A Comparison of Seabird Abundance in Three Inlets in Nootka Sound, British Columbia: Muchalat, Zeballos, & Tahsis

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Abstract

It is becoming increasingly important to conduct seabird surveys to track how populations are changing, and how the environment is changing. There has been little research on the density and abundance of seabirds in coastal Canadian waters. Seabird abundance surveys were made aboard the R/V *Welander* that was launched from the R/V *Thomas G. Thompson* from 14-16 December 2015, in three inlets of Nootka Sound, British Columbia, Canada. Tahsis inlet provided the highest count of birds per hour (503 birds/hr), followed by Muchalat (224 birds/hr) and Zeballos (136 birds/hr). Ducks were the leading category of seabirds found in all three inlets followed by gulls. This study's purpose is to give other researchers a baseline so that more studies like this can be done in this region.

Introduction

The changing role of seabirds in the global marine ecosystem is key to understanding change in our oceans. They indicate the health and productivity of our oceans because they are strongly influenced by climate and anthropogenic driven threats (Paleczny et al. 2015). Compared to terrestrial species, marine bird species are more globally threatened, with declines of 70% in the last 60 years (Sollmann et al. 2015). It is becoming increasingly important to conduct seabird surveys to track how populations are changing, and how the environment is changing. Fisheries Biologist Daniel Pauly coined the term “shifting baselines syndrome”. It is the idea that humans measure change based on a short-term view because of their lack of knowledge of past conditions (Campbell et al. 2009). This idea emphasizes the importance of doing abundance studies because it gives future scientists the resources to understand how our ecosystem is evolving.

There are several parameters changing in our oceans that have the potential to negatively affect seabirds. One of the most notable includes climate change. Fossil fuel combustion produces an extensive amount of atmospheric carbon dioxide, which in turn alters global climate patterns. This has huge implications for the future of seabirds because it can have indirect trophic effects facilitated by other species, as well as direct effects, which can change the organism physiologically (Frederikson & Haug, 2015). One specific climate driven factor impacting marine birds and other top predators includes El Niño. At the time of the study, the Pacific Ocean was undergoing El Niño anomalies in which the sea surface temperatures were much warmer than average. A rise in sea surface temperatures negatively impacts zooplankton, fish abundance and crab stock, which are all prey for seabirds. During the 1983 El Niño event, zooplankton density was 30% that of non-El Niño years (Miller et al., 1985). This may have negative consequences on nesting success for seabirds due to reduced food supply. On the Washington coast, after the 1983 El Niño event, Double-Crested Cormorants were occupying fewer nests than during non-El Niño years because of their decrease in population (Wilson, 1991).

There has been little research on the density and abundance of seabirds in coastal Canadian waters. Much effort on bird research has been focused on terrestrial birds because of their accessibility compared to seabirds. Hay (1992) did seabird abundance surveys on the western coast of Vancouver Island with transects very close to Nootka Sound. Hay made several observations based on the data he collected. Seabirds were concentrated seaward of the shelf break, around sharp irregularities in the shelf, and in areas with strong tidal currents. He also found that seabird abundance was positively correlated with zooplankton concentrations. Overall, seabird abundance was patchy, which made sense due to the fact that their prey is also patchy.

Seabirds can be classified into different categories in terms of occupied habitat. Pelagic seabirds, such as albatrosses, are found spending the majority of their lives in the open ocean. Coastal seabirds, such as ducks, are found spending the majority of their lives in coastal waters. There are also water birds that are adapted to living in fresh and brackish waters, such as herons. Seabirds breed in large colonies, usually on islands, and migrate afterwards to areas with high productivity. They spend nearly all of their time at or above the sea surface and all of their food comes from the ocean (Oro et al.). The types of marine birds commonly found around coastal Canadian waters include waterfowl, cormorants, auklets, and herons. These birds have different feeding strategies and follow unique migratory patterns. Having insight on the life history of these birds can give us an understanding of their preferred habitat.

Nootka Sound, B.C., Canada is a fjord estuary located on the west coast of Vancouver island and comprises several inlets including, Muchalat, Zeballos, and Tahsis. There are riverine inputs in all three inlets, Gold River in Muchalat, Tahsis River in Tahsis, and Zeballos River in Zeballos. The wintertime in this region is fairly benign with frequent rain and temperatures between 4°C and 10°C. These inlets provide suitable habitats for seabird colonies such as Mergansers, Cormorants, Murrelets, and Goldeneyes. Past studies have indicated that these inlets are different from one another in terms of average temperature, salinity, and oxygen saturation (Koehlinger, 2015). They also vary in zooplankton abundance, and diversity (Pelle, 2015). These varying oceanographic properties can influence seabird habitat preference.

In the winter months seabirds spend their time feeding and bulking up so that they are ready for mating season when the weather gets warmer. This is the best time to study them because they are easily accessible. The birds seen during this study either spend their time in B.C. to winter, or are stopping by mid-migration on their way to their wintering areas. These birds have become adapted to a specific set of oceanic conditions that Nootka Sound provides. These oceanic conditions are associated with average salinity, nutrient concentrations, productivity, and many others. Seabirds rely on an abundant food source during this time, which could be shifted and altered by these same oceanic conditions. They rely heavily on circulation and upwelling to bring nutrients to the surface to provide for the lower trophic levels that the birds feed on. Estuarine circulation is when saline water coming from the ocean enters at depth and upwells and mixes with freshwater coming from river input (Geyer & Cannon, 1982). These inlets are an ideal location for upwelling to occur because they are narrow and have a constant source of oceanic and river water.

