

FINAL

**King County Marine Habitat Report
Prepared in support of the Wastewater Treatment Division
Habitat Conservation Plan and
the Brightwater Marine Outfall Siting Study**

**Appendix A
Compilation of Existing Fish Food Web Data**

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Submitted to:

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Appendix A

Compilation of Existing Fish Food Web Data

The accompanying tables (Tables 1 through 11) contain synopsized data from archived, unpublished, or “gray” literature sources. Data are included from the main basins of Puget Sound (from the south tip of Whidbey Island south) and Hood Canal. Three large studies that supplied much of the data bear mentioning. First, Kurt Fresh (Washington Department of Fish and Wildlife) and others conducted extensive sampling in north and south Puget Sound in 1978 and 1979 using a variety of gear types—this data is denoted as “Fresh unpublished” in the tables. A brief summary of this data was presented in Fresh et al. 1981. Second, a number of fish species were trapped in and around piers and docks in Commencement Bay from 1984-86. Some of this data appeared in a University of Washington Master’s thesis and an unpublished document (Ratte and Salo 1985), but it remains largely unpublished. This is denoted as “Cordell and Simenstad unpublished. Third, Stephen Bollens (San Francisco State University) and J. Cordell analyzed a large number of salmon, herring, hake, and other species from Dabob Bay, Hood Canal from 1985-87. Salmon diet data from this study has been analyzed for a paper to be submitted to the Canadian Journal of Fisheries and Aquatic Sciences and is referenced as such in the tables, but information for other fish species has not been formally worked up. This data set is referred to as “Bollens and Cordell unpublished”.

For each group of fish entered, in the accompanying tables, all prey categories that comprised over 5% of prey biomass are listed in order of abundance. Brief notes on food web connotations for each prey category are also included, as is the source of the data. The findings for each species are summarized as follows:

Chinook Salmon (*Oncorhynchus tshawytscha*)

There are datasets for chinook salmon (mainly juveniles) that spanned a period from 1978 through 1999. The data indicates two broad categories of chinook feeding: (1) nearshore feeding fish that consumed mainly gammarid amphipods and other epibenthic crustaceans, and terrestrial (neustonic) insects; and (2) pelagic feeding fish that fed as small juveniles on planktonic crustaceans (primarily euphausiids) and as larger juveniles and adults on herring and other fish. Thus, the important habitats and food web connections for chinook salmon in Puget Sound are:

1. Intertidal and shallow subtidal areas that produce amphipods and other epibenthic crustaceans. As has been established for juvenile chum salmon, these probably include intertidal flats as well as vegetation and areas of high detritus buildup.
2. Nearshore vegetated terrestrial habitats that are the source of terrestrial insects in the diets.
3. Feeding on planktonic grazers such as euphausiids, shrimp and crab larvae, planktonic amphipods, and copepods.
4. Feeding on other secondary pelagic consumers such as herring and other fish.

Coho Salmon (*Oncorhynchus nerka*)

There was much less diet data for Coho than for Chinook salmon. It appears that food web linkages for Puget Sound Coho salmon are similar to those for Chinook, with larger fish feeding on herring and other “baitfish” and smaller fish feeding on planktonic crustaceans. Coho differ from Chinook in being less dependent on benthic/epibenthic habitats, evidenced by fewer cases of diet dominated by taxa such as gammarid amphipods. Although the resolution of the data presented here does not show it, even when amphipods occurred as important prey for Coho, they were often pelagic types, particularly such taxa as the gammarid *Cyphocaris challengerii* and the hyperiid *Parathemisto pacifica*.

Chum Salmon (*Oncorhynchus keta*)

Similarly to Chinook, Chum salmon depended on two major habitats for feeding. In the spring when they were small, they fed primarily on the epibenthic harpacticoid copepods *Harpacticus* and *Tisbe*. Food web linkages at this stage have been presumed to be detritus based, but may also include some epibenthic primary production (e.g., diatoms). At this time they also fed on epibenthic aquatic insect larvae such as chironomids. In late spring to early summer, Chum salmon switched to feeding on planktonic primary consumers such as larvaceans and planktonic copepods. In the summer, they fed on larger zooplankton such as euphausiids, hyperiid amphipods, and fish larvae.

