangagm, Aiktak, and Midun Islands, that *Mallotus villosus* was the most important prey on Egg Island, and that Ammodytes *hexapterus* was the most important prey on Suklik, Fox, Middleton, and Cathedral Islands, that *A. hexapterus* and *M. villosus* were equally important on Noisy and Cliff Islands, and that *Oncorhynchus keta* was the most important prey on Naked Island.

Appendix Table 7.4. Marine bird prey preferences: Northern California Current (PICES sub-region CAN) in summer (June-August). Approximate percent composition of diet is given for each prey category. Unidentified Fish were assumed to be of medium energy density.

Species	Misc. Invertebrates ~4kj/g	Crustacean Zooplankton ~4kj/g	Small Cephalopods ~3.5kj/g	Fish (Low Energy Density) ~3kj/g*	Fish (Medium Energy Density) ~5kj/g*	Fish (High Energy Density) ~7kj/g*	Carrion &Offal ~4kj/g	Unknown ~4kj/g	Major Prey Species	References
Leach's Storm-Petrel	0	0.35	0	0	0.39	0	0	0.26	Fish & *Paracallisoma coecus*	Vermeer & Devito 1988
Fork-tailed Storm-Petrel	0	0.28	0	0	0.44	0	0	0.28	Fish & *Paracallisoma coecus*	Vermeer & Devito 1988
Pelagic Cormorant	0	0	0	0	0.69	0	0	0.31	Crescent Gunnel	Robertson 1974
Double-crested Cormorant	0	0	0	0	1.00	0	0	0	Penpoint Gunnel	Robertson 1974
Common Murre	0	0	0.20	0	0.40	0.40	0	0	*Ammodytes hexapterus* & *Clupea harengus*	Vermeer 1992
Pigeon Guillemot	0	0	0	0.35	0.65	0	0	0	*Mallotus villosus*	Krasnow & Sanger 1986
Ancient Murrelet[1]	0	0.005	0.01	0.255	0.73	0	0	0	*Sebastes sp.*	Vermeer et al. 1985
Cassin's Auklet[2,3,4,5]	0.028	0.7	0.003	0	0.15	0	0	0.122	*Neocalanus cristatus*	Vermeer 1985
Rhinoceros Auklet[6,7]	0	0	0.003	0.1	0.43	0.465	0	0	*Cololabis saira* & *Nansenia candeda*	Vermeer 1979
Tufted Puffin	0	0	0.035	0	0.08	0.705	0.176	0.001	*Ammodytes hexapterus*	Vermeer 1979

*: Low density (~3kj/g) = Cod, Rockfish, Pollock, etc.; Medium density (~5kj/g) = Capelin, Sandlance, etc.; High density (~7kj/g) = Lanternfish, Herring, Saury, Sardine, etc.

1/ Sealy (1975) found that *Thysanoessa spinifera* (42.7% numbers) and *Euphausia pacifica* (49.7% numbers) made up the greatest portion of the breeding adult Ancient Murrelet diet, that *Thysanoessa spinifera* (48.7%) and *Ammodytes hexapterus* (41.2% numbers) made up the greatest portion of subadult murrelet diets, and that *Ammodytes hexapterus* (98.3% numbers) made up most of the newly fledged murrelet diet.

2/ Burger & Powell (1990) found that *Ammodytes hexapterus* made up 58% on average of the Cassin's Auklet diet, and that euphausiids made up 28%. Vermeer et al. (1985) found Cassin's Auklets to have a diet similar to this one.

3/ Vermeer et al. (1985) found that *Neocalanus cristatus* made up 46% and euphausiids made up 31.2% of prey by wet weight.

4/ Vermeer (1984) found that scyphomedusae were present (2-5% wet weight) in the diet of Cassin's Auklet.

5/ Vermeer (1981) found that *Calanus cristatus* made up 38.6% of diet of Cassin's auklets.

6/ Vermeer & Westrheim (1984) found that *Ammodytes hexapterus* made up 27-59% of the biomass of the Rhinoceros Auklet diet, and that *Cololabis saira* and Herring (*Clupea harengus*) were very important in some areas.

7/ Vermeer (1980) found that Pacific Saury (*Cololabis saira)* dominated diets in 1976, Sandlance (*Ammodytes hexapterus)* and Sauries dominated in 1977, and rockfish and bluethroat argentines dominated in 1988 at Triangle Island.

Appendix Table 7.5. Marine bird prey preferences: Eastern Subarctic (PICES sub-region ESA) in summer (June-August). Approximate percent composition of diet is given for each prey category. Unidentified Fish were assumed to be of medium energy density.

Species	Miscellaneous Invertebrates ~4kj/g	Gelatinous Zooplankters ~3kj/g	Crustacean Zooplankters ~4kj/g	Small Cephalo pods ~3.5kj/g	Large Cephalo pods ~4kj/g	Fish (Low Energy Density) ~3kj/g*	Fish (Medium Energy Density) ~5kj/g*	Fish (High Energy Density) ~7kj/g*	Birds & Mammals ~7kj/g	Carrion, Offal & Discards ~5kj/g	Unknown ~5kj/g	Major Prey Species	Refe-rences
	No information available												

*: Low density (~3kj/g) = Cod, Rockfish, Pollock, etc.; Medium density (~5kj/g) = Capelin, Sandlance, etc.; High density (~7kj/g) = Lanternfish, Herring, Saury, Sardine, etc.

Appendix Table 7.6. Marine bird prey preferences: Western Subarctic (PICES sub-region WSA) in summer (June-August). Approximate percent composition of diet is given for each prey category. Unidentified Fish were assumed to be of medium energy density.

Species	Miscellaneous Invertebrates ~4kj/g	Gelatinous Zooplankters ~3kj/g	Crustacean Zooplankters ~4kj/g	Small Cephalo pods ~3.5kj/g	Large Cephalo pods ~4kj/g	Fish (Low Energy Density) ~3kj/g*	Fish (Medium Energy Density) ~5kj/g*	Fish (High Energy Density) ~7kj/g*	Birds & Mammals ~7kj/g	Carrion, Offal & Discards ~5kj/g	Unknown ~5kj/g	Major Prey Species	Refe-rences
Sooty Shearwater	0	0	0.001	0.001	0	0	0.423	0.567	0	0	0.008	*Sardinops melanosticta*	Shiomi & Ogi 1992
Short-tailed Shearwater	0	0.004	0.182	0.188	0	+	0.625	+	0	0	0.001	*Pleurogrammus monopterigius*	Ogi et al. 1980
Thick-billed Murre	0	0	0.072	0.795	0	+	0.065	+	0	0	0.068		Ogi 1980

*: Low density (~3kj/g) = Cod, Rockfish, Pollock, etc.; Medium density (~5kj/g) = Capelin, Sandlance, etc.; High density (~7kj/g) = Lanternfish, Herring, Saury, Sardine, etc.

Table 7.7. Marine bird prey preferences: Kamchatka & Kurile Islands (PICES sub-region KM/KL) in summer (June-August). Approximate percent composition of diet is given for each prey category. Unidentified Fish were assumed to be of medium energy density.

Species	Miscellaneous Invertebrates ~4kj/g	Gelatinous Zooplankters ~3kj/g	Crustacean Zooplankters ~4kj/g	Small Cephalo pods ~3.5kj/g	Large Cephalo pods ~4kj/g	Fish (Low Energy Density) ~3kj/g*	Fish (Medium Energy Density) ~5kj/g*	Fish (High Energy Density) ~7kj/g*	Birds & Mammals ~7kj/g	Carrion, Offal & Discards ~5kj/g	Unknown ~5kj/g	Major Prey Species	References
Short-tailed Shearwater	0	0	0	0	0	0	1	0	0	0	0	*Pleurogrammus sp.*	Ogi et al. 1980
Thick-billed Murre	0	0	0.981	0	0	0	0.018	0	0	0	0.001	*Thysanoessa inermis*	Ogi 1980
Tufted Puffin	+	+	+	+	0	0	+	0	0	0	+	Fish, Euphausiidae, Cephalopoda	Ogi 1980

*: Low density (~3kj/g) = Cod, Rockfish, Pollock, etc.; Medium density (~5kj/g) = Capelin, Sand lance, etc.; High density (~7kj/g) = Lanternfish, Herring, Saury, Sardine, etc.

Table 7.8. Marine bird prey preferences: Okhotsk Sea (PICES sub-region OKH) in summer (June-August). Approximate percent composition of diet is given for each prey category. Unidentified Fish were assumed to be of medium energy density.

Species	Miscellaneous Invertebrates ~4kj/g	Gelatinous Zooplankters ~3kj/g	Crustacean Zooplankters ~4kj/g	Small Cephalo pods ~3.5kj/g	Large Cephalo pods ~4kj/g	Fish (Low Energy Density) ~3kj/g*	Fish (Medium Energy Density) ~5kj/g*	Fish (High Energy Density) ~7kj/g*	Birds & Mammals ~7kj/g	Carrion, Offal & Discards ~5kj/g	Unknown ~5kj/g	Major Prey Species	References
Short-tailed Shearwater	0	0	0.946	0	0	0	0.054	0	0	0	0	*Thysanoessa raschii*	Ogi et al. 1980

*: Low density (~3kj/g) = Cod, Rockfish, Pollock, etc.; Medium density (~5kj/g) = Capelin, Sandlance, etc.; High density (~7kj/g) = Lanternfish, Herring, Saury, Sardine, etc.

Appendix Table 7.9. Marine bird prey preferences: California Current South (PICES sub-region CAS) in summer (June-August). Approximate percent composition of diet is given for each prey category. Unidentified Fish were assumed to be of medium energy density.

Species	Miscellaneous Invertebrates ~4kj/g	Gelatinous Zooplankters ~3kj/g	Crustacean Zooplankters ~4kj/g	Small Cephalopods ~3.5kj/g	Fish (Low Energy Density) ~3kj/g*	Fish (Medium Energy Density) ~5kj/g*	Fish (High Energy Density) ~7kj/g*	Birds & Mammals ~7kj/g	Carrion, Offal & Discards ~5kj/g	Unknown ~5kj/g	Major Prey Species	References
Sooty Shearwater	0	0	0.065	0.055	0.305	0.085	0.485	0	0	0.005	*Engraulis mordax*	Chu 1984
Leach's Storm-Petrel	0	0.44	0.47	0.01	0	0.08	0	0	0	0	Hydrozoa	Wiens & Scott 1975
Brandt's Cormorant	0	0	0	0.015	0.26	0.655	0.07	0	0	0	*Sebastes spp.*	Ainley et al. 1990
Pelagic Cormorant	0	0	0	0	0.545	0.45	0	0	0	0.005	*Sebastes spp.*	Ainley et al. 1990
Double-crested Cormorant[2]	0	0	0	0	0	0.99	0	0	0	0.01	*Cymatogaster aggregata*	Ainley et al. 1990
Western Gull	0.018	0	0.007	0.17	0.043	0.352	0.251	0.066	0.076	0.017	*Engraulis mordax*	Hunt & Butler 1980
Common Murre [3,4]	0	0	0	0.227	0.257	0.133	0.383	0	0	0	*Engraulis mordax & Sebastes spp.*	Ainley et al. 1990
Pigeon Guillemot [5]	0	0	0	0.163	0.343	0.493	0	0	0	0.001	*Sebastes spp.*	Ainley et al. 1990
Xantus' Murrelet	0	0	0	0	0	0.4	0.59	0	0	0.01	*Engraulis mordax*	Hunt et al. 1979
Cassin's Auklet [4,6,7,8]	0	0	0.808	0.005	0.183	+	0	0	0	0.004	*Thysanoessa spinifera & Euphausia pacifica*	Ainley et al. 1990
Rhinoceros Auklet [9]	0			0.02	0.405	0.02	0.555	0	0	0	*Engraulis mordax*	Sydeman et al. 1997
Tufted Puffin	0.002	0	0	0.159	0.062	+	0.577	0	0	0.2	*Engraulis mordax*	Ainley et al. 1990

*: Low density (~3kj/g) = Cod, Rockfish, Pollock, etc.; Medium density (~5kj/g) = Capelin, Sandlance, etc.; High density (~7kj/g) = Lanternfish, Herring, Saury, Sardine, etc.
1/ Sydeman et al. 1997 found that *Sebastes* spp. made up 57.2% of the Brandt's Cormorant diet. Wiens & Scott 1975 found that *Engraulis mordax* was the major prey species in the Brandt's Cormorant diet.
2/ Hunt et al. (1979) found that Scorpaenidae spp. made up 25% by weight of Brandt's Cormorant diet, and *Sebastes* spp. made up 86.9% of diet by volume of Double-crested cormorants.
3/ Wiens & Scott 1975 found that Crustaceans made up 27 % of the Common Murre diet.
4/ Briggs et al. 1988 found that *Thysanoessa spinifera, Euphausia pacifica* and *Sebastes* spp. were abundant in the diets of Cassin's auklet and common murre.
5/ Sydeman et al. 1997 found that miscellaneous invertebrates made up 0.1% of the Pigeon Guillemot diet and that *Sebastes jordani* was the principal prey species.
6/ Sydeman et al. 1997 found that *Euphausia pacifica* was the most important prey item in the Cassin's Auklet diet.
7/ Manuwal 1974 found major prey to be *Thysanoessa spinifera*, Amphipods (*Phromema*), and immature squid in the diet of Cassin's Auklet.
8/ Hunt et al. (1979) found that fish, especially *Sebastes* spp. were important in diet for Cassin's Auklet.
9/ Prey percentages based on number of individuals.

Appendix Table 7.10. Marine bird prey preferences: Eastern Transition Zone (PICES sub-region ETZ) in summer (June-August).

Approximate percent composition of diet is given for each prey category. Unidentified Fish were assumed to be of medium energy density.

Species	Miscellaneous Invertebrates ~4kj/g	Gelatinous Zooplankters ~3kj/g	Crustacean Zooplankters ~4kj/g	Small Cephalopods ~3.5kj/g	Large Cephalopods ~4kj/g	Fish (Low Energy Density) ~3kj/g*	Fish (Medium Energy Density) ~5kj/g*	Fish (High Energy Density) ~7kj/g*	Carrion, Offal & Discards ~5kj/g	Unknown ~5kj/g	Major Prey Species	References
Black-footed Albatross	0.01	0	0.003	0.02	0.739	+	0.1	0.1	+	0.028	*Ommastrephes bartrami*	Gould et al. 1997a
Laysan Albatross	0.036	+	0.01	0.014	0.746	+	0.121	0.073	+	0	*Ommastrephes bartrami*	Gould et al. 1997a
Sooty Shearwater	0.02	+	0.746	0.003	0.113	+	0.047	0.071	+	0	*Lepas fascicularis*	Gould, unpubl. data
Short-tailed Shearwater	0.001	0	0.835	+	0.045	0	0.093	0.025	+	0.001	*Lepas fascicularis*	Gould unpubl. data
Buller's Shearwater	+	0	0.02	0.001	0	0	0.112	0.866	+	0.001	*Cololabis saira*	Gould et al. 1998
Flesh-footed Shearwater	0.019	+	0.029	0.007	0.168	0	0.306	0.471	+	0	*Cololabis saira*	Gould et al. 1997b

*: Low density (~3kj/g) = Cod, Rockfish, Pollock, etc.; Medium density (~5kj/g) = Capelin, Sandlance, etc.; High density (~7kj/g) = Lanternfish, Herring, Saury, Sardine, etc.

Appendix Table 7.11. Marine bird prey preferences: Western Transition Zone (PICES sub-region WTZ) in summer (June-August). Approximate percent composition of diet is given for each prey category. Unidentified Fish were assumed to be of medium energy density.