In terms of the three inlets incorporated in Nootka Sound, there have been no abundance surveys on seabirds in these locations. This study provides information on different species of seabirds living in Nootka Sound, and their general abundance in each of the inlets. Oceanographic data was collected to try and explain why these species are found here, and why seabirds may prefer one inlet to another. Most importantly, it gives future seabird biologists and ecologists the resources to track our ever-changing oceans in the technique of seabird surveys.

Methods

Abundance Surveys

Seabird abundance surveys were made aboard the R/V *Welander* that launched from the R/V *Thomas G. Thompson* from 14-16 December 2015, in three inlets of Nootka Sound, British Columbia, Canada. Surveys were always done in the early afternoon due to sufficient sunlight. Rather than following a transect, the R/V *Welander* followed the coastline for 1.25 to 1.33 hours. A general reference guide from Bird Studies Canada with a list of common seabird species found in B.C. Canada was used during every survey (birdscanada.org). Seabird census was conducted in a similar manner of Hay (1992).

1. Birds were counted and identified in a 180 degree field forward, and to approximately 1 km to the left and right of the boat. The R/V *Welander* was moving at a speed of about 8 knots.

2. Observations were done using Bushnell 10x50 binoculars with an observer on each side of the bow.
3. Bird counts were recorded non-stop during the entire transect. All birds were classified by species level.
4. Surveys were not conducted in heavy fog & rain.

Other Data Sampled

A Seabird CTD with 24 10 liter rosette bottles took measurements of temperature, salinity, pH, and dissolved oxygen concentration data at several different stations throughout each inlet (Figure 1, Table 2). Additional salinity measurements were taken in the R/V *Welander* using a YSI 556 meter at several stations per inlet. The meter was lowered over the side of the boat at about a meter deep. At stations marked in red (Fig 1.) nutrient samples were collected from the rosette bottles by filtering water through a 0.45 syringe filter into a 60 mL bottle. These samples were frozen and transported back to the University of Washington for analysis. The School of Oceanography's Marine Chemistry Lab used a Technicon AAII System to analyze the samples. Nitrate values were used for this study because it is the most likely to be a limiting nutrient compared to the others. Fluorescence data was also collected from the R/V *Thomas G. Thompson's* DAS system. This system collects data at intervals of 1 sample every 2 seconds using sensors 2 meters below the ship that can detect surface fluorescence.

Results

Abundance

Seabird abundance varied among the three inlets (Table 1). All birds observed were listed in the Bird Studies Canada reference guide. 20 out of 69 species of seabirds from the reference guide were seen in the inlets. A total of 1.35 hours were spent in Zeballos, 1.33 hours in Tahsis, and 1.77 hours in Muchalat. A higher number of seabirds were found in Tahsis (671) versus the other two inlets. In order to normalize the data, the average density of seabirds was calculated per inlet (Figure 2). Tahsis inlet provided the highest count of birds per hour (503 birds/hr), followed by Muchalat (224 birds/hr) and Zeballos (136 birds/hr). Seabirds were then separated into eight different categories; herons/egrets, gulls, ducks, cormorants, auks/murres/puffins, swans, grebes/loons, other. Once categorized, counts were averaged throughout the three inlets and plotted (Figure 3). Orders of variance were measured using standard deviation. The plot shows (with statistical significance due to the non-overlapping standard deviation) that ducks were the leading category of seabirds found in all three inlets followed by gulls.

Salinity

Surface salinity values were taken from all stations in each inlet (Figure 1, Table 2). An isosurface plot was created using Ocean Data View (ODV) with values ranging from 0.05 PSU to 29.8 PSU (Figure 4). Values were lowest near river inputs (Gold River, Tahsis River and Zeballos River). Values were highest near the mouths of inlets where there is salt-water input from the Pacific Ocean.

Fluorescence

Surface fluorescence values were taken from the R/V *Thomas G. Thompson's* DAS system on the three days seabird surveys were conducted. An isosurface plot was created using ODV with values ranging from 1.7 mg/m^3 to 2.1 mg/m^3 (Figure 5). Values were fairly consistent throughout the inlets with an exception in Zeballos where values reached 2.1 mg/m^3. There was also a point of relatively higher surface fluorescence near the mouth of Muchalat inlet (49°39'25.17"N, 126°25'0.50"W).

Nutrients

Surface nitrate values were taken from stations marked in red throughout Muchalat and Tahsis inlets (Figure 1). This data is absent in Zeballos because water samples were not collected in this inlet. An isosurface plot was created using ODV with nitrate values ranging from 3.81 µmol/L to 11.93 µmol/L (Figure 6). Tahsis inlet shows [NO_3^-] values from 8.58 – 11.93 µmol/L while Muchalat values are from 3.81 – 7.6 µmol/L. Nutrient values are absent in Zeballos because water samples were not taken at these stations.

