

Dietary and Spatial Analysis of Salmon in the San Juan Archipelago and the Salish Sea

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Abstract

Salmon in the Salish Sea and the San Juan Archipelago are important keystone species with both ecological and commercial value. Analysis of the diets of king, pink, and silver salmon between the years of 2018 to 2021 suggest temporal changes in the amount and presence of the prey species of interest. Pacific herring and Pacific sand lance displayed the most variance in abundance and frequency of occurrence in all prey species observed. Herring displayed an increase in abundance in 2021, while sand lance displayed a decrease in abundance. Spatial analysis also suggests a separation in the spatial distribution of species, as well as differences in distribution based on prey type consumed. Additionally, shifts in the diet of pink salmon from crustaceans to herring have been observed.

Introduction

In the ecological sciences the study of the dietary compositions of predatory species is extremely important. Analyzing the composition of the diets of species within an ecosystem is a reliable technique for assessing the health and behavior of a population. Dietary analysis can provide information on the feeding behavior of a species, as well as give insights into the availability of prey and possible competition between species (Ahlbeck & Hjerne, 2012, p. 1184). In addition to dietary analysis, determining the spatial distribution of a species can be used to explain other aspects of a species feeding behavior. Additionally, analyzing the diet of a species also provides insight into the relationships that a predatory species has with species on lower trophic levels. A stable supply of food is essential for most heterotrophic organisms, especially predatory species, such as salmon (Amundsen & Sánchez-Hernández, 2019, p. 1365). By studying the diet and spatial distribution of three salmon species; king salmon (*Oncorhynchus*

tshawytscha), silver salmon (*Oncorhynchus kisutch*), and pink salmon (*Oncorhynchus gorbuscha*), insights can be made into their reliance on different prey species as well as their relationships with other species in other trophic levels.

Salmon and other pelagic predatory fish species are a particularly useful group of fish for studying diet composition, as they often consume prey species whole, making much of the contents easy to identify (Amundsen & Sánchez-Hernández, 2019, p.1365). Observed prey species commonly found in the stomach samples of this study include Pacific sand lance (*Ammodytes personatus*), Pacific Herring (*Clupea pallasii*), and multiple crustacean species including large pelagic shrimp, krill, mysids, amphipods, and small planktonic species. Of all North Pacific salmon species, king salmon have been found to have the most variability in their diets. Silver salmon have also been reported to have a highly variable diet (Brodeur et al, 2007, p. 190). Although these species have a high amount of variability in their prey species, they have been found to mostly consume forage fish (Brodeur et al, 2007, p. 190). Pink salmon also consume forage fish, but they also tend to consume higher amounts of crustaceans than other salmon species (Brodeur et al, 2007, p. 190). Additionally, the feeding behaviors of these salmon species is reported to be more influenced by spatial distribution than temporal factors, with fish caught in more northern environments having higher stomach fullness ratios (Brodeur et al, 2007, p. 195). However, it is important to note that salmon are generalist consumers and may drastically alter their diets based on prey availability (Dixon et al, 2019, p. 556).

This study is based in the Salish Sea, with most samples being gathered around the San Juan Archipelago and Puget Sound. The Salish Sea is composed of the Strait of Juan De Fuca, Puget Sound, and the Strait of Georgia. Within the Salish Sea, just below the US-Canadian border, lies the San Juan Archipelago. The diverse bathymetry and strong tidal current of the

archipelago support a diverse array of marine species (Baker & Sisson, 2017, p. 613). Puget Sound lies South of the San Juan Archipelago and provides a migratory channel for salmon species and receives freshwater input from over 100 streams and rivers. The structure of Puget Sound and large amount of the freshwater input sources within the Puget Sound provide a prime habitat for salmon (Lossee et al, 2019, p. 936).

Although there are many studies on the feeding behavior of salmon in freshwater habitats, little has been researched on the feeding behavior of salmon during the saltwater portion of their lifespans. Pacific salmon spend over half of their lives at sea, but this portion of their life cycle is poorly understood (Graham et. al, 2021, p. 2). Previous studies in the area have come to differing conclusions about the diet and spatial distribution of salmon in the Salish Sea. A study done in 2018 by Eva Hasegawa found higher amounts of herring in salmon stomachs than other prey species. A lack of variance in the stomach fullness ratios during the time of study was also observed, likely due to a relatively constant availability of prey over the entire year (Hasegawa, 2018, p. 8). Analysis done in 2019 done by Julia Glassy concluded that herring composed a majority of king salmon diets, while crustaceans made up most of the sampled pink salmon diets. Additionally, Glassy found lower rates of empty stomachs than had been found in 2018 (Glassy, 2019, p. 8). In 2020 Connor Brainard found herring to have the highest frequency of occurrence in silver salmon and king salmon, as well making up most of the mass of identifiable king salmon stomach contents. Crustaceans made up the highest proportional prey mass for silver salmon in this region. Additionally, his spatial analysis concluded that salmon were mostly found around seamounts and coastal areas, with all salmon that had consumed sand lance coming from one site (Brainard, 2020, p. 4-5).

Studying stomach samples obtained in the Salish Sea can provide great insights into the diet of the local salmon populations. Stomach content analysis has been used to determine what prey items a species is consuming and how much of a prey item a species consumes.

Additionally, including a spatial component in this project allows exploration of how a species spatial distribution correlate with their feeding behaviors. The intention of this study is to analysis the spatial distribution of salmon in the Salish Sea, as well as to the analyze dietary patterns of this species. The purpose of these analyses is to gain insight into what salmon are eating, how much they are eating, and where they are feeding.

Methods

Study Area

The area of this study encompassed the entirety of the archipelago and extended south into Puget Sound (Fig 1). This study area falls between 47°36'00.0"N - 48°43'49.5"N and 123°11'35.0"W - 123°08'18.7"W.

Data collection

Sample collection

All samples were collected within the Salish Sea by local charter fishermen. Most samples were tagged with longitude and latitude coordinates or a catch location name. 144 samples have been provided from 2018 to 2021 with 65 samples provided in 2021. In total 76 king, 48 silver, and 20 pink salmon stomachs were provided between 2018 and 2021.

Dissections

Samples were provided as a mass of organs which included the stomach, esophagus, liver, intestinal tract, and the pyloric caeca of each individual fish. During the dissection process the stomach was separated from the other organs provided. Stomachs were emptied of contents and the contents then were separated into groups based on identifiable species (Pacific herring, Pacific sand lance, crustaceans), bones, and unidentifiable digested remains. All samples were weighed with a KitchenTour EG5001 scale to the nearest hundredth of a gram. Any loose prey items regurgitated during the capture process were weighed as well. Additional data collected during dissections by past PEF apprentices Connor Brainard, Julia Glassy, and Eva Hasegawa between 2018-2020 were also included in the sample set.

The presence-absence method (PA)

This presence-absence method is based on identifying specific prey types, without taking a numerical or spatial count of the amount of each prey type. This method is useful for simply cataloguing what prey types are present or absent from a sample or sample group. While the presence-absence method is useful for recording what prey species are present, it can lead to overestimations of the importance of small prey types or sparsely found prey types. As such, the presence-absence method does not provide reliable estimates of the amount of a prey type but can be used to explore how frequently a prey type is found in a sample group (Amundsen & Sánchez-Hernández, 2019, p.1365).

The numerical method (NM)

The numerical method involves counting every individual identifiable prey species found within the stomach of a salmon. It is then expressed as a frequency of the number of each specific prey type. This method relies on stomach contents being identifiable and unfragmented. It does not account for digested material, unidentifiable remains, or heavily fragmented remains.

This method can also give misleading results when large numbers of very small prey species are present in a stomach (Amundsen & Sánchez-Hernández, 2019, p.1365).

The gravimetric method (MM)

Of all the stomach analysis methods used in this study, the gravimetric method provides the most accurate read of the ratios between the amounts of different prey types in a stomach. In this method, each category of prey type is weighed separately and expressed as a percentage of the total stomach content mass. This method also accounts for digested and unidentifiable remains, but it may overestimate the importance of slowly digested remains (Amundsen & Sánchez-Hernández, 2019, p.1365).

Data analysis

Frequency of occurrence

Frequency of occurrence refers to the number of stomachs in which a specific prey type is found, which is then expressed as a percentage of the total stomach samples. The following formula provided by Amundsen & Sánchez-Hernández was used to calculate the frequency of occurrence (Amundsen & Sánchez-Hernández, 2019, p. 1366).

$$f_i = N_i / N$$

Where N is the total number of salmon with identifiable stomach contents, and i is prey type.

Relative prey abundance

Relative prey abundance refers to the proportion of total identifiable stomach contents of all predators to the total stomach contents of a specific prey type. Stomach contents can be represented as a mass, volume, or number. In this study relative prey abundance has been calculated using mass. Relative prey abundance is defined by the following formula found in Amundsen & Sánchez-Hernández (2019, p. 1366).

$$p_i = \Sigma S_i / \Sigma S_T$$

Where S_i is the mass of the prey type of interest, S_T is the total amount of all identifiable prey types, and i is prey type.

Stomach Fullness Ratio

Stomach fullness ratios compare the masses of full and empty stomachs to provide information on the amount of food a fish has consumed. The stomach fullness ratio equation is as follows.

$$R = s/s_0$$

Where R is the fullness ratio, s is the mass of the full stomach, and s_0 is the mass of the empty stomach. (Hasegawa, 2018, p. 5)

Spatial Analysis

Spatial analyses of multiple variables were performed in ArcMap 10.8.1. Coordinates provided by charter fishermen were converted into the Decimal Degree (DD) format. The coordinates of samples with only the catch location name provided were estimated. Coordinates were imported into ArcMap as .csv files, and then were exported and converted into shapefiles and placed onto a base map using the WGS1984 geographic coordinate system. Any points with inaccurate or outlying XY coordinates were removed. The variables plotted on these maps include year of capture, species, presence-absence of Pacific sand lance, and presence-absence of any stomach contents.

Results

Total Salmon Diets

Based on the relative prey abundance analysis performed on 144 stomachs, most of the mass of identifiable contents in salmon stomachs between 2018-2021 were composed of Pacific herring, followed by crustaceans, and sand lance. In total, 75% of the mass of identifiable contents was herring, 17% was crustaceans, and the final 8% was made up of sand lance (Fig 2). When gravimetric analysis was performed on the 65 salmon stomachs provided in 2021, similar percentages of prey content were seen, although there were some differences. Herring still made up most of the mass of the stomach contents, at 86%, which was greater than the percentage in previous years. Crustaceans made up 13% and sand lance made up 1% of the total mass (Fig 3). Of all masses recorded for each prey species, only 4 measurements weighed over 20 grams, which were identified as herring (Fig 4). In addition to having a lower relative prey abundance, sand lance also displayed lower frequency of occurrence. In total sand lance were found in 20.6% of the 63 total stomachs with identifiable contents and were found in 13% of the 23 stomachs sampled in 2021. Herring also displayed a lower frequency of occurrence, dropping

from 53.4% for all samples, to 47.8% in the samples from 2021. Crustacean frequency of occurrence increased, rising from being found in 41.3% of all samples, to being found in 52.2% of the samples from 2021 (Fig 5, Table 1). A majority of sand lance found in samples were in fish caught when sand lance were present in the water column. However, salmon stomachs caught towards the end of the dormancy period contained higher masses of sand lance (Fig 6). Stomach fullness ratios of all 131 samples varied over time with no obvious trend, with large outliers being found between July 2021 to September 2021 (Fig 7). However, these values vary with no obvious differences found between 2018 and 2021 (Fig 7). Average stomach fullness ratios of all species from July 2021 to September 2021 were plotted, and similar peaks were seen in August of 2021 (Fig 8).