Species	Miscellaneous Invertebrates ~4kj/g	Gelatinous Zooplankters ~3kj/g	Crustacean Zooplankters ~4kj/g	Small Cephalopods ~3.5kj/g	Large Cephalopods ~4kj/g	Fish (Low Energy Density) ~3kj/g*	Fish (Medium Energy Density) ~5kj/g*	Fish (High Energy Density) ~7kj/g*	Carrion, Offal & Discards ~5kj/g	Unknown ~ 5kj/g	Major Prey Species	References
Black-footed Albatross	0.001	0	0.012	0.02	0.739	+	0.1	0.1	+	0.028	*Ommastrephes bartrami*	Gould et al. 1997a
Laysan Albatross	0.002	+	0.044	0.014	0.746	+	0.121	0.073	+	0	*Ommastrephes bartrami*	Gould et al. 1997a
Sooty Shearwater	+	0.017	0.13.4	0.333	0	0	0.378	0.137	0	0.011	*Lepas fascicularis, small squid*	Shiomi & Ogi 1992
Short-tailed Shearwater	0.001	0	0.835	+	0.045	0	0.093	0.025	+	0.001	*Lepas fascicularis*	Gould unpubl.
Buller's Shearwater	+		0.02	0.001	0	0	0.112	0.866	+	0.001	*Cololabis saira*	Gould et al. 1998
Flesh-footed Shearwater	0.019	+	0.029	0.007	0.168	0	0.306	0.471	+	0	*Cololabis saira*	Gould et al. 1997b

*: Low density (~3kj/g) = Cod, Rockfish, Pollock, etc.; Medium density (~5kj/g) = Capelin, Sandlance, etc.; High density (~7kj/g) = Lanternfish, Herring, Saury, Sardine, etc.

Appendix Table 7.12. Marine bird prey preferences: Kuroshio and Oyashio Currents (PICES sub-region KR/OY) in summer (June-August). Approximate percent composition of diet is given for each prey category. Unidentified Fish were assumed to be of medium energy density.

Species	Miscellaneous Invertebrates ~4kj/g	Gelatinous Zooplankters ~3kj/g	Crustacean Zooplankters ~4kj/g	Small Cephalo pods ~3.5kj/g	Large Cephalo pods ~4kj/g	Fish (Low Energy Density) ~3kj/g*	Fish (Medium Energy Density) ~5kj/g*	Fish (High Energy Density) ~7kj/g*	Birds & Mammals ~7kj/g	Carrion, Offal & Discards ~5kj/g	Unknown ~5kj/g	Major Prey Species	References
Thick-billed Murre	0	0	0.139	0	0	0	0.861	0	0	0	0	*Pleurogrammus monopterigius*	Ogi 1980
Horned Puffin	0	0	0	0	0	0	+	0	0	0	+	*Pleurogrammus monopterigius*	Ogi 1980

*: Low density (~3kj/g) = Cod, Rockfish, Pollock, etc.; Medium density (~5kj/g) = Capelin, Sandlance, etc.; High density (~7kj/g) = Lanternfish, Herring, Saury, Sardine, etc.

Appendix Table 7.13. Marine bird prey preferences: Sea of Japan (PICES sub-region SJP) in summer (June-August). Approximate percent composition of diet is given for each prey category. Unidentified Fish were assumed to be of medium energy density.

Species	Miscellaneous Invertebrates ~4kj/g	Gelatinous Zooplankters ~3kj/g	Crustacean Zooplankters ~4kj/g	Small Cephalopod s ~3.5kj/g	Large Cephalop ods ~4kj/g	Fish (Low Energy Density) ~3kj/g*	Fish (Medium Energy Density) ~5kj/g*	Fish (High Energy Density) ~7kj/g*	Birds & Mammals ~5kj/g	Carrion, Offal & Discards ~5kj/g	Unknown ~5kj/g	Major Prey Species	References
Slaty-backed Gull	0	0	0	0	0	0	0	0	++	0	0	Black-tailed Gull	Watanuki 1983

*: Low density (~3kj/g) = Cod, Rockfish, Pollock, etc.; Medium density (~5kj/g) = Capelin, Sandlance, etc.; High density (~7kj/g) = Lanternfish, Herring, Saury, Sardine, etc.

Appendix Table 7.14. Marine bird prey preferences: East China Sea (PICES sub-region ECS) in summer (June-August). Approximate percent composition of diet is given for each prey category. Unidentified Fish were assumed to be of medium energy density.

Species	Miscellaneous Invertebrates ~4kj/g	Gelatinous Zooplankters ~3kj/g	Crustacean Zooplankters ~4kj/g	Small Cephalo pods ~3.5kj/g	Large Cephalo pods ~4kj/g	Fish (Low Energy Density) ~3kj/g*	Fish (Medium Energy Density) ~5kj/g*	Fish (High Energy Density) ~7kj/g*	Birds & Mammals ~5kj/g	Carrion, Offal & Discards ~5kj/g	Unknown ~ 5kj/g	Major Prey Species	References
	No Information available												

*: Low density (~3kj/g) = Cod, Rockfish, Pollock, etc.; Medium density (~5kj/g) = Capelin, Sandlance, etc.; High density (~7kj/g) = Lanternfish, Herring, Saury, Sardine, etc.

Appendix 8. Estimates of the amount of prey consumed by marine birds

Appendix Table 8.1. Metric tons of prey consumed by marine birds: Bering Sea Continental Shelf & Shelfbreak (PICES sub-region BSC), Summer (June-August).

Species	Miscellaneous Invertebrates	Gelatinous Zooplankters	Crustacean Zooplankters	Small Cephalopods	Large Cephalopods	Fish (Low Energy Density)	Fish (Medium Energy Density)	Fish (High Energy Density)	Birds & Mammals	Carrion, Offal & Discards	Unknown	Total
Northern Fulmar	0	0	1947	6879	0	19661	3926	0	0	0	32.33083	32,446
Short-tailed Shearwater	0	0	429494	492	0	0	62060	0	0	0	491.7293	492,538
Red-faced Cormorant	1	0	174	0	0	177	790	0	0	0	3.759398	1,145
Black-legged Kittiwake	0	0	3626	496	0	22497	16140	5611	0	0	1290.977	49,662
Red-legged Kittiwake	0	0	96	181	0	2272	1383	5458	0	0	152.6316	9,543
Common Murre	0	0	6545	2123	0	99403	68980	0	0	0	0	177,051
Thick-billed Murre	257	0	45095	13581	0	101466	92241	1025	0	0	2563.158	256,229
Parakeet Auklet	1294	0	2669	23	0	247	1217	0	0	0	54.88722	5,506
Crested Auklet	0	0	39518	0	0	0	322	0	0	0	361.6541	40,202
Least Auklet	0	0	20011	0	0	65	86	0	0	0	1424.06	21,586
Horned Puffin	209	0	595	37	0	2179	2088	0	0	0	245.8647	5,353
Tufted Puffin	2160	0	617	309	0	3086	11687	0	0	0	290.2256	18,150
Total*	3,921	0	550	24,122	0	251,053	260,920	12,094	0	0	6,911	1,109,409

* Prey totals represent 98% of the known summer energy demands of marine birds in the area
(Sum of Occupancy x daily energy demands of species listed above divided by Sum of Occupancy x daily energy demands of species from Appendix Table 6.1.)

Appendix Table 8.2. Metric tons of prey consumed by marine birds: Bering Sea Pelagic/Russia/Aleutian Islands (PICES sub-region BSP) in summer (July-August).

Species	Miscellaneous Invertebrates	Gelatinous Zooplankters	Crustacean Zooplankters	Small Cephalopods	Large Cephalopods	Fish (Low Energy Density)	Fish (Medium Energy Density)	Fish (High Energy Density)	Birds & Mammals	Carrion, Offal & Discards	Unknown	Total
Short-tailed Shearwater	0	0	8,930	93,327	0	0	6,534	0	0	0	109	108,900
Parakeet Auklet	343	572	606	239	0	113	74	12	0	0	0	1,960
Crested Auklet	177	0	77,019	10,675	0	352	0	0	0	0	0	88,223
Least Auklet	222	0	19,919	0	0	0	0	0	0	0	40	20,181
Whiskered Auklet	+	0	69	+	0	0	+	0	0	0	0	69
Total*	742	572	106,544	104,241	0	466	6,609	12	0	0	149	219,334

* Prey totals represent 36% of the known summer energy demands of marine birds in the area
(Sum of Occupancy x daily energy demands of species listed above divided by Sum of Occupancy x daily energy demands of species from Appendix Table 6.2)

Appendix Table 8.3. Metric tons of prey consumed by marine birds: Gulf of Alaska (PICES sub-region ASK) in summer (June-August).

Species	Miscellaneous Invertebrates	Gelatinous Zooplankters	Crustacean Zooplankters	Small Cephalopods	Large Cephalopods	Fish (Low Energy Density)	Fish (Medium Energy Density)	Fish (High Energy Density)	Birds & Mammals	Carrion, Offal & Discards	Unknown	Total
Northern Fulmar	28	+	125	13,339	0	84	306	0	13	+	0	13,895
Sooty Shearwater	113	0	1,922	30,071	0	0	80,944	0	0	0	0	113,050
Short-tailed Shearwater	3,544	0	142,783	3,939	0	197	46,478	0	0	0	0	196,942
Fork-tailed Storm-Petrel	109	0	2,673	5,071	0	142	351	0	0	0	8	8,355
Red-faced Cormorant	0	0	0	0	0	21	488	11	0	0	5	525
Pelagic Cormorant	1	0	3	0	0	3	398	0	0	0	0	404
Red-necked Phalarope	743	0	317	206	0	0	317	0	0	0	0	1,583
Glaucous-winged Gull	145	0	81	0	0	19	8,705	0	+	+	100	9,049
Common Gull	11	0	375	0	0	0	21	0	0	0	0	407
Black-legged Kittiwake	438	0	2,226	20	0	238	15,886	0	0	0	1,073	19,881
Arctic Tern	1	0	882	0	0	0	27	0	0	0	11	920
Aleutian Tern	15	0	783	0	0	0	198	0	0	0	1	998
Common Murre	65	0	3,466	33	0	3,826	24,328	0	0	0	982	32,701
Thick-billed Murre	4	0	403	2,967	0	93	564	0	0	0	0	4,031
Pigeon Guillemot	11	0	307	0	0	37	430	0	0	0	0	785
Ancient Murrelet	0	0	2,369	7	0	37	625	0	0	0	15	3,053
Cassin's Auklet	5	0	5,442	64	0	0	266	0	0	0	0	5,778
Parakeet Auklet	0	0	622	0	0	0	439	0	0	0	0	1,061
Crested Auklet	0	0	121	0	0	0	0	0	0	0	+	121
Rhinoceros Auklet	0	0	0	55	0	0	4,237	68	0	0	125	4,485
Horned Puffin	5	0	36	63	0	5	5,061	0	0	0	21	5,191
Tufted Puffin	142	0	7,933	5,525	0	426	56,806	0	0	0	0	70,832
Total*	5,381	0	172,871	61,360	0	5,128	246,873	78	13	0	2,341	494,046

* Prey totals represent 99% of the known summer energy demands of marine birds in the area
(Sum of Occupancy x daily energy demands of species listed above divided by Sum of Occupancy x daily energy demands of species from Appendix Table 6.3).

Appendix Table 8.4. Metric tons of prey consumed by marine birds: California Current North (PICES sub-region CAN) in summer (June-August).

Species	Miscellaneous Invertebrates	Gelatinous Zooplankters	Crustacean Zooplankters	Small Cephalopods	Large Cephalopods	Fish (Low Energy Density)	Fish (Medium Energy Density)	Fish (High Energy Density)	Birds & Mammals	Carrion, Offal & Discards	Unknown	Total
Leach's Storm-Petrel	0	0	148	0	0	0	164	0	0	0	110	421
Fork-tailed Storm-Petrel	0	0	206	0	0	0	324	0	0	0	206	736
Pelagic Cormorant	0	0	0	0	0	0	462	0	0	0	208	670
Double-crested Cormorant	0	0	0	0	0	0	309	0	0	0	0	309
Common Murre	0	0	0	669	0	0	1,338	1,338	0	0	0	3,345
Pigeon Guillemot	0	0	0	0	0	23	42	0	0	0	0	65
Ancient Murrelet	0	0	9	19	0	477	1,365	0	0	0	0	1,870
Cassin's Auklet	83	0	2,070	9	0	0	435	0	0	0	361	2,957
Rhinoceros Auklet	0	0	0	9	0	305	1,317	1,417	0	0	0	3,048
Tufted Puffin	0	0	0	30	0	0	72	610	0	152	1	865
Total*	83	0	2,433	736	0	804	5,828	3,365	0	152	885	14,285

* Prey totals represent 48% of the known summer energy demands of birds in the area.
(Sum of Occupancy x daily energy demands of species listed above divided by Sum of Occupancy x daily energy demands of species from Appendix Table 6.4).

Appendix Table 8.5. Metric tons of prey consumed by marine birds: Eastern Subarctic (PICES sub-region ESA) in summer (June-August).

Species	Miscellaneous Invertebrates	Gelatinous Zooplankters	Crustacean Zooplankters	Small Cephalopods	Large Cephalopods	Fish (Low Energy Density)	Fish (Medium Energy Density)	Fish (High Energy Density)	Birds & Mammals	Carrion, Offal & Discards	Unknown	Total
	No information available											

* Prey totals represent 0.0% of the known summer biomass of marine birds in the area

Appendix Table 8.6. Metric tons of prey consumed by marine birds: Western Subarctic (PICES sub-region WSA) in summer (June-August).

Species	Miscellaneous Invertebrates	Gelatinous Zooplankters	Crustacean Zooplankters	Small Cephalopods	Large Cephalopods	Fish (Low Energy Density)	Fish (Medium Energy Density)	Fish (High Energy Density)	Birds & Mammals	Carrion, Offal & Discards	Unknown	Total
Sooty Shearwater	0	0	90	90	0	0	38,208	51,216	0	0	722	90,327
Short-tailed Shearwater	0	442	1,773	2,435	0	0	8,096	0	0	0	13	12,759
Thick-billed Murre	0	0	188	2,071	0	0	169	0	0	0	177	2,604
Total*	0	442	2,051	4,596	0	0	46,473	51,216	0	0	912	105,690

* Prey totals represent 36% of the known summer energy demands of marine birds in the area
(Sum of Occupancy x daily energy demands of species above divided by Sum of Occupancy x daily energy demands of species from Appendix Table 6.6).

Appendix Table 8.7. Metric tons of prey consumed by marine birds: Kamchatka and Kurile Islands (PICES sub-region KM/KL) in summer (June-August).

Species	Miscellaneous Invertebrates	Gelatinous Zooplankters	Crustacean Zooplankters	Small Cephalopods	Large Cephalopods	Fish (Low Energy Density)	Fish (Medium Energy Density)	Fish (High Energy Density)	Birds & Mammals	Carrion, Offal & Discards	Unknown	Total
Thick-billed Murre	0	0	2,173	0	0	0	40	0	0	0	3	2,216
Total*	0	0	2,173	0	0	0	40	0	0	0	3	2,216

* Prey totals represent 2.4% of the known summer energy demands of marine birds in the area
(Sum of Occupancy x daily energy demands of species listed above is divided by Sum of Occupancy x daily energy demands of species from Table 6.7).

Appendix Table 8.8. Metric tons of prey consumed by marine birds: Sea of Okhotsk (PICES sub-region OKH) in summer (June-August).