Discussion

There are many different physical and biological factors that may influence whether a seabird species spends their time in a particular area. Marine birds are termed as a "K-selected" species. This means that they are "relatively long-lived, have delayed reproductive maturity, and low reproductive output" (Ballance et al. 2006). Therefore, oceanographic factors will influence their reproductive output rather than their survivability. These factors are important to consider with their wintering grounds because this is where they are prepping themselves for reproduction.

It is not surprising that the majority of the seabirds found in Nootka Sound were waterfowl. In the winter months, waterfowl form large feeding flocks in areas with accessible prey (Zipkin et al. 2014). They spend very little of their time flying like other seabirds. This creates an observer bias because they are much easier to see than other birds. Nootka Sound presents a great habitat for foraging sea ducks therefore it is understandable that they are frequently seen there.

Surface salinity has many different implications for seabirds and the organisms seabirds prey on. The drainage area for Gold River in Muchalat is 1010.0 km^2, which is much higher than the Tahsis (77.4 km^2) and Zeballos (189.1 km^2) rivers (Jackson & Cook, 1999). Salinity values in Muchalat are much lower than Tahsis and Zeballos because of this large freshwater flux (Figure 4). This large input creates extensive turbulence and mixing so the fresher water may be a little bit lower than the surface. Studies have shown that piscivores prefer areas of low surface salinity compared to planktivores (Ballance et al. 2006). Piscivore species found during this study include mergansers, cormorants, murrelets, grebes, loons, bald eagles, and king fishers. Mergansers were the only piscivorous bird that was found more abundant in Muchalat than the other inlets. This means that there must be some other factor that inhibits piscivorous seabirds from living in Muchalat. The most abundant species in Muchalat was the Common Goldeneye who are open water divers that feed on the benthos. A past study done in Nootka Sound looked at the benthic community in Muchalat and found that there was a large population of *Mytilus*, a mussel highly preyed upon by ducks and other diving seabirds. They believed that there are more mussels present in Muchalat because their major predator, the sea star, cannot live in low saline environments (Morris, 2015**)**. The low saline environment allows some species of aquatic organisms to thrive, while others do not. Therefore, the food web in Muchalat is altered because of the less briny waters, which favors some species of seabirds but not others.

Surface fluorescence has been long used as a means of assessing phytoplankton biomass. Fluorescence is emitted from the chlorophyll molecule within a phytoplankton cell when excited by light, therefore with higher fluorescence comes high biomass of phytoplankton. Looking at figure 5, there is not much fluctuation of fluorescence in Muchalat and Tahsis inlets. There is a small peak at around 49°39'25.17"N, 126°25'0.50"W near the mouth of Muchalat inlet. There is a small fisheries located in this area but it is not operated in the wintertime so it wouldn’t have been a source of nutrients for phytoplankton. There are also overall much higher fluorescence values in Zeballos inlet than the other two inlets. If there is high phytoplankton biomass it is fair to make the assumption that the area is productive, and it should also yield high counts of zooplankton compared to the other inlets. Planktivorous waterbirds seen during this study include dabbling ducks such as mallards and wood ducks, and dabbling geese such as the trumpeter swan. You would assume with a highly productive inlet with high phytoplankton and zooplankton abundance you would see a lot of dabbling ducks and geese. This is not the case in this study because Zeballos not only yielded the smallest count of seabirds compared to the other two inlets (Fig 2), but it was also particularly low in mallards, wood ducks, and trumpeter swans. This implies that there must be something making Zeballos an unfit habitat for seabirds that isn’t related to high primary production or that the birds were just not spending time in Zeballos during the survey. A reason for Zeballos being an unfit habitat could be interspecies competition between seabirds and other higher trophic level animals that feed on the same prey. During surveying for this study we saw several young California sea lions that may be the source of competition for these seabirds.

High nutrient levels are indicative of a productive ecosystem and therefore a fit habitat for seabirds. Phytoplankton use nutrients in the Redfield ratio (106:16:1) to photosynthesize. With high nutrients more photosynthesis can occur, therefore higher phytoplankton abundance, zooplankton abundance, and fish abundance. Since birds feed on zooplankton and fish they prefer to live in areas with high nutrients. Figure 6 shows that values for surface nitrate in Muchalat were overall lower than in Tahsis. There was also a much higher biomass of seabirds seen in Tahsis inlet than in Muchalat inlet (Fig 2). There are many different factors influencing nutrient concentrations in estuaries. One notable factor that could be the reason why Tahsis has higher nutrient values than Muchalat is its proximity to a town. Runoff coming from active towns may reach its way to the surface waters carrying large amounts of organic and inorganic matter (Baranová et al. 2015). This can either provide valuable nutrients to the organisms living in this body of water, or it can pollute it.

To explore the nitrate values further, depth profiles using ODV were made for nitrate in these two inlets (Fig 7). Although surface nitrate may be higher in Tahsis, the two inlets follow similar trends: increasing nitrate concentration with depth. In order for the nutrients at depth to be utilized by the phytoplankton, it must be upwelled to the surface. Genevieve Hinde, another student researcher on the cruise, observed downward isopycnals which indicated downwelling. She also looked at turbidity in Muchalat inlet and saw that there was higher light transmission, which means that light was not a limiting factor for phytoplankton (Hinde, 2016). This leads us to believe that surface nutrient concentration could have limited phytoplankton growth, therefore making Muchalat an unfit environment for seabirds. The fluorescence values did not reflect this hypothesis which is why zooplankton net tows could have been a helpful tool during this study.

