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Seasonal Variation in Understory Kelp Bed Habitats of the Strait of Juan de Fuca

J. Anne Shaffer

Washington Department of Fish and Wildlife
332 E. 5th Street
Port Angeles, WA 98362, U.S.A.
shaffjas@dfw.wa.gov

ABSTRACT

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Kelp habitats in Washington state, including the Strait of Juan de Fuca, are classified as a critical habitat for a number of federally listed, proposed listed, and declining stocks, including Chinook, coho and chum salmon, and quilback, copper, and brown rockfish, surfsmelt, sandlance, and northern abalone. The Strait of Juan de Fuca supports the majority of kelp resources in the state of Washington. Despite this importance, virtually no information exists on kelp habitat community structure for the Strait of Juan de Fuca. This study defined understory composition of two dominant kelp habitats of the Strait. The understory composition of two *Macrocystis integrifolia* and *Nereocystis luetkeana* beds were sampled seasonally for one year. Variables assessed included macroalgal composition and abundance of three commercially and recreationally important species of urchin and one species of abalone. Similarities and differences were found with bed type, season, and geographic location. Similarities included strong seasonal variation in understory cover, and the dominance of the perennial, understory kelp *Pterygophora californica.* Both bed types were also similar in their difference from understory communities described for Puget Sound kelp beds.

Differences between the two kelp bed types included variation in total algal cover. *Macrocystis* beds showed less seasonal variation in total cover and algal composition, and had greater overall percent cover, which *M. integrifolia* contributed to seasonally. *Nereocystis* beds showed seasonal changes in percent algal cover. However, *N. luetkeana* did not contribute to the understory algal cover of these beds. *Nereocystis* beds had higher total number of urchins and abalone than *Macrocystis* beds.

Recent increases in kelp habitat management activities, combined with differences in kelp community with season, bed type, and location observed in this study underscore the need for well defined goals and detailed site studies for successful kelp habitat management, including restoration and preservation.

ADDITIONAL INDEX WORDS: *Puget sound, commercial fishing, kelp habitat management.*

INTRODUCTION

The Strait of Juan de Fuca links Pacific coastal waters with the marine and estuarine waters of interior western Washington and Canada (Figure 1). Influenced heavily by coastal waters, inland Puget Sound, the Strait of Georgia, and the Fraser River, the Strait of Juan de Fuca is a marine system at the entrance which shifts to estuarine as it flows eastward and thereby is the only waterbody in Washington to concurrently have substantial marine and estuarine features.

The Strait of Juan de Fuca supports approximately 100 shoreline kilometers of vegetated habitats. In total, surface canopies of Strait kelp beds make up approximately 78% of the kelp resources found along coastal Washington (from THOM and HALLUM, 1990). By aerial canopy coverage, kelp beds of the Strait of Juan de Fuca are the majority of Washington's coastal kelp resources. Seventy three percent of all *Macrocystis* and 82% of all *Nereocystis* canopy of coastal Washington are found here (VANWAGENAN, 1996). Three dominant species, each with different life history parameters, make up these extensive beds: overstory kelps *Macrocystis integrifolia,* or giant kelp and *Nereocystis luetkeana,* or bull kelp, and the understory kelp *Pterygophora californica.* Like kelp beds throughout Washington, these beds collectively support complex nearshore assemblages of fish and plant life, including two federally listed species of salmon, four species of bottom fish currently candidates for formal listing, and are considered critical habitats by local and national resource managers alike (KVITEK *et al.,* 1989; SHAFFER *et al.,* 1995; SIMENSTAD *et al.,* 1979 a, b, 1988; U.S. DEPARTMENT OF INTERIOR, 1995, WASHINGTON ADMINISTRATIVE CODE, 1994.).

The Strait of Juan de Fuca also supports, and is affected by, numerous human activities. It is a heavily used transportation corridor for Puget Sound and Canada: cargo ships and fuel tankers ply its waters daily. The Strait, and its nearshore resources, are therefore vulnerable to large oilspills, and have experienced at least two such events in the last twenty years. The most recent, the *Tenyo Maru* oilspill which occurred in July 1991 spilled 3.8×10^5 liters into waters of the Strait and coastal Washington.