Species	Miscellaneous Invertebrates	Gelatinous Zooplankters	Crustacean Zooplankters	Small Cephalopods	Large Cephalopods	Fish (Low Energy Density)	Fish (Medium Energy Density)	Fish (High Energy Density)	Birds & Mammals	Carrion, Offal & Discards	Unknown	Total
	No information available											

* Prey totals represent 0.0% of the known summer biomass of marine birds in the area

Appendix Table 8.9. Metric tons of prey consumed by marine birds: California Current South (PICES sub-region CAS) in summer (June-August).

Species	Miscellaneous Invertebrates	Gelatinous Zooplankters	Crustacean Zooplankters	Small Cephalopods	Large Cephalopods	Fish (Low Energy Density)	Fish (Medium Energy Density)	Fish (High Energy Density)	Birds & Mammals	Carrion, Offal & Discards	Unknown	Total
Sooty Shearwater	0	0	735	622	0	3,450	961	5,486	0	0	57	11,311
Leach's Storm-petrel	0	247	264	6	0	0	45	0	0	0	0	561
Brandt's Cormorant	0	0	0	89	0	1,548	3,901	417	0	0	0	5,955
Pelagic Cormorant	0	0	0	0	0	1,354	1,118	0	0	0	12	2,484
Double-crested Cormorant	0	0	0	0	0	0	1,041	0	0	0	11	1,051
Western Gull	143	0	56	1,349	0	341	2,793	1,991	524	603	135	7,934
Common Murre	0	0	0	2,932	0	3,320	1,718	4,947	0	0	0	12,917
Pigeon Guillemot	0	0	0	96	0	202	290	0	0	0	0	588
Xantus' Murrelet	0	0	0	0	0	0	6	9	0	0	0	16
Cassin's Auklet	0	0	1,869	12	0	423	0	0	0	0	9	2,313
Rhinoceros Auklet	0	0	0	3	0	66	3	91	0	0	0	163
Tufted Puffin	1	0	0	68	0	27	0	247	0	0	86	429
Total*	144	247	2,924	5,177	0	10,731	11,876	13,189	524	603	310	45,723

*Prey totals represent 83% of the known summer energy demands of marine birds in the area
(Sum of Occupancy x daily energy demands of species listed above divided by sum of occupancy x daily energy demands of species from Appendix Table 6.9).

Appendix Table 8.10. Metric tons of prey consumed by marine birds: Eastern Transition Zone (PICES sub-region ETZ) in summer (June-August).

Species	Miscellaneous Invertebrates	Gelatinous Zooplankters	Crustacean Zooplankters	Small Cephalopods	Large Cephalopods	Fish (Low Energy Density)	Fish (Medium Energy Density)	Fish (High Energy Density)	Birds & Mammals	Carrion, Offal & Discards	Unknown	Total
Black-footed Albatross	105	0	32	210	7,778	0	1,052	1,052	0	0	295	10,524
Laysan Albatross	2,261	0	628	879	46,847	0	7,598	4,585	0	0	0	62,797
Sooty Shearwater	302	0	11,266	45	1,706	0	710	1,072	0	0	0	15,102
Short-tailed Shearwater	3	0	1,830	0	98	0	203	55	0	0	3	2,192
Buller's Shearwater	0	0	1	1	0	0	11	81	0	0	1	95
Total*	2,671	0	13,758	1135	56,429	0	9,575	6,844	0	0	299	90,711

* Prey totals represent 67% of the known summer energy demands of marine birds in the area
(Sum of Occupancy x daily energy demands of species listed above divided by Sum of Occupancy x daily energy demands of species from Appendix Table 6.10).

Appendix Table 8.11. Metric tons of prey consumed by marine birds: Western Transition Zone (PICES sub-region WTZ) in summer (June-August).

Species	Miscellaneous Invertebrates	Gelatinous Zooplankters	Crustacean Zooplankters	Small Cephalopods	Large Cephalopods	Fish (Low Energy Density)	Fish (Medium Energy Density)	Fish (High Energy Density)	Birds & Mammals	Carrion, Offal & Discards	Unknown	Total
Black-footed Albatross	7	0	74	124	4,585	+	621	621	0	+	174	6,206
Laysan Albatross	73	+	1,600	509	27,121	+	4,400	2,655	0	+	0	36,358
Sooty Shearwater	+	13,488	98,376	264,185	0	0	299,886	108,689	0	0	8,727	793,350
Short-tailed Shearwater	31	0	25,408	+	1,370	0	2,830	761	0	+	31	30,430
Buller's Shearwater	+	+	753	37	0	0	4,215	32,592	0	+	37	37,634
Total*	111	13,488	126,211	264,855	33,076	0	311,952	145,317	0	0	8,970	903,978

* Prey totals represent 85% of the known summer energy demands of marine birds in the area
(Sum of Occupancy x daily energy demands of species listed above divided by Sum of Occupancy x daily energy demands of species from Appendix Table 6.11).

Appendix Table 8.12. Metric tons of prey consumed by marine birds: Kuroshio/Oyashio Currents (PICES sub-region KR/OY) in summer (June-August).

Species	Miscellaneous Invertebrates	Gelatinous Zooplankters	Crustacean Zooplankters	Small Cephalopods	Large Cephalopods	Fish (Low Energy Density)	Fish (Medium Energy Density)	Fish (High Energy Density)	Birds & Mammals	Carrion, Offal & Discards	Unknown	Total
No information available												

* Prey totals represent 0.0% of the known summer energy demands of marine birds in the area

Appendix Table 8.13. Metric tons of prey consumed by marine birds: Sea of Japan (PICES sub-region SJP) in summer (June-August).

Species	Miscellaneous Invertebrates	Gelatinous Zooplankters	Crustacean Zooplankters	Small Cephalopods	Large Cephalopods	Fish (Low Energy Density)	Fish (Medium Energy Density)	Fish (High Energy Density)	Birds & Mammals	Carrion, Offal & Discards	Unknown	Total
No information available												

* Prey totals represent 0.0% of the known summer energy demands of marine birds in the area

Appendix Table 8.14. Metric tons of prey consumed by marine birds: East China Sea (PICES sub-region ECS) in summer (June-August).

Species	Miscellaneous Invertebrates	Gelatinous Zooplankters	Crustacean Zooplankters	Small Cephalopods	Large Cephalopods	Fish (Low Energy Density)	Fish (Medium Energy Density)	Fish (High Energy Density)	Birds & Mammals	Carrion, Offal & Discards	Unknown	Total
No information available												

* Prey totals represent 0.0% of the known summer energy demands of marine birds in the area

Appendix 9. Marine mammal abundance and energy requirements in PICES marine ecosystems

Appendix Table 9.1. (Sub-region: BSC). Abundance codes indicate methods used to derive estimates: L=line transect, S=strip transect, M=mark-recapture, C=colony counts, E=catch per unit effort, D=density index. Residency=dates present in area or subarea; occupancy=number of mammal or bird days in area or subarea. Average body mass figures are from Trites and Pauly (1997), and allometric daily energy needs were calculated using the formulas derived by Perez and McAllister (1993).

Species	Summer (June-September)				Mean body mass(kg)	Individual allometric daily energy requirements	Summer energy requirements (1000 kjoules)	References
	Abundance	Code	Residency	Occupancy				
Steller sea lion	9,930	C	Jun-Sep	1,211,460	198	82.0	99,339,720	Loughlin *et al*. 1992, Sease and Loughlin 1999
Northern fur seal	1,002,500	C	Jun-Sep	122,305,000	28	18.8	2,299,334,000	Hill and DeMaster 1998
Harbor seal	13,300	C	Jun-Sep	1,622,600	60	18.0	29,206,800	Hill and DeMaster 1998
Spotted seal	?		?	?	43	14.2	?	
Bearded seal	?		?	?	200	44.4	?	
Ringed seal	?		?	?	43	14.2	?	
Ribbon seal	?		?	?	71	20.5	?	
Walrus	46,100	S	Jun-Sep	5,624,200	1,200	317.3	1,784,600,000	Fay 1982, Fay *et al*. 1997
Polar bear	0		0	0	0	0	0	
Sea otter	?		?	?	25	24.3	?	Kenyon 1969
Beluga whale: E. Bering Sea and Bristol Bay	18,800	L/C	Jun-Sep	2,293,600	303	96.3	220,873,680	Lowry and Frost 1999, Lowry *et al.* 1999
Beluga whale: Beaufort and Chuckchi	0	S/C	----	0	800	199.5	0	Hill and DeMaster 1998
Killer whale	?		?	?	2,280	437.6	?	
Pac.white-sided dolphin	?	L	?	?	79	35.1	?	Hill and DeMaster 1998
Harbor porpoise	10,900	L	Jun-Sep	1,329,800	31	17.4	23,138,520	Hill and DeMaster 1998
Dalls porpoise	?	L	?	?	62	29.3	?	Hill and DeMaster 1998
Gray whale	25,235		Jun/Jul-Aug/Sep	919,675	19,600	1,330.7	1,223,812,200	Highsmith and Coyle 1992, Hobbs and Rugh 1998, DeMaster, pers. comm..
Humpback whale	?		?	?	30,408	1,849.7	?	
Fin whale	?		?	?	55,590	2,908.3	?	
Minke whale	?		?	?	6,566	586.0	?	
Northern right whale	?		?	?	24,069	1,552.3	?	
Bowhead whale	0		----	0	31,506	3,136.3	0	Zeh *et al.* 1995

Appendix Table 9.2. Marine mammal abundance and energy requirements in PICES marine ecosystems (Sub-region: BSP). Abundance codes indicate methods used to derive estimates: L=line transect, S=strip transect, M=mark-recapture, C=colony counts, E=catch per unit effort, D=density index. Residency=dates present in area or subarea; occupancy=number of mammal or bird days in area or subarea. Average body mass figures are from Trites and Pauly (1997), and allometric daily energy needs were calculated using the formulas derived by Perez and McAllister (1993).

Species	Summer (June-September, 122 days)				Mean body mass (kg)	Individual allometric daily energy requirements (1000 kjoules)	Energy requirements (1000 kJoules)	References
	Abundance	Code	Residency	Occupancy				
Bearded seal	180,000	S?	Jun-Sep	21,960,000	200	44.4	973,934,784	Popov (1982)
Blue whale	?	-	Jun-Sep	?	102,736	4609.8	?	
Bowhead whale	?	-	Jun-Sep	?				
Dall's porpoise	?	-	Jul-Sep	?	61	28.9	?	
Fin whale	?	-	Jun-Sep	?	55,590	2908.3	?	
Harbor porpoise	?	-	Jun-Sep	?				
Harbor seal	?	-	Jun-Sep	?	63	18.7	?	
Humpback whale	?	-	Jun-Sep	?	30,408	1849.7	?	
Killer whale	?	-	Jun-Sep	?				
Minke whale	?	-	Jun-Sep	?	6,566	586.0	?	
Northern fur seal	200,000	C	Jun-Sep	24,400,000	28	18.8	458,720,000	
Northern right whale	?	-	Jun-Sep	?				
Ribbon seal	13,000	S?	Jun-Sep	1,586,000	71	20.5	32,515,538	Popov (1982)
Ringed seal	86,500	S	Jun-Sep	10,553,000	43	14.2	150,122,757	Popov (1982)
Sea otter	?	-	Jun-Sep	?				
Sei whale	?	-	Jun-Sep	?	16,811	1186.0	?	
Sperm whale	?	-	Jun-Sep	?	26,939	2788.9	?	
Spotted seal	13,000	S?	Jun-Sep	1,586,000	63	18.7	29,658,200	Popov (1982)
Steller sea lion	1,500	C	Jun-Sep	183,000	200	82.8	15,152,400	Loughlin *et al.* (1992)
Ziphiids	?	-	Jun-Sep	?	?	?	?	

*: only males migrate to the Bering Sea.

Appendix Table 9.3. Marine mammal abundance and energy requirements in PICES marine ecosystems (Sub-region: ASK). Abundance codes indicate methods used to derive estimates: L=line transect, S=strip transect, M=mark-recapture, C=colony counts, E=catch per unit effort, D=density index. Residency=dates present in area or subarea; occupancy=number of mammal or bird days in area or subarea. Average body mass figures are from Trites and Pauly (1997), and allometric daily energy needs were calculated using the formulas derived by Perez and McAllister (1993).

Species	Summer (June-September)				Mean body mass(kg)	Individual allometric daily energy requirements (1000 kjoules)	Summer energy requirements (1000 kjoules)	References
	Abundance	Code	Residency	Occupancy				
Steller sea lion	39,800	C	Jun-Sep	4,855,600	198	82.0	398,159,200	Loughlin et al. 1992, Sease and Loughlin 1999
Northern fur seal	?	C	?	?	28	18.8	?	
Harbor seal	66,600	C	Jun-Sep	8,125,200	60	18.0	146,253,600	Hill and DeMaster 1998
Northern elephant seal	?	C	?	?	371	70.7	?	
Beluga whale	834	C	Jun-Sep	101,748	303	96.3	9,798,332	Hill and DeMaster 1998
Sea otter	?		Jun-Sep	?	25	24.3	?	
Killer whale	?	M	?	?	2,280	437.6	?	
Pacific white-sided dolphin	?	L	?	?	79	35.1	?	
Harbor porpoise	18,800	L	Jun-Sep	2,293,600	31	17.4	39,908,640	Hill and DeMaster 1998
Dalls porpoise	?	L	?	?	62	29.3	?	
Sperm whale	?		?	?	18,518	2,105.5	?	
Baird=s beaked whale	?		?	?	3,484	601.7	?	
Cuvier=s beaked whale	?		?	?	927	222.8	?	
Gray whale	100		?	?	16,177	1,152.3	?	Hill and DeMaster 1998
Humpback whale	?		?	?	30,408	1,849.7	?	
Fin whale	?		?	?	55,590	2,908.3	?	
Minke whale	?		?	?	6,566	586.0	?	
Northern right whale	?		?	?	24,069	1,552.3	?	

Appendix Table 9.4. Marine mammal abundance and energy requirements in PICES marine ecosystems (Sub-region: CAN). Abundance codes indicate methods used to derive estimates: L=line transect, S=strip transect, M=mark-recapture, C=colony counts, E=catch per unit effort, D=density index. Residency=dates present in area or subarea; occupancy=number of mammal or bird days in area or subarea. Average body mass figures are from Trites and Pauly (1997), and allometric daily energy needs were calculated using the formulas derived by Perez and McAllister (1993).

Species	Summer (June-September)				Mean body mass(kg)	Individual allometric daily energy requirements (1000 kjoules)	Summer energy requirements (1000 kjoules)	References
	Abundance	Code	Residency	Occupancy				
Steller sea lion	13,800	C	Jun-Sep	1,683,600	198	82.0	138,055,200	Hill and DeMaster 1998
Northern fur seal	?	C	?	?	28	18.8	?	
Harbor seal					60	18.0		
Northern elephant seal	?	C	?	?	371	70.7	?	
Sea otter	?		?	?	25	24.3	?	
Killer whale	1,078	M	Jun-Sep	131,516	2,280	437.6	57,551,401	Hill and DeMaster 1998
Pac. white-sided dolphin	?	L	?	?	79	35.1	?	
Harbor porpoise	10,301	L	Jun-Sep	1,256,722	31	17.4	21,866,962	Hill and DeMaster 1998
Dalls porpoise	?	L	?	?	62	29.3	?	
Sperm whale	?		?	?	18,518	2,105.5	?	
Cuvier's beaked whale	?		?	?	927	222.8	?	
Gray whale	150		?	?	16,177	1,152.3	?	Hill and DeMaster 1998
Humpback whale	?		?	?	30,408	1,849.7	?	
Fin whale	?		?	?	55,590	2,908.3	?	
Minke whale	?		?	?	6,566	586.0	?	
Northern right whale	?		?	?	24,069	1,552.3	?	