In order to get a better grasp of nutrients in Tahsis and Muchalat the surface nitrate and phosphorous concentrations were plotted against each other to get a ratio between the two (Figure 8). The ratio of nitrate to phosphorous throughout the water column was about 8:1. This is indicative of Nootka Sound trending toward an oligotrophic body of water. This has significant implications for the phytoplankton and zooplankton community. In oligotrophic waters, microzooplankton dominate the surface waters and control phytoplankton biomass (Zhou et al. 2015). Microzooplankton provide less of a caloric value for seabirds because they are smaller. They also provide less caloric value for the fishes that seabirds prey on. This may impact whether the birds will inhabit these inlets.

This study did not focus on sampling seabird prey such as fish and zooplankton. A study done in Nootka Sound in 2014 looked at zooplankton biomass in Tahsis and Muchalat inlets during the same time of year that this study was done (Pelle, 2015). He found areas in Tahsis inlet with much higher zooplankton densities (>1000 organisms m^{-3}) than in Muchalat (<330 organisms m^{-1}). He also found that densities were highest at the surface. Birds will be present in higher numbers in areas with larger prey abundance and easier prey accessibility. This may be evidence that Tahsis is more productive and therefore a more suitable environment for seabirds.

Conclusion

It is becoming increasingly more important to study seabird abundance while our oceans are changing so drastically. This study provides a baseline for future research on Nootka Sound and other bodies of water similar to it. Because this study was done over a span of three days it was difficult to make any true conclusions on preferred seabird habitat. Suggestions for further work in this area include following a precise transect. Because a transect wasn't followed there is a high possibility birds could have been double counted or missed. Zooplankton net tows would have been beneficial to conduct in each inlet in order to determine prey biomass and productivity. Lastly, more time must be spent in each of the inlets in order to get more accurate data and a better view of different seabird species. This type of research is important to gain information on the health and productivity of our oceans and the anthropogenic influences. It would be worthwhile to spend more time in Nootka Sound doing more extensive seabird research.

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Table 1. Number of seabirds per species per inlet

Species	no./inlet Inlet:	Muchalat	Tahsis	Zeballos
Common Merganser *Mergus merganser*		46	11	8
California Gull *Larus californicus*		62	69	20
Common Loon *Gavia immer*		0	8	0
Pelagic Cormorant *Phalacrocorax pelagicus*		4	17	2
Barrow's Goldeneye *Bucephala islandica*		0	184	34
Western Grebe *Aechmophorus occidentalis*		0	3	1
Bufflehead *Bucephala albeola*		1	30	61
Glaucous-winged Gull *Larus glaucescens*		0	9	3
Surf Scoter *Melanitta perspicillata*		0	243	38
Trumpeter Swan *Cygnus buccinator*		0	23	5
Marbeled Murrelet *Brachyramphus marmoratus*		2	19	1
Bald Eagle *Haliaeetus leucocephalus*		0	1	3
Great Blue Heron *Ardea herodias*		0	3	1
Mallard *Anas platyrhynchos*		43	50	0
Double-crested Cormorant *Phalacrocorax auritus*		0	1	0
Belted Kingfisher *Megaceryle alcyon*		1	0	0
Red-necked Grebe *Podiceps grisegena*		1	0	7
Common Goldeneye *Bucephala clangula*		220	0	0
Brandt's Cormorant *Phalacrocorax penicillatus*		1	0	0
Wood Duck *Aix sponsa*		0	0	0
TOTAL		396	671	184

Table 2. Station Locations

Station Name	Location
M01	49°39'23.88"N, 126°24'16.37"W
M02	49°38'52.80"N, 126°22'18.69"W
M03	49°38'34.80"N, 126°17'60.00"W
M04	49°39'34.93"N, 126°13'15.56"W
M05	49°40'12.00"N, 126°10'11.49"W
M06	49°40'1.20"N, 126° 8'34.29"W
M07	49°39'54.43"N, 126° 6'26.93"W
M08	49°40'43.82"N, 126° 6'56.02"W
M09	49°40'54.91"N, 126° 6'40.10"W
M10	49°40'59.30"N, 126° 6'33.30"W
M11	49°38'16.80"N, 126° 5'16.29"W
T01	49°47'20.40"N, 126°38'52.80"W
T02	49°51'21.60"N, 126°39'39.60"W
T03	49°54'50.40"N, 126°39'25.20"W
T04	49°55'10.99"N, 126°39'30.60"W
T05	49°55'15.64"N, 126°39'27.83"W
T06	49°55'18.91"N, 126°39'27.32"W
T07	49°55'20.68"N, 126°39'28.12"W
T08	49°55'22.51"N, 126°39'28.94"W
T09	49°55'24.38"N, 126°39'31.21"W
Z01	49°53'11.98"N, 126°48'42.62"W
Z02	49°56'13.20"N, 126°48'27.22"W
Z03	49°57'0.00"N, 126°49'8.40"W
Z04	49°57'7.45"N, 126°49'3.61"W
Z05	49°58'8.40"N, 126°51'10.80"W
Z06	49°58'25.07"N, 126°51'12.60"W
Z07	49°58'36.30"N, 126°51'13.82"W
Z08	49°58'54.70"N, 126°51'15.08"W

Figure 1. A map of stations in Zeballos, Tahsis and Muchalat inlet where CTD casts were done (red & purple), nutrient samples were taken (red), and salinity measurements were gathered from YSI on R/V *welander* (orange).

