39. BRITISH COLUMBIA COASTAL ECOSYSTEM STRUCTURE THROUGH THE LENS OF ADULT CHINOOK SALMON DIETS

Will Duguid[1], Bridget Maher, Wesley Greentree, Jessica Qualley, Micah Quindazzi, Katie Innes and Francis Juanes[2], University of Victoria, Victoria, B.C., [1]willduguid@hotmail.com, [2]juanes@uvic.ca

39.1. Highlights

- Pacific Herring remained the most important prey for Chinook Salmon in all regions in both summer and winter in 2021.
- Stomach fullness was highest in the Strait of Georgia and lowest in the Strait of Juan de Fuca.
- Winter stomach fullness in the Haro Strait and Southern Gulf Islands region was higher in 2021 than in other years, with diets dominated by small age-0 Pacific Herring.
- As in previous years, Howe Sound was the only region where Northern Anchovy were important in diets in 2021. The importance was reduced relative to 2017/18.

39.2. Description of the time series

The Adult Salmon Diet Program (ASDP) is a citizen science initiative of the Juanes Lab at the University of Victoria (Quindazzi et al. 2020) and was supported by Pacific Salmon Foundation, Project Watershed and Fisheries and Oceans Canada in 2021. The ASDP employs analysis of salmon stomach contents to better understand forage fish communities in coastal B.C. Diet sampling can provide insights into fine scale distribution and relative abundance of different age/size classes of forage fish that may not be available through other research methods (Thayer et al. 2008) and can be a valuable complement to traditional fishery-independent surveys. In the short term, the ASDP seeks to characterize spatial and seasonal variation in adult salmon diets and provide insight into the ecology of forage species. Over the long term, the program will provide a novel perspective on variability and trends in forage fish populations and their implications for salmon trophic ecology. This is the 5th year of data in the timeseries.

Digestive tracts of Chinook and Coho Salmon captured in the public fishery were submitted by individual fishers or collected at fish cleaning stations or derbies. Samples were frozen with a catch card indicating species, capture location, capture date, adipose fin status (clipped or unclipped) and length and/or weight along with additional capture observations. In the lab, stomach items were allocated to a prey category and weights were recorded. Presence and absence of diagnostic hard parts of a subset of prey categories in the intestines were also recorded, although results are not presented here.

To investigate temporal changes in diet composition and feeding intensity on different forage species, mean “partial fullness scores” (Magnussen 2011) for prey categories were compared among regions, seasons, and years. These scores were calculated as 1000 * prey category weight (g) divided by the cube of salmon length (cm). A length-based index of fullness was utilized as lengths of Chinook Salmon were more frequently available than weights. Seasons were defined as winter (October to March) and summer (April to September). To prevent splitting the winter between calendar years, the months of October to December were assigned

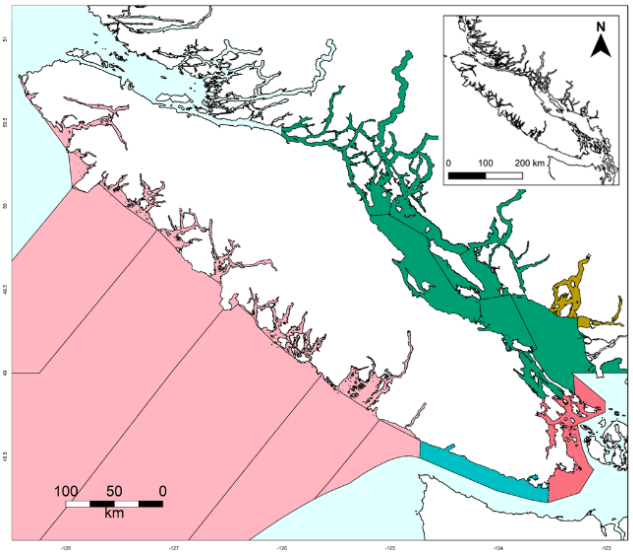

Figure 39-1. PFMA groupings for Chinook Salmon diet data reported in this document. Regions are referred to as Strait of Georgia (green), Howe Sound (orange), Haro Strait and Southern Gulf Islands (red), Strait of Juan de Fuca (teal) and West Coast Vancouver Island (pink).

to the following calendar year. The periods from April 1 to July 15 (Strait of Georgia) or April 1 to July 31 (Haro Strait/Gulf Islands, Howe Sound and Strait of Juan de Fuca) were excluded from analysis as retention of Chinook Salmon was partially or completely closed during these periods beginning in 2019. We undertook cluster analysis of a Bray-Curtis dissimilarity matrix of mean percent weight of prey categories pooled into Pacific Fishery Management Areas (PFMAs) within the Salish Sea from April to September (Greentree 2021). This resulted in identification of four distinct regions with varying diets (Figure 39-1). Fullness scores were also aggregated for West Coast Vancouver Island although data for this region were not included in the cluster analysis which was focused only on the Salish Sea. Of the 2872 Chinook Salmon diet samples processed to date by the ASDP, 1969 were used for the time series presented here.