King Salmon Diets

Herring was the primary prey species found in king salmon diets. The relative prey abundance analysis of all 76 king salmon stomach samples between 2018 and 2021 resulted in herring making up the majority of identifiable prey species stomach content mass, at 75%. Crustaceans made up 14% of the mass and sand lance made up 11% of the mass of identifiable stomach contents (Fig 9). Of the 22 samples analyzed in 2021, the identifiable stomach content masses were comprised of 81% Herring, 17% crustaceans, and 2% sand lance (Fig 10). Between all years studied, herring was found most frequently in king stomach samples, being found in 59.5% of samples containing identifiable contents, followed by sand lance and crustaceans. Both species were found in 27% of all stomachs containing identifiable contents. In 2021, crustaceans were found to have the highest frequency of occurrence, being found in 50% of samples. Herring were found with a frequency of 40% and sand lance were found in 30% of the samples (Table 2). An annual alternation of prey species with the highest frequency of occurrence was observed

between 2018 and 2021. Herring were found to have the highest frequency of occurrence in 2018 and 2020, while crustaceans had higher frequencies of occurrence in 2019 and 2021 (Fig 11). King salmon stomach fullness ratios saw variation between values of 1 and 2, with an outlier of 3.77 being found in August 2021. However, all error bars overlapped, suggesting obvious differences in variation over time (Fig 12).

Pink Salmon Diets

The relative abundance of prey species found in pink salmon stomach samples varied between the two years of study, 2019 and 2021. In total, herring made up 52% of the mass of identifiable stomach contents, and crustaceans made up 45%. Sand lance comprised 3% of the total identifiable mass, but this value was estimated based on average masses of other sand lance, as measurements of these masses were missing from the sample set (Fig 13). In 2021 herring made up 86%, while crustaceans made up 14% of the total identifiable mass, and no sand lance were present (Fig 14). In all years studied, crustaceans had the highest frequency of occurrence, appearing in 85.7% of stomachs with identifiable contents in 2019, 83.3% in 2021, and 84.6% for all years. Herring was found in 23.1% of samples and sand lance was found in 15.4% of samples for the two years studied (Fig 15, Table 3). Stomach fullness ratios displayed variance between the values of 1 and 2.5, and no obvious differences in the variation of stomach fullness ratios between months observed (Fig 16).

Silver Salmon Diets

48 samples of silver salmon were provided between 2018 and 2021, with 30 of these samples being caught in 2021. Herring had a relative abundance of 91% in stomachs collected in 2018-2021 as well as a relative abundance of 91% in stomachs collected only in 2021. Crustaceans had a relative abundance of 8% in previous years, and a relative abundance of 9% in

2021. Sand lance had a relative abundance of 1% between 2018-2021 and none were identified in 2021 (Fig 17-18). Only 1 stomach had identifiable contents in 2018, in which sand lance and herring were present. In 2020 crustaceans displayed a frequency of occurrence of 60% and herring displayed a frequency of occurrence of 40%. In 2021 herring had a higher frequency of occurrence, being found in 71.4% of samples, while crustaceans were found in 28.6%. Overall herring showed the highest frequency of occurrence at 61.5%, followed by crustaceans at 38.5%, and sand lance at 7.7% (Fig 19, Table 4). Little variance in the stomach fullness ratios of silver salmon was observed between until July of 2021, likely due to small sample sizes. The most variance was seen in August 2021, with values ranging from 1 to 2.91. However, no obvious differences in variation can be stated (Fig 20)

Spatial Analysis

Figure 11 displays the distribution of all samples with provided locations (N=108) between the years 2018-2021. Distribution varies, with large clusters of fish being found around sea mounts, banks, and shelves, as well as near shorelines. Very few samples were obtained in deep open waters (Fig 21). Distribution variance between species was also observed. Most king salmon were found around the archipelago. Most pink salmon samples were collected south of the archipelago, but north of Admiralty Inlet. Silver salmon were found in scattered distributions around the site of study but displayed higher frequency in South Puget Sound (Fig 22). The presence of sand lance was plotted as well, and most fish containing sand lance were found around the archipelago. All samples collected south of Admiralty Inlet lacked sand lance (Fig 23). The presence and absence of any stomach contents was plotted as well. Both full and empty stomachs were found in scattered distributions with no clear correlations to their location of collection (Fig 24).

Discussion

Based on the findings of this study, herring made up a majority of the mass of all prey species, and was most commonly found in the diets of king and silver salmon. Large percentages of the identifiable prey masses were composed of herring for both species, and they also both displayed high frequencies of occurrence in the stomachs sampled for these species. In previous years, crustaceans were found to have much higher relative abundance than in 2021. In 2021 it seems that the diets of pink salmon have shifted to include higher amounts of herring. However, the frequency of occurrence of crustaceans in pink salmon stomachs stayed relatively constant over the period of study, possibly indicating that these species prefer to target crustaceans, but may take advantage of spikes in the populations of other prey species such as herring.

There appears to be periodic spikes in the consumption of herring for all species of study. Large prey items (> 25 g) all were herring, indicating periodic increases in their availability. Most of the masses of identifiable stomach contents were less than 20 grams. However, outliers weighing over 25 grams were found between January 2018 and March 2018. Additionally, outliers exceeding 50 grams were found between July 2021 and September 2021 (Fig 4). These high masses were all identified as herring. The outliers observed between July 2021 and September 2021 are of particular interest, as they occurred during the same time that outliers of high stomach fullness ratios were being observed. Additionally, similar spikes in the average stomach fullness ratios for each species were observed in August 2021 (Fig 8). These high stomach fullness ratios and high masses of herring occurring at the same time may suggest that all species surveyed increased their consumption of herring during this time. More evidence of a spike in the frequency of predation on herring is displayed in the increase of the relative abundance of herring present in samples caught in 2021 for all species. One possible reason for

the increase in the predation of herring is a spike in the local populations of herring, or an influx of herring into the Salish Sea. Salmon may prefer to target herring due to its large size in comparison to other prey species as well.

Low levels of sand lance presence could be explained by the diel migration these species undergo. Sand lance burrow at night to avoid predators and conserve energy and will emerge during the day to feed (van der Kooij et al, 2008, p. 201). They are also known to stay in close proximity to appropriate substrate during the day (van der Kooij et al, 200, p. 207). In a previous study in Alaska, predation on sand lance was seen to increase as sand lance transition from pelagic environments to benthic environments. However, in this study none of the observed predatory species included salmon (Hobson, 1986, p. 223-224). It is possible that the pelagic activity of sand lance occurs at a time or environment where salmon are either not present or not actively feeding. Another factor that may influence the presence of sand lance in salmon stomachs is their dormancy period. Pacific sand lance in the San Juan Archipelago enter a dormancy period in which they burrow into sediment for months at a time. This dormancy is likely caused by a need to conserve energy in periods of low phytoplankton abundance, as well as to avoid predators. This dormancy period usually occurs after the fall transition and between the months of November and March (Baker et al, 2019, p. 238-239). When the dormancy period of sand lance is compared to the presence of sand lance in salmon stomachs, some interesting relationships can be seen. Sand lance stomach masses have been plotted in comparison to sand lance dormancy periods, which are shaded in blue (Fig 5). A majority of sand lance found in stomachs were found in samples caught after the end of the sand lance dormancy period. However, salmon caught toward the end of the sand lance dormancy period contained much higher masses of sand lance (Fig 5). This may suggest that when sand lance are in the water

column they may be fed on opportunistically, but not strongly targeted by salmon. The high masses of sand lance found towards the end of the dormancy period may be explained by salmon targeting them as they leave the sediment. This may be due to a lack of other food at this time, or sand lance may be easier targets as they leave the sediment.

The spatial distribution of salmon also indicates trends associate with their feeding behaviors and preferences. Spatial analysis using ArcMap revealed differences in the distribution of salmon by species as well as by the presence of sand lance. King salmon were found with the highest frequency along the shores of the San Juan Archipelago, as well as in a clustered group associated with sand banks south of the archipelago. Pink salmon were captured in these sand banks as well, and few samples were found elsewhere. Silver salmon were collected in scattered distributions north of Admiralty Inlet but in clumped distributions in South Puget Sound. Silver salmon were also more frequently found in South Puget Sound (Fig 22). Previous studies on the marine distribution of salmon have proposed that shelves and nearshore habitats are critical habitats for the marine portion of the salmon life cycle, but very little research has been done on the distribution of marine salmon (Flintcroft et al, 2018, p. 433-434). There appears to be a clear separation in the general spatial distribution based on salmon species, although there is overlap in their distributions. When plotting the distribution of salmon based on the presence of sand lance found in the sample, clear trends are noticeable. Most samples containing sand lance were collected along the shore of the San Juan Archipelago, as well as in the sand banks south of the Archipelago. No samples collected south of Admiralty Inlet contained sand lance (Fig 23). The clear separation in the distribution of samples containing sand lance and the samples lacking sand lance suggest that South Puget Sound does not contain the appropriate habitats for thriving

sand lance populations. This may be the reason that no sand lance were present in the salmon stomach samples collected in this area.

While stomach analysis can provide much information on the dietary composition of salmon, the method is not without its inconsistencies. One major problem with stomach content analysis is that prey species are digested at different speeds based on their chemical composition and size. This can lead to some species being overrepresented in the recorded diets of the fish. Another caveat of the method is that partially digested stomach contents can be difficult to identify with the naked eye, and more accurate, but less available methods, such as DNA analysis, may be necessary to provide a reliable description of the stomach contents. Fragmentation of remains can also make it difficult to assess the true number of each prey species present (Amundsen & Sánchez-Hernández, 2019, p. 1365). Stomach contents only stay in the gut of a salmon for a short period of time, so other methods, such as isotope analysis may be necessary to study the long-term diets of these fish (Dixon et al, 2017, p. 556). Incomplete or inaccurate data from past studies also affected this study. In some cases, prey types were recorded as being present, but no weights were taken, such as sand lance in pink salmon stomachs. This resulted in estimates based on the weights of other samples being necessary for some data points. Additionally, many of the coordinates used in the spatial analysis portion of this study had to be estimated based on location names, as not all samples were labeled with coordinates. Additionally, there was no way to verify the accuracy of the provided coordinates, as sample collection was not part of this project.

Further research into the diets of salmon in the Salish Sea should consist of higher sample amounts, as low sample counts can skew results significantly. Additionally, future studies would benefit from samples being collected at regular temporal intervals, which would make trends in

the temporal effect on salmon diets more obvious. This study was impacted by a short period of study in previous years as well as low sample amounts. As stomach content analysis continues in the upcoming years, a more robust data set will be created, and new trends may be observed. Identifying and recording infrequently found prey species is also recommended for future studies, as well as identifying crustaceans by species rather than one category of prey type. The addition of population analysis of prey species would also improve the results of a stomach analysis study, as one could compare the populations of a prey species with the consumption of the prey species. Unfortunately, robust information on prey species in this area focuses mostly on sand lance, and data is lacking for the populations of herring and crustaceans in the Salish Sea.

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series. Finally, I would like to thank my fellow research apprentices in the PEF course for their help with this project and for their moral support and friendship throughout the quarter.

