The Role of Seagrasses and Kelps in Marine Fish Support

by Derrick Blackmon, Tina Wyllie-Echeverria, and Deborah J. Shafer

BACKGROUND: The U.S. Army Corps of Engineers (USACE) has been involved in regulating certain activities in the nation's waters since 1890. Until 1968, the primary focus of USACE's regulatory program was the construction and maintenance of navigation infrastructure. Since then, the program has evolved to one that reflects national concerns for both protection and utilization of important resources. Activities that involve construction, excavation, fill, and certain other modifications of the "waters of the U.S." are regulated by USACE under the authority of Section 10 of the Rivers and Harbors Act of 1899, Section 404 of the Clean Water Act, and other regulatory policies. In estuarine waters, some of these regulated activities have the potential to impact sensitive aquatic resources such as seagrasses and kelps that provide important habitat for many commercially and recreationally important fish species.

PURPOSE: This report provides a comprehensive summary of research related to fish utilization of seagrass and kelp habitats in the Pacific Northwest in a single document that will serve as a useful reference for resource managers. Preparation of this document was sponsored by the USACE Wetlands Regulatory Assistance Program (WRAP) at the request of the Seattle District of the U.S. Army Corps of Engineers, Regulatory Branch.

ORGANIZATION: This document is organized into two major sections. The first is a general review of the importance of seagrass and kelp habitats to fishes and invertebrates in marine and estuarine ecosystems. This section presents a broad summary of general results and trends from numerous studies conducted both in the United States and abroad, and provides a foundation for interpretation of the site-specific information provided in the following section. In the second section, the focus is narrowed to include only the results of those studies conducted in fiord-like estuaries of the Pacific Northwest.

OVERVIEW OF FISH UTILIZATION OF SEAGRASS AND KELP HABITATS:

Role of Life History Strategies in Estuarine Habitat Utilization. Estuaries throughout the world have been extensively examined for their importance to coastal community structure and function. Critical estuarine functions include: food chain support, provision of refuge from predation, foraging and spawning habitat, resting sites and a transition habitat for anadromous and catadromous species. About 75 percent of the commercially important and 80-90 percent of the recreationally important marine fish species of the United States depend on estuaries for their survival. Estuarine resident species, such as white perch (*Morone americana*), catfishes (*Ictalurus* spp.), some clams (e.g., *Mercenaria mercenaria*), and some oysters (e.g., *Crassostrea virginica*), that spend their entire life in the estuary are confined to a geographical area because of salinity, bottom type, depth, and/or currents. Estuarine transients, such as striped bass (*Roccus saxatilis*), spot (*Leiostomus xanthrus*), Atlantic menhaden (*Brevoortia tyrannus*), Atlantic croaker (*Micropogonias undulatus*), weakfish (*Cynoscion regalis*), southern and summer flounder (*Paralichthys lethostigma* and *P. dentatus*), shrimps (*Penaeus* spp.), and blue crab (*Callinectes sapidus*), may spend only a

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portion of their life cycle in estuaries. Although highly mobile anadromous and catadromous fishes (e.g., salmonids, river herrings, and shads) spend the majority of their lives in saltwater, they use estuaries as conduits to reach spawning headwaters. Juvenile life history stages of anadromous species also use the estuary as they move from fresh water to the open ocean (Simenstad et al. 1982).

Many of these estuarine-dependent species are vulnerable to over-fishing, degradation of water quality, and loss of critical habitats. The 1996 Sustainable Fisheries Act amendments to the Magnuson-Stevens Act focus on essential fish habitats. The Act mandates identification and description of estuarine habitats used by managed species for spawning, feeding, breeding or growth, and identification of anthropogenic threats to these habitats (Rader and Davis 1997), and specifically targets managed species.

The role of seagrasses as a nursery area for early life history stages of some species is a frequently cited function of submerged aquatic vegetation (SAV) (Beck et al. 2001). SAV provides a rich source of food in the form of epibenthic and epiphytic organisms (Ryer 1987, Haas 2002, Webb 1991, Webb and Parsons 1992). By spending a portion of their lives in seagrasses, juveniles of some commercially important species are able to survive and grow at optimal rates (Kikuchi 1980, Thayer et al. 1984, Zieman and Zieman 1989). For example, megalopa of the blue crab are known to migrate from the continental shelf to estuarine seagrass beds where they metamorphose into juveniles, and remain for a large portion of their early life (Montane et al. 1995). However, most of what we know about the importance of seagrasses as nursery habitats comes from subtropical and tropical regions in the western Atlantic Ocean and Australia. The role of seagrasses as nursery habitat in temperate or boreal regions is not as well understood. For example, two studies conducted in temperate Australia and Cape Cod, Massachusetts indicated that seagrasses are not as important to commercially valuable species as once thought (Heck et al. 1995, Gilanders and Kingsford 1996). This evidence highlights the need for detailed examination of seagrasses at a regional level to determine their role as habitat for ecologically and economically important species. Density, growth, survival, and movement need to be evaluated to determine the importance of a particular area/habitat as a nursery (Beck et al. 2001).