39.3. Status and trends

Pacific Herring dominated Salish Sea Chinook Salmon diets across years and were the most important prey in all regions and seasons in 2021 (Figure 39-2). As in past years, the highest overall stomach fullness was observed in the Strait of Georgia in both summer and winter, with the lowest fullness in summer observed in the Strait of Juan de Fuca (no winter samples were available from this region in 2021). Preliminary length reconstructions for Pacific Herring in diets, based on otolith width to standard length regression (Greentree, unpublished), suggest that Strait of Georgia summer diets are dominated by age-2+ Pacific Herring (mean contribution to diets = 48%). While age-0 and age-1 Pacific Herring were important to summer diets in other regions, age-2+ fish were much less important (mean contribution to diets: Southern Gulf Islands = 8%; Strait of Juan de Fuca: = 6%).

Stomach fullness in the Haro Strait and Southern Gulf Islands region was higher in winter 2021 than in other years. This fullness was apparently driven by elevated occurrence of age-0 Pacific Herring that would have hatched in spring 2020. Preliminary length reconstruction further suggested that these juveniles were smaller than in previous years.

Northern Anchovy remained important in winter diets in Howe Sound but not in other regions, with a mean partial fullness score similar to 2019 and 2020 but approximately half of that measured in 2017 and 2018 (only a small sample of 14 stomachs were obtained for this region in winter 2021). As in previous years, summer diets on the West Coast of Vancouver Island in 2021 contained more invertebrates (primarily squid) than in other regions. It should be noted that in the initial years of the ASDP (2017-2018) Pacific Sand Lance were primarily encountered between April and July in the Haro Strait and Gulf Island Region. The time series presented here, therefore, do not accurately represent the importance of Pacific Sand Lance in diets.