Commercial fishing of species that depend on kelp habitats, including three species of red (*Strongylocentrotus franciscanus*), green (*S. droebachiensis*), and purple (*S. purpuratus*) urchins, and one species of abalone (*Haliotis kamtschatkana)* is

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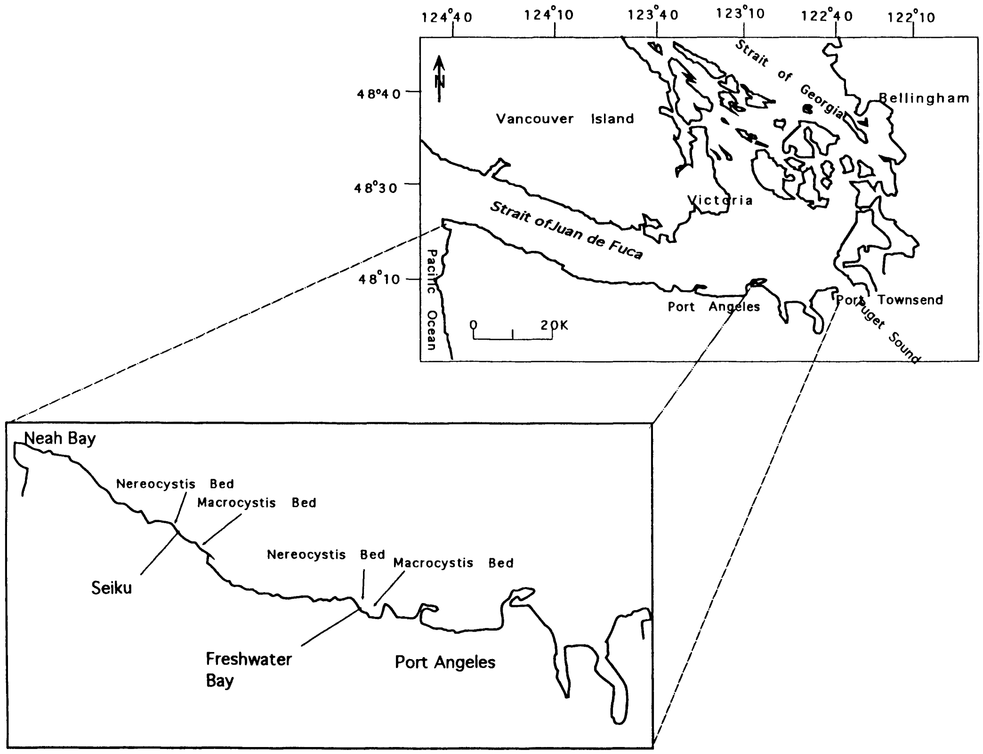

Figure 1. Study sites.

a dominant feature of Strait nearshore environments (CARTER and VANBLARICOM, 1998). Illustration of overharvesting is given in the northern abalone, which was the focus of both recreational and commercial fisheries until precipitous declines in numbers forced its closure by the early 1990's. Despite almost a decade of closure, numbers of abalone have not recovered (Bradbury, personal communication). Habitat and resource shifts related to these fishing pressures are an important component to Washington waters.

Non-point and point source input to the Strait from rural and urban development and industrial effluent from forest product mills are associated with towns along the Strait including Port Angeles, Sequim, and Port Townsend, as well as transboundary contributions from international cities including Victoria, British Columbia. Timber extraction is one of the dominant economic bases for the Olympic Peninsula. Sediment contribution to the Strait of Juan de Fuca from timber management, as well as upland development, is a growing concern to nearshore resource managers. As use of the Strait for transportation and effluent discharge increase, so does the likelihood of nearshore habitat impact.

Despite the unique identity, heavy use, and designated critical habitat supported by the Strait of Juan de Fuca, little is known about its nearshore vegetated habitats, including seasonal variation in composition or function. The most basic information including geographic and seasonal variation in habitat composition and use, is lacking for most Strait kelp beds. Management of these habitats is being conducted despite the current lack of information. For example, federal recovery plans, including habitat management recommendations, are currently being developed for federally listed Chinook and chum salmon. One tool, Marine Protected Areas (MPA's) is receiving increasing consideration, and sites proposed within Washington include areas along the Strait of Juan de Fuca. Habitat restoration is also being considered for marine areas of the Strait thought degraded by oilspills. Both of these management tools require detailed knowledge of targeted marine habitats, including their composition and variability, to be effective (LUBCHENCO *et al.*, 1997; SCHIEL and FOSTER, 1992). Specifically, preservation and restoration efforts will be less effective if species targeted for restoration and/or preservation are not well defined relative to the geographic location and species of kelp habitat being considered.