Appendix Table 9.5. Marine mammal abundance and energy requirements in PICES marine ecosystems (Sub-region: ESA). Abundance codes indicate methods used to derive estimates: L=line transect, S=strip transect, M=mark-recapture, C=colony counts, E=catch per unit effort, D=density index. Residency=dates present in area or subarea; occupancy=number of mammal or bird days in area or subarea. Average body mass figures are from Trites and Pauly (1997), and allometric daily energy needs were calculated using the formulas derived by Perez and McAllister (1993).

Species	Summer (June-September)				Mean body mass(kg)	Individual allometric daily energy requirements (1000 kjoules)	Summer energy requirements (1000 kjoules)	References
	Abundance	Code	Residency	Occupancy				
Northern fur seal	?		?	?	28	18.8	?	
Northern elephant seal	?		?	?	371	70.7	?	
Killer whale	?		?	?	2,280	437.6	?	
Pacific white-sided dolphin	?		?	?	79	35.1	?	
Dalls porpoise	?		?	?	62	29.3	?	
Sperm whale	?		?	?	18,518	2,105.5	?	
Baird=s beaked whale	?		?	?	3,484	601.7	?	
Cuvier=s beaked whale	?		?	?	927	222.8	?	
Stejneger's beaked whale	?		?	?			?	
Humpback whale	?		?	?	30,408	1,849.7	?	
Fin whale	?		?	?	55,590	2,908.3	?	
Minke whale	?		?	?	6,566	586.0	?	
Northern right whale	?		?	?	24,069	1,552.3	?	

Appendix Table 9.6. Marine mammal abundance and energy requirements in PICES marine ecosystems (Sub-region: WSA). Abundance codes indicate methods used to derive estimates: L=line transect, S=strip transect, M=mark-recapture, C=colony counts, E=catch per unit effort, D=density index. Residency=dates present in area or subarea; occupancy=number of mammal or bird days in area or subarea. Average body mass figures are from Trites and Pauly (1997), and allometric daily energy needs were calculated using the formulas derived by Perez and McAllister (1993).

Species	Summer (June-September, 122 days)				Mean body mass (kg)	Individual allometric daily energy requirements (1000 kjoules)	Energy requirements (1000 kJoules)	References
	Abundance	Code	Residency	Occupancy				
Blue whale	?	-	Jun-Sep	?	102,736	4609.8	?	
Dall's porpoise	?	-	Jun-Sep	?	61	28.9	?	
Fin whale	?	-	Jun-Sep	?	55,590	2908.3	?	
Humpback whale	?	-	Jun-Sep	?	30,408	1849.7	?	
Killer whale								
Minke whale	?	-	Jun-Sep	?	6,566	586.0	?	
Northern fur seal	?	-	?	?	28	18.8	?	
Northern right whale								
dolphin	?	-	Jun-Sep	?	105	43.6	?	
Pacific white-sided dolphin	?	-	Jun-Sep	?	79	35.1	?	
Sei whale	?	-	Jun-Sep	?	16,811	1186.0	?	
Sperm whale	2,323+	L	Jun-Sep	283,406+	18,518	2,105.5	596,711,333+	Kato *et al*. (1997)
Steller sea lion	?	-	?	?	200	82.8	?	
Ziphiids	?	-	Jun-Sep	?	?	?	?	

Appendix Table 9.7. Marine mammal abundance and energy requirements in PICES marine ecosystems (Sub-region: KM/KL). Abundance codes indicate methods used to derive estimates: L=line transect, S=strip transect, M=mark-recapture, C=colony counts, E=catch per unit effort, D=density index. Residency=dates present in area or subarea; occupancy=number of mammal or bird days in area or subarea. Average body mass figures are from Trites and Pauly (1997), and allometric daily energy needs were calculated using the formulas derived by Perez and McAllister (1993).

Species	Summer (June-September, 122 days)				Mean body mass (kg)	Individual allometric daily energy requirements (1000 kjoules)	Energy requirements (1000 kJoules)	References
	Abundance	Code	Residency	Occupancy				
Baird's beaked whale	?	-	Jun-Sep	?				
Blue whale	?	-	Jun-Sep	?	102,736	4609.8	?	
Dall's porpoise	(1,925,000)[1]	D/S	Jun-Sep	(234,850,000)[1]	61	28.9	(6,787,165,000)[1]	Kato & Miyazaki (1986)
Fin whale	?	-	Jun-Sep	?	55,590	2908.3	?	
Gray whale	?	-	Jun-Sep	?				
Harbor porpoise	?	-	Jun-Sep	?				
Harbor seal	3,400	C	Jun-Sep	414,800	63	18.7	7,756,760	
Humpback whale	?	-	Jun-Sep	?	30,408	1849.7	?	
Killer whale	?	-	Jun-Sep	?				
Minke whale	5,841	L	Jun-Sep	712,602	6,566	586.0	417,584,772	Kato *et al*. (1997)
Northern fur seal	45,000	C	Jun-Sep	5,490,000	28	18.8	103,212,000	
Northern right whale	?	-	Jun-Sep	?	24,069	1552.3	?	
Northern right whale dolphin	(740,000)[1]	L/D	Jun-Sep	(90,280,000)[1]	105	43.6	(3,936,208,000)[1]	Miyashita (1992)
Pacific white-sided dolphin	(1,000,000)[1]	L	Jun-Sep	(122,000,000)[1]	79	35.1	(4,282,200,000)[1]	Miyashita (1992)
Sea otter	?	-	Jun-Sep	?	?	?	?	
Sei whale	?	-	Jun-Sep	?	16,811	1186.0	?	
Sperm whale	?	-	Jun-Sep	?	18,518	2,105.5	?	
Steller sea lion	5,100	C	Jun-Sep	622,200	200	82.8	51,518,160	
Ziphiids	?	-	Jun-Sep	?				

1: combined estimate for areas WTZ+ WSA+ ESA+ ETZ.

Appendix Table 9.8. Marine mammal abundance and energy requirements in PICES marine ecosystems (Sub-region: OKH). Abundance codes indicate methods used to derive estimates: L=line transect, S=strip transect, M=mark-recapture, C=colony counts, E=catch per unit effort, D=density index. Residency=dates present in area or subarea; occupancy=number of mammal or bird days in area or subarea. Average body mass figures are from Trites and Pauly (1997), and allometric daily energy needs were calculated using the formulas derived by Perez and McAllister (1993).

Species	Summer (June-September, 122 days)				Mean body mass (kg)	Individual allometric daily energy requirements (1000 kjoules)	Energy requirements (1000 kJoules)	References
	Abundance	Code	Residency	Occupancy				
Baird's beaked whale	660	L	Jul-Sep	80,520	3,484	601.7	48,448,884	Miyashita & Kato (1992)
Bearded seal	200,000	S?	Jun-Sep	24,400,000	200	44.4	1,083,360,000	Popov (1982)
Bowhead whale	?	-	Jun-Sep	?	31,506	3136.3	?	Brownel *et al.* (1996)
Dall's porpoise	554,000	L	Jul-Sep	50,968,000	110	28.9	1,472,975,200	Kato *et al*. (1997)
Fin whale	?	-	Jun-Sep	?	55,590	2908.3	?	
Gray whale	< 200	BG	Jul-Sep	18,400	16,177	1152.3	21,202,320	Brownel *et al.* (1997)
Harbor porpoise	?	-	Jun-Sep	?				
Humpback whale	?	-	Jun-Sep	?	30,408	1849.7	?	
Killer whale	?	-	?	?	2,280	437.6	?	
Minke whale	19,209+	L	Jul-Sep	1,767,228	6,566	586.0	1,035,595,608	Buckland et al. (1993)
Northern fur seal	56,000	?	Jun-Sep	6,832,000	28	18.8	128,441,600	NPFSC (1984)
Northern right whale	922	L	Jul-Sep	112,484	24,069	1552.3	174,608,913	Miyashita & Kato (1998)
Pacific white-sided dolphin	?	-	Jun-Oct	?	79	35.1	?	
Ribbon seal	130,000	S?	Jun-Sep	15,860,000	71	20.5	325,130,000	Popov (1982)
Ringed seal	86,500	S	Jun-Sep	10,553,000	43	14.1	148,797,300	Popov (1982)
Spotted seal	130,000	S?	Jun-Sep	15,860,000	43	14.1	223,626,000	Popov (1982)
Steller sea lion	1,500	C	Jun-Sep	183,000	200	82.8	15,152,400	Loughlin *et al.* (1992)
White whale	?	-	Jul-Sep	?	303	96.3	?	
Ziphiids	?	-	?	?	-	-	?	

Appendix Table 9.9. Marine mammal abundance and energy requirements in PICES marine ecosystems (Sub-region: CAS). Abundance codes indicate methods used to derive estimates: L=line transect, S=strip transect, M=mark-recapture, C=colony counts, E=catch per unit effort, D=density index. Residency=dates present in area or subarea; occupancy=number of mammal or bird days in area or subarea. Average body mass figures are from Trites and Pauly (1997), and allometric daily energy needs calculated using the formulas derived by Perez and McAllister (1993).

Species	Summer (June-September)				Mean body mass(kg)	Ind. allometric daily energy requirements (1000 kjoules)	Summer energy requirements (1000 kjoules)	References
	Abundance	Code	Residency	Occupancy				
Steller sea lion	9,350	C	Jun-Sep	1,140,700	198	82.0	93,537,400	Loughlin *et al*. 1992, Hill and DeMaster 1998
California sea lion	177,500		Jun-Sep	21,655,000	69	28.6	619,333,000	Barlow *et al.* 1997
Northern fur seal	?		?	?	28	18.8	?	
Guadelupe fur seal	?		?	?	27	18.1	?	
Harbor seal	75,200		Jun-Sep	9,174,400	60	18.0	166,056,640	Barlow *et al.* 1997
Northern elephant seal	?		?	?	371	70.7	?	
Sea otter	2,539		Jun-Sep	309,758	25	24.3	7,527,119	LaRoe *et al*. 1995
Killer whale	843		Jun-Sep	102,846	2,280	437.6	45,005,409	Barlow *et al.* 1997
Pac. white-sided dolphin	121,693		Jun-Sep	14,846,546	79	35.1	521,113,760	Barlow *et al.* 1997
Risso's dolphin	?		?	?	224	76.8	?	
Bottlenose dolphin	2,695		?	?	188	67.3	?	Barlow *et al.* 1997
Striped dolphin	?		?	?	116	46.9	?	
Short-beaked com. dolphin	?		?	?			?	
Long-beaked com.dolphin	8,980		Jun-Sep	1,095,560			?	Barlow *et al.* 1997
N. right whale dolphin	21,332		Jun-Sep	2,602,504	105	43.6	113,469,170	Barlow *et al.* 1997
Harbor porpoise	47,661		Jun-Sep	5,814,642	31	17.4	101,174,770	Barlow *et al.* 1997
Dalls porpoise	169,350		Jun-Sep	20,660,700	62	29.3	605,358,510	Barlow *et al.* 1997
Pygmy/dwarf sperm whales	?		?	?	140		?	
Sperm whale	?		?	?	18,518	2,105.5	?	
Short-finned pilot whale	1,004		?	?	643	169.4	?	Barlow *et al.* 1997
Baird’s beaked whale	380		?	?	3,484	601.7	?	Barlow *et al.* 1997
Mesoplodont beaked whales	?		?	?		?	?	
Cuvier’s beaked whale	?		?	?	927	222.8	?	
Gray whale	150		?	?	16,177	1,152.3	?	DeMaster, pers. comm.
Humpback whale	597		?	?	30,408	1,849.7	?	Barlow *et al.* 1997
Blue whale	1,785		?	?	102,736	4,609.8	?	Barlow *et al.* 1997
Fin whale	?		?	?	55,590	2,908.3	?	
Bryde's whale	?		?	?	16,945	1,193.1	?	
Minke whale	201		Jun-Sep	24,522	6,566	586.0	14,369,892	Barlow *et al.* 1997
Sei whale	?		?	?	16,811	1,186.0	?	

Appendix Table 9.10. Marine mammal abundance and energy requirements in PICES marine ecosystems (Sub-region: ETZ). Abundance codes indicate methods used to derive estimates: L=line transect, S=strip transect, M=mark-recapture, C=colony counts, E=catch per unit effort, D=density index. Residency=dates present in area or subarea; occupancy=number of mammal or bird days in area or subarea. Average body mass figures are from Trites and Pauly (1997), and allometric daily energy needs were calculated using the formulas derived by Perez and McAllister (1993).

Species	Summer (June-September)				Mean body mass(kg)	Individual allometric daily energy requirements (1000 kjoules)	Summer energy requirements (1000 kjoules)	References
	Abundance	Code	Residency	Occupancy				
Northern fur seal	?		?	?	28	18.8	?	
Northern elephant seal	?		?	?	371	70.7	?	
Hawaiian monk seal	1,238		Jun-Sep	1510,036			?	Barlow *et al.* 1997
Killer whale	?		?	?	2,280	437.6	?	
Risso's dolphin	?		?	?	224	76.8	?	
Bottlenose dolphin	2,695		?	?	188	67.3	?	Barlow *et al.* 1997
Striped dolphin	?		?	?	116	46.9	?	
Short-beaked com. dolphin	?		?	?	?	?	?	
Rough-toothed dolphin	?		?	?			?	
Pantropical spotted dolphin	?		?	?			?	
Spinner dolphin	?		?	?			?	
Melon-headed whale	?		?	?			?	
Pygmy killer whale	?		?	?			?	
False killer whale	?		?	?			?	
Dalls porpoise	?		?	?	62	29.3	?	
Pygmy/dwarf sperm whales	?		?	?	140		?	
Sperm whale	?		?	?	18,518	2,105.5	?	
Short-finned pilot whale	1,004		?	?	643	169.4	?	Barlow *et al.* 1997
Baird’s beaked whale	380		?	?	3,484	601.7	?	Barlow *et al.* 1997
Mesoplodont beaked whales	?		?	?			?	
Cuvier’s beaked whale	?		?	?	927	222.8	?	
Gray whale	?		?	?	16,177	1,152.3	?	
Humpback whale	597		?	?	30,408	1,849.7	?	Barlow *et al.* 1997
Blue whale	1,785		?	?	102,736	4,609.8	?	Barlow *et al.* 1997
Fin whale	?		?	?	55,590	2,908.3	?	
Bryde's whale	?		?	?	16,945	1,193.1	?	
Sei whale	?		?	?	16,811	1,186.0	?	

Appendix Table 9.11. Marine mammal abundance and energy requirements in PICES marine ecosystems (Sub-region: WTZ). Abundance codes indicate methods used to derive estimates: L=line transect, S=strip transect, M=mark-recapture, C=colony counts, E=catch per unit effort, D=density index. Residency=dates present in area or subarea; occupancy=number of mammal or bird days in area or subarea. Average body mass figures are from Trites and Pauly (1997), and allometric daily energy needs were calculated using the formulas derived by Perez and McAllister (1993).