Pacific Herring (*Clupea harengus*)

The herring sampled from Puget Sound and Hood Canal fed almost exclusively on plankton. This consisted mainly of planktonic copepods in smaller juvenile fish and euphausiids and amphipods in larger juveniles and

adults. It is interesting to note that in the diet from herring sampled from Padilla Bay (this small data set is included as a reference), which has extensive eelgrass beds, the diet had a significant amount of epibenthic harpacticoid copepods. Therefore, this habitat should not be ruled out as providing food web linkages for this species.

Surf Smelt (*Hypomesus pretiosus*)

There were only a few data sets for surf smelt. One fairly large group of 32 individuals from the Kurt Fresh data fed mainly on zooplankton. As for herring, a group of surf smelt captured at Padilla Bay fed on harpacticoid copepods and other epibenthic taxa.

Pacific Sand Lance (*Ammodytes hexapterus*)

The only data set with appreciable numbers of sand lance was that from Hood Canal (Bollens and Cordell data). In these fish, planktonic copepods were the dominant prey. Like surf smelt, sand lance from Padilla Bay fed on harpacticoid copepods.

Pacific Hake (*Merluccius productus*)

Virtually all of the data for Pacific Hake in the table came from the Dabob Bay data set of Bollens and Cordell. In this deep fjord, hake appear to be euphausiid specialists, with minor contributions by other zooplankton species.

Other Species

Very little data was found for other listed/candidate fish species. There is some extant data on feeding by juvenile rockfish analyzed by Ray Buckley (Washington Department of Fish and Wildlife). This data is in raw numerical form and must be further analyzed by the University of Washington's GUTBUGS diet analysis program in order to make sense of it. This should be done before a final draft of the food web document is completed.

Summary

Perhaps the most striking result of this review of diet data for ESA listed and candidate fish species in Puget sound is the preponderance of zooplankton species used by the fish. This points directly to a large gap in our understanding of the biology of these fish. Salmon ecology and the effects of

habitat degradation on juvenile salmon in estuaries and nearshore marine habitats in Puget Sound and other waters in the Pacific Northwest are relatively well studied (Simenstad et al. 1991, Aitken 1998, Simenstad and Cordell in press). In contrast, the ecology of juvenile salmon and other listed and candidate fish in water column habitats of Puget Sound is poorly known. Elsewhere in the region the role of the nearshore pelagic environment, and particularly the importance of zooplankton feeding, has been established for juvenile salmon. For example, juvenile pink and chum salmon off northern Vancouver Island had more material in their stomachs, were in better condition, and had higher potential growth rates than pink and chum salmon off southern Vancouver Island; these variations were consistent with spatial differences in zooplankton biomass, there being more plankton in the northern region (Perry et al. 1996). Brodeur et al. (1992) suggested that juvenile coho and chinook salmon off of Oregon and Washington experienced planktonic food limitation during years of unusually low productivity (e.g., El Niño). The few relevant studies (e.g., Fresh et al. 1981, Bollens et al. submitted) and the data summarized here indicate that the pelagic habitat is important for Puget Sound salmon and several of their important forage fish. Especially notable is the importance of euphausiids in the diet of a variety of fish species, in both Puget Sound and Hood Canal. The dominant euphausiid, *Euphausia pacifica*, requires deep basins for reproduction, and apparently breeding populations of this species occur only in Carr Inlet, Port Susan, and Dabob Bay, within the area examined (Cooney 1971, Ross et al. 1982). Thus, euphausiid populations may be a limiting factor for many of their predators in Puget Sound, and this subject bears investigation. Unfortunately, virtually nothing is known about how Puget Sound zooplankton species vary in time and space and how this relates to the fish that feed on them.