Figures

Area of Study

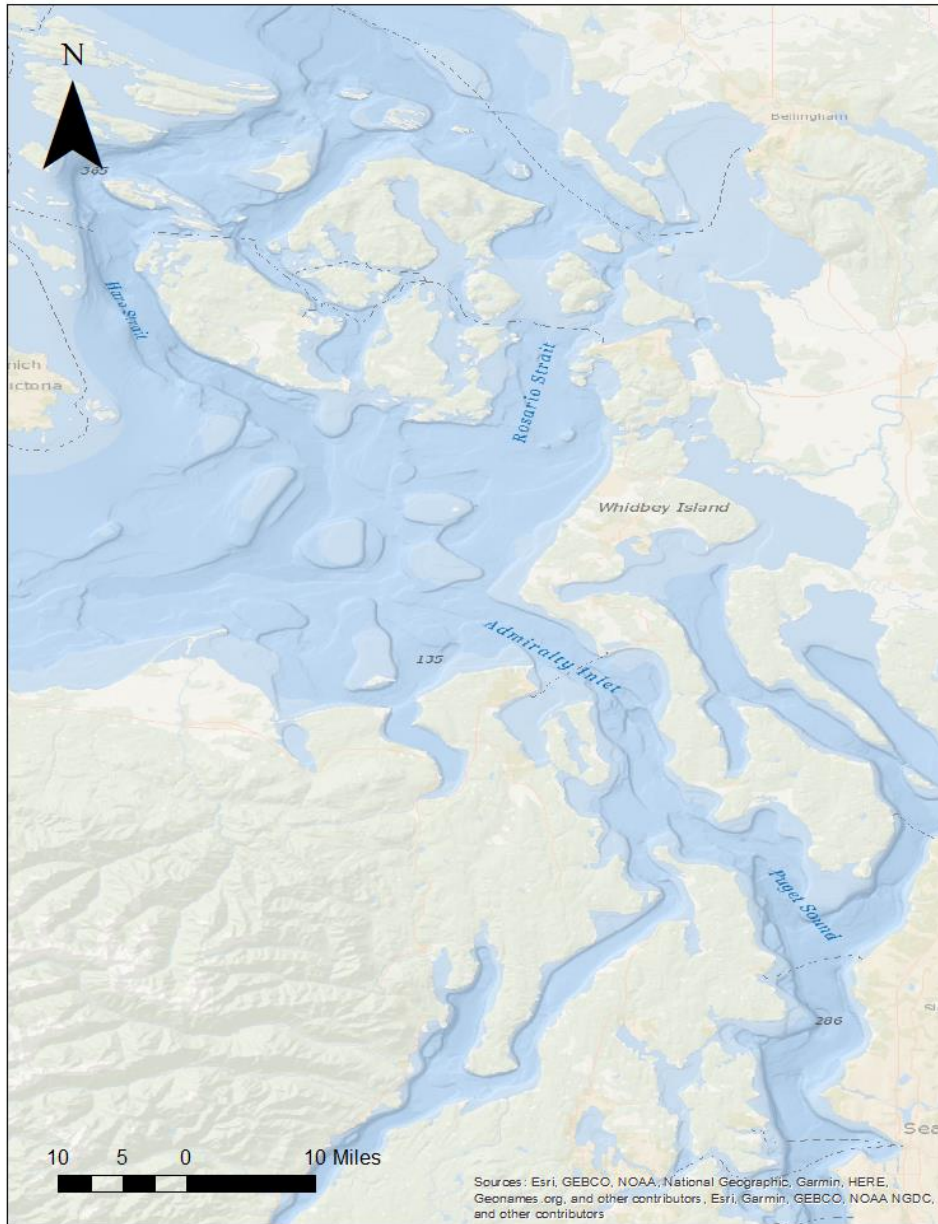


Figure 1. Area of study for this analysis

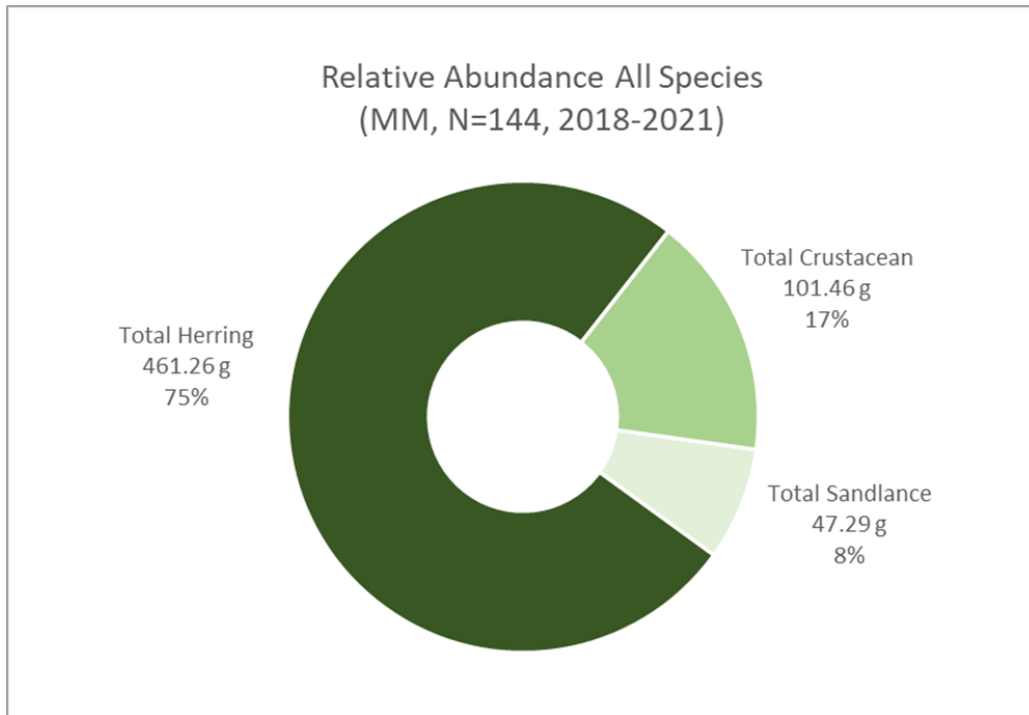


Figure 2. Relative abundance analysis of identifiable prey species masses using the gravimetric method (MM), 144 samples, all species surveyed included. 2018-2021.

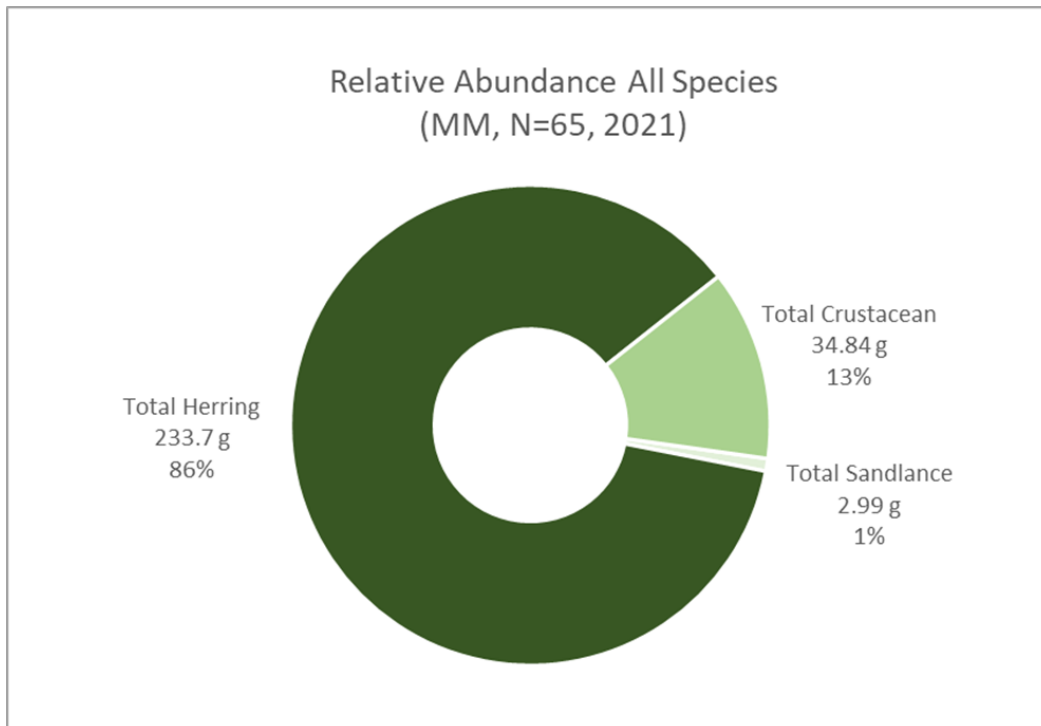


Figure 3. Relative abundance analysis of identifiable prey species masses using the gravimetric method (MM), 65 samples, all species surveyed included. 2021.

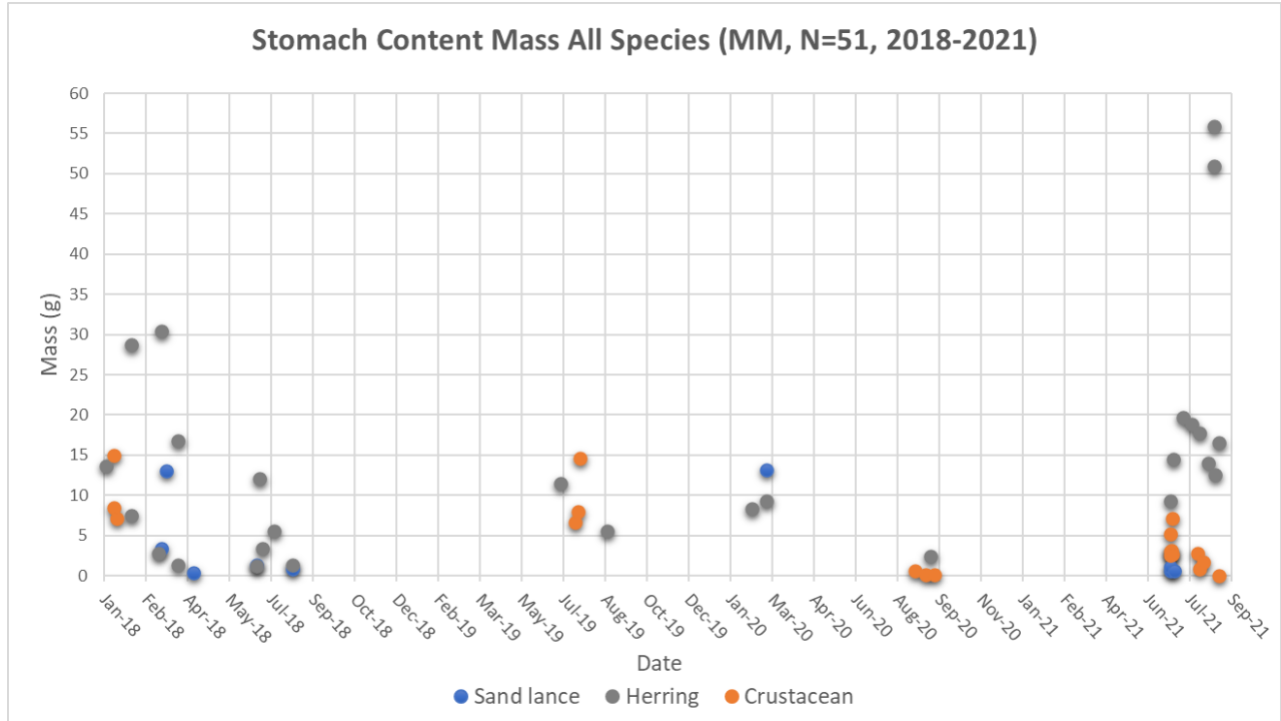


Figure 4. Temporal distribution of identifiable stomach content mass using the gravimetric method (MM), 51 samples, all species, 2018-2021.