Species	Summer (June-September, 122 days)				Mean body mass (kg)	Individual allometric daily energy requirements (1000 kjoules)	Energy requirements (1000 kJoules)	References
	Abundance	Code	Residency	Occupancy				
Blue whale	?	-	Jun-Sep	?	102,736	4609.8	?	
Bottlenose dolphin	156000	L	Jun-Sep	19032000	188	67.3	1280853600	Miyashita (1993a)
Bryde's whale	7,417+	L	Jun-Sep	904,874+	16,945	1193.1	1,079,605,169+	Shimada & Miyashita (1997)
Commom dolphin	?	-	Jun-Sep	?				
Dall's porpoise	(1,925,000)[1]	D/S	Jun-Sep	(234,850,000)[1]	110	28.9	(6,787,165,000)[1]	Kato & Miyazaki (1986)
Dwarf sperm whale	?	-	Jun-Sep	?				
False killer whale	?	-	Jun-Sep	?				
Fin whale	?	-	Jun-Sep	?	55,590	2908.3	?	
Fraser's dolphin	?	-	Jun-Sep	?				
Killer whale	?	-	Jun-Sep	?				
Minke whale	?	-	Jun-Sep	?	6,566	586.0	?	
Northern fur seal	190,000	L	Jun-Sep	23,180,000	28	18.8	435,784,000	Baba *et al*. (unpublished)
Northern right whale	?	-	Jun-Sep	?				
Northern right whale dolphin	(740,000)[1]	L/D	Jun-Sep	(90,280,000)[1]	105	43.6	(3,936,208,000)[1]	Miyashita (1992)
Pacific white-sided dolphin	(1,000,000)[1]	L	Jun-Sep	(122,000,000)[1]	79	35.1	(4,282,200,000)[1]	Miyashita (1992)
Pygmy killer whale	?	-	Jun-Sep	?				
Pygmy sperm whale	?	-	Jun-Sep	?				
Risso's dolphin	93000	L/D	Jun-Sep	11346000	224	76.8	871372800	Miyashita (1993a)
Rough-toothed dolphine	?	-	Jun-Sep	?				
Sei whale	?	-	Jun-Sep	?	16,811	1186.0	?	
Short-finned pilot whale-N	?	-	Jun-Sep	?				
Short-finned pilot whale-S	53,000	L	Jun-Sep	6,466,000	643	169.4	1,095,340,400	Miyashita (1993a)
Sperm whale	17,128+ +	L	Jun-Sep	2,089,616+ +	18,518	2105.5	4,399,686,488+ +	Kato *et al.* (1997)
Spinner dolphine	?	-	Jun-Sep	?				
Spotted dolphin	438,000	L	Jun-Sep	53,436,000	65	30.4	1,624,454,400	Miyashita (1993a)
Striped dolphin	568,000[2]	L	Jun-Sep	69,296,000[2]	116	46.9	3,249,982,400[2]	Miyashita (1993a)
Ziphiids	?	-	?	?	-	-	?	

1: combined estimate for areas WTZ+ WSA+ ESA+ ETZ.
2: combined estimate for areas WTZ+ KROY.

Appendix Table 9.12. Marine mammal abundance and energy requirements in PICES marine ecosystems (Sub-region: KR/OY). Abundance codes indicate methods used to derive estimates: L=line transect, S=strip transect, M=mark-recapture, C=colony counts, E=catch per unit effort, D=density index. Residency=dates present in area or subarea; occupancy=number of mammal or bird days in area or subarea. Average body mass figures are from Trites and Pauly (1997), and allometric daily energy needs were calculated using the formulas derived by Perez and McAllister (1993).

Species	Summer (June-September, 122 days)				Mean body mass (kg)	Individual allometric daily energy requirements (1000 kjoules)	Energy requirements (1000 kJoules)	References
	Abundance	Code	Residency	Occupancy				
Baird's beaked whale	4,200	L	Jun-Aug	386,400	3,484	601.7	232,496,880	Miyashita and Kato (1994)
Blue whale	?	-	Jun-Sep	?				
Bottlenose dolphin	?	-	Jun-Sep	?	188	67.3	?	
Bryde's whale	58+	L	Jun-Sep	7,076+	16,945	1,193.1	8,442,376	Kishino *et al*. (1997)
Common dolphin	?	-	Jun-Sep	?				
Dall's porpoise	?	-	?	?	62	29.3	?	Miyashita (1993a)
Dwarf sperm whale	?	-	Jun-Sep	?				
False killer whale	?	-	Jun-Sep	?				
Fin whale	?	-	Jun-Sep	?				
Finless porpoise	?	-	Jun-Sep	?				
Fraser's dolphin	?	-	Jun-Sep	?				
Harbor porpoise	?	-	Jun-Sep	?				
Harbor seal	?	-	?	?	63	18.7	?	
Killer whale	?	-	Jun-Sep	?				
Minke whale	?	-	Jun-Sep	?	6,566	586.0	?	
Northern fur seal	-	-	-	-	28	18.8	?	
Northern right whale	?	-	Jun-Sep	?				
Northern right whale dolphin	?	-	Jun-Sep	?				
Pacific white-sided dolphin	50,818	L	Jun-Sep	4,675,256	79	35.1	164,101,486	Kato *et al.* (1997)
Pygmy killer whale	?	-	Jun-Sep	?				
Pygmy sperm whale	?	-	Jun-Sep	?				
Risso's dolphin	?	-	Jun-Sep	?	224	76.8	?	
Rough-toothed dolphin	?	-	Jun-Sep	?				
Sei whale	?	-	Jun-Sep	?				
Short-finned pilot whale-N	5,300	L	Jun-Sep	646,600	643	169.4	109,534,040	Miyashita (1993a)
Short-finned pilot whale-S	53,000	L	Jun-Sep	6,466,000	643	169.4	1,095,340,400	Miyashita (1993a)
Sperm whale	1,137+ +	L	Jun-Sep	138,714+ +	18,518	2,105.5	292,062,327+ +	Kato *et al*. (1997)
Spinner dolphin	?	-	Jun-Sep	?				
Spotted dolphin	?	-	Jun-Sep	?	65	30.0	?	
Spotted seal	?	-	?	?	63	18.7	?	
Steller sea lion	-	-	-	-	200	82.8	?	
Striped dolphin	?	L	Jun-Sep	?	116	46.9	?	
Ziphiids	?	-	?	?	?	?	?	
*: Some of 568,000 in WTZ are in the ROY.								

Appendix Table 9.13. Marine mammal abundance and energy requirements in PICES marine ecosystems (Sub-region: SJP). Abundance codes indicate methods used to derive estimates: L=line transect, S=strip transect, M=mark-recapture, C=colony counts, E=catch per unit effort, D=density index. Residency=dates present in area or subarea; occupancy=number of mammal or bird days in area or subarea. Average body mass figures are from Trites and Pauly (1997), and allometric daily energy needs were calculated using the formulas derived by Perez and McAllister (1993).

Species	Summer (June-September, 122 days)				Mean body mass (kg)	Individual allometric daily energy requirements (1000	Energy requirements (1000 kJoules)	References
	Abundance	Code	Residency	Occupancy				
Baird's beaked whale	1,600+	L	Jun-Sep	195,200+	3,484	601.7	117,451,840+	Miyashita pers comm.
Bottlenose dolphin	?	-	Jun-Sep	?				
Commom dolphin	?	-	Jun-Sep	?				
Dwarf sperm whale	?	-	Jun-Sep	?				
False killer whale	?	-	Jun-Sep	?				
Fin whale	?	-	Jun-Sep	?	55,590	2908.3	?	
Finless porpoise	?	-	Jun-Sep	?				
Killer whale	?	-	Jun-Sep	?				
Minke whale	1,900+	L	Jun-Sep	231,800+	6,566	586.0	135,834,800+	Miyashita *et al* (1995)
Northern fur seal	?	?	?	?	?	?	?	
Pacific white-sided dolphin	?	-	Jul-Sep	?	79	35.1	?	
Pygmy sperm whale	?	-	Jun-Sep	?				
Risso's dolphin	?	-	Jun-Sep	?				
Spotted seal	?	-	?	?			?	
Steller sea lion	?	?	?	?	?	?	?	
Ziphiids	?	-	Jun-Sep	?				

Appendix 10.   Marine mammal prey preference

Appendix Table 10.1. Marine mammal prey preferences in PICES marine ecosystems (Sub-region: BSC). Approximate percent composition (by weight or volume) is given for general prey categories. The parenthetical values are general trophic level estimates by Pauly et al. (1998) for diet composition based on diet studies from marine areas around the world and throughout the year; therefore, these general values may not be directly relevant to the actual diet composition in this PICES subarea during summer. Note that the category *benthic invertebrates* includes all invertebrates inhabiting bottom habitats (e.g., bivalves, octopi, crabs, shrimp, amphipods, etc.).

Species	Benthic invertebrates	Crustacean zooplankton	Squid		Fish			Birds and mammals	References
			Small	Large	Small epipelagic	Mesopelagic	Misc.		
Steller sea lion	15 (15)		20 (20)	0 (15)	10 (5)		50 (40)	5 (5)	Lowry *et al*. 1982, 1989, Merrick *et al*. 1997
Northern fur seal			30 (15)	0 (15)	25 (25)	15 (15)	30 (30)		Baba, pers. comm., Perez and Bigg 1989, Lowry *et al*. 1982
Harbor seal	10 (10)		10 (10)	0 (5)	30 (30)		50 (45)		Lowry *et al*. 1982, 1989
Spotted seal	25 (15)		0 (5)	0 (5)	30 (30)		45 (45)		Gol'tsev 1971, Lowry *et al*. 1982, Bukhtiyarov *et al*. 1984
Bearded seal	(65)	(15)			(5)		(15)		Kosygin 1971, Lowry *et al*. 1980a, 1982, Antonelis *et al*. 1994
Ringed seal	(20)	(20)			(15)	(5)	(40)		Lowry *et al*. 1980b, 1982
Ribbon seal	(35)		50 (10)		25 (25)		25 (30)		Arseniev 1941, Shustov 1965, Frost and Lowry, 1980, Lowry *et al*. 1982 Baba, pers. comm.
Walrus	94(85)						2 (5)	4 (10)	Fay (1982), Lowry *et al*. 1982, Fay *et al*. (1977), Lowry and Fay 1984
Polar bear								(100)	Lowry *et al*. 1982
Sea otter	90						10		Kenyon 1969, Riedman and Estes 1990
Beluga: E. Bering Sea & Bristol Bay	20 (20)		0 (5)	0 (5)	20 (20)	0 (10)	60 (40)		Lowry *et al*. 1982, Seaman *et al*. 1982, Forst *et al*. 1984
Killer whale			(5)	(5)	(10)		(40)	(40)	Lowry *et al*. 1982
Pacific white-sided dolphin	(10)		(15)	(10)	(15)	(10)	(40)		Lowry *et al*. 1982
Harbor porpoise	0 (5)		10 (10)	0 (10)	30 (30)		60 (45)		Lowry *et al*. 1982
Dalls porpoise	0 (5)		35 (30)	0 (10)	5 (20)	55 (20)	5 (15)		Ohizumi *et al*. in press, Lowry *et al*. 1982
Gray whale	90 (90)	10 (5)							Lowry *et al*. 1982, Kim and Oliver 1989, Highsmith and Coyle 1992
Humpback whale		(55)			? (15)		? (30)		Lowry *et al*. 1982
Fin whale		(80)	(5)		? (5)	(5)	? (5)		Lowry *et al*. 1982
Minke whale		(65)			? (30)		? (5)		Lowry *et al*. 1982
N. right whale		(100)							Lowry *et al*. 1982
Bowhead whale	(20)	(80)							Lowry *et al*. 1982

Appendix Table 10.2. Marine mammal prey preferences in PICES marine ecosystems (Sub-region: BSP). Approximate percent composition (by weight or volume) is given for general prey categories. The parenthetical values are general trophic level estimates by Pauly et al. (1998) for diet composition based on diet studies from marine areas around the world and throughout the year; therefore, these general values may not be directly relevant to the actual diet composition in this PICES subarea during summer. Note that the category *benthic invertebrates* includes all invertebrates inhabiting bottom habitats (e.g., bivalves, octopi, crabs, shrimp, amphipods, etc.).

	Main prey categories (based on summer diet data)										
Species	Benthic	Crustacean	Squid			Fish				Birds and	References
	invertebrates	zooplankton	Small	Large	All squid	Small epipelagic	Mesopelagic	Misc.	All fish	mammals	
Bearded seal	(65)	(15)	(5)		(5)			(15)	(15)		
Blue whale		(100)									
Bowhead whale	(20)	(80)									
Dall's porpoise	(5)		(30)	(10)	(40)	(20)	(20)	(15)	(55)		
Fin whale		(80)	(5)		(5)	(5)	(5)	(5)	(15)		
Harbor porpoise	(5)		(10)	(10)	(20)	(30)		(45)	(75)		
Harbor seal	(10)		(10)	(5)	(15)	(30)		(45)	(75)		
Humpback whale		(55)				(15)		(30)	(45)		
Killer whale			(5)	(5)	(10)	(10)		(40)	(50)	(40)	
Minke whale		(65)				(30)		(5)	(35)		
Northern fur seal			(15)	(15)	(30)	(25)	(15)	(30)	(70)		
Northern right whale		(100)									
Ribbon seal	(35)		(10)		(10)	(25)		(30)	(55)		
Ringed seal	(20)	(20)				(15)	(5)	(40)	(60)		
Sea otter	(80)		(5)		(5)	(5)		(10)	(15)		
Sei whale		(80)	(5)		(5)	(5)	(5)	(5)	(15)		
Sperm whale	(5)		(10)	(60)	(70)	(5)	(5)	(15)	(25)		
Spotted seal	(15)		(5)	(5)	(10)	(30)		(45)	(75)		
Steller sea lion	(15)		(20)	(15)	(35)	(5)		(40)	(45)	(5)	
Ziphiids											

Appendix Table 10.3. Marine mammal prey preferences in PICES marine ecosystems (Sub-region: ASK). Approximate percent composition (by weight or volume) is given for general prey categories. The parenthetical values are general trophic level estimates by Pauly et al. (1998) for diet composition based on diet studies from marine areas around the world and throughout the year; therefore, these general values may not be directly relevant to the actual diet composition in this PICES subarea during summer. Note that the category *benthic invertebrates* includes all invertebrates inhabiting bottom habitats (e.g., bivalves, octopi, crabs, shrimp, amphipods, etc.).

Species	Benthic invertebrates	Crustacean zooplankton	Squid		Fish			Birds and mammals	References
			Small	Large	Small epipelagic	Meso-pelagic	Misc.		
Steller sea lion	15 (15)		20 (20)	0 (15)	10 (5)		50 (40)	5 (5)	Pitcher 1981, Merrick *et al*. 1997, Lowry, pers comm.
Northern fur seal			30 (15)	0 (15)	25 (25)	15 (15)	30 (30)		Perez and Bigg 1986, Baba, pers. comm.
Harbor seal	(10)		10 (10)	0 (5)	30 (30)		50 (45)		Pitcher 1980, Lowry, pers comm.
Northern elephant seal	(5)		(40)	(20)		(20)	(15)		
Sea otter	90						10		Kenyon 1969, Riedman and Estes 1990
Beluga whale	20 (20)		0 (5)	0 (5)	20 (20)	0 (10)	60 (40)		Calkins 1986, Lowry, pers comm.
Killer whale			(5)	(5)	(10)		(40)	(40)	Calkins 1986
Pacific white-sided dolphin	(10)		(15)	(10)	(15)	(10)	(40)		Calkins 1986
Harbor porpoise	0 (5)		10 (10)	0 (10)	30 (30)		60 (45)		Calkins 1986, Lowry, pers comm.
Dalls porpoise	0 (5)		35 (30)	0 (10)	5 (20)	55 (20)	5 (15)		Calkins 1986, Ohizumi *et al*. in press
Sperm whale	(5)		(10)	(60)	(5)	(5)	(15)		Calkins 1986
Baird's beaked whale	(10)		(30)	(25)	(10)	(10)	(15)		
Cuvier's beaked whale	(10)		(30)	(30)		(15)	(15)		
Gray whale	(90)	(10)							Calkins 1986
Humpback whale		(55)			(15)		(30)		Calkins 1986
Fin whale		(80)	(5)		(5)	(5)	(5)		Calkins 1986
Minke whale		(65)			(30)		(5)		Calkins 1986
Northern right whale		(100)							

Appendix Table 10.4. Marine mammal prey preferences in PICES marine ecosystems (Sub-region: CAN). Approximate percent composition (by weight or volume) is given for general prey categories. The parenthetical values are general trophic level estimates by Pauly et al. (1998) for diet composition based on diet studies from marine areas around the world and throughout the year; therefore, these general values may not be directly relevant to the actual diet composition in this PICES subarea during summer. Note that the category *benthic invertebrates* includes all invertebrates inhabiting bottom habitats (e.g., bivalves, octopi, crabs, shrimp, amphipods, etc.).