The intent of this work is to improve knowledge necessary for reasoned kelp habitat management decisions and planning by defining four basic features of the dominant understory of *Macrocystis integrifolia* and *Nereocystis luetkeana* kelp habitats of the Strait of Juan de Fuca. Specifically, 1) Basic composition of the understory habitat of these dominant kelp beds; 2) The geographic variation in their basic composition; 3) The seasonal variation in composition, and; 4) Variation of abundance of urchins and abalone which are commercially important species, and grazers in these habitats. Information on what kelp beds of the Strait are made up of, how they differ from each other and other kelp beds in Washington state, who uses them, and how they change sea-

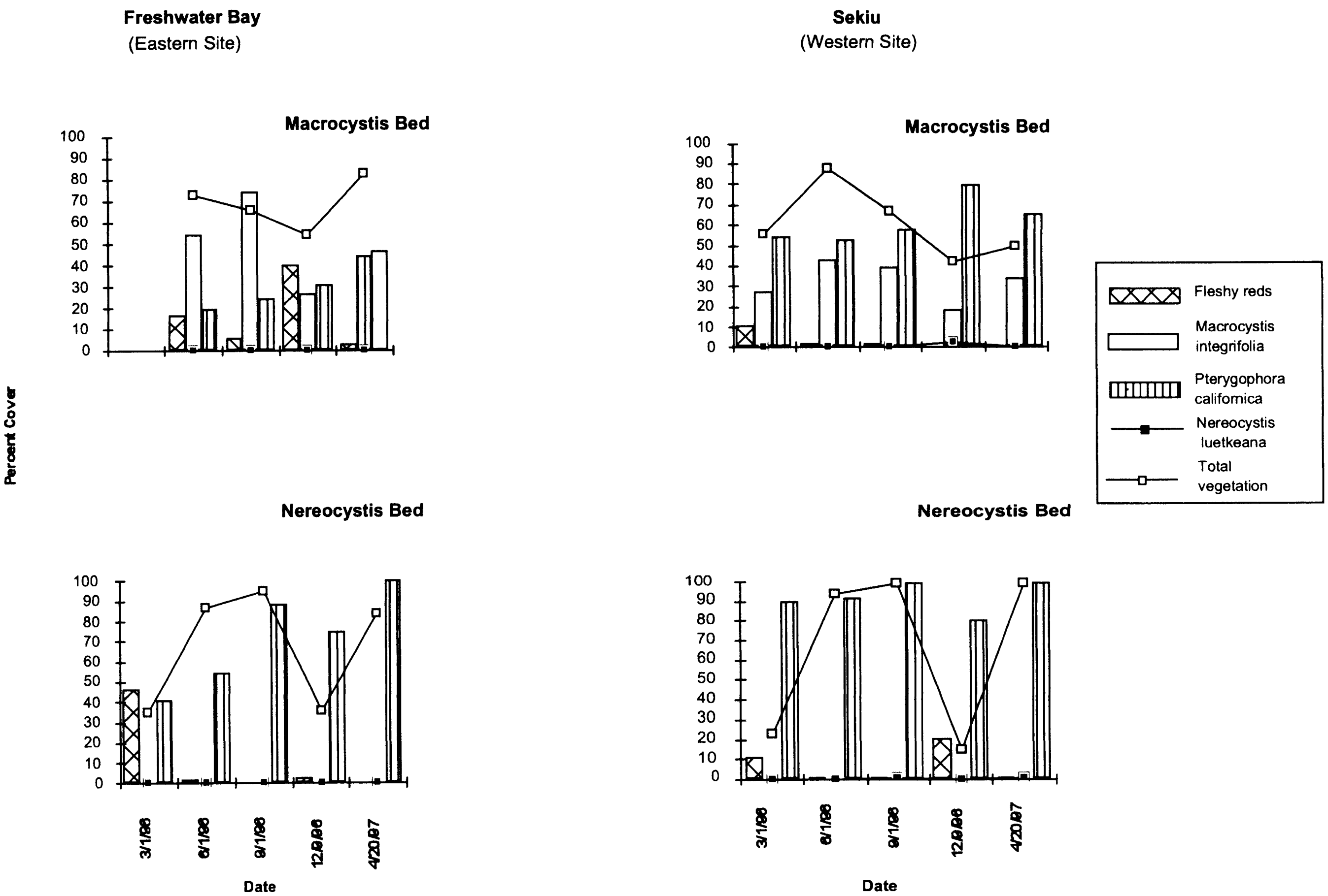

Figure 2. Average percent cover of understory vegetation for *Nereocystis* and *Macrocystis* beds, Strait of Juan de Fuca.

sonally will help managers begin understanding how the habitat they are charged with, works. Equally important, it will illustrate where further detailed work should be directed.

