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Final Narrative Report to California Sea Grant

Project # R/F-195

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Abstract

We collated information on population size, diet composition, energy requirements, energy densities of prey species, and assimilation efficiency from the literature to estimate annual prey consumption by Common Murres (*Uria aalge*) between Cape Blanco, Oregon and Point Conception, California in 2004. We estimated that the population consumed approximately 242,250 metric tons of prey, including 70,500 metric tons consumed by breeding adults, 51,920 metric tons consumed by non-breeding adults and subadults during the breeding season (March – August), 119,620 metric tons consumed by all birds during the wintering period (September – February), and 214 metric tons consumed by dependent chicks prior to leaving breeding colonies. Pacific hake (*Merluccius productus*) and market squid (*Loligo opalescens*) each made up over 20% of annual prey consumption. Other species making up at least 10% of annual consumption included shiner surfperch (*Cymatogaster aggregata*), northern anchovy (*Engraulis mordax*), and rockfish (*Sebastes* spp.). Chick diet was dominated by anchovy / sardine (*Sardinops sagax*; 63%), rockfish (21%), and smelt (*Osmeridae* spp.; 7%). Understanding these prey requirements is important for understanding the dynamics of predator and prey populations and for effective management of ocean resources.

Introduction

Seabirds are top predators in marine ecosystems and have substantial energetic needs (Brooke 2004, Hunt et al. 2005). Estimates of local fish harvests by seabird species or communities range from 5% - 64% of pelagic production (reviewed in Montevecchi 1993). In addition, commercial fisheries and other top predators (large fish and marine mammals) often compete with seabirds for the same prey resources (Furness 1990, Jahncke et al. 2004). Some researchers have estimated that seabirds and commercial fisheries harvest similar quantities of prey (Brown and Nettleship 1984, Brooke 2004), while others have found overlap in the size classes harvested by seabirds and humans (Schaffner 1986, Bunce 2001). As a result of overlapping resource use, commercial fisheries may directly compete with seabirds for prey. Indeed, commercial harvest of forage fishes has been linked to seabird population declines in some areas (Burger and Cooper 1984, Tasker et al. 2000). Conversely, fisheries may, in some instances, enhance prey populations by removing large, predatory fish from the system that would otherwise compete with seabirds for prey (Hatch and Sanger 1992, Tasker et al. 2000).

The Common Murre (*Uria aalge*) is one of the most abundant seabird species in the California Current throughout the year (Briggs et al. 1987, Ford et al. 2004). The population is currently recovering from dramatic population declines due to egg collecting, gill-net mortality, and oil spills, though it remains well below historical levels (Takekawa et al. 1990, Manuwal et al. 2001). We estimated murre prey consumption using information on energy requirements, diet composition, energy densities of prey, assimilation efficiency, and population size in order to better understand murre prey requirements and predator and prey population dynamics. Specifically, we used existing data to (1) develop a bioenergetics model for murres between Cape Blanco, Oregon and Point Conception, California, (2) estimate prey consumption for all subsets of the population, including breeding birds, non-breeding birds, wintering birds, and chicks at breeding colonies, and (3) compare prey consumption estimates by prey species to determine which ones are most heavily utilized by murres.

Methods

Model Overview

We focused on the region between Cape Blanco and Point Conception because it is oceanographically and biologically distinct from the areas to the north and south (Figure 1). We assumed that murre diets were similar throughout the region. We calculated prey consumption for the breeding (March – August) and non-breeding (September – February) seasons separately. We chose these time periods based on general patterns of murre breeding phenology. We treated breeding birds during the breeding season, non-breeding birds during the breeding season, and wintering birds during the wintering period separately. The non-breeding and wintering categories include subadult and adult birds. The wintering category also includes juveniles (chicks produced earlier in the year). We gathered the most recent and applicable information on energy requirements, diet composition, energy densities of prey, assimilation efficiency, and population size available. We did not include chicks at breeding colonies in the bioenergetics model. Instead, we estimated chick prey consumption from direct observations of chick feedings. Details regarding parameter values are described below. Results for subadult and adult birds are rounded to the nearest ten metric tons. Results for chicks at breeding colonies are rounded to the nearest metric ton.

Energy requirements

We used a breeding season estimate of 1789 kJ/day as the basis for our model (Cairns et al. 1990). The value reflects the field metabolic rate of breeding murres in Newfoundland, Canada. Field metabolic rate is affected by both mass and latitude (Ellis and Gabrielson 2002), and we adjusted that estimate to reflect the higher mass and the lower latitude for birds in our study area. The resulting value was 1652 kJ/day. We used a lower field metabolic rate (1502 kJ/day) for non-breeding and wintering birds based on the assumption that they have lower energy requirements than breeding birds (Ricklefs 1983, Gales and Green 1990). We assumed that the energy requirements of non-breeding and wintering birds are similar due to similar foraging requirements and a relatively mild climate throughout the year.

Diet Composition

We used percent mass from Ainley et al. (1996) as our measure of subadult and adult diet composition. Those authors summarized diet composition (percent mass) for the pre-breeding

(March – April), breeding (April – August), and non-breeding (September – February) seasons in coastal, mid-shelf, and outer shelf habitats. We calculated weighted averages for the breeding season as we defined it (March – August) based on the number of months in Ainley et al.'s (1996) pre-breeding and breeding seasons. We then calculated weighted averages across habitat types for the breeding and wintering periods based on the densities of murres in each habitat type. The densities were based on data collated by the National Oceanic and Atmospheric Administration's National Centers for Coastal Ocean Science (NCCOS 2003). We determined chick diet composition from direct observations of chick feedings at a colony on Southeast Farallon Island (SEFI; 37° 42′ N 123° 00′ W) from 2000 – 2004.

Prey energy densities

We obtained energy densities for most prey species from the literature (Table 1). We made the following minor substitutions because we could not find published values for a few specific prey species: a value for "euphausiids" (Davis et al. 1998) was used for both *Euphasia pacifica* and *Thysanoessa spinifera*, a value for market squid (Spear 1993) was used for octopus (*Octopus rufescens*), a value for "surfperch" (Roby et al. 2003) was used for both kelp (*Brachyistius frenatus*) and shiner surfperch, and a value for topsmelt (*Atherinops affinis*; Dahdul and Horn 2003) was used for jacksmelt (*Atherinopsis californiensis*). We obtained estimates for Pacific hake and Pacific butterfish (*Peprilus simmillimus*) that were calculated from published values of percent lipid and percent protein of Pacific hake (protein = 15.7%, lipid = 1.44%) and Atlantic butterfish (*Peprilus triacanthus*; protein = 16.55%, lipid = 1.60%) fillets (Chris Harvey, NOAA, pers. comm.). Protein values were then multiplied by their calorific equivalent of 17 kJ/g, and lipid values were multiplied by 38 kJ/g. We used a value for short-bellied rockfish (*Sebastes jordani*; Spear 1993) for all rockfish species and an average for all prey items, weighted by diet composition, to estimate the energy density of the "unknown" prey.

Assimilation efficiency

Assimilation efficiency is a measure of the efficiency with which food is converted to useful energy. We used an average value of 0.7839 for two different prey types reported by Hilton et al. (2000) for murres.

Breeding season population size (March – August)

We used complete counts from 1988 and partial counts from 2004 to determine breeding population size in Oregon (D. Pitkin, USFWS, pers. comm.). Specifically, we reduced the 1988 count by 11% based on a comparison of common sites that were counted in both years. We used complete counts from 2004 to determine breeding population size in California (G. McChesney, USFWS, pers. comm.). We used a correction factor of 1.5 to adjust the raw counts to account for birds away from the colony at the time of the survey (Sydeman et al. 1997). Our total population estimate for breeding birds was 715,000. We multiplied the number of breeding pairs by 0.86 (average hatching success on SEFI from 2000 – 2004) to calculate a total of 307,450 chicks hatched at breeding colonies. We used demographic data from Southeast Farallon Island to estimate the proportion of the population that were non-breeding birds. We averaged the results from two different demographic analyses with different estimates of juvenile, subadult, and adult survival to arrive at an estimate for the non-breeding population that equaled 44.9% of the total population, or 579,150 birds.

Wintering population size (September – February)

We used data summarized in the Marine Mammal and Seabird Computer Database Analysis System: Washington, Oregon, California 1975 – 1997, Version 2.1 (ECI 2001) to estimate wintering population size. The database contains seabird distribution and abundance data summarized as densities for each 5′ latitude by 5′ longitude block based on low aerial and ship transects that extended beyond the shelf-break and encompassed the murre distribution. We created tables with murre density and area for each 5′ x 5′ block for the breeding and non-breeding seasons. We used that data to calculate the number of birds present during each season. We then calculated the non-breeding season / breeding season ratio (1.2) and multiplied that value by the 2004 breeding population estimate for a total of 1,552,970 birds.

Results

We estimated that the murre population in our study area (Cape Blanco to Point Conception) consumed approximately 242,250 metric tons of prey in 2004 (Tables 2 and 3). Our estimate included 70,500 metric tons for breeding adults, 51,920 metric tons for non-breeding adults and subadults during the breeding season, 119,620 metric tons for birds present during the wintering period, and 214 metric tons for chicks at breeding colonies (Tables 2 and 3). Pacific hake and market squid each made up over 20% of annual consumption (excluding chicks at breeding colonies) at 58,330 metric tons and 57,950 metric tons, respectively (Table 2). Other species making up at least 10% of annual consumption included shiner surfperch (28,330 metric tons), northern anchovy (26,760 metric tons), and rockfish species (23,320 metric tons). Chick diet was dominated by anchovy / sardine (63%), rockfish species (21%), and smelt species (7%; Table 3). Most of the anchovy / sardine category were likely northern anchovy (94% of those identified to species).

Discussion

Our results demonstrate the substantial prey requirements of a dominant seabird in the California Current. Importantly, these requirements represent only a portion of total prey consumption for predators in our study area. Baltz and Morejohn (1977) found that anchovy, squid, rockfish species, and flatfish species were common in the diets of most seabirds wintering in Monterey Bay. Morejohn et al. (1978) considered seabirds and other top predators in Monterey Bay and found substantial overlap in the diets of seabirds, marine mammals, and predatory fish. The combined harvest of these top predators is substantial, though estimates of the relative prey consumption by top predators varies. Briggs and Chu (1987) estimated that marine mammal prey consumption is 3 – 11 times that of seabird prey consumption in California. Conversely, Furness (1990) estimated that predatory fish consumption was 53% of seabird consumption and seal consumption was 19% of seabird consumption in the North Sea. Commercial fisheries also have an impact on some of these prey populations. The squid fishery is currently the largest fishery in California (CDFG 2005b) and harvested 40,068 metric tons of squid in 2004 (CDFG 2005a); peak squid catches have exceeded 100,000 metric tons in some years (Zeidberg et al. 2006). Commercial fisheries in California also harvested 6,793 metric tons of anchovy and 4,742 metric tons of hake (CDFG 2005a). Murre consumption exceeded commercial fisheries catch in each case. More information on prey consumption by other top predators relative to prey population sizes is necessary to assess the impact of seabirds and their competitors, including humans, on prey populations. In addition to more information on predator – prey relationships, prey consumption, and prey biomass, a greater understanding of prey consumption under varying environmental conditions would be beneficial. Understanding the interactions between seabirds, commercial fisheries, and other top predators and assessing the impact of the combined harvest on prey populations is important to a multi-species, ecosystem-based approach to management of living marine resources that ensures healthy populations of both predators and prey.