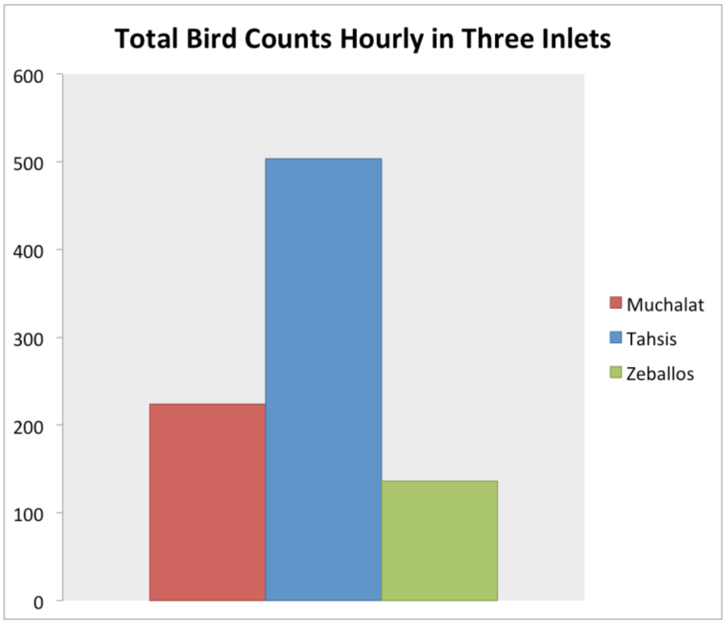

Figure 2. The total amount of birds counted in Muchalat, Tahsis and Zeballos inlet divided by the time spent in each inlet.

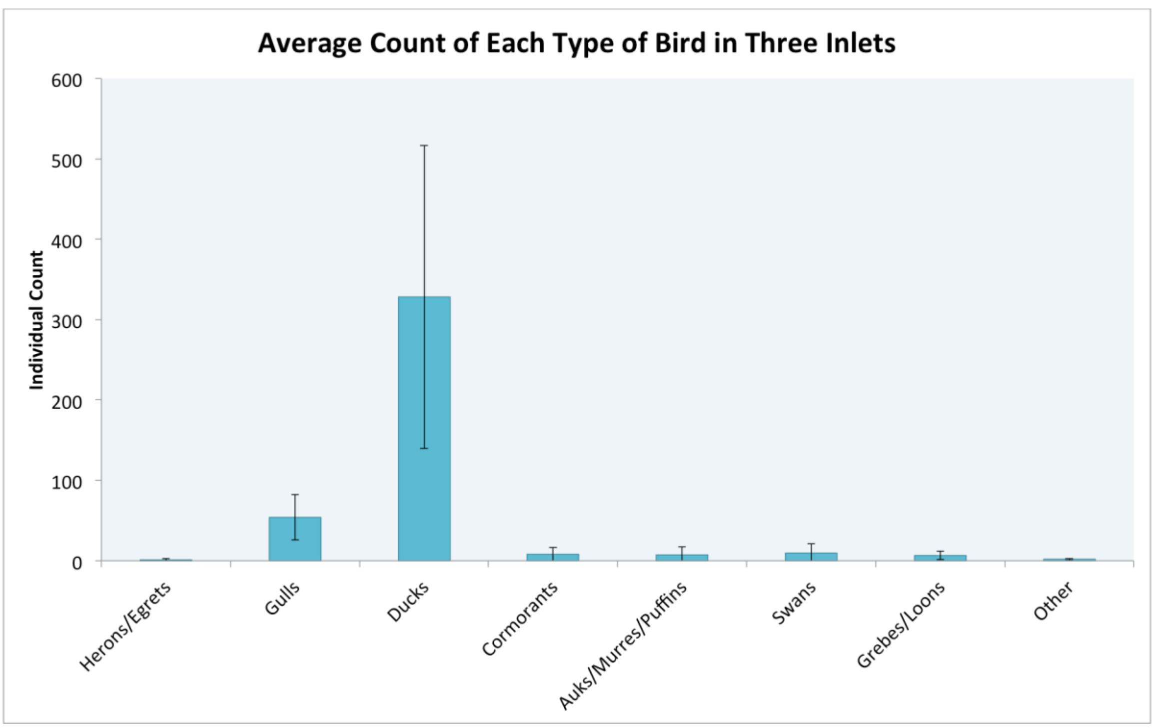

Figure 3. Average count of birds in all three inlets (Muchalat, Tahsis, & Zeballos) belonging to eight different categories. Error bars show variances using standard deviation.

