Macro-Ecology of North Pacific Ecosystems:
Plankton-Seabird Associations in Space and Time

NPRB Project 801 Final Report

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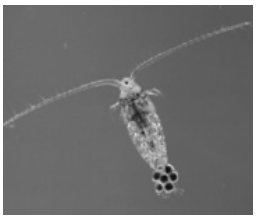
ABSTRACT



We conducted surveys of marine birds and mammals in association with the North Pacific Continuous Plankton Recorder (CPR) program from June 2002 through June 2007. We report findings from 16 surveys (3 "seasons" over 6 years) supported by NPRB grants 206, 409, 611 and 801, focusing on the open ocean habitats of the Gulf of Alaska and western North Pacific. This research is motivated by the concept that plankton and seabird community composition and abundance reflect temporal and spatial variability in the marine environment, and hence can be used as indicators of ecosystem structure, function and dynamics. Based on previous research which suggested (1) differential responses of seabird species to North Pacific climate variability and (2) seasonal and geographic variation in plankton-seabird community structure, we tested the hypothesis that surface-feeding seabirds (Procellariformes and Laridae) and diving seabirds (Alcidae) varied in their relationships to primary productivity and mesozooplankton (e.g., copepod, euphausiid) abundance and diversity. To test this hypothesis, we developed statistical models including season, year, and geographic region to investigate associations between the distribution and abundance of 20 relatively common seabird species, net primary productivity, and 12 zooplankton taxonomic groups (mainly at the genus level). We found associations at the "bulk" level (i.e., total zooplankton abundance and diversity was positively related to net primary productivity; total seabird density was positively related to zooplankton abundance, but not diversity), and many relationships at the individual species level, though few involve presumed direct predator-prey relationships. Most of the associations were positive, indicating general relationships between the distribution and abundance of seabirds and lower trophic level productivity. A few associations were negative, mostly for the alcids, which could indicate potential competitive relationships with other top predators, possibly salmonids, but may also be a statistical artifact of places where there is plankton, but few birds. Macro-ecological studies of North Pacific ecosystems using plankton and seabirds as ecological indicators provides both a framework understanding and a process for monitoring and assessing spatial and temporal ecosystem "health" and resilience, dynamics which are impossible to assess by other means. The CPR-MBM time series is currently too short to be used to investigate climate change impacts on North Pacific ecosystems, but it can contribute in novel ways to integrated ecosystem assessments and other syntheses.

Key Words
copepods, distribution and abundance, ecosystem indicators, euphausiids, macro-ecology, mesozooplankton, open ocean, primary productivity, seabirds

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Study Chronology

- The study began with funding under NPRB project 206 (August 2002 -November 2003) and was extended through June 2007 under project 409 and 611.
- Progress reports were submitted in January 2003 - 2006 and July 2003 - 2006.
- Final report for 206 submitted in 2004.
- Final report for 409 was submitted in December 2006.
- Final report for 611 was merged with this report.
- The title of the project changed:
    - *206: Integration of Marine Bird and Mammal Observations with the Continuous Plankton Recorder Program*
    - *409: Integration of Marine Bird and Mammal Observations with the Pacific Continuous Plankton Recorder (CPR) Program: Temporal Variability in Ecosystem Structure Across Three Basins*
    - *611: Spatio-Temporal Variability In North Pacific Meso-Marine Ecosystem (MME) Structure: Basin-wide Responses to a Cooling Transition*
    - *801: Integration of Marine Bird and Continuous Plankton Data for the Gulf of Alaska*.

Introduction

The North Pacific Research Board (NPRB) aims to develop a comprehensive, science-based program to better understand the marine ecosystems and the fisheries they support in the North Pacific Ocean and Bering Sea. This project addresses the form and function of North Pacific marine ecosystems from the basin-scale or *macro-ecological* perspective (Brown and Maurer 1989), coinciding with one of the main research priorities (large-scale ecosystem-level research) highlighted by the NPRB Science Plan. Our research provides a novel, inter-disciplinary perspective by obtaining and relating simultaneous surveys of plankton communities and top predator (seabird) distribution and abundance across much of the sub-arctic North Pacific Ocean including the Gulf of Alaska, Bering Sea-Aleutian Shelf, and western North Pacific large marine ecosystems.

In this report we consider macro-ecological seabird-plankton associations for open ocean habitats of the Gulf of Alaska (GoA) and western North Pacific. Most studies of seabird predator-prey associations in space have been accomplished on fine scales, usually < 10km (Russell et al. 1992). Due to limited sampling and unique attributes (Unimak Pass), the eastern Bering Sea-Aleutian Shelf region was excluded from this analysis, and will be treated separately elsewhere. Based on previous study results suggesting (1) that seabird and plankton communities respond strongly to ocean climate variability in the North Pacific (Sydeman et al. 2006a, Brodeur and Ware 1992, respectively), and (2) that these communities co-occur in time and space, at least within seasons (Batten et al. 2006), we tested the overarching hypothesis that seabird-plankton associations vary in relation to the foraging mode (surface vs. diving) of the seabirds examined. In particular, we surmise that surface (or near surface) foraging procellarid and larid seabirds (albatrosses, petrels, shearwaters, and gulls) would show associations with different mesozooplankton groups than diving seabirds (alcids). We address this operational hypothesis as a means to evaluate the utility of simultaneous plankton and predator surveys to

understand and describe large-scale ecosystem variation and dynamics in the North Pacific Ocean. Ultimately, we envision 3 distinct applications of plankton-seabird associations (Brander et al. 2003): (i) as indicators to variation in overall ecosystem productivity, (ii) as indicators to ecosystem conditions that drive fish populations, with application to fisheries management, and (iii) as indicators for marine spatial integration, with application in the design, monitoring, and protection of ecosystems (e.g., design of marine protected area networks).

Objectives

Initial funding provided by NPRB (project 206) supported a pilot study to determine appropriate survey methods for marine birds and mammals from commercial vessels of opportunity. In this project, we demonstrated that it was possible to survey top predators from vessels of opportunity transiting the North Pacific. Details of the methodology we developed are provided by Hyrenbach et al. (2007).

Building on the success and initial data collected during project 206, the principal objective of project 409 was to establish a large-scale, inter-disciplinary monitoring program for North Pacific marine ecosystems using vessels of opportunity. With our principal collaborator, Dr. Sonia Batten, we accomplished this objective by incorporating observations of marine birds and mammals along the 7,500 km east-west survey line of the Pacific Continuous Plankton Recorder (CPR) project. One motivation for this work was to establish the habitats of top predators in the region. Secondly, and perhaps most importantly, because marine birds and mammals use prey resources not sampled by the CPR program, e.g., forage fish, such as myctophids and squids, key micronekton of the sub-arctic North Pacific (Beamish et al. 1999, Kaeriyama et al. 2004) we thought that observations of top predators would provide complementary information on these difficult-to-sample mid trophic level species. Furthermore, we were motivated by the idea that replicate surveys on the distributions of plankton and top predators could reveal areas of heightened biological interactions in the open ocean, sites where energy flow from lower to upper trophic-levels was concentrated. These sites could then be monitored and/or protected to assess and/or ensure ecosystem resilience.

Our objective in project 611 was to continue the survey during a period of cooling in the North Pacific. The Pacific Decadal Oscillation was in a positive phase throughout most of project 409, and switched to negative late in 409 and during 611. We felt that assessing predator-plankton spatial associations and relationships during colder ocean temperatures would provide new information on coupled climate-ecosystem variability.

In 801, we seek to integrate various plankton and seabird datasets in a retrospective data analysis context, specifically for the Gulf of Alaska region. We have extended this objective to include the western North Pacific, but owing to limited sampling and unusual dynamics (e.g., the Unimak Pass “hotspot”, which accounts for the majority of seabird and mammal sightings) we have not included the Bering Sea – Aleutian Shelf region in this analysis.

Methods

We surveyed plankton, marine birds and mammals from British Columbia, Canada to Honshu, Japan. This survey covers eastern (northern California Current) and western (Kuroshio) boundary currents of the North Pacific, eastern and western subarctic gyres, and portions of the

Bering Sea / Aleutian Island region. During the boreal spring (April-May), summer (June-July), and fall (September-October), we conducted a total of 16 surveys; cruise dates and the trackline varied somewhat across seasons and years (Figure 1, Table 1). A total of 199 days of sampling of plankton and predators was made from June 2002 through June 2007.

Surveys

One observer (M.F. Henry) identified and counted marine birds and mammals from the flying bridge / pilot house / focsle deck of the bulk-cargo carrier M/V *Skaubryn*, at an eye height above the water of 25m / 25m / 10m, respectively. The M/V *Skaubryn* is 182m in length and 42.5m wide. Surveys were conducted during daylight hours while the ship was underway generally at speeds of 10-15k. Observations were halted during periods of heavy rain, fog, or rough seas, and when impaired visibility of the survey strip made identification or enumeration of marine birds and mammals impossible. Identifications were confirmed using 10x50 power binoculars. Surveys were performed concurrently with the towing of the CPR device. We identified and enumerated all seabirds that entered a 90° arc from bow to the beam on the side of the vessel with the best survey conditions (least sun glare, precipitation or wind). All birds were identified to the lowest taxonomic level possible and associated behaviors were recorded (mainly "in flight" or "sitting on water"). Ship-following individuals (birds that were attracted to the vessel and diverted their normal flight path / behavior) were recorded when first encountered and ignored thereafter. Ship followers were not included in this data analysis, which combined "flying" and "sitting" birds. Due to the large size of the M/V *Skaubryn*, modifications were made to the standardized marine bird survey techniques (Tasker et al. 1984, Buckland et al. 1993). During initial surveys in June 2002 and October 2002, we made bird observations out to 800m from the vessel and assigned each sighting to one of four discrete survey strip transects (0-100m, 100-200m, 200-400m, 400-800m). Species-specific detection and identification curves revealed that the optimal strip-width for this vessel was 400m (Hyrenbach et al. 2007). During all ensuing surveys, we used a 400m strip transect to survey birds. Therefore, marine bird relative abundance is expressed as "density" (# / km^2). Due to large numbers of sightings, the observer did not record flight direction. For this analysis, we selected daily samples in which at least 100km of ocean was observed.

During the first four surveys seabird counts were recorded in series of discrete 5-minute transects ("bins"). Counts within each bin were summed by species. GPS positions were recorded at the beginning and end of each series, hourly, and when the vessel turned or slowed its speed. Geo-referencing of start, end, and midpoints of the 5-minute bins was performed post-survey in Microsoft Excel; lengths and areas of survey bins were calculated, and the data was imported into a GIS (ArcGIS 9.1, ESRI, 2005). Since October 2003, we have employed a hand-held Husky *fex*21 computer (Itronix, Coventry, England, UK) running the FLK ("flock") continuous data-logging program. Continuous data was geo-referenced and divided into discrete bins of 1.5 km, the approximate distance traveled in 5 minutes by a vessel traveling at 10 knots. A total of ~18,000 survey bins were considered in our analyses. However, to avoid problems of pseudo-replication and spatial autocorrelation, we selected the "*observation day*" as the sampling unit and we pooled adjacent bins into daily counts. Excluding the Bering Sea – Aleutian Shelf region, this resulted in 138 daily and independent samples (each day was separated by night-time periods with no survey effort in which the ship traveled between ~100-200 km) of aligned plankton and seabird data. Twenty (20) bird species had sufficient data to be included in the

analysis. Total bird density by day and bird diversity (Shannon-Weiner Index; Colwell and Futuyma 1971) were also analyzed.

Plankton Surveys

Batten sampled plankton distributions continuously using a Continuous Plankton Recorder (CPR) device towed behind the vessel at a depth ~7m. The CPR contains a filter band which traps plankton as water is forced through the device. In the lab, the filter band is cut into 18.4km blocks and every 3rd block is sub-sampled with zooplankton identified to the lowest possible taxonomic resolution and biomass estimated by multiplying the abundance of each taxon by its taxon-specific dry weight and summing these values for each sample (Batten et al. 2006). As we summarized the seabird data by day including days with at least 100km of seabird observations, we filtered the plankton survey to include days in which there was a minimum of 54km (at least 3 18km blocks) of plankton data, and centered the samples on noon each day to avoid the problem of crepuscular vertically migration plankton influence abundance and biomass estimates. To simplify the plankton dataset for analysis, we summarized the mesozooplankton estimates of abundance to genus, creating indices for the following genera and higher level taxonomic resolution: *Acartia sp., Calanus sp.*, Chaetognatha, copepod nauplii, *Eucalanus sp.*, Euphausiacea, Harpacticoida, Hyperiidea, Larvacea, *Limacina helicina, Metridia sp., Neocalanus sp., Oithona sp., Paracalanus/Pseudocalanus sp.*, and *Pseudocalanus sp.* adults (life stage). In the final regression modeling effort, we dropped the life stages "copepod nauplii" and "*Pseudocalanus* adults" and relatively rare Harpacticoida from analyses (see below).

Net Primary Productivity

We obtained estimates of net primary productivity (NPP) for each day of the survey, geo-referenced by the position of the ship at noon each day, from the website: http://web.science.oregonstate.edu/ocean.products. We also obtained and processed SeaWIFS data which provides an index of chl-a concentrations. In the end, after confirming the high degree of correlation between NPP and chl-a concentrations, we dropped the chl-a estimates form analyses.

Data Summation and Analysis

We examined the relationships between NPP, mesozooplankton abundance, diversity, and biomass, and the distribution and abundance of seabirds using Pearson correlation, ANCOVA and regression (GLM) techniques. We used the *STATA v8.2* statistical software (Stata Corporation, College Station, Texas) for analyses.

Initially, we sought to analyze the associations between seabirds and plankton by meso-marine ecosystems (MME), as defined by Batten et al. (2006). Batten et al. identified 10 MMEs in the study region (Figure 2), but both Batten et al. and Sydeman et al. (2006a) found that only MMEs in the east were persistent through time (by season and year). Therefore, we first summarized the data and then performed a correlation analyses for the 4 MME in the east (B.C. slope, eastern GoA, central GoA, and western GoA), 1 combined MME for the eastern and western Aleutian Shelf, and 1 combined MME in the west (including central Bering, southern Bering, western Pacific including coastal Japan). For each of these MME, we calculated the mean and standard deviation of each parameter (bird density and zooplankton abundance and diversity) (Tables 2 and 3), and then correlated plankton against plankton (Appendices 1-6, summarized in Appendix

25), birds against birds (Appendices 7-12, summarized in Appendix 26), and birds against plankton (Appendices 13-18). This resulted in many significant, but often difficult-to-interpret correlations. Ultimately we decided that this MME by MME level of analysis was an unreasonable approach.

Next, to simplify the data and analysis, we collapsed all of the eastern GoA MME (MMEs 1-4 in Tables and Appendices) into one region, hereafter referenced as "eastern North Pacific" or "GoA". Moreover, at this stage, we also discarded MME 5/6 from further consideration because it included the Unimak Pass "hotspot" which we felt needed to be treated separately owing to disproportionately high sampling variance in this region, particularly for the seabirds (Figure 2). Moreover, sampling in the eastern/western Aleutian Shelf was very sparse in comparison with other open ocean sampling areas. Sampling in the "Aleutian Basin" and "western Bering Sea" was essentially in open ocean habitat, and plankton and seabird communities in this region were not indistinct from communities further west (Batten et al. 2006, Sydeman et al. 2006a). Consequently, we combined these and other western MME and refer to this region as "west" or "western North Pacific".

These regional data were then stratified by season and correlations were calculated for bird densities against NPP and mesozooplankton abundances (Appendices 19-24, a summary of significant correlations by region can be found in Appendix 27). Also, to address the possibility that most of the correlations were driven by the prevalence of zeros for individual species, we removed zeroes from the dataset and generated a pair-wise correlation matrix for each species by region and species (Appendix 28).

These correlation analyses are provided in the report, but only as background material, and to demonstrate the process we followed from basic data summarization to model development.

Following this overly-complex correlation analysis, we developed GLM (ANCOVA and forward stepwise regression) models of plankton-seabird associations in space and time. We included the following independent variables in ANCOVA and regression models: "year", "season" (defined as spring (March-May), summer (June-July) and fall (September-October), and "region" (meaning east = Gulf of Alaska or west = western North Pacific). An analysis of co-variance (ANCOVA) was performed on zooplankton abundance, biomass, and diversity to test for a relationship with net primary productivity (Table 4). Net primary productivity (NPP) was treated as a continuous variable, whereas year, season, and region were treated as categorical variables. An ANCOVA was also conducted to investigate the relationships between NPP, mesozooplankton diversity, and mesozooplankton abundance with seabird community and species abundance (density) variables (Table 5). Mesozooplankton (taxon-specific) abundance was treated as a continuous variable, whereas year, season, and region were treated as categorical variables. Last, we performed a forward stepwise regression on bird species densities by zooplankton species and region, stratified by season (Table 6). We used a forward stepwise modeling procedure to determine models that best described variation in daily seabird abundance. Owing to the results of ANCOVA (see Table 5), we did not include a term for year in the forward regression modeling approach. We consider model "failure" when neither regional variation or plankton parameters were found to be significant.

Results

Surveys

We completed 16 replicate cruises, spanning three "seasons" over 5 years (2002 – 2007, 5 years spring, 6 years summer, 5 years fall). A total of 27,261 km were surveyed. Over the study years, sampling dates within each season did not progressively become earlier or later, but there was temporal variability in survey dates. Spring surveys took place between March and mid-May, summer surveys between late May and mid-July, and fall surveys between mid-September and mid-October.

Bulk NPP-Plankton-Seabird Associations

Accounting for season, region, and year, zooplankton abundance and diversity were positively related to NPP (Table 4). There was annual, seasonal and regional variation (more birds occurred in the west) in overall seabird density, and a positive correlation to zooplankton abundance (Table 5, Figure 4). There was both seasonal and regional variation in seabird diversity (more diversity in the east, but in this case diversity was not related to either zooplankton abundance or diversity).

Bulk Plankton-Seabird Species Associations

Somewhat surprisingly there was no annual variation found for any seabird species (Table 5). We found seasonal variation for Black-legged Kittiwake, Fork-tailed Storm-Petrel, Horned Puffin, Laysan Albatross, Least Auklet, Leach's Storm-Petrel, and Tufted Puffin (Table 5). A regional effect was found for Black-footed Albatross (more abundant in the east), Black-legged Kittiwake (west), Fork-tailed Storm-Petrel (west), Laysan Albatross (west), Least Auklet (west), Northern Fulmars (west), Slaty-backed Gull (west), Sooty Shearwaters (east), and Short-tailed Shearwaters (west). With the exception of the Least Auklet, none of the alcid species had clear regional association. Crested Auklet was clearly more abundant in the west, but with large variance in density, this difference was insignificant. Least Auklet, Leach's Storm-Petrel and Northern Fulmar were positively associated with NPP (Figure 4). Zooplankton diversity was negatively correlated with Cassin's Auklet (Table 5, not illustrated). Zooplankton abundance was positively associated with Black-footed Albatross, Cassin's Auklet, Parakeet Auklet, and Short-tailed Shearwater (Figure 5). Fork-tailed Storm-Petrel was positively related to zooplankton biomass (not illustrated).

Species-Specific Seabird-Plankton Associations

Using forward stepwise regression, we found no obvious phylogenetic/foraging behavior associations between individual seabird species and variation in zooplankton abundance stratified by season (Table 6). In summary, 28% of the 60 models developed failed completely, meaning that we found no variation in species-specific seabird density estimates between regions and no associations with plankton. Approximately 57% of the 60 models we developed were successful in establishing associations between seabirds and plankton. For 15% of the models, we found regional variation, but not relationships with plankton. Most of the associations were positive, but some were negative indicating low or no seabirds in areas with moderate to high plankton abundances. Interestingly, non-alcid species were correlated with more zooplankton species than alcids in the winter and summer, though alcids were correlated with many more during the fall season. Across all seasons, seabirds had relationships (both positive and negative)

with Euphausiacea most often (9 correlations), followed by *Acartia sp.* (7 correlations), and then *Eucalanus sp.*, *Calanus sp.*, and *Pseudocalanus sp.* (6 correlations for each).

Results varied by season, sometimes dramatically. Across all seasons, Tufted Puffin did not correlate with any zooplankton species, though all other seabirds did in at least one season.

In the winter season, 60% of the models were successful, though only 45% (11/20) showed relationships with zooplankton. Most of the failed models were for alcids, and the alcids also accounted for approximately 50% of the models for seabird species that lacked associations with zooplankton. Half of the correlations with Euphausiacea were negative.

In the summer, 25% of the models failed. Most of the species with failed models, or those that lacked relationships with zooplankton were alcids. A total of 65% of species showed a relationship with one or more zooplankton species. The five negative relationships that were found were only with two zooplankton groups, *Calanus sp.* and Euphausiacea. Northern Fulmars and Rhinoceros Auklets were negatively correlated with both of those groups.

In the fall, models failed for 20% of the seabird species, and 60% of the models developed incorporated relationships with zooplankton. Both Horned Puffin and Parakeet Auklet correlated with Larvacea, negatively. Those correlations accounted for half of all of the negative relationships that were found in this season.

Discussion

Herein, we have investigated the basin-scale (macro-) ecology of Pacific sub-arctic ecosystems using continuous plankton and seabird records from a 7,500 km trans-Pacific survey conducted 16 times over 6 years. Based on previous research which suggested: (1) differential responses of seabird species to North Pacific climate variability (Sydeman et al. 2006a), and (2) seasonal and geographic variation in plankton and seabird community structures, we developed and tested a hypothesis that surface/near surface-feeding seabirds (represented by Procellariformes and Laridae) and diving seabirds (Alcidae) would vary in their relationships to primary productivity and mesozooplankton (e.g., copepod, euphausiid) abundance, biomass, and diversity. To test this hypothesis, we developed statistical models including season, year, and geographic region to examine associations between the distribution and abundance of 20 common seabird species (those with sufficient data for this kind of modeling) to net primary productivity (NPP) and 12 zooplankton taxonomic groups (mainly at the genus level). To our knowledge, this is the first integrative study of plankton-seabird associations conducted at this scale (100s to 1000s of km). Therefore, fundamental information pertaining to ecosystem structure of the subarctic North Pacific Ocean may be derived from this study.

Spatial Variability

Temporal and spatial variability of plankton and seabirds in this study was high. As first described Wahl et al. (1989), later confirmed by Springer et al. (1999), and corroborated by Sydeman et al. (2006a) for this dataset, we found that seabird densities in the western North Pacific were considerably greater than in the eastern North Pacific. We have built upon this broad bio-geographic pattern in showing that overall seabird density is related to overall zooplankton abundance in these regions. We also investigated patterns of biodiversity, and

showed greater seabird diversity, measured using Shannon H', in the eastern North Pacific, but we were unable to relate this to any bulk zooplankton characteristics (abundance, biomass or diversity).

We found that key species (9/20) of the North Pacific avifaunal community showed regional variability, and most had associations with bulk plankton characteristics: Least Auklet (west), Leach's Storm Petrel (east, but marginally significant), and Northern Fulmar (west), were related to NPP; Black-footed Albatross (east), Cassin's Auklet and Parakeet Auklet (no regional patterns), and Short-tailed Shearwater (west) were associated with areas of greater mesozooplankon abundance; and, Fork-tailed Storm Petrel (west) was associated with higher zooplankton biomass. Black-legged Kittiwake, Laysan Albatross, and Slaty-backed Gull showed greater densities in the west, but no associations with plankton. Both divers and surface foragers showed bulk plankton associations, though there were more regional affiliations for the surface-foraging seabird group represented by procellariformes (90%) and larids (2/2) versus alcids (30%), including 3 species (Leach's Storm-Petrel, Thick-billed Murre, and Tufted Puffin) with marginally significant results (i.e., $p<0.07$). This may be because the alcids are widely distributed in coastal habitats in both the west and east and along the Aleutian shelf. Most of the alcids are also locally breeding species, whereas the procellarids are migrants "wintering" in the North Pacific during the austral winter.