Role of Physical Structure in Habitat Utilization. Physical structure often plays a key role in determining the distribution and abundance of marine organisms in estuaries (Sale and Douglas 1984, Smock et al. 1985, Carpenter and Lodge 1986). Patterns in organism distribution and abundance in structurally complex habitats like seagrasses, marshes, and kelps (versus sand, mud, and other bare bottom environments) have been the subject of extensive study.

Seagrasses are often the dominant subtidal vegetation in coastal environments (Sogard and Able 1991, Orth 1992), and comprise the biological and physical constructs for coastal ecosystems from the tropics to boreal regions (Hemminga et al. 1991). The prevailing paradigm, based on studies in the United States, holds that seagrasses harbor greater concentrations of fishes than do unvegetated habitats (Heck et al. 1989, 1997; Edgar and Shaw 1995; Jordan et al. 1996; Jenkins et al. 1997; Kenyon et al. 1997; Levin et al. 1997; Guidetti 2000; Hindell et al. 2000; Short et al. 2001; Stunz et al. 2002). Habitat complexity, survival potential, and habitat preference are often cited as primary reasons for the increased densities of organisms found in vegetated habitats (Choat 1982, Orth et al. 1984, Orth 1992, Edgar and Robertson 1992, Levin and Hay 1996). An extensive literature exists on the role of submerged aquatic vegetation in providing a refuge from predation (see review by Orth et al. (1984) and the references therein; Wilson et al. 1987, 1990; Heck and Crowder 1991; Sogard and Able 1991).

Within seagrass habitats, increasing plant biomass and density (i.e. complexity) have been shown to be correlated with higher density and biomass of many fisheries species (Heck and Thoman 1981, Gotceitas et al. 1997, Attrill et al. 2000, Hyndes et al. 2003). In Waquoit and Buttermilk Bays, Massachusetts, 10 of the 13 most common fish species sampled showed maximum abundance where eelgrass (Zostera marina) complexity was highest, and both abundance and biomass of fish decreased along a gradient of decreasing eelgrass complexity (Hughes et al. 2002). Similarly, in a trawl survey in Buzzards Bay and Chesapeake Bay, USA, Wyda et al. (2002) found that fish abundance, biomass, and species richness increased along an increasing submerged aquatic vegetation gradient, with the highest values associated with the most complex habitats. This is likely to be due in part to the reduced foraging efficiency of mobile predators within areas of high structural complexity, as evidenced in numerous studies (Heck and Thoman 1981, Crowder and Cooper 1982, Salvino and Stein 1982; Orth et al. 1984, Werner and Gilliam 1984; Irlandi and Peterson 1991; Mattila 1995; Irlandi et al. 1995, Irlandi and Crawford 1997; Heck et al. 1997; Eggleston et al. 1998; Micheli and Peterson 1999).

A few commercially important invertebrate species (e.g., blue crab, *Callinectes sapidus*, and queen conch, *Strombus gigas*) have been shown to display increased survival with increased habitat complexity (Ray and Stoner 1995; Hovel and Lipcius 2001). In Chesapeake Bay, USA, blue crab survival increased with habitat complexity, regardless of the size of the seagrass patch (Hovel and Lipcius 2001). Juvenile blue crab densities were inversely correlated with seagrass area (i.e. as patch size increased blue crab survival decreased). Increased fragmentation due to defoliation and bioturbation created more seagrass edge, which in turn led to increased blue crab survival. Furthermore, juvenile blue crab density was significantly lower in isolated seagrass patches separated by large areas of unvegetated habitats, compared to seagrasses interspersed with small patches of sand or mud. These results suggest that SAV patch size and complexity control population dynamics of the blue crab, and that fragmented habitats may be valuable refuges for some species (Hovel and Lipcius 2001).

Although increased structure is believed to be an important determinant of habitat preference for many smaller fishes (Werner et al. 1977; Crowder and Cooper 1982; Orth 1992; Butler and Jernakoff 1999; Hughes et al. 2002), individual species may respond positively, negatively, or not at all, to reduced seagrass density (Bell and Westoby 1986c; Horinouchi and Sano 1999, 2001). In Australia, Connolly (1994) found that removal of the seagrass canopy had no effect on density of small fish. Similarly, Horinouchi and Sano (1999, 2001) provided evidence that juvenile gobies were not attracted to the structure of *Zostera*, and therefore their distribution patterns were potentially determined by prey availability rather than habitat structural complexity.

Since seagrass habitats increase in complexity from the edge to the center of the patch, mobile predators may be able to forage more successfully along the less complex edges of seagrass habitats (Johannes and Larkin 1961), resulting in higher densities of prey organisms in the interior of the seagrass patch (Heck and Orth 1980, Stoner and Lewis 1985).

Few studies have addressed the interaction between seagrass landscape characteristics (patch size and architecture) and the density and composition of seagrass-associated resident invertebrate fauna. Bologna and Heck (2002) sampled faunal distribution from *Thalassia testudinum* edges to the center, and quantified the structural habitat characteristics. In general, their findings suggested that there were no significant differences in densities of most invertebrate phyla (including amphipods, polychaetes, and decapods) between the center and edges of the patch. Only gastropods were found in greater numbers in the center than the edge. Similarly, Bell et al. (2001) found that patch size had no consistent relationship with density of resident fauna at different spatial scales, and with the exception of infaunal bivalves, there were no consistent patterns of increased faunal utilization of either seagrass patch edges or centers.

While most seagrass studies emphasize the importance of the interaction between predation intensity and seagrass density in determining community composition, the role of larval abundance and settlement is poorly understood. Bell and Westoby (1986a) suggest that for species with pelagic larvae, total abundance and species richness in seagrass beds is ultimately controlled by larval supply, and that larvae do not discriminate among beds based on density when they settle (Bell et al. 1987). They argue that survival of individuals that settle in the first available habitat structure should exceed that of those who preferentially select sites with high structural complexity, because overall survival in seagrass is probably greater than in unvegetated habitats, as evidenced by numerous other studies. Once settled, individuals may then redistribute themselves within a bed to those areas with a micro-climate more favorable to survival (e.g., higher complexity) (Bell and Westoby 1986b). Therefore, over larger spatial scales, there may be very little, if any, correlation between seagrass density and faunal abundance and species richness (Bell and Westoby 1986a; Worthington et al. 1992).

Canopy-forming kelp forests are also known to support diverse and abundant fish assemblages (Miller and Geibel 1973, Leaman 1980), particularly compared to areas devoid of kelps (Larson and DeMartini 1984, Bodkin 1988). In a study conducted at several sites near San Nicolas Island, California, USA, 45 fish species representing 18 different families were observed in kelp beds (Cowen and Bodkin 1993). In general, most diverse fish assemblages were associated with the greatest kelp vertical relief, but the strength of this relationship varied among different kelp species. Bodkin (1986) found approximately 2.4 times more fish biomass in Macrocystis than Nereocystis, indicating that the simple presence of kelps may not be as important as the particular species or structure.

Few studies have addressed increasing habitat complexity with standing kelp; most have simply noted that more diverse fish assemblages are found in areas with kelp than in those where kelp is absent (Bodkin 1988, Levin and Hay 1996). One study conducted off the coast of Chile suggested that fish densities in kelp beds were not affected by increased habitat complexity, but that foraging behavior was altered from benthic to pelagic feeding in high versus low structure, for both carnivores and omnivores (Angel and Ojeda 2001).

FISH UTILIZATION OF SEAGRASS AND KELP HABITATS IN PACIFIC NORTHWEST ESTUARIES

Geographic Scope. This section summarizes available information on utilization of seagrass and kelp habitats within fjord-like estuaries from Puget Sound, through the Gulf Islands, to Southeastern Alaska. Similarities in geomorphology, tidal range, and climate are likely to contribute to similar patterns of species composition and habitat utilization within these ecosystems.

In general, vegetated estuarine habitats on the west coast have not been as well-studied as those in other areas of the United States. Most studies have focused on utilization of seagrass habitat by economically important finfish and invertebrate species (e.g. salmonids and Dungeness crabs).

Fish Utilization of Eelgrass Habitats

Overview. Although six species of seagrass occur in Puget Sound, most of the research on habitat structure and function has been focused on eelgrass (*Zostera marina*), the most abundant seagrass in northeastern Pacific estuaries (Thayer et al. 1984). Another species in the genus *Zostera*, *Z. japonica,* was introduced from Asia around the turn of the 20th century and now forms extensive beds in the mid-intertidal zone, usually above or bordering the eelgrass zone. Although *Z. japonica* is known to be a food source for migratory brant geese, little else is known regarding its functional role in nearshore estuarine communities. There has also been limited research involving *Ruppia maritima*, and virtually none that addresses the ecological roles of the three *Phylospadix* species.

Eelgrass is a significant food source for estuarine consumers via eelgrass leaves, seeds, associated epibenthos, or the detritus their decaying leaves produce. For example, micro-invertebrates associated with eelgrass, including harpacticoid copepods, gammarid amphipods, and cumaceans, are widely reported to provide important contributions to the diets of juvenile Pacific salmonids, herring, smelts and flatfishes (Sibert 1979, Simenstad et al. 1980, D'Amours 1987, Simenstad et al. 1988, Thom et al. 1989, Webb 1989, Simenstad and Cordell 1992, Wyllie-Echeverria et al. 1995). Furthermore, these beds harbor species of infauna and epifauna including polychaetes, gastropods, bivalves, amphipods, echinoderms, and other crustaceans that are known prey of many commercially valuable fish and invertebrates (Jewett et al. 1999, Irlandi and Peterson 1991). A three-year survey of food habits of nearshore fish in the Straits of Juan de Fuca revealed that epibenthos comprised 64 percent of the prey species examined (Miller et al. 1980). The authors reasoned that since epibenthic prey forming the trophic base of the nearshore food web are detritivores, conversion of nearshore vegetation to detritus "is the most important process determining nearshore food web structure in the region" (Miller et al. 1980).

Miller et al. (1978) concluded that eelgrass was the richest pelagic fish fauna of all the habitats sampled in Puget Sound. Dominant fishes inhabiting eelgrass beds include sculpins (Cottidae), greenlings (Hexagrammidae), blennies (Pholidae), surf perches (Embiotocidae), sticklebacks (Gasterosteidae), pipefishes (Syngnathidae) and tubesnouts (Aulorhynchidae) (Stober and Salo 1973, Jeffrey 1976, Miller et al. 1978, Gardner 1978, Miller et al. 1980, Borton 1982, Garrison and Miller 1982, Thom et al. 1984). This group of primarily resident species is often part of the diet of birds and other fishes. Murphy et al. (2000) noted that gunnels (mostly Pholis laeta) and greenlings were common within eelgrass in Prince William Sound. Pricklebacks, sculpins, and other taxa were also found.

Investigations of the relationship between seagrass density and faunal abundance in West Coast estuaries are rare. In a study along Guemes Channel, Puget Sound, Wyllie-Echeverria et al. (2002) surveyed fish abundance using a 37-m beach seine along a 9000-m shoreline that included patches of eelgrass ranging from 140 to 660 shoots per square meter. Juvenile salmonids (chum, coho and Chinook), sand lance, surf smelt and herring, as well as resident species were collected. Based on the results of studies in other coastal regions of the United States, sites with higher seagrass density may be expected to support greater numbers of fishes. However, no significant differences in the number of fishes sampled between stations of varying eelgrass density were detected. A more detailed and directed study aimed at investigating the density of small eelgrass beds, fish densities, and the significance of the distance between beds is needed.

Important fish species in Pacific northwest estuaries. West coast estuaries support a diverse assemblage of economically and ecologically important invertebrates and fishes. Commercially valuable invertebrates include different species of shrimp, the red king crab (*Paralithodes camtschaticus*), Dungeness crab (*Cancer magister*), geoduck (*Panope abrupta*), and the Pacific oyster (*Crassostrea gigas*). Commercially and ecologically important fish species include Pacific cod (*Gadus macrocephalus*), pollock (*Theragra chalcogramma*), a variety of rockfishes (*Sebastes* spp.), salmonids (*Oncorhynchus* spp.), English sole (*Parophyrys vetulus*), sand sole (*Psettichthys melanostictus*), starry flounder (*Platyichthes stellatus*), surf smelt (*Hypomesus pretiosus*), sand lance (*Ammodytes hexapterus*), lingcod (*Ophiodon elongatus*) and Pacific herring (*Clupea harengus*) (Wingert et al. 1979, Leaman 1980, Emmett et al. 2000). The following sections will review the importance of eelgrass to several commercially and/or ecologically important fish species in the Pacific Northwest.

Figure 1. Dungeness Crab

Dungeness Crab. Eelgrass beds have been studied for their importance as nursery habitats for juvenile and young adult Dungeness crab (Dinnel et al. 1986, Armstrong et al. 1988, McMillan et al. 1988, Doty et al. 1989, Gutermuth and Armstrong 1989, Jamieson and Armstrong 1991, Armstrong et al. 1995, McMillan et al. 1995). Many of these studies compared the nursery potential of eelgrass beds to that of mud flats or shell habitats. The findings suggest that the importance of eelgrass as nursery habitat varies with location. Dinnel et al. (1986) concluded that shallow areas of Puget Sound serve as nursery grounds for young-of-the-year Dungeness crab and that extensive flats with abundant eelgrass and algal cover are of particular importance. Armstrong et al. (1988) also found that: 1) young-of-the-year Dungeness crabs recruited to eelgrass and algae (especially Ulva) over other substrates, 2) 1- to 3-year-old crabs inhabited both eelgrass and sandy areas, and 3) ovigerous females migrated to shallow depths and were highly associated with eelgrass beds. Dinnel et al. (1986) also noted the presence of ovigerous females associated with eelgrass. McMillan et al. (1995) sampled habitat, density, and growth of 0+ aged Dungeness crabs at five sites in Puget Sound. Highest densities were found in mixed sand and gravel with algal overgrowth, followed by eelgrass and lowest on open sand. Armstrong et al. (1995) also noted that predation rates of staghorn sculpin (*Leptocottus armatus*) on juvenile Dungeness crab were much lower in eelgrass beds than in unvegetated habitat types.

Conversely, in open coastal estuaries such as Grays Harbor, Fernandez et al. (1993) reported that newly settled Dungeness crab densities were higher in intertidal shell habitat than intertidal eelgrass, and that shell provided the best protection from predation. Similarly, in open coastal estuaries such as Willapa Bay and Grays Harbor, measurements of intertidal 0+ crabs suggested that shell habitats contained higher densities of Dungeness crab than eelgrass or unstructured habitat (Doty et al.

1989). Algae and eelgrass appear to be optimal habitat for juvenile Dungeness crab in Puget Sound, but may not be as important in open-coast estuaries in Washington where shell habitat also exists.

Figure 2. Brown rockfish

Rockfish. Of the 64 species of rockfish that occur along the west coast of the United States, 26 occur in Puget Sound. Species include shallow-dwelling quillback (*Sebastes maliger*) and brown (*S. auriculatus*) (Figure 2), mid-water black (*S. melanops*), Puget Sound (S. emphaus), and copper (S. caurinus), and the deep-dwelling splitnose (*S. diploproa*) and yelloweye (*S. ruberrimus*), among others. Rockfish produce planktonic larvae that settle in the shallower portions of kelp beds, in eelgrass beds and floating kelp mats (Buckley 1997, Dean et al. 2000, Murphy et al. 2000, Wright et al. 2000, Gomez-Buckley 2001). The density of fishes in eelgrass habitats seems to vary with location. However, since rockfish exhibit wide inter-annual recruitment variability (Love et al. 1991, Hobson et al. 2000), comparisons of habitat utilization are probably only valid with long-term data sets, which do not exist for nearshore species in Pacific Northwest estuaries (see review by Sato and Wyllie-Echeverria (2004)).

Dean et al. (2000), using visual censuses during 1990, 1996, and 1997, observed two species of rockfish (dusky and copper) within eelgrass habitats in Prince William Sound, Alaska, but only at very low densities. On average, less than one rockfish was found in eelgrass (per diver transect). In contrast, Murphy et al. (2000) found an average of 7.4 rockfish per seine in eelgrass habitat near Craig, Alaska. Of the rockfish, 97 percent collected resided in eelgrass beds, and there were twice as many rockfish (copper, black, brown, bocaccio, and unidentified) than all other fish species. Matthews (1990) reported that juvenile rockfishes and adult brown and copper rockfishes occupied eelgrass beds in July and August, and their densities peaked in high-relief rocky reefs during periods of maximum cover by macroalgae. While the previously cited studies document rockfish occurrence in eelgrass beds, they do not address the underlying reasons for the observed variability in density or what role eelgrass plays (e.g., nursery habitat, refuge, or food source) in determining their distribution and abundance.

Another habitat that serves as a refuge and feeding grounds for juvenile rockfish is drift vegetation. Shaffer et al. (1995) considered the effects of drift vegetation habitat (comprised of *Fucus*, *Zostera* and *Nereocystis* plants matted together and floating on the surface) on juvenile splitnose rockfish density. Their results indicated that small splitnose feed selectively on planktonic copepods and cladocerans located in drift vegetation. Older splitnose, not found in these vegetated habitats, were observed feeding primarily on large, vegetation-associated amphipods. They concluded that juvenile splitnose used drift vegetation not only as a refuge from predation, but also as a foraging area. Gomez-Buckley (2001) found juvenile splitnose rockfish in drift vegetation primarily in August in the San Juan Archipelago. Juveniles fed mainly on planktonic calanoid copepods near drift vegetation and gammarid amphipods found in the drift habitat. These few studies highlight the importance of vegetation as a refuge and food source for juvenile rockfish.

Salmon. The salmon fishery is one of the most important commercial fisheries in the Pacific Northwest. These species are anadromous, and can range up to hundreds of miles inshore to thousands of miles offshore, making management decisions challenging. In 1999, 17 populations representing four of the five species of Pacific salmon (Chinook, chum, coho, pink, and sockeye) in the Pacific Northwest were listed under the Endangered Species Act as proposed threatened, threatened, or endangered.

Estuaries are considered a transitional habitat for Pacific salmon, between the open ocean and streams or lakes. Transitions from fresh to salt water and salt to fresh water can be difficult, life-threatening periods for salmon (Levings 1994). Many Pacific salmon traverse estuaries as part of the progression of their life histories (Kacyzinski et al. 1973, Healey 1979); however, juvenile chum and Chinook are thought to be most reliant on the habitats found within estuaries (Simenstad et al. 1982). The majority of Pacific salmon studies are conducted in freshwater systems, leading to a better understanding of factors that limit production in that environment (Brodeur et al. 2000). Despite evidence that suggests the estuarine environment may strongly influence population variability, comparatively little is known about habitat utilization in these areas (Bradford 1995, 1997). Of those papers that address the passage of salmon through coastal estuaries, most focused on salmonid occurrence in either wetlands or marsh habitats. For example, a 4-year research program conducted in the Fraser River Estuary for Chinook fry found that estuarine marshes are especially important as a nursery habitat (Levy and Northcote 1981). Similarly, juvenile Chinook, chum, coho, and pink salmon were collected in three restored wetlands, further emphasizing the likely importance of these habitats as both refuges and prey sources (Levy and Northcote 1982, Shreffler et al. 1992, Simenstad and Thom 1996).

One of the earliest documented examples of eelgrass usage by juvenile salmon in the fjord-type estuaries of the Pacific Northwest was provided by Thayer and Phillips (1977) and Fresh (1979). Subsequent studies addressing the question of habitat use by juvenile salmonids have sampled the area from Alaska to Puget Sound. In Klawock Inlet, Alaska, Chinook, coho and chum were found in all three vegetated habitats sampled: algae, kelp, and eelgrass, with chum occurring in higher numbers in eelgrass (Murphy et al. 2000). At Prince of Wales Island, Alaska, Murphy et al. (2000) found pink, chum, and coho smolts in eelgrass beds at roughly the same densities as those species found in unvegetated sites except during June, when chum were found in significantly lower densities in eelgrass. Similarly, Healey (1979) captured juvenile salmon in tidal channels containing eelgrass during low tides. In the Nainaimo River Estuary, British Columbia, Chinook and chum were found adjacent to eelgrass (Healey 1979, 1980). At Roberts Bank, Chinook, chum, and coho were more abundant at eelgrass sites (Gordon and Levings 1984). Chum and pinks were present in eelgrass during out migration (D'Amours 1987, Webb 1991). In Puget Sound, out-migrating juvenile salmon were collected from sites with gravel (pink, chum) and sites with sand and eelgrass (chum) (Miller et al. 1978). At Drayton Harbor, Thom et al. (1989) found chum, Chinook, and pink salmon at eelgrass sites. Chum salmon were also collected from eelgrass beds in Padilla Bay (Simenstad et al. 1988), and in Hood Canal (Simenstad et al. 1980). In a comparative study at eelgrass versus non-eelgrass sites at Alki Beach in Puget Sound, Borton (1982) caught 44 of 45 total Chinook salmon in the eelgrass habitat. Another recent study sampled juvenile salmonids from sand, cobble, and rip-rap substrates and found Chinook, coho, and chum feeding in these nonvegetated habitats (Toft et al. 2004).

The relationship between epibenthic prey resources in eelgrass beds and utilization of those prey by all five species of juvenile Pacific salmon has been established throughout the fjord estuaries in British Columbia (D’Amours 1987; Webb 1989, 1991; Godin 1981; Healey 1979; Raymond et al.

1985; Sibert 1979; MacDonald et al. 1987) and Puget Sound (Kaczynski et al.1973, Feller and Kaczynski 1975, Simenstad et al. 1980, Simenstad and Salo 1982, Simenstad et al. 1988, Thom et al. 1989, Wyllie-Echeverria et al. 1994). These works suggest that eelgrass habitats play an important role as foraging habitat for early life stages of these fishes throughout the Pacific Northwest.

The previous studies acknowledge the importance of estuarine habitat for migratory juvenile salmon, particularly those species that reside for extended periods as juveniles in estuaries (i.e. chum and Chinook (Simenstad et al. 1982)). A better understanding of the role of eelgrass in support of the salmon fishery may be critical for future management decisions on how to reduce the loss of threatened or endangered salmonid species.

Figure 3. English sole

Other fishes. English sole (Figure 3) have been collected from eelgrass beds in Puget Sound (Miller et al. 1978, Fresh 1979) and were reported in both eelgrass and open sand habitats at Alki Point, Washington (Borton 1982). Juvenile English sole appeared by April and stayed in an eelgrass bed in San Juan County for about one year (Miller et al. 1978). Based on the limited data available, habitat preferences of juvenile English sole for either eelgrass beds or unvegetated areas cannot be clearly defined (Gunderson et al. 1990). Pacific cod (*Gadus macrocephalus*) is another important fishery in the Northeastern Pacific Ocean. Juvenile cod have been reported to be closely associated with eelgrass near Craig, Alaska (Dean et al. 2000).

Forage fishes. Forages fishes are mentioned in this review due to their ecological role in the life histories of commercially important species such as salmon and rockfish. Surf smelt and sand lance spawn in the upper intertidal on sandy or sand/gravel beaches throughout Puget Sound (Lemberg et al. 1998, Pentilla 2000). Pacific herring spend most of their adult life in offshore waters. However, they spawn inshore, primarily on vegetated habitats, including red and brown algae, eelgrass, and rock kelp (Hay 1985) and feed on pelagic prey (Simenstad et al. 1988). In Puget Sound, Phillips (1984) reported that eelgrass is the primary substrate used by herring to deposit eggs. In southeastern Alaska, however, Murphy et al. (2000) found eelgrass and non-eelgrass habitats to be equally important for herring and sand lance. Herring larvae go through two or three metamorphoses before they begin to feed on mollusk larvae, copepods, and other larval fish (Hart 1973). However, Levings (1983) noted that young juveniles (45-55mm TL) feed primarily on eelgrass-associated invertebrates such as copepods and amphipods. Since the largest source of mortality for Pacific herring is predation by fishes, crabs, and birds, eelgrass may provide an important refuge from predation for young herring.

Fish Utilization of Kelp Habitats. Leaman (1980) documented the extensive use of kelp habitat by fishes in Barkley Sound, British Columbia and found a higher diversity and abundance of fishes in kelp beds than elsewhere. In Washington, the kelp beds of the Strait of Juan de Fuca harbor a diverse assemblage of fish species including Chinook, coho, and chum salmon, several species of rockfish, surf smelt, and other species (Simenstad et al. 1979, Shaffer et al. 1995, U.S. Department of Interior 1995, Shaffer 2000). Murphy et al. (2000) compared eelgrass, algae, and kelp habitat preferences by commercial or economically valuable fish species. Their data from eelgrass and adjacent subtidal habitats near Craig, Alaska, indicated that more fish species were captured in either eelgrass or kelps than at sites with only filamentous algae (41 species in eelgrass, 38 in kelp, and 26 in filamentous algae). In San Juan County, Puget Sound, kelp greenlings dominated in kelp along with copper, quillback, black and yellowtail rockfishes, but were not present in winter and spring. Densities of lingcod were highest in summer and lowest in fall and winter. Whereas greenlings were seen in kelp only, all other species were seen equally in and out of the kelp zone (Miller et al 1978).

The following statements summarize the most important habitats for several commercial fisheries according to Murphy et al. (2000):

- Salmonids (7 species) were caught mainly in eelgrass beds (>300 individuals) and kelps (>100 individuals), and over filamentous algae (<40 individuals).
- Rockfishes were caught in both eelgrass and kelps, but not in algae.
- Pacific herring were caught mainly in filamentous algae (36 individuals in algae compared to <2 in either seagrass or kelp).
- Sculpin species were caught in approximately the same densities in all three habitats.
- Surf perch were caught in highest numbers in eelgrass, then algae, then kelp (29, 15, and 9 individuals, respectively).

A similar study conducted in Prince William Sound, Alaska compared the distribution of nearshore fishes in kelp and eelgrass communities (Dean et al. 2000). This study found juvenile Pacific cod and greenlings were primarily associated with eelgrass beds; however, contrary to Murphy et al. (2000), sculpins and rockfish were primarily associated with kelps. As noted earlier, these studies occurred in different years and the effect of interannual variability in population numbers and habitat characteristics is unknown.

Anthropogenic Impacts. Anthropogenic influences on critical habitats in marine environments have become increasingly problematic. Human impacts on seagrasses, marshes, and coral reefs via over-fishing, pollution, dredging, trawling, and recreational activities have had dramatic effects on many of the world's fisheries. Habitat fragmentation, a reduction in the availability and connectivity of essential habitats, has become an increasingly common problem in many areas. This has prompted the implementation of management rules like the Magnuson-Stevens Act, which requires the identification and protection of habitats essential for spawning, feeding, breeding, or growth to maturity of commercially and ecologically important organisms.

In the State of Washington, approximately one third (~1230 km) of the Puget Sound shoreline has been anthropogenically modified in the 150 years since the designation of the Washington Territory (Bailey et al. 1998). The remaining shoreline is fringed by rocky reefs, mud flats, and approximately 200 km^2 of eelgrass beds (Berry et al. 2003). The population in this region has more than doubled in the last 50 years (Puget Sound Regional Council 2001). Anthropogenic modifications of the shoreline include armoring and stabilization, and the construction of facilities ranging from private docks and marinas to large-scale port facilities and ferry terminals. Unlike other temperate and tropical regions, there is very little information on the role of eelgrass and kelp landscape architecture in determining habitat function in the Pacific Northwest.

Degradation of estuarine landscapes has been a contributing factor in the decline of salmonid populations in the Pacific Northwest (National Research Council 1996, Simenstad and Cordell

2000). For example, in a study that investigated the effects of over-water structures on juvenile salmonid habitat, Haas (2002) found that epibenthic prey resources were reduced under docks built for the ferry system in Puget Sound. These changes were probably caused by four interacting factors: 1) direct disturbance or removal by vessel traffic, 2) reduced benthic vegetation, 3) physical habitat alterations (e.g., shading), and 4) biological habitat alterations (e.g., epibenthic declines). With reduced abundance of both vegetation and epibenthic prey under ferry docks, the habitat value for juvenile salmon is compromised.

RECOMMENDATIONS FOR FUTURE RESEARCH: Despite the widely accepted notion of these nearshore vegetated habitats as nursery areas for many commercially and ecologically important fish species, a growing number of scientists are beginning to challenge this paradigm (Beck et al. 2001). In general, an area has been described as a nursery if "a juvenile fish or invertebrate species occurs at higher densities, avoids predation more successfully, or grows faster there than in a different habitat" (Beck et al. 2001). In order to document the nursery role of seagrasses and wetlands as nursery habitats, studies addressing an organism's density, survival, growth, and movement are needed (Beck et al. 2001). The majority of studies involving the nursery role concept have compared species density in vegetated versus unvegetated habitats (see review by Orth et al. (1984)). The few studies that have compared juvenile survival in vegetated versus unvegetated habitats generally indicate that survival is greater in vegetated than in unvegetated habitats (Orth et al. 1984). Even fewer studies have compared growth rates of juveniles between vegetated and unvegetated habitats (see review by Heck et al. (1997)). Surprisingly, the results of these studies indicate that growth of certain fish and invertebrate species was not always greater in vegetated seagrass habitats than in unvegetated habitats (Heck et al. 1997). Finally, it has proved extremely difficult to document successful movement of organisms from putative juvenile nursery habitats to adult habitats. The limited evidence supporting this movement is largely indirect (Beck et al. 2001).

While most seagrass studies have emphasized the importance of the interaction between predation intensity and seagrass abundance in determining community composition, the role of larval abundance and settlement in determining eelgrass community composition is poorly understood. At the landscape level, these are likely to be major determinants of faunal abundance and distribution, particularly for those species with pelagic larvae (Bell and Westoby 1986a).

In addition, the importance of these nearshore vegetated habitats as nursery areas appears to vary by geographic region. For example, a recent study in Australia concluded that there was very little strong evidence to indicate that seagrasses functioned as critical nursery habitat for the majority of finfish species (Butler and Jernakoff 1999). Similarly, a New England study found that very few commercially important fish and invertebrate species were totally dependent on eelgrass habitat (Heck et al. 1995). These studies suggest that these organisms will opportunistically use seagrass beds, but can survive well in unvegetated areas as well.

Although there is limited evidence to support the nursery role of eelgrass and kelp habitats for a few fish species, understanding of how these areas function is incomplete. This problem is even more pronounced in the Pacific Northwest, since most of the studies have been conducted in warm temperate areas or along the Atlantic coast of the United States. Integrative regional studies that track densities, growth, survival, and movement of juvenile fish between different areas and between juvenile and adult habitats will address this critical question. The next phase of ecological studies must also address the structure and complexity of multiple habitat types in order to discern the role of seagrasses, kelps, and other nearshore habitats in the life history of commercially and ecologically important species.

Aside from their nursery role, nearshore vegetated habitats are highly productive and play an important role in ecosystem food chain support. While this concept is widely recognized, understanding of the overall importance of eelgrass and kelp habitats for food web productivity in the Pacific Northwest is limited (Healey 1979, Godin 1981, Wyllie-Echeverria et al. 1994). There is an emerging need to incorporate a landscape perspective into the next generation of studies of seagrass habitats. Systematic studies of fish utilization of eelgrass or kelp in conjunction with measures of density and patchiness are needed. Long-term studies at multiple sites would increase understanding of inter-annual patterns in population densities of both plants and animals.

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POINTS OF CONTACT: For additional information, contact Deborah J. Shafer (601-634-3650, Deborah.J.Shafer@erdc.usace.army.mil), U. S. Army Engineer Research and Development Center, or the Manager of the Wetlands Regulatory Assistance Program, Mr. Bob Lazor (601-634-2935, Bob.L.Lazor@erdc.usace.army.mil). This technical note should be cited as follows:

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