References

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Table 1. Chinook Salmon (*Oncorhynchus tshawytscha*)

Location	Date	Habitat, Gear #, LH Stage	Principal Prey Taxa	Food Web Comments	Source
Carr Inlet, Wollochet Bay, Gibson Pt., Anderson Is., Johnson Pt., Hale Pass, Fox Pt., Pt. Defiance	Feb-July 78	Townet	11 Juvenile, 14 Adu Clupea harengus Teleostei	Unidentified Fish Herring	Fresh, unpublished data
Wollochet Bay	Jul-78	8 Juvenile	Polychaeta Insecta	Benthic Worms (but may have pelagic phase) Terrestrial Insects	
Anderson Is. -Lyle Point	Aug-78	12 Juvenile	Teleostei Theragra chalcogramma Cymatogaster aggregata	Unidentified Fish Walleye Pollock Shiner Perch	
Johnson Point	Aug-78	14 Juvenile	Teleostei Clupea harengus	Unidentified Fish Herring	
Wollochet Bay	Aug-78	12 Juvenile	Decapoda Brachyura Insecta Teuthidida	Crab Larvae Terrestrial Insects Squid	
	12009 Aug-78	13 Juvenile	Insecta Polychaeta Ostracoda Gammaridea Decapoda Brachyura	Terrestrial Insects Benthic Worms (but may have pelagic phase) Epibenthic Crustaceans Epibenthic Crustaceans Crab Larvae	
Anderson Is. -Lyle Point	Sep-78	15 Juvenile	Clupea harengus Gadidae Teleostei	Herring Cod Family Unidentified Fish	
Henderson Inlet	Sep-78	5 Juvenile	Polychaeta	Benthic Worms (but may have pelagic stage)	
Fox Island	Sep-78	4 Juvenile	Gammaridea Insecta Ampipoda	Can't tell from level of identification Terrestrial (neuston) Can't tell from level of identification	
Wollochet Bay	Sep-78	6 Juvenile	Euphausiacea Teleostei Decapoda-Brachyura	Planktonic Crustaceans Unidentified Fish Crab Larvae	
Wollochet Bay	Sep-78	5 Juvenile	Euphausiacea	Planktonic Crustaceans	
Anderson Is. -Lyle Point	Oct-78	10 Juvenile	Teleostei Gadidae Theragra chalcogramma Clupea harengus	Unidentified Fish Cod Family Walleye Pollock Herring	

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Location	Date	Habitat, Gear	#, LH Stage	Principal Prey Taxa	Food Web Comments	Source
Gibson Pt., Fox Is., Wollochet Bay, Hale Pass, Green Pt., Anderson Is. -Lyle Pt.	Nov-78		32 Juvenile, 1 Adult	Teleostei Clupea harengus	Unidentified Fish Herring	
Fox Is., Gibson Pt. Nisqually Reach, Wollochet Bay, Anderson Is., Johnson Pt.	Dec-78		16 Juvenile	Clupea harengus Teleostei	Unidentified Fish Herring	
Gibson Pt., Fox Pt., Wollochet Bay, Johnson Pt., Day Is.	Jan-79		10 Juvenile, 1 Adult	Clupea harengus Loligo sp.	Herring Squid	
Hale Pass	Feb-79		11 Juvenile	Euphausiacea Clupea harengus	Planktonic Crustaceans Herring	
Hale Pass	Feb-79		7 Juvenile	Clupea harengus	Herring	
Hale Pass	Feb-79		5 Juvenile	Euphausiacea Teleostei	Planktonic Crustaceans Unidentified Fish	
Hale Pass	Feb-79		15 Juvenile	Euphausiacea	Planktonic Crustaceans	
Hale Pass	Feb-79		17 Juvenile	Euphausiacea Clupea harengus	Planktonic Crustaceans Herring	
Hale Pass	Feb-79		10 Juvenile	Clupea harengus Euphausiacea Teleostei	Herring Planktonic Crustaceans Unidentified Fish	
Hale Pass	Feb-79		15 Juvenile	Clupea harengus Teleostei	Herring Unidentified Fish	
Port Madison	Feb-79	Purse Seine	14 Adult	Gammaridea Mysidacea Teleostei	Can't tell from level of identification Can't tell from level of identification Unidentified Fish	
Port Madison	Feb-79	Purse Seine	10 Adult	Teleostei Clupea harengus	Unidentified Fish Herring	
W. Blake Island	Feb-79	Purse Seine	15 Juvenile	Hyperidea Teleostei Polychaeta	Planktonic Amphipods Unidentified Fish Benthic Worms (but may have pelagic phase)	
W. Blake Island	Feb-79	Purse Seine	7 Juvenile	Clupea harengus	Herring	
Port Madison, Hale Pass, Solo Point	Feb-79		19 Juvenile, 62 Adu	Euphausiacea	Planktonic Crustaceans	