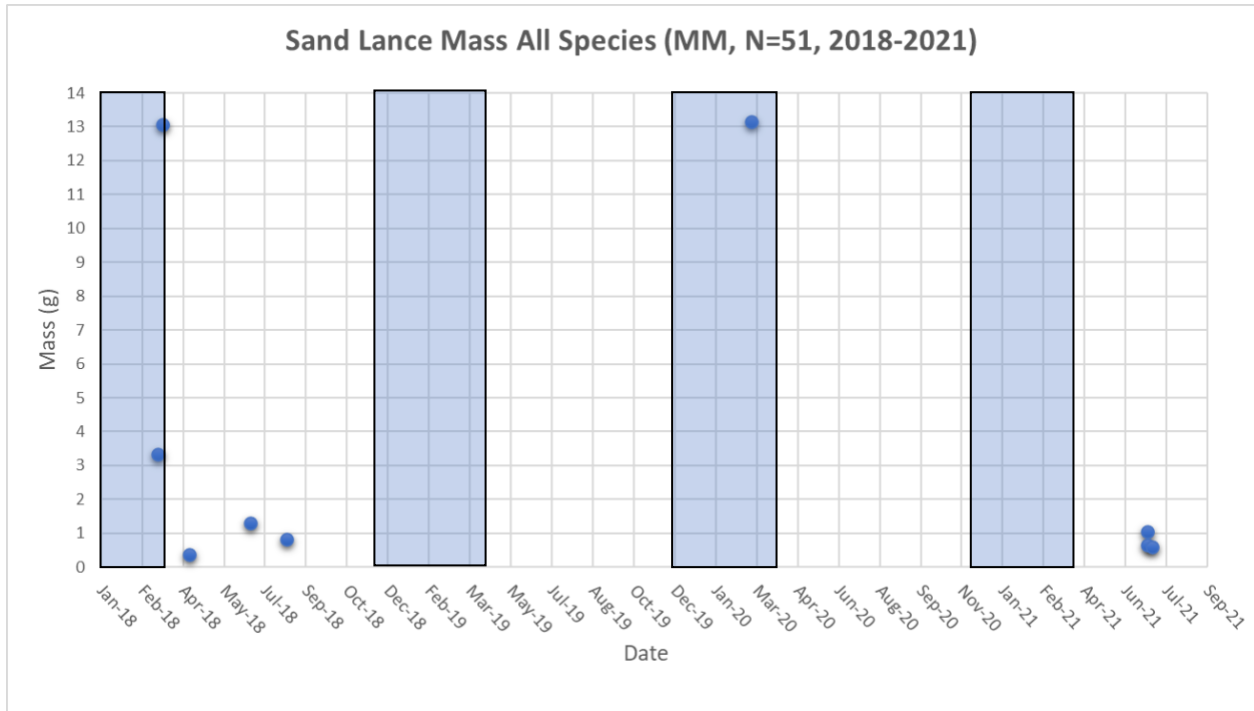


Figure 5. Temporal distribution of identifiable sand lance mass using the gravimetric method (MM), sand lance dormancy periods highlighted in blue, 51 samples, all species, 2018-2021.

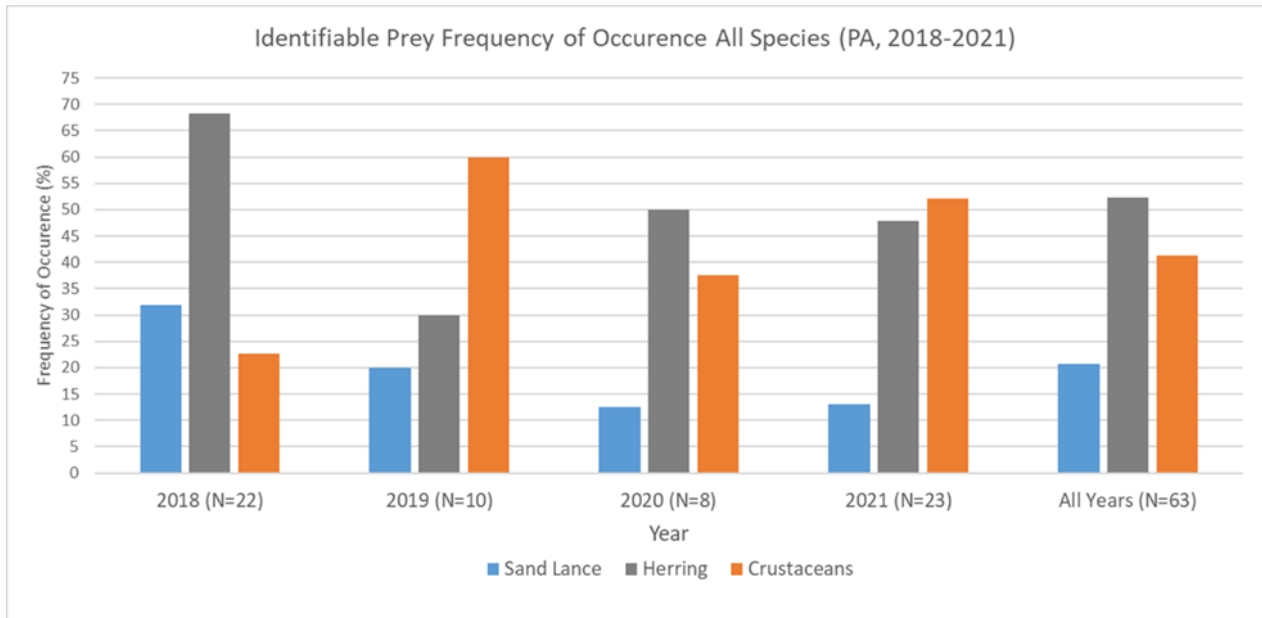


Figure 6. Frequency of Occurrence of identifiable prey for all species using the presence-absence method (PA), 2018-2021, N=63

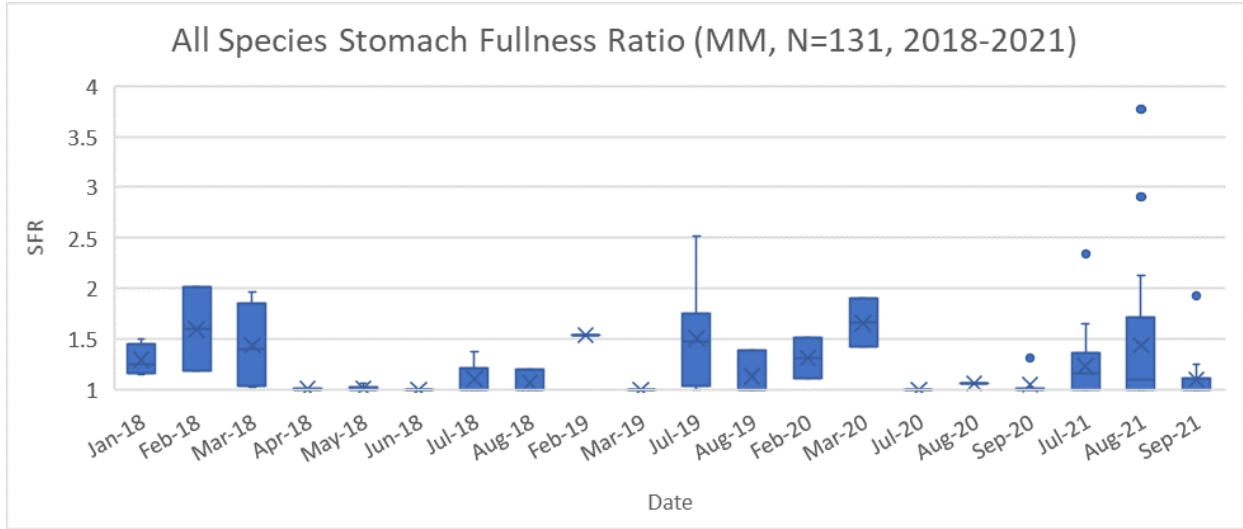


Figure 7. Stomach fullness ratios for all species using gravimetric method (MM), 131 samples, 2018-2021.

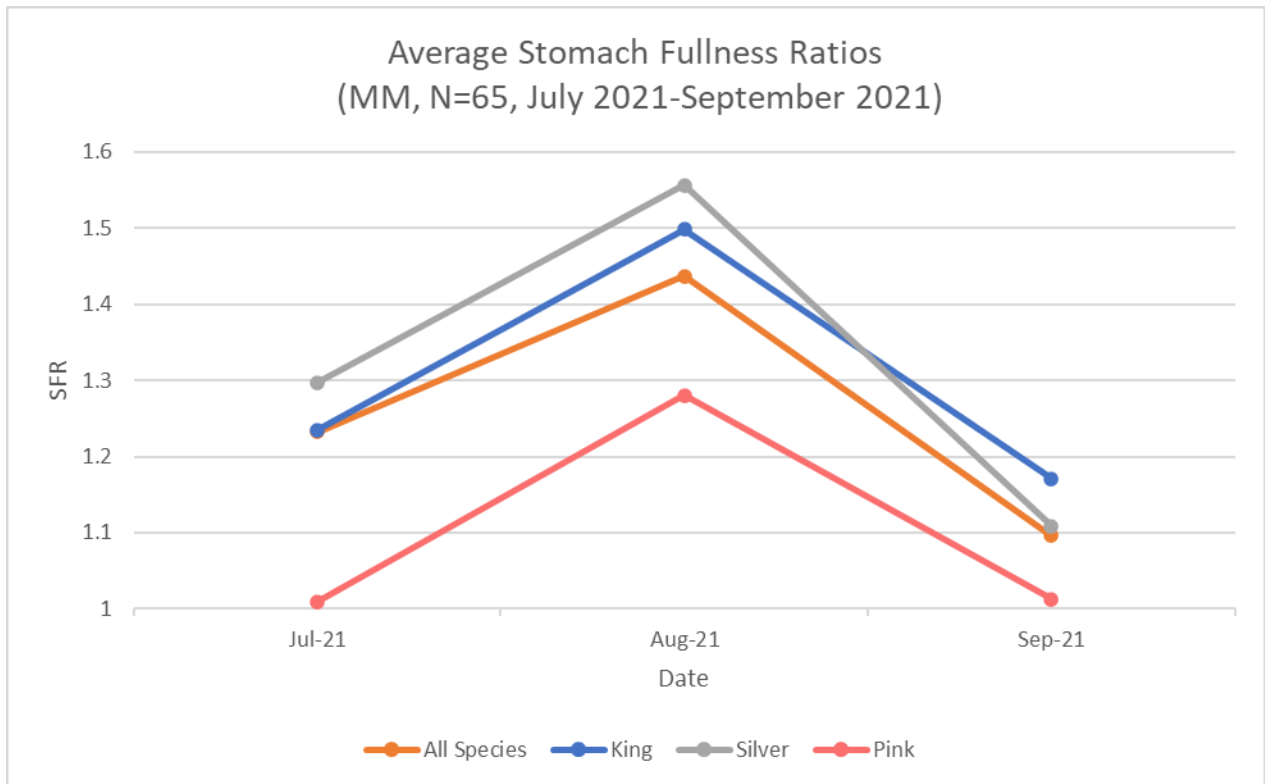


Figure 8. Average stomach fullness ratios calculated for all species using the gravimetric method (MM), 65 samples, July 2021-September 2021

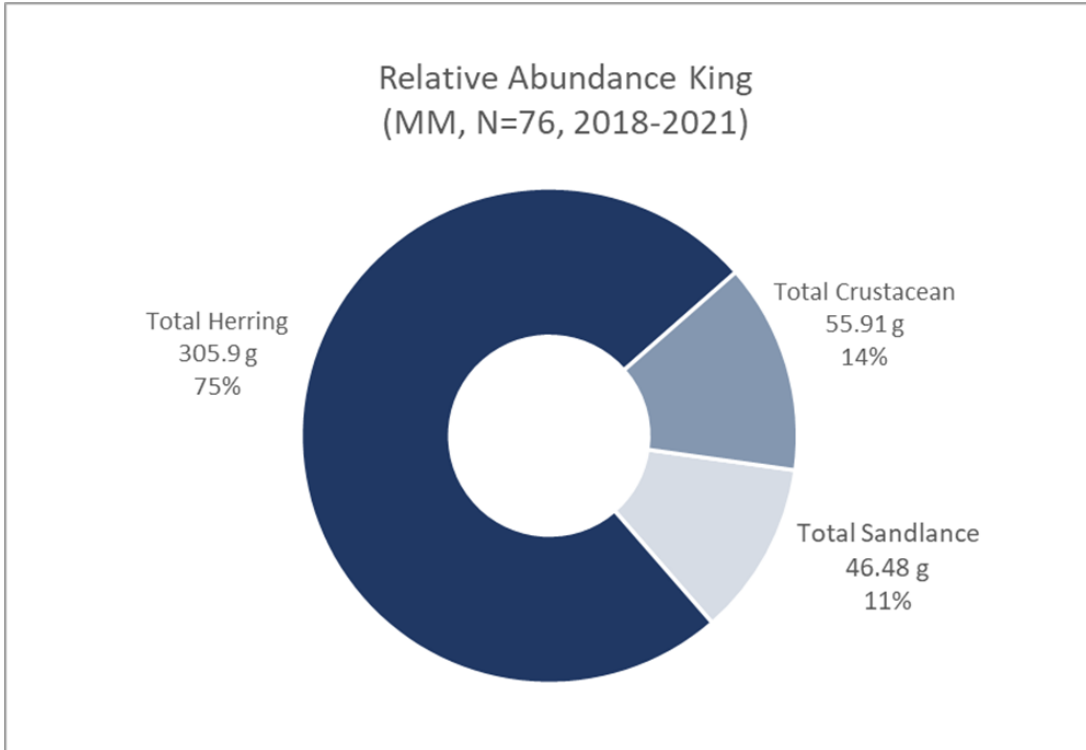


Figure 9. Relative abundance analysis of identifiable prey species masses using the gravimetric method (MM), 76 King Salmon samples, 2018-2021.