METHODS

Two each *Nereocystis luetkeana* and *Macrocystis integrifolia* beds, hereafter termed *Nereocystis* and *Macrocystis* beds, were sampled seasonally for dominant understory vegetation density and percent cover, and substrate percent cover from March 1996 to April 1997. Paired beds were selected along western and central Strait of Juan de Fuca, in 10–20 feet depth range (Figure 1). To define variation in use, densities of recreationally and commercially important macroinvertebrates were also recorded. These included the green urchin, (*Strongylocentrotus droebachiensis),* red urchin (*S. franciscanus*) and purple urchin (*S. purpuratus*), and northern abalone, (*Haliotis kamtschatkana*). During each sampling, two 30 meter transect lines were randomly sampled within permanent locations within each bed. Five randomly selected 1.0 m^2 quadrats were sampled along each line every three to four months for a minimum of one year. Understory information (from the substrate to 1.0m above the substrate) collected included visual estimates of total vegetation percent cover, and the relative percent cover (to sum to 100%) and density of dominant macroalgal species, substrate type percent cover, and urchin and abalone densities.

Total vegetation and dominant species percent cover and density were summarized for each bed and season. Invertebrate total for each bed type and season were tested for heterogeneity, and chi-square analysis comparing the invertebrate totals of the two bed types for each geographic region and season was also conducted.

RESULTS

Understory vegetation species composition, percent cover and densities varied with site, kelp bed type, and season (Figures 2 and 3).

Percent Cover

Total percent cover of *Macrocystis* beds varied from 50–80% and 45–90%. *Nereocystis* bed total percent cover varied from 35–95% and 15–100%, depending on season and location. Highest total percent cover was found in summer and fall, lowest in spring and winter. Individual species percent cover also varied by species, season, and site. Within *Macrocystis*