In reference to these results in general, Taniguchi (1999; our Figure 6) showed greater nutrient and chlorophyll-a concentrations and mesozooplankton biomass in the western Subarctic Gyre over the Gulf of Alaska, but these differences are not as substantial as the regional variation in seabird density. Seabird density in the west was upwards of 3.5 times greater than in the east, whereas nitrate, chlorophyll in mg C m^{-3}, and mesozooplankton in mg C m^{-3} were 1.5, 1.1, and 1.1 times greater in the western subarctic gyre than Gulf of Alaska, respectively. Sugimoto and Tadakoro (1997) and Mackas and Tsuda (1999) provide similar results. Therefore, it seems reasonable to suggest that the greater seabird abundance in the west is related to greater ocean productivity in that region, though additional data, particularly on micronekton (forage fishes and squids) is needed to test this hypothesis directly.

Cassin's Auklet was also negatively related to zooplankton diversity, the only species to show such a relationship. We attribute this finding to the fact that the zooplankton community may in fact be less productive, and/or contain smaller, lipid-poor species, when diversity is higher. Cassin's Auklet may also be more specific with respect to the type of mesozooplankton found in its habitats. Hooff and Peterson (2006) demonstrate this for the central Oregon portion of California Current. When waters are warmer, smaller, lipid-poor, sub-tropical copepod species dominate the mesozooplankton community, with consequences to upper trophic levels. Salmon survival is compromised in this region when the copepod community is comprised mostly of subtropical species (Peterson and Schwing 2003). Cassin's Auklet is found predominantly in our study area in the B.C. slope and Aleutian shelf regions, with the latter not included in our analyses. Mackas et al. (2007) have shown that copepod diversity and energy transfer to the upper trophic levels are inversely related for the B.C. shelf/slope area. Thus, we surmise that the auklets are more dispersed at sea and show lower densities when there are more warm-water copepods in the region.

Temporal Variability

In addition to the regional variation just described, seasonal variation was substantial, so substantial in fact that we decided to stratify all species-specific analyses between plankton and seabirds by season. Indeed, associations between seabirds and mesozooplankton abundance and seabirds and region were dependent on season, with no species showing consistency in regional affiliations or zooplankton associations across all seasons (Table 6). This is perplexing; despite the migratory and/or transitory nature of most of the seabird species in the subarctic Pacific, it is odd that none of them would demonstrate consistent associations with mesozooplankton groups, and that there regional affiliations would hold up over all seasons. This level of variability is seemingly remarkable. Furthermore, variability and specificity among the relationships between birds and zooplankton did not fall into any general characterizations, including the diving-surface foraging dimension that we thought would be important. We therefore reject this hypothesis, and conclude that there are no consistent plankton-seabird associations by foraging mode (or phylogeny).

The results of this study can best be described on a species-species basis, making them very particular. One of the positive aspects of this approach, however, is that for the most part, the regression models developed held reasonable explanatory power with coefficients of determination ranging from 8% to 99%, with many models (17 of the 43 "successful" models – 17 failed to produce any results) with r^2>=.30. We failed to produce models for at least 2 seasons for Crested Auklet, Horned Puffin, Slaty-backed Gull, and Tufted Puffin.

From the plankton perspective, 9 of the models included euphausiids, 7 included *Acartia sp.*, and 6 included *Eucalanus, Calanus*, and *Pseudocalanus/Paracalanus* spp., 4 included *Limacina helicina*, Chaetognatha, and Larvacea. Five of the euphausiid associations were negative, 4 with species known to consume euphausiids (Cassin's Auklet, Common Murre, Rhinoceros Auklet and Northern Fulmar – the last species was Mottled Petrel).

Subarctic Pacific Seabird-Plankton Associations as Ecosystem Indicators

Seabirds can be excellent sentinels and indicators of coupled climate-marine ecosystem change (Bertram et al. 2001, Piatt et al. 2007) in part because they may amplify variation in physical oceanographic attributes or biological productivity at lower trophic levels (Taylor et al. 2002). The relative abundance of seabirds at sea is thought to reflect water mass and prey base characteristics (Cairns 1987, Briggs et al. 1987, Hyrenbach and Veit 2003, Hedd et al. 2006, Piatt et al. 2007, Sydeman et al. 2001, 2006a,b, 2009). Mesozooplankton have also been put forth as reliable indicators of ecosystem change (Beaugrand et al. 2002, 2005, McGowan et al. 1996, Hooff and Peterson 2006, Lavaniegos and Ohman 2007, Mackas et al. 2007, Richardson 2008). Plankton are: (1) ectothermic, making their physiology and metabolic rates sensitive to changes in ocean temperature and ocean chemistry, (2) lower in the trophic chain, suggesting a more direct connection with the physical environment, and (3) passive drifters in the ocean realm, such that changes in distribution must reflect changes in currents and/or water mass distributions. On the other hand, seabirds are endothermic, higher in trophic level, and move rapidly from place to place in search of favorable prey fields.

The CPR-MBM survey has revealed changes in plankton and seabird abundance, diversity and community structure in the subarctic Pacific. Such changes are related to changes in underlying

physical oceanography and to the bulk and species-specific associations described here. Some seabirds consume some of the larger mesozooplankton (*Neocalanus sp.*, euphausiids) we studied directly, but many species undoubtedly feed on mid trophic level micronekton, specifically gonatid squids and lanternfish (myctophids), not sampled by the CPR -- or any other ecosystem monitoring program in the region. Therefore, by investigating the combined distributions of mesozooplankton and seabirds in the subarctic open ocean of the North Pacific, we may learn more about the relative abundance and distribution of critically important mid trophic level food items. Micronekton are important to other top predators, such as salmonids, in these ecosystems (Kaeriyama et al. 2004), and it has been well-established that myctophids in the region directly consume many of the mesozooplankton sampled by the CPR (Beamish et al. 1999). Therefore, continuation of the CPR-MBM program for the foreseeable future is essential to provide new insights into vast expanses of the North Pacific that are difficult to sample using traditional methods.

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Table 1. Dates of East-West Pacific Continuous Plankton Recorder (CPR) Marine Bird and Mammal (MBM) surveys, 2002-2007.

Year	Spring	Summer	Fall
2002	--	6/1 -6/14	10/5 – 10/20
2003	4/1 – 4/19	5/31 – 6/10	9/28 – 10/14
2004	4/2 – 4/16	6/1 – 6/15	10/2 – 10/18
2005	4/4 – 4/17	5/28 – 6/11	9/16 – 9/29
2006	5/3 – 5/18	7/7 – 7/23	9/19 - 10/4
2007	3/26 – 4/10	5/28 - 6/11	

Table 2. Mean (standard deviation) for plankton parameters (no. sample^{-1}) by MME.

MME	1	2	3	4	5	6
Zooplankton Biomass	217.751(437.033)	188.077(297.827)	62.950(54.599)	90.025(90.733)	125.018(174.859)	71.735(140.635)
Zooplankton Diversity (H')	1.595(0.276)	1.423(0.401)	1.424(0.405)	1.180(0.569)	1.330(0.610)	1.372(0.472)
Acartia sp.	661.500(1786.928)	90.462(101.699)	17.818(63.341)	63.000(146.910)	291.118(489.531)	33.091(76.838)
Calanus sp.	202.333(290.602)	40.923(79.528)	130.636(270.712)	132.143(233.244)	68.941(97.874)	102.935(260.908)
Chaetognatha	14.667(21.798)	2.846(4.543)	23.318(53.150)	18.143(25.349)	20.647(79.243)	23.831(40.029)
Copepod nauplii	40.833(58.477)	79.154(110.546)	106.909(161.906)	133.000(265.220)	34.588(84.453)	134.909(215.816)
Eucalanus sp.	0.250(0.622)	3.308(6.921)	1.682(3.884)	3.286(5.810)	2.471(3.693)	7.532(23.081)
Euphausiacea	36.417(66.611)	4.077(7.399)	9.273(32.192)	9.714(21.168)	37.118(87.833)	7.961(26.364)
Harpacticoida	16.333(38.146)	37.692(109.848)	2.227(10.447)	0.000(0.000)	0.000(0.000)	0.636(5.584)
Hyperiidea	5.333(8.195)	3.385(2.987)	3.227(7.795)	5.143(7.305)	11.235(26.848)	8.818(14.347)
Larvacea	20.417(44.116)	120.615(333.905)	57.909(115.794)	14.000(29.951)	8.647(19.255)	17.182(56.075)
Limacina helicina	4.083(14.145)	41.462(39.231)	24.500(56.073)	38.500(79.659)	51.882(70.308)	25.455(58.741)
Metridia sp.	2.250(4.845)	0.691(1.653)	14.500(26.329)	3.071(43.938)	7.647(15.240)	7.818(18.985)
Neocalanus sp.	156.667(361.667)	226.923(330.977)	77.955(107.863)	103.429(183.074)	76.647(97.004)	90.519(199.247)
Oithona sp.	142.917(266.309)	147.000(209.805)	222.727(456.097)	413.000(886.535)	72.059(112.430)	214.455(283.389)
Paracalanus/Pseudocalanus sp.	294.000(357.642)	124.385(129.047)	109.136(101.363)	119.000(156.982)	250.765(469.635)	164.182(194.668)
Pseudocalanus Adults	212.333(288.252)	67.846(106.865)	66.818(109.615)	45.500(106.080)	314.176(511.592)	85.909(158.610)

Table 3. Mean (standard deviation) for bird parameters (no. km^{-2}) by MME.

MME	1	2	3	4	5	6
Bird Density	12.701(15.377)	4.058(4.965)	2.883(2.599)	8.255(7.485)	819.479(1902.693)	54.446(143.030)
Bird Diversity (H')	1.360(0.416)	1.160(0.457)	1.514(0.342)	1.682(0.327)	1.024(0.534)	1.227(0.458)
Ancient Murrelet	0.046(0.074)	0.185(0.519)	0.050(0.213)	0.115(0.266)	1.065(2.125)	0.083(0.245)
Black-footed Albatross	0.227(0.273)	0.099(0.229)	0.014(0.015)	0.041(0.050)	0.113(0.281)	0.011(0.037)
Black-legged Kittiwake	1.168(2.232)	0.192(0.531)	0.168(0.524)	0.680(1.237)	28.234(100.211)	1.270(2.010)
Cassin's Auklet	4.148(12.603)	0.238(0.641)	0.031(0.129)	0.024(0.045)	0.136(0.479)	0.000(0.003)
Common Murre	0.331(1.048)	0.000(0.000)	0.001(0.003)	0.004(0.011)	0.770(1.761)	0.006(0.014)
Crested Auklet	0.000(0.000)	0.000(0.000)	0.000(0.000)	1.850(5.570)	1.706(6.599)	14.637(87.906)
Fork-tailed Storm-Petrel	0.439(0.503)	0.205(0.230)	0.291(0.395)	0.697(0.760)	8.934(28.906)	2.167(3.981)
Horned Puffin	0.000(0.000)	0.004(0.008)	0.041(0.069)	0.141(0.279)	0.088(0.125)	0.035(0.094)
Laysan Albatross	0.002(0.006)	0.005(0.010)	0.022(0.032)	0.119(0.180)	0.102(0.103)	0.560(0.947)
Leach's Storm-Petrel	2.550(2.999)	1.721(2.912)	0.269(0.441)	0.843(1.209)	0.348(0.789)	0.587(1.659)
Least Auklet	0.000(0.000)	0.000(0.000)	0.000(0.000)	0.014(0.034)	0.055(0.127)	0.303(1.106)
Mottled Petrel	0.000(0.000)	0.004(0.013)	0.187(0.221)	0.141(0.152)	0.139(0.502)	0.660(2.295)
Northern Fulmar	0.276(0.267)	0.550(1.661)	0.308(0.575)	1.215(1.725)	11.821(17.843)	5.685(7.465)
Parakeet Auklet	0.004(0.007)	0.016(0.032)	0.035(0.133)	0.355(0.133)	0.445(0.962)	0.016(0.038)
Rhinoceros Auklet	0.389(0.869)	0.021(0.034)	0.000(0.000)	0.000(0.000)	0.003(0.009)	0.201(1.507)
Short-tailed Shearwater	0.005(0.009)	0.000(0.000)	0.003(0.006)	0.013(0.025)	722.151(1863.654)	26.288(108.246)
Slaty-backed Gull	0.000(0.000)	0.000(0.000)	0.000(0.000)	0.000(0.000)	0.001(0.004)	0.164(0.488)
Sooty Shearwater	1.801(2.039)	0.444(1.449)	0.558(1.412)	0.506(1.052)	0.353(1.126)	0.111(0.436)
Thick-billed Murre	0.057(0.189)	0.001(0.005)	0.020(0.080)	0.218(0.417)	2.344(4.587)	0.175(0.435)
Tufted Puffin	0.029(0.049)	0.213(0.621)	0.473(0.781)	0.846(0.895)	2.371(2.838)	0.810(1.451)

Table 4. Results of ANCOVA. Dependent variables were plankton parameters (listed below), and independent variables were season, region, year, and net primary productivity. Net primary productivity was treated as a continuous variable.

	Model			Net Primary Productivity	
Species	Model, Residual df	F (p>F)	r^2	F (p>F)	Coefficient Sign
Zooplankton Abundance	9, 127	3.78(0.003)	0.2113	16.67(0.0001)	+
Zooplankton Biomass	9, 127	2.32(0.0186)	0.1414	1.07(0.3030)	
Zooplankton Diversity	9, 127	1.74(0.0867)	0.1097	7.69(0.0064)	+

Table 5. Results of ANCOVA. Dependent variables were bird species densities and other parameters (listed below). Independent variables were season, region, year, net primary productivity, zooplankton diversity, zooplankton abundance, and zooplankton biomass. Net primary productivity, zooplankton diversity, zooplankton abundance, and zooplankton biomass were treated as continuous variables.

	Model	df= 12, 124	Season	Year	Region	
Species	F (p>F)	r^2	F (p>F)	F (p>F)	F (p>F)	dominant region
Bird Density	**3.15(0.0006)**	0.2338	**4.61(0.0117)**	**2.31(0.0482)**	**7.90(0.0057)**	West
Bird Diversity	**2.65(0.0034)**	0.2041	**6.87(0.0015)**	0.50(0.7762)	**9.57(0.0024)**	East
Ancient Murrelet	0.97(0.4824)	0.0857	1.59(0.2073)	0.81(0.5463)	0.00(0.9797)	
Black-footed Albatross	**2.71(0.0028)**	0.2076	0.68(0.5100)	1.26(0.2847)	**9.80(0.0022)**	East
Black-legged Kittiwake	**3.47(0.0002)**	0.2515	**11.71(<0.0001)**	2.03(0.0784)	**6.96(0.0094)**	West
Cassin's Auklet	**7.11(<0.0001)**	0.4076	1.21(0.3003)	1.13(0.3499)	1.12(0.2916)	
Common Murre	1.00(0.4555)	0.0880	1.23(0.2966)	1.31(0.2621)	1.93(0.1670)	
Crested Auklet	0.73(0.7239)	0.0656	1.27(0.2853)	0.79(0.5591)	1.32(0.2522)	
Fork-tailed Storm-Petrel	**3.75(0.0001)**	0.2665	**8.30(0.0004)**	0.26(0.9363)	**14.88(0.0002)**	West
Horned Puffin	**1.53(0.0037)**	0.1287	**5.87(0.0037)**	1.07(0.3821)	1.05(0.3077)	
Laysan Albatross	**3.49(0.0002)**	0.2526	**4.10(0.0188)**	1.82(0.1136)	**19.02(<0.0001)**	West
Least Auklet	**4.34(<0.0001)**	0.2959	**10.45(0.0001)**	0.58(0.7136)	**9.59(0.0024)**	West
Leach's Storm-Petrel	**2.39(0.0081)**	0.1881	**4.15(0.0180)**	0.38(0.8617)	3.38(0.0683)	
Mottled Petrel	0.89(0.5574)	0.0794	1.60(0.2067)	0.59(0.7048)	2.70(0.1032)	
Northern Fulmar	**3.60(0.0001)**	0.2583	1.52(0.2219)	0.62(0.6852)	**26.38(<0.0001)**	West
Parakeet Auklet	1.74(0.0667)	0.1439	1.64(0.1990)	0.73(0.6050)	2.49(0.1170)	
Rhinoceros Auklet	0.94(0.5095)	0.0834	1.06(0.3492)	0.63(0.6763)	0.41(0.5247)	
Slaty-backed Gull	1.81(0.0531)	0.1491	0.75(0.4754)	1.99(0.0846)	**7.02(0.0091)**	West
Sooty Shearwater	**2.59(0.0042)**	0.2003	1.83(0.1652)	1.44(0.2142)	**14.38(0.0002)**	East
Short-tailed Shearwater	**2.30(0.0112)**	0.1818	2.80(0.0648)	1.26(0.2846)	**4.31(0.0398)**	West
Thick-billed Murre	**2.47(0.0062)**	0.1931	2.30(0.1046)	1.99(0.0850)	3.38(0.0683)	
Tufted Puffin	1.53(0.1221)	0.1289	**3.16(0.0459)**	1.88(0.1030)	3.50(0.0639)	

Table 5 continued

Species	Net Primary Productivity		Zooplankton Diversity		Zooplankton Abundance		Zooplankton Biomass	
	F (p>F)	Coefficient Sign	F (p>F)	Coefficient Sign	F (p>F)	Coefficient Sign	F (p>F)	Coefficient Sign
Bird Density	0.31(0.5812)		1.14(0.2880)		**8.52(0.0042)**	+	3.00(0.0857)	
Bird Diversity	0.02(0.8843)		0.74(0.3899)		0.90(0.3448)		0.39(0.5352)	
Ancient Murrelet	1.35(0.2472)		0.13(0.7202)		1.46(0.2294)		0.55(0.4616)	
Black-footed Albatross	3.83(0.0526)		0.00(0.9902)		**5.94(0.0162)**	+	3.62(0.0596)	
Black-legged Kittiwake	1.15(0.2866)		0.62(0.4325)		1.02(0.3149)		0.01(0.9279)	
Cassin's Auklet	0.86(0.3554)		**10.11(0.0019)**	-	**59.50(<0.0001)**	+	3.12(0.0798)	
Common Murre	1.20(0.2761)		0.63(0.4300)		2.37(0.1265)		0.00(0.9482)	
Crested Auklet	0.04(0.8383)		1.01(0.3174)		0.02(0.9021)		0.33(0.5648)	
Fork-tailed Storm-Petrel	0.13(0.7195)		0.07(0.7873)		0.73(0.3947)		**5.51(0.0205)**	+
Horned Puffin	1.40(0.2391)		0.83(0.3640)		0.34(0.5628)		0.27(0.6013)	
Laysan Albatross	0.01(0.9269)		0.21(0.6456)		0.43(0.5118)		1.12(0.2930)	
Least Auklet	**21.55(<0.0001)**	+	0.69(0.4094)		0.74(0.3901)		0.00(0.9848)	
Leach's Storm-Petrel	**5.38(0.0220)**	+	0.08(0.7729)		0.18(0.6731)		0.12(0.7246)	
Mottled Petrel	2.15(0.1452)		0.00(0.9991)		0.11(0.7413)		0.31(0.5803	
Northern Fulmar	**4.86(0.0293)**	+	0.00(0.9872)		0.02(0.8971)		3.71(0.0565)	
Parakeet Auklet	0.95(0.3317)		0.88(0.3495)		**10.52(0.0015)**	+	0.28(0.5953)	
Rhinoceros Auklet	1.92(0.1686)		0.07(0.7967)		0.84(0.3613)		1.78(0.1851)	
Slaty-backed Gull	0.13(0.7201)		0.44(0.5069)		0.14(0.7114)		0.83(0.3647)	
Sooty Shearwater	3.06(0.0828)		0.17(0.6846)		0.06(0.8036)		1.87(0.1740)	
Short-tailed Shearwater	0.75(0.3894)		0.43(0.5133)		**12.05(0.0007)**	+	2.26(0.1356)	
Thick-billed Murre	0.09(0.7667)		3.16(0.0779)		0.03(0.8720)		0.48(0.4882)	
Tufted Puffin	0.60(0.4414)		0.90(0.3452)		0.28(0.5998)		0.86(0.3549)	

Table 6. Results of forward stepwise regression ($p<.05$) of bird species densities, by season. Independent factors were region and zooplankton species densities. For Season, 1=spring (March-May), 2=summer (June-July), and 3=fall (September-October).

		Model			Factor		
Species/Factor	Season	F(df model, df residual)	p>f	r^2	t	p<|t|	Coefficient sign
Ancient Murrelet	1	6.58(1.44)	0.0138	0.1300			
Euphausiacea					2.56	0.014	+
	2	0.00(0, 51)	.	.			
	3	6.47(1, 38)	0.0151	0.1455			
Eucalanus sp.					2.54	0.015	+
Black-footed Albatross	1	7.18(1, 44)	0.0103	0.1403			
Region					-2.68	0.010	-
	2	0.00(0, 51)	.	.			
	3	85.59(2, 37)	<0.0001	0.8223			
Pseudocalanus Adults					3.41	0.002	+
Acartia sp.					10.79	0.000	+
Black-legged Kittiwake	1	0.00(0, 45)	.	.			
	2	26.95(4, 47)	<0.0001	0.6964			
Eucalanus sp.					2.55	0.014	+
Acartia sp.					3.35	0.002	+
Calanus sp.					3.57	0.001	+
Limacina helicina					5.88	0.000	+
	3	18.40(1, 38)	0.0001	0.3262			
Region					4.29	0.000	+
Cassin's Auklet	1	0.00(0, 45)	.	.			
	2	5.64(1, 50)	0.0215	0.1013			
Region					-2.37	0.021	-
	3	1338.66(3, 36)	<0.0001	0.9911			
Acartia sp.					51.89	0.000	+
Calanus sp.					-2.98	0.005	-
Euphausiacea					-2.58	0.014	-
Common Murre	1	5.55(2, 43)	0.0072	0.2050			
Euphausiacea					-2.40	0.021	-
Chaetognatha					3.32	0.002	+
	2	0.00(0, 51)	.	.			
	3	4.71(1, 38)	0.0363	0.1103			
Region					2.17	0.036	+
Crested Auklet	1	0.00(0, 45)	.	.			
	2	4.60(1, 50)	0.0369	0.0842			
Eucalanus sp.					2.14	0.037	+
	3	0.00(0, 39)	.	.			