Species	Benthic invertebrates	Crustacean zooplankton	Squid		Fish			Birds and mammals	References
			Small	Large	Small epipelagic	Mesopelagic	Misc.		
Steller sea lion	(15)		(20)	(15)	(5)		(40)	(5)	
Northern fur seal			30 (15)	0 (15)	25 (25)	15 (15)	30 (30)		Baba, pers. comm.
Harbor seal	(10)		(10)	(5)	(30)		(45)		
Northern elephant seal	(5)		(40)	(20)		(20)	(15)		
Sea otter	100								Kenyon 1969, Riedman and Estes 1990
Killer whale			(5)	(5)	(10)		(40)	(40)	
Pac. white-sided dolphin	(10)		(15)	(10)	(15)	(10)	(40)		
Harbor porpoise	0 (5)		10 (10)	0 (10)	30 (30)		60 (45)		Lowry, pers comm.
Dalls porpoise	0 (5)		35 (30)	0 (10)	5 (20)	55 (20)	5 (15)		Ohizumi *et al.* in press
Sperm whale	(5)		(10)	(60)	(5)	(5)	(15)		
Cuvier's beaked whale	(10)		(30)	(30)		(15)	(15)		
Gray whale	100 (90)	(5)							Oliver et al. 1984, Weitkamp *et al.* 1992
Humpback whale		(55)			(15)		(30)		
Fin whale		(80)	(5)		(5)	(5)	(5)		
Minke whale		(65)			(30)		(5)		
Northern right whale		(100)							

Appendix Table 10.5. Marine mammal prey preferences in PICES marine ecosystems (Sub-region: ESA). Approximate percent composition (by weight or volume) is given for general prey categories. The parenthetical values are general trophic level estimates by Pauly et al. (1998) for diet composition based on diet studies from marine areas around the world and throughout the year; therefore, these general values may not be directly relevant to the actual diet composition in this PICES subarea during summer. Note that the category *benthic invertebrates* includes all invertebrates inhabiting bottom habitats (e.g., bivalves, octopi, crabs, shrimp, amphipods, etc.).

Species	Benthic invertebrates	Crustacean zooplankton	Squid		Fish			Birds and mammals	References
			Small	Large	Small epipelagic	Mesopelagic	Misc.		
Northern fur seal			(15)	(15)	(25)	(15)	(30)		
Northern elephant seal	(5)		(40)	(20)		(20)	(15)		
Killer whale			(5)	(5)	(10)		(40)	(40)	
Pacific white-sided dolphin	(10)		(15)	(10)	(15)	(10)	(40)		
Dalls porpoise	(5)		(30)	(10)	(20)	(20)	(15)		
Sperm whale	(5)		(10)	(60)	(5)	(5)	(15)		
Baird’s beaked whale	(10)		(30)	(25)	(10)	(10)	(15)		
Cuvier’s beaked whale	(10)		(30)	(30)		(15)	(15)		
Stejneger's beaked whale			50	45			5		
Humpback whale		(55)			(15)		(30)		
Fin whale		(80)	(5)		(5)	(5)	(5)		
Minke whale		(65)			(30)		(5)		
Northern right whale		(100)							

Appendix Table 10.6. Marine mammal prey preferences in PICES marine ecosystems (Sub-region: WSA). Approximate percent composition (by weight or volume) is given for general prey categories. The parenthetical values are general trophic level estimates by Pauly et al. (1998) for diet composition based on diet studies from marine areas around the world and throughout the year; therefore, these general values may not be directly relevant to the actual diet composition in this PICES subarea during summer. Note that the category *benthic invertebrates* includes all invertebrates inhabiting bottom habitats (e.g., bivalves, octopi, crabs, shrimp, amphipods, etc.).

	Main prey categories (based on summer diet data)										
Species	Benthic invertebrates	Crustacean zooplankton	Squid			Fish				Birds and mammals	References
			Small	Large	All squid	Small epipelagic	Mesopelagic	Misc.	All fish		
Blue whale		(100)									
Dall's porpoise	(5)		(30)	(10)	(40)	(20)	(20)	(15)	(55)		
Fin whale		(80)	(5)		(5)	(5)	(5)	(5)	(15)		
Humpback whale		(55)				(15)		(30)	(45)		
Killer whale			(5)	(5)	(10)	(10)		(40)	(50)	(40)	
Minke whale		(65)				(30)		(5)	(35)		
Northern fur seal			(15)	(15)	(30)	(25)	(15)	(30)	(70)		
Northern right whale		(100)									
Northern right whale dolphin			(30)	(20)	(50)		(40)	(10)	(50)		
Pacific white-sided dolphin	(10)		(15)	(10)	(25)	(15)	(10)	(40)	(65)		
Sei whale		(80)	(5)		(5)	(5)	(5)	(5)	(15)		
Sperm whale	(5)		(10)	(60)	(70)	(5)	(5)	(15)	(25)		
Steller sea lion	(15)		(20)	(15)	(35)	(5)		(40)	(45)	(5)	
Ziphiids											

Appendix Table 10.7. Marine mammal prey preferences in PICES marine ecosystems (Sub-region: KM/KL). Approximate percent composition (by weight or volume) is given for general prey categories. The parenthetical values are general trophic level estimates by Pauly et al. (1998) for diet composition based on diet studies from marine areas around the world and throughout the year; therefore, these general values may not be directly relevant to the actual diet composition in this PICES subarea during summer. Note that the category *benthic invertebrates* includes all invertebrates inhabiting bottom habitats (e.g., bivalves, octopi, crabs, shrimp, amphipods, etc.).

Species	Main prey categories (based on summer diet data)										References
	Benthic invertebrates	Crustacean zooplankton	Squid			Fish				Birds and mammals	
			Small	Large	All squid	Small epipelagic	Mesopelagic	Misc.	All fish		
Baird's beaked whale	(10)		(30)	(25)	(55)	(10)	(10)	(15)	(35)		
Blue whale		(100)									
Dall's porpoise	(5)		(30)	(10)	(40)	(20)	(20)	(15)	(55)		
Fin whale		(80)	(5)		(5)	(5)	(5)	(5)	(15)		
Gray whale	(90)	(5)					(5)		(5)		
Harbor porpoise	(5)		(10)	(10)	(20)	(30)		(45)	(75)		
Harbor seal	(10)		(10)	(5)	(15)	(30)		(45)	(75)		
Humpback whale		(55)				(15)		(30)	(45)		
Killer whale			(5)	(5)	(10)	(10)		(40)	(50)	(40)	
Minke whale		(65)				(30)		(5)	(35)		
Northern fur seal			(15)	(15)	(30)	(25)	(15)	(30)	(70)		
Northern right whale		(100)									
Northern right whale dolphin			(30)	(20)	(50)		(40)	(10)	(50)		
Pacific white-sided dolphin	(10)		(15)	(10)	(25)	(15)	(10)	(40)	(65)		
Sea otter	(80)		(5)		(5)	(5)		(10)	(15)		
Sei whale		(80)	(5)		(5)	(5)	(5)	(5)	(15)		
Sperm whale	(5)		(10)	(60)	(70)	(5)	(5)	(15)	(25)		
Steller sea lion	(15)		(20)	(15)	(35)	(5)		(40)	(45)	(5)	
Ziphiids											

Appendix Table 10.8. Marine mammal prey preferences in PICES marine ecosystems (Sub-region: OKH). Approximate percent composition (by weight or volume) is given for general prey categories. The parenthetical values are general trophic level estimates by Pauly et al. (1998) for diet composition based on diet studies from marine areas around the world and throughout the year; therefore, these general values may not be directly relevant to the actual diet composition in this PICES subarea during summer. Note that the category *benthic invertebrates* includes all invertebrates inhabiting bottom habitats (e.g., bivalves, octopi, crabs, shrimp, amphipods, etc.).

Species	Main prey categories (based on summer diet data)										References
	Benthic invertebrates	Crustacean zooplankton	Squid			Fish				Birds and mammals	
			Small	Large	All squid	Small epipelagic	Mesopelagic	Misc.	All fish		
Baird's beaked whale	(10)		(30)	(25)	(55)	(10)	(10)	(15)	(35)		
Bearded seal	(65)		(15)		(15)	(5)		(15)	(20)		
Bowhead whale	(20)	(80)									
Dall's porpoise	(5)		40(30)	(10)	40(40)	20(20)	40(20)	(15)	60(55)		Kato pers comm.
Fin whale		(80)	(5)		(5)	(5)	(5)	(5)	(15)		
Gray whale	95(90)	(5)	5		5		(5)		(5)		
Harbor porpoise	(5)		(10)	(10)	(20)	(30)		(45)	(75)		
Humpback whale		(55)				(15)		(30)	(45)		
Killer whale			(5)	(5)	(10)	(10)		(40)	(50)	(40)	
Minke whale		90(65)				10(30)		(5)	10(35)		Fujise et al., 1998
Northern fur seal			30(15)	(15)	30(30)	20(20)	20(15)	30(30)	70(65)		Baba pers comm.
Northern right whale		(100)									
Pacific white-sided dolphin			(30)	(5)	(35)	(30)	(20)	(15)	(65)		
Ribbon seal	(33)		50(10)		50(10)	20(25)	10	20(5)	50(30)		Kato, 1982
Ringed seal	(20)	(20)				(15)	(5)	(40)	(60)		
Spotted seal	10(15)		20(5)	(5)	20(10)	20(5)		50(45)	70(50)		Kato, 1982
Steller sea lion	40(15)		(20)	(15)	(35)	10(5)		50(40)	60(45)	(5)	Kato, 1977
White whale	(20)		(5)	(5)	(10)	(20)	(10)	(40)	(70)		
Ziphiids											

Appendix Table 10.9. Marine mammal prey preferences in PICES marine ecosystems (Sub-region: CAS). Approximate percent composition (by weight or volume) is given for general prey categories. The parenthetical values are general trophic level estimates by Pauly et al. (1998) for diet composition based on diet studies from marine areas around the world and throughout the year; therefore, these general values may not be directly relevant to the actual diet composition in this PICES subarea during summer. Note that the category *benthic invertebrates* includes all invertebrates inhabiting bottom habitats (e.g., bivalves, octopi, crabs, shrimp, amphipods, etc.).

Species	Benthic invertebrates	Crustacean zooplankton	Squid		Fish			Birds and mammals	References
			Small	Large	Small epipelagic	Mesopelagic	Misc.		
Steller sea lion	(15)		(20)	(15)	(5)		(40)	(5)	
California sea lion	(10)		(20)	(15)	(25)		(30)		
Northern fur seal			(15)	(15)	(25)	(15)	(30)		
Guadelupe fur seal									
Harbor seal	(10)		(10)	(5)	(30)		(45)		
Northern elephant seal	(5)		(40)	(20)		(20)	(15)		
Sea otter	100								Kenyon 1969, Riedman and Estes 1990
Killer whale			(5)	(5)	(10)		(40)	(40)	
Pac. white-sided dolphin	(10)		(15)	(10)	(15)	(10)	(40)		
Risso's dolphin									
Bottlenose dolphin			(20)	(5)	(15)		(60)		
Striped dolphin									
Short-beaked com. dolphin									
Long-beaked com.dolphin									
N. right whale dolphin			(30)	(20)		(40)	(10)		
Harbor porpoise	(5)		(10)	(10)	(30)		(45)		
Dalls porpoise	(5)		(30)	(10)	(20)	(20)	(15)		
Pygmy/dwarf sperm whales									
Sperm whale	(5)		(10)	(60)	(5)	(5)	(15)		
Short-finned pilot whale			(30)	(30)	(10)	(10)	(20)		
Baird’s beaked whale	(10)		(30)	(25)	(10)	(10)	(15)		
Mesoplodont beaked whales									
Cuvier’s beaked whale	(10)		(30)	(30)		(15)	(15)		
Gray whale	(90)	(5)							
Humpback whale		(55)			(15)		(30)		
Blue whale		(100)							
Fin whale		(80)	(5)		(5)	(5)	(5)		
Bryde's whale									
Minke whale		(65)			(30)		(5)		
Sei whale									

Appendix Table 10.10. Marine mammal prey preferences in PICES marine ecosystems (Sub-region: ETZ). Approximate percent composition (by weight or volume) is given for general prey categories. The parenthetical values are general trophic level estimates by Pauly et al. (1998) for diet composition based on diet studies from marine areas around the world and throughout the year; therefore, these general values may not be directly relevant to the actual diet composition in this PICES subarea during summer. Note that the category *benthic invertebrates* includes all invertebrates inhabiting bottom habitats (e.g., bivalves, octopi, crabs, shrimp, amphipods, etc.).

Species	Benthic invertebrates	Crustacean zooplankton	Squid		Fish			Birds and mammals	References
			Small	Large	Small epipelagic	Mesopelagic	Misc.		
Northern fur seal			(15)	(15)	(25)	(15)	(30)		
Northern elephant seal	(5)		(40)	(20)		(20)	(15)		
Hawaiian monk seal									
Killer whale			(5)	(5)	(10)		(40)	(40)	
Risso's dolphin									
Bottlenose dolphin			(20)	(5)	(15)		(60)		
Striped dolphin									
Short-beaked com. dolphin									
Rough-toothed dolphin									
Pantropical spotted dolphin									
Spinner dolphin									
Melon-headed whale									
Pygmy killer whale									
False killer whale									
Dalls porpoise	(5)		(30)	(10)	(20)	(20)	(15)		
Pygmy/dwarf sperm whales									
Sperm whale	(5)		(10)	(60)	(5)	(5)	(15)		
Short-finned pilot whale			(30)	(30)	(10)	(10)	(20)		
Baird’s beaked whale	(10)		(30)	(25)	(10)	(10)	(15)		
Mesoplodont beaked whales									
Cuvier’s beaked whale	(10)		(30)	(30)		(15)	(15)		
Gray whale	(90)	(5)							
Humpback whale		(55)			(15)		(30)		
Blue whale		(100)							
Fin whale		(80)	(5)		(5)	(5)	(5)		
Bryde's whale									
Sei whale									

Appendix Table 10.11. Marine mammal prey preferences in PICES marine ecosystems (Sub-region: WTZ). Approximate percent composition (by weight or volume) is given for general prey categories. The parenthetical values are general trophic level estimates by Pauly et al. (1998) for diet composition based on diet studies from marine areas around the world and throughout the year; therefore, these general values may not be directly relevant to the actual diet composition in this PICES subarea during summer. Note that the category *benthic invertebrates* includes all invertebrates inhabiting bottom habitats (e.g., bivalves, octopi, crabs, shrimp, amphipods, etc.).