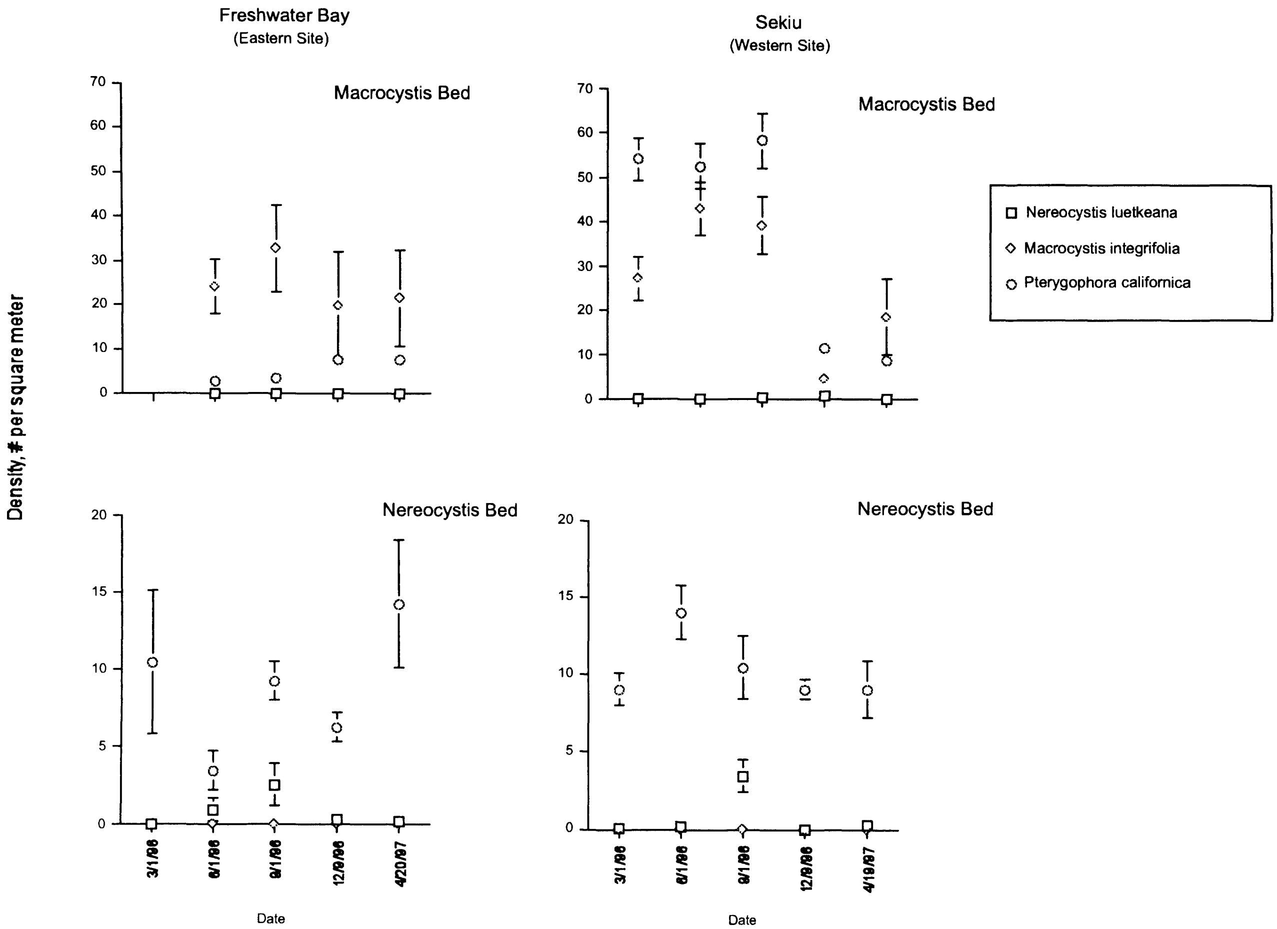

Figure 3. Average density and standard error of dominant understory macrovegetation of *Macrocystis* and *Nereocystis* beds, Strait of Juan de Fuca.

beds, *Macrocystis integrifolia* percent cover was highest in spring, summer, and fall months, when it contributed from 40–80% of the total cover. Winter percent covers were lower and ranged from 20–30% of the total cover. *Pterygophora californica* was the next dominant species, and for the western (Sekiu) site, had higher percent cover than *M. integrifolia* ranging from 50–80% of the total cover. Higher relative *P. californica* percent cover was found in winter months in both *Macrocystis beds,* when it contributed from 30–70% of the total vegetation percent cover. Fleshy reds were also seasonally present in the *Macrocystis beds,* and contributed from 10–50% of the total cover depending on season and site.

Percent cover of *Nereocystis* beds show more striking seasonal variation than found in the *Macrocystis beds* (Figure 2). Total vegetation ranged from 10–30 % during winter, 20–90% during spring, and 90–100% in summer and fall months. *Nereocystis luetkeana* however was not the dominant contributor to understory habitat, and never comprised more than 2% of the relative percent cover. *Pterygophora californica* was the dominant species for percent cover for all seasons sampled. *P. californica* relative percent cover appeared to vary with site, and ranged from 40–90% in the eastern (Freshwater Bay) bed, to 80–100 % relative cover in the western *Nereocystis* bed. Fleshy reds were again seasonally present, and covered from 10–45% of the total cover during winter and spring months, but less than 5% during summer months.

Kelp Densities

Average understory kelp densities varied by bed type, season, and species. Within the *Macrocystis beds, Macrocystis integrifolia* densities ranged from 5–45 stipes/m^2, with highest densities in summer and fall months (Figure 3). *Pterygophora californica* was the only other dominant understory kelp, but had much higher average densities in the western bed (15–60 stipes/m^2) than the eastern bed (2–10 stipes/m^2).

Kelp densities in *Nereocystis* beds also showed strong seasonal differences. *Nereocystis luetkeana* densities ranged from 0 stipes/m^2 to 3.5 stipes/m^2. *M. integrifolia* densities were highest in summer and fall months. *Pterygophora californica* was by far the dominant understory component of the *Nereocystis* beds sampled, with densities ranging from 3 to 14 stipes/m^2. *P. californica* densities appeared highly variable with both site and season. Highest densities were found dur-