Table 6 continued

		Model			Factor		
Species/Factor	Season	F(df model, df residual)	p>f	r^2	t	p<|t|	Coefficient sign
Fork-tailed Storm-Petrel	1	76.85(2, 43)	<0.0001	0.7814			
Euphausiacea					12.03	0.000	+
Oithona sp.					2.91	0.006	+
	2	13.46(2, 49)	<0.0001	0.3546			
Region					3.93	0.000	+
Metridia sp.					3.25	0.002	+
	3	0.00(0, 39)	.	.			
Horned Puffin	1	0.00(0, 45)	.	.			
	2	0.00(0, 51)	.	.			
	3	7.16(2, 37)	0.0024	0.2789			
Larvacea					-3.03	0.004	-
Limacina helicina					3.61	0.001	+
Laysan Albatross	1	6.39(2, 43)	0.0037	0.2291			
Region					2.45	0.019	+
Neocalanus sp.					2.77	0.008	+
	2	8.92(4, 47)	<0.0001	0.4315			
Region					2.94	0.005	+
Pseudocalanus sp.					3.61	0.001	+
Calanus sp.					-2.71	0.009	-
Chaetognatha					3.05	0.004	+
	3	9.82(1, 38)	0.0033	0.2054			
Region					3.13	0.003	+
Least Auklet	1	48.60(2, 43)	<0.0001	0.6933			
Region					2.80	0.008	+
Euphausiacea					9.18	0.000	+
	2	14.97(2, 49)	<0.0001	0.3792			
Region					2.28	0.027	+
Euphausiacea					4.96	0.000	+
	3	23.08(1, 38)	<0.0001	0.3779			
Metridia sp.					4.80	0.000	+
Leach's Storm-Petrel	1	14.31(2, 43)	<0.0001	0.3997			
Neocalanus sp.					5.28	0.000	+
Acartia sp.					-2.40	0.021	-
	2	6.50(1, 50)	0.0139	0.1150			
Larvacea					2.55	0.014	+
	3	10.04(3, 36)	0.0001	0.4556			
Region					-2.77	0.0090	-
Acartia sp.					3.46	0.001	+
Eucalanus sp.					2.98	0.005	+

Table 6 continued

		Model			Factor		
Species/Factor	Season	F(df model, df residual)	p>f	r^2	t	p<|t|	Coefficient sign
Mottled Petrel	1	6.16(2, 43)	0.0045	0.2226			
Limacina helicina					3.48	0.001	+
Euphausiacea					-2.41	0.020	-
	2	11.28(1, 50)	0.0015	0.1841			
Eucalanus sp.					3.36	0.002	+
	3	5.91(1, 38)	0.0199	0.1345			
Metridia sp.					2.43	0.020	+
Northern Fulmar	1	11.38(1, 44)	0.0016	0.2056			
Region					3.37	0.002	+
	2	15.97(4, 47)	<0.0001	0.5761			
Region					4.48	0.000	+
Euphausiacea					-3.34	0.002	-
Calanus sp.					-3.53	0.001	-
Pseudocalanus Adults					6.35	0.000	+
	3	9.64(1, 38)	0.0036	0.2024			
Region					3.11	0.004	+
Parakeet Auklet	1	27.87(1, 44)	<0.0001	0.3878			
Oithona sp.					5.28	0.000	+
	2	0.00(0, 51)	.	.			
	3	6.75(3, 36)	0.0010	0.3601			
Larvacea					-2.87	0.007	-
Limacina helicina					3.26	0.002	+
Calanus sp.					2.62	0.013	+
Rhinoceros Auklet	1	0.00(0, 45)	.	.			
	2	17.12(3, 48)	<0.0001	0.5169			
Pseudocalanus Adults					7.16	0.000	+
Calanus sp.					-3.51	0.001	-
Euphausiacea					-2.52	0.015	-
	3	5.48(1, 38)	0.0246	0.1260			
Pseudocalanus Adults					2.34	0.025	+
Slaty-backed Gull	1	0.00(0, 45)	.	.			
	2	15.06(2, 49)	<0.0001	0.3807			
Eucalanus sp.					2.93	0.005	+
Acartia sp.					4.02	0.000	+
	3	0.00(0, 39)	.	.			

Table 6 continued

		Model			Factor		
Species/Factor	Season	F(df model, df residual)	p>f	r^2	t	p<|t|	Coefficient sign
Sooty Shearwater	1	4.60(1, 44)	0.0375	0.0946			
Region					-2.14	0.038	-
	2	10.56(2, 49)	0.0002	0.3011			
Region					-2.10	0.041	-
Larvacea					3.59	0.001	+
	3	106.98	<0.0001	0.7379			
Acartia sp.					10.34	0.000	+
Short-tailed Shearwater	1	0.00(0, 45)	.	.			
	2	41.20(1, 50)	<0.0001	0.4517			
Pseudocalanus Adults					6.42	0.000	+
	3	5.29(1, 38)	0.0271	0.1222			
Chaetognatha					2.30	0.027	+
Thick-billed Murre	1	4.53(1, 44)	0.0389	0.0934			
Hyperiidea					-2.13	0.039	-
	2	12.00(1, 50)	0.0011	0.1935			
Chaetognatha					3.46	0.001	+
	3	5.92(1, 38)	0.0197	0.1349			
Oithona sp.					2.43	0.020	+
Tufted Puffin	1	0.00(0, 45)	.	.			
	2	4.55(1, 50)	0.0378	0.0834			
Region					2.13	0.038	+
	3	0.00(0, 39)	.	.			

Figure 1. Pacific Continuous Plankton Recorder (CPR) study area (enclosed box) and daily survey tracks for seabirds and marine mammals in the North Pacific Ocean.

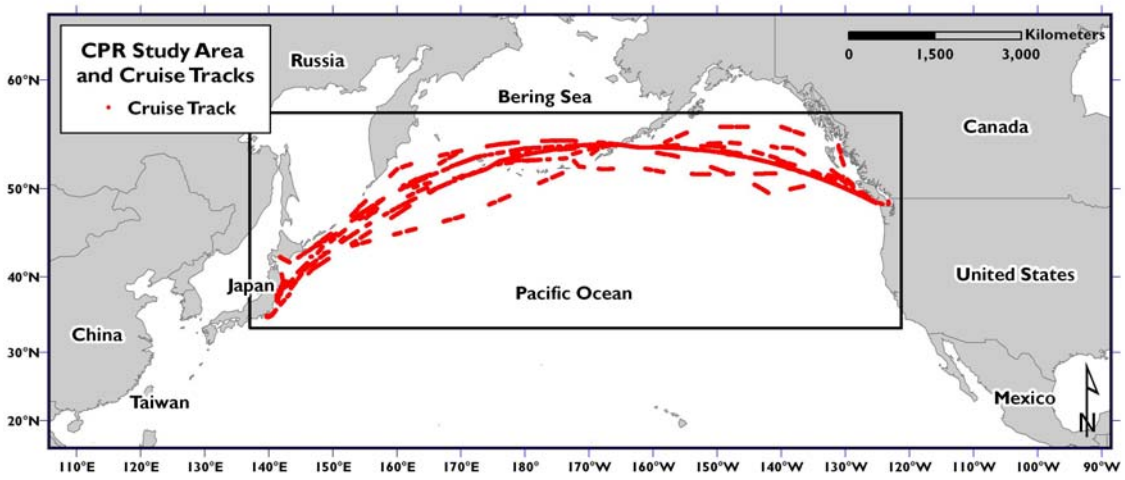
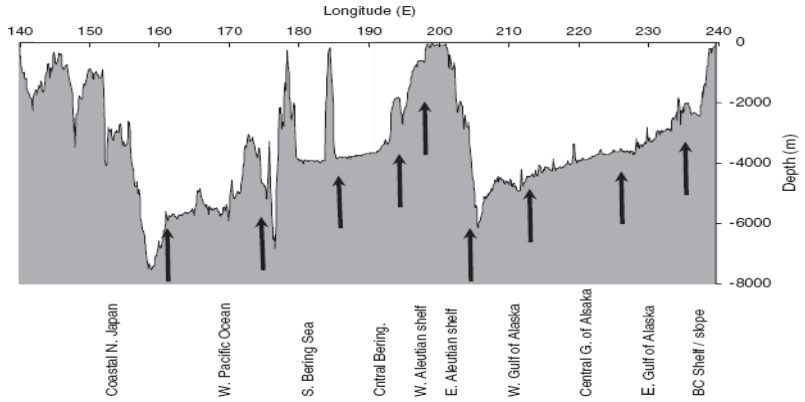


Figure 2. Meso-marine ecosystems of the North Pacific as defined by Batten et al. (2006), and their characteristics.

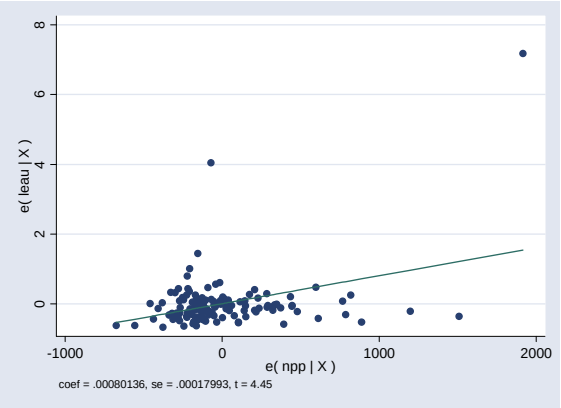


Characteristics of the meso-marine ecosystems of the North Pacific, showing the mean (±SD) of physical and biological characteristics

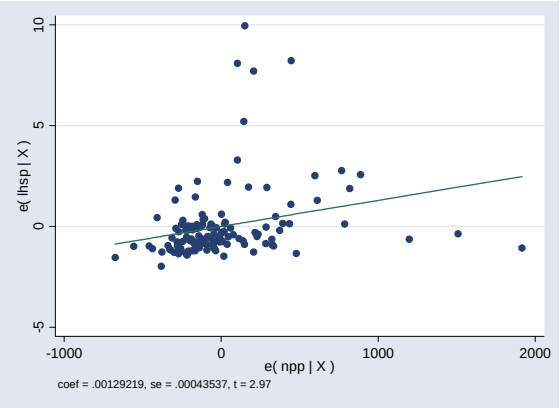
MME	Depth (m)	SST (°C, from logger at ~7 m)	Chl *a* (mg m^{-3}, from SeaWifs)	~Thermocline depth (m, from XBTs)	Mesozooplankton Biomass (mg dry weight sample^{-1})	Seabird density (# km^{-2})
BC shelf/slope	1550 (777)	10.18 (0.41)	1.62 (0.62)	10	88.92 (83.94)	4.06 (3.96)
Eastern GoA	3280 (525)	9.00 (0.46)	0.44 (0.36)	38	112.50 (63.75)	1.00 (1.06)
Central GoA	3911 (250)	8.49 (0.21)	0.30 (0.05)		39.31 (28.48)	6.34 (9.71)
Western GoA	4894 (379)	8.16 (0.25)	0.68 (0.51)	24	24.38 (39.10)	3.06 (1.32)
E. Aleutian shelf	69 (44)	7.45 (1.07)	1.42 (0.55)		71.14 (43.60)	323.40 (487.34)
W. Aleutian shelf	803 (419)	6.61 (0.41)	2.81 (2.02)		128.10 (94.54)	107.45 (156.64)
Aleutian Basin	3733 (61)	5.98 (0.28)	0.55 (0.08)	20	60.67 (33.53)	30.32 (51.88)
W. Bering Sea	3918 (43)	4.80 (0.22)	0.43 (0.08)		46.52 (21.13)	32.94 (31.00)
W. open Pacific	4686 (730)	4.79 (0.34)	0.34 (0.05)	40	3.22 (5.90)	6.70 (1.70)
Coastal N. Japan	1428 (1173)	4.76 (1.36)	5.17 (3.29)	<10	9.13 (6.93)	29.59 (72.94)

Figure 3. Added variable plots of seabird species densities as related to net primary productivity from regression models including season, region, year, zooplankton abundance, zooplankton biomass, and zooplankton diversity as independent variables. a) Least Auklet, b) Leach's Storm-Petrel, and c) Northern Fulmar.

a)



b)



c)

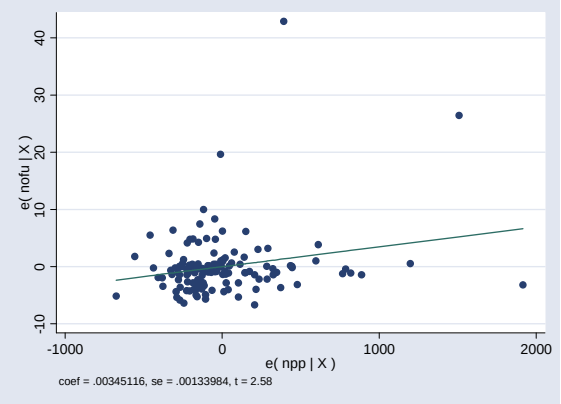


Figure 4. Added variable plot of overall bird density and total zooplankton abundance from a regression model including season, region, year, net primary productivity, zooplankton biomass, and zooplankton diversity as independent variables.

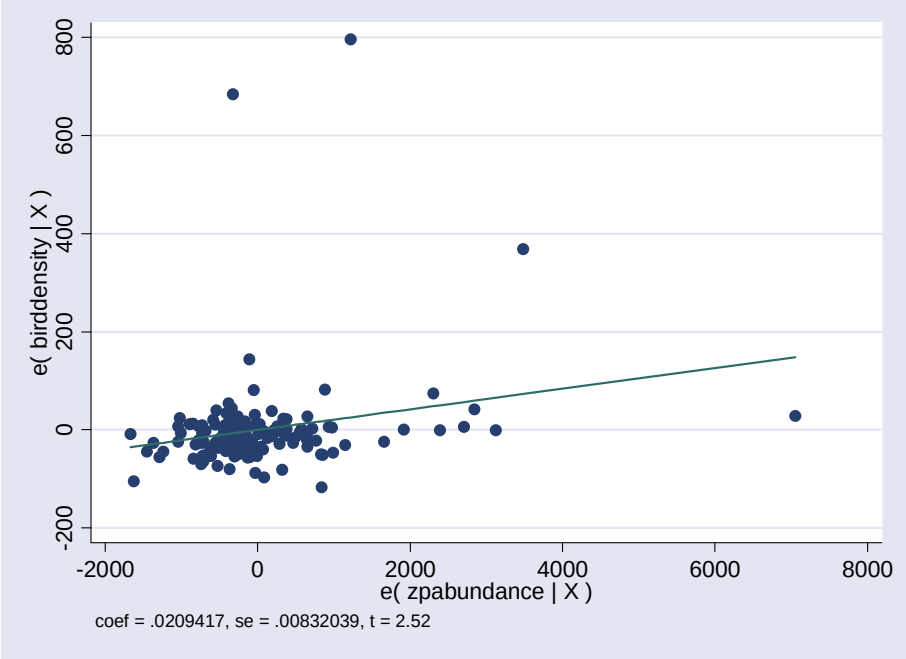
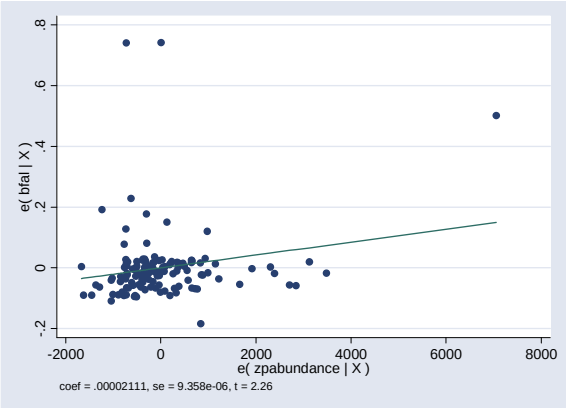
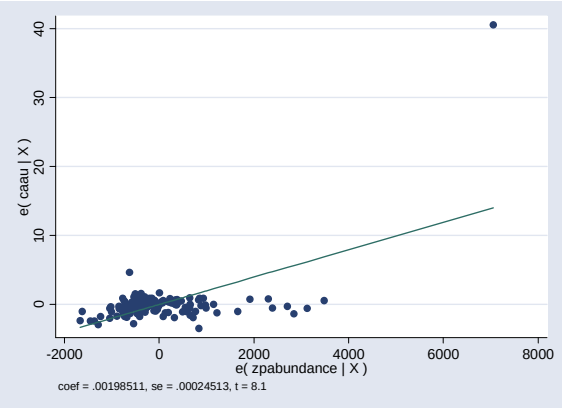


Figure 5. Added variable plots of seabird species densities as predicted by zooplankton abundance from a regression model also including season, region, year, net primary productivity, zooplankton biomass, and zooplankton diversity as independent variables. a) Black-footed Albatross, b) Cassin's Auklet, c) Parakeet Auklet, and d) Short-tailed Shearwater.

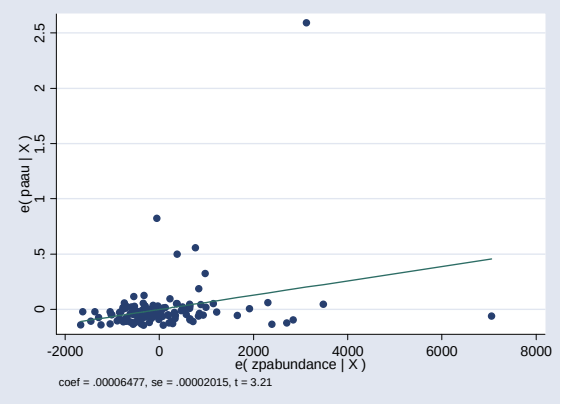
a)



b)



c)



d)

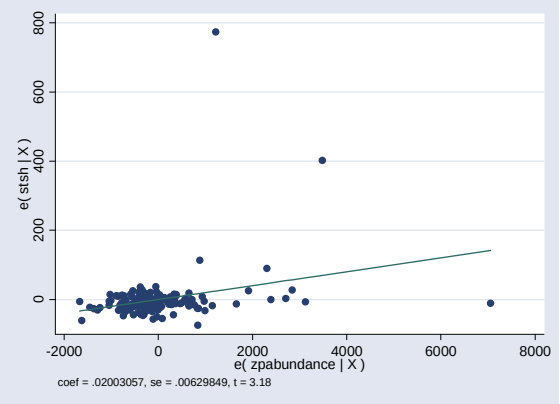


Figure 6. Table from Taniguchi (1999) showing variation in lower trophic level productivity in different subarctic North Pacific marine ecosystems.

Average stocks of nitrate, phytoplankton chlorophyll *a*, holomicrozooplankton and mesozooplankton in the surface layer of different water masses in the subarctic Pacific in summer

Water mass	Nitrate[a]		Chlorophyll[b]		Microzooplankton[c] (mg C m^{-3})		Mesozooplankton[d]		Reference
	(μM)	(mg C m^{-3})	(μg l^{-1})	(mg C m^{-3})	Ciliates	Total	(mg WW m^{-3})	(mg C m^{-3})	
Bering Basin	15	1193	0.9	45	2.4	8.4*	450	22.5	4, 8
South of Aleutians	13	1034	0.3	15	3.1	10.9*	200	10.0	4, 8
Gulf of Alaska	8	636	0.3	15	2.9	10.8	210**	10.5**	1, 2
Western Subarctic Gyre	12	954	0.5	25	2.4	8.7	190	9.5	4, 5, 7
Oyashio Region	2	159	0.5	25	0.4	1.1	340	17.0	3, 6, 8

Appendix 1. Plankton-plankton correlations for MME 1. N = 12 and $p < 0.05$ when critical value > 0.476.

a. general groups

	Chlorophyll-a	Zooplankton Biomass	Zooplankton Diversity
Net Primary Production	**0.677**	0.195	-0.412
Chlorophyll-a		0.226	-0.113
Zooplankton Biomass			-0.265

b. general vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida
Net Primary Production	0.345	-0.144	0.195	-0.114	**0.541**	0.363
Chlorophyll-a	0.023	-0.232	0.009	0.035	0.100	-0.081
Zooplankton Biomass	-0.064	-0.150	-0.109	-0.074	0.171	-0.172
Zooplankton Diversity	**-0.603**	-0.150	-0.353	**0.549**	-0.438	-0.463

	Hyperiidea	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Net Primary Production	0.045	-0.342	0.374	0.099	0.174	0.159	0.003
Chlorophyll-a	0.099	-0.377	0.077	0.118	0.311	-0.111	-0.019
Zooplankton Biomass	0.072	-0.231	0.023	**0.964**	**0.976**	-0.171	**0.480**
Zooplankton Diversity	0.094	0.373	0.031	-0.275	-0.242	-0.332	-0.465

c. species vs. species

	Calanus sp.	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida	Hyperiidea
Acartia sp.	-0.007	**0.531**	-0.158	**0.597**	**0.653**	-0.025
Calanus sp.		-0.161	-0.195	-0.058	-0.192	**0.756**
Chaetognatha			-0.262	**0.731**	0.221	-0.220
Eucalanus sp.				-0.218	-0.188	-0.143
Euphausiacea					0.288	-0.092
Harpacticoida						-0.190

	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus*
Acartia sp.	-0.165	-0.047	-0.127	-0.134	**0.881**	0.379
Calanus sp.	-0.295	-0.053	-0.112	-0.163	0.200	-0.134
Chaetognatha	-0.099	**0.510**	0.025	-0.245	0.337	0.182
Eucalanus sp.	-0.041	-0.127	-0.204	-0.029	-0.182	-0.120
Euphausiacea	-0.258	**0.745**	0.204	0.003	0.389	0.302
Harpacticoida	-0.216	-0.135	-0.217	-0.203	**0.523**	0.096
Hyperiidea	-0.329	-0.090	0.039	0.055	0.317	-0.052
Larvacea		-0.146	-0.172	-0.214	-0.011	-0.387
Limacina helicina			0.114	-0.132	-0.169	0.000
Metridia sp.				**0.919**	-0.241	0.401
Neocalanus sp.					-0.241	0.410
Oithona sp.						0.259

Appendix 2. Plankton-plankton correlations for MME 2. N =13 and $p < 0.05$ when critical value > 0.457.

a. general groups

	Chlorophyll-a	Zooplankton Biomass	Zooplankton Diversity
Net Primary Production	**0.796**	-0.395	-0.157
Chlorophyll-a		**-0.542**	-0.269
Zooplankton Biomass			0.131

b. general vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida
Net Primary Production	-0.395	-0.030	-0.380	-0.274	-0.263	0.357
Chlorophyll-a	**-0.482**	-0.338	-0.448	-0.055	-0.244	**0.527**
Zooplankton Biomass	0.203	0.249	**0.794**	-0.174	0.229	-0.206
Zooplankton Diversity	**0.622**	0.194	0.218	0.388	0.035	0.160

	Hyperiidea	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Net Primary Production	0.049	0.274	-0.049	0.317	-0.366	0.060	**-0.513**
Chlorophyll-a	-0.007	-0.038	-0.062	0.356	**-0.538**	0.049	-0.170
Zooplankton Biomass	0.453	-0.144	0.041	-0.235	**0.939**	-0.008	0.057
Zooplankton Diversity	0.158	-0.376	**0.614**	-0.116	0.179	0.318	**0.467**

c. species vs. species

	Calanus sp.	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida	Hyperiidea
Acartia sp.	0.456	-0.038	0.386	-0.081	-0.331	0.131
Calanus sp.		-0.114	-0.149	-0.184	-0.191	-0.302
Chaetognatha			0.041	**0.551**	-0.135	**0.606**
Eucalanus sp.				0.240	-0.135	-0.079
Euphausiacea					-0.124	0.425
Harpacticoida						-0.172

	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Acartia sp.	-0.224	0.235	-0.282	0.399	0.103	**0.459**
Calanus sp.	0.107	-0.245	0.007	**0.481**	0.002	-0.163
Chaetognatha	-0.210	0.130	-0.218	**0.605**	-0.227	0.091
Eucalanus sp.	-0.130	0.115	0.111	-0.201	-0.188	**0.553**
Euphausiacea	-0.130	0.129	0.098	0.043	-0.303	0.036
Harpacticoida	-0.112	0.071	-0.156	-0.255	**0.712**	0.009
Hyperiidea	-0.231	0.306	-0.143	0.356	-0.261	0.099
Larvacea		-0.322	0.021	-0.192	0.069	-0.317
Limacina helicina			0.339	-0.067	0.316	0.319
Metridia sp.				-0.285	-0.271	0.022
Neocalanus sp.					-0.011	0.082
Oithona sp.						0.103

Appendix 3. Plankton-plankton correlations for MME 3. N = 22 and $p < 0.05$ when critical value > 0.352.

a. general groups

	Chlorophyll-a	Zooplankton Biomass	Zooplankton Diversity
Net Primary Production	**0.483**	0.170	-0.282
Chlorophyll-a		-0.197	**-0.556**
Zooplankton Biomass			**0.423**

b. general vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida
Net Primary Production	0.092	0.341	-0.116	**-0.449**	0.190	-0.188
Chlorophyll-a	-0.152	0.084	-0.049	-0.108	-0.028	-0.103
Zooplankton Biomass	**0.443**	0.066	-0.088	0.173	**0.420**	0.031
Zooplankton Diversity	**0.442**	0.111	0.316	-0.073	**0.384**	**0.357**

	Hyperiidea	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Net Primary Production	0.130	-0.106	**0.369**	-0.261	0.046	-0.276	0.116
Chlorophyll-a	-0.189	-0.144	0.006	-0.169	-0.237	-0.148	0.030
Zooplankton Biomass	**0.512**	-0.054	0.226	0.200	**0.470**	0.297	0.333
Zooplankton Diversity	**0.398**	**0.383**	0.156	0.275	0.278	-0.003	0.217

c. species vs. species

	Calanus sp.	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida	Hyperiidea
Acartia sp.	-0.096	-0.106	-0.014	**0.961**	-0.063	**0.937**
Calanus sp.		-0.036	-0.159	-0.070	-0.027	-0.130
Chaetognatha			-0.159	-0.043	**0.562**	-0.103
Eucalanus sp.				-0.114	-0.097	-0.112
Euphausiacea					-0.064	**0.951**
Harpacticoida						-0.064

	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Acartia sp.	-0.132	-0.129	0.273	0.040	0.074	**0.377**
Calanus sp.	**0.474**	**0.809**	-0.228	-0.138	0.047	0.229
Chaetognatha	0.205	-0.062	-0.167	-0.110	-0.138	0.236
Eucalanus sp.	-0.154	-0.016	**0.485**	0.344	**0.869**	0.252
Euphausiacea	-0.148	-0.101	0.153	-0.081	0.026	**0.452**
Harpacticoida	**0.455**	-0.098	-0.123	0.060	-0.013	-0.025
Hyperiidea	-0.145	-0.147	0.138	-0.030	0.079	**0.422**
Larvacea		0.317	-0.174	-0.109	-0.003	-0.019
Limacina helicina			-0.159	-0.018	0.183	0.231
Metridia sp.				**0.543**	0.309	0.230
Neocalanus sp.					0.179	0.064
Oithona sp.						**0.443**

Appendix 4. Plankton-plankton correlations for MME 4. N = 14 and $p < 0.05$ when critical value > 0.441.

a. general groups

	Chlorophyll-a	Zooplankton Biomass	Zooplankton Diversity
Net Primary Production	**0.746**	-0.182	-0.197
Chlorophyll-a		-0.023	-0.150
Zooplankton Biomass			0.396

b. general vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Hyperiidea
Net Primary Production	0.097	0.218	-0.211	-0.250	-0.127	-0.105
Chlorophyll-a	0.052	0.106	-0.141	-0.261	-0.151	-0.245
Zooplankton Biomass	0.106	0.162	0.045	0.420	0.181	**0.499**
Zooplankton Diversity	**0.516**	**0.464**	**0.676**	0.135	0.341	0.364

	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Net Primary Production	0.399	-0.206	-0.165	-0.023	**0.486**	0.174
Chlorophyll-a	0.264	-0.112	-0.112	0.343	**0.486**	0.305
Zooplankton Biomass	-0.025	0.005	0.050	**0.731**	0.108	**0.488**
Zooplankton Diversity	0.216	**0.576**	**0.511**	0.181	0.082	0.424

c. species vs. species

	Calanus sp.	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Hyperiidea	Larvacea
Acartia sp.	**0.801**	**0.633**	-0.261	0.050	0.377	0.204
Calanus sp.		**0.509**	0.012	0.219	**0.496**	**0.650**
Chaetognatha			-0.049	**0.583**	**0.491**	0.052
Eucalanus sp.				-0.062	-0.043	0.235
Euphausiacea					**0.771**	0.001
Hyperiidea						-0.010

4c. continued

	Limacina helicina	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Acartia sp.	**0.661**	0.347	-0.079	0.083	0.371
Calanus sp.	0.345	**0.544**	-0.104	0.051	0.085
Chaetognatha	**0.550**	**0.818**	-0.264	-0.155	0.109
Eucalanus sp.	-0.058	0.168	0.287	-0.284	-0.313
Euphausiacea	0.018	**0.652**	-0.188	-0.190	-0.124
Hyperiidea	0.016	**0.548**	0.015	-0.084	0.093
Larvacea	0.066	0.273	-0.148	0.232	-0.028
Limacina helicina		0.060	-0.154	-0.096	0.344
Metridia sp.			-0.265	-0.217	-0.221
Neocalanus sp.				0.369	**0.476**
Oithona sp.					**0.680**

Appendix 5. Plankton-plankton correlations for MME 5. N = 17 and p < 0.05 when critical value > 0.4.

a. general groups

	Chlorophyll-a	Zooplankton Biomass	Zooplankton Diversity
Net Primary Production	**0.839**	0.274	**0.507**
Chlorophyll-a		0.083	0.380
Zooplankton Biomass			0.389

b. general vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Hyperiidea
Net Primary Production	**0.726**	0.386	-0.106	0.209	0.044	0.078
Chlorophyll-a	**0.662**	**0.521**	-0.153	0.239	-0.084	-0.118
Zooplankton Biomass	0.096	-0.077	0.027	0.063	0.286	0.157
Zooplankton Diversity	0.224	0.255	0.143	**0.475**	**0.469**	0.264

	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Net Primary Production	-0.113	0.056	-0.176	**0.469**	**0.479**	0.343
Chlorophyll-a	-0.163	0.103	-0.209	0.364	**0.604**	0.249
Zooplankton Biomass	-0.029	0.119	-0.049	**0.833**	0.100	-0.017
Zooplankton Diversity	0.380	**0.520**	0.274	0.374	**0.469**	0.200

c. species vs. species

	Calanus sp.	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Hyperiidea	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Acartia sp.	0.319	0.052	-0.169	-0.101	0.073	-0.252	0.218	-0.043	0.300	**0.462**	**0.574**
Calanus sp.		0.041	0.201	-0.011	0.060	-0.243	0.112	-0.084	0.044	**0.558**	0.056
Chaetognatha			-0.173	-0.057	**0.938**	-0.108	0.344	0.377	-0.198	-0.060	-0.145
Eucalanus sp.				0.332	-0.044	-0.018	0.219	-0.161	0.074	0.039	-0.199
Euphausiacea					-0.009	**0.539**	**0.542**	-0.069	0.352	0.212	-0.108
Hyperiidea						-0.170	0.282	0.293	-0.092	-0.116	-0.165
Larvacea							0.091	0.366	0.092	0.110	0.011
Limacina helicina								0.027	0.065	**0.504**	0.299
Metridia sp.									-0.268	0.012	0.144
Neocalanus sp.										0.198	0.014
Oithona sp.											**0.606**

Appendix 6. Plankton-plankton correlations for MME 6. N = 77 and $p < 0.05$ when critical value > 0.188.

a. general groups

	Chlorophyll-a	Zooplankton Biomass	Zooplankton Diversity
Net Primary Production	**0.841**	0.106	**0.369**
Chlorophyll-a		0.088	**0.305**
Zooplankton Biomass			0.150

b. general vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida
Net Primary Production	**0.356**	**0.403**	**0.199**	**0.234**	**0.251**	0.020
Chlorophyll-a	**0.369**	0.146	**0.204**	0.093	**0.353**	-0.015
Zooplankton Biomass	0.101	0.125	0.041	0.150	**0.790**	-0.047
Zooplankton Diversity	**0.242**	**0.325**	**0.415**	0.047	**0.282**	-0.021

	Hyperiidea	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus*
Net Primary Production	**0.189**	0.116	**0.208**	0.131	**0.194**	**0.234**	**0.473**
Chlorophyll-a	0.046	0.153	**0.258**	**0.197**	**0.331**	0.127	**0.367**
Zooplankton Biomass	**0.307**	0.110	0.137	-0.003	**0.753**	-0.039	0.128
Zooplankton Diversity	**0.229**	**0.324**	**0.477**	**0.413**	0.157	0.077	**0.398**

c. species vs. species

	Calanus sp.	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida	Hyperiidea
Acartia sp.	0.111	0.139	**0.268**	0.176	-0.050	0.010
Calanus sp.		0.060	-0.053	0.146	-0.046	-0.053
Chaetognatha			-0.096	0.112	-0.060	0.179
Eucalanus sp.				-0.036	-0.038	-0.033
Euphausiacea					-0.030	**0.224**
Harpacticoida						0.001

	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Acartia sp.	0.064	**0.252**	0.097	0.082	0.051	**0.325**
Calanus sp.	**0.564**	**0.402**	0.067	**0.276**	**0.195**	**0.273**
Chaetognatha	**0.262**	**0.274**	**0.350**	0.016	0.092	0.178
Eucalanus sp.	-0.068	0.031	-0.081	-0.036	0.090	0.156
Euphausiacea	0.150	**0.266**	0.044	**0.559**	-0.043	0.169
Harpacticoida	-0.035	-0.050	-0.048	-0.047	-0.027	-0.097
Hyperiidea	0.004	0.036	0.100	0.061	0.117	**0.229**
Larvacea		**0.681**	**0.367**	**0.227**	0.113	0.071
Limacina helicina			**0.471**	**0.206**	0.019	0.149
Metridia sp.				0.054	-0.018	0.184
Neocalanus sp.					-0.076	0.182
Oithona sp.						0.168

Appendix 7. Bird-bird correlations for MME 1. N = 12 and $p < 0.05$ when critical value > 0.476.

a. general groups

	Bird Diversity
Bird Density	-0.135

b. general vs. species

	Ancient Murrelet	Black-footed Albatross	Black-legged Kittiwake	Cassin's Auklet	Common Murre	Fork-tailed Storm-Petrel	Laysan Albatross
Bird Density	-0.007	**0.533**	0.101	**0.904**	0.229	0.396	-0.260
Bird Diversity	**0.630**	-0.073	0.392	-0.342	0.454	-0.155	0.374

	Leach's Storm-Petrel	Northern Fulmar	Parakeet Auklet	Rhinoceros Auklet	Sooty Shearwater	Short-tailed Shearwater	Thick-billed Murre	Tufted Puffin
Bird Density	0.366	**0.513**	0.351	0.285	**0.617**	0.227	0.248	-0.119
Bird Diversity	**-0.534**	0.233	-0.353	**0.485**	0.421	0.328	0.401	-0.007

c. species vs. species

	Black-footed Albatross	Black-legged Kittiwake	Cassin's Auklet	Common Murre	Fork-tailed Storm-Petrel	Laysan Albatross
Ancient Murrelet	-0.392	0.326	-0.213	**0.622**	-0.293	0.291
Black-footed Albatross		-0.246	**0.497**	-0.261	**0.731**	-0.293
Black-legged Kittiwake			-0.171	0.394	-0.276	-0.014
Cassin's Auklet				-0.107	0.261	-0.148
Common Murre					0.065	-0.100
Fork-tailed Storm-Petrel						-0.401

7c. continued

	Leach's Storm-Petrel	Northern Fulmar	Parakeet Auklet	Rhinoceros Auklet	Sooty Shearwater	Short-tailed Shearwater	Thick-billed Murre	Tufted Puffin
Ancient Murrelet	-0.375	-0.087	-0.377	**0.551**	0.361	0.440	**0.578**	-0.369
Black-footed Albatross	**0.706**	**0.779**	0.197	-0.183	0.157	-0.003	-0.259	**0.538**
Black-legged Kittiwake	**-0.485**	0.159	-0.244	0.334	**0.568**	0.001	0.377	-0.244
Cassin's Auklet	0.362	0.432	**0.506**	-0.032	0.281	0.295	-0.080	-0.107
Common Murre	-0.276	-0.139	-0.190	**0.965**	**0.709**	-0.116	**0.997**	-0.186
Fork-tailed Storm-Petrel	**0.771**	**0.530**	0.393	0.067	0.121	-0.183	0.082	**0.569**
Laysan Albatross	-0.381	0.014	-0.257	-0.176	-0.261	0.455	-0.141	-0.270
Leach's Storm-Petrel		0.321	0.142	-0.289	-0.108	-0.086	-0.257	0.314
Northern Fulmar			0.288	-0.135	0.197	0.281	-0.162	**0.525**
Parakeet Auklet				-0.140	-0.185	-0.041	-0.152	0.314
Rhinoceros Auklet					**0.784**	-0.161	**0.967**	-0.218
Sooty Shearwater						0.001	**0.709**	-0.325
Short-tailed Shearwater							-0.158	-0.208
Thick-billed Murre								-0.188

Appendix 8. Bird-bird correlations for MME 2. N = 13 and $p < 0.05$ when critical value > 0.457.

a. general groups

	Bird Diversity
Bird Density	-0.045

b. general vs. species

	Ancient Murrelet	Black-footed Albatross	Black-legged Kittiwake	Cassin's Auklet	Fork-tailed Storm-Petrel	Horned Puffin	Laysan Albatross
Bird Density	**0.630**	**0.600**	0.260	**0.547**	**0.558**	-0.190	0.351
Bird Diversity	0.274	0.371	**0.477**	0.239	-0.112	**0.546**	0.188

	Leach's Storm-Petrel	Mottled Petrel	Northern Fulmar	Parakeet Auklet	Rhinoceros Auklet	Sooty Shearwater	Thick-billed Murre	Tufted Puffin
Bird Density	**0.631**	-0.227	**0.561**	**0.659**	0.194	**0.524**	0.150	0.149
Bird Diversity	**-0.505**	0.416	0.329	0.390	0.405	-0.177	0.389	0.408

c. species vs. species

	Black-footed Albatross	Black-legged Kittiwake	Cassin's Auklet	Fork-tailed Storm-Petrel	Horned Puffin	Laysan Albatross	Leach's Storm-Petrel
Ancient Murrelet	**0.985**	0.232	**0.976**	-0.131	-0.136	0.030	-0.061
Black-footed Albatross		0.332	**0.969**	-0.148	-0.089	0.012	-0.158
Black-legged Kittiwake			0.200	0.259	**0.463**	0.330	-0.232
Cassin's Auklet				-0.272	-0.161	-0.127	-0.164
Fork-tailed Storm-Petrel					-0.002	**0.585**	**0.710**
Horned Puffin						0.021	-0.311
Laysan Albatross							**0.505**

8c. continued

	Mottled Petrel	Northern Fulmar	Parakeet Auklet	Rhinoceros Auklet	Sooty Shearwater	Thick-billed Murre	Tufted Puffin
Ancient Murrelet	-0.107	**0.983**	**0.732**	-0.057	-0.105	0.008	0.021
Black-footed Albatross	-0.030	**0.993**	**0.756**	-0.015	-0.085	0.110	0.122
Black-legged Kittiwake	-0.092	0.304	**0.766**	**0.809**	-0.118	**0.972**	**0.971**
Cassin's Auklet	-0.112	**0.984**	**0.649**	-0.153	-0.117	-0.026	-0.019
Fork-tailed Storm-Petrel	-0.168	-0.210	0.283	**0.511**	**0.501**	0.339	0.339
Horned Puffin	-0.158	-0.082	0.170	**0.668**	-0.162	**0.474**	**0.508**
Laysan Albatross	0.327	-0.088	**0.472**	**0.505**	-0.111	0.369	0.370
Leach's Storm-Petrel	-0.178	-0.204	0.050	0.051	**0.527**	-0.178	-0.185
Mottled Petrel		-0.100	-0.152	-0.184	-0.083	-0.083	-0.096
Northern Fulmar			**0.717**	-0.048	-0.102	0.078	0.089
Parakeet Auklet				**0.563**	-0.143	**0.633**	**0.643**
Rhinoceros Auklet					-0.063	**0.841**	**0.843**
Sooty Shearwater						-0.092	-0.106
Thick-billed Murre							**0.997**

Appendix 9. Bird-bird correlations for MME 3. N = 22 and $p < 0.05$ when critical value > .0352.

a. general groups

	Bird Diversity
Bird Density	-0.173

b. general vs. species

	Ancient Murrelet	Black-footed Albatross	Black-legged Kittiwake	Cassin's Auklet	Common Murre	Fork-tailed Storm-Petrel	Horned Puffin	Laysan Albatross
Bird Density	0.043	0.108	**0.525**	-0.066	0.028	**0.685**	0.105	0.173
Bird Diversity	-0.051	0.106	0.221	-0.002	-0.254	0.126	0.000	**0.391**

	Leach's Storm-Petrel	Mottled Petrel	Northern Fulmar	Parakeet Auklet	Sooty Shearwater	Short-tailed Shearwater	Thick-billed Murre	Tufted Puffin
Bird Density	0.210	**0.516**	**0.475**	0.064	**0.523**	0.118	-0.055	**0.508**
Bird Diversity	-0.491	0.021	0.070	-0.062	**-0.412**	-0.085	0.016	0.121

c. species vs. species

	Black-footed Albatross	Black-legged Kittiwake	Cassin's Auklet	Common Murre	Fork-tailed Storm-Petrel	Horned Puffin	Laysan Albatross
Ancient Murrelet	-0.203	-0.061	-0.059	-0.052	-0.162	-0.137	-0.117
Black-footed Albatross		0.007	-0.186	-0.206	0.277	-0.004	**0.355**
Black-legged Kittiwake			0.161	-0.072	0.276	-0.173	-0.101
Cassin's Auklet				-0.053	-0.119	-0.100	-0.177
Common Murre					-0.130	-0.133	-0.158
Fork-tailed Storm-Petrel						**0.465**	**0.423**
Horned Puffin							0.087

	Leach's Storm-Petrel	Mottled Petrel	Northern Fulmar	Parakeet Auklet	Sooty Shearwater	Short-tailed Shearwater	Thick-billed Murre	Tufted Puffin
Ancient Murrelet	-0.148	-0.161	-0.097	**0.988**	-0.095	-0.128	-0.060	-0.138
Black-footed Albatross	0.047	0.248	-0.050	-0.230	-0.046	-0.030	-0.204	0.154
Black-legged Kittiwake	-0.132	0.018	**0.368**	-0.053	-0.128	-0.141	0.190	0.172
Cassin's Auklet	-0.153	-0.209	-0.051	-0.040	-0.099	-0.131	**0.996**	-0.023
Common Murre	-0.056	-0.017	-0.110	-0.058	0.256	-0.117	-0.055	-0.031
Fork-tailed Storm-Petrel	0.045	**0.482**	**0.427**	-0.152	0.124	-0.058	-0.122	**0.842**
Horned Puffin	**0.619**	-0.029	0.130	-0.107	-0.095	0.080	-0.087	0.244
Laysan Albatross	-0.133	**0.652**	-0.173	-0.183	0.098	0.117	-0.178	0.248
Leach's Storm-Petrel		-0.005	-0.041	-0.135	0.283	0.138	-0.144	-0.217
Mottled Petrel			-0.180	-0.215	**0.690**	0.142	-0.204	0.193
Northern Fulmar				-0.004	-0.165	0.184	-0.042	**0.638**
Parakeet Auklet					-0.106	-0.070	-0.035	-0.114
Sooty Shearwater						0.345	-0.101	-0.054
Short-tailed Shearwater							-0.110	-0.070
Thick-billed Murre								-0.051

Appendix 10. Bird-bird correlations for MME 4. N = 14 and $p < 0.05$ when critical value > 0.441.

a. general groups

	Bird Diversity
Bird Density	-0.392

b. general vs. species

	Ancient Murrelet	Black-footed Albatross	Black-legged Kittiwake	Cassin's Auklet	Common Murre	Crested Auklet	Fork-tailed Storm-Petrel	Horned Puffin	Laysan Albatross
Bird Density	0.356	**0.491**	**0.710**	0.152	**0.710**	**0.841**	0.326	0.096	0.036
Bird Diversity	0.342	0.114	**-0.531**	-0.049	**-0.644**	**-0.609**	0.214	0.099	**0.496**

	Least Auklet	Leach's Storm-Petrel	Mottled Petrel	Northern Fulmar	Parakeet Auklet	Sooty Shearwater	Short-tailed Shearwater	Thick-billed Murre	Tufted Puffin
Bird Density	**0.448**	-0.024	-0.096	0.267	**0.673**	-0.181	0.055	0.163	0.293
Bird Diversity	0.315	0.119	-0.379	0.162	0.073	-0.250	0.238	-0.309	0.413

c. species vs. species

	Black-footed Albatross	Black-legged Kittiwake	Cassin's Auklet	Common Murre	Crested Auklet	Fork-tailed Storm-Petrel	Horned Puffin	Laysan Albatross
Ancient Murrelet	**0.431**	-0.061	-0.036	-0.120	0.109	0.274	-0.048	0.073
Black-footed Albatross		0.020	**0.562**	0.044	0.082	**0.658**	0.237	0.021
Black-legged Kittiwake			0.063	**0.949**	**0.894**	-0.245	-0.266	-0.012
Cassin's Auklet				0.039	-0.051	0.361	0.116	-0.100
Common Murre					**0.913**	-0.213	-0.189	-0.232
Crested Auklet						-0.184	-0.181	-0.156
Fork-tailed Storm-Petrel							**0.695**	0.170
Horned Puffin								-0.120

10c. continued

	Least Auklet	Leach's Storm-Petrel	Mottled Petrel	Northern Fulmar	Parakeet Auklet	Sooty Shearwater	Short-tailed Shearwater	Thick-billed Murre	Tufted Puffin
Ancient Murrelet	**0.977**	-0.166	-0.399	0.093	**0.879**	-0.192	-0.138	-0.003	0.299
Black-footed Albatross	**0.472**	-0.120	**-0.467**	**0.849**	0.426	-0.079	**0.535**	-0.066	**0.587**
Black-legged Kittiwake	0.045	-0.346	0.221	-0.100	0.218	-0.225	-0.185	**0.548**	-0.270
Cassin's Auklet	-0.094	-0.219	-0.351	**0.759**	-0.100	-0.196	**0.491**	**0.467**	0.223
Common Murre	-0.031	-0.260	0.237	-0.110	0.189	-0.175	-0.187	**0.535**	-0.346
Crested Auklet	0.202	-0.242	0.212	-0.146	**0.450**	-0.169	-0.179	0.346	-0.206
Fork-tailed Storm-Petrel	0.262	**0.479**	**-0.541**	**0.701**	0.290	-0.141	0.400	-0.275	**0.802**
Horned Puffin	-0.115	**0.592**	**-0.445**	0.348	-0.100	-0.177	0.203	-0.265	**0.621**
Laysan Albatross	0.175	0.255	-0.094	0.106	0.165	-0.229	0.068	-0.332	**0.483**
Least Auklet		-0.202	-0.308	0.115	**0.918**	-0.192	-0.094	-0.073	0.324
Leach's Storm-Petrel			-0.283	-0.039	-0.036	-0.080	0.002	-0.378	**0.488**
Mottled Petrel				-0.293	-0.231	0.128	-0.019	-0.148	**-0.442**
Northern Fulmar					0.065	-0.136	**0.743**	-0.082	**0.653**
Parakeet Auklet						-0.217	-0.139	-0.047	0.301
Sooty Shearwater							-0.143	-0.259	-0.190
Short-tailed Shearwater								-0.275	**0.492**
Thick-billed Murre									**-0.484**

Appendix 11. Bird-bird correlations for MME 5. N = 17 and $p < 0.05$ when critical value > 0.4.

a. general groups

	Bird Diversity
Bird Density	**-0.606**

b. general vs. species

	Ancient Murrelet	Black-footed Albatross	Black-legged Kittiwake	Cassin's Auklet	Common Murre	Crested Auklet	Fork-tailed Storm-Petrel	Horned Puffin	Laysan Albatross	Least Auklet
Bird Density	-0.030	-0.036	0.303	-0.061	-0.157	-0.100	-0.052	0.031	0.062	-0.021
Bird Diversity	0.020	0.140	-0.104	0.117	0.268	0.267	0.038	-0.085	0.201	0.121

	Leach's Storm-Petrel	Mottled Petrel	Northern Fulmar	Parakeet Auklet	Rhinoceros Auklet	Slaty-backed Gull	Sooty Shearwater	Short-tailed Shearwater	Thick-billed Murre	Tufted Puffin
Bird Density	0.219	-0.041	**0.559**	0.028	-0.077	-0.047	**0.883**	**0.996**	-0.131	0.204
Bird Diversity	-0.354	-0.287	-0.217	-0.043	0.063	0.090	**-0.446**	**-0.599**	0.330	-0.178

c. species vs. species

	Black-footed Albatross	Black-legged Kittiwake	Cassin's Auklet	Common Murre	Crested Auklet	Fork-tailed Storm-Petrel	Horned Puffin	Laysan Albatross	Least Auklet
Ancient Murrelet	0.182	-0.119	**0.895**	0.167	-0.123	**0.880**	**0.529**	0.127	**0.829**
Black-footed Albatross		0.063	-0.064	-0.140	-0.108	-0.087	**0.719**	-0.207	-0.143
Black-legged Kittiwake			-0.083	-0.103	-0.055	-0.074	-0.110	0.274	0.041
Cassin's Auklet				-0.041	-0.016	**0.984**	0.306	0.200	**0.963**
Common Murre					0.303	-0.074	-0.111	0.029	-0.045
Crested Auklet						-0.085	-0.011	0.142	0.114
Fork-tailed Storm-Petrel							0.278	0.166	**0.941**
Horned Puffin								-0.052	0.256
Laysan Albatross									0.394

11c. continued

	Leach's Storm-Petrel	Mottled Petrel	Northern Fulmar	Parakeet Auklet	Rhinoceros Auklet	Slaty-backed Gull	Sooty Shearwater	Short-tailed Shearwater	Thick-billed Murre	Tufted Puffin
Ancient Murrelet	0.153	-0.145	0.140	-0.157	**0.802**	**0.890**	0.127	-0.041	-0.219	**0.595**
Black-footed Albatross	**0.515**	-0.096	0.187	-0.065	-0.138	-0.104	-0.105	-0.041	-0.210	0.371
Black-legged Kittiwake	0.338	0.058	**0.901**	**0.432**	-0.067	-0.072	-0.091	0.225	-0.131	0.188
Cassin's Auklet	-0.093	-0.084	0.133	-0.109	**0.918**	**0.997**	0.141	-0.075	-0.070	**0.557**
Common Murre	-0.159	-0.127	-0.139	-0.065	-0.087	-0.046	-0.117	-0.156	0.175	-0.253
Crested Auklet	-0.120	-0.076	-0.051	0.020	-0.089	-0.067	-0.077	-0.098	**0.873**	-0.213
Fork-tailed Storm-Petrel	-0.081	0.076	0.134	-0.122	**0.907**	**0.988**	0.139	-0.065	-0.139	**0.536**
Horned Puffin	**0.719**	-0.197	0.105	-0.207	0.187	0.271	-0.013	0.034	-0.175	**0.622**
Laysan Albatross	0.030	-0.162	0.253	-0.088	0.094	0.202	0.011	0.032	**0.324**	0.318
Least Auklet	-0.054	-0.107	0.231	-0.079	**0.867**	**0.960**	0.126	-0.044	0.102	**0.553**
Leach's Storm-Petrel		-0.031	**0.424**	0.017	-0.145	-0.108	-0.105	0.200	-0.234	0.303
Mottled Petrel			-0.002	-0.072	-0.095	-0.072	-0.093	-0.043	-0.144	-0.188
Northern Fulmar				**0.409**	0.143	0.137	0.238	**0.493**	-0.164	0.347
Parakeet Auklet					0.247	-0.100	-0.122	-0.003	-0.091	-0.103
Rhinoceros Auklet						**0.924**	0.120	-0.089	-0.151	**0.445**
Slaty-backed Gull							0.153	-0.061	-0.106	**0.552**
Sooty Shearwater								**0.907**	-0.055	0.183
Short-tailed Shearwater									-0.118	0.167
Thick-billed Murre										-0.300

Appendix 12. Bird-bird correlations for MME 6. N = 77 and $p < 0.05$ when critical value > 0.188.

a. general groups

	Bird Diversity
Bird Density	**-0.524**

b. general vs. species

	Ancient Murrelet	Black-footed Albatross	Black-legged Kittiwake	Cassin's Auklet	Common Murre	Crested Auklet	Fork-tailed Storm-Petrel	Horned Puffin	Laysan Albatross	Least Auklet
Bird Density	**0.287**	0.160	-0.078	-0.031	-0.037	**0.602**	0.165	0.117	**0.249**	-0.046
Bird Diversity	-0.066	-0.019	0.076	-0.054	0.093	**-0.304**	-0.182	-0.167	0.048	0.133

	Leach's Storm-Petrel	Mottled Petrel	Northern Fulmar	Parakeet Auklet	Rhinoceros Auklet	Slaty-backed Gull	Sooty Shearwater	Short-tailed Shearwater	Thick-billed Murre	Tufted Puffin
Bird Density	0.029	-0.055	**0.554**	**0.265**	**0.675**	**0.195**	-0.047	**0.772**	-0.047	**0.475**
Bird Diversity	-0.084	-0.087	**-0.362**	-0.057	**-0.241**	-0.172	0.014	**-0.410**	0.168	-0.061

c. species vs. species

	Black-footed Albatross	Black-legged Kittiwake	Cassin's Auklet	Common Murre	Crested Auklet	Fork-tailed Storm-Petrel	Horned Puffin	Laysan Albatross	Least Auklet
Ancient Murrelet	**0.244**	-0.143	-0.039	0.082	**0.495**	**0.407**	0.046	0.036	**0.361**
Black-footed Albatross		0.011	-0.036	**0.193**	0.146	-0.103	0.060	**0.309**	-0.081
Black-legged Kittiwake			0.026	0.178	-0.038	-0.158	-0.048	0.069	-0.092
Cassin's Auklet				-0.045	-0.019	-0.063	-0.043	-0.066	-0.001
Common Murre					0.034	-0.071	0.077	0.050	-0.089
Crested Auklet						0.170	-0.006	-0.005	-0.014
Fork-tailed Storm-Petrel							**0.193**	0.172	0.051
Horned Puffin								-0.045	-0.082
Laysan Albatross									-0.121

12c. continued

	Leach's Storm-Petrel	Mottled Petrel	Northern Fulmar	Parakeet Auklet	Rhinoceros Auklet	Slaty-backed Gull	Sooty Shearwater	Short-tailed Shearwater	Thick-billed Murre	Tufted Puffin
Ancient Murrelet	-0.036	-0.078	0.013	**0.562**	-0.033	0.058	-0.074	-0.048	-0.030	**0.628**
Black-footed Albatross	-0.057	-0.082	0.132	-0.045	0.134	0.181	0.115	0.072	-0.109	0.047
Black-legged Kittiwake	-0.180	-0.169	-0.040	-0.040	-0.078	0.045	0.061	-0.075	**0.288**	-0.143
Cassin's Auklet	-0.041	-0.033	0.078	-0.048	-0.015	**0.764**	-0.029	-0.028	-0.026	-0.055
Common Murre	-0.047	-0.069	0.013	0.117	-0.053	-0.096	-0.096	-0.076	**0.276**	0.172
Crested Auklet	0.034	-0.048	0.110	**0.349**	-0.021	**0.224**	-0.043	-0.041	-0.058	**0.758**
Fork-tailed Storm-Petrel	-0.057	-0.065	-0.013	**0.326**	-0.062	-0.030	-0.098	0.045	-0.014	**0.310**
Horned Puffin	-0.041	-0.010	0.034	0.164	-0.003	-0.080	0.111	0.152	-0.037	0.085
Laysan Albatross	0.003	-0.066	**0.343**	-0.067	**0.377**	0.037	-0.033	**0.286**	0.110	0.071
Least Auklet	-0.095	-0.069	-0.061	**0.583**	-0.037	0.013	-0.066	-0.051	-0.047	-0.010
Leach's Storm-Petrel		-0.052	0.062	-0.010	0.038	-0.092	**0.542**	-0.001	-0.098	0.033
Mottled Petrel			-0.092	-0.078	-0.039	-0.098	-0.042	-0.037	-0.084	-0.073
Northern Fulmar				0.000	**0.716**	**0.207**	0.107	**0.564**	-0.009	0.064
Parakeet Auklet					-0.056	-0.065	-0.065	0.046	0.107	**0.483**
Rhinoceros Auklet						0.120	-0.004	**0.846**	-0.053	-0.008
Slaty-backed Gull							-0.050	0.054	-0.052	0.007
Sooty Shearwater								-0.041	-0.064	-0.094
Short-tailed Shearwater									-0.020	-0.013
Thick-billed Murre										0.165

Appendix 13. Bird-plankton correlations for MME 1. N = 12 and $p < 0.05$ when critical value > 0.476.

a. general groups

	Net Primary Productivity	Chlorophyll-a	Zooplankton Biomass	Zooplankton Diversity
Bird Density	0.248	0.101	-0.165	**-0.499**
Bird Diversity	**-0.575**	-0.089	-0.336	0.360

b. general vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida
Bird Density	**0.894**	-0.245	**0.609**	-0.157	0.426	**0.553**
Bird Diversity	-0.359	-0.020	-0.038	0.348	**-0.508**	**-0.594**

	Hyperiidea	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Bird Density	-0.246	0.098	-0.164	-0.186	-0.190	**0.748**	0.201
Bird Diversity	-0.130	0.197	-0.259	-0.313	-0.264	-0.302	0.041

13b. continued

	Net Primary Productivity	Chlorophyll-a	Zooplankton Biomass	Zooplankton Diversity
Ancient Murrelet	-0.295	-0.109	-0.198	-0.091
Black-footed Albatross	0.107	-0.162	-0.263	0.043
Black-legged Kittiwake	0.066	**0.679**	-0.177	0.053
Cassin's Auklet	0.281	0.002	-0.095	**-0.535**
Common Murre	-0.339	-0.077	-0.153	0.034
Fork-tailed Storm-Petrel	-0.076	-0.279	0.231	-0.067
Laysan Albatross	-0.415	-0.281	-0.156	0.102
Leach's Storm-Petrel	0.379	-0.216	0.131	-0.314
Northern Fulmar	-0.216	-0.102	-0.320	0.076
Parakeet Auklet	-0.133	-0.081	**0.522**	-0.169
Rhinoceros Auklet	-0.279	-0.024	-0.140	0.084
Sooty Shearwater	0.121	0.368	-0.264	-0.130
Short-tailed Shearwater	-0.179	-0.215	-0.176	**-0.573**
Thick-billed Murre	-0.309	-0.062	-0.120	0.020
Tufted Puffin	**-0.481**	**-0.476**	-0.169	0.433

c. species vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida
Ancient Murrelet	-0.173	-0.129	**0.538**	-0.173	0.076	-0.293
Black-footed Albatross	0.462	-0.270	-0.014	0.180	0.114	0.220
Black-legged Kittiwake	-0.183	-0.223	0.056	-0.181	-0.291	-0.245
Cassin's Auklet	**0.990**	-0.054	**0.496**	-0.088	**0.548**	**0.662**
Common Murre	-0.115	-0.167	**0.521**	-0.131	-0.150	-0.148
Fork-tailed Storm-Petrel	0.236	-0.360	0.013	-0.096	0.033	0.058
Laysan Albatross	-0.096	0.454	-0.136	-0.188	-0.244	-0.200
Leach's Storm-Petrel	0.390	-0.248	0.091	-0.272	0.369	0.394
Northern Fulmar	0.375	-0.360	-0.031	0.033	-0.082	0.083
Parakeet Auklet	0.438	-0.221	0.053	0.096	0.262	0.201
Rhinoceros Auklet	-0.050	-0.218	**0.517**	0.099	-0.134	-0.124
Sooty Shearwater	0.275	-0.308	**0.480**	0.081	-0.058	0.063
Short-tailed Shearwater	0.333	0.231	0.105	-0.223	0.050	0.109
Thick-billed Murre	-0.090	-0.163	**0.533**	-0.133	-0.122	-0.125
Tufted Puffin	-0.203	-0.132	-0.407	0.160	-0.286	-0.145

	Hyperiidea	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Ancient Murrelet	-0.326	-0.066	0.293	-0.048	-0.243	-0.321	0.262
Black-footed Albatross	-0.285	**0.659**	-0.162	-0.362	-0.262	**0.508**	-0.093
Black-legged Kittiwake	-0.055	-0.055	-0.165	-0.167	-0.052	-0.225	-0.152
Cassin's Auklet	-0.078	-0.124	-0.099	-0.163	-0.153	**0.871**	0.331
Common Murre	-0.222	0.210	-0.099	0.036	-0.143	-0.177	-0.226
Fork-tailed Storm-Petrel	-0.345	**0.785**	-0.230	0.236	0.222	0.254	-0.023
Laysan Albatross	**0.557**	-0.216	-0.135	-0.166	-0.193	0.194	0.425
Leach's Storm-Petrel	-0.271	**0.515**	0.114	0.110	0.065	0.350	0.014
Northern Fulmar	-0.348	**0.573**	-0.309	-0.408	-0.282	0.433	0.152
Parakeet Auklet	-0.149	-0.045	-0.173	0.466	**0.494**	0.346	0.400
Rhinoceros Auklet	-0.241	0.162	-0.136	0.008	-0.124	-0.137	-0.217
Sooty Shearwater	-0.250	0.133	-0.254	-0.235	-0.198	0.144	-0.150
Short-tailed Shearwater	-0.144	-0.256	-0.160	-0.201	-0.174	0.201	**0.614**
Thick-billed Murre	-0.206	0.198	-0.095	0.069	-0.113	-0.156	-0.241
Tufted Puffin	-0.308	**0.734**	-0.182	-0.161	-0.133	-0.080	-0.374

Appendix 14. Bird-plankton correlations for MME 2. N = 13 and $p < 0.05$ when critical value > 0.457.

a. general groups

	Net Primary Productivity	Chlorophyll-a	Zooplankton Biomass	Zooplankton Diversity
Bird Density	0.179	0.269	-0.410	**-0.592**
Bird Diversity	**-0.691**	-0.278	-0.180	-0.018

b. general vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida
Bird Density	**-0.580**	-0.138	-0.373	-0.090	-0.192	-0.164
Bird Diversity	0.351	-0.297	-0.187	**0.489**	0.131	-0.166

	Hyperiidea	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Bird Density	-0.450	**0.471**	-0.282	**0.578**	-0.447	-0.302	-0.033
Bird Diversity	-0.183	-0.228	0.115	-0.138	-0.191	0.079	**0.551**

14b. continued

	Net Primary Productivity	Chlorophyll-a	Zooplankton Biomass	Zooplankton Diversity
Ancient Murrelet	-0.300	-0.003	-0.221	-0.211
Black-footed Albatross	-0.390	-0.069	-0.226	-0.251
Black-legged Kittiwake	-0.310	0.061	-0.234	**-0.594**
Cassin's Auklet	-0.282	0.018	-0.230	-0.150
Fork-tailed Storm-Petrel	0.452	0.377	-0.294	**-0.718**
Horned Puffin	-0.320	-0.209	-0.271	0.075
Laysan Albatross	0.101	0.318	-0.233	-0.207
Leach's Storm-Petrel	**0.632**	0.431	-0.262	-0.257
Mottled Petrel	-0.242	-0.111	0.004	0.332
Northern Fulmar	-0.375	-0.067	-0.196	-0.231
Parakeet Auklet	-0.256	0.154	-0.323	**-0.553**
Rhinoceros Auklet	-0.048	0.226	-0.327	**-0.489**
Sooty Shearwater	0.257	-0.008	-0.143	-0.417
Thick-billed Murre	-0.217	0.084	-0.189	**-0.589**
Tufted Puffin	-0.245	0.045	-0.188	**-0.578**

c. species vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida
Ancient Murrelet	-0.199	-0.157	-0.176	0.136	-0.129	-0.133
Black-footed Albatross	-0.153	-0.164	-0.191	0.121	-0.149	-0.161
Black-legged Kittiwake	-0.268	-0.195	-0.211	-0.050	-0.179	-0.135
Cassin's Auklet	-0.211	-0.193	-0.148	0.124	-0.163	0.015
Fork-tailed Storm-Petrel	-0.447	-0.071	-0.410	-0.305	-0.017	-0.246
Horned Puffin	0.155	-0.231	-0.146	0.447	-0.004	-0.195
Laysan Albatross	-0.095	-0.061	-0.306	-0.066	-0.084	-0.184
Leach's Storm-Petrel	**-0.484**	0.022	-0.227	-0.198	-0.046	-0.044
Mottled Petrel	**0.601**	-0.045	-0.122	0.117	-0.166	-0.103
Northern Fulmar	-0.169	-0.173	-0.150	0.134	-0.154	-0.121
Parakeet Auklet	-0.385	-0.201	-0.297	-0.013	-0.178	-0.188
Rhinoceros Auklet	-0.209	-0.212	-0.269	0.206	-0.037	-0.228
Sooty Shearwater	-0.276	0.051	-0.201	-0.088	-0.079	-0.101
Thick-billed Murre	-0.267	-0.155	-0.188	-0.144	-0.166	-0.103
Tufted Puffin	-0.260	-0.159	-0.190	-0.153	-0.160	-0.128

	Hyperiidea	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Ancient Murrelet	-0.374	-0.140	-0.276	0.213	-0.170	-0.271	**0.469**
Black-footed Albatross	-0.377	-0.112	-0.325	0.096	-0.167	-0.258	**0.482**
Black-legged Kittiwake	-0.316	-0.141	-0.382	-0.111	-0.237	-0.268	-0.143
Cassin's Auklet	-0.370	-0.137	-0.321	0.051	-0.180	-0.165	**0.482**
Fork-tailed Storm-Petrel	-0.108	0.450	-0.097	**0.573**	-0.342	-0.239	-0.540
Horned Puffin	-0.326	-0.176	0.144	-0.123	-0.324	-0.020	-0.109
Laysan Albatross	0.011	-0.174	0.412	**0.718**	-0.239	-0.190	0.082
Leach's Storm-Petrel	-0.082	**0.486**	0.181	**0.800**	-0.341	-0.155	-0.326
Mottled Petrel	0.364	-0.064	0.433	-0.126	0.084	0.211	**0.623**
Northern Fulmar	-0.380	-0.125	-0.367	0.038	-0.141	-0.243	**0.461**
Parakeet Auklet	-0.430	-0.198	-0.284	0.328	-0.308	-0.384	0.126
Rhinoceros Auklet	-0.249	-0.113	-0.143	0.221	-0.369	-0.349	-0.286
Sooty Shearwater	-0.243	**0.991**	-0.294	0.104	-0.217	0.066	-0.284
Thick-billed Murre	-0.240	-0.109	-0.318	-0.126	-0.204	-0.211	-0.290
Tufted Puffin	-0.257	-0.123	-0.289	-0.119	-0.205	-0.204	-0.295

Appendix 15. Bird-plankton correlations for MME 3. N = 22 and $p < 0.05$ when critical value > 0.352.

a. general groups

	Net Primary Productivity	Chlorophyll-a	Zooplankton Biomass	Zooplankton Diversity
Bird Density	-0.162	0.026	0.082	-0.256
Bird Diversity	-0.149	0.317	0.043	-0.115

b. general vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida
Bird Density	-0.189	-0.086	-0.117	**0.460**	-0.200	0.009
Bird Diversity	-0.047	-0.125	0.101	0.279	-0.063	-0.223

	Hyperiidea	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Bird Density	-0.202	-0.232	-0.080	0.145	0.296	**0.431**	0.125
Bird Diversity	-0.052	-0.064	-0.255	**0.361**	-0.004	0.213	0.063

	Net Primary Productivity	Chlorophyll-a	Zooplankton Biomass	Zooplankton Diversity
Ancient Murrelet	-0.263	-0.054	-0.186	-0.068
Black-footed Albatross	-0.051	0.018	-0.248	-0.137
Black-legged Kittiwake	-0.336	0.003	0.188	-0.188
Cassin's Auklet	-0.301	0.010	-0.208	-0.009
Common Murre	-0.050	-0.258	-0.058	-0.008
Fork-tailed Storm-Petrel	-0.130	0.196	-0.069	-0.190
Horned Puffin	-0.096	-0.024	0.224	0.344
Laysan Albatross	0.188	**0.394**	-0.168	-0.264
Leach's Storm-Petrel	-0.006	-0.263	0.186	0.308
Mottled Petrel	0.268	0.204	-0.117	-0.100
Northern Fulmar	-0.201	0.140	**0.373**	-0.253
Parakeet Auklet	-0.311	-0.118	-0.117	-0.039
Sooty Shearwater	0.247	-0.159	0.051	0.118
Short-tailed Shearwater	0.134	-0.300	**0.715**	**0.458**
Thick-billed Murre	-0.314	-0.018	-0.164	0.003
Tufted Puffin	-0.154	0.307	-0.129	-0.294

c. species vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida
Ancient Murrelet	0.104	-0.050	-0.081	0.255	-0.065	-0.052
Black-footed Albatross	-0.060	0.192	0.129	-0.030	-0.066	0.032
Black-legged Kittiwake	-0.090	-0.107	-0.136	**0.887**	-0.076	-0.072
Cassin's Auklet	-0.070	-0.080	-0.109	0.028	-0.038	-0.053
Common Murre	-0.063	-0.106	-0.073	-0.097	-0.064	-0.048
Fork-tailed Storm-Petrel	-0.157	-0.163	0.076	0.171	-0.107	0.067
Horned Puffin	0.180	-0.139	**0.504**	-0.246	0.220	**0.721**
Laysan Albatross	-0.112	0.162	-0.081	-0.013	-0.123	-0.158
Leach's Storm-Petrel	0.025	-0.053	**0.458**	-0.179	0.029	**0.827**
Mottled Petrel	-0.210	0.324	-0.074	-0.013	-0.172	-0.189
Northern Fulmar	-0.148	-0.213	-0.136	0.227	-0.096	-0.088
Parakeet Auklet	0.096	-0.084	-0.094	0.256	-0.077	-0.058
Sooty Shearwater	-0.083	0.217	-0.103	-0.133	-0.102	-0.044
Short-tailed Shearwater	**0.381**	**0.371**	-0.186	-0.036	0.296	-0.117
Thick-billed Murre	-0.072	-0.082	-0.112	0.056	-0.042	-0.055
Tufted Puffin	-0.157	-0.220	-0.083	0.067	-0.094	-0.126

	Hyperiidea	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Ancient Murrelet	-0.101	-0.123	-0.104	-0.118	-0.165	0.115	-0.228
Black-footed Albatross	-0.117	**0.444**	0.076	0.034	-0.151	-0.007	-0.035
Black-legged Kittiwake	-0.070	-0.166	0.044	0.270	0.182	**0.874**	0.315
Cassin's Auklet	-0.075	-0.125	-0.109	-0.083	-0.122	-0.122	-0.162
Common Murre	0.079	-0.112	-0.098	-0.098	0.075	-0.013	0.191
Fork-tailed Storm-Petrel	-0.167	-0.134	-0.139	0.275	-0.013	0.190	0.035
Horned Puffin	0.225	0.190	-0.220	0.029	-0.101	-0.085	0.106
Laysan Albatross	-0.217	-0.012	-0.038	**0.404**	0.128	-0.055	0.221
Leach's Storm-Petrel	0.052	0.268	-0.103	-0.153	0.241	-0.089	0.063
Mottled Petrel	-0.265	0.036	0.161	0.151	0.219	0.062	0.217
Northern Fulmar	-0.039	-0.235	-0.099	-0.075	0.001	0.159	-0.114
Parakeet Auklet	-0.085	-0.111	-0.115	-0.129	-0.161	0.118	-0.255
Sooty Shearwater	-0.088	-0.029	0.090	-0.012	**0.474**	-0.095	0.046
Short-tailed Shearwater	0.346	0.090	0.306	0.326	**0.504**	-0.027	0.226
Thick-billed Murre	-0.068	-0.129	-0.104	-0.071	-0.111	-0.081	-0.137
Tufted Puffin	-0.146	-0.225	-0.181	0.177	-0.111	-0.020	-0.130

Appendix 16. Bird-plankton correlations for MME 4. N = 14 and $p < 0.05$ when critical value > 0.441.

a. general groups

	Net Primary Productivity	Chlorophyll-a	Zooplankton Biomass	Zooplankton Diversity
Bird Density	-0.088	0.230	-0.068	-0.185
Bird Diversity	0.377	0.360	0.381	0.399

b. general vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Hyperiidea	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Bird Density	0.196	-0.045	-0.090	-0.312	-0.291	-0.249	-0.166	0.191	-0.315	0.196	0.098	0.242
Bird Diversity	0.095	0.164	0.249	-0.136	0.411	0.379	0.157	-0.015	0.269	0.192	0.340	**0.461**