Species	Main prey categories (based on summer diet data)										References
	Benthic invertebrates	Crustacean zooplankton	Squid			Fish				Birds and mammals	
			Small	Large	All squid	Small epipelagic	Mesopelagic	Misc.	All fish		
Blue whale		(100)									
Bottlenose dolphin			(20)	(5)	(35)	(15)		(60)	(75)		
Bryde's whale		(40)				(20)	(20)	(20)	(60)		
Commom dolphin			(15)	(15)	(30)	(10)	(40)	(20)	(70)		
Dall's porpoise	(5)		10(30)	(10)	10(40)	10(20)	70(20)	10(15)	90(55)		Ohizimi in press
Dwarf sperm whale	(10)		(40)	(40)	(80)		(5)	(5)	(10)		
False killer whale											
Fin whale		(80)	(5)		(5)	(5)	(5)	(5)	(15)		
Fraser's dolphin	(5)		(30)	(5)	(35)	(5)	(35)	(20)	(60)		
Killer whale			(5)	(5)	(10)	(10)		(40)	(50)	(40)	
Minke whale		10(65)				70(30)	10(5)	10	90(40)		Fujise (1996)
Northern fur seal			(15)	(15)	(30)	(25)	(15)	(30)	(70)		
Northern right whale		(100)									
Northern right whale dolphin			(30)	(20)	(50)		(40)	(10)	(50)		
Pacific white-sided dolphin			(30)	(5)	(35)	(30)	(20)	(15)	(65)		
Pygmy killer whale			(30)	(20)	(50)	(10)		(20)	(30)	(20)	
Pygmy sperm whale	(5)		(35)	(40)	(75)		(10)	(10)	(20)		
Risso's dolphin	(5)		(50)	(35)	(85)	(5)		(5)	(10)		
Rough-toothed dolphine	(10)		(20)	(10)	(30)	(20)		(40)	(60)		
Sei whale		(80)	(5)		(5)	(5)	(5)	(5)	(15)		
Short-finned pilot whale-N			(30)	(30)	(60)	(10)	(10)	(20)	(40)		
Short-finned pilot whale-S			(30)	(30)	(60)	(10)	(10)	(20)	(40)		
Sperm whale	(5)		(10)	(60)	(70)	(5)	(5)	(15)	(25)		
Spinner dolphine			(20)	(20)	(40)		(40)	(20)	(60)		
Spotted dolphin			(30)	(20)	(50)	(10)		(40)	(50)		
Striped dolphin	(5)		(20)	(15)	(35)	(5)	(30)	(25)	(60)		
Ziphiids											

Appendix Table 10.12. Marine mammal prey preferences in PICES marine ecosystems (Sub-region: KR/OY). Approximate percent composition (by weight or volume) is given for general prey categories. The parenthetical values are general trophic level estimates by Pauly et al. (1998) for diet composition based on diet studies from marine areas around the world and throughout the year; therefore, these general values may not be directly relevant to the actual diet composition in this PICES subarea during summer. Note that the category *benthic invertebrates* includes all invertebrates inhabiting bottom habitats (e.g., bivalves, octopi, crabs, shrimp, amphipods, etc.).

Species	Main prey categories (based on summer diet data)										References
	Benthic invertebrates	Crustacean zooplankton	Squid			Fish				Birds and mammals	
			Small	Large	All squid	Small epipelagic	Mesopelagic	Misc.	All fish		
Baird's beaked whale	(10)		(20)	(10)	(30)	(20)	(20)	(20)	(60)		
Blue whale		(100)									
Bottlenose dolphin			(20)	(5)	(25)	(15)		(60)	(75)		
Bryde's whale		(40)				(20)	(20)	(20)	(60)		
Commom dolphin			(15)	(15)	(30)	(10)	(40)	(20)	(70)		
Dall's porpoise	(5)		(30)	(10)	(40)	(20)	(20)	(15)	(55)		
Dwarf sperm whale	(10)		(40)	(40)	(80)		(5)	(5)	(10)		
False killer whale											
Fin whale		(80)	(5)		(5)	(5)	(5)	(5)	(15)		
Finless porpoise	(10)		(40)		(40)	(20)	(10)	(20)	(50)		
Fraser's dolphin	(5)		(30)	(5)	(35)	(5)	(35)	(20)	(60)		
Harbor porpoise	(5)		(10)	(10)	(20)	(30)		(45)	(75)		
Harbor seal	(10)		(10)	(5)	(15)	(30)		(45)	(75)		
Killer whale			(5)	(5)	(10)	(10)		(40)	(50)	(40)	
Minke whale		(65)				(30)		(5)	(35)		
Northern fur seal			(15)	(15)	(30)	(25)	(15)	(30)	(70)		
Northern right whale		(100)									
Northern right whale dolphin			(30)	(20)	(50)		(40)	(10)	(50)		
Pacific white-sided dolphin			(30)	(5)	(35)	(30)	(20)	(15)	(65)		
Pygmy killer whale			(30)	(20)	(50)	(10)		(20)	(30)	(20)	
Pygmy sperm whale	(5)		(35)	(40)	(75)		(10)	(10)	(20)		
Risso's dolphin	(5)		(50)	(35)	(85)	(5)		(5)	(10)		
Rough-toothed dolphin	(10)		(20)	(10)	(30)	(20)		(40)	(60)		
Sei whale		(80)	(5)		(5)	(5)	(5)	(5)	(15)		
Short-finned pilot whale-N			(30)	(30)	(60)	(10)	(10)	(20)	(40)		
Short-finned pilot whale-S			(30)	(30)	(60)	(10)	(10)	(20)	(40)		
Sperm whale	(5)		(10)	(60)	(70)	(5)	(5)	(15)	(25)		
Spinner dolphin			(20)	(20)	(40)		(40)	(20)	(60)		
Spotted dolphin			(30)	(20)	(50)	(10)		(40)	(50)		
Spotted seal	(15)		(5)	(5)	(10)	(30)		(45)	(75)		
Steller sea lion	(15)		(20)	(15)	(35)	(5)		(40)	(45)	(5)	
Striped dolphin	(5)		(20)	(15)	(35)	(5)	(30)	(25)	(60)		
Ziphiids											

Appendix Table 10.13. Marine mammal prey preferences in PICES marine ecosystems (Sub-region: SJP). Approximate percent composition (by weight or volume) is given for general prey categories. The parenthetical values are general trophic level estimates by Pauly et al. (1998) for diet composition based on diet studies from marine areas around the world and throughout the year; therefore, these general values may not be directly relevant to the actual diet composition in this PICES subarea during summer. Note that the category *benthic invertebrates* includes all invertebrates inhabiting bottom habitats (e.g., bivalves, octopi, crabs, shrimp, amphipods, etc.).

Species	Main prey categories (based on summer diet data)										
	Benthic	Crustacean	Squid			Fish				Birds and	References
	invertebrates	zooplankton	Small	Large	All squid	Small epipelagic	Mesopelagic	Misc.	All fish	mammals	
Baird's beaked whale	(10)		(30)	(25)	(55)	(10)	(10)	(15)	(35)		
Bottlenose dolphin			(20)	(5)	(35)	(15)		(60)	(75)		
Commom dolphin			(15)	(15)	(30)	(10)	(40)	(20)	(70)		
Dwarf sperm whale	(10)		(40)	(40)	(80)		(5)	(5)	(10)		
False killer whale											
Fin whale		(80)	(5)		(5)	(5)	(5)	(5)	(15)		
Finless porpoise	(10)		(40)		(40)	(20)	(10)	(20)	(50)		
Killer whale			(5)	(5)	(10)	(10)		(40)	(50)	(40)	
Minke whale		(65)				(30)		(5)	(35)		
Northern fur seal			(15)	(15)	(30)	(25)	(15)	(30)	(70)		
Pacific white-sided	(10)		(15)	(10)	(25)	(15)	(10)	(40)	(65)		
Pygmy sperm whale	(5)		(35)	(40)	(75)		(10)	(10)	(20)		
Risso's dolphin	(5)		(50)	(35)	(85)	(5)		(5)	(10)		
Spotted seal	(15)		(5)	(5)	(10)	(30)		(45)	(75)		
Steller sea lion	(15)		(20)	(15)	(35)	(5)		(40)	(45)	(5)	
Ziphiids											

Appendix Table 11.1. Estimated summer prey consumption by marine mammals in PICES marine ecosystems (Sub-region: BSC). Total consumption estimates indicate the minimum amount of prey consumed during the summer period only (i.e., June-September). Values given as 1000s metric tons. Values in parentheses are estimated by using diet composition parameters shown in Appendix Table 10.1, and assuming the following energetic values: benthic invertebrates, 4 kj/g; crustacean zooplankton, 4 kj/g; small squid, 3.5 kj/g; large squid, 4 kj/g; small epipelagic fish, 7 kj/g; meso-pelagic fish, 7 kj/g; misc. fish, 5 kj/g; and birds and mammals, 7 kj/g.

Species	Estimated biomass of prey consumed (1000s metric tons) for main prey categories										Total prey consumed by each predator species
			Squid			Fish					
	Benthic invertebrates	Crustacean zooplankton	Small	Large	All	Small epipelagic	Meso-pelagic	Misc.	All	Birds and mammals	
Steller sea lion	4.08		5.44		5.44	2.72		13.6	16.32	1.36	27.2
Northern fur seal			171.48		171.48	142.9	85.74	171.48	400.12		571.6
Harbor seal	.73		.73		.73	2.19		3.65	5.84		7.3
Spotted seal											
Bearded seal											
Ringed seal											
Ribbon seal											
Walrus	538.9							11.5	11.5	23.0	573.3
Polar bear											
Beluga: Chuckchi											
Beluga: Bristol	11.3					11.3		33.9	45.2		56.5
Killer whale											
Pacific white-sided dolphin											
Harbor porpoise			.56		.56	1.68		3.36	5.04		5.6
Dalls porpoise											
Gray whale	366.21	40.69									406.9
Humpback whale											
Fin whale											
Minke whale											
Northern right whale											
Bowhead whale											
Total min. consumption	921.22	40.69	178.21		178.21	160.79	85.74	237.49	484.02	24.36	1648.4

Appendix Table 11.2. Estimated summer prey consumption by marine mammals in PICES marine ecosystems (Sub-region: BSP). Total consumption estimates indicate the minimum amount of prey consumed during the summer period only (i.e. June-September). Values are given as metric ton. Values in parenthesis are estimated by using diet composition parameter of Pauly et al. (1997).

Species	Main prey categories (based on summer diet data)									
	Benthic invertebrates	Crustacean zooplankton	Small squid	Large squid	All squid	Small epipelagic fish	Mesopelagic fish	Miscellaneous	All fish	Total prey
Bearded seal	(204.1)	(47.1)	(15.7)		(15.7)			(47.1)	(47.1)	(314.0)
Blue whale										
Bowhead whale										
Dall' s porpoise										
Fin whale										
Harbor porpoise										
Harbor seal										
Humpback whale										
Killer whale										
Minke whale										
Northern fur seal			(16.9)	(16.9)	(33.8)	(28.1)	(16.9)	(33.7)	(78.7)	(112.5)
whale										
Ribbon seal	(3.0)		(0.9)		(0.9)	(2.2)		(2.6)	(4.8)	(8.7)
Ringed seal	(8.0)	(8.0)				(6.0)	(2.0)	(16.0)	(24.0)	(40.0)
Sea otter										
Sei whale										
Sperm whale *										
Spotted seal	(1.1)		(0.4)	(0.4)	(0.8)	(2.2)		(3.3)	(5.5)	(7.4)
Steller sea lion	(0.7)		(0.9)	(0.7)	(1.6)	0.2		(1.8)	(2.0)	(4.3)
Total	(217.9)	(55.1)	(34.8)	(18.0)	(52.8)	(38.7)	(18.9)	(104.5)	(162.1)	(486.9)

*: only males migrate to the Bering Sea.

Appendix Table 11.3. Estimated summer prey consumption by marine mammals in PICES marine ecosystems (Sub-region: ASK). Total consumption estimates indicate the minimum amount of prey consumed during the summer period only (i.e., June-September). Values given as 1000s metric tons. Values in parentheses are estimated by using diet composition parameters shown in Appendix Table 10.3, and assuming the following energetic values: benthic invertebrates, 4 kj/g; crustacean zooplankton, 4 kj/g; small squid, 3.5 kj/g; large squid, 4 kj/g; small epipelagic fish, 7 kj/g; meso-pelagic fish, 7 kj/g; misc. fish, 5 kj/g; and birds and mammals, 7 kj/g.

Species	Estimated biomass of prey consumed (1000s metric tons) for main prey categories										Total prey consumed by each predator species
	Benthic invertebrates	Crustacean zooplankton	Squid			Fish				Birds and mammals	
			Small	Large	All	Small epipelagic	Meso-pelagic	Misc.	All		
Steller sea lion	17.65		23.54		23.54	11.77		58.85	70.62	5.89	117.7
Northern fur seal											
Harbor seal	3.64		3.64		3.64	10.92		18.2	29.12		36.4
Northern elephant seal											
Beluga whale	.5					.5		1.5	2.0		2.5
Killer whale											
Pacific white-sided dolphin											
Harbor porpoise			.97		.97	2.91		5.82	8.73		9.7
Dalls porpoise											
Sperm whale											
Baird's beaked whale											
Cuvier's beaked whale											
Gray whale											
Humpback whale											
Fin whale											
Minke whale											
Northern right whale											
Total min. consumption	26.02		28.15		28.15	26.1		84.37	110.47	5.89	166.3

Appendix Table 11.4. Estimated summer prey consumption by marine mammals in PICES marine ecosystems (Sub-region: CAN). Total consumption estimates indicate the minimum amount of prey consumed during the summer period only (i.e., June-September). Values given as 1000s metric tons. Values in parentheses are estimated by using diet composition parameters shown in Appendix Table 10.4, and assuming the following energetic values: benthic invertebrates, 4 kj/g; crustacean zooplankton, 4 kj/g; small squid, 3.5 kj/g; large squid, 4 kj/g; small epipelagic fish, 7 kj/g; meso-pelagic fish, 7 kj/g; misc. fish, 5 kj/g; and birds and mammals, 7 kj/g.

Species	Estimated biomass of prey consumed (1000s metric tons) for main prey categories										Total prey consumed by each predator species
	Benthic invertebrates	Crustacean zooplankton	Squid			Fish				Birds and mammals	
			Small	Large	All	Small epipelagic	Meso-pelagic	Misc.	All		
Steller sea lion	6.19		8.26	6.19	14.45	2.06		16.52	18.58	2.06	41.3
Northern fur seal											
Harbor seal											
Northern elephant seal											
Killer whale			.66	.66	1.32	1.31		5.24	6.55	5.24	13.1
Pac. white-sided dolphin											
Harbor porpoise			.53		.53	1.59		3.18	4.77		5.3
Dalls porpoise											
Sperm whale											
Cuvier's beaked whale											
Gray whale											
Humpback whale											
Fin whale											
Minke whale											
Northern right whale											
Total min. consumption	6.19		9.45	6.85	16.3	4.96		24.94	29.9	7.3	59.7

Appendix Table 11.5. Estimated summer prey consumption by marine mammals in PICES marine ecosystems (Sub-region: ESA). Total consumption estimates indicate the minimum amount of prey consumed during the summer period only (i.e., June-September). Values given as 1000s metric tons. Values in parentheses are estimated by using diet composition parameters shown in Appendix Table 10.5.b, and assuming the following energetic values: benthic invertebrates, 4 kj/g; crustacean zooplankton, 4 kj/g; small squid, 3.5 kj/g; large squid, 4 kj/g; small epipelagic fish, 7 kj/g; meso-pelagic fish, 7 kj/g; misc. fish, 5 kj/g; and birds and mammals, 7 kj/g.