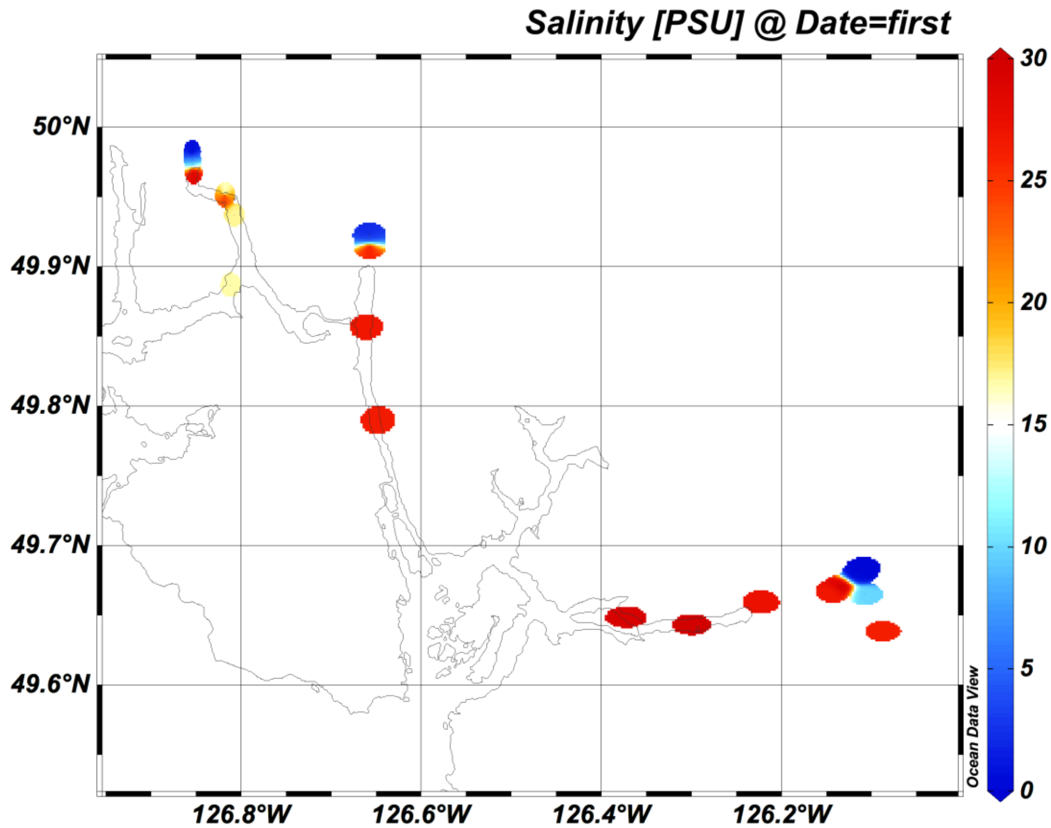

Figure 4. Surface Salinity (PSU) values taken from CTD casts in Muchalat, Tahsis and Zeballos inlets. Other salinity data was borrowed from Rachel Axtman who took data closer to the main river inputs using the YSI meter on the R/V *Welander*.

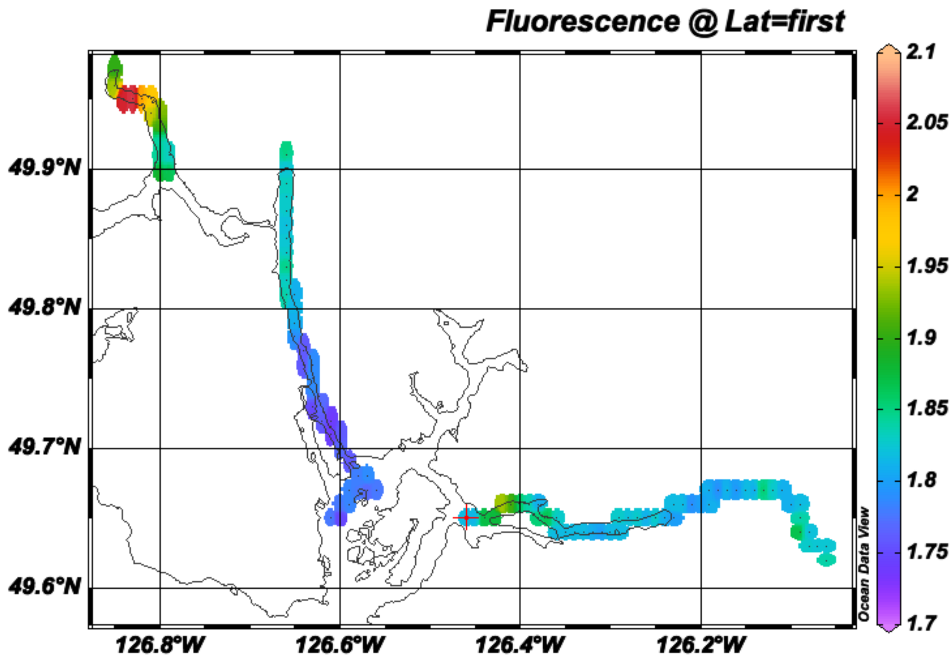

Figure 5. Surface Fluorescence (mg/m^3) values taken from the flow through data on the R/V *Thomas G. Thompson* and averaged for the three days seabirds were surveyed.