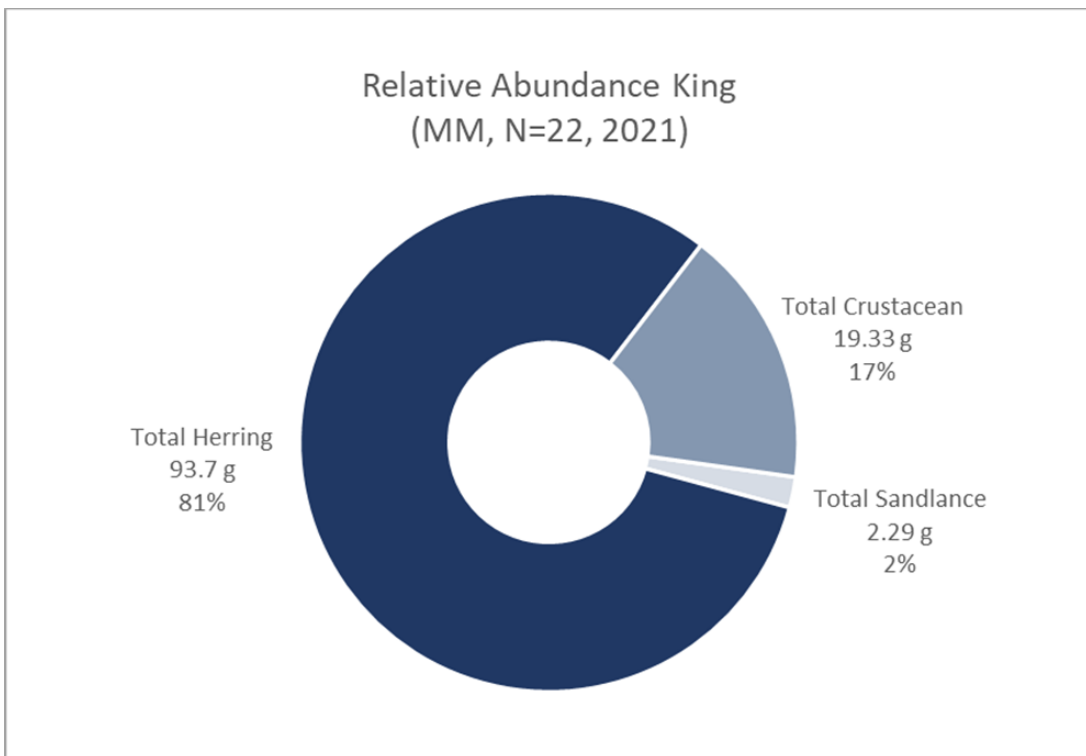


Figure 10. Relative abundance analysis of identifiable prey species masses using the gravimetric method (MM), 22 King Salmon samples, 2021.

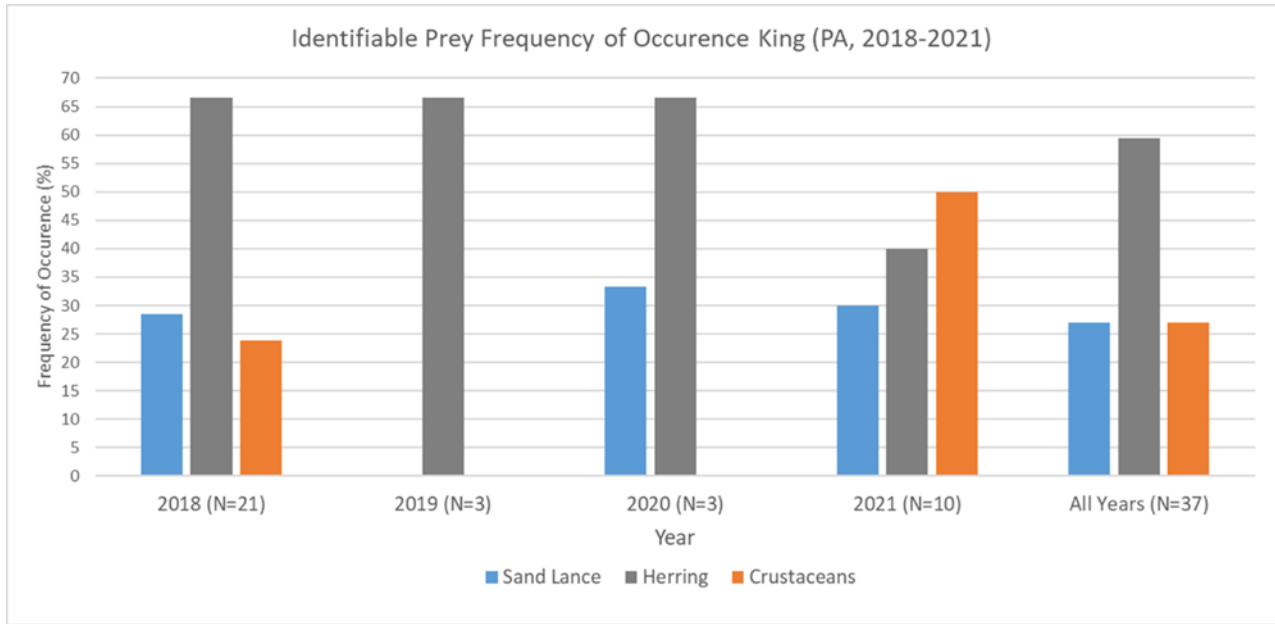


Figure 11. Frequency of Occurrence of identifiable prey for King Salmon using the presence-absence method (PA), 2018-2021 N=37

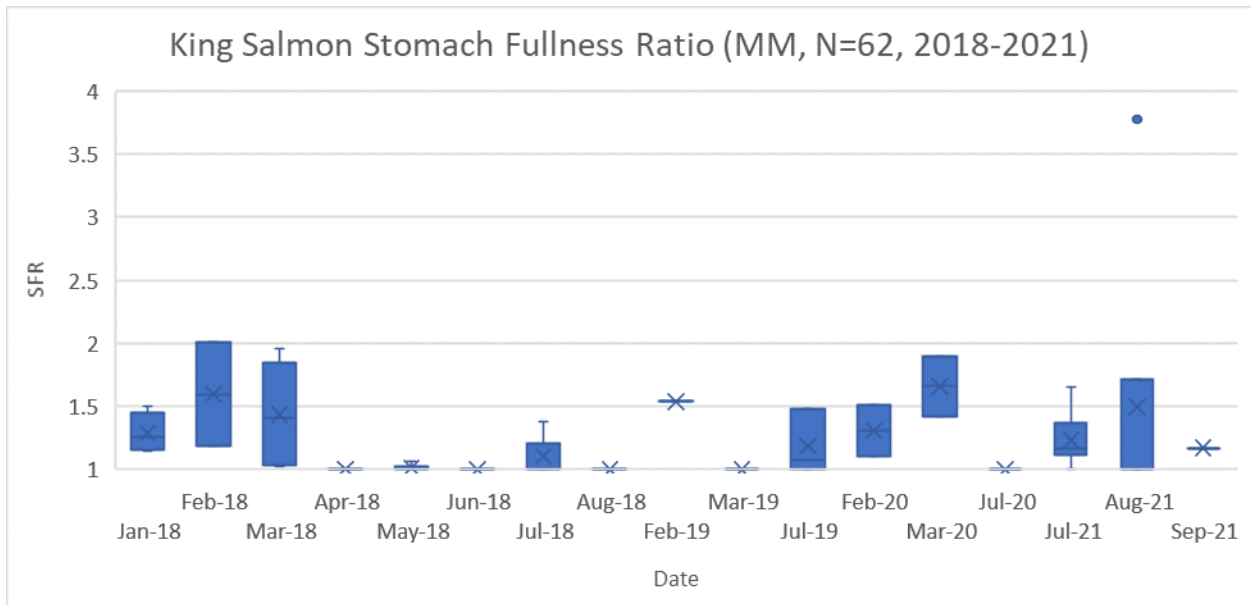


Figure 12. Stomach fullness ratios for king salmon using gravimetric method (MM), 62 samples, 2018-2021.

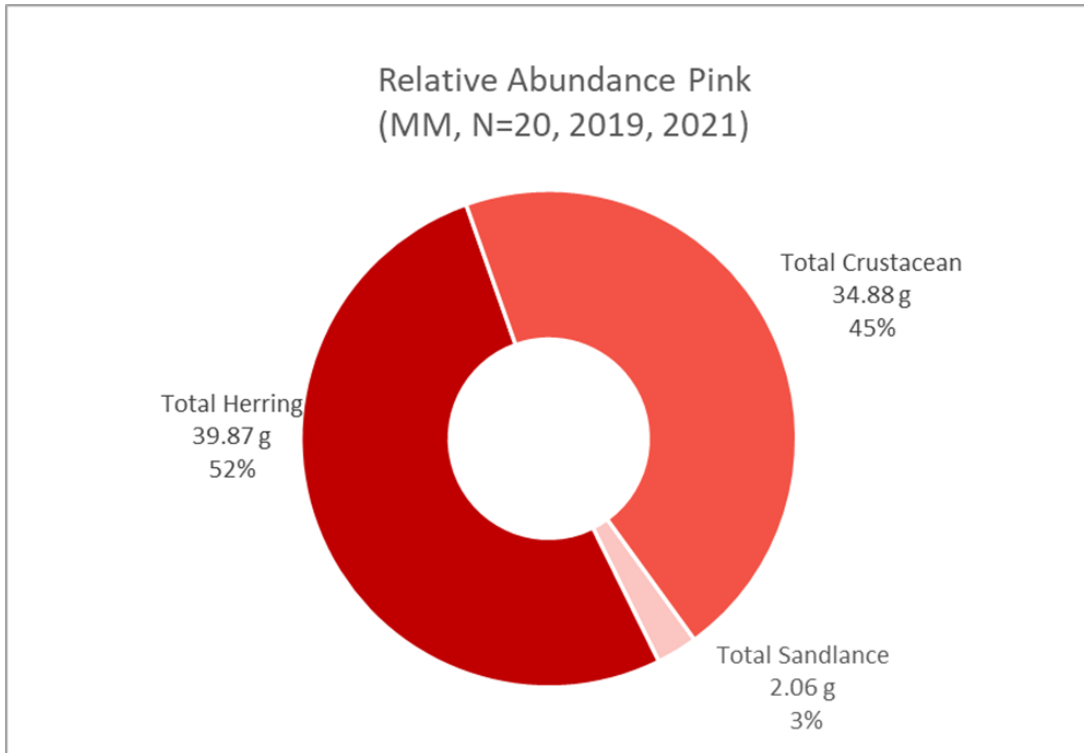


Figure 13. Relative abundance analysis of identifiable prey species masses using the gravimetric method (MM), 2019 and 2021.

