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**Seasonal changes in subarctic sea urchin populations from different habitats**

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**Abstract** This paper documents seasonal variation in certain sea urchