Appendix D. Life Histories of Key Taxa

The food web model that was used to evaluate the long-term effects of the proposed mussel raft in Totten Inlet was based the life history information provided in the following sections. The purpose of this review is not to describe all aspects of life history for each key taxa, but rather to focus on what key taxa are present, the population size (represented by biomass, standing stock, and production) and seasonal distribution, and the prey composition. Information sources included site-specific data collected by the Pacific Shellfish Institute, data from both peer-reviewed and gray literature, and personal communications with regional experts, including State and Tribal biologists. Where possible, life history data from Totten Inlet or south Puget Sound were used to develop the food web. However, regional data for some species is limited; in such cases, data from broader regions were used to fill data gaps.

Zooplankton

Zooplankton are a remarkably diverse assemblage of small water-column organisms. They include not only animals that are planktonic throughout their entire life (holoplankton), but also animals that are planktonic only in their larval form (meroplankton). Two important categories of zooplankton, microzooplankton and gelatinous zooplankton (jellyfish) will be discussed separately below. Zooplankton provide a crucial link between the photosynthetic phytoplankton and the fish and shellfish resources in Puget Sound. Although there is a substantial amount of information on zooplankton population structure and abundance in Puget Sound, there is considerably less data on zooplankton in Totten Inlet.

Data on population structure and seasonal population size was collected in Totten Inlet by PSI and Budd Inlet (Giles and Cordell 1998). As with phytoplankton, zooplankton populations cycle throughout the year, both in abundance and in species composition. PSI examined zooplankton in water samples collected during their extensive phytoplankton sampling effort in Totten Inlet in 2002 and 2003 (Cheney, et al. unpublished data). Once monthly, five gallon water samples from discrete water depths were examined for phytoplankton (identified to species) and zooplankton (macroplankton and microplankton identified to family). Peak zooplankton abundance was observed in June and July, with sporadic presence in May and from August to November. No zooplankton were observed in February or March. Because this effort sampled limited water volumes from discrete depths (generally near surface) and zooplankton have diel vertical migration patterns, it is likely that the reported abundance is an underestimate. This is reflected in the low densities of copepods, which are typically numerically dominant in Puget Sound. This sampling effort did, however, provide a good characterization of the microzooplankton community. *Heleocostamella* and other tintinnids were the most common microzooplankton, occurring most frequently and comprising 60% to >90% of the zooplankton observed in samples. Other dominant groups were copepods, barnacle and crab nauplii, and *Tiarina*. In August/September, unidentified species ("other") were numerically dominant. Based on Giles and Cordell (1998), these may be larvaceans or cladocerans.

Giles and Cordell (1998) conducted a zooplankton study in Budd Inlet examining abundance, biomass, and species distribution of macroplankton zooplankton (>200 um) throughout the inlet. Vertical zooplankton tows were conducted in six locations in Budd Inlet on 21 sampling events from October 1996 to September 1997 using a 220-µm mesh net. The northern and central

portions of Budd Inlet were most similar to conditions in north Totten Inlet and were used for this evaluation.

At the northern portion of the inlet, zooplankton abundance was lowest during the fall and winter months and was generally less than 1000 ind/m^3 from November to February. Abundance increased in spring and early summer from 5,000 to 30,000 ind/m^3 between mid-March to mid-July. This was presumably a response to increasing phytoplankton abundance with increasing light. Abundance declined throughout the summer as various species of fish and crustacean larvae successively develop. This increased the predatory pressure on the zooplankton population, as well as decreasing the contribution of meroplankton to the zooplankton biomass. The decreased abundance observed in the mid-summer months can allow a second phytoplankton bloom in the late summer. Zooplankton abundances in late July to September were approximately 5,000 ind/m^3. Abundance in the mid-bay stations was generally similar; however, peak abundance in early June reached 65,000 ind/m^3.

Average zooplankton biomass followed a similar seasonal pattern as abundance (Figure D1.) with peak biomass occurring from April to August. From October 1996 to September 1997 in the North Bay and Central Bay stations the average zooplankton biomass was 0.097 g dry wt/m^3. Assuming the 50% of the dry weight was carbon (Winter et al. 1975; Rodhouse and Roden 1987), the average standing stock was 0.49 gC/m^2, with a seasonal average of 0.19 gC/m^2 (95% CI: 0.15 gC/m^2) in the Fall/Winter and 0.74 gC/m^2 (95% CI: 0.40 gC/m^2) in the spring/summer. It is difficult to discern whether the data in Giles and Cordell (1998) are reported for the entire sample or as g DW/m^3. Priekshot and Beattie (2001) used this data as g DW/m^3 in estimating zooplankton wet weight for Puget Sound. Futhermore, the zooplankton biomass observed in Budd Inlet is similar to the annual range of <0.1 to 0.7 g dry weight/m^3 reported by Anderson et al. (1984) in central Puget Sound. Additionally, when the biomass is converted to standing stock, the resulting standing stock is to the value of 0.01 gC/m^3 reported by Winter et al. (1975). Based on these comparisons, the values of 0.19 gC/m^2 and 0.74 gC/m^2 will be used here for the fall/winter and spring/summer periods, respectively.

There is a wide range of production to biomass (P:B) ratios for zooplankton, ranging from <5 to 55 per year (Dalsgaard et al. 1998); however, for omnivorous zooplankton, the P:B ratio is typically between 10 and 20 (Valiela 1995; Dalgaard et al. 1998) and a value of 15 will be used here. Based on the P:B ratio of 15, average annual production would be 7.5 gC/m^2/yr, with seasonal average values of 2.9 gC/m^2/yr in fall/winter and 11.1 gC/m^2/yr in the spring/summer.

Giles and Cordell (1998) found that temporal variation in species composition was greater than spatial variation, with similar species composition throughout Budd Inlet. Crustaceans dominated the zooplankton composition throughout the year, comprising 60% to >90% of the total zooplankton population between December and September. Dominant crustaceans were copepods and crab and barnacle larvae. Larvaceans were the dominant taxon in October through November. Other dominant groups were cnidarians, and polychaete larvae.
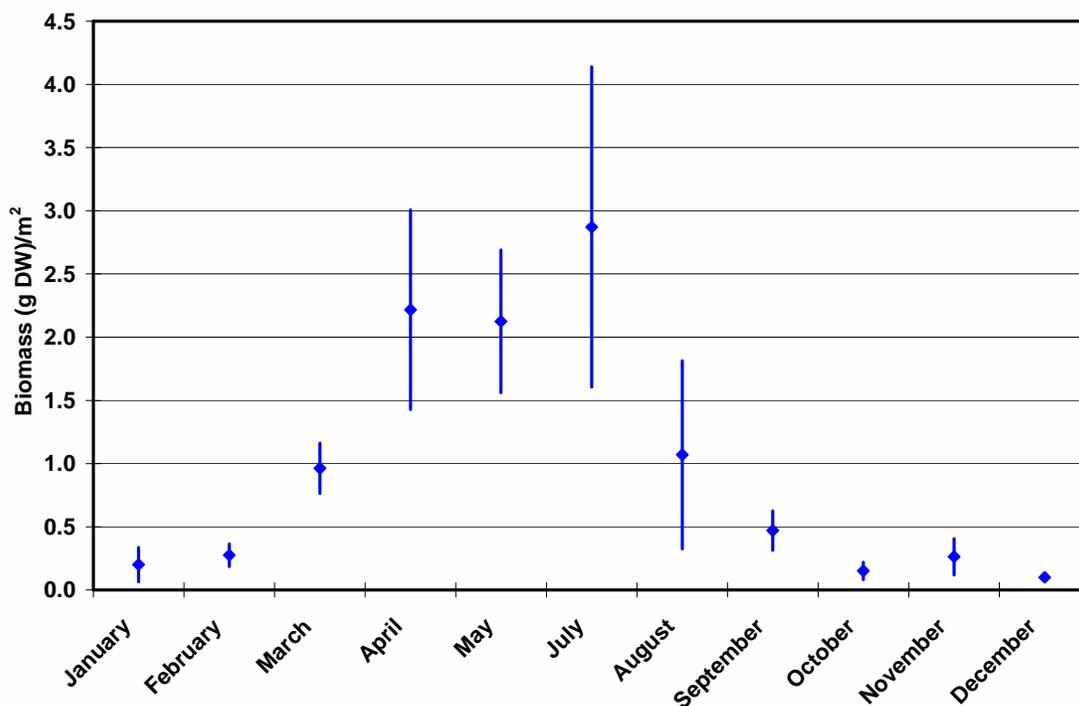
Figure D1. Zooplankton Biomass (g dw/m^2) in Budd Inlet (**Giles and Cordell (1998)**