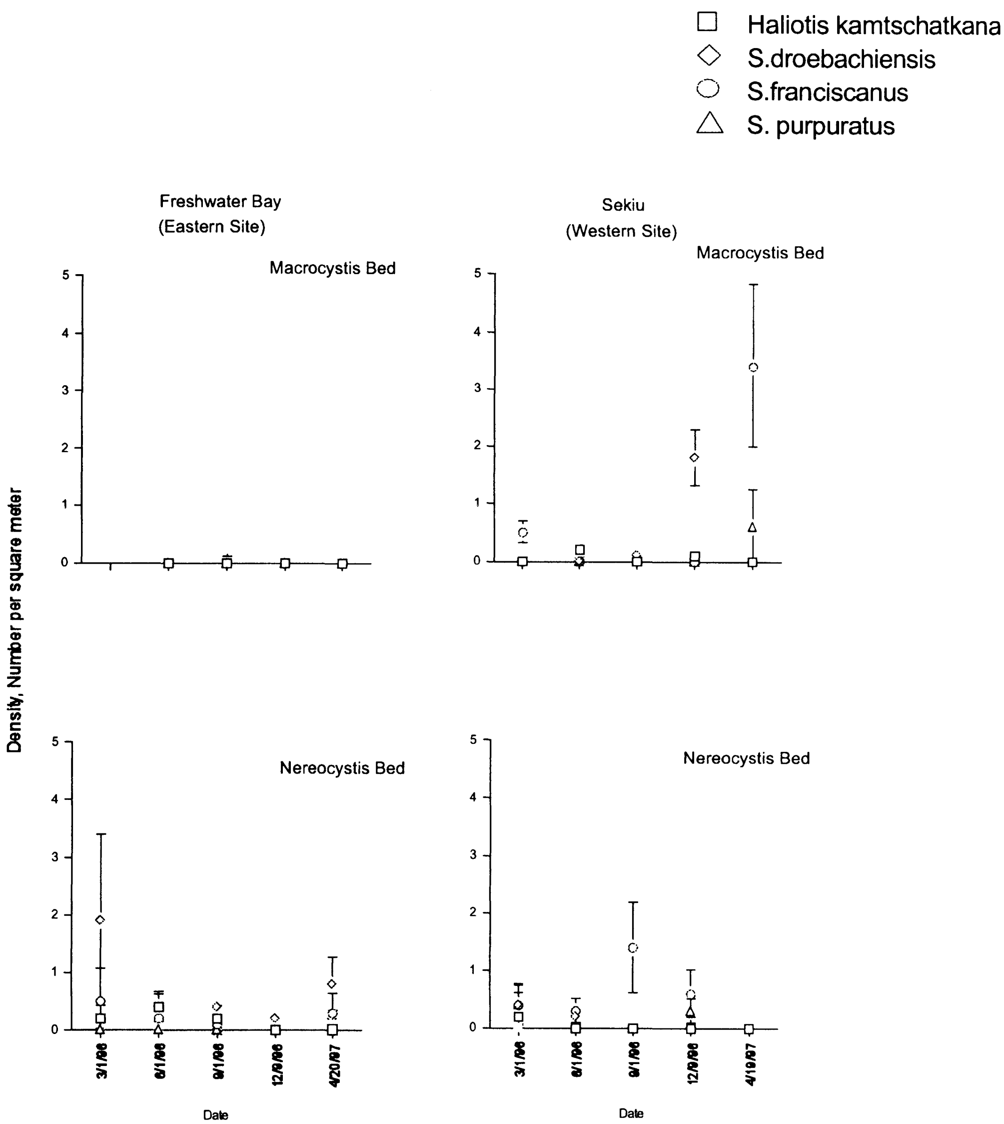

Figure 4. Average urchin and abalone densities of *Macrocystis* and *Nereocystis* beds, Strait of Juan de Fuca.

ing summer and fall months in the western bed (average densities 11–14 stipes/m^2), fall and spring in the eastern bed (9–11 stipes/m^2).

Invertebrate Densities

Urchin and abalone density varied substantially between and within the two types of kelp beds (Figure 4). When sampling dates were combined, *Nereocystis* beds had significantly higher total number of these four species than *Macrocystis beds* (Fisher's Exact test, $G_{adj} = 66.35$, $p < 0.001$). *Nereocystis* beds had higher densities than *Macrocystis beds* for three of the five sampling dates. Two of these dates were significantly different (spring and summer, ($G_{adj} = 24.43$ and 4.44 respectively; $p < 0.05$; Table 1). Numbers of abalone were low for all sampling (Figure 4).

Substrate

Substrate of all kelp beds consisted of a mixture of rock, boulder, cobble, gravel, and sand, dominated by larger substrate types (Figure 5). Overall, *Nereocystis* beds consisted of a broader array of substrate types: the eastern bed consisted of 38% boulder, 30% cobble, and a mixture of gravel and sand. *Macrocystis* beds were dominated by rock substrate (85% of the eastern site and 48 % of the western site), with smaller contributions of cobble, and gravel, and sand.

DISCUSSION

Comparing the two kelp bed types reveals both similarities and differences. Similarities include the seasonal variation in total percent cover of each of the habitats and the dominance of *Pterygophora californica* in the understory.

Table 1. *Fisher's Exact Test for total number of green urchin,* Strongylocentrotus droebachiensis, *red urchin,* S. franciscanus, *purple urchin,* S. purpuratus, *and northern abalone,* Haliotis kamtschatkana *within* Macrocystis *and* Nereocystis *kelp beds along the Strait of Juan de Fuca.* * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$.

Date 96/97	Total Number of Urchins and Abalone: Freshwater Bay (Eastern site)** Macrocystis	Freshwater Bay (Eastern site)** Nereocystis	Sekiu (Western site)** Macrocystis	Sekiu (Western site)** Nereocystis	DF	Gadj
3 March	—	26	5	10	—	—
8 June	0	10	2	2	1	4.44**
12 Sept	0	7	1	13	1	1.58
9 Dec	0	2	19	9	1	3.34
4 April	0	17	40	30	1	24.43***
Total	0	62	67	64	1	66.35***

The similarities in seasonal variation observed in kelp communities of this study are also consistent with observations for other regions, and may be partially dictated by light, water temperature, physical and biological disturbance, and nutrient supply (FOSTER and SCHIEL, 1985; SHAFFER and PARKS, 1994; ZIMMERMAN and KREMER, 1984).

Important differences observed in the *Macrocystis* and *Nereocystis* beds include: 1) structure of *Macrocystis beds* shows less variation than *Nereocystis* beds; 2), Within *Macrocystis* beds, the overstory plant appears to comprise much more of the understory habitat than in *Nereocystis* beds; 3) *P. californica,* a perennial understory species not visible from the sea surface, is a dominant feature of both bed types, but *Nereocystis* beds in particular, and; 4) Densities of invertebrates selected for observation differ between bed type, with higher densities and total numbers in *Nereocystis* beds than in *Macrocystis beds.*

There are many plausible reasons for these differences, including life history strategies of the kelp and invertebrate species involved. *Macrocystis integrifolia* is a perennial, and is structurally much more diverse than *Nereocystis luetkeana* (ABBOT and HOLLENBERG, 1976) . As evidenced here, it offers more surface area, and does so throughout the year more than *Nereocystis luetkeana.* The *Macrocystis* beds, and their understory community, therefore appear less variable than the *Nereocystis* beds. *N. luetkeana* on the other hand is an annual, and in the understory is structurally much more sparse than *M. integrifolia.* As these data show, *Nereocystis* individually therefore offers less structure to the understory throughout the year, and as a habitat type experience much greater seasonal changes within its understory.

Kelp derived carbon greatly influences the subtidal and intertidal communities of kelp beds, and is the basis for complex food chains (BUSTAMANTE and BRANCH, 1996; CARTER, 1999; DUGGINS, *et al.,* 1989; SIMENSTAD *et al.,* 1993). The larger variation in understory cover within *Nereocystis* beds may indicate a larger relative contribution of detritus available to grazers, and partially account for their higher num-

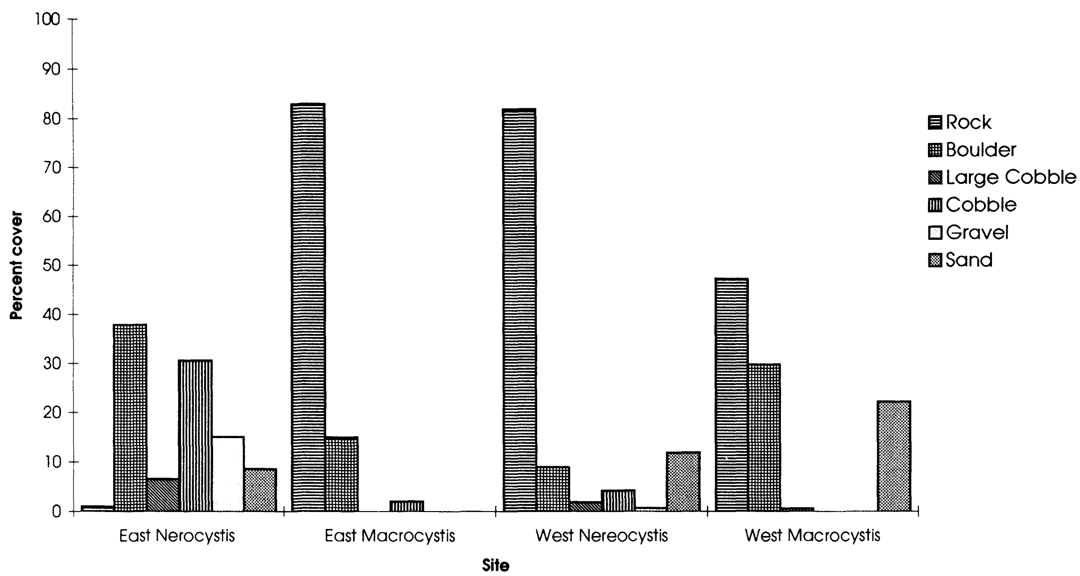

Figure 5. Substrate percent cover. Eastern sites are Freshwater Bay, Western sites, Sekiu.

bers. This higher seasonal variation in *Nereocystis* understory may subsequently support more invertebrates and a higher invertebrate diversity through increased food resource availability and biological disturbance. Alternatively, change in algal cover may also allow for greater water circulation, decreased biological disturbance, and so greater settlement of grazers and their predators.

Substrate undoubtedly also plays a role in defining the understory community. The greater substrate diversity of *Nereocystis* beds may offer a broader array of habitat types, and result in higher numbers and species of invertebrates as noted in this study. Whatever the reason, these differences may be extremely important for habitat managers interested in preserving and restoring kelp habitats, and should be considered a priority for future work.

These beds are also quite different from those studied in other geographic areas within Washington. Seasonal variations of *Nereocystis luetkeana* beds of Puget Sound are so pronounced that they effectively represent distinct habitats (SHAFFER, 1994). SHAFFER and PARKS (1994) found that summer *Nereocystis* beds were dominated by understory Laminarians, while winter beds were dominated by fleshy red algae. While differences in total percent cover were observed in both *Nereocystis* and *Macrocystis* beds in this study, overall composition of the dominant understory algal community appeared to stay relatively constant, indicating less of a seasonal shift in the kelp composition than in other Puget Sound kelp beds.

Further, differences in targeted invertebrate densities between geographic areas illustrates the strong variation that is possible within a kelp bed type, and the importance of both species and location for kelp bed function. Reasons for these differences are many, and may include natural variation, relative location to the Strait entrance and associated oceanic waters, substrate type, and relative exposure to, and impacts from human activities including fishing, upland development and associated non-point pollution. More focused work defining the functional roles of different kelp beds for culturally, commercial and recreationally important species including abalone, urchins, salmon, and bottomfish, is warranted.

This geographic gradation in the relative stability and community composition of the kelp understory has intriguing implications to habitat function. In short, while they both change with season, *Nereocystis luetkeana* beds of Puget Sound are not the same as those in the Strait of Juan de Fuca, and so may not be interchangeable in either a biological or a management context. This point is particularly important when designing kelp habitat preservation, restoration, and/ or mitigation plans on a multibasin scale. Also, the interaction between the seasonal stability of the algal species that make up the kelp bed, and invertebrates that use it as illustrated in abundance of targeted invertebrate species of this study, is an important point when managing kelp habitats.

Alternatively, the lower seasonal changes in total percent cover, consistently equal or higher total percent cover throughout the year, and the higher diversity of the understory macroalgal community of *Macrocystis* beds may offer a more stable environment for guilds that depend on the kelp habitat for refuge and food, including phyto- and zooplankton, shell and fin fish, sea otters, and birds. These guilds are often targeted in Marine Protected Areas and kelp restoration activities. Each have different and undoubtedly complex requirements from these habitats. It quickly becomes apparent that well defined management goals, as well as detailed site specific habitat information, are needed prior to implementing such management activities if effective kelp bed habitat management for a species restoration is to be achieved.

In summary, there are some striking differences within and between *Nereocystis* and *Macrocystis beds* of the Strait of Juan de Fuca. These beds also differ largely from kelp habitats within Puget Sound. The variation in understory of *Nereocystis* and *Macrocystis* observed with bed type, location, and season illustrates the need to define the specific goals of kelp habitat management tools, including Marine Protected Areas and kelp bed restoration. These tools should incorporate well defined habitat requirements, including geographic location and species of kelp, in addition to the use by the targeted shell or fin fish. Further, variation found in this study underscores the need for detailed long term studies if habitat restoration and preservation are to be documented, and successful.

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