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Location	Date	Habitat, Gear #, LH Stage	Principal Prey Taxa	Food Web Comments	Source
Pt. Defiance, Gibson Pt., Glen Cove, Anderson Is., Green Pt., Johnson Pt.	Mar-'79	14 Adult	Clupeidae Teleostei Gadidae	Herring Unidentified Fish Cod Family	
Commencement Bay	Apr-June 1983	152 Juvenile	Teleostei Euphausiacea Clupeidae Harpacticoida Crangonidae Cancridae	Unidentified Fish Planktonic Crustaceans Herring Epibenthic Copepods Shrimp Larvae Cancer Crab Larvae	Cordell and Simenstad unpublished
Commencement Bay	April-June 1984	9 Juvenile	Insecta Harpacticoida	Terrestrial Insects Epibenthic Copepods	
Commencement Bay	Apr-June 1985	82 Juvenile	Insecta Teleostei	Terrestrial Insects Unidentified Fish	
Duwamish Head	Jul-84	Eelgrass	Ischyrocerus sp. Eogammarus confervicolu Callicopiis sp. Crangon sp.	Epibenthic gammarid amphipods Epibenthic gammarid amphipods Epibenthic gammarid amphipods Benthic shrimp	Simenstad and Cordell unpublished
Dabob Bay (Hood Canal)	June-July 1985-87 Offshore Station	12 Juvenile	Euphausiacea Teleostei Calanoida Hyperidea	Planktonic Crustaceans Unidentified Fish Planktonic Copepods Planktonic Amphipods	Bollens et al. submitted
Dabob Bay (Hood Canal)	August 1985-87 Offshore Station	18 Juvenile	Euphausiacea Hyperidea Insecta	Planktonic Crustaceans Planktonic Amphipods Terrestrial Insects	
Dabob Bay (Hood Canal)	October 1985-87 Offshore Station	35 Juvenile	Euphausiacea Gammaridea Insecta	Planktonic Crustaceans Can't tell from level of identification Terrestrial Insects	
Dabob Bay (Hood Canal)	June-July 1985-87 Inshore Station	18 Juvenile	Decapoda Teleostei	Crab and Shrimp Larvae Unidentified Fish	
Dabob Bay (Hood Canal)	August 1985-87 Inshore Station	15 Juvenile	Insecta Decapoda	Terrestrial Insects Crab and Shrimp Larvae	
Dabob Bay (Hood Canal)	October 1985-87 Inshore Station	19 Juvenile	Insecta Hyperidea Pteropoda	Terrestrial Insects Planktonic Amphipods Planktonic Molluscs	
Shishole Bay	June-Aug 1999 Beach Seine	45 Juvenile	Gammaridea Clupea harengus Daphnia	Epibenthic/benthic Amphipods Herring Freshwater Cladocera (from below locks)	Cordell unpublished