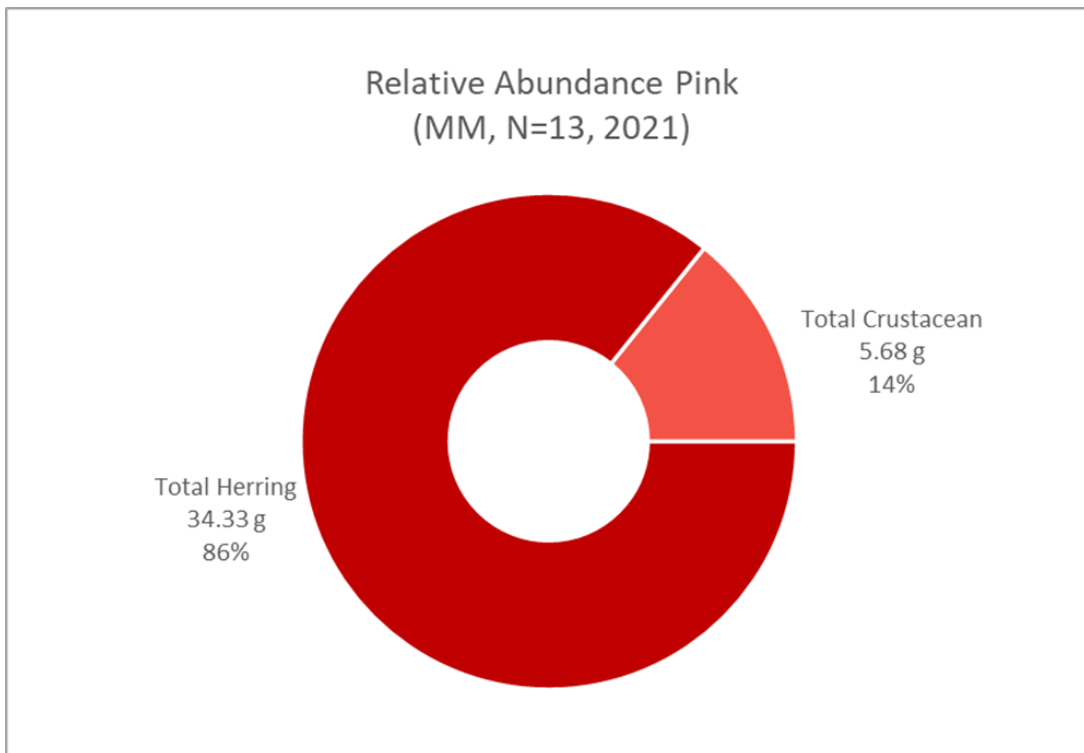


Figure 14. Relative abundance analysis of identifiable prey species masses using the gravimetric method (MM), 13 Pink Salmon samples, 2021.

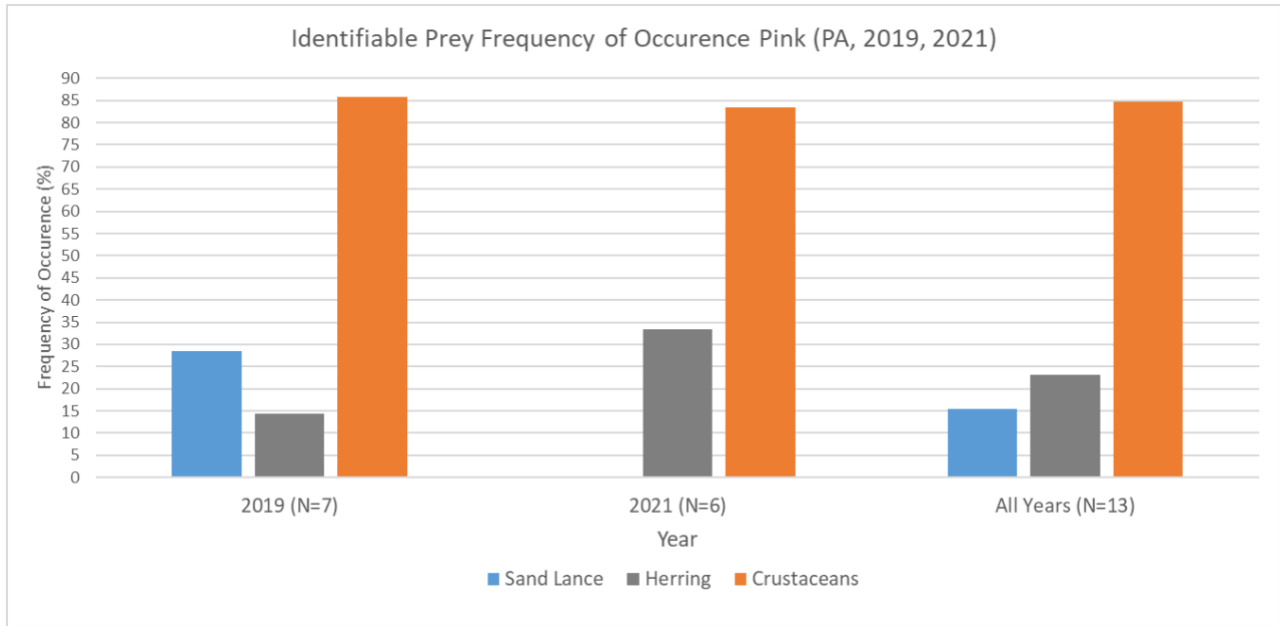


Figure 15. Frequency of Occurrence of identifiable prey for Pink Salmon using the presence-absence method (PA), 2019, 2021, N=13

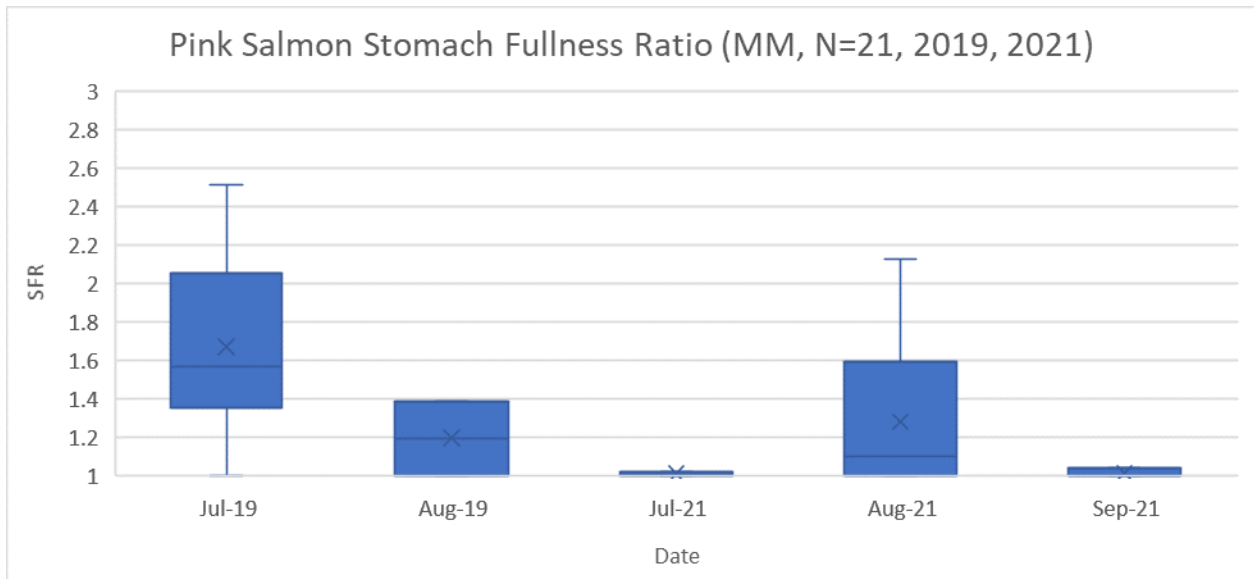


Figure 16. Stomach fullness ratios for pink salmon using gravimetric method, 21 samples (MM), 2019 and 2021.

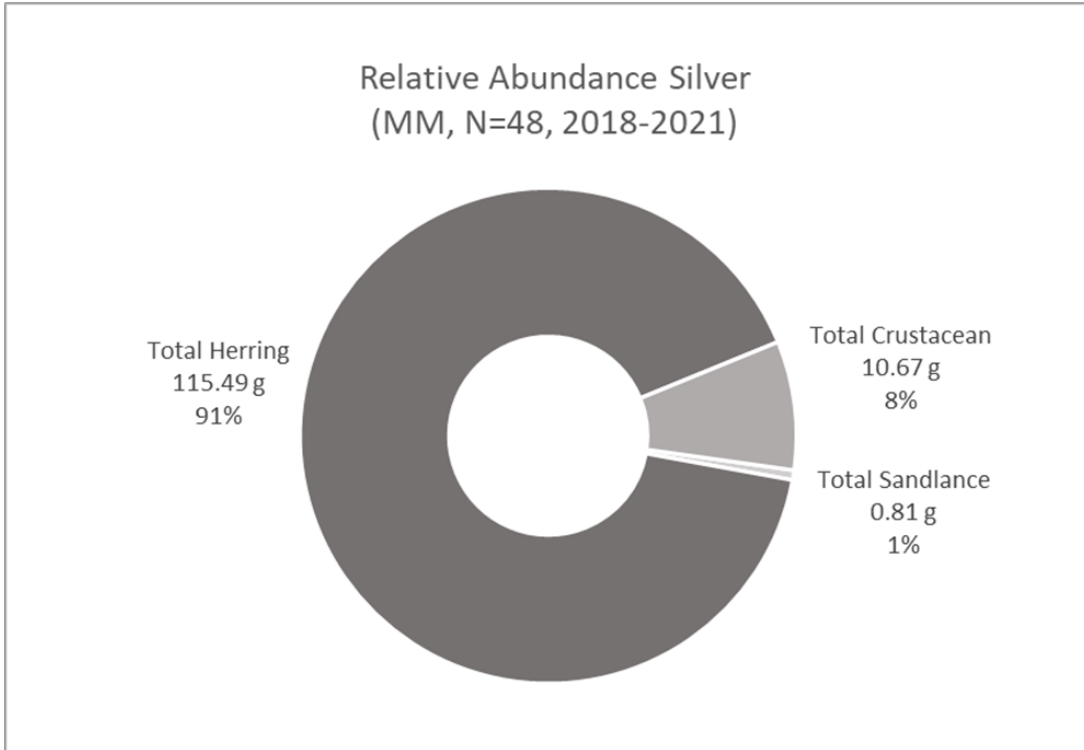


Figure 17. Relative abundance analysis of identifiable prey species masses using the gravimetric method (MM), 48 Silver Salmon samples, 2018-2021.

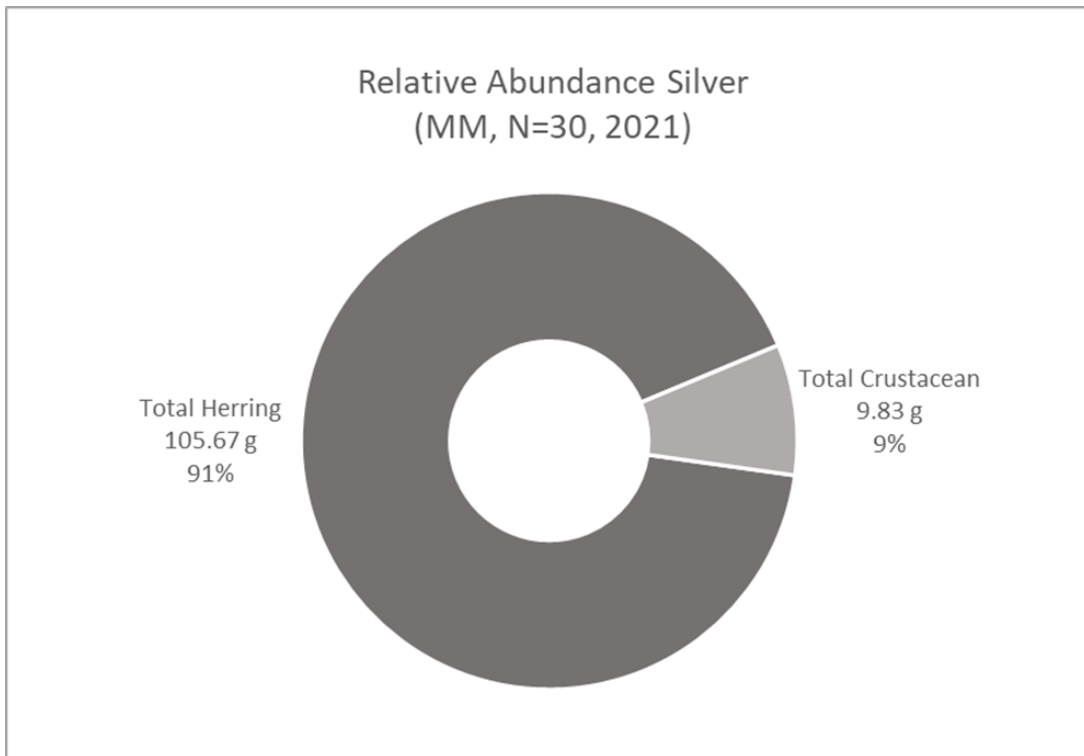


Figure 18. Relative abundance analysis of identifiable prey species masses using the gravimetric method (MM), 30 Silver Salmon samples, 2021.