The observations of the Giles and Cordell (1998) and the PSI surveys combined with previous characterizations of the neritic food web in Puget Sound (Simenstad 1983; Strickland 1981; Dumbauld 1985) indicate that crustaceans (dominated by copepods and larval barnacles and crab) dominate the zooplankton community during the spring and summer blooms, with larvaceans and micro-zooplankton becoming more dominant during non-bloom periods in late summer and early fall. Unlike northern Puget Sound, the sheltered waters of south Puget Sound allow for year-round populations of larger zooplankton (Strickland 1985) such as copepods; however, they are likely to remain in the deeper waters of the central inlet during the winter months.

Copepods

Calanoid copepods are a family of crustaceans that dominates the zooplankton of Puget Sound and are a critical component of salmonid and forage fish diets. Calanoid copepods have preferences for phytoplankton or zooplankton food sources, and their sizes and feeding structures differ accordingly. While the copepod community in Totten Inlet is not well understood, Giles and Cordell (1998) provide a detailed analysis of the species distribution of South Puget Sound copepods. For outer and central Budd Inlet, *Acartia* (*Acartiura*) spp. were the numerically dominant neritic copepod from March through mid-June. In early July through September, *Paracalanus* spp. was numerically dominant, comprising 90% of the calanoid copepods observed in both the outer and central inlet. In October to March, *Paracalanus* and *Pseudocalanus* were dominant in the outer inlet; whereas *Acartia* was more dominant in the central inlet. *Pseudocalanus* was also numerically important between December and late May. Although not

numerically important, the larger *Calanus* sp. copepod and the carnivorous copepod, *Tortanus* spp., were also present in the spring and summer months.

Acartia, *Pseudocalanus*, and *Paracalanus* are smaller copepods (approximately 0.01 mg/ind.) that are widely distributed in Puget Sound. Using modified mouth parts that essentially rake the water preferentially, they size-select high quality food particles (Sell, unpublished data). Bollins and Penry (2003) showed that *Acartia* spp. in South Bay and San Pablo Bay, California feed selectively on prey items >10 um in size, despite phytoplankton communities dominated by high numbers of smaller phytoplankton (nanoplankton). During periods of high food abundance, smaller copepods have been shown to preferentially select ciliates and dinoflagellates. However, during blooms, feeding rates on diatoms increase to 188% of body carbon per day (Bollins and Penry 2003; Suzuki et al. 1999). As predicted by optimal foraging theory, copepods will feed on a diverse diet of available food; however, when food abundance is high, the diet becomes less diverse as a result of selective feeding on ciliates and flagellates.

Although not the most abundant copepod, the larger copepod, *Calanus* spp. (170 µg dry wt./ind.), comprises a large fraction of the copepod biomass in Puget Sound. It is a grazer that as an adult consumes diatoms, although will also eat some protozoans or larvae (Strickland 1983). However, in mesocosm experiments with simulated diatom blooms and a subsequent ciliate population increase, *Calanus* preferred ciliates >30 um in size, comprising 74% of the carbon ingestion during ciliate blooms (Nejstgaard et al. 1997). Diatoms and smaller ciliates comprised the remaining diet. During non-bloom periods, ciliates consumption was significantly lower. The primary impact of *Calanus* on the phytoplankton community was indirect, through the consumption of ciliates.

Copepods rely exclusively on sexual reproduction. Although copepods reproduce continuously throughout the year, maximum egg production is typically linked to bloom events. Soon after laying, copepod eggs hatch into free-swimming larvae called nauplii. Nauplii feed on the tiniest phytoplankton and molt eleven times before reaching adult size. The entire life-cycle takes approximately one month in summer or several months in winter. Most zooplankters continue feeding and laying eggs throughout the summer while the food supply lasts. During winter, copepods restrict their activities, conserving energy while living off of stored food.

Other Zooplankton

Although numerically not dominant, euphausiids and mysids are an important link between zooplankton and fish. Euphausiids and mysids are shrimp-like crustaceans that consume both zooplankton and phytoplankton. Because of their larger size, they are a preferred component of juvenile salmonids diets and are second only to copepods in herring diets.

Much larger than copepods, euphausiids get to be 20 mm in length. Generally, euphausiids cluster in schools, migrating to deeper waters in the daytime and feeding at the surface during the nighttime. Euphausiids feed on both phytoplankton and zooplankton, including copepod adults and nauplii. There is little quantitative data on the abundance or biomass of euphausiids in South Puget Sound.

Larval Forms

Larval forms of benthic invertebrates and fish are a critical seasonal component of the zooplankton community. Based on Giles and Cordell (1998), barnacle and crab larvae comprise 30% to 40% of the zooplankton abundance in Budd Inlet during migrations. Duffy (2003) found that in neritic waters, juvenile chum stomach contents were dominated by crab larvae. A number of phyla have swimming larval forms, including echinoderms, annelids, crustaceans, molluscs, and fish. Just as there are a variety of larval forms, there are a variety of feeding strategies, including omnivores, carnivores, and larvae that do not feed or use lipid stores during their swimming phase. For the purposes of this evaluation, larval forms are included with zooplankton.

Microzooplankton

Microzooplankton are a critical link between phytoplankton and zooplankton and bivalves. Many zooplankton, previously thought to be herbivores, feed almost as heavily on ciliate and flagellate protozoans as on phytoplankton (Bollins and Penry 2003; Strom et al. 2001; Uye et al. 1996). During periods of low primary productivity, microzooplankton support the food chain. They are often the more numerically important class of zooplankton since their abundance appears to be less affected by algal boom-bust cycles. In Totten Inlet, tintinnids are the dominant microzooplankton species (Figure 2), with abundance ranging from 3.0×10^6 ind./m^3 in winter to 7.7×10^6 ind./m^3 in late summer (Cheney et al., unpublished data). Tintinnids are ciliates, unicellular organisms featuring cilia as food-catching and locomotor organs. They are mostly solitary, free-swimming organisms that range in size from 50 to 150 µm in size. Tintinnids are distinguished by protective vase-like cases that the protozoan secretes and adorns with particles of sand. Heleocostamella is the most common tintinnid encountered in Totten Inlet. The armored ciliate, *Tiarina* was also relatively common, particularly in summer and fall. *Tiarina* feeds on dinoflagellates and was likely associated with the fall bloom.

Microzooplankton biomass in Totten Inlet was estimated at 10 g wet wt/m^2 (based on Cheney et al. unpublished data). Standing stock estimates were based on a relationship developed in Uye et al. (1996) that was then applied to the PSI data set collected at Deepwater Point. Mean annual standing stock was estimated to be 0.5 gC/m^2 with seasonal estimates of 0.25 gC/m^2 for fall/winter and 0.64 gC/m^2 for spring/summer. These estimates are consistent with a carbon/wet weight conversion factor of 0.0828 (Sherr and Sherr 1984; Dow et al. 2006) and with a general relationship to phytoplankton [0.13 * phytoplankton standing stock biomass] developed from data collected in the English Channel, Narragansett Bay, and the North Sea (Dow et al. 2006). Microzooplankton production can be highly variable, with boom and bust cycles. Annual production reported in the Sea of Japan was 29 gC/m^2/yr (Uye et al. 1996). Dow et al. (2006) report a P:B ratio of 72 for ciliates, the dominant microzooplankton observed in Totten Inlet. Dalgaard et al. (1998) use a P:B ratio for the Strait of Georgia. Based on an average P:B ratio of 64, the average annual production for microzooplankton would be 32.8 gC/m^2/yr. Estimated seasonal production would be 14.6 gC/m^2/yr for fall/winter and 40.1 gC/m^2/yr forspring/summer.

Microzooplankton feed primarily on bacterioplankton, comprising 40% to 50% of the diet. Smaller size classes of phytoplankton, nanoplankton and picoplankton, including diatoms and dinoflagellates are estimated to comprise 15% of microzooplankton diet, with detritus and other microzooplankton comprising the remainder of the diet (Uye et al. 1996; Dow et al. 2006).
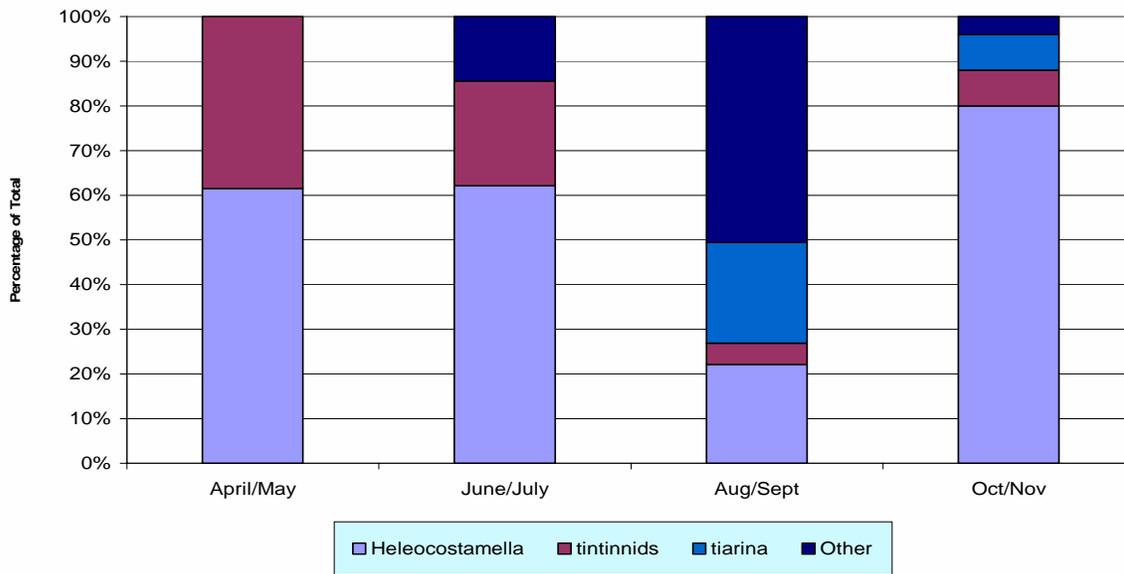
Figure 2. **Microzooplankton Distribution at Deepwater Point**.

Gelatinous Zooplankton (Jellyfish)

The presence of medusae, siphonophores, and ctenophores (collectively referred to as 'pelagic coelenterates') in Totten Inlet is not well documented. Available data has been collected visually or with non-closing nets; however, there is a lack of true quantitative data for gelatinous zooplankton in southern Puget Sound (Erik Thuesen, personal communication). Determination of population or biomass for gelatinous zooplankton can be problematic due to extremely high variability between years. "In one year for example, you can have hundreds of thousands or millions of a specific jelly in a region, and the following year that species might be almost absent." (personal communication, Ladd Rutherford).

In several embayments of the southern Puget Sound, including Boston Harbor, Budd Inlet, Eld Inlet, and Totten Inlet, sporadic blooms of a variety of species have been observed during various seasons over the last 12 years. These include *Aurelia labiata*, *Phacellophora camtschatica*, *Pleurobrachia bachei*, *Bolinopsis infundibulum*, *Aequorea victoria*, and *Clytia lomae* (Erik Thuesen, personal communication). In a study conducted specifically in Budd Inlet from 2000 through 2003, 12 species of pelagic Cnidaria were collected. These included the hydrozoa anthomedusae *Euphysa flammea*, *Halitholus* sp., *Polyorchis penicillatus*, and *Sarsia* sp.; the leptomedusae *Aequorea victoria*, *Clytia gregaria*, and *Eutonina indicans*; the limnomedusae *Proboscidactyla flavicirrata*; the calycophora *Muggiaea atlantica*; and the scyphozoa sematostomae *Aurelia labiata*, *Cyanea capillata*, and *Phacellophora camtschatica* (Rutherford and Thuesen, 2005).

Although dietary composition for jellyfish largely depends on the availability of prey, primary food sources include ichthyoplankton and zooplankton. Similar selectivity among groups of species for either hard-bodied prey (i.e., crustaceans) or soft-bodied prey (i.e., fish larvae, larvaceans, and other gelatinous organisms) has been documented. Generally, species present in the southern Puget Sound region eat hard-bodied prey (most anthomedusae) or a combination of hard- and soft-bodied prey (leptomedusae and some scyphozomedusae). Gut content data from one study indicated that *Aurelia labiata* medusae contained 75% small crustaceans and 10% larvaceans, whereas *Cyanea capillata* medusae contained large amounts of soft-bodied prey. Similarly, *Aequorea vicotria* consistently contained high percentage of soft-bodied prey, but low percentages of crustacean prey (Purcell and Sturdevant, 2001).

Giles and Cordell (1998) reported the jellyfish comprised less than 5% of the zooplankton in Budd Inlet between December and May. Cnidarians comprised 10% to 30% of zooplankton sampled between June and October. Based on percent biomass and an estimated carbon content of 20% of dry weight, the average annual standing stock for jellyfish was estimated at 0.24 gC/m^2, with seasonal averages of 0.03 gC/m^2 in the fall/winter and 0.42 gC/m^2 in spring/summer. This estimate for average annual standing stock is very similar to that used by Preikshot and Beattie (1998) for south Puget Sound (0.2 gC/m^2). Annual production can vary widely depending upon the frequency and severity of blooms (Ladd Rutherford, pers. comm.). Dalgaard et al. (1998) have used an annual P:B ratio of 3 for the Strait of Georgia; whereas Green (2006) uses an annual value of 40. Based on the abundance data for Budd Inlet, the production would be expected to be higher in the spring/summer months and lower in the fall/winter months (although these time periods are less clearly defined than for other species) and we will therefore use the P:B ratio of 40 for the spring/summer and 3 for the fall/winter period. Thus, seasonal production is estimated to be 0.11 gC/m^2/ fall-winter and 16.8 gC/m^2/spring-summer.

There is little information available on the importance of the interaction between pelagic coelenterate populations and fish. However, this relationship has received increasing attention due to potential impacts to commercial fisheries from predatory interactions between jellyfish, ichthyoplankton, and fish. In relation to fish, jellyfish are predators, competitors, and prey. Through consumption of zooplankton such as copepods, jellyfish impact the availability of similar food sources to bivalves and fish thereby leading to an imbalance in local fisheries during periods of large blooms (Mills, 1995). Jellyfish also impact fish abundance by feeding on the eggs and larvae of fish. Conversely, jellyfish are also predated by fish. An examination of the stomach contents of over 50 fish species revealed that gelatinous organisms formed a sizable portion of their diets. In fact, it was documented that the consumption of gelatinous organisms by chum salmon is variable, but can comprise a primary portion of their diet thereby reducing competition with other salmon species (Purcell and Arai, 2001).

A study conducted in Prince William Sound, Alaska revealed that dietary similarities between jellyfish and juvenile fishes were greatest among crustacean-eating species and larvacean-eating species. The diets of *Aurelia labiata* and *Pleurobrachia bachei* overlapped 67% to 75% and 41% to 63%, respectively, with diets of juvenile walleye pollock, sandlance, and herring. The diets of *Cyanea capillata* and *Aequorea aequorea* overlapped 78 and 59%, respectively, with diet of juvenile pink salmon (Purcell and Sturdevant, 2001).

Bivalves of Totten Inlet

The bivalve community in Totten Inlet is comprised of a natural community and existing cultivated stocks. The natural community includes intertidal and subtidal clams, geoducks, oysters, and a number of small bivalves that are part of the benthic infaunal community. Cultivated shellfish stocks include oysters, intertidal clams, and mussels.

Geoduck

Geoduck are present in the lower intertidal and subtidal sediments. WDFW has conducted geoduck surveys for subtidal populations of geoduck, estimated geoduck abundance in Totten Inlet at 217,000 individuals, with an average density of 0.026 ind./ft^2 or 0.28 ind./m^2 (WFDW 2003). Surveys conducted in the area of the proposed mussel raft and in Inner Totten Inlet indicate that geoduck populations in these muddy areas are very low (Goodwin 1997; Gordon King personal communication). There is likely to be discrepancies in this estimate since geoduck are a benthic substrate organism and WDFW only surveyed to -70 ft. MLLW; therefore there is an absence-by-depth bias introduced to this data set. Based on the wet weight per individual estimated by WDFW of 1,394 g/ind., the average wet weight biomass of geoduck in Totten Inlet is estimated to be 390 g/m^2 with a standing stock of 13.3 gC/m^2 (based on 3.4% carbon content).

Geoduck population densities are fairly static, with life spans of greater than 100 years (Goodwin and Pease 1989). Natural mortality is approximately 2% and growth rates are less than 1% in a mature stock (Bradbury et al. 2001; Valero et al. 2004). Growth rates for geoduck less than 5 yrs old are quite high, nearly doubling biomass annually. After five years, this rate slows considerably and after 10 to 15 years, growth rates slow to less than 1%. Based on low mortality, low settlement rates, and slow growth at maturity, annual production of a mature stock is likely to be quite low. Despite the importance of this species in terms of standing stock, the annual production is estimated to be 0.27 gC/m^2/yr based on 2% replacement annually. Production would not be expected to vary greatly with season, given the mature population in Totten Inlet. Harvesting can alter this production estimate. Geoduck harvesting has occurred in north Totten Inlet, with 8.6 x 10^5 geoduck harvested in the 1980s. However, the community in Totten Inlet is now considered to be a mature community. For this reason, trophic transfer to growth is considered to be lower for geoduck, than other bivalves.

Geoduck are filter feeders, clearing 49.2 L/h/ind. There is little data on geoduck feeding behavior. They appear to feed exclusively on phytoplankton (WDFW, unpublished data); however, what proportion of this diet that is derived from detritus at the sediment-water interface and what is derived from the water column is unclear.

Intertidal Clams

The clam community is dominated by the intertidal clams, *Tapes japonica*, *Prototheca staminea*, *Clinocardium nutallii*, and *Saxidomas nuttalli* and the subtidal clam, *Tresus* sp. The total estimated abundance of clams in Totten Inlet is 9.0 x 10^7 (EDAW 1998) or 10.5 ind/m^2. WDFW (2001) determined that the average biomass of intertidal clams in Totten Inlet was 19.9 g/ind. wet wt. Average wet wt. biomass of clams in Totten Inlet is then estimated at 209 g/m^2 with a standing stock of 9 gC/m^2. Based on a P:B ratio of 0.5 (Dalgaard et al. 1998), the estimated annual production would be 4.5 gC/m^2/yr. Intertidal clams feed on phytoplankton,

bacterioplankton, microzooplankton, benthic diatoms, and detrital organic material (Sorokin and Giovanardi 1995; Word 1990).

Two species of oyster are present in Totten Inlet, the native Olympia oyster (*Ostrea conchaphila*) and the Japanese oyster, *Crassotrea gigas*. *Crassostrea gigas* are size-selective, filter-feeding bivalves that consume phytoplankton, bacterioplankton, and benthic-diatoms in size classes of 3 to 40 µm in diameter (Ward et al. 2003; Cognie et al 2001). *Ostrea conchaphila* feed larger particles, primarily phytoplankton. The estimated annual average wet wt biomass of cultivated and wild oysters in Totten Inlet is approximately 19 g/m^2, or 0.64 gC/m^2 (EDAW 1998), and annual production is estimated at 0.32 gC/m^2/yr.

Mussels

Both wild and cultivated mussels are present in Totten Inlet. The total estimate biomass of cultivated and wild mussels in Totten Inlet is 1.5 x10^6 kg, or 32 g/m^2 wet weight Based on a carbon content of 3.5% of wet weight, the standing stock is 1.1 gC/m^2 and annual production is estimated to be 0.6 gC/m^2/yr. Based on growth rates developed by PSI in Totten Inlet, the spring/summer months represented 75% of the annual growth, with mean daily growth rates of 0.10 g/d. Growth rates in fall/winter were observed to be 0.04 g/d. Based on growth rates, the seasonal production estimates would be 0.2 gC/m^2/yr during the fall/winter period and 1.0 gC/m^2/yr during spring/summer.

Mussels consume organic and inorganic nitrogen and carbon through active filtration of suspended seston (phytoplankton, microzooplankton, dissolved organic particles) present in the water column (Hawkins et al 1998).

Forage Fish

The term forage fish refers to a number of fish species that are common prey items for large juvenile and adult salmonids. In Puget Sound, this includes herring, Pacific sand lance, eulachon, surf smelt, and longfin smelt. In Totten Inlet there are known populations of herring, sand lance, and surf smelt. Although the temperature in Totten Inlet may reach temperatures thought to be prohibitive to forage fish, currently there is not sufficient data available to exclude these fish in the summer portion of the food web model (Kurt Stick, WDFW biologist, personal communication 2006).

Pacific Herring *(Clupea harengus pallasi)*

Herring distribution in south Puget Sound is poorly understood. While there is reliable data regarding the spawning population and locations of spawning activity, there is little data on the movement of adults or juveniles. Because the both the distribution and feeding habits of herring adults and juveniles differ, they will be evaluated separately in the food web model.

Herring spawn in distinct locations throughout Puget Sound, each with specific grounds and timing. The peak of spawning seldom varies by more than seven days from year to year (Pentilla 2000). The Squaxin Pass stock is the only South Puget Sound herring stock and is considered moderately healthy. Squaxin Pass herring spawn in January to April, with spawning grounds including Squaxin Pass, portions of the eastern shore of North Totten Inlet north of Gallagher Cove, a small portion of Little Skookum Inlet, and the mouth of Hamersley Inlet (WDFW 2004). The average adult run size is estimated using hydroacoustic surveys of spawning schools and by

estimating adult biomass from egg densities, using age-class specific mortality rates. Between 1977 and 2004 the average estimated herring biomass for the Squaxin Pass stock was 819 tons (7.4×10^5 kg; WDFW 2004) which is nearly twice that of previous estimates (WDFW 1998; Preikshot and Beattie 2001), largely due to increased biomass estimates in 2001-2003.   Based on the area of south Puget Sound (394 km^2), this would represent an adult wet weight biomass of 1.9 g wet wt/m^2. Based on a wet weight to carbon (B:C) of 9%, the estimated standing stock was estimated at 0.17 gC/m^2. The bulk of this biomass is present from January to April. Based on a P:B ratio of 0.6 (Dalgaard et al. 1998), production would be estimated to be 0.10 gC/m^2/yr.

 Some herring remain in Puget Sound during the Spring/Summer period. However, there is some indication that herring will move to cooler waters during the summer months avoiding water >15°C (MACSIS 2002; Anderson 2005). Late summer temperatures at depth in Totten Inlet can exceed 15°C which may push herring out of the inlet. Some herring summer in coastal areas of Washington and southern British Columbia (Trumble 1983); this has not necessarily been linked to summer warming in Puget Sound (Kurt Stick, personal communication). Fresh et al. (1981) found herring throughout the year in parts of south Puget Sound. For the purposes of the food web model, the adult herring population in the Spring/Summer period will be set at 10% of the annual standing stock and production, 0.017 gC/m^2 and 0.01 gC/ m^2/yr respectively.

Adult herring feed primarily on planktonic crustaceans throughout their life cycle (ADFG 1986). Stomach contents analysis of herring in central and south Puget Sound indicated that juvenile herring in sublittoral habitats feed on calanoid copepods (45%), decapod larvae (23%), and chaetognaths (10%; Fresh et al. 1981). However, they are opportunistic feeders as well, and will consume other forage fish.   In neritic habitats, prey items are dominated by calanoid and harpacticoid copepods and euphausiids.

Herring eggs hatch after 10-14 days, at which point the larvae drift at the surface with local currents. Food availability is critical during this stage and strongly linked to year class strength (Sinclair and Tremblay 1984).   Following metamorphosis at 3 months of age, young herring spend a year in Puget Sound, although not necessarily close to natal waters. Herring mortality in Puget Sound is quite high, with 25% to 30% survival. Natural mortality is the predominant cause of mortality (60% to 70%), with fishery-related mortalities of approximately 5 to 10% (WDFW 1998, on-line data 2004). Natural mortality is due in large part to predation of floating eggs, as well as juvenile and adult forms, from Pacific cod, whiting, lingcod, halibut, coho and chinook salmon, seabirds, and marine mammals (Barnhart 1988; ADFG 1986; Grosse and Hay 1988). Disease can also be a significant contributor to herring survival, effectively cropping the older, more reproductively successful herring from the population (Hershburger, P, unpublished data).

Fecundity rates (eggs/female) for Pacific herring are related to length, and range from 10,000 to 50,000 for females from 150 to 220 mm in length in Washington waters (Stout et al. 2001). The Squaxin Pass stock is dominated by 2 to 3 year olds (152mm and 161mm mean length; Stick 2005) and would be expected to have a fecundity of approximately 15,000 eggs per female. Based on an estimated biomass of 91 g/ind. (Stout et al. 2001), the total number of spawners would be estimated to be 8,190,000, with ~4,000,000 females. Assuming 80% of the females spawn in a given year, the total annual egg production would be estimated to be 4.8×10^{10} eggs. Mortality is extremely high for both the embryo and larval stages with ~80% mortality for eggs and 90% for larvae (Barnhart 1988). An estimated 0.96 billion larvae would then be released into south Puget Sound. Based on a mean biomass for herring larvae of 2.0 grams (Paul Hershberger, personal communication), the expected biomass for larvae in south Puget Sound would be

4.3 g/m^2. Based on a wet weight to carbon conversion of 9%, the estimated standing stock was estimated at 0.39 g C/m^2. Based on a P:B ratio of 0.6 (Dalsgaard et al. 1998), the mean production for juveniles would be 0.24 gC/m^2/yr.

As soon as the yolk is exhausted, herring larvae begin exogenous feeding. This is a critical period because the margin between sufficient nutrition and starvation is exceedingly narrow. The first food consists mainly of invertebrate eggs, copepod nauplii, and diatoms. Juvenile herring consume mostly crustaceans such as copepods, amphipods, cladocerans, decapods, barnacle larvae, and euphausiids (Barnhart 1988).

Sand Lance (*Ammodytes hexapterus*)

While sand lance are widely distributed throughout Puget Sound, there is surprisingly little information on abundance or distribution. Forage fish surveys have not found spawning grounds inside Totten Inlet. There are, however, spawning areas in Squaxin Pass and Pickering Passage (Pentilla 1997; WDFW 1998) and it is likely that larval and adult sand lance are present in Totten Inlet. Sand lance spawn between November 1 and February 15, and deposit eggs on a fine sand to gravel beaches from +5 ft. to 0 ft. MLLW. Eggs hatch in approximately four weeks and move into the water column. Larvae reside in the nearshore, migrating passively with currents and tides. Once larvae reach adult size, they travel in schools feeding in the open water during the daylight hours. At night, sand lance move to the bottom and burrow into the substrate. Little is known about the movement of adults in Puget Sound, however, based on some plankton surveys conducted by WDFW (referred to in WDFW 1998), they appear to be common and quite numerous throughout the Sound. Fresh et al. (1981) found sand lance in Central Puget Sound from May to August in surveys that included hook and line, purse-seine, mid-water trawls, and beach seine sampling of nearshore and neritic waters. No sand lance were found in South Puget Sound stations from September to April.