	Net Primary Productivity	Chlorophyll-a	Zooplankton Biomass	Zooplankton Diversity
Ancient Murrelet	0.084	**0.621**	**0.507**	0.194
Black-footed Albatross	-0.071	0.170	0.362	0.403
Black-legged Kittiwake	-0.331	-0.122	-0.313	-0.358
Cassin's Auklet	-0.263	-0.106	-0.166	**0.461**
Common Murre	-0.284	-0.118	-0.261	-0.359
Crested Auklet	-0.317	-0.056	-0.172	-0.378
Fork-tailed Storm-Petrel	**0.515**	**0.585**	0.016	0.064
Horned Puffin	0.387	0.323	-0.028	-0.342
Laysan Albatross	0.093	0.067	-0.020	0.175
Least Auklet	0.062	**0.580**	**0.482**	0.162
Leach's Storm-Petrel	**0.544**	0.273	-0.015	-0.150
Mottled Petrel	-0.121	-0.292	**-0.571**	-0.233
Northern Fulmar	0.021	0.091	-0.045	0.414
Parakeet Auklet	0.060	**0.562**	0.338	0.082
Sooty Shearwater	-0.009	-0.323	0.134	0.195
Short-tailed Shearwater	0.094	-0.041	-0.156	0.234
Thick-billed Murre	-0.317	-0.043	-0.165	0.035
Tufted Puffin	0.325	0.354	0.103	0.114

c. species vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Hyperiidea
Ancient Murrelet	0.041	-0.067	-0.083	-0.067	-0.165	-0.099
Black-footed Albatross	0.345	0.045	0.187	0.028	-0.150	-0.162
Black-legged Kittiwake	-0.214	-0.138	-0.205	-0.060	-0.130	-0.278
Cassin's Auklet	0.248	0.005	**0.584**	0.198	-0.029	-0.321
Common Murre	-0.160	-0.054	-0.197	-0.019	-0.118	-0.224
Crested Auklet	-0.108	-0.174	-0.204	-0.195	-0.163	-0.175
Fork-tailed Storm-Petrel	**0.443**	0.171	0.166	-0.193	-0.181	-0.185
Horned Puffin	0.066	-0.166	-0.050	-0.172	-0.155	-0.129
Laysan Albatross	0.427	0.367	0.269	-0.365	0.234	0.345
Least Auklet	0.061	-0.052	-0.138	-0.146	-0.162	-0.082
Leach's Storm-Petrel	**0.586**	**0.526**	0.138	-0.235	-0.112	0.277
Mottled Petrel	-0.205	-0.142	-0.279	**-0.459**	-0.026	-0.131
Northern Fulmar	0.377	0.025	0.356	-0.146	-0.095	-0.269
Parakeet Auklet	0.255	0.091	-0.036	-0.280	-0.169	-0.024
Sooty Shearwater	-0.104	-0.112	-0.254	0.280	-0.137	0.022
Short-tailed Shearwater	0.245	-0.061	0.188	-0.256	-0.114	-0.190
Thick-billed Murre	-0.235	0.000	0.135	**0.482**	-0.090	-0.356
Tufted Puffin	**0.484**	0.081	0.132	-0.433	-0.220	-0.058

	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Ancient Murrelet	-0.105	-0.118	-0.137	**0.848**	**0.473**	**0.608**
Black-footed Albatross	-0.012	**0.724**	-0.267	0.373	0.134	**0.629**
Black-legged Kittiwake	0.040	-0.191	-0.112	-0.144	-0.174	-0.314
Cassin's Auklet	0.034	**0.686**	0.281	-0.209	-0.179	0.108
Common Murre	0.130	-0.123	-0.119	-0.162	-0.158	-0.283
Crested Auklet	-0.167	-0.173	-0.213	0.041	0.008	-0.079
Fork-tailed Storm-Petrel	0.016	**0.615**	-0.207	0.105	0.077	0.377
Horned Puffin	-0.231	0.223	-0.255	-0.173	-0.204	0.126
Laysan Albatross	-0.026	0.092	0.211	-0.063	-0.019	0.060
Least Auklet	-0.103	-0.098	-0.222	**0.837**	**0.490**	**0.618**
Leach's Storm-Petrel	0.131	0.160	0.094	-0.227	-0.015	0.073
Mottled Petrel	0.012	-0.237	-0.209	-0.415	0.081	-0.261
Northern Fulmar	0.004	**0.860**	-0.144	-0.081	0.012	**0.459**
Parakeet Auklet	-0.124	-0.029	-0.159	**0.708**	**0.466**	**0.551**
Sooty Shearwater	-0.181	0.125	-0.257	0.203	-0.154	-0.134
Short-tailed Shearwater	0.050	**0.617**	-0.239	-0.241	0.420	**0.545**
Thick-billed Murre	0.349	-0.156	0.394	-0.107	-0.234	-0.379
Tufted Puffin	-0.219	**0.504**	-0.270	0.090	0.122	**0.571**

Appendix 17. Bird-plankton correlations for MME 5. N = 17 and $p < 0.05$ when critical value > 0.4.

a. general groups

	Net Primary Productivity	Chlorophyll-a	Zooplankton Biomass	Zooplankton Diversity
Bird Density	0.060	0.017	0.151	0.362
Bird Diversity	**-0.473**	**-0.544**	**-0.443**	-0.271

b. general vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Hyperiidea
Bird Density	0.033	0.239	-0.100	0.288	**0.887**	-0.091
Bird Diversity	**-0.497**	-0.343	0.176	-0.175	**-0.485**	0.174

	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Bird Density	**0.422**	**0.484**	-0.153	0.233	0.257	-0.144
Bird Diversity	0.078	-0.356	0.332	**-0.614**	**-0.443**	0.000

	Net Primary Productivity	Chlorophyll-a	Zooplankton Biomass	Zooplankton Diversity
Ancient Murrelet	0.138	0.259	0.096	0.278
Black-footed Albatross	**0.543**	0.185	0.065	0.385
Black-legged Kittiwake	-0.015	-0.087	-0.099	-0.080
Cassin's Auklet	-0.138	0.027	0.102	0.161
Common Murre	-0.233	-0.145	-0.242	-0.331
Crested Auklet	-0.347	0.271	-0.190	**-0.490**
Fork-tailed Storm-Petrel	-0.101	0.045	0.257	0.205
Horned Puffin	**0.585**	**0.559**	0.086	**0.514**
Laysan Albatross	-0.037	0.081	-0.235	-0.154
Least Auklet	-0.155	0.047	0.036	0.068
Leach's Storm-Petrel	**0.587**	**0.649**	0.063	0.378
Mottled Petrel	0.034	-0.114	**0.885**	0.029
Northern Fulmar	0.019	-0.066	-0.009	0.142
Parakeet Auklet	-0.217	-0.222	-0.239	-0.119
Rhinoceros Auklet	-0.206	-0.031	0.044	0.154
Slaty-backed Gull	-0.137	0.036	0.113	0.176
Sooty Shearwater	-0.076	-0.122	0.174	0.374
Short-tailed Shearwater	0.046	0.008	0.158	0.372
Thick-billed Murre	-0.373	-0.243	-0.306	**-0.595**
Tufted Puffin	**0.504**	**0.434**	0.100	**0.491**

c. species vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Hyperiidea
Ancient Murrelet	-0.070	-0.041	-0.138	**0.555**	0.018	-0.054
Black-footed Albatross	0.086	0.270	-0.082	0.370	0.048	0.232
Black-legged Kittiwake	0.152	0.334	-0.047	-0.056	-0.098	-0.016
Cassin's Auklet	-0.164	-0.170	-0.079	**0.463**	-0.017	-0.069
Common Murre	-0.189	-0.268	-0.115	-0.221	-0.139	-0.174
Crested Auklet	-0.161	-0.191	-0.068	-0.179	-0.107	-0.104
Fork-tailed Storm-Petrel	-0.152	-0.181	-0.066	**0.448**	-0.002	-0.047
Horned Puffin	0.209	**0.508**	-0.056	**0.528**	0.064	0.131
Laysan Albatross	0.018	0.062	-0.191	-0.175	-0.140	-0.265
Least Auklet	-0.140	-0.156	-0.089	0.388	-0.055	-0.106
Leach's Storm-Petrel	0.239	**0.814**	-0.109	0.368	0.006	0.018
Mottled Petrel	-0.056	-0.137	-0.066	-0.179	0.009	0.012
Northern Fulmar	0.043	0.335	-0.084	0.222	0.217	0.000
Parakeet Auklet	0.000	-0.054	-0.097	-0.218	-0.167	-0.125
Rhinoceros Auklet	-0.174	-0.240	-0.086	0.366	-0.050	-0.103
Slaty-backed Gull	-0.153	-0.182	-0.067	**0.456**	-0.009	-0.069
Sooty Shearwater	-0.138	-0.081	-0.080	0.342	**0.963**	-0.082
Short-tailed Shearwater	-0.005	0.221	-0.092	0.295	**0.916**	-0.086
Thick-billed Murre	-0.288	-0.329	-0.130	-0.164	-0.122	-0.201
Tufted Puffin	**0.483**	0.246	-0.185	0.382	0.130	-0.072

17c. continued

	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Ancient Murrelet	-0.198	0.279	-0.231	0.108	-0.080	-0.102
Black-footed Albatross	-0.178	-0.078	-0.095	-0.010	0.077	0.108
Black-legged Kittiwake	-0.127	-0.178	0.035	-0.232	-0.162	-0.128
Cassin's Auklet	-0.136	0.333	-0.112	0.050	-0.172	-0.058
Common Murre	-0.042	-0.255	0.012	-0.247	-0.193	-0.124
Crested Auklet	-0.116	-0.194	-0.136	-0.211	-0.170	-0.114
Fork-tailed Storm-Petrel	-0.143	0.326	-0.111	0.171	-0.159	-0.075
Horned Puffin	-0.241	0.289	-0.152	0.082	**0.493**	0.205
Laysan Albatross	0.272	-0.115	-0.313	-0.056	0.068	0.146
Least Auklet	-0.088	0.270	-0.160	0.003	-0.169	-0.080
Leach's Storm-Petrel	-0.197	-0.015	-0.158	0.104	**0.490**	-0.089
Mottled Petrel	-0.128	-0.214	-0.066	**0.663**	-0.075	-0.103
Northern Fulmar	-0.034	0.073	-0.115	-0.122	-0.118	-0.246
Parakeet Auklet	-0.170	0.058	-0.101	-0.336	-0.120	-0.114
Rhinoceros Auklet	-0.154	0.395	-0.140	-0.021	-0.177	-0.096
Slaty-backed Gull	-0.116	0.349	-0.095	0.059	-0.165	-0.057
Sooty Shearwater	**0.531**	**0.599**	-0.160	0.276	0.151	-0.118
Short-tailed Shearwater	**0.450**	**0.500**	-0.151	0.246	0.274	-0.152
Thick-billed Murre	0.078	-0.315	-0.193	-0.274	-0.224	-0.133
Tufted Puffin	-0.080	**0.476**	-0.148	0.148	0.398	**0.553**

Appendix 18. Bird-plankton correlations for MME 6. N = 77 and $p < 0.05$ when critical value > 0.188.

a. general groups

	Net Primary Production	Chlorophyll-a	Zooplankton Biomass	Zooplankton Diversity
Bird Density	0.142	0.031	0.088	**0.217**
Bird Diversity	-0.012	0.078	-0.120	-0.172

b. general vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida	Hyperiidea
Bird Density	**0.233**	**0.326**	0.008	0.166	0.033	-0.034	-0.071
Bird Diversity	-0.136	**-0.339**	0.105	-0.143	-0.081	0.123	**0.233**

	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Bird Density	0.140	0.106	-0.063	0.048	0.050	**0.465**
Bird Diversity	0.030	-0.070	0.125	-0.074	0.057	**-0.210**

c. species vs. species

	Net Primary Production	Chlorophyll-a	Zooplankton Biomass	Zooplankton Diversity
Ancient Murrelet	**0.305**	**0.446**	0.166	0.053
Black-footed Albatross	0.167	0.046	-0.074	0.121
Black-legged Kittiwake	-0.110	-0.073	-0.176	-0.091
Cassin's Auklet	-0.106	-0.047	-0.046	-0.033
Common Murre	-0.071	-0.068	-0.091	**-0.231**
Crested Auklet	0.051	0.025	0.048	0.125
Fork-tailed Storm-Petrel	0.106	0.104	**0.498**	0.026
Horned Puffin	-0.074	-0.062	0.080	0.106
Laysan Albatross	0.184	0.005	-0.032	0.145
Least Auklet	**0.411**	**0.735**	0.100	**0.202**
Leach's Storm-Petrel	0.151	0.004	0.034	**0.223**
Mottled Petrel	-0.110	-0.077	0.035	-0.019
Northern Fulmar	**0.300**	0.127	-0.124	0.075
Parakeet Auklet	**0.353**	**0.630**	**0.202**	**0.198**
Rhinoceros Auklet	**0.214**	0.055	-0.028	0.089
Slaty-backed Gull	-0.047	-0.022	-0.076	0.042
Sooty Shearwater	0.114	0.054	-0.066	0.099
Short-tailed Shearwater	0.111	0.001	0.069	0.172
Thick-billed Murre	**-0.201**	-0.109	-0.074	**-0.231**
Tufted Puffin	0.050	0.040	0.103	-0.007

18c. continued

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida
Ancient Murrelet	**0.224**	0.010	0.061	0.063	0.185	-0.039
Black-footed Albatross	-0.088	-0.019	0.068	-0.056	-0.001	0.048
Black-legged Kittiwake	-0.039	0.046	-0.073	-0.128	-0.089	-0.043
Cassin's Auklet	-0.050	-0.046	-0.011	-0.038	-0.035	-0.013
Common Murre	-0.143	-0.118	0.032	-0.071	-0.085	-0.045
Crested Auklet	0.151	-0.063	0.025	**0.272**	-0.024	-0.019
Fork-tailed Storm-Petrel	**0.371**	0.123	-0.027	0.081	**0.398**	-0.052
Horned Puffin	0.169	**0.363**	0.092	-0.018	0.073	-0.026
Laysan Albatross	0.167	-0.047	**0.209**	0.008	-0.072	0.003
Least Auklet	**0.247**	0.096	0.147	-0.020	**0.359**	-0.032
Leach's Storm-Petrel	-0.049	0.052	0.079	0.091	0.074	0.173
Mottled Petrel	-0.074	-0.082	-0.074	**0.323**	-0.063	-0.030
Northern Fulmar	0.101	-0.015	-0.010	0.028	-0.121	-0.010
Parakeet Auklet	**0.229**	**0.311**	**0.222**	-0.005	**0.360**	-0.048
Rhinoceros Auklet	0.164	0.021	-0.061	0.017	-0.017	-0.015
Slaty-backed Gull	0.134	-0.086	-0.041	0.079	-0.075	-0.039
Sooty Shearwater	-0.062	0.065	0.047	-0.082	0.014	-0.029
Short-tailed Shearwater	0.162	**0.477**	-0.018	-0.012	0.055	-0.026
Thick-billed Murre	-0.066	0.016	0.060	-0.103	-0.044	-0.047
Tufted Puffin	0.004	-0.038	0.101	0.106	-0.002	0.010

18c. continued

	Hyperiidea	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Ancient Murrelet	0.024	0.002	0.042	0.113	**0.333**	-0.114	**0.235**
Black-footed Albatross	0.082	-0.092	-0.090	-0.081	-0.123	-0.080	**0.255**
Black-legged Kittiwake	-0.054	0.096	0.040	-0.058	-0.184	0.057	-0.097
Cassin's Auklet	-0.047	-0.035	-0.050	0.080	-0.043	-0.087	-0.097
Common Murre	0.036	-0.122	-0.083	-0.115	-0.090	0.005	-0.036
Crested Auklet	0.009	-0.049	-0.011	-0.051	-0.031	-0.073	0.112
Fork-tailed Storm-Petrel	0.121	0.008	0.130	0.149	**0.338**	-0.131	**0.191**
Horned Puffin	0.053	-0.027	-0.026	-0.037	0.017	0.062	0.065
Laysan Albatross	0.052	0.075	-0.093	0.023	-0.092	0.086	**0.430**
Least Auklet	-0.070	0.122	0.181	**0.333**	**0.331**	-0.049	0.162
Leach's Storm-Petrel	-0.030	0.063	-0.026	-0.061	0.030	0.109	-0.001
Mottled Petrel	0.009	-0.069	0.050	0.076	-0.030	-0.006	0.125
Northern Fulmar	-0.129	-0.122	-0.060	-0.118	-0.123	0.000	**0.303**
Parakeet Auklet	-0.034	0.144	**0.219**	**0.276**	**0.382**	0.023	**0.328**
Rhinoceros Auklet	-0.073	-0.041	-0.048	-0.055	-0.049	0.081	**0.442**
Slaty-backed Gull	-0.106	-0.103	-0.074	0.024	-0.112	-0.167	0.029
Sooty Shearwater	-0.007	0.050	0.016	-0.062	-0.088	0.060	-0.040
Short-tailed Shearwater	-0.092	**0.232**	0.147	-0.041	0.086	0.128	**0.475**
Thick-billed Murre	-0.180	-0.030	0.049	-0.099	-0.033	-0.150	-0.003
Tufted Puffin	0.051	-0.075	-0.024	0.056	0.094	-0.171	0.148

Appendix 19. Bird-plankton correlations for MME 1-4 combined, spring. N = 22 and $p < 0.05$ when critical value > 0.352.

a. general groups

	Net Primary Production	Chlorophyll-a	Zooplankton Abundance	Zooplankton Biomass	Zooplankton Diversity
Bird Density	0.270	0.349	0.039	-0.184	-0.346
Bird Diversity	0.164	0.089	**0.437**	**-0.357**	**0.426**

b. general vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Hyperiidea
Bird Density	-0.121	0.031	0.200	-0.291	-0.065	-0.011
Bird Diversity	0.301	0.240	0.218	0.215	0.080	-0.105

	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Bird Density	-0.171	-0.311	-0.222	-0.094	0.199	0.028
Bird Diversity	0.139	0.035	0.288	-0.172	0.321	**0.502**

19b. continued

	Net Primary Production	Chlorophyll-a	Zooplankton Abundance	Zooplankton Biomass	Zooplankton Diversity
Ancient Murrelet	-0.104	-0.040	0.188	-0.098	-0.104
Black-footed Albatross	0.203	0.155	-0.089	-0.110	0.054
Black-legged Kittiwake	**0.544**	**0.658**	-0.091	-0.152	-0.267
Cassin's Auklet	-0.091	-0.101	-0.155	-0.160	0.230
Common Murre	0.168	0.130	-0.137	-0.099	0.097
Crested Auklet	-0.140	-0.066	-0.050	-0.084	**-0.531**
Fork-tailed Storm-Petrel	0.027	0.077	**0.359**	-0.037	-0.053
Horned Puffin	-0.172	-0.204	-0.156	-0.118	0.070
Laysan Albatross	-0.013	0.076	**0.630**	0.093	0.123
Least Auklet	0.045	0.156	**0.570**	0.107	-0.006
Leach's Storm-Petrel	**0.441**	0.240	0.160	**0.426**	0.279
Mottled Petrel	-0.338	-0.281	-0.041	-0.175	**-0.403**
Northern Fulmar	-0.083	-0.041	-0.018	-0.141	-0.235
Parakeet Auklet	-0.043	0.086	**0.490**	0.045	-0.175
Rhinoceros Auklet	0.298	0.211	-0.167	-0.081	0.166
Sooty Shearwater	**0.705**	**0.638**	-0.116	-0.044	0.265
Short-tailed Shearwater	0.047	-0.046	**0.414**	-0.062	0.143
Thick-billed Murre	-0.104	-0.056	-0.325	-0.157	-0.156
Tufted Puffin	-0.136	-0.070	0.057	-0.100	**-0.402**

c. species vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Hyperiidea
Ancient Murrelet	0.033	-0.049	-0.040	0.008	-0.199	-0.162
Black-footed Albatross	-0.032	-0.035	-0.263	-0.078	-0.145	-0.025
Black-legged Kittiwake	-0.066	0.126	0.114	-0.198	-0.084	0.280
Cassin's Auklet	-0.024	0.047	-0.144	-0.104	0.034	-0.247
Common Murre	0.010	0.010	**0.655**	-0.169	0.284	-0.162
Crested Auklet	-0.120	-0.130	-0.100	-0.189	-0.192	-0.027
Fork-tailed Storm-Petrel	-0.187	**0.387**	0.024	-0.001	0.239	-0.083
Horned Puffin	0.042	-0.244	-0.126	0.308	0.227	-0.004
Laysan Albatross	0.105	0.152	-0.006	-0.108	-0.174	0.160
Least Auklet	0.074	0.177	-0.016	-0.143	-0.118	0.164
Leach's Storm-Petrel	-0.112	-0.022	-0.074	-0.098	-0.053	0.324
Mottled Petrel	-0.302	-0.120	-0.173	-0.013	-0.300	-0.211
Northern Fulmar	-0.120	0.079	-0.133	0.108	0.040	-0.226
Parakeet Auklet	0.032	0.042	-0.068	-0.190	-0.242	0.109
Rhinoceros Auklet	-0.039	0.001	**0.603**	-0.186	0.290	-0.111
Sooty Shearwater	0.015	0.047	**0.458**	-0.261	0.141	0.214
Short-tailed Shearwater	**0.499**	0.126	0.105	-0.112	-0.164	-0.127
Thick-billed Murre	-0.290	0.334	**0.651**	0.147	**0.486**	-0.302
Tufted Puffin	-0.200	-0.181	-0.213	-0.153	0.006	-0.100

19c. continued

	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Ancient Murrelet	-0.153	-0.215	-0.189	0.038	0.222	0.220
Black-footed Albatross	-0.077	-0.180	-0.216	-0.071	-0.111	0.210
Black-legged Kittiwake	-0.144	-0.159	-0.150	-0.162	-0.001	-0.054
Cassin's Auklet	-0.010	-0.182	-0.153	-0.175	-0.125	0.037
Common Murre	0.041	-0.119	-0.081	-0.142	-0.102	-0.105
Crested Auklet	-0.101	-0.137	-0.121	-0.041	0.079	-0.090
Fork-tailed Storm-Petrel	0.049	0.019	0.008	0.142	**0.595**	-0.004
Horned Puffin	-0.107	0.000	0.303	-0.060	-0.165	-0.096
Laysan Albatross	0.080	-0.074	0.197	**0.433**	**0.642**	0.272
Least Auklet	-0.070	-0.089	-0.112	**0.382**	**0.644**	0.232
Leach's Storm-Petrel	-0.115	-0.008	0.069	**0.389**	0.055	0.110
Mottled Petrel	0.341	-0.020	0.326	-0.138	0.144	-0.198
Northern Fulmar	-0.113	-0.099	-0.144	-0.062	0.053	0.146
Parakeet Auklet	-0.121	-0.169	-0.153	0.297	**0.613**	0.160
Rhinoceros Auklet	0.019	-0.148	-0.113	-0.142	-0.130	-0.110
Sooty Shearwater	-0.045	-0.220	-0.076	-0.074	-0.176	-0.002
Short-tailed Shearwater	-0.047	-0.155	0.335	0.010	-0.079	**0.697**
Thick-billed Murre	0.007	-0.019	-0.107	-0.223	-0.191	-0.339
Tufted Puffin	-0.098	-0.182	-0.004	0.035	0.259	-0.091

Appendix 20. Bird-plankton correlations for MME 1-4 combined, summer. N = 22 and $p < 0.05$ when critical value > 0.352.

a. general groups

	Net Primary Production	Chlorophyll-a	Zooplankton Abundance	Zooplankton Biomass	Zooplankton Diversity
Bird Density	**0.363**	0.254	-0.028	-0.076	-0.217
Bird Diversity	-0.222	-0.066	0.009	-0.193	-0.292

b. general vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida
Bird Density	-0.225	-0.004	-0.087	0.010	-0.221	-0.015
Bird Diversity	-0.237	-0.159	-0.083	0.172	-0.017	-0.321

	Hyperiidea	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Bird Density	-0.289	**0.471**	-0.283	-0.153	-0.156	-0.070	-0.055
Bird Diversity	0.138	-0.272	0.030	-0.059	-0.339	**0.358**	-0.009