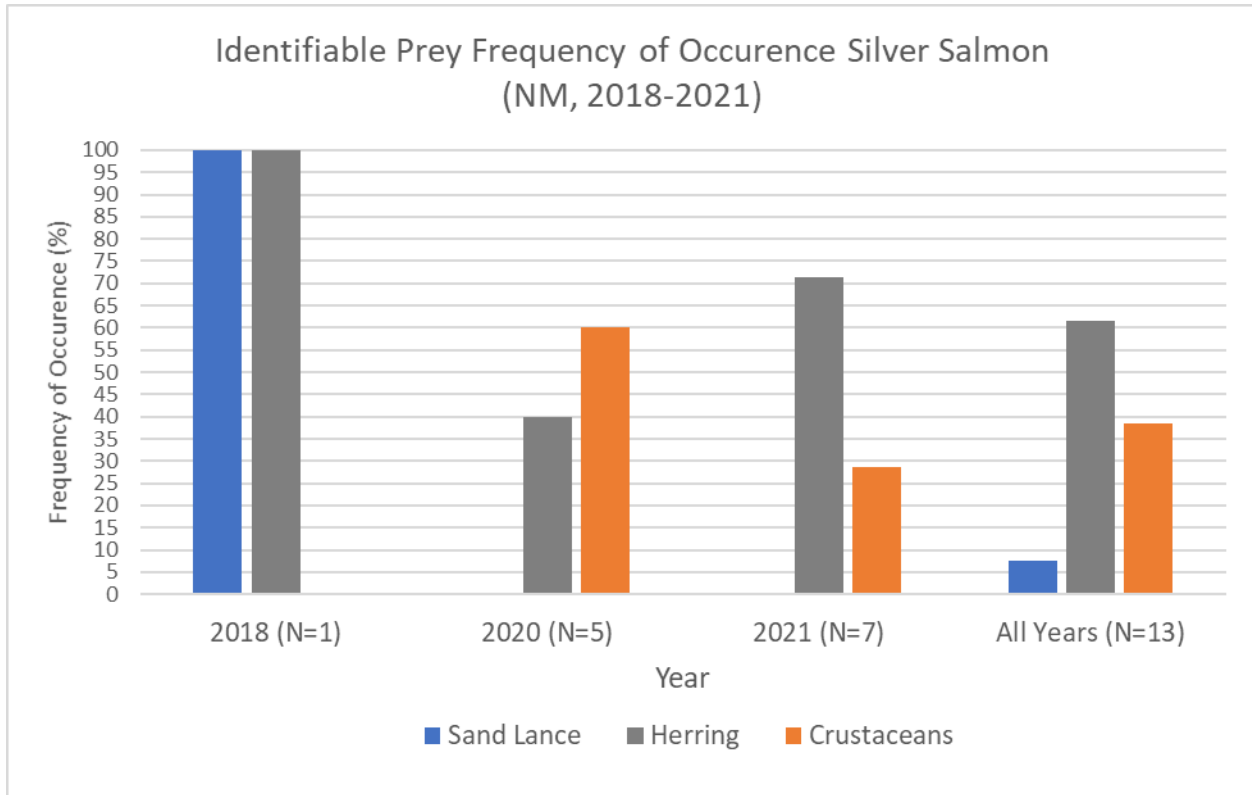


Figure 19. Frequency of Occurrence of identifiable prey for Silver Salmon using the presence-absence method (PA), 2018, 2020, 2021, N=13

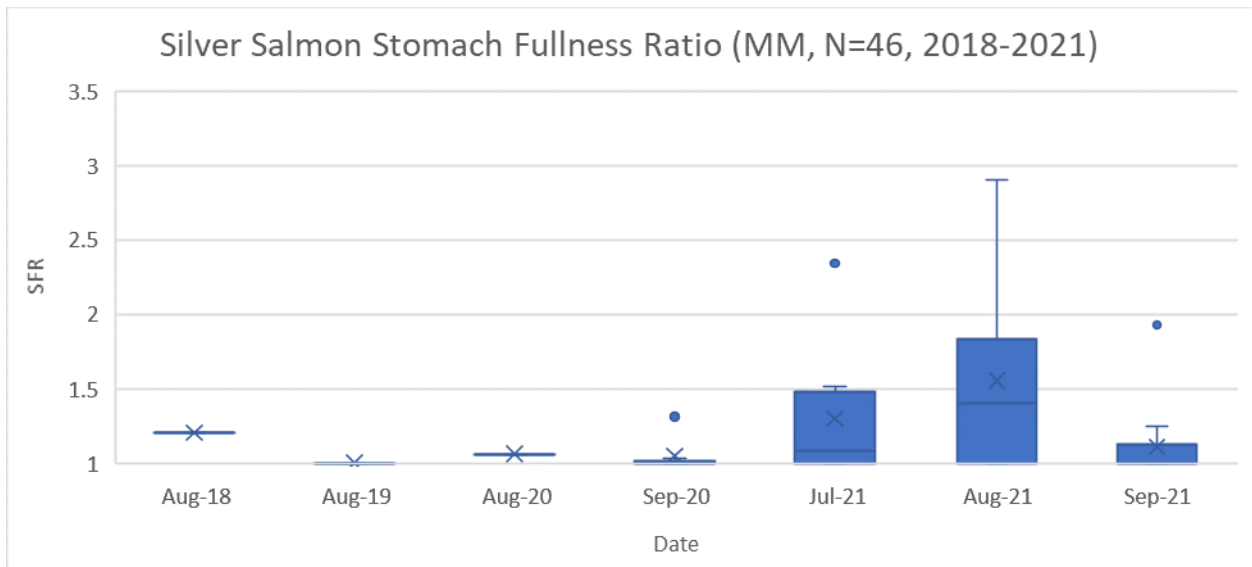


Figure 20. Stomach fullness ratios for silver salmon using gravimetric method (MM), 46 samples, 2018-2021.

Salmon Distribution 2018-2021 (N=108)

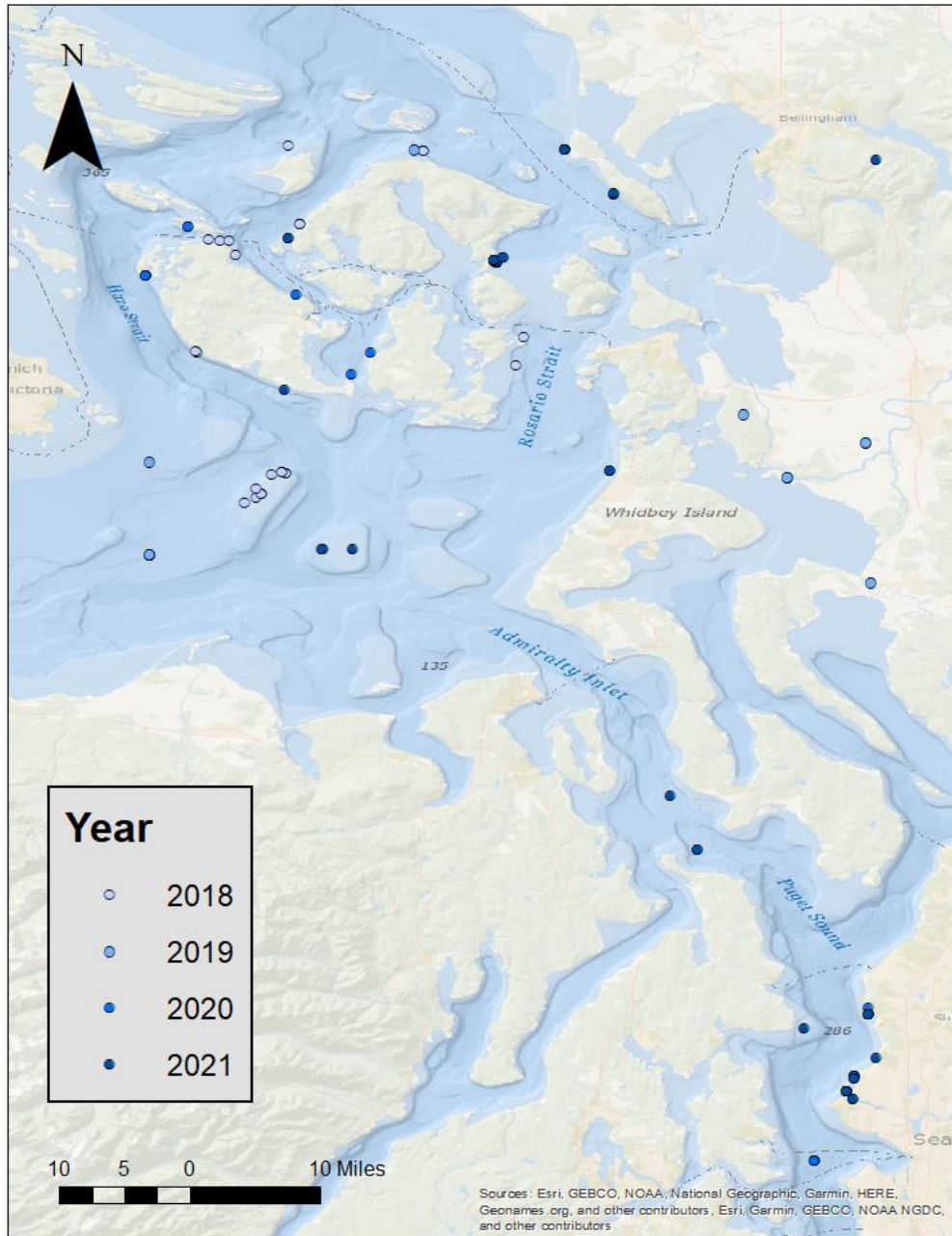


Figure 21. Spatial distribution of all samples with provided XY coordinates or location names, created with ArcMap, 2018-2021

Species Distribution 2018-2021 (N=108)