Larval and adult sand lance feed on primarily on zooplankton. Sand lance stomach contents from central Puget Sound (Fresh et al. 1981) were dominated by calanoid copepods (71%), with some harpacticoid and cyclopoid copepods. Sand lance are an important trophic link between zooplankton and larger predators. Sand lance comprise 35 percent of salmon diets in Puget Sound and are also important components of Pacific cod, Pacific hake, and dogfish diets (WDFW 1998).

Surf Smelt (*Hypomesus pretiosus*)

Surf smelt are common, year-round residents of nearshore Puget Sound waters. As with sand lance, there is little data to estimate abundance. However, based on estimates of surf smelt spawner biomass from an egg production model which was based on spawner beach surveys (Pentilla 1997; WDFW 1998), the South Puget Sound biomass is approximately 4.2 million kilograms wet weight.

In south Puget Sound, spawning occurs in the fall and winter months. Spawning grounds in south Puget Sound include Totten Inlet, Hammersley Inlet, Pickering and Squaxin Passages, Eld Inlet, and Budd Inlet (WDFW 1998; Pentilla 1997). Adults spawn on at the water's edge during high tide. Eggs hatch after 27 to 56 days. Hatching larva move passively in the currents and tides in the nearshore waters until they mature after approximately three months. The movement of juvenile and adult smelt is virtually unknown. Stocks of mixed juvenile and recovering-spent surf smelt in the general vicinity of spawning grounds suggest long-term residency. Based on research trawls, there does not appear to be a migration out of Puget Sound, nor are surf smelt found in the

mid-water. Thus it appears that Puget Sound surf smelt are resident in Puget Sound, if not regionally within Puget Sound and they reside either in the shallower nearshore zones or close to the bottom.

As with other forage fish, surf smelt feed primarily on planktonic organisms and are an important component of seabird, marine mammal, and fish diets. Fresh et al. (1981) found that surf smelt ate primarily pelagic prey including calanoid copepods (24%), urochordates (25%), carideans (10%) and euphausiids (10%). However, the presence of small numbers of harpacticoid copepods in a large proportion of the stomachs observed indicate that surf smelt are also epibenthic feeders.

Annual Productivity Estimate for Surf Smelt and Sand Lance. Both surf smelt and sand lance populations are considered present in variable abundance throughout the year. Based on Priekshot and Beattie (2001), the estimated biomass for forage fish (excluding herring) is 3.6 g wet wt/m^2. Based on C:B of 9% and P:B ratio of 0.6, the standing stock would be 0.3 gC/m^2 and 0.19 gC/m^2/yr.

Salmonids

The low gradient streams that feed Totten Inlet support runs of fall chum and coho salmon and winter steelhead trout. Though not well documented, it is also likely that there are coastal cutthroat trout in the Totten Inlet watersheds. While there was some historic evidence of fall chinook in Little Skookum Inlet, they were considered strays from the Elson Creek hatchery and not naturally supported by the small streams and low flows in this watershed (WSCC 2003, Joseph Peters, pers. comm..); therefore chinook will not be included in this assessment. The salmon stocks in south Puget Sound are not Federally listed at Threatened or Endangered; however, the Puget Sound steelhead were proposed for a listing as threatened (71 FR 15666). The occurrence and life histories of the salmon runs currently in Totten Inlet are discussed below.

Fall chum *(Oncorhynchus keta)*

Totten Inlet supports three genetically and/or geographically distinct fall chum stocks, the Totten Inlet stock, the Upper Skookum Creek stock, and the Skookum Inlet stock. The chum population in Totten Inlet is classified as "healthy" and is characterized as a mixed stock with both native (Totten Inlet and Upper Skookum Creek) and hatchery reared (Skookum Inlet) fish.

Adult chum salmon enter South Puget Sound during early October and spawn in late October through January, depending on the stock. The Totten Inlet stock spawns in Kennedy Creek from late October to early December, peaking in mid-November. Kennedy Creek is one of the most productive chum-rearing streams in Puget Sound, with a mean escapement of 41,000 fish between 1992 and 2001 (WDFW 2002). Skookum Inlet chum are primarily fish (WSCC 2003) from the Elson Creek Hatchery, with contributions from native stocks in lower Skookum Creek and its tributaries. Mean escapement from this stock was 7,000 fish between 1993 and 2000 (WSCC 2003). The Upper Skookum Creek chum are primarily wild fish, with mean escapement of 11,900 fish during this same time period. Spawning in the Skookum Inlet and Skookum Creek stocks occurs in December and January (WSCC 2003). The ratio of males to females for the entire run is considered to be 1:1, with males more dominant early in the run and females more dominant later in the run (Salo 1991).

On average, females lay approximately 3,000 eggs (WDFW 2002). Chum fry emerge from the gravel from March to May and migrate immediately downstream to the estuary. Chum salmon

are highly dependent upon the estuary during fry development, moving from the upper to lower estuary depending upon productivity (Salo 1991). Chum fry remain in the estuary for several months, with the timing of smoltification dependent upon the warming of marine waters and spring plankton blooms (WDFW 2002). Duffy (2003) found juvenile chum abundance in South Puget Sound estuaries/deltas peaked in early April to early May. Abundance in the nearshore marine waters peaked in mid-May and decreased in mid-June. Bax (1983) found that chum fry entering the nearshore areas of Hood Canal in February and March migrated more rapidly (7-14 km/d) than fry that enter the nearshore area later in Spring (May and June) as epibenthic and neritic food resources increase, suggesting that residence time in the nearshore area is related to food availability. Simenstad et al. (1982) suggest that the summer out-migration of juveniles northward along Washington and British Columbia coastlines is related to declining food in Hood Canal and diet changes towards more nektonic and pelagic organisms. This agrees with observations by Duffy (2003) that juvenile chum abundance at neritic sites peaks in mid-June.

Chum fry enter the nearshore areas at size classes <40 mm fork length (FL), or 0.8 g (Salo 1991; Duffy 2003). Growth rates in the nearshore are exponential, averaging 3.4% body weight per day, based on a natural food diet (Salo 1991). Juvenile chum are typically leaving the nearshore and moving offshore when they reach lengths that allow them to feed on larger neritic prey (55 to 90 mm length or 1.2 g to approximately 3 g/ind.). Fresh et al. (1981) found chum in the sublittoral zone at 47 to 101 mm FL (mean = 69 mm FL); whereas in the neritic zone, juvenile chum ranged from 80 mm to 128 mm (mean =100 mm FL).