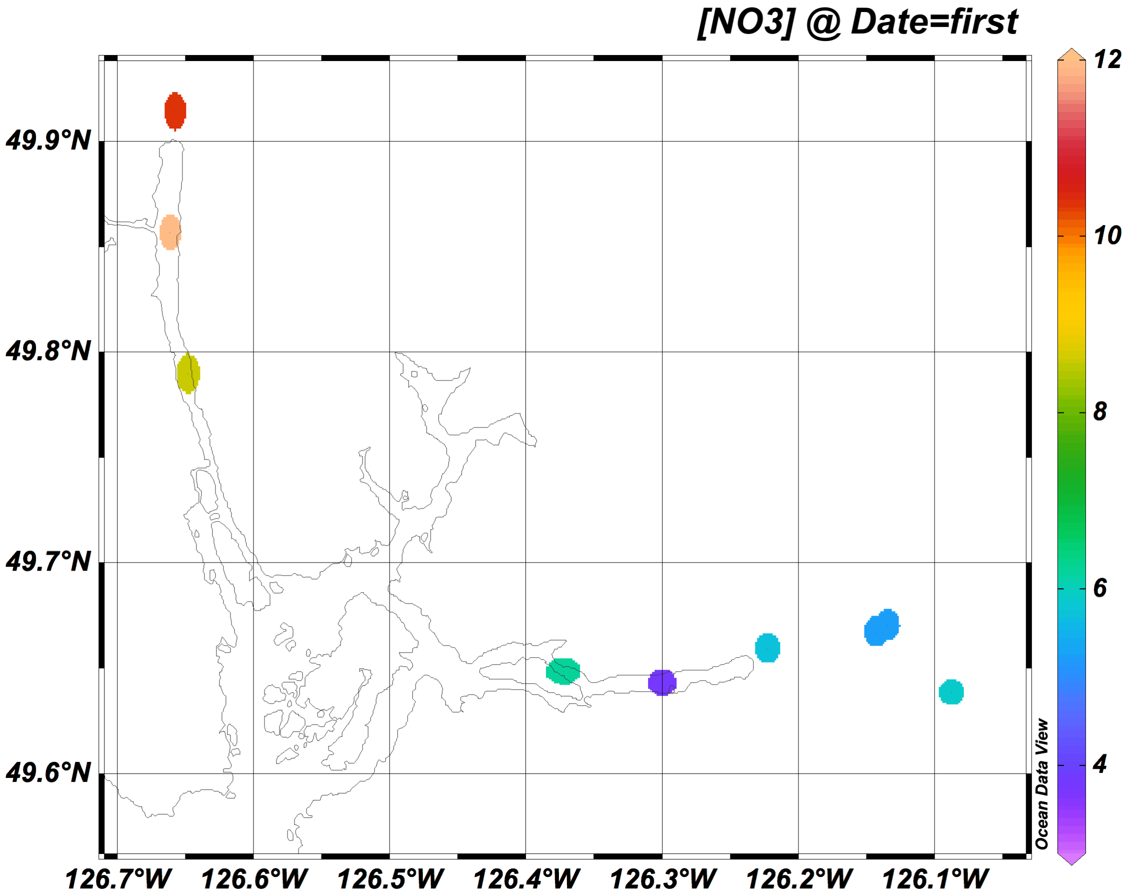

Figure 6: Surface [NO_3^-] values taken from several CTD casts throughout Muchalat and Tahsis inlets.