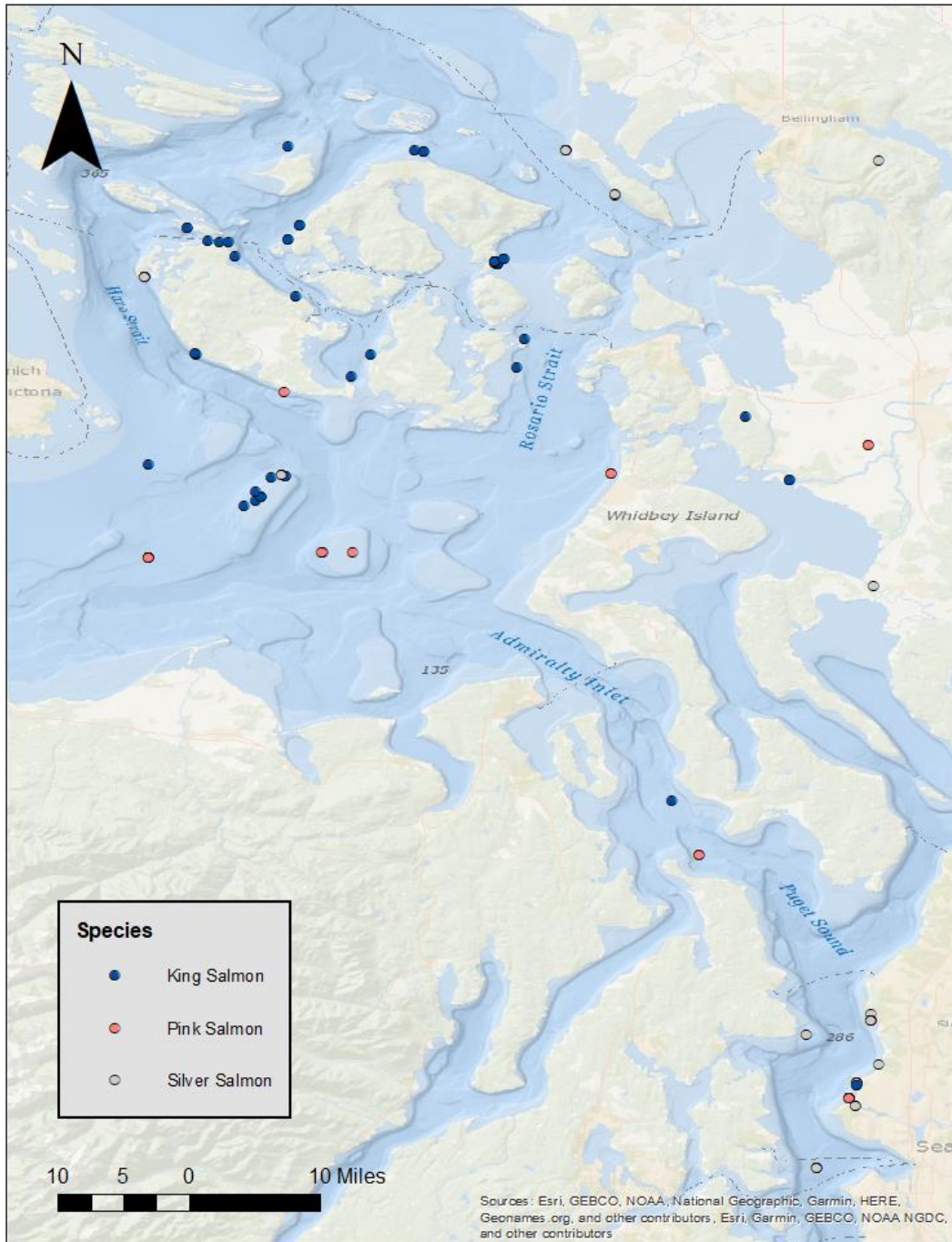


Figure 22. Spatial distribution of all samples with provided XY coordinates or location names, separated by species, created with ArcMap, 2018-2021

Pacific Sand Lance Presence Distribution 2018-2021 (N=108)

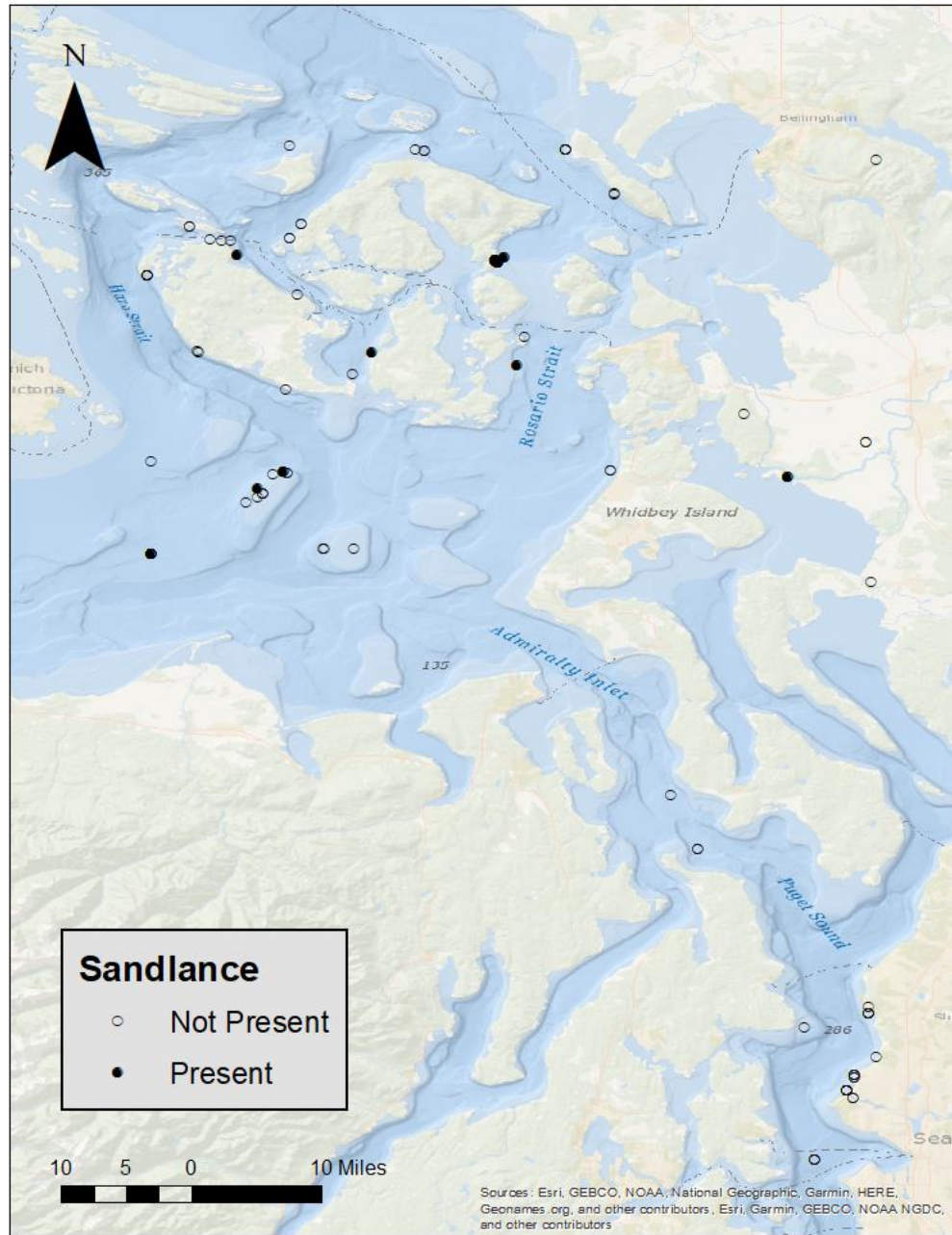


Figure 23. Spatial distribution of all samples with provided XY coordinates or location names, separated by the presence or absence of Pacific sand lance, created with ArcMap, 2018-2021.

Stomach Contents Presence Distribution 2018-2021 (N=108)

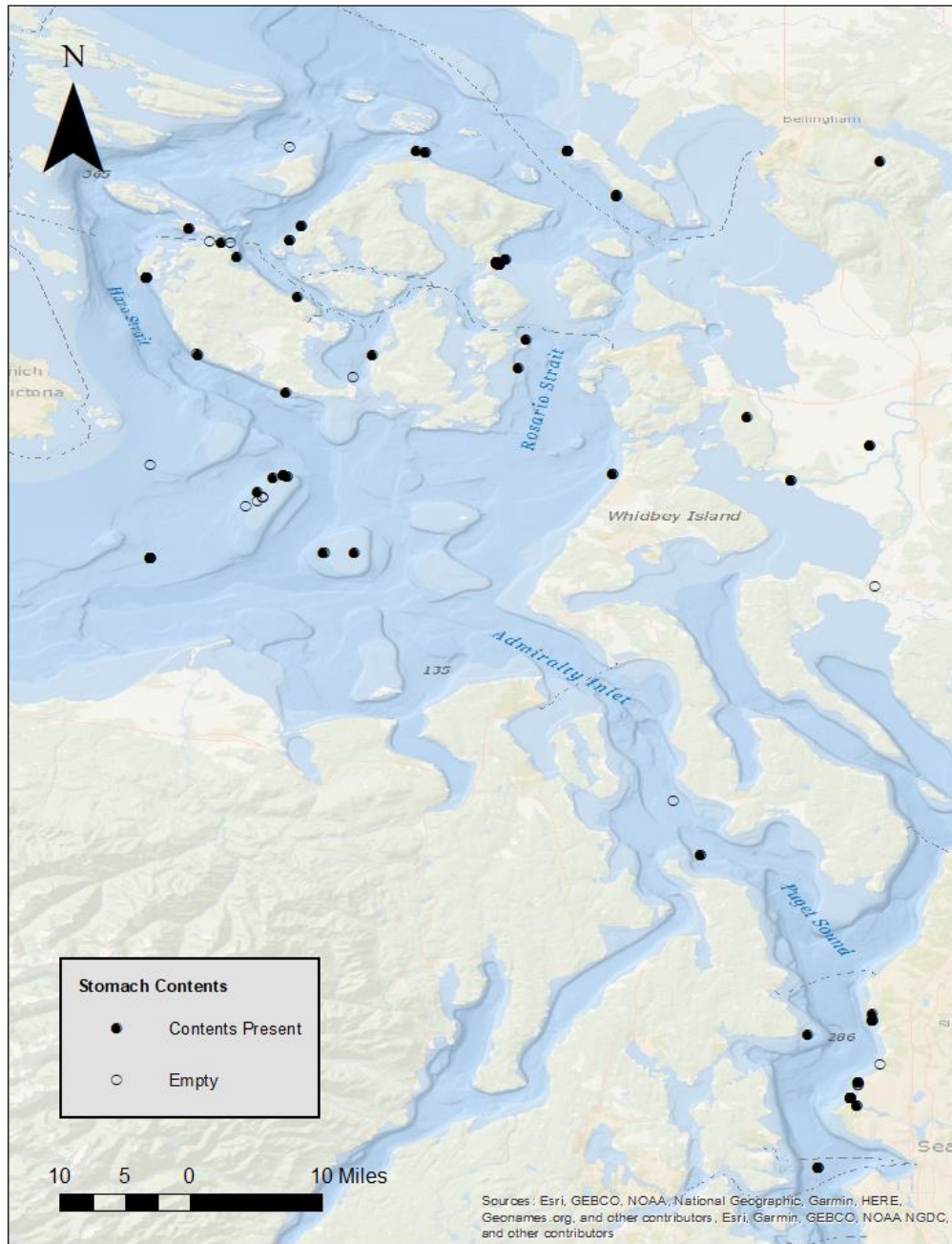


Figure 24. Spatial distribution of all samples with provided XY coordinates or location names, separated by the presence or absence of any stomach contents, created with ArcMap, 2018-2021.

Tables

Table 1. Frequency of Occurrence of identifiable prey for all species using the presence-absence method (PA), 2018-2021, N=63

Year	Sand Lance	Herring	Crustaceans
2018 (N=22)	31.82	68.18	22.73
2019 (N=10)	20	30	60
2020 (N=8)	12.5	50	37.5
2021 (N=23)	13.04	47.83	52.17
All Years (N=63)	20.63	52.38	41.27

Table 2. Frequency of Occurrence of identifiable prey for King Salmon using the presence-absence method (PA), 2018-2021, N=37

Year	Sand Lance	Herring	Crustaceans
2018 (N=21)	28.57	66.67	23.81
2019 (N=3)	0	66.67	0
2020 (N=3)	33.33	66.67	0
2021 (N=10)	30	40	50
All Years (N=37)	27.03	59.46	27.03

Table 3. Frequency of Occurrence of identifiable prey for Pink Salmon using the presence-absence method (PA), 2019, 2021, N=13

Year	Sand Lance	Herring	Crustaceans
2019 (N=7)	28.57	14.29	85.71
2021 (N=6)	0	33.33	83.33
All Years (N=13)	15.38	23.08	84.62

Table 4. Frequency of Occurrence of identifiable prey for Silver Salmon using the presence-absence method (PA), 2018, 2020, 2021, N=13

Year	Sand Lance	Herring	Crustaceans
2018 (N=1)	100	100	0
2020 (N=5)	0	40	60
2021 (N=7)	0	71.43	28.57
All Years (N=13)	7.69	61.54	38.46

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