Products

We gave two presentations (see below) on the above work and are currently preparing one paper for submission to ICES Journal of Marine Science.

- Roth, J.E., Nur, N., Warzybok, P., and Sydeman, W.J. Annual prey consumption of Common Murres from Cape Blanco, Oregon to Point Conception, California. Oral presentation at the 34th Annual Meeting of the Pacific Seabird Group, Asilomar, California, 7 – 11 February 2007.

- Warzybok, P., Roth, J.E., Nur, N., Bradley, R.W., Sydeman, W.J., and Golightly, R.T. Modeling prey consumption for Common Murre chicks (*Uria aalge*) at a colony in central California: effects of chick age and environmental variation. Oral presentation at the 34th Annual Meeting of the Pacific Seabird Group, Asilomar, California, 7 – 11 February 2007.

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Table 1. Published energy densities (kJ/g wet weight) for Common Murre diet items. Diet compostion was based on Ainley et al. (1996). Bold values indicate substitutions explained in the text.

Prey Species	Energy Density kJ/g wet weight	Source
Euphausia pacifica	**3.11**	1
Thysannoessa spinifera	**3.11**	1
Market squid	4.14	2
Octopus	**4.14**	2
Northern anchovy	5.56	3
Shiner surfperch	**4.16**	4
Kelp surfperch	**4.16**	4
Pacific whiting	**3.2**	5
Lingcod	3.98	6
Pacific sanddab	3.47	2
Plainfin Midshipman	5.23	2
Spotted cusk-eel	3.39	2
Pacific herring	5.78	4
Night smelt	4.33	2
Rockfish	4.85	2
Jacksmelt	**4.44**	3
Pacific butterfish	**3.4**	5
Unidentified	**4.14**	N/A

[1]Davis et al. (1998)

[2]Spear (1993)

[3]Dahdul and Horn (2003)

[4]Roby et al. (2003)

[5]Chris Harvey, NOAA, pers. comm.

[6]Anthony et al. (2000)

Table 2. Biomass (metric tons) of each prey type consumed by Common Murres from Cape Blanco, Oregon to Point Conception, California in 2004.

Prey Species	Breeding Birds	Non-breeding Birds	Wintering Birds	Total
Euphausia pacifica	200	150	0	350
Thysanoessa spinifera	970	720	720	2,410
Market Squid	5,420	3,990	48,540	57,950
Octopus	220	160	0	380
Northern anchovy	8,530	6,280	11,950	26,760
Shiner surfperch	2,800	2,060	23,470	28,330
Kelp surfperch	1,120	830	0	1950
Pacific hake	33,590	24,740	0	58,330
Lingcod	2,310	1,700	0	4,010
Pacific sanddab	4,620	3,400	0	8,020
Plainfin Midshipman	0	0	11,920	11,920
Spotted cusk-eel	130	100	2,440	2,670
Pacific herring	2,790	2,050	4,610	9,450
Night smelt	260	190	2,680	3,130
Rockfish	6,670	4,910	11,740	23,320
Jacksmelt	810	590	0	1,400
Pacific butterfish	0	0	1,310	1,310
Unidentified	60	50	240	350
Total	70,500	51,920	119,620	242,040

Table 3. Biomass (metric tons) of each prey type consumed by Common Murre chicks from Cape Blanco, Oregon to Point Conception, California in 2004.