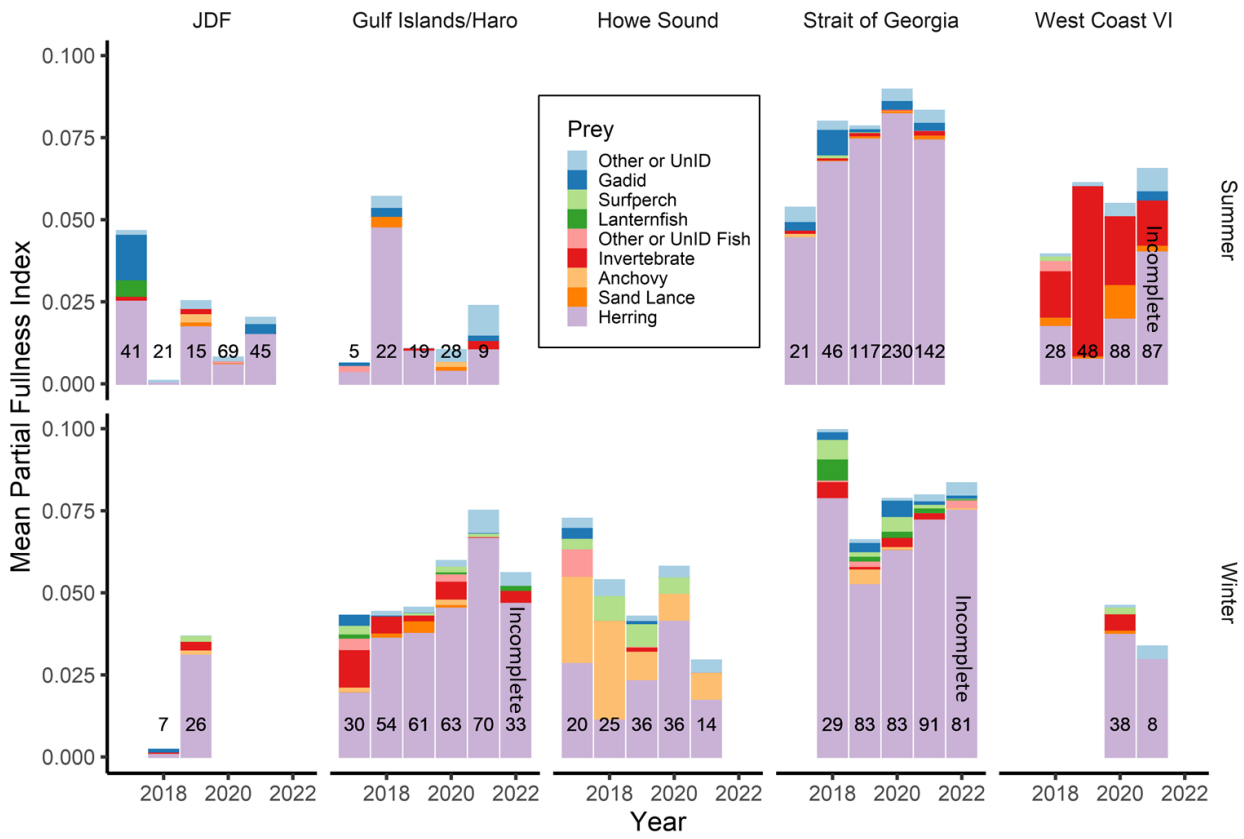

Figure 39-2. Mean prey group-specific partial fullness indices for Chinook Salmon stomachs in summer (April to September) and winter (October to March) for five regions (Figure 39-1) of Coastal B.C. from 2017 to early 2022. Note that the October-December have been moved to the following calendar year to prevent splitting a season. Total sample size is overlayed. JDF= Juan de Fuca; VI= Vancouver Island.

39.4. Factors influencing trends

As the ASDP is relatively new, trends in the data should be interpreted cautiously. The consistently high stomach fullness and large contribution of age 2+ Pacific Herring to Chinook Salmon diets in the Strait of Georgia is interesting given that the main assessed Strait of Georgia Pacific Herring stock is considered to be primarily migratory. The Strait of Georgia Pacific Herring spawning stock biomass has been high throughout the duration of the ASDP (Cleary et al. 2022, Section 21). We lack an understanding of the factors which might control whether Pacific Herring remain within the Strait of Georgia in summer and, in turn, regulate their availability to salmon and other predators. This is an important subject for future research.

Northern Anchovy abundance in the Salish Sea was anomalously high during warm conditions in 2015 and 2016 (Duguid et al. 2019). Declining importance of Northern Anchovy in adult Chinook Salmon diets after 2018 mirrored reduced frequency of occurrence of Northern Anchovy in the age-0 Pacific Herring survey in fall 2019 (Boldt et al., Section 37). While the fall 2021 age-0 Pacific Herring survey detected increased occurrence of juvenile Northern Anchovy (no survey occurred in fall 2020), the availability of these fish will primarily be reflected in 2022 adult salmon diets.

39.5. Implications of those trends

Changes in the partial fullness scores for different prey groups may reflect both changes in the abundance of those prey groups and in the abundance of alternative prey. An example of this is provided by winter diets in the Haro Strait and Southern Gulf Islands region where the frequency of occurrence of both empty stomachs and invertebrate prey has decreased with increasing frequency of occurrence of Pacific Herring and with overall stomach fullness. Going forward, prey-specific and aggregate partial fullness scores will reveal whether Chinook Salmon are able to obtain adequate alternative prey in regions and periods where herring are less abundant. Summer Chinook Salmon diet samples from the Strait of Georgia also provide an index of the abundance of non-migratory Pacific Herring, a potentially critical ecosystem component for which we otherwise lack indicators. Changes in abundance of these fish could result from changes in either migratory patterns or abundance of the aggregate spawning stock. The Chinook Salmon diet-based index will facilitate interpretation of the possible causes and ecological consequences of future changes in non-migratory Pacific Herring abundance. The ASDP is also well placed to detect the geographic extent and importance to Chinook Salmon of climate change-driven changes in range or abundance of species such as Northern Anchovy.

39.6. References

Duguid, W.D.P., Boldt, J.L., Chalifour, L., Greene, C.M., Galbraith, M., Hay, D., Lowry, D., McKinnell, S., Qualley, J., Neville, C., Sandell, T., Thompson, M., Trudel, M., Young, K., and Juanes, F. 2019. Historical fluctuations and recent observations of Northern Anchovy *Engraulis mordax* in the Salish Sea. Deep Sea Research II: Topical Studies in Oceanography. 159: 22-41.

Greentree, W. 2021. Using adult Chinook salmon diets to understand the spatial structure of forage assemblages in the Salish Sea. University of Victoria. BSc (Honours) thesis.

Magnussen, E. 2011. Food and feeding habits of cod (*Gadus morhua*) on the Faroe Bank. ICES J Mar. Sci. 68: 1909-1917.

Quindazzi, M.J., Duguid, W.D.P., Innes, K.G., Qualley, J., and Juanes, F. 2020. Engaging recreational salmon anglers in fisheries ecology. Fisheries. 45(9): 492-494.

Thayer, J.A., Bertram, D.F., Hatch, S.A., Hepfner, M.J., Slater, L., Sydeman, W.J. and Watanuki, Y. 2008. Forage fish of the Pacific Rim as revealed by diet of a piscivorous seabird: synchrony and relationships with sea surface temperature. Can. J. Fish. Aquat. Sci. 65: 1610-1622.