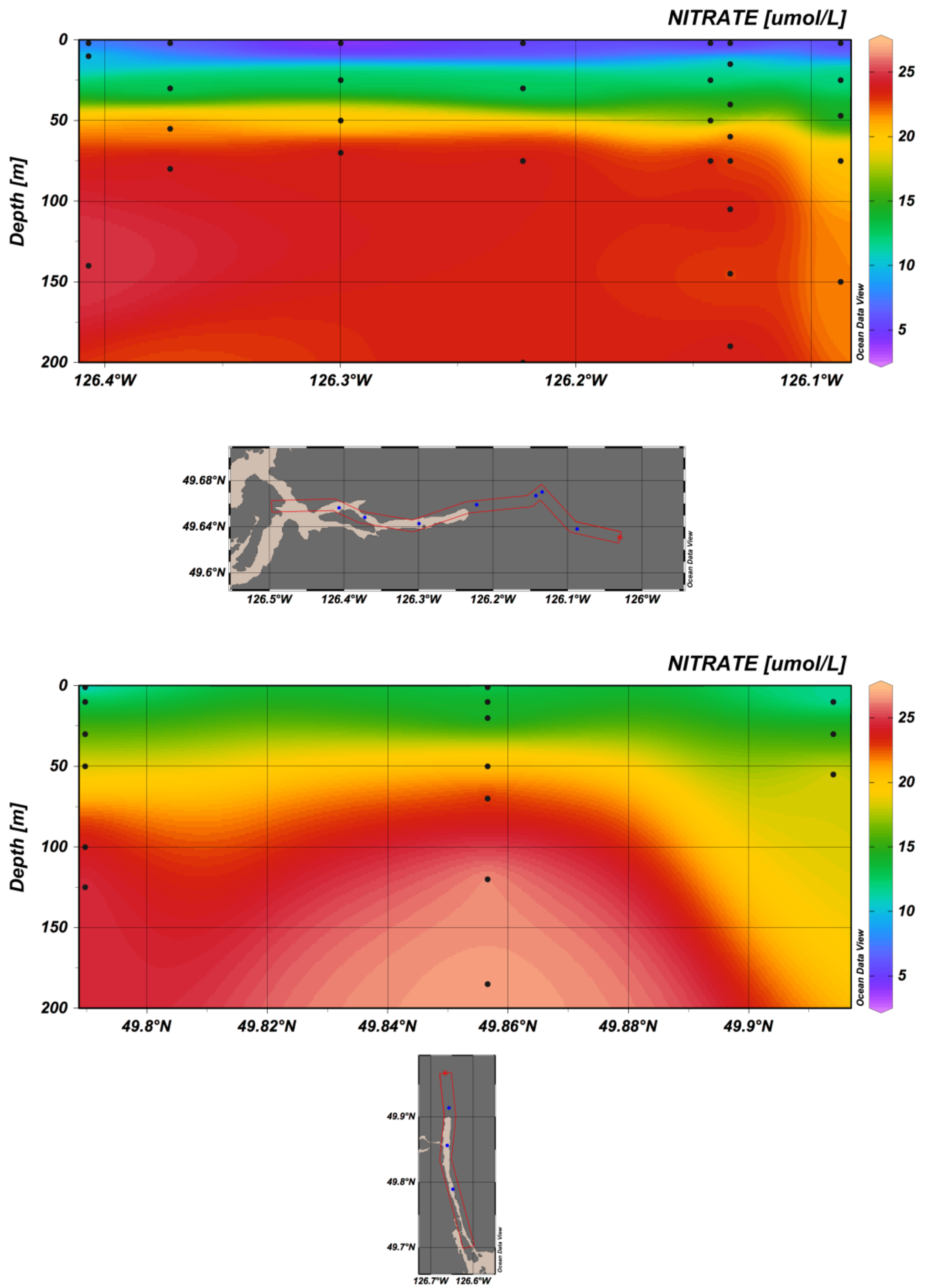

Figure 7: Nitrate (µmol/L) depth profiles in Muchalat (top) and Tahsis (bottom) inlets from stations marked in red on figure 1. Black dots indicate depths where samples were taken.

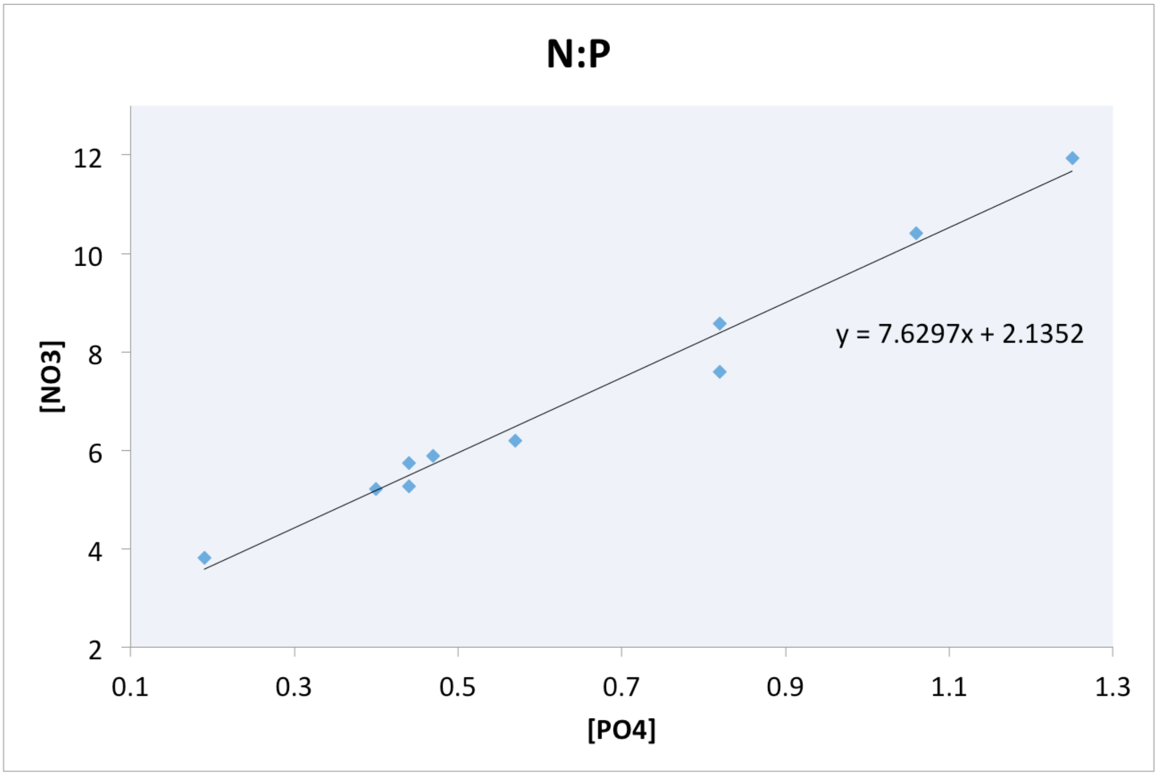

Figure 8: Surface nitrate and phosphorous (µmol/L) values plotted against each other.