Prey Species	Chicks
Rockfish	44
Northern anchovy / Pacific sardine	134
Smelt spp.	15
Squid spp.	8
Pacific butterfish	3
Flatfish spp.	1
Salmon spp.	4
Pacific saury	< 1
Pacific sandlance	< 1
Lingcod	< 1
Unidentified / Other	4
Total	214

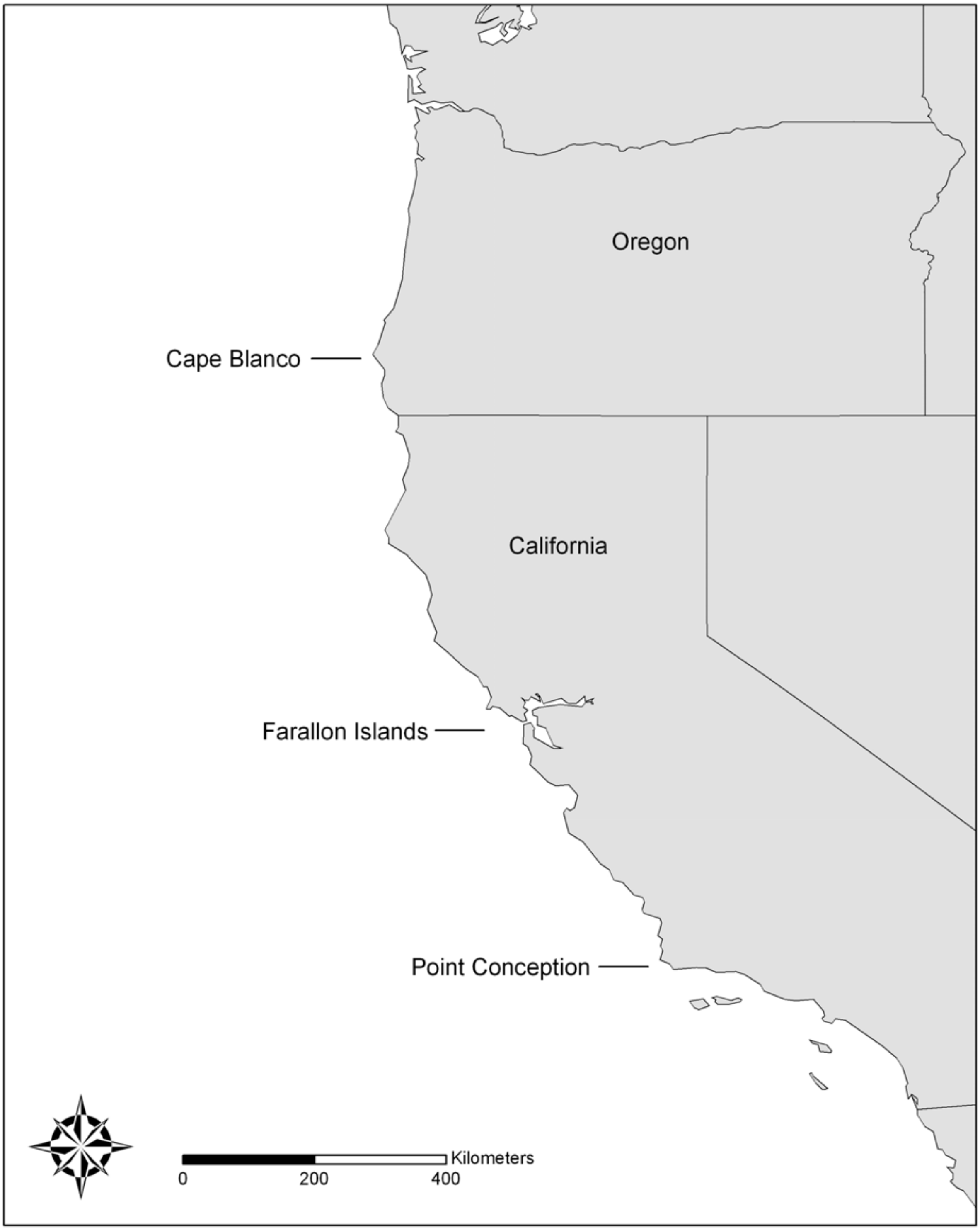

Figure 1. Map showing the area included, Cape Blanco, Oregon to Point Conception, California, in the Common Murre prey consumption estimates for 2004.