Survival rate of eggs is dependent upon a number of complex interactions between environmental, biological, and human factors. Based on a review of survival rates of egg to fry and fry to adult in Washington, British Columbia, Alaska, USSR, and Japanese waters, mean survival rates to fry were 10.1% (1.5% to 27.6%; Salo 1991). Survival of fry to adult was considerably lower, at 1.8% (range: 0.8% to 2.8%; Salo 1991). An estimate of the number of fry entering Totten Inlet can be calculated using mean survival of fry to adult, mean escapement data for each of the chum runs, and the overall sex ratio of 1:1.

No. Smolts = (Mean Escapement/2) x (Eggs/Female) x Survival Rate $_{(egg-fry)}$ *Eq 2*

Based on the average Kennedy Creek escapement of 41,000 adults and an overall male to female ratio of 1:1, an estimated 6.2 million fry would enter the Kennedy Creek estuary in February to April. Based on the mean escapement of 18,900 fish for the Skookum Inlet and Upper Skookum Creek runs combined, 2.8 million fry would enter via Skookum Inlet. It is important to note that chum mortality within the nearshore areas of Totten Inlet is fairly high, perhaps as high as 95% during the first five months (Salo 1991). Smolt mortality in marine waters is largely due to predation from birds and other fish species, such as coho and cutthroat trout. Based on bioenergetics and population models (Preikshot and Beattie 2001), the emigrating population would be approximately 43,804 smolts. Biomass increases at a rate similar to mortality, such that total biomass ranges from 0.43 g wet wt./m^2 at immigration to 0.39 g wet wt./m^2 at smolt outmigration. Based on a B:C ratio of 9%, the standing stock would be estimated to be 0.04 gC/m^2 and based on a P:B ratio of 2.2 (Preikshot and Beattie 1998), smolt production would be estimated to be 0.073 gC/m^2/yr, occurring exclusively during the spring/summer period.

During their residence in the estuary, the dominant prey items for juvenile chum are chironomids, harpacticoid copepods, larvaceans, insect larvae and benthic invertebrates (Gardiner 2003; WDFW 2003; Duffy 2003). Once in the nearshore zone, juvenile chum feed primarily over

submerged tidal flats, feeding in the water column during the daylight hours and feeding on epibenthic prey at night (Feller 1974). Stomach contents analysis of fish captured in May in South Puget Sound confirm this trend, with epibenthic organisms comprising >75% of prey during the dusk and dark hours (Duffy 2003). During daylight hours, planktonic and insect prey comprised >60% of the diet. However, chum preferentially feed during the daylight and crepuscular hours, indicating that planktonic and insect prey are more important overall.

Juvenile chum appear to have distinct nearshore and offshore stages, for both feeding and residence. Duffy (2003) noted a shift from epibenthic feeding in the deltas during April and May to more planktonic and neustonic feeding in the nearshore in June and July. Gut contents analysis of juvenile chum in the nearshore area of South Puget Sound indicate that their diet is dominated by euphausiids, calanoid copepods, gammarid amphipods, ostracods, larvaceans, as well as harpacticoid copepods (Duffy 2003). This is consistent with gut content analyses conducted on fish from Hood Canal, which indicated that gammarid amphipods and calanoid copepods were the dominant prey from nearshore and neritic sampling sites (Simenstad 1976, Fresh et al. 1981). In the neritic sites sampled by Duffy (2003), copepods, larvaceans, and crab larvae were the dominant prey items. Chum salmon tend to be both size and taxa selective in the neritic environment (Healey et al. 1982; Simenstad et al 1982). Selectivity is based on visual perception, active selection based on gape, and optimal bioenergetics of foraging (Salo 1991).

Duffy (2003) further evaluated consumption by juvenile salmonids in South Puget Sound (SPS) using the Wisconsin bioenergetics model. This model uses an energy-balance approach in which total energy consumption equals the sum of growth, metabolic costs, and waste losses. Proportional prey consumption was then calculated based on stomach contents analysis and prey energy densities, expressed as Joules per gram. In simulations of SPS sites, average weekly individual consumption increased from 0.7 g in late April to 1.1 g prey in early June to satisfy their estimated growth rates. Proportion consumption for different prey categories were: copepods (38% to 68%), crab larvae (2% to 25%), insects (4% to 28%), and other prey, including larval forms, amphipods, and fish (14% to 20%). As was noted above, the diet shifted towards more pelagic and neustonic prey items with season.

It is important to note that juvenile chum are also opportunistic and are able to adapt their diet to available food (Gardiner 2003; von Saunders 2004), provided available prey is within their size selection range. Gardiner (2003) showed that the stomach contents of juvenile chum from estuarine channels were dominated by marine ostracods that were transported by wind driven currents/tides into the estuary. Juvenile salmonids in highly stressed urban estuaries may shift their diet to available prey items in selected size classes (von Saunders 2004).

Coho *(Oncorhynchus kisutch)*

Both Kennedy and Skookum Creek support significant coho salmon runs. Adult coho enter the freshwater to spawn in mid-September to mid-November. Adults typically make short migrations into the streams, and then return to salt water prior to up-migration. Up-migration will then occur during a high flow event. Escapement from Totten, Hammersley and Eld inlets have shown a decreasing trend with mean escapement of 3,500 fish between 1993 and 2002 (SSHIAP 1999; WSCC 2003). The sex ratio of coho salmon smolts is 1:1; however, up-migrating stocks include early migrating "jacks". Jacks are males that only stay in marine water for 4 to 6 months. Thus, the sex ratio of the adult return can be variable with males comprising greater than 50% of smolts. In the absence of coho biomass estimates specifically for Totten Inlet, the entire mean escapement

will be attributed to Totten Inlet to ensure the estimated effect of the mussel raft on the food web is sufficiently protective of coho salmon.

Female coho salmon lay approximately 2,500 eggs. Fry emerge in late spring, and remain in freshwater, rearing in the streams for just over one year. Downstream migration begins in the spring. Duffy (2003) observed juvenile coho arriving in the deltas in April to early June, with abundance peaking in mid-May. There was little difference between peak abundance in the delta and nearshore sites, suggesting a relatively short residence time in the estuariids prior to entering the nearshore zone. Coho residence time in nearshore areas is tied to environmental conditions and food availability. Juvenile coho spend several months in the nearshore zone prior to migrating to the Pacific Ocean (Sandercock 1991). Duffy (2003) found that coho residence time in South Puget Sound was approximately 18 weeks; however, juveniles appeared to move throughout the region, with local residence times of 1 to 3 weeks.

A variety of estimates have been made for fry to smolt and smolt to adult survival. Fry to smolt survival estimates range from 0.7% to 9.65% in the Pacific Northwest; however, 1% to 2% appear to be the average range (for the purposes of this study, 2% will be used). Smolt to adult survival rates for northwest coho runs range 3.2% to 10.8%, with an average survival of 7.1% (Sandercock 1991). Because the sex ratio is variable due to the presence of jacks, it is difficult to know the extent of this imbalance. For the sake of estimating abundance of juvenile salmon in Totten Inlet, a ratio of 1:1 will be used. Based on an escapement of 3,500 adults, it is estimated that approximately 87,500 smolts enter Totten Inlet. While in the estuary, coho smolts are exposed to predation from both birds and fish, such as cutthroat trout. In the neritic waters, coho are also exposed to predation from dogfish and marine mammals. Based on survival rates for the first six months, the population of coho smolts in Totten Inlet is estimated as high as 87,500 in the estuaries to 6,125 emigrating fish after six months. Based on bioenergetics and population modeling in south Puget Sound, Preikshot and Beattie (2001) estimate that 25% of entering smolts emigrate in July and that biomass increases during that period by approximately 8-fold. Smolt biomass at entry is estimated at 0.14 g wet wt/m^2 and 0.28 g wet wt/m^2 at emigration. Production rates are relatively low for returning salmon, since most growth has already occurred at sea. Estimated production is based on a growth rate of 3%. Tertiary production for chum and Coho smolts is estimated at 1.4 gC/m^2/yr.

While in the nearshore zone, coho smolts feed on various planktonic crustaceans, pink and chum salmon fry, herring, sand lance, and other fishes. Juvenile fish from sublittoral habitats had stomach contents consisting mainly of decapod crustacean larvae, plus fishes (mostly herring), amphipods and polychaetes (MACSIS, Marine and Coastal Species Information System). Duffy (2003) found gut contents in south Puget Sound coho shifted as the fish moved from the river delta to the nearshore to the neritic waters. In the delta, juvenile coho diet was comprised of polychaetes, gammarid amphipods, insects, isopods, and crab larvae. In the nearshore zone, juvenile coho consumed gammarid amphipods, mysid shrimp, euphausiids, and fish. Once in the neritic zone, gut contents was almost exclusively crab larvae and fish (Pacific sand lance and herring). Young coho from the offshore pelagic zone consumed euphausiids, fishes (mostly herring), gammarids, and decapod larvae (Salo 1991). Fishes formed the highest biomass in stomach contents, but occurred in only 30% of the coho salmon stomachs analyzed. Juvenile coho can consume fish up to 50% of their body length. Coho size analysis indicated that mean nearshore size is 84 mm and 110-130 mm at neritic sites.

Based on bioenergetics model analysis, Duffy (2003) calculated apparent growth rates for juvenile coho at 1.3 to 2.0% body weight per day. Based on this growth rate, consumption rates were calculated at 3.4 g to 8.4 g of prey per week. Using prey energy density and stomach contents analysis, juvenile coho consumed 0.00 - 0.33 g of amphipods, 0.08 - 0.18 g of euphausiids, 0.28 - 2.41 g crab larvae, and 0.93 - 2.76 g of other invertebrate prey in order to satisfy estimated growth. Similar prey items were important in the nearshore fish in 2002. In the neritic sample, crab larvae comprised 82% of the diet; however, this was only one sample.

The food of marine adults is more pelagic and more varied than that of many Pacific salmon. Fishes made up 70% to 80% of the coho diet and 20% to 30% were invertebrates. The following species were common prey items: pilchard, herring, anchovy, coho salmon, capelin, laternfish, Pacific saury, hake, whiting, rockfishes, black cod, sculpins, sand lance, squid, barnacles, isopods, amphipods, euphusiids, crab larvae, and jelly fish (ADFG 1986). Herring and sand lance made up 75% of the biomass. Cloud (2001 in WSCC 2003) indicated that returning coho are not feeding prior to entering their natal streams.

Coastal Cutthroat Trout *(Oncorhynchus clarki clarki)*

Coastal cutthroat trout are the most widely distributed salmonid in the Totten Inlet watersheds (WSCC 2003), with the anadromous populations occurring in most South Puget Sound tributaries. Adult, sea-run cutthroat trout return to their natal stream to spawn. Migration begins in November, peaking in January/February. Spawning occurs in late winter and spring. Spawned sea-run cutthroat can return to marine waters, and generally migrate downstream in late March to early April. Smolt traps deployed in Skookum Creek indicated that mean cutthroat smolts ranged in size from 148 to 163 mm between 2001 and 2004 (Joseph Peters, Squaxin Tribe, personal communication). Smolts runs were observed from early April to late June and abundance ranged from 504 to 2,430 fish per year during that time. However, captured fish were not tagged, so it is difficult to determine whether fish were being resampled during the trapping events, and more quantitative distribution and abundance data are currently unavailable (Joseph Peters, Squaxin Tribe biologist, personal communication 2006).

Adults will return to salt water if available to them (NOAA fisheries biologist, personal communication), but their distribution and movement is unknown. In the nearshore areas, sea-run cutthroat remain near the mouth of their natal river (within 50 km). Schools of cutthroat feed and migrate along the shoreline, mostly in water less than 3 m deep. Although residence time in marine waters varies, cutthroat return to freshwater in the same year they migrated out. Based on estimates in Oregon, smolt survival is 20% to 40%. Predation by Pacific hake, spiny dogfish, harbor seals and adult salmon accounts for the majority of smolt mortality (Trotter 1997). Cutthroat trout smolts are generally larger than the juvenile salmonids in Puget Sound, ranging from 148 mm (Peters, personal communication) and 356 ± 82 mm FL (Fresh et al. 1981). Based on a mean smolt production estimate of 1300 smolts/year and mortality of 30%, the smolt population would be estimated at 900 smolts per year. Based on wet weight relationship of 0.02 g/mm, the estimated wet weight biomass would range from 0.0001 g/m^2 to 0.0004 g/m^2 and mean annual production would be 0.0002 to 0.0009 $gC/m^2/yr$

In the marine environment, cutthroat trout feed on gammarid amphipods, isopods, callianassid shrimp, immature crabs, and various fish, including chum salmon, pink salmon, and sand lance. Herring and sculpins have also been observed in cutthroat trout stomachs (Jaquet 2002). Cutthroat trout from central and south Puget Sound were mostly piscivorius, with fish comprising

74% of the stomach contents (Fresh et al. 1981). Sand lance made up 60% of the fish prey biomass. The major invertebrate prey was gammarid amphipods, making up 16% of the prey biomass.

Winter Steelhead *(Oncorhynchus mykiss)*

Totten Inlet steelhead spawn in Kennedy, Skookum, and Schneider Creeks; however, low flows and limited spawning habitat limit production within the watershed (WSCC 2003). The status of these stocks is poorly understood.

Winter steelhead typically enter freshwater December through mid-March and spawn in early February to early April. Outmigration to marine waters is determined primarily by size and environmental factors. In this region, juvenile steelhead typically enter marine waters at two years of age (WSCC 2003). Steelhead in sampled central and south Puget Sound were 259 mm ± 125 mm FL (Fresh et al. 1981). Winter steelhead and coastal cutthroat are present in the spring through late summer. Resident adult standing stock is 0.16 gC/m^2. The steelhead diet is dominated by fish and gammarid amphipods, whereas coastal cutthroat are feeding primarily on fishes, as well as euphausiids and decapod larvae (Pearcy 1997). Production is likely to be higher in the spring as younger adults enter south Puget Sound; however, due to the limited data regarding stocks, it is not possible to estimate annual production.

In the marine environment steelhead have a diet similar that of coho, with smaller fish feeding on benthic and nearshore invertebrates and larger fish feeding on small fish (Costello 1977). The prey found in stomachs of adult steelhead captured in central and south Puget Sound were numerically dominated by euphausiids, gammarids, insects, and decapod larvae (Fresh et al 1981). Herring were also present and dominated the prey biomass in larger fish.