Species	Estimated biomass of prey consumed (1000s metric tons) for main prey categories										Total prey consumed by each predator species(1000s metric tons)
	Benthic invertebrates	Crustacean zooplankton	Squid			Fish				Birds and mammals	
			Small	Large	All	Small epipelagic	Meso-pelagic	Misc.	All		
Northern fur seal											
Northern elephant seal											
Killer whale											
Pacific white-sided dolphin											
Dalls porpoise											
Sperm whale											
Baird’s beaked whale											
Cuvier’s beaked whale											
Stejneger's beaked whale											
Humpback whale											
Fin whale											
Minke whale											
Northern right whale											

Appendix Table 11.6. Estimated summer prey consumption by marine mammals in PICES marine ecosystems (Sub-region: WSA). Total consumption estimates indicate the minimum amount of prey consumed during the summer period only (i.e. June-September). Values are given as metric ton. Values in parenthesis are estimated by using diet composition parameter of Pauly et al. (1997).

Species	Main prey categories (based on summer diet data)									
	Benthic invertebrates	Crustacean zooplankton	Small squid	Large squid	All squid	Small epipelagic fish	Mesopelagic fish	Miscellaneous	All fish	Total prey
Blue whale										
Dall's porpoise										
Fin whale										
Humpback whale										
Killer whale										
Minke whale										
Northern fur seal										
Northern right whale										
Northern right whale dolphin										
Pacific white-sided dolphin										
Sei whale										
Sperm whale	(9.0)		(18.0)	(108.2)	(126.2)	(9.0)	(9.0)	(27.1)	(45.1)	(180.3)
Steller sea lion										
Ziphiids										
Total	(9.0)		(18.0)	(108.2)	(126.2)	(9.0)	(9.0)	(27.1)	(45.1)	(180.3)

Appendix Table 11.7. Estimated summer prey consumption by marine mammals in PICES marine ecosystems (Sub-region: KM/KL). Total consumption estimates indicate the minimum amount of prey consumed during the summer period only (i.e. June-September). Values are given as metric ton. Values in parenthesis are estimated by using diet composition parameter of Pauly et al. (1997).

Species	Main prey categories (based on summer diet data)									
	Benthic invertebrates	Crustacean zooplankton	Small squid	Large squid	All squid	Small epipelagic	Mesopelagic fish	Miscellaneou s	All fish	Birds and mammals	Total prey
Baird's beaked whale											
Blue whale											
Dall's porpoise	(86.8)		(520.8)	(173.6)	(694.4)	(347.2)	(347.2)	(260.4)	(954.8)		(1736.0)
Fin whale											
Gray whale											
Harbor porpoise											
Harbor seal	(0.1)		(0.2)	(0.2)	(0.4)	(0.6)		(0.9)	(1.5)		(2.0)
Humpback whale											
Killer whale											
Minke whale		(72.9)				(33.7)		(5.6)	(39.3)		(112.2)
Northern fur seal			(3.8)	(3.8)	(7.6)	(6.3)	(3.8)	(7.6)	(17.7)		(25.3)
Northern right whale											
N. right whale dolphin			(305.0)	(203.3)	(508.3)		(406.6)	(101.7)	(508.3)		(1016.6)
dolphin	(112.2)		(168.3)	(112.2)	(280.5)	(168.3)	(112.2)	(448.9)	(729.4)		(1122.1)
Sea otter											
Sei whale											
Sperm whale											
Steller sea lion	(2.2)		(3.0)	(2.2)	(5.2)	(0.7)		(6.0)	(6.7)	(0.7)	(14.8)
Ziphiids											
Total	(201.3)	(72.9)	(1001.1)	(495.3)	(1496.4)	(556.8)	(869.8)	(831.1)	(2257.7)	(0.7)	(4029.0)

Appendix Table 11.8. Estimated summer prey consumption by marine mammals in PICES marine ecosystems (Sub-region: OKH). Total consumption estimates indicate the minimum amount of prey consumed during the summer period only (i.e. June-September). Values are given as metric ton. Values in parenthesis are estimated by using diet composition parameter of Pauly et al. (1997).

Species	Main prey categories (based on summer diet data)									
	Benthic invertebrates	Crustacean zooplankton	Small squid	Large squid	All squid	Small epipelagic fish	Mesopelagic fish	Miscellaneous	All fish	Birds and mammals	Total prey
Baird's beaked whale	1.1		3.4	2.8	6.2	1.1	1.1	1.7	3.9		11.2
Bearded seal	(217.8)	(50.3)				(16.8)		(50.3)	(67.1)		(335.2)
Bowhead whale											
Dall's porpoise			139.9		139.9	70.0	139.9		209.9		349.8
Fin whale											
Gray whale	70.5		3.7		3.7						74.2
Harbor porpoise											
Humpback whale											
Killer whale											
Minke whale		288.3				32.0			32.0		320.3
Northern fur seal			9.6		9.6	6.4	6.4	9.6	22.4		32.0
Northern right whale		(9.5)									(9.5)
Pac. white-sided dolphin											
Ribbon seal			44.6		44.6	17.8	8.9	17.8	44.5		89.1
Ringed seal	(7.9)	(7.9)				(5.9)	(2)	(15.8)	(23.7)		(39.5)
Spotted seal	5.9		11.9		11.9	11.9		29.7	41.6		59.4
Steller sea lion	1.7					0.4		2.1	2.5		4.2
White whale											
Ziphiids											
Total	304.9	356.0	213.1	2.8	215.9	162.3	158.3	127.0	477.6		1324.4

Appendix Table 11.9. Estimated summer prey consumption by marine mammals in PICES marine ecosystems (Sub-region: CAS). Total consumption estimates indicate the minimum amount of prey consumed during the summer period only (i.e., June-September). Values given as 1000s metric tons. Values in parentheses are estimated by using diet composition parameters shown in Appendix Table 10.9, and assuming the following energetic values: benthic invertebrates, 4 kj/g; crustacean zooplankton, 4 kj/g; small squid, 3.5 kj/g; large squid, 4 kj/g; small epipelagic fish, 7 kj/g; meso-pelagic fish, 7 kj/g; misc. fish, 5 kj/g; and birds and mammals, 7 kj/g.

Species	Estimated biomass of prey consumed (1000s metric tons) for main prey categories										Total prey consumed by each predator species
	Benthic invertebrates	Crustacean zooplankton	Squid			Fish				Birds and mammals	
			Small	Large	All	Small epipelagic	Meso-pelagic	Misc.	All		
Steller sea lion	4.2		5.6	4.2	9.8	1.4		11.2	12.6	1.4	28.0
California sea lion	16.64		33.28	24.96	58.24	41.6		49.92	91.52		166.4
Northern fur seal											
Guadelupe fur seal											
Harbor seal	4.17		4.17	2.08	6.25	12.51		18.76	31.27		41.7
Northern elephant seal											
Killer whale			.51	.51	1.02	1.02		4.08	5.1	4.08	10.2
Pac. white-sided dolphin	13.67		20.51	13.67	34.18	20.51	13.67	54.68	88.86		136.7
Risso's dolphin											
Bottlenose dolphin											
Striped dolphin											
Short-beaked com. dolphin											
Long-beaked com.dolphin											
N. right whale dolphin			8.79	5.86	14.65		11.72	2.93	14.65		29.3
Harbor porpoise	1.27		2.54	2.54	5.08	7.62		11.43	19.05		25.4
Dalls porpoise	7.74		46.44	15.48	61.92	30.96	30.96	23.22	85.14		154.8
Pygmy/dwarf sperm whale											
Sperm whale											
Short-finned pilot whale											
Baird’s beaked whale											
Mesoplodont beaked whales											
Cuvier’s beaked whale											
Gray whale											
Humpback whale											
Blue whale											
Fin whale											
Bryde's whale											
Minke whale		2.54				1.17		.19	1.36		3.9
Sei whale											
Sea otter	2.5										2.5
Total min. consumption	50.19	2.54	121.84	69.3	191.14	116.79	56.35	180.94	349.45	5.48	598.9

Appendix Table 11.10. Estimated summer prey consumption by marine mammals in PICES marine ecosystems (Sub-region: ETZ). Total consumption estimates indicate the minimum amount of prey consumed during the summer period only (i.e., June-September). Values given as 1000s metric tons. Values in parentheses are estimated by using diet composition parameters shown in Appendix Table 10.10, and assuming the following energetic values: benthic invertebrates, 4 kj/g; crustacean zooplankton, 4 kj/g; small squid, 3.5 kj/g; large squid, 4 kj/g; small epipelagic fish, 7 kj/g; meso-pelagic fish, 7 kj/g; misc. fish, 5 kj/g; and birds and mammals, 7 kj/g.

Species	Estimated biomass of prey consumed (1000s metric tons) for main prey categories										Total prey consumed by each predator species
	Benthic invertebrates	Crustacean zooplankton	Squid			Fish				Birds and mammals	
			Small	Large	All	Small epipelagic	Meso-pelagic	Misc.	All		
Northern fur seal											
Northern elephant seal											
Hawaiian monk seal											
Killer whale											
Risso's dolphin											
Bottlenose dolphin											
Striped dolphin											
Short-beaked com. dolphin											
Rough-toothed dolphin											
Pantropical spotted dolphin											
Spinner dolphin											
Melon-headed whale											
Pygmy killer whale											
False killer whale											
Dalls porpoise											
Pygmy/dwarf sperm whale											
Sperm whale											
Short-finned pilot whale											
Baird's beaked whale											
Mesoplodont beaked whales											
Cuvier's beaked whale											
Gray whale											
Humpback whale											
Blue whale											
Fin whale											
Bryde's whale											
Sei whale											

Appendix Table 11.11. Estimated summer prey consumption by marine mammals in PICES marine ecosystems (Sub-region: WTZ). Total consumption estimates indicate the minimum amount of prey consumed during the summer period only (i.e. June-September). Values are given as metric ton. Values in parenthesis are estimated by using diet composition parameter of Pauly et al. (1997).

Species	Main prey categories (based on summer diet data)									
	Benthic invertebrates	Crustacean zooplancton	Small squid	Large squid	All squid	Small epipelagic fish	Mesopelagic fish	Miscellaneous	All fish	Birds and mammals	Total prey
Blue whale											
Bottlenose dolphin			(68.8)	(17.2)	(86.0)	(51.6)		(206.5)	(258.1)		(344.1)
Bryde's whale		(106.4)				(53.2)	(53.2)	(53.2)	(159.6)		(266.0)
Common dolphin											
Dall's porpoise			(140.0)		(140.0)	(140.0)	(979.7)	(140.0)	(1259.7)		(1399.7)
Dwarf sperm whale											
False killer whale											
Fin whale											
Fraser's dolphin											
Killer whale											
Minke whale											
Northern fur seal			(16.0)	(16.0)	(32.0)	(26.7)	(16.0)	(32.1)	(74.8)		(106.8)
Northern right whale											
N. right whale dolphin											
Pac. white-sided dolphin			(310.7)	(51.8)	(362.5)	(310.7)	(207.1)	(155.3)	(673.1)		(1035.6)
Pygmy killer whale											
Pygmy sperm whale											
Risso's dolphin	14.7		146.7	102.7	249.4	14.7		14.7	29.4		293.5
Rough-toothed dolphin											
Sei whale											
Short-finned pilot whale-N											
Short-finned pilot whale-S			(94.0)	(94.0)	(188.0)	(31.3)	(31.3)	(62.7)	(125.3)		(313.3)
Sperm whale	(66.5)		(133.0)	(797.9)	(930.9)	(66.5)	(66.5)	(199.5)	(332.5)		(1329.9)
Spinner dolphin											
Spotted dolphin			(142.5)	(95.0)	(237.5)	(47.5)		(189.9)	(237.4)		(474.9)
Striped dolphin	(41.6)		(166.2)	(124.7)	(290.9)	(41.6)	(249.4)	(207.8)	(498.8)		(831.3)
Ziphiids											
Total	122.8	106.4	1,217.9	1,299.3	2,517.2	783.8	1,603.2	1,261.7	3,648.7		6,395.1

Appendix Table 11.12. Estimated summer prey consumption by marine mammals in PICES marine ecosystems (Sub-region: KR/OY). Total consumption estimates indicate the minimum amount of prey consumed during the summer period only (i.e. June-September). Values are given as metric ton. Values in parenthesis are estimated by using diet composition parameter of Pauly et al. (1997).

Species	Main prey categories (based on summer diet data)									
	Benthic invertebrates	Crustacean zooplankton	Small squid	Large squid	All squid	Small epipelagic fish	Mesopelagic fish	Miscellaneous	All fish	Total prey
Baird's beaked whale	(5.8)		(11.7)	(5.8)	(17.5)	(11.7)	(11.7)	(11.7)	(35.1)	(58.4)
Blue whale										
Bottlenose dolphin										
Bryde's whale		(0.8)				(0.4)	(0.4)	(0.4)	(1.2)	(2.0)
Commom dolphin										
Dall's porpoise										
Dwarf sperm whale										
False killer whale										
Fin whale										
Finless porpoise										
Fraser's dolphin										
Harbor porpoise										
Harbor seal										
Killer whale										
Minke whale										
Northern fur seal										
Northern right whale										
N. right whale dolphin										
Pac. white-sided dolphin										
Pygmy killer whale										
Pygmy sperm whale										
Risso's dolphin										
Rough-toothed dolphin										
Sei whale										
Short-finned pilot whale-N			(9.4)	(9.4)	(18.8)	(3.1)	(3.1)	(6.3)	(12.5)	(31.3)
Short-finned pilot whale-S			(94.0)	(94.0)	(188.0)	(31.3)	(31.3)	(62.7)	(125.3)	(313.3)
Sperm whale	(4.4)		(8.8)	(53.0)	(61.8)	(4.4)	(4.4)	(13.2)	(22.0)	(88.2)
Spinner/spotted/striped dolphins										
Spotted seal										
Steller sea lion										
Ziphiids			(11.9)	(2.0)	(11.9)	(11.9)	(7.9)	(6.0)	(25.8)	(39.7)
Total	(10.2)	(0.8)	(135.8)	(164.2)	(298.0)	(62.8)	(58.8)	(100.3)	(221.9)	(532.9)

Appendix Table 11.13. Estimated summer prey consumption by marine mammals in PICES marine ecosystems (Sub-region: SJP). Total consumption estimates indicate the minimum amount of prey consumed during the summer period only (i.e. June-September). Values are given as metric ton. Values in parenthesis are estimated by using diet composition parameter of Pauly et al. (1997).

Species	Main prey categories (based on summer diet data)									
	Benthic invertebrates	Crustacean zooplankton	Small squid	Large squid	All squid	Small epipelagic fish	Mesopelagic fish	Miscellaneous	All fish	Total prey
Baird's beaked whale	(3.4)		(10.2)	(8.5)	(18.7)	(3.4)	(3.4)	(5.1)	(11.9)	(34.0)
Bottlenose dolphin										
Common dolphin										
Dwarf sperm whale										
False killer whale										
Fin whale										
Finless porpoise										
Killer whale										
Minke whale		(23.7)				(10.9)		(1.8)	(12.7)	(36.5)
Northern fur seal										
Pac. white-sided dolphin										
Pygmy sperm whale										
Risso's dolphin										
Spotted seal										
Steller sea lion										
Ziphiids										
Total	(3.4)	(23.7)	(10.2)	(8.5)	(18.7)	(14.3)	(3.4)	(6.9)	(24.6)	(70.5)

Appendix 12. Bibliography of prey use by seabirds of the North Pacific Ocean

The literature on marine birds of the North Pacific is voluminous and diverse. Unfortunately, most published studies are local and seasonal, and there are few major syntheses for large areas or time frames. In this compendium, we have attempted to assemble references to the majority of papers important for assessing the food habits of marine birds in the North Pacific Ocean. We have also included here numerous papers that deal with other regions, but were vital to the development of this report.

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