4.0 BIOLOGICAL PATHWAYS

Exposure pathway assessment is necessary to identify the resources at risk within the Injury Study Area (per 11.25 and 11.63 of 43 CFR Subtitle A). Exposure pathways may be direct or indirect and include direct contact with/or ingestion of, contaminated surface water, groundwater, and sediment; inhalation of contaminated air; and ingestion of contaminated food. To assess these pathways, information related to the chemical and physical characteristics of the hazardous substance released, rate or mechanism of its transport within the natural media, and exposure concentrations must be evaluated. This information may either be obtained by inference from previous studies of similar circumstances, through modeling efforts, or through direct field measurements or laboratory experiments.

Section 4.0 contains four subsections. The first subsection describes the principal sources, release mechanisms, and dynamics of the SOCs within the Injury Study Area to identify the key exposure pathways from abiotic media to biological resources. The second subsection discusses the feeding and behavioral habits of key biological resources. The third section combines the information presented in the first two sections to present a conceptual model of exposure pathways of SOCs to the key biological resources. The final subsection discusses the evidence of exposure to resources of Commencement Bay.

4.1 GENERAL DESCRIPTION OF BIOTIC-ABIOTIC INTERACTIONS

This section describes the principal exposure pathways of SOCs from their release to various media and resources. The release, transport, and fate of SOCs are discussed in a general manner. A discussion of the ecotoxicity of the SOCs is provided in Appendix D.

4.1.1 Primary Receiving Media and Important Processes

Upon release, the transport and fate of a contaminant is determined by the nature of the release, the physical and chemical dynamics and conditions in the receiving media, and the physical and chemical characteristics of the contaminant. The combination of these factors will determine the persistence of the contaminant in the form in which it is released (particulate or dissolved), which will affect the exposure and potential for injury to biological resources.

Chemical conditions in the waterways are likely to be different from those in the runoff, effluent stream, or groundwater environment of the primary source. Important chemical conditions include pH, redox potential, salinity, concentration gradients, competing chemical species, concentration of complexing agents, and available sorptive surfaces. The potential to change from a dissolved phase to a particulate phase and back again will depend upon both thermodynamics (relative stability) and kinetics (relative rates of transport and transformation). For example, zinc may dissolve from a particulate phase upon entering the waterway due to high chloride levels in the estuarine water, or dissolved PCBs in a contaminated groundwater plume may sorb to suspended matter in the waterway and settle out of the water column.

With time, a substance will reach quasi-equilibrium within the waterway environment, and be subject to the transport and fate processes within the waterway. Potential fate processes for inorganic substances include volatilization and adsorption/precipitation as well as speciation changes such as complexation and microbial transformation (e.g., methylation). These processes may be influenced by changes in sediment redox potential. Organic compounds are also subject to volatilization and adsorption, but may also be degraded through photolysis, hydrolysis, and biodegradation. The relative rates of these processes will be highly dependent upon the nature of the substance and the physical and chemical conditions in the waterway.

If a contaminant is associated with particulate matter, sediment transport processes including deposition, resuspension, and burial will be influential in determining its location and residence time within the waterway. Sorption to particulate matter also tends to inhibit volatilization, microbial degradation, and other degradation processes. These processes will determine the extent, severity, and location of contaminated media, as well as the potential exposure pathway.

If a substance remains in solution, either in the dissolved state or associated with suspended particulate matter or colloids that do not readily settle out, it is likely to be carried from the source through the natural circulation of the system, diluted, and possibly degraded or volatilized. Because the dissolved concentrations of contaminants are generally the most relevant with respect to exposure, estimation or measurement of these concentrations, from both a temporal and spatial perspective, are most important in assessing resources at risk.

4.1.2 Exposure to Biota

Exposure of biological resources to an SOC is dependent upon the location and speciation of the substance, its persistence, and the behavior and location of biota. Potentially important exposure pathways include uptake from water and air; uptake via direct contact with sediments; direct contact with, or ingestion of, interstitial water; and ingestion of contaminated food. Therefore, if biological resources are collocated with an SOC, and it is in a form accessible by that species (i.e., it is bioavailable), toxicity (injury) may result if the species is sensitive to that particular SOC or combination of SOCs at the concentrations present at that location.

The general conclusion that dissolved substances are generally more bioavailable to aquatic organisms than contaminants sorbed to particulate matter has been borne out in numerous toxicity studies including both water and sediment exposures involving nonpolar, hydrophobic organic chemicals, as well as several metals. However, availability and effects are controlled by a variety of factors that can be species-specific and must be considered when assessing potential pathways of exposure.

Partitioning models, such as the equilibrium partitioning (EqP) model for non-polar hydrophobic chemicals, as well as the acid volatile sulfide (AVS) model for some metals, have been developed to assess the potential availability of dissolved substances from contaminated sediments. In these models, the available fraction is related to the bulk sediment concentration of the contaminant normalized to the concentration of a "controlling phase." In both of these models, the available fraction of the contaminant is assumed to be the fraction dissolved in interstitial water. EqP theory asserts that characteristics of the substance and the concentration of sedimentary organic carbon control the ratio of the dissolved to the sorbed concentration for nonpolar, hydrophobic organic compounds. The AVS theory states that the potential dissolved concentration of several metals is related to the abundance of AVS in the sediment. EqP appears to provide an approach that can yield a good, although imprecise indicator of the availability of nonpolar, hydrophobic organic compounds such as DDT, HPAHs, PCBs, and certain insecticides bound to sediments (Di Toro et al., 1991). AVS appears to have the potential for predicting the bioavailability of sediment-bound cadmium and nickel, and perhaps copper, lead, and zinc (Ankley et al., 1991; Di Toro et al., 1992). Therefore, if a biological resource of concern is likely to come into contact with interstitial water, then the EqP and AVS models can be used to estimate whether concentrations of some of the SOCs in sediments have the potential to injure these species through interstitial water uptake. However, other researchers (Landrum and Robbins, 1990) have demonstrated the nonequilibrium behavior of PAHs, suggesting exposure through sediment ingestion or direct contact would have to be considered separately from the EqP and AVS models discussed above. Additional field verification of these models, and others, is ongoing, and project-specific field verification has been recommended.

For water column species, the EqP and AVS models theoretically can be used to estimate the concentration of SOCs in the water column through the use of diffusion/advection models, or they can be used in conjunction with uptake models to predict the concentration of an SOC in food. Exposure of biological resources to SOCs that do not have a high affinity for sediments is related to the mixing pattern of the water body, persistence and concentration of these substances, and the speciation of the contaminant, especially in the case of metals. Even though models can be used, actual field measurements of concentrations in water and tissue are recommended.

4.2 FOOD WEB INTERACTIONS

As discussed above, the biological resources of Commencement Bay can be exposed to contaminants through direct contact with contaminated media (e.g., flatfish ingesting contaminated sediment) or through trophic interactions (e.g., flatfish ingesting contaminated polychaete worms). In addition to direct exposure to contaminants through food, higher-trophic-level consumers can also be impacted if the quality or quantity of their food resources are reduced by exposure to contaminated media. To evaluate the potential for the key resources of Commencement Bay to be impacted by contaminants through the trophic pathway, information on the ecological relationships was gathered for the key resources identified in Section 3.0. This section identifies the principal prey species, food webs, and habitats for the key biological resources—salmonids, flatfishes, benthic and epibenthic species, and birds.

4.2.1 Salmonids

Salmonids use several habitats in Commencement Bay during their lifetimes. During their juvenile life stage, salmon species are characterized as opportunistic drift and benthic feeders, primarily consuming insects in the stream-rearing phase of life (Emmett et al., 1991). During the day, the fish remain in a small home area, and at night they settle to the bottom, usually after moving inshore. Juvenile salmon migrate downstream from the tributaries to overwinter in larger streams, often living in the substrate.

As they mature, juvenile salmon use a wide range of invertebrate prey while retaining their insectivorous feeding habits during their estuarine residence (Emmett et al., 1991). Fry and subyearlings in saltmarsh and other shallow habitats prey principally upon emergent insects and epibenthic crustaceans such as gammarid amphipods, mysids, and cumaceans. The dominant prey taxa found in the diet of juvenile Pacific salmon species in Commencement Bay were epibenthic invertebrates including gammarid amphipods, harpacticoid copepods, and dipteran insects (Meyer et al., 1981b; Dames & Moore, 1981b). In neritic habitats, juvenile salmon feed upon small nekton (decapod larvae, larval and juvenile fishes, and euphausiids) and neustonic drift insects. Juvenile steelhead trout generally recruit into the estuary at a larger size than the salmon and their preferred prey include mysid shrimp, insects, and juvenile fish (Meyer et al., 1981b). As juvenile salmon grow and move farther out into the marine environment, their diets include crab zoea, Pacific sand lance (*Ammodytes hexapterus*), eulachon (*Thaleichthys pacificus*), copepods, euphausiids, cephalopods, isopods, and amphipods.

Adult chinook, coho, chum, and pink salmon and steelhead trout use the Injury Study Area of Commencement Bay as a migratory corridor and staging area before migrating to spawning grounds in the upper reaches of the Puyallup River basin. Adult salmonids are present within the bay from June through early January. Residence times within the bay before migrating up the Puyallup River vary by species and flow conditions in the river, but generally range from 3 to 40 days (Dames & Moore, 1981b; Shapiro and Associates, 1993b) (Table 3-4). Feeding of prespawning adult salmonids within the Injury Study Area has not been studied. However, limited observation in other estuaries has found that the dominant prey of adults in marine environments are pelagic and demersal fish including herring and sandlance supplemented by invertebrates including shrimp, euphausiids, and squid

(Hart, 1973). Detailed descriptions of the feeding habits and other life history information of chinook and pink salmon are included in Appendix E.

4.2.2 Flatfish

Flatfish of the families Pleuronectidae and Bothidae constitute another key resource group that uses Commencement Bay. As larvae, flatfish are planktivorous and consume primarily copepods (Emmett et al., 1991). Other food sources include tintinnids, invertebrate eggs, and nauplii. As juveniles, flatfish are considered to be opportunistic and generalized benthic feeders, with selection only at the level of major taxonomic groups of prey (Emmett, et al., 1991). Within prey groups, the diet varies with local seasonal prey abundance. The most commonly found species preyed upon by juvenile flatfish include polychaetes, amphipods, cumaceans, and bivalve siphons.

Studies have found that the feeding habits of adult flatfish are similar to those of juveniles. These studies found amphipods, polychaetes, and cumaceans to make up the major dietary component of adults. Like juveniles, adults were found to feed opportunistically on a wide variety of benthic invertebrates including shrimp, small molluscs, and crabs, in addition to polychaetes. The taxonomic composition of diets of adult flatfish includes shallow-burrowing and surface-active prey (Emmett, 1991). Adults are also capable of digging into sediments to capture deeper-burrowing prey. Wingert et al. (1979) found that English sole, rock sole, and Dover sole, collected in central Puget Sound, fed primarily on polychaetes, gammarid amphipods, and bivalves. Polychaete worms were found to be the dominant prey item of these three species comprising 49 to 75 percent of stomach contents (measured by percent total index of relative importance of prey taxa). Gammarid amphipods comprised 13 to 28 percent of diet, while bivalves comprised 2 to 11 percent. Detailed descriptions of the feeding habits and other life history information for two of the most common flatfish species, English sole and rock sole, are included in Appendix E.

4.2.3 Benthic and Epibenthic Community

As identified in Sections 4.2.1 and 4.2.2, the benthic and epibenthic community (as described in Section 3.2.1.2) plays a critical role in the Commencement Bay ecosystem as a food resource for key higher-trophic-level consumers such as juvenile salmonids and juvenile and adult flatfish (see Table 3-2). These benthic species provide a pathway from sediment and interstitial water to predator species.

Benthic species themselves are exposed to contaminated media directly and indirectly. Direct exposure comes from the feeding habits of numerous species that ingest sediments along with prey or feed primarily on the organic matter deposited on and in the sediment. Indirect exposure comes from feeding on fellow benthic species; from ingestion of contaminated interstitial water; and from absorption through the gills and skin from interstitial water. For example, adult Dungeness crab (*Cancer magister*) consume benthic fish, molluscs, and crustaceans.

4.2.4 Threatened and Endangered Species

A number of species listed under the Endangered Species Act occur or are thought to occur in the Commencement Bay area, including the bald eagle and peregrine falcon. Both species feed in Commencement Bay at the top of the food chain and therefore are more vulnerable to contamination through biomagnification. Typical prey items for peregrine falcons are shorebirds and ducks. Bald eagles also are predominantly avian predators, in addition to feeding on dead fish and vertebrates (Knight et al., 1990; Vermeer et al., 1987). Preferred species are typically dabbling ducks, such as wigeon, mallard, pintail, and common (green-winged) teal. All of these species occur in Commencement Bay and typically feed on aquatic and shoreline vegetation and some epibenthic organisms (Bellrose, 1981).

4.3 CONCEPTUAL MODEL OF EXPOSURE PATHWAYS IN COMMENCEMENT BAY

From the information presented in Sections 4.1 and 4.2, a conceptual model was constructed to illustrate the generalized pathways for contaminant migration, including exposure routes to biota (Figure 4-1). Because exposure through the food chain was considered a significant pathway, a conceptual generalized food web model was constructed to illustrate the relationships between functional feeding groups and their food resources (Figure 4-2). This section discusses both of these models to link the previous two sections and show exposure pathways from release to key biological resources.

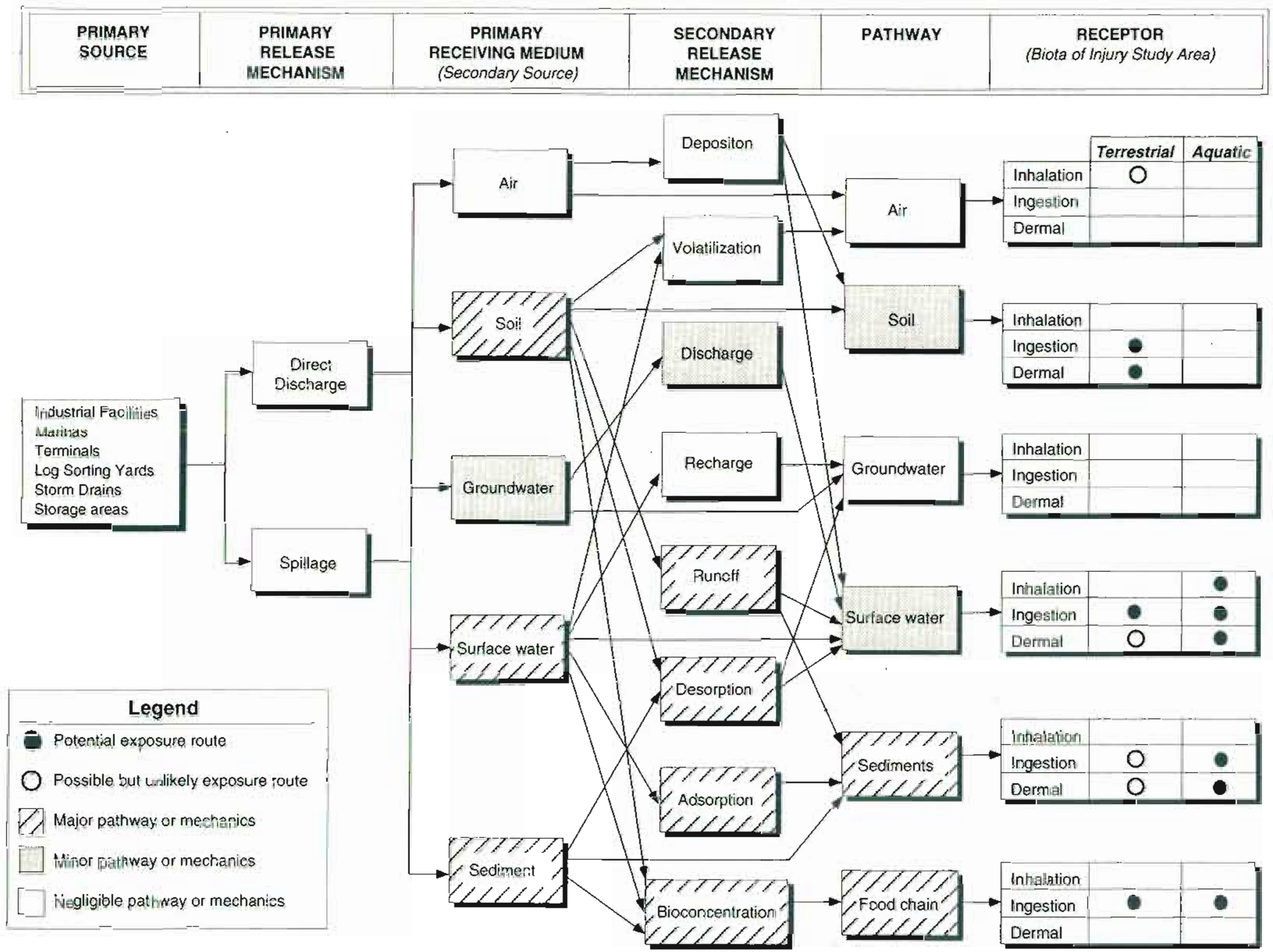

Figure 4-1. Conceptual model of exposure pathways.

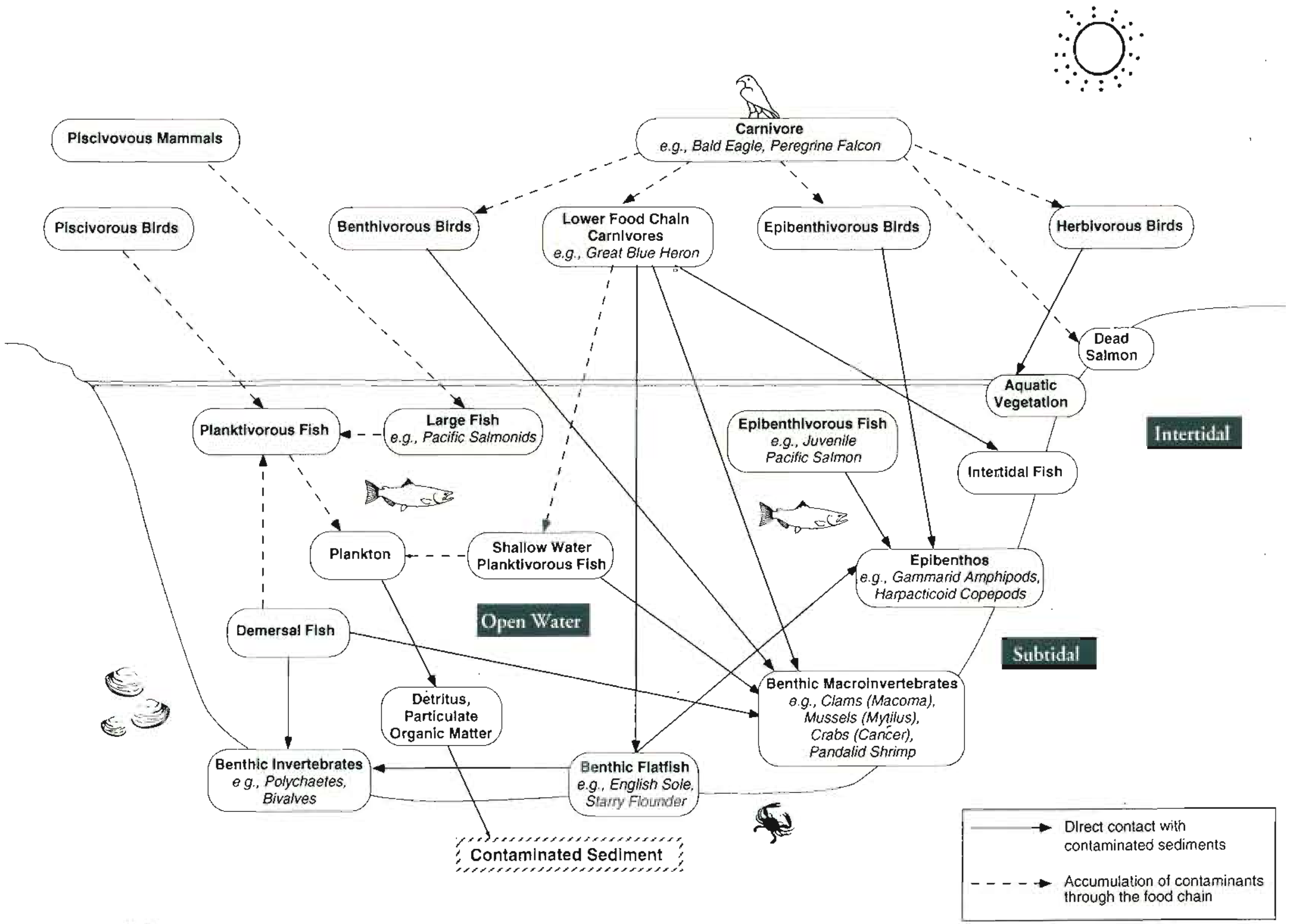

Figure 4-2. Conceptual food web model of Commencement Bay.

The model in Figure 4-1 presents a summary of the movement of contaminants from their sources to exposure media in the Injury Study Area. In addition, the primary routes through which receptors can be exposed to these media are presented. In Commencement Bay, the principal pathways in which biota can be exposed to contamination are through contact with, and ingestion of, sediments and the food web. Contact with, and ingestion of, surface water, and to some extent soil, also provide important exposure pathways. Air and groundwater pathways are considered to be less important exposure routes to natural resources in the Injury Study Area.

The primary route of exposure from sediments is through ingestion of, and dermal contact with, contaminated sediments and interstitial water. This pathway is of particular concern to the demersal species, because they are in intimate contact with the sediments and many actively ingest sediment particles and associated organic matter and interstitial water.

To further investigate the potential for exposure through the food web, a conceptual model of the food web of Commencement Bay was constructed. This model focuses on the key resources identified in Section 3.0 and indicates representative biological species only. In addition, only the major trophic pathways are presented (Figure 4-2). This model demonstrates potential exposure pathways to SOCs through feeding as well as the importance of some groups as prey for key species. Injury to prey may have an impact on their consumers even in the absence of their direct exposure to SOCs.

For this model, species were categorized into the following functional feeding guilds:

- Carnivore (feeds exclusively on other animal species)
- Herbivore (feeds exclusively on plant species)
- Omnivore (feeds on both plant and animal species)
- Piscivore (specialized carnivore that feeds predominantly on fish species)
- Benthivore (specialized carnivore that feeds on benthic species)
- Epibenthivore (specialized carnivore that feeds on epibenthic species)
- Planktivore (consumes plankton species or life stages of species of plants and animals)

Figure 4-2 shows these functional feeding guilds and their relationships to food resources as well as contaminated media. In Commencement Bay, the benthic community is the principal food resource for the majority of the higher-trophic-level key species. Benthic invertebrates serve directly as the food resources for benthivorous fish (e.g., English sole), benthivorous birds (e.g., surf scoter), and to a lesser extent for some predatory birds (e.g., great blue heron). Epibenthic species are the primary food resource for epibenthivorous fish (e.g., juvenile salmon) and birds (e.g., dunlin).

Because benthic invertebrates are directly exposed to the reservoir of SOCs found in the sediments, they provide the key link in the pathway to higher-level consumers. In addition, because they are so heavily used as food by such a variety of key resources in Commencement Bay, disruption of the benthic community would have wide-ranging impacts on a variety of higher-level species.

In summary, abiotic resources, such as surface water and sediment, are contaminated from release of SOCs into Commencement Bay. Contaminated sediment serves as a continuing source of exposure to the Commencement Bay ecosystem directly through contact and ingestion by the benthic community, and indirectly through the food chain as shown in Figure 4-2. Section 5.0 discusses the potential injuries that may result from these exposures.

4.4 EVIDENCE OF EXPOSURE IN COMMENCEMENT BAY

The presence of key biological resources in locations with high concentrations of SOCs in Commencement Bay can be considered an initial indicator of the exposure through the pathways established in Sections 4.1 to 4.3. Measurement of the SOCs in the tissues of key resources is additional evidence that exposure of those biological resources is occurring. This subsection provides a summary of the data that establish the presence of the key biological resources in locations where high concentrations of the SOCs are found in the sediments of the Injury Study Area, as well as the available field data documenting the presence of SOCs in the tissues of biological resources.

4.4.1 Distribution of Key Biological Resources

The key biological resources are distributed both spatially and temporally in the Injury Study Area based on their ecological habits. This section provides a summary of areas within the Injury Study Area that are used by the key resources and the time periods during which those resources are present. Key resources in Commencement Bay that are the focus of this summary are juvenile and adult salmonids, flatfish, benthic invertebrates (infaunal, epibenthic, and macroinvertebrates), and birds.

4.4.1.1 Salmonids

The Commencement Bay estuary provides critical nursery habitat for juvenile salmonids. Juveniles use the Injury Study Area as a transition zone from fresh water to marine environments, as critical forage area, and as protection from predators (Meyer et al., 1981a,b; Dames & Moore, 1981a; Duker et al., 1989). Adult salmonids use the bay as a staging area prior to spawning migrations into the Puyallup River basin.

Juvenile Salmonids

The areal and temporal distributions of juvenile salmonids within the Commencement Bay nearshore environment have been well studied. Meyer et al. (1981a), Dames & Moore (1981a), Duker et al. (1989), and Varanasi et al. (1993) have collected juvenile salmonids in beach and purse seines and in tow nets throughout the nearshore portions of the bay, including within all of the waterways, along most of the Ruston Shoreline, and along most of the shoreline between the Hylebos Waterway and Browns Point. Beach seines have sampled the bottom 3 m of the water column within intertidal/shallow subtidal areas, while tow nets and purse seines have sampled the top 3-4.5 m of the subtidal nearshore areas. Table 4-1 summarizes the temporal distribution and Figure 4-3 shows the spatial distribution of juvenile salmonids in Commencement Bay.

Data indicate that juvenile salmonids use all of the waterways and most of the nearshore environment between Ruston and Browns Point during their estuarine nursery period. The greatest abundance of juvenile salmonids appears to be near the mouths of the Puyallup River, Milwaukee Waterway, and Sitcum Waterway, both the Ruston and Browns Point shorelines, and mudflat areas within the Hylebos Waterway.

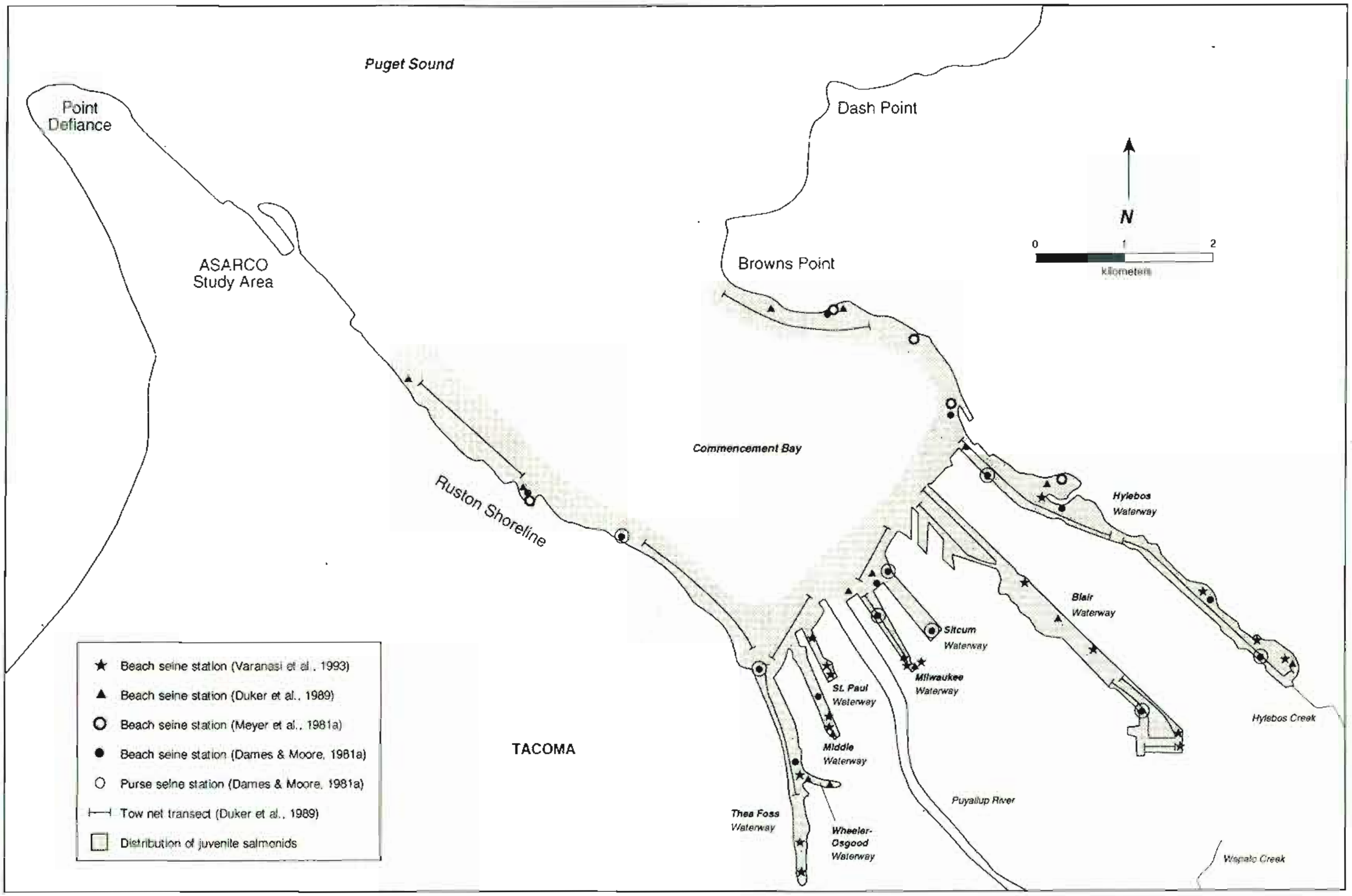

Figure 4-3. Distribution of juvenile salmonids in Commencement Bay.

EVS

Table 4-1. Timing of Adult Salmonid Migrations Through Commencement Bay to the Puyallup River

Species	Timing		Residence Time in Bay
	Peak	Range	(Days)
Adult			
Chinook (fall)	late Aug.–Sept.	July–Sept.	27–40
Chinook (spring)	unknown	April–June	unknown
Coho	mid Sept.–early Oct.	June–Oct.	13–40
Chum	late Sept.–Nov.	Sept.–Dec.	3–40
Pink	mid Aug.–mid Sept.	July–Sept.	7–14
Steelhead (winter)	late Nov.–early Jan.	Nov.–Feb.	unknown
Juvenile			
Chinook (fall)	May–mid June	Late March–mid July	80–90
Coho	May	Late March–late May	50–90
Chum	Early April–late May	Late March–mid July	80–90
Pink[a]	April	April	30
Steelhead (winter)	unknown	unknown	unknown

Source: Dames & Moore (1981a), Duker et al. (1989), Shapiro and Associates (1993a).
[a] Pink salmon juveniles are present during even-numbered years; adults are present during odd-numbered years.

Meyer et al. (1981a,b), Dames & Moore (1981a), and Duker et al. (1989) found that juvenile chinook salmon were the most abundant species associated with the nearshore of the Injury Study Area. Chum, coho, and pink salmon followed chinook salmon in relative abundance, with juvenile pink salmon present only during-even numbered years. Steelhead trout and sea-run cutthroat trout were rare and appeared to be less associated with nearshore areas.

Juvenile chinook salmon have been reported to use the study area for more than 12 weeks from late March to mid-July, with peak abundances observed from mid-May to mid-June (Duker et al., 1989). The greatest abundance of juvenile chinook salmon has been found on either side of the Milwaukee Waterway near the mouth of the Puyallup River (Dames & Moore, 1981a; Duker et al., 1989). High numbers have also been observed in Thea Foss Waterway and along the Ruston and Browns Point shores. Low abundances have been observed in Hylebos and Blair Waterways.

Chum salmon have been reported to use the study area during the same time period as chinook salmon, though in much lower abundances, with a peak between early April and late May. This species has a relatively even distribution throughout the study area with concentrations observed at Ruston Shoreline, Browns Point, and a mudflat within the Hylebos Waterway (Dames & Moore, 1981a; Duker et al., 1989).

Juvenile coho salmon have been reported to use Commencement Bay for approximately 8 weeks between the end of March and the end of May, with a peak during May. They have been observed at the highest abundances near the mouth of the Puyallup River, the Ruston Shoreline, and the Browns Point shore (Dames & Moore, 1981a; Duker et al., 1989).

Pink salmon have been reported to use Commencement Bay for approximately 4 weeks in April. Similar to chum juveniles, they have been observed most often on the Ruston Shoreline, Browns Point shore, and mudflat areas of the Hylebos Waterway (Dames & Moore, 1981a; Duker et al., 1989).

Adult Salmonids

The temporal distribution of adult salmonids in Commencement Bay is fairly well known; most data are from tribal and recreational catch statistics. The spatial distribution of adult salmonids in the bay, however, is not well known. Some observations as to their areal distribution can be made by examining the distribution of the recreational fishing effort but, to date, trawl surveys have not been conducted in the Injury Study Area.

Adult salmonids stage in Commencement Bay for 3-40 days before migrating into the Puyallup River (Dames & Moore, 1981a; Duker et al., 1989; Shapiro and Associates, 1993a). Chinook and coho salmon remain in the bay for longer periods of time, while chum and pink salmon stage for relatively shorter periods (Table 4-1). It is not known how long steelhead remain in the bay before migrating up river.

Adult salmonids can be present in Commencement Bay for most of the year. An adult resident chinook salmon, often referred to as a "blackmouth," can be found in the bay year-round. Fall chinook salmon stage in the Injury Study Area between July and September, with a peak in late August. Coho salmon overlap this period, first arriving in June, continuing through October with a peak in mid-September. Adult pink salmon arrive in the bay primarily in odd-numbered years between July and September with a peak between mid-August and mid-September. Chum are generally the last of the salmon species to arrive, staging in the bay for short periods between September and December, with a peak in

November. Steelhead trout arrive later than any of the salmon species, arriving in the bay between November and February, with a peak in December (Table 4-1).

4.4.1.2 Flatfish

The spatial distribution of flatfishes has been fairly well studied in the nearshore subtidal areas of Commencement Bay. Dames & Moore (1981a) and Tetra Tech (1985) conducted 37 bottom trawls, which included all of the waterways, the Ruston Shoreline, and the Browns Point shore (Figure 4-4).

English sole, rock sole, flathead sole, sand sole, and speckled sanddab were commonly collected at all of the waterway and shoreline trawl stations occupied by Dames & Moore (1981a), indicating a bay-wide distribution. English and flathead sole were found in greater abundance within the waterways than along the two shorelines, while rock sole were more abundant along the Ruston Shoreline and Browns Point shore. Starry flounder were present only in the waterways and at the mouth of the Puyallup River (this species is tolerant of very low salinities), while C-O sole were observed only along the shorelines (Figure 4-4).

Flatfishes spawn primarily in winter and spring (Hart, 1973). During spawning, fish move to deeper waters in bays (Ketchen, 1956; Forrester, 1969a,b). Emmett et al. (1991) reported that pre-metamorphic juvenile sole (pelagic stage) are carried into estuaries by currents. After metamorphosis (eye migration, demersal existence), smaller fish tend to reside in shallow waters, while larger fish are more abundant in deeper water. Dames & Moore (1981a) found that although a greater abundance of English sole resided within the waterways, the larger fish were present along the two shorelines.

Dames & Moore (1981a) was the only investigator to conduct fish trawls seasonally over a 1-year period within Commencement Bay. In general, large seasonal shifts in species were not observed among the eight flatfish species collected by Dames & Moore (1981a). In most cases, the greatest number of flatfish species and number of individuals were observed during the summer sampling period. However, English sole, rock sole, and speckled sanddab were abundant during all four seasons, and rock sole and starry flounder were abundant during three of four seasons. Dover sole, however, were abundant during the summer only, rare during the fall, and absent during the winter and spring (Dames & Moore, 1981a).

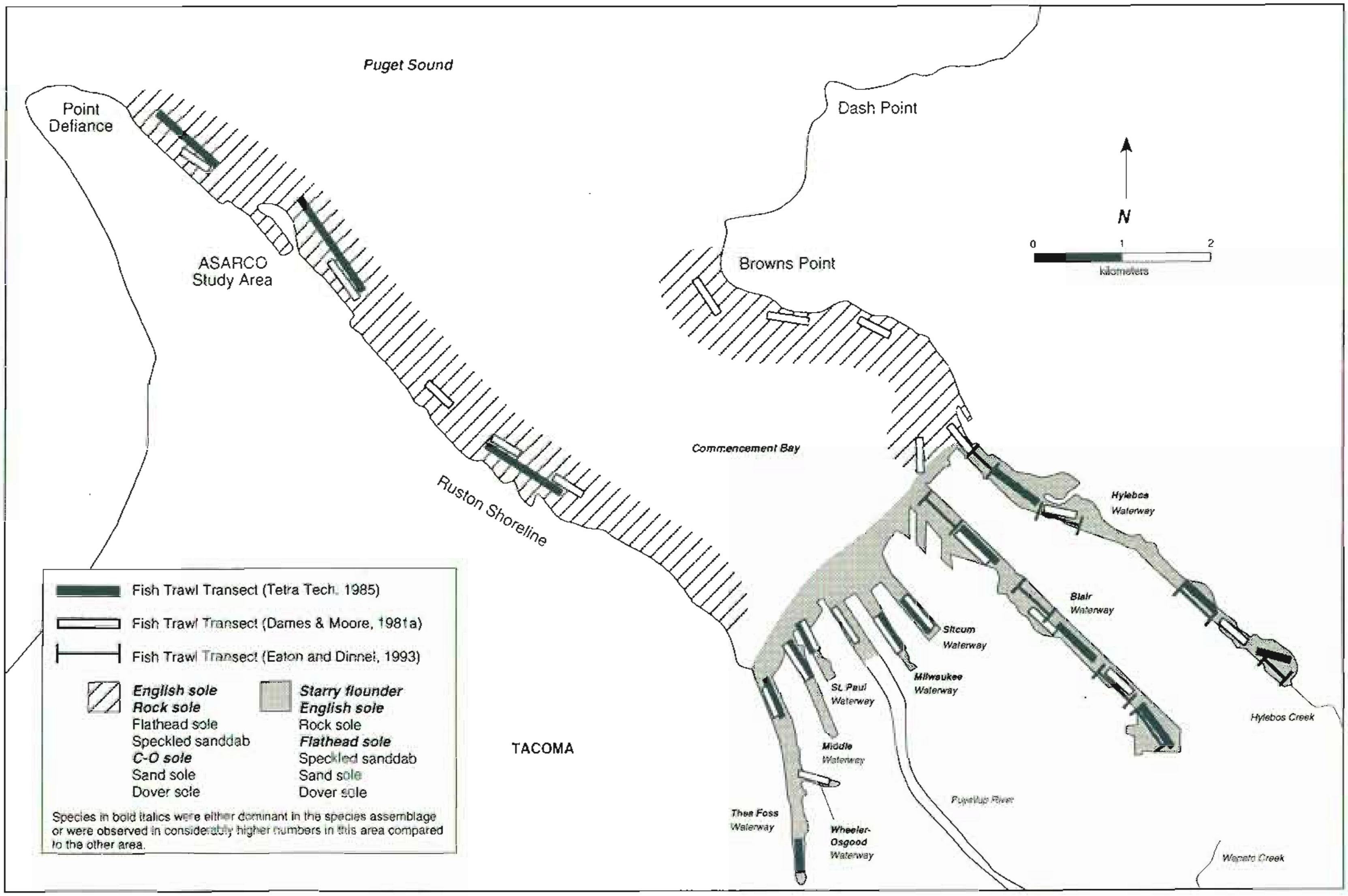

Figure 4-4. Fish trawl investigations and the distribution of common flatfish species within Commencement Bay.

The observation of seasonal shifts in nearshore flatfish abundances in Commencement Bay is consistent with the group's seasonal movements within the bay. These data indicate that most flatfish species are present in Commencement Bay all year, and most are present in all marine/estuarine locations. Migration/movements beyond those described above are not thought to be extensive.

4.4.1.3 Benthic Infauna

As described earlier, the benthic infaunal community (in the waterways and adjacent to the ASARCO property) has been reasonably well characterized. Multi-waterway investigations have been conducted by Tetra Tech (1985), Dames & Moore (1981b), and Chapman et al. (1984). Parametrix (1990b, 1991a) conducted a limited benthic survey at the mouth of the St. Paul Waterway. Several benthic surveys have also been conducted in the vicinity of the ASARCO property (Parametrix 1989a,b; 1990a; 1991b). Benthic infaunal surveys have been limited along the Browns Point shore.

No comprehensive deepwater surveys have been conducted. Clarke (1986) investigated the benthic communities in the deeper parts of Commencement Bay west of Browns Point, while PTI (1988) collected deep-water benthic samples adjacent to the dredged material disposal site located in the central portion of the bay. A summary of the benthic infauna surveys is shown in Figure 4-5. In general, data indicate that benthic infauna are distributed within all of the waterways and along nearshore subtidal shorelines.

4.4.1.4 Epibenthic Invertebrates

As discussed earlier, studies of epibenthic invertebrates have been less comprehensive than those for the benthic infauna (Figure 4-6); therefore, characterization of the epibenthic community in Commencement Bay, both spatially and temporally, has been limited (Simenstad et al., 1993). However, existing data support the conclusion that the epibenthic species are present in all areas of the bay.

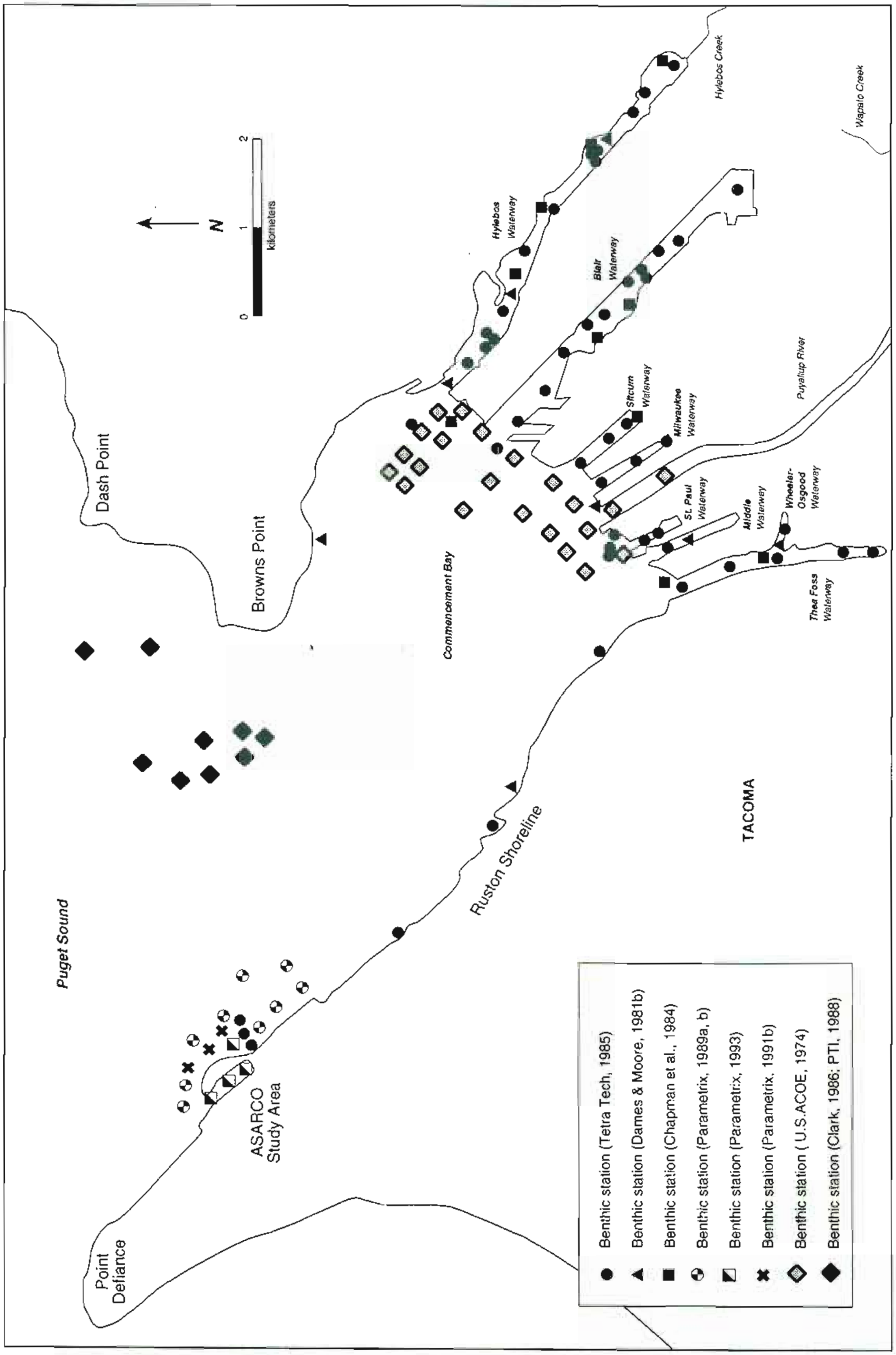

Figure 4-5. Benthic stations sampled in Commencement Bay.

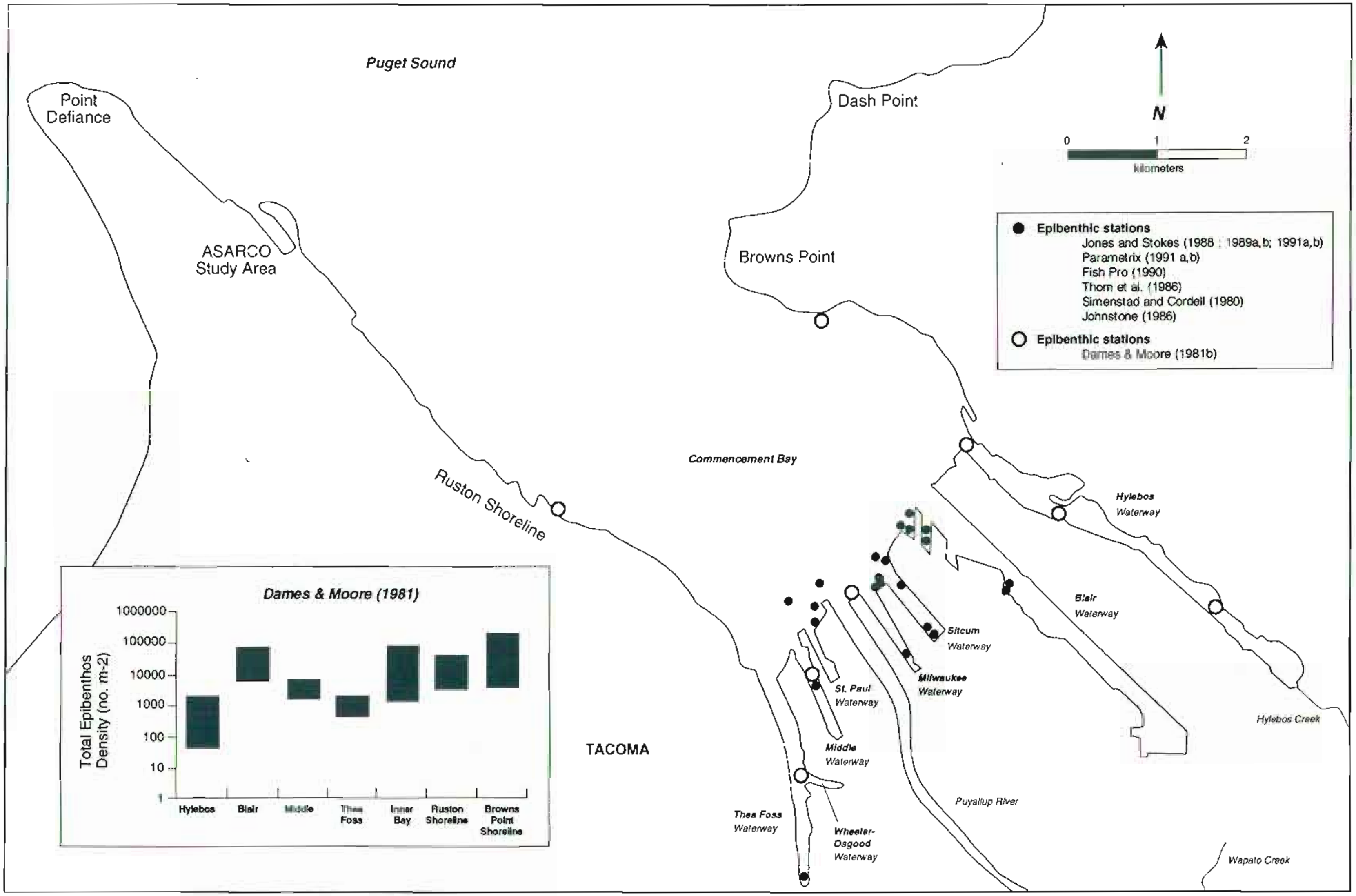

Figure 4-6. Epibenthic stations sampled in Commencement Bay and epibenthic density observed by Dames & Moore (1981).

4.4.1.5 Larger Invertebrates

Surveys of invertebrates have been limited in Commencement Bay. Creel, diving, and trawl surveys have concentrated primarily on species of economic importance and most have been qualitative (Eaton and Dinnel, 1993; Dinnel et al., 1986; Malins et al., 1981; Noviello, 1981; Salo and McComas, 1980; Salo et al., 1980; Nakatani et al., 1973) (Figure 4-7).

Eaton and Dinnel (1993) reported dock shrimp and sand shrimp to be present in both the Hylebos and Blair Waterways. Dinnel et al. (1986) reported dock shrimp to be plentiful to abundant off Browns Point at transects of 10 and 80 m deep. Pink and sidestripe shrimps were also observed, but in lower numbers. Nakatani et al (1973), Salo and McComas (1980), and Salo et al. (1980) reported large numbers of dock shrimp near the ASARCO facility, in other areas along the Ruston Shoreline, and in Milwaukee Waterway. Shrimps were usually associated with submerged logs and debris. Malins et al. (1981) observed dock and pink shrimps in Hylebos Waterway. The species *Crangon alaskensis* was also observed in low numbers in the Hylebos Waterway.

Creel surveys by Noviello (1981) reported the recreational harvest of Dungeness crab and red rock crab on the Ruston Shoreline, Browns Point to Hylebos Waterway, Blair Waterway, and Thea Foss Waterway. In trawl surveys, Eaton and Dinnel (1993) reported purple crab and Dungeness crab to be present in the Hylebos and Blair Waterways. Dinnel et al. (1986) did not observe Dungeness crab, but did report red rock crab near Browns Point, while Malins et al. (1981) observed Dungeness crab in Hylebos Waterway, but no red rock crab. Nakatani et al. (1973) observed Dungeness crab near the ASARCO facility along the Ruston Shoreline. Salo and McComas (1980) observed crabs in the Milwaukee Waterway.

Temporally, the highest numbers of pandalid shrimp were observed during the summer and the lowest numbers were observed during the winter. There is no temporal information on other macroinvertebrate species for Commencement Bay.

4.4.1.6 Birds

The distribution of birds within the waterways is variable. In a study by Dames & Moore (1981d), data from the Christmas bird count for the years 1977-1979 were compiled for the

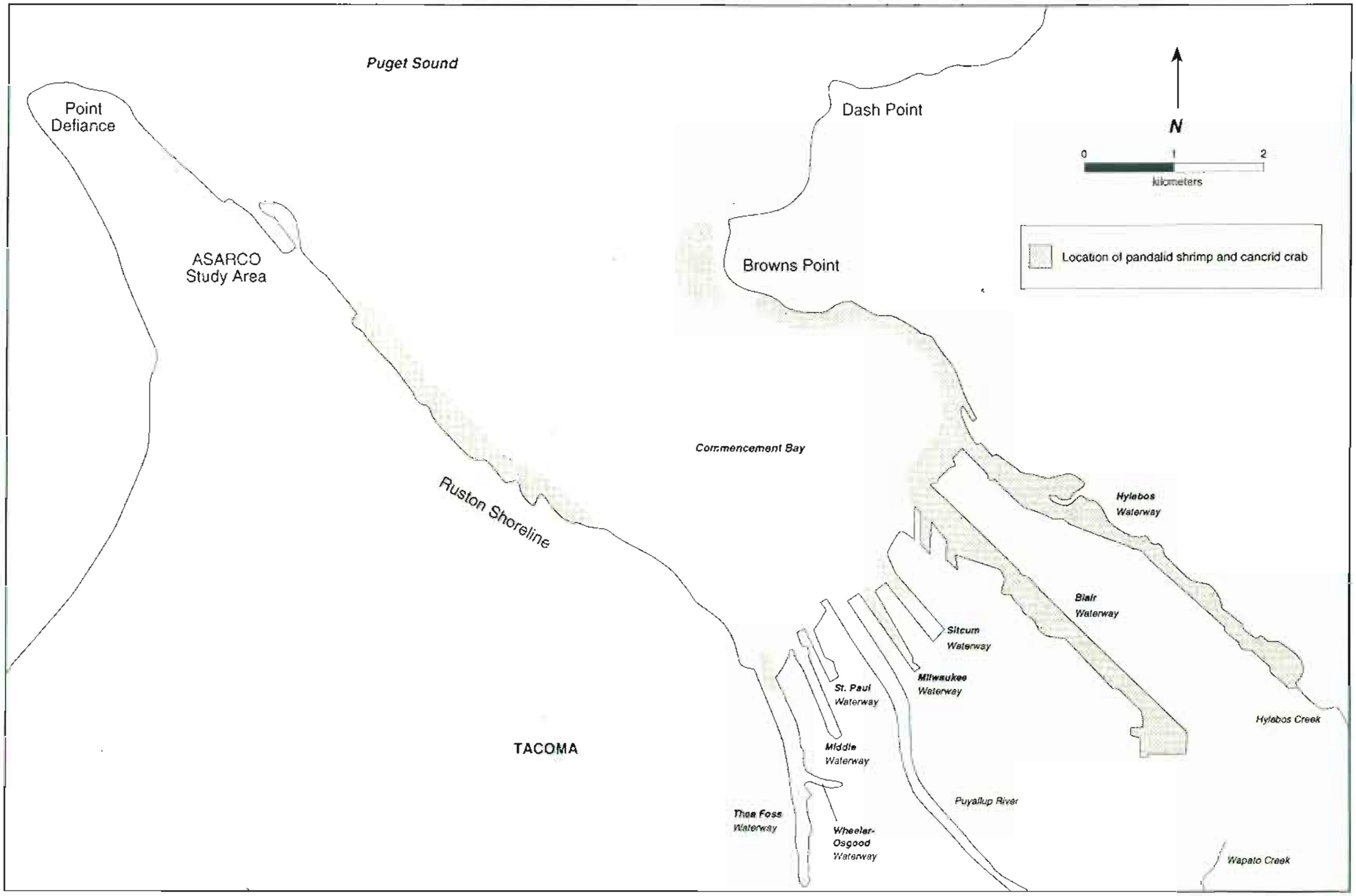

Figure 4-7. Reported observance of pandalid shrimp and cancrid crab in Commencement Bay.

individual waterways in Commencement Bay. Also, an additional 3 years (1980-1982) of Christmas bird count data on individual waterways were compiled. Area-specific data for the Thea Foss Waterway were not available. The Hylebos and Blair Waterways were found to contain the highest number of species, followed by the Puyallup River area. The number of individuals observed in the waterways followed the same pattern found for a number of species. The dominance of gulls in the Milwaukee and St. Paul Waterways and the Puyallup River is indicative of low avian diversity at these sites. The high number of species along the Puyallup River reflects the presence of both fresh and marine water habitats (Bock, personal communication 1994).

To summarize the areal and temporal distribution of avian species in the Injury Study Area, species have been combined into groups based on similar life histories, habitat selection, and food habits. Specific information will be presented on the more common species. The species groups and representative species include:

- **Intertidal herbivores:** mallard (*Anas* sp.), Canada goose (*Branta canadensis*), and wigeon (*Anas* sp.)
- **Piscivores:** western grebe (*Aechmophorus occidentalis*), cormorants (Phalacrocoraxi, sp.), pigeon guillemont (*Cepphus columba*), and horned grebe (*Podiceps auritus*)
- **Benthivores:** goldeneye (*Bucephala* sp.), scaup (*Aythya* sp.), and surf scoter (*Melanitta perspicillata*)
- **Carnivores:** bald eagle (*Haliaeetus leucocephalus*) and great blue heron (*Ardea herodias*)
- **Omnivores:** glaucous-winged gull (*Larus glaucenscens*)

Areal distributions have been complied from anecdotal observations, general life history information (e.g., Ehrlich et al., 1988), life history studies from the Pacific Northwest, and observations from 17 years (1977-1993) of Christmas bird counts. The Christmas bird count data are from Area II of Tacoma, which includes all of Commencement Bay and a portion of the coastal area east of Browns Point.

Intertidal Herbivores

The most common avian herbivores using the intertidal areas of the Injury Study Area are dabbling ducks and the Canada goose. The majority of these birds are migrants and winter residents, however, some mallards and the Canada goose are year-round residents of Commencement Bay. These species use the intertidal habitats of the Injury Study Area for feeding and the shallow subtidal habitats for roosting (Figure 4-8).

Piscivores

Fish-eating birds can be further divided into open-water species and shallow-water species. The most common open-water species based on Christmas bird counts is the western grebe. As many as 1,685 (mean count 637) have been observed. This species is typically observed well offshore, especially off the mouth of the Puyallup River. However, they are often seen seeking protection in the waterways during severe weather. The western grebe is primarily a fall and winter resident of the Injury Study Area with individuals beginning to arrive as early as August. Some individuals appear to remain all year. The flock using Commencement Bay appears to remain constant in numbers through the winter, indicating site fidelity (Norman, personal communication 1994). The double-crested cormorant is regularly found roosting and feeding in Commencement Bay, typically in areas shallower than the areas where western grebe have been observed. Christmas bird counts have recorded it throughout the Injury Study Area, especially in the Hylebos Waterway. The cormorant is also primarily a winter resident of the Injury Study Area with individuals arriving in September and staying until May. Pigeon guillemots are uncommon year-round residents of Commencement Bay. They have been documented in the Christmas bird count in only 4 of the last 17 years; however, recent observations indicate that numbers may be increasing in association with renovation of docks along the old Tacoma Waterfront. Figure 4-9 shows the areas within Commencement Bay where these open-water species can be found.

The most common shallow-water, fish-eating bird is the horned grebe. The horned grebe is a winter resident with individuals arriving in September and remaining until May. Individuals are observed close to shore, usually feeding within a few meters of the shoreline. Figure 4-10 shows the areas of usage typical of the horned grebe.

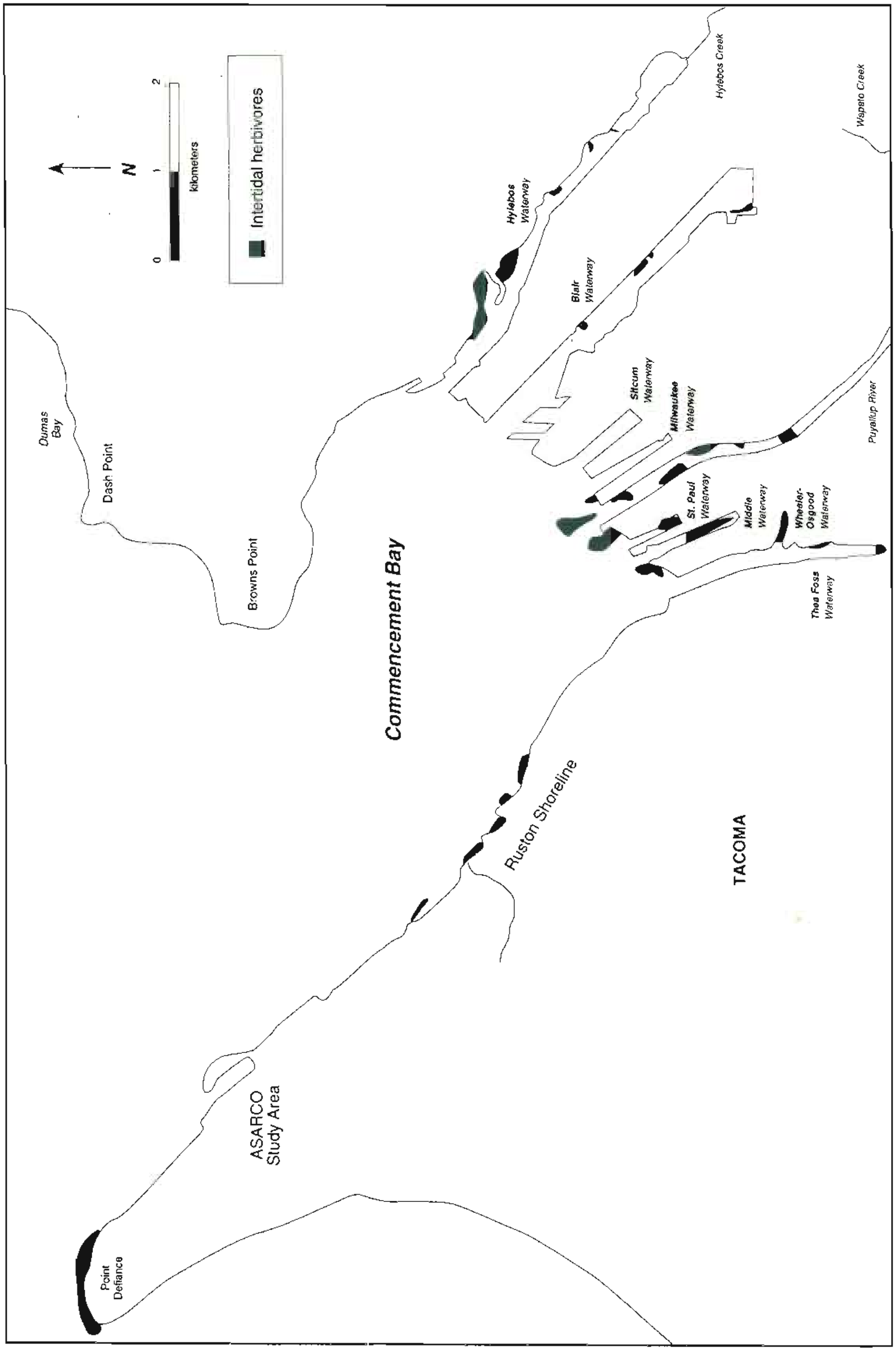

Figure 4-8. Distribution of intertidal herbivores in Commencement Bay.

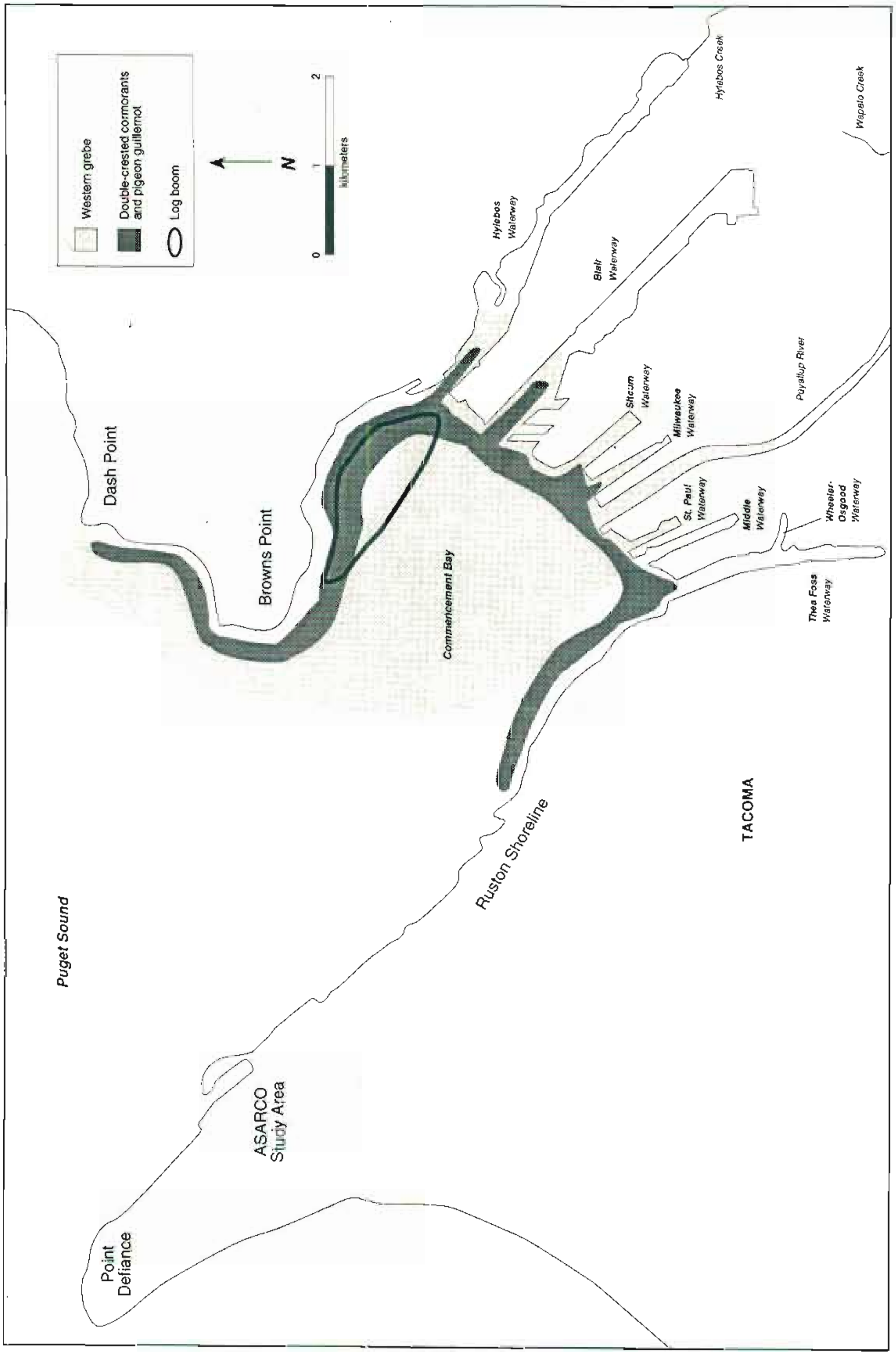

Figure 4-9. Distribution of open-water, fish-eating birds in Commencement Bay.