	Net Primary Production	Chlorophyll-a	Zooplankton Abundance	Zooplankton Biomass	Zooplankton Diversity
Ancient Murrelet	-0.096	0.076	-0.193	-0.028	**-0.397**
Black-footed Albatross	0.329	0.053	0.011	-0.113	0.184
Black-legged Kittiwake	-0.242	-0.144	-0.151	-0.074	0.063
Cassin's Auklet	**0.767**	**0.591**	0.125	0.335	0.169
Common Murre	0.240	-0.007	-0.037	-0.132	0.196
Fork-tailed Storm-Petrel	**0.404**	**0.514**	-0.081	0.099	**-0.434**
Horned Puffin	-0.055	0.222	-0.271	-0.114	**-0.497**
Laysan Albatross	-0.028	0.154	-0.307	-0.109	**-0.559**
Least Auklet	-0.249	-0.158	-0.121	0.054	-0.120
Leach's Storm-Petrel	**0.607**	**0.417**	0.115	0.072	-0.091
Mottled Petrel	-0.131	-0.152	0.083	-0.171	0.088
Northern Fulmar	-0.163	-0.023	-0.175	-0.105	-0.185
Parakeet Auklet	0.103	**0.368**	-0.284	-0.050	**-0.609**
Rhinoceros Auklet	**0.555**	**0.682**	0.349	**0.798**	0.037
Sooty Shearwater	-0.061	-0.199	-0.033	-0.186	-0.001
Short-tailed Shearwater	0.030	0.047	**0.636**	-0.111	-0.110
Thick-billed Murre	-0.215	-0.028	-0.098	0.267	-0.077
Tufted Puffin	-0.155	0.104	-0.278	-0.122	**-0.491**

c. species vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida	Hyperiidea
Ancient Murrelet	-0.164	-0.020	-0.091	0.210	-0.099	-0.109	0.068
Black-footed Albatross	0.113	-0.015	-0.068	-0.021	-0.084	-0.021	-0.128
Black-legged Kittiwake	-0.251	-0.171	-0.100	0.013	-0.135	-0.115	-0.023
Cassin's Auklet	0.202	0.022	-0.104	-0.136	0.041	**0.503**	-0.139
Common Murre	0.060	-0.123	-0.061	-0.080	-0.098	-0.077	-0.134
Fork-tailed Storm-Petrel	-0.070	-0.140	-0.024	0.020	-0.116	-0.110	-0.215
Horned Puffin	-0.195	-0.166	0.163	0.037	-0.042	-0.003	0.001
Laysan Albatross	-0.286	0.003	-0.092	0.069	-0.150	-0.131	-0.107
Least Auklet	-0.142	-0.102	-0.052	0.288	-0.062	-0.065	0.141
Leach's Storm-Petrel	0.037	-0.038	-0.007	-0.107	-0.088	0.189	-0.237
Mottled Petrel	-0.295	0.248	-0.075	-0.121	-0.165	-0.135	-0.204
Northern Fulmar	-0.324	-0.247	-0.128	-0.010	-0.208	-0.158	-0.076
Parakeet Auklet	-0.180	-0.153	-0.084	-0.055	-0.095	-0.096	-0.107
Rhinoceros Auklet	**0.420**	-0.038	-0.091	-0.115	0.177	-0.129	-0.031
Sooty Shearwater	-0.292	0.218	-0.083	0.164	-0.180	-0.125	-0.187
Short-tailed Shearwater	-0.060	0.196	-0.107	-0.051	0.058	-0.133	0.128
Thick-billed Murre	-0.119	-0.160	-0.082	0.231	-0.030	-0.106	0.134
Tufted Puffin	-0.331	-0.232	-0.133	0.042	-0.197	-0.163	-0.057

	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Ancient Murrelet	-0.126	-0.183	-0.122	-0.106	-0.132	0.103
Black-footed Albatross	0.060	-0.155	-0.094	-0.159	-0.030	-0.150
Black-legged Kittiwake	-0.128	0.059	-0.138	-0.133	0.018	0.054
Cassin's Auklet	-0.077	-0.278	0.103	0.235	-0.122	0.280
Common Murre	0.034	-0.163	-0.076	-0.168	-0.011	-0.117
Fork-tailed Storm-Petrel	0.097	-0.279	-0.072	0.014	-0.076	0.033
Horned Puffin	-0.081	-0.241	-0.049	-0.197	-0.121	-0.024
Laysan Albatross	-0.133	-0.124	-0.132	-0.108	-0.157	-0.023
Least Auklet	-0.076	-0.137	-0.078	-0.017	-0.083	0.211
Leach's Storm-Petrel	**0.506**	**-0.377**	-0.041	-0.043	-0.073	0.021
Mottled Petrel	-0.104	0.250	-0.090	-0.048	0.237	0.033
Northern Fulmar	-0.151	-0.182	-0.201	-0.252	0.142	-0.025
Parakeet Auklet	-0.112	-0.202	-0.085	-0.129	-0.116	-0.077
Rhinoceros Auklet	0.041	-0.144	0.297	**0.703**	-0.100	**0.663**
Sooty Shearwater	**0.495**	0.105	-0.117	-0.099	-0.095	-0.154
Short-tailed Shearwater	-0.107	-0.215	0.047	-0.185	**0.875**	0.239
Thick-billed Murre	-0.124	-0.163	-0.012	0.151	-0.124	**0.388**
Tufted Puffin	-0.181	-0.199	-0.191	-0.240	0.022	0.012

Appendix 21. Bird-plankton correlations for MME 1-4 combined, fall. N = 17 and $p < 0.05$ when critical value > 0.4.

a. general groups

	Net Primary Production	Chlorophyll-a	Zooplankton Abundance	Zooplankton Biomass	Zooplankton Diversity
Bird Density	**0.578**	**0.576**	**0.857**	0.162	-0.180
Bird Diversity	**-0.657**	**-0.502**	-0.293	-0.099	-0.106

b. general vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida	Hyperiidea
Bird Density	**0.958**	-0.127	0.056	0.014	**0.523**	0.100	-0.118
Bird Diversity	-0.283	0.078	0.299	-0.356	-0.212	-0.371	0.121

	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Bird Density	-0.214	0.006	-0.049	-0.042	**0.557**	**0.772**
Bird Diversity	-0.121	-0.123	0.198	-0.024	-0.186	-0.275

	Net Primary Production	Chlorophyll-a	Zooplankton Abundance	Zooplankton Biomass	Zooplankton Diversity
Ancient Murrelet	0.240	0.230	-0.176	0.074	0.000
Black-footed Albatross	**0.614**	**0.615**	**0.890**	0.245	-0.132
Black-legged Kittiwake	-0.169	-0.132	-0.217	-0.191	-0.350
Cassin's Auklet	**0.599**	**0.585**	**0.897**	0.188	-0.208
Fork-tailed Storm-Petrel	-0.139	-0.053	0.182	-0.125	0.105
Horned Puffin	-0.304	-0.202	0.021	-0.092	0.321
Laysan Albatross	-0.295	-0.223	-0.208	-0.074	-0.204
Least Auklet	-0.204	-0.135	-0.062	-0.161	-0.005
Leach's Storm-Petrel	**0.628**	**0.551**	0.337	0.192	-0.006
Mottled Petrel	**-0.477**	-0.396	-0.284	-0.282	-0.369
Northern Fulmar	-0.164	-0.076	0.134	-0.023	0.277
Parakeet Auklet	-0.121	-0.067	0.137	0.175	0.392
Rhinoceros Auklet	**0.647**	**0.625**	**0.879**	0.204	-0.202
Sooty Shearwater	**0.530**	**0.517**	**0.866**	0.145	-0.238
Short-tailed Shearwater	-0.108	-0.047	0.234	0.007	0.263
Thick-billed Murre	**0.595**	**0.581**	**0.897**	0.186	-0.212
Tufted Puffin	-0.376	-0.273	-0.125	-0.223	0.039

c. species vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida
Ancient Murrelet	-0.102	-0.155	-0.152	**0.778**	0.106	-0.159
Black-footed Albatross	**0.965**	-0.087	0.100	-0.048	**0.584**	0.089
Black-legged Kittiwake	-0.098	-0.194	-0.150	-0.114	-0.090	-0.121
Cassin's Auklet	**0.994**	-0.069	0.076	-0.083	**0.557**	0.173
Fork-tailed Storm-Petrel	0.164	-0.162	0.109	-0.023	-0.068	-0.176
Horned Puffin	-0.090	-0.120	0.195	-0.164	-0.173	-0.174
Laysan Albatross	-0.141	0.042	-0.069	-0.179	-0.140	-0.236
Least Auklet	-0.078	-0.183	-0.035	-0.126	-0.150	-0.133
Leach's Storm-Petrel	**0.457**	-0.135	-0.096	**0.626**	0.377	0.062
Mottled Petrel	-0.239	0.055	-0.019	-0.281	-0.259	-0.298
Northern Fulmar	0.029	-0.113	0.116	-0.129	-0.076	-0.118
Parakeet Auklet	0.002	0.330	0.157	-0.068	-0.097	-0.134
Rhinoceros Auklet	**0.985**	-0.072	0.048	0.033	**0.570**	0.146
Sooty Shearwater	**0.951**	-0.022	0.000	-0.086	**0.500**	0.104
Short-tailed Shearwater	0.103	-0.011	0.064	-0.138	-0.044	-0.103
Thick-billed Murre	**0.994**	-0.065	0.077	-0.086	**0.555**	0.167
Tufted Puffin	-0.142	-0.135	0.055	-0.211	-0.251	-0.241

21c. continued

	Hyperiidea	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Ancient Murrelet	-0.178	-0.214	0.234	-0.027	0.230	-0.286	-0.022
Black-footed Albatross	-0.114	-0.178	0.025	-0.125	0.044	**0.568**	**0.833**
Black-legged Kittiwake	-0.060	-0.161	-0.137	-0.096	-0.028	-0.244	-0.301
Cassin's Auklet	-0.059	-0.124	-0.158	-0.120	-0.099	**0.614**	**0.780**
Fork-tailed Storm-Petrel	-0.226	-0.303	**0.449**	**0.474**	0.049	0.127	0.239
Horned Puffin	-0.194	-0.175	**0.596**	0.249	0.184	0.013	0.166
Laysan Albatross	0.169	-0.175	-0.013	0.102	-0.043	-0.174	-0.327
Least Auklet	-0.192	-0.180	0.387	-0.140	0.130	-0.104	-0.027
Leach's Storm-Petrel	-0.039	-0.178	0.072	-0.089	0.072	0.128	0.310
Mottled Petrel	-0.270	0.003	-0.165	**0.656**	-0.231	-0.266	-0.249
Northern Fulmar	-0.147	-0.176	**0.639**	-0.074	0.239	0.065	0.250
Parakeet Auklet	0.249	-0.034	**0.485**	0.065	0.049	0.218	0.089
Rhinoceros Auklet	-0.042	-0.153	-0.151	-0.122	-0.083	**0.585**	**0.776**
Sooty Shearwater	-0.142	-0.077	-0.082	0.127	-0.122	**0.615**	**0.730**
Short-tailed Shearwater	-0.195	-0.032	**0.706**	-0.146	0.215	0.135	0.297
Thick-billed Murre	-0.057	-0.123	-0.160	-0.118	-0.103	**0.612**	**0.779**
Tufted Puffin	-0.189	-0.234	0.307	**0.561**	0.003	-0.061	-0.082

Appendix 22. Bird-plankton correlations for MME 6, spring. N = 24 and $p < 0.05$ when critical value > 0.337.

a. general groups

	Net Primary Production	Chlorophyll-a	Zooplankton Abundance	Zooplankton Biomass	Zooplankton Diversity
Bird Density	0.252	0.266	0.144	-0.127	0.043
Bird Diversity	0.257	0.264	0.207	0.163	0.018

b. general vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Hyperiidea
Bird Density	0.162	0.196	0.154	-0.208	0.242	0.064
Bird Diversity	0.232	0.237	**0.353**	0.098	0.249	-0.268

	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Bird Density	0.160	0.269	0.275	0.019	-0.139	0.237
Bird Diversity	0.280	0.004	0.028	0.198	0.013	0.068

22b. continued

	Net Primary Production	Chlorophyll-a	Zooplankton Abundance	Zooplankton Biomass	Zooplankton Diversity
Ancient Murrelet	**0.979**	**0.983**	**0.829**	**0.349**	**0.407**
Black-footed Albatross	-0.017	-0.047	-0.057	0.011	0.095
Black-legged Kittiwake	-0.140	-0.135	-0.257	-0.225	-0.229
Cassin's Auklet	-0.068	-0.048	-0.120	-0.072	-0.007
Common Murre	-0.072	-0.078	-0.122	-0.084	**-0.342**
Crested Auklet	0.084	0.121	-0.035	-0.110	-0.100
Fork-tailed Storm-Petrel	**0.915**	**0.914**	**0.738**	0.280	**0.349**
Horned Puffin	-0.102	-0.081	-0.160	-0.139	**-0.365**
Laysan Albatross	0.153	0.050	**0.359**	**0.411**	0.332
Least Auklet	**0.846**	**0.849**	**0.697**	0.199	**0.429**
Leach's Storm-Petrel	0.027	-0.067	**0.346**	**0.779**	0.138
Mottled Petrel	0.002	-0.051	0.250	-0.046	0.250
Northern Fulmar	-0.046	0.011	-0.189	-0.195	-0.153
Parakeet Auklet	**0.929**	**0.932**	**0.771**	0.279	0.307
Rhinoceros Auklet	-0.042	-0.043	-0.132	-0.104	-0.154
Slaty-backed Gull	-0.132	-0.094	-0.231	-0.145	0.020
Sooty Shearwater	0.067	0.014	0.299	-0.029	0.277
Short-tailed Shearwater	0.022	-0.046	0.158	-0.040	0.250
Thick-billed Murre	-0.117	-0.105	-0.196	-0.189	**-0.380**
Tufted Puffin	**0.461**	**0.459**	**0.339**	0.164	**-0.341**

c. species vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Hyperiidea
Ancient Murrelet	**0.815**	**0.901**	**0.828**	0.036	**0.972**	0.094
Black-footed Albatross	-0.068	0.023	-0.076	-0.051	-0.056	-0.091
Black-legged Kittiwake	-0.178	0.023	-0.190	-0.157	-0.144	-0.270
Cassin's Auklet	-0.068	-0.090	0.072	-0.065	-0.056	0.060
Common Murre	-0.112	0.122	-0.172	0.130	-0.084	-0.214
Crested Auklet	0.036	0.022	0.007	-0.109	0.111	0.082
Fork-tailed Storm-Petrel	**0.749**	**0.855**	**0.765**	0.018	**0.902**	0.062
Horned Puffin	-0.112	-0.028	0.251	-0.095	-0.079	-0.248
Laysan Albatross	0.085	0.100	0.057	-0.128	0.019	0.096
Least Auklet	**0.676**	**0.800**	**0.713**	0.000	**0.828**	0.116
Leach's Storm-Petrel	-0.062	-0.001	0.040	-0.116	-0.085	0.118
Mottled Petrel	0.096	-0.083	-0.007	-0.078	-0.068	0.277
Northern Fulmar	-0.097	-0.052	-0.006	-0.165	0.015	-0.146
Parakeet Auklet	**0.771**	**0.895**	**0.765**	0.011	**0.920**	0.058
Rhinoceros Auklet	-0.068	-0.090	-0.104	-0.065	-0.056	-0.091
Slaty-backed Gull	-0.142	-0.168	-0.019	-0.129	-0.103	0.018
Sooty Shearwater	0.145	-0.017	0.047	-0.079	-0.004	0.280
Short-tailed Shearwater	0.030	-0.001	-0.039	-0.109	-0.065	0.141
Thick-billed Murre	-0.136	0.011	-0.132	-0.099	-0.109	**-0.337**
Tufted Puffin	**0.377**	**0.375**	**0.342**	**0.474**	**0.442**	-0.161

22c. continued

	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Ancient Murrelet	**0.890**	**0.663**	**0.478**	**0.524**	**0.391**	**0.724**
Black-footed Albatross	-0.059	-0.087	-0.106	-0.032	-0.137	-0.006
Black-legged Kittiwake	-0.178	0.163	-0.143	-0.203	**-0.348**	-0.159
Cassin's Auklet	-0.059	-0.087	0.144	-0.085	-0.137	-0.140
Common Murre	-0.098	0.270	-0.146	-0.124	-0.226	0.002
Crested Auklet	0.065	0.007	-0.018	0.011	-0.182	-0.055
Fork-tailed Storm-Petrel	**0.800**	**0.602**	**0.414**	**0.418**	0.303	**0.663**
Horned Puffin	-0.098	0.040	-0.175	-0.140	-0.226	-0.100
Laysan Albatross	0.224	0.171	0.266	**0.416**	0.221	**0.349**
Least Auklet	**0.727**	**0.530**	**0.666**	**0.356**	**0.372**	**0.582**
Leach's Storm-Petrel	0.314	0.025	0.015	**0.701**	0.291	0.206
Mottled Petrel	-0.072	**0.406**	**0.497**	-0.044	0.203	**0.491**
Northern Fulmar	-0.069	-0.162	0.031	-0.123	-0.206	-0.102
Parakeet Auklet	**0.818**	**0.681**	**0.453**	**0.436**	0.296	**0.744**
Rhinoceros Auklet	-0.059	-0.087	-0.080	-0.097	-0.137	-0.140
Slaty-backed Gull	-0.124	-0.182	0.117	-0.158	-0.248	-0.258
Sooty Shearwater	-0.016	**0.440**	**0.513**	-0.016	0.223	**0.522**
Short-tailed Shearwater	-0.072	0.220	0.244	-0.054	0.063	0.298
Thick-billed Murre	-0.136	0.121	-0.194	-0.168	-0.293	-0.031
Tufted Puffin	**0.398**	0.257	0.068	0.154	0.090	**0.392**

Appendix 23. Bird-plankton correlations for MME 6, summer. N = 29 and $p < 0.05$ when critical value > 0.306.

a. general groups

	Net Primary Production	Chlorophyll-a	Zooplankton Abundance	Zooplankton Biomass	Zooplankton Diversity
Bird Density	0.107	0.049	**0.447**	0.004	0.293
Bird Diversity	-0.199	-0.223	**-0.561**	-0.096	**-0.466**

b. general vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Hyperiidea
Bird Density	0.233	0.276	-0.036	0.105	-0.021	-0.129
Bird Diversity	**-0.322**	**-0.462**	0.170	-0.086	-0.183	0.216

	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Bird Density	0.246	0.108	-0.075	0.010	0.044	**0.639**
Bird Diversity	**-0.376**	-0.281	0.119	-0.160	0.046	**-0.419**

23b. continued

	Net Primary Production	Chlorophyll-a	Zooplankton Abundance	Zooplankton Biomass	Zooplankton Diversity
Ancient Murrelet	-0.114	-0.071	-0.157	0.069	-0.191
Black-footed Albatross	**0.426**	**0.421**	0.093	-0.094	0.202
Black-legged Kittiwake	-0.049	0.062	**0.616**	0.104	**0.354**
Common Murre	-0.198	-0.186	-0.139	-0.055	-0.154
Crested Auklet	0.031	0.051	-0.035	0.002	0.186
Fork-tailed Storm-Petrel	-0.218	-0.160	0.091	**0.555**	0.010
Horned Puffin	-0.267	-0.204	**0.401**	0.031	0.131
Laysan Albatross	0.041	-0.077	0.160	-0.091	0.123
Least Auklet	-0.063	-0.054	0.178	**0.848**	0.084
Leach's Storm-Petrel	0.160	0.050	-0.022	-0.122	**0.331**
Mottled Petrel	-0.255	-0.198	-0.218	-0.014	-0.215
Northern Fulmar	**0.505**	**0.483**	0.177	-0.208	0.186
Parakeet Auklet	**-0.315**	-0.260	0.290	0.172	0.208
Rhinoceros Auklet	0.299	0.169	0.270	-0.085	0.113
Slaty-backed Gull	**0.352**	**0.384**	0.105	-0.033	0.231
Sooty Shearwater	0.161	0.214	-0.030	-0.116	0.123
Short-tailed Shearwater	0.088	-0.002	**0.594**	0.003	0.209
Thick-billed Murre	-0.176	-0.164	0.071	-0.073	-0.026
Tufted Puffin	-0.138	-0.144	-0.131	0.010	-0.023

c. species vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Hyperiidea
Ancient Murrelet	0.064	-0.156	-0.060	0.003	-0.060	0.053
Black-footed Albatross	-0.023	-0.105	-0.030	0.051	-0.092	-0.124
Black-legged Kittiwake	**0.525**	**0.598**	-0.105	0.217	0.132	-0.105
Common Murre	-0.167	-0.159	**0.346**	-0.104	-0.111	-0.086
Crested Auklet	0.148	-0.110	0.088	0.261	-0.060	0.014
Fork-tailed Storm-Petrel	**0.403**	0.011	-0.030	-0.053	**0.432**	**0.322**
Horned Puffin	0.209	**0.408**	0.158	-0.080	-0.021	-0.010
Laysan Albatross	0.286	-0.164	**0.472**	-0.003	-0.104	-0.141
Least Auklet	**0.374**	0.081	-0.039	0.085	**0.758**	**0.438**
Leach's Storm-Petrel	-0.115	-0.019	0.269	0.014	0.046	-0.040
Mottled Petrel	-0.171	-0.147	-0.114	**0.393**	-0.104	0.048
Northern Fulmar	0.088	-0.062	-0.058	-0.012	-0.192	-0.236
Parakeet Auklet	-0.075	**0.307**	0.197	-0.086	0.087	0.066
Rhinoceros Auklet	0.166	-0.024	-0.124	-0.030	-0.048	-0.133
Slaty-backed Gull	**0.687**	-0.132	-0.082	**0.384**	-0.081	-0.031
Sooty Shearwater	-0.103	0.053	0.185	-0.120	-0.073	-0.084
Short-tailed Shearwater	0.161	**0.458**	-0.122	-0.086	0.024	-0.171
Thick-billed Murre	-0.025	0.044	**0.541**	-0.186	-0.037	-0.194
Tufted Puffin	-0.130	-0.124	0.153	-0.005	-0.101	0.033

23c. continued

	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Ancient Murrelet	-0.141	-0.150	0.119	0.207	-0.236	0.015
Black-footed Albatross	-0.109	-0.103	-0.066	-0.135	-0.074	**0.382**
Black-legged Kittiwake	**0.685**	**0.748**	-0.030	0.243	-0.028	**0.312**
Common Murre	-0.113	-0.142	-0.074	0.059	-0.252	0.022
Crested Auklet	-0.079	-0.039	-0.036	-0.111	-0.118	0.127
Fork-tailed Storm-Petrel	-0.021	0.154	**0.501**	**0.558**	-0.279	0.150
Horned Puffin	0.014	-0.043	0.016	0.058	0.127	0.033
Laysan Albatross	-0.190	-0.175	0.184	-0.137	0.053	**0.619**
Least Auklet	0.145	0.190	-0.073	**0.662**	-0.218	0.057
Leach's Storm-Petrel	0.072	-0.079	0.005	-0.197	0.182	-0.078
Mottled Petrel	-0.105	-0.089	-0.072	-0.123	-0.035	-0.014
Northern Fulmar	-0.155	-0.078	-0.121	-0.237	0.082	**0.474**
Parakeet Auklet	0.137	0.059	**0.390**	0.224	-0.026	0.244
Rhinoceros Auklet	-0.069	-0.094	-0.046	-0.128	0.130	**0.629**
Slaty-backed Gull	-0.115	0.098	-0.055	-0.192	-0.105	**0.396**
Sooty Shearwater	0.102	0.066	-0.050	-0.135	0.045	-0.135
Short-tailed Shearwater	**0.397**	0.176	-0.076	0.109	0.159	**0.676**
Thick-billed Murre	0.096	0.081	-0.061	-0.010	-0.054	0.117
Tufted Puffin	-0.147	-0.140	0.174	0.061	-0.265	0.105

Appendix 24. Bird-plankton correlations for MME 6, fall. N = 22 and $p < 0.05$ when critical value > 0.352.

a. general groups

	Net Primary Production	Chlorophyll-a	Zooplankton Abundance	Zooplankton Biomass	Zooplankton Diversity
Bird Density	0.139	0.024	**0.401**	0.083	0.271
Bird Diversity	-0.010	-0.005	-0.135	0.254	-0.025

b. general vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida
Bird Density	-0.239	**0.394**	**0.394**	-0.103	-0.032	-0.076
Bird Diversity	0.262	-0.337	-0.232	0.018	0.249	0.138

	Hyperiidea	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Bird Density	-0.129	-0.153	-0.023	0.238	-0.037	0.119	0.217
Bird Diversity	0.304	0.346	0.242	0.044	0.139	-0.081	-0.081

24b. continued

	Net Primary Production	Chlorophyll-a	Zooplankton Abundance	Zooplankton Biomass	Zooplankton Diversity
Ancient Murrelet	0.061	0.091	-0.018	-0.080	0.066
Black-footed Albatross	0.173	0.105	-0.019	0.040	0.121
Black-legged Kittiwake	-0.049	0.105	-0.122	-0.249	-0.144
Common Murre	-0.158	-0.112	-0.296	-0.300	**-0.428**
Crested Auklet	0.014	0.098	-0.052	-0.064	0.038
Fork-tailed Storm-Petrel	-0.007	-0.040	-0.233	-0.118	-0.239
Horned Puffin	-0.137	-0.099	-0.219	0.274	0.115
Laysan Albatross	0.220	0.157	-0.073	-0.125	0.020
Least Auklet	-0.165	-0.236	0.185	**0.380**	**0.360**
Leach's Storm-Petrel	-0.028	-0.102	-0.273	-0.212	-0.122
Mottled Petrel	0.008	-0.088	0.069	-0.023	0.068
Northern Fulmar	-0.037	-0.088	-0.253	-0.252	-0.130
Parakeet Auklet	-0.307	-0.268	-0.070	-0.205	-0.206
Rhinoceros Auklet	0.339	0.142	0.202	0.024	0.138
Slaty-backed Gull	**0.377**	0.237	0.206	-0.028	0.099
Sooty Shearwater	-0.236	-0.110	-0.164	0.151	-0.032
Short-tailed Shearwater	0.111	0.006	**0.461**	0.169	0.302
Thick-billed Murre	-0.272	-0.122	-0.056	0.046	-0.320
Tufted Puffin	0.047	-0.032	-0.302	0.083	0.196

c. species vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida
Ancient Murrelet	-0.191	-0.065	-0.106	0.231	-0.104	-0.059
Black-footed Albatross	-0.303	0.120	-0.075	0.041	0.262	-0.022
Black-legged Kittiwake	-0.047	0.235	-0.248	0.074	-0.076	-0.186
Common Murre	-0.211	**-0.366**	-0.142	-0.132	-0.043	-0.107
Crested Auklet	-0.151	-0.172	-0.176	0.282	-0.116	-0.051
Fork-tailed Storm-Petrel	0.002	-0.009	-0.018	0.054	-0.239	-0.065
Horned Puffin	-0.104	-0.129	0.033	-0.242	**0.842**	-0.055
Laysan Albatross	-0.346	0.137	-0.189	0.325	-0.252	-0.074
Least Auklet	0.338	-0.134	0.272	0.005	-0.058	-0.097
Leach's Storm-Petrel	-0.220	-0.147	-0.238	-0.053	-0.129	**0.951**
Mottled Petrel	-0.261	0.097	0.224	-0.192	-0.022	-0.050
Northern Fulmar	0.068	-0.234	0.029	-0.070	-0.222	-0.007
Parakeet Auklet	0.194	-0.234	0.214	-0.290	-0.068	-0.110
Rhinoceros Auklet	-0.159	**0.418**	0.235	-0.129	0.057	-0.049
Slaty-backed Gull	-0.213	**0.425**	0.129	-0.049	-0.003	-0.074
Sooty Shearwater	-0.089	-0.052	-0.233	-0.181	**0.705**	-0.097
Short-tailed Shearwater	-0.202	**0.446**	**0.437**	-0.149	0.043	-0.059
Thick-billed Murre	-0.170	-0.152	-0.204	-0.246	**0.501**	-0.107
Tufted Puffin	**0.452**	**-0.434**	0.137	-0.236	0.059	0.173

	Hyperiidea	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Ancient Murrelet	0.067	-0.102	-0.107	-0.129	0.045	-0.204	0.236
Black-footed Albatross	0.004	-0.199	-0.153	-0.182	-0.063	-0.297	0.351
Black-legged Kittiwake	-0.254	0.061	-0.170	-0.217	-0.187	0.148	-0.115
Common Murre	-0.156	-0.186	-0.153	-0.171	-0.124	-0.070	-0.139
Crested Auklet	0.146	-0.089	-0.093	-0.111	0.120	-0.172	0.172
Fork-tailed Storm-Petrel	0.037	-0.070	-0.164	-0.144	-0.057	-0.077	-0.103
Horned Puffin	0.008	-0.156	-0.086	-0.007	-0.117	-0.201	-0.032
Laysan Albatross	0.025	0.235	-0.152	-0.149	0.081	-0.146	0.193
Least Auklet	0.228	**0.481**	**0.805**	**0.678**	-0.147	-0.076	-0.257
Leach's Storm-Petrel	-0.102	0.019	-0.113	-0.121	0.086	-0.107	-0.211
Mottled Petrel	-0.186	0.019	0.073	0.330	-0.100	-0.002	-0.135
Northern Fulmar	-0.118	-0.177	-0.107	-0.120	-0.038	-0.195	0.069
Parakeet Auklet	-0.247	-0.192	-0.041	-0.013	-0.143	0.125	-0.193
Rhinoceros Auklet	-0.148	-0.085	-0.089	-0.096	-0.083	-0.118	**0.429**
Slaty-backed Gull	-0.134	-0.123	-0.135	-0.155	-0.067	-0.097	**0.466**
Sooty Shearwater	-0.034	-0.087	-0.174	-0.129	-0.073	-0.045	-0.027
Short-tailed Shearwater	-0.111	-0.101	0.043	0.340	-0.037	0.209	0.125
Thick-billed Murre	-0.056	-0.148	-0.115	-0.112	-0.161	0.264	-0.190
Tufted Puffin	0.217	-0.128	0.102	0.014	0.152	**-0.469**	-0.015

Appendix 25. Summary of MMEs for which the cross-correlation coefficient for plankton-plankton correlations was significant.

a. general vs. species

	Zooplankton Diversity	*Acartia sp.*	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida
Zooplankton Biomass	3	3		2		3, 6	
Zooplankton Diversity		2, 3, 4, 6	4, 6	4, 6	1, 5	3, 5, 6	3

	Hyperiidea	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Zooplankton Biomass	3, 4, 6			1	1, 2, 3, 4, 5, 6		1, 4
Zooplankton Diversity	3, 6	3, 6	2, 4, 5, 6	4, 6		5	2, 6

b. species vs. species

	Calanus sp.	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida	Hyperiidea
Acartia sp.	4	1, 4	6	1, 3	1	3
Calanus sp		4				1, 4
Chaetognatha				1, 2, 4	3	2, 4, 5
Eucalanus sp.						
Euphausiacea						3, 4, 6

	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Acartia sp.		4, 6			1, 5	2, 3, 5, 6
Calanus sp	3, 4, 6	3, 6	4	2, 6	5, 6	6
Chaetognatha	6	1, 4, 6	4,6	2		
Eucalanus sp.			3		3	2
Euphausiacea	5	1, 5, 6	4	6		3
Harpacticoida	3				1, 2	
Hyperiidea			4			3, 6
Larvacea		6	6	6		
Limacina helicina			6	6	5	
Metridia sp.				1, 3		
Neocalanus sp.						4
Oithona sp.						3, 4, 5
Paracalanus/Pseudocalanus sp.						1

Appendix 26. Summary of MMEs for which the cross-correlation coefficient for bird-bird correlations was significant.

a. general vs. species

	Ancient Murrelet	Black-footed Albatross	Black-legged Kittiwake	Cassin's Auklet	Common Murre	Crested Auklet	Fork-tailed Storm-Petrel	Horned Puffin	Laysan Albatross	Least Auklet
Bird Density	2, 6	1, 2, 4	3, 4	1	2, 4	4, 6	2, 3		6	4
Bird Diversity	1		2					2	3, 4	

	Leach's Storm-Petrel	Mottled Petrel	Northern Fulmar	Parakeet Auklet	Rhinoceros Auklet	Slaty-backed Gull	Sooty Shearwater	Short-tailed Shearwater	Thick-billed Murre	Tufted Puffin
Bird Density	2	3	1, 2, 3, 5, 6	2, 4, 6	6	6	2, 3, 5	5, 6		3, 6
Bird Diversity					1		3			

b. species vs. species

	Black-footed Albatross	Black-legged Kittiwake	Cassin's Auklet	Common Murre	Crested Auklet	Fork-tailed Storm-Petrel	Horned Puffin	Laysan Albatross	Least Auklet
Ancient Murrelet	2, 4, 6		5	1, 2	6	5, 6	5		4, 5, 6
Black-footed Albatross			1, 4	2, 6		1, 4	5	3, 6	4
Black-legged Kittiwake				4	4				
Cassin's Auklet						5			5
Common Murre					4				
Crested Auklet									
Fork-tailed Storm-Petrel							3, 4, 6	2, 3	5

26b. continued

	Leach's Storm-Petrel	Mottled Petrel	Northern Fulmar	Parakeet Auklet	Rhinoceros Auklet	Slaty-backed Gull	Sooty Shearwater	Short-tailed Shearwater	Thick-billed Murre	Tufted Puffin
Ancient Murrelet			2	2, 3, 4, 6	1, 5	5			1	5, 6
Black-footed Albatross	5		1, 2, 4	2				4		1, 4
Black-legged Kittiwake			3, 5	2, 5	2		1		2, 4, 6	2
Cassin's Auklet			2, 4	1, 2	5	5, 6		4	3, 4	5
Common Murre					1		1		1, 4, 6	
Crested Auklet				4, 6		6			5	6
Fork-tailed Storm-Petrel	1, 2, 4	3	1, 3, 4	6	2, 5	5	2			3, 4, 5, 6
Horned Puffin	3, 4, 5				2				2	2, 4, 5
Laysan Albatross	2	3	6	2	6			6	5	4
Least Auklet				4, 6	5	5				5
Leach's Storm-Petrel			5				2, 6			4
Mottled Petrel							3			
Northern Fulmar				2, 5	6	6		4, 5, 6		1, 3, 4
Parakeet Auklet					2				2	2, 6
Rhinoceros Auklet						5	1	6	1, 2	2, 5
Slaty-backed Gull										5
Sooty Shearwater								5	1	
Short-tailed Shearwater										4
Thick-billed Murre										2

Appendix 27. Summary of MME regions and seasons for which the cross-correlation coefficient for bird-plankton correlations were significant. W=West=MME 6 and E=East=MME 1-4 combined. 1=spring, 2=summer, and 3=fall. For example, E-1,2, W-3 means the correlations between those species were significant in MME 1-4 during spring and summer, and MME 6 in the fall.

a. general groups

	Net Primary Production	Chlorophyll-a	Zooplankton Abundance	Zooplankton Biomass	Zooplankton Diversity
Bird Density	E-2,3, W-1	E-3,	E-3, W-2,3		
Bird Diversity	E-3	E-3	E-1, W-2	E-1	E-1, W-2

b. general vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida	Hyperiidea
Bird Density	E-3	W-3	W-3		E-3		
Bird Diversity	W-2	W-2	W-1				

	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Bird Density	E-2				E-3	E-3, W-2
Bird Diversity	W-2				E-2	E-1, W-2

27b. continued

	Net Primary Production	Chlorophyll-a	Zooplankton Abundance	Zooplankton Biomass	Zooplankton Diversity
Ancient Murrelet	W-1	W-1	W-1	W-1	E-2, W-1
Black-footed Albatross	E-2,3	E-3, W-2	E-3		
Black-legged Kittiwake	E-1	E-1	W-2		W-2
Cassin's Auklet	E-2,3	E-2,3	E-3		
Common Murre					W-1,3
Crested Auklet					E-1
Fork-tailed Storm-Petrel	E-2, W-1	E-2, W-1	E-1, W-1	W-2	E-2, W-1
Horned Puffin			W-2		E-2, W-2
Laysan Albatross			E-1		E-2
Least Auklet	W-1	W-1	E-1, W-1	W-2,3	W-1,3
Leach's Storm-Petrel	E-1-3	E-2,3	W-1	E-1, W-1	W-2
Mottled Petrel	E-3				E-1
Northern Fulmar	W-2	W-2			
Parakeet Auklet	W-1,2	E-2, W-1	E-1, W-1		E-2
Rhinoceros Auklet	E-3, W-2	E-2,3	E-3	E-2	
Slaty-backed Gull	W-3				
Sooty Shearwater	E-1,3, W-2	E-1,3, W-2	E-3		
Short-tailed Shearwater			E-1,2, W-3		
Thick-billed Murre	E-3	E-3	E-3, W-2		W-1
Tufted Puffin	W-1	W-1	W-1		E-1,2, W-1

c. species vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Harpacticoida
Ancient Murrelet	W-1	W-1	W-1	E-3	W-1	
Black-footed Albatross	E-3				E-3	
Black-legged Kittiwake	W-2	W-2				
Cassin's Auklet	E-3		W-2		E-3	E-2
Common Murre		W-3	E-1			
Crested Auklet						
Fork-tailed Storm-Petrel	W-1,2	E-1, W-1	W-1		W-1,2	
Horned Puffin		W-2			E-3	
Laysan Albatross			W-2			
Least Auklet	W-1,2	W-1	W-1		W-1,2	
Leach's Storm-Petrel	E-3			E-3		W-3
Mottled Petrel				W-2		
Northern Fulmar						
Parakeet Auklet	W-1	W-1,2	W-1		W-1	
Rhinoceros Auklet	E-2,3	W-3	E-1		E-3	
Slaty-backed Gull		W-3	E-1			
Sooty Shearwater	E-3, W-2			W-2	E-3, W-3	
Short-tailed Shearwater	E-1	W-3	W-3			
Thick-billed Murre	E-3	W-2	E-1		E-1,3, W-3	
Tufted Puffin	W-1,3	W-1,3	W-1,2	W-1	W-1	

27c. continued

	Hyperiidea	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*	*Oithona sp.*	*Paracalanus/ Pseudocalanus sp.*
Ancient Murrelet		W-1	W-1	W-1	W-1	W-1	W-1
Black-footed Albatross						E-3	E-3, W-2
Black-legged Kittiwake		W-2	W-2			W-1	W-2
Cassin's Auklet						E-3	E-3
Common Murre							
Crested Auklet							
Fork-tailed Storm-Petrel	W-2	W-1	E-3, W-1	E-3, W-1,2	W-1,2	E-1	W-1
Horned Puffin			E-3				
Laysan Albatross					E-1, W-1	E-1	W-1,2
Least Auklet	W-2	W-1,3	W-1,3	W-1,3	E-1, W-1,2	E-1, W-1	W-1
Leach's Storm-Petrel		E-2	E-2		E-1		
Mottled Petrel			W-1	E-3, W-1			W-1
Northern Fulmar			E-3				W-2
Parakeet Auklet		W-1	E-3, W-1	W-1,2	W-1	E-1	W-1
Rhinoceros Auklet					E-2	E-3	E-2,3, W-2,3
Slaty-backed Gull							W-3
Sooty Shearwater		E-2	W-1	W-1		E-3	E-3, W-1,2
Short-tailed Shearwater			E-3			E-2	E-1
Thick-billed Murre	W-1	W-2				E-3	E-2,3, W-2
Tufted Puffin		W-1		E-3		W-3	W-1

Appendix 28. Summary of MME regions and seasons for which the correlation coefficient for bird-plankton pairwise correlations were significant. Only positive values were used. W=West=MME 6 and E=East=MME 1-4 combined. 1=spring, 2=summer, and 3=fall. For example, E-1,2, W-3 means the correlations between those species were significant in MME 1-4 during spring and summer, and MME 6 in the fall.

a. general groups

	Bird Density	Bird Diversity	Net Primary Productivity	Chlorophyll-a	Zooplankton Abundance	Zooplankton Biomass
Bird Diversity	W-2,3					
Net Primary Productivity	E-2,3	E-3				
Chlorophyll-a	E-3	E-3	W-1-3, E-1-3			
Zooplankton Abundance	W-2, E-3	W-2, E-1	W-1,3, E-3	W-1,3, E-3		
Zooplankton Biomass			W-1,3, E-3	W-1, E-2,3	W-1,3, E-1	
Zooplankton Diversity		W-2, E-1	W-1	W-1	W-1,2	W-3, E-3

b. general vs. species

	Bird Density	Bird Diversity	Net Primary Productivity	Chlorophyll-a	Zooplankton Abundance	Zooplankton Biomass	Zooplankton Diversity
Acartia sp.	E-3			W-2	E-2,3		E-3
Calanus sp.	W-1	W-2	W-1	W-1,3	W-1-3		W-1
Chaetognatha	W-3	W-1	W-1	W-1	W-1	W-1,3	W-3
Eucalanus sp.			W-2				
Euphausiacea	W-1		W-1, E-3	W-1, E-3	W-1, E-2	W-2,3, E-3	W-1, E-2
Hyperiidea			W-3, E-1	W-3, E-1	W-3	W-2,3	W-3
Larvacea	W-2				W-2		W-3
Limacina helicina	W-2	W-2			W-2, E-3	W-2,3	
Metridia sp.		E-1	W-1	W-1	W-1	W-3, E-1	W-1,3, E-2
Neocalanus sp.		E-2	W-1,3, E-2	W-1,3, E-2	W-1,2, E-1	W-1,2, E-1,2	
Oithona sp.	E-3	E-2,3	E-3	E-2,3	W-1,3, E-1-3		W-3
Paracalanus/ Pseudocalanus sp.	W-2, E-3	E-1	W-1,3, E-2,3	W-1,3, E-2,3	W-1-3, E-1-3	W-3, E-2	W-1
Ancient Murrelet		E-2	W-1	W-1	W-1		W-1
Black-footed Albatross	W-3, E-2,3		E-3	E-3	E-3		
Black-legged Kittiwake	E-1	W-2	E-1	W-2, E-1	W-2	W-2	W-2
Cassin's Auklet	E-3				E-3		
Common Murre							W-3
Crested Auklet	W-1,2						
Fork-tailed Storm-Petrel	W-1, E-2		W-1, E-2	W-1, E-2	W-1, E-2	W-1,2	W-1
Horned Puffin	E-2,3			E-2	E-2	W-3	
Laysan Albatross	E-1	E-3		E-1		E-1	
Least Auklet			W-1	W-1	W-1	W-2,3	W-1
Leach's Storm-Petrel	W-1, E-2,3	W-1, E-3	W-1, E-1-3	W-1, E-2,3	W-1, E-2	W-1	W-2
Mottled Petrel	W-1,3, E-2	W-3					
Northern Fulmar	W-1,2	W-1-3, E-2	W-2	W-2			
Parakeet Auklet	W-2, E-1,2		W-1	W-1, E-1	W-1, E-1	W-1, E-1	
Rhinoceros Auklet	W-2, E-1,3			E-2	E-3	E-2	
Slaty-backed Gull	W-3					W-2	
Sooty Shearwater	E-1-3		E-1,3	E-1,3	E-3		
Short-tailed Shearwater	W-2,3	W-2,3			W-2,3, E-2		
Thick-billed Murre		W-2					E-2
Tufted Puffin	W-2, E-3	E-2	W-1	W-1			

c. species vs. species

	Acartia sp.	*Calanus sp.*	Chaetognatha	*Eucalanus sp.*	Euphausiacea	Hyperiidea	Larvacea	*Limacina helicina*	*Metridia sp.*	*Neocalanus sp.*
Calanus sp.										
Chaetognatha		W-1, E-3								
Eucalanus sp.										
Euphausiacea		W-1	W-1	W-1, E-1,2						
Hyperiidea		E-3			E-2					
Larvacea		W-2								
Limacina helicina					W-2					
Metridia sp.	E-3	W-2	W-3		W-1, E-2	E-2	W-3			
Neocalanus sp.			W-1	E-2	W-2	W-2,3	W-2	W-2	W-2, E-1	
Oithona sp.	E-3	W-3		E-1	E-3				E-2	
Paracalanus/ Pseudocalanus sp.	E-1,3	W-1	W-1		W-1, E-3	W-3	W-2		W-1,2, E-3	W-3, E-2
Ancient Murrelet		W-1	W-1		W-1	W-1			W-1, E-3	
Black-footed Albatross	E-3									
Black-legged Kittiwake										
Cassin's Auklet	E-3									
Common Murre			E-1			E-1				
Crested Auklet	W-2									
Fork-tailed Storm-Petrel		W-1	W-1		W-1			E-3	W-1	W-1,2
Horned Puffin					W-3					
Laysan Albatross			W-2							E-1
Least Auklet		W-1	W-1,3	W-2	W-1,2				W-1,3	W-2
Leach's Storm-Petrel			W-1	W-2						W-1
Mottled Petrel		E-2				E-1				
Northern Fulmar								E-3		
Parakeet Auklet	E-1	W-1, E-3	W-1		W-1	E-1		W-1,2		W-1, E-1
Rhinoceros Auklet	E-3	W-2	E-1		E-2				E-2	E-2
Slaty-backed Gull			W-3						W-1,3	
Sooty Shearwater	E-3		E-1		W-3, E-3			E-3	E-3	
Short-tailed Shearwater		W-3	W-3				W-2	W-2		W-1
Thick-billed Murre	W-3	W-2, E-1	W-2, E-1						W-1	
Tufted Puffin	W-3	W-1	W-1	W-1	W-1		W-2			

28c. continued

	Oithona sp.	*Paracalanus/ Pseudocalanus sp.*	Ancient Murrelet	Black-footed Albatross	Black-legged Kittiwake	Cassin's Auklet	Common Murre	Crested Auklet	Fork-tailed Storm-Petrel	Horned Puffin
Paracalanus/ Pseudocalanus sp.	E-2,3									
Ancient Murrelet		W-1								
Black-footed Albatross	E-3	W-3, E-3	E-1							
Black-legged Kittiwake										
Cassin's Auklet	E-1	E-3	E-1	E-3						
Common Murre		E-1								
Crested Auklet			W-2							
Fork-tailed Storm-Petrel	E-1	W-1, E-2	W-1, E-1	E-2						
Horned Puffin		E-1	W-2	W-3, E-3					E-2,3	
Laysan Albatross		W-2	E-1		E-3				E-1	
Least Auklet		W-1	W-1		W-2		W-3		W-1,2	
Leach's Storm-Petrel	E-3	E-2	E-3	E-1,2					E-2	E-2
Mottled Petrel	W-3, E-3	W-1			W-3		W-3			
Northern Fulmar	E-1	W-2	E-1	E-1				W-1	W-3, E-1,3	E-3
Parakeet Auklet		W-1						W-2	W-1,3	
Rhinoceros Auklet		W-2, E-3		E-3		E-3	E-1			
Slaty-backed Gull	W-1	W-1							W-2	
Sooty Shearwater	E-3	E-3		E-3	E-1,2	E-3	E-1			W-3
Short-tailed Shearwater	E-2	W-2			E-2				E-3	
Thick-billed Murre	E-1	W-2,3			W-1					E-2
Tufted Puffin	E-1	W-1	W-1,2					W-2	W-1, E-1-3	E-2,3

28c. continued

	Laysan Albatross	Least Auklet	Leach's Storm-Petrel	Mottled Petrel	Northern Fulmar	Parakeet Auklet	Rhinoceros Auklet	Slaty-backed Gull	Sooty Shearwater	Short-tailed Shearwater	Thick-billed Murre
Least Auklet											
Leach's Storm-Petrel	E-2										
Mottled Petrel			E-2								
Northern Fulmar	W-2										
Parakeet Auklet	E-1,3	W-1	W-2								
Rhinoceros Auklet			W-2		E-3						
Slaty-backed Gull											
Sooty Shearwater			W-2	E-2,3		E-1,2	E-1,3				
Short-tailed Shearwater	W-1,2	W-3		W-3, E-3	W-2, E-3	W-1	W-2				
Thick-billed Murre	W-2										
Tufted Puffin					E-2,3	W-2			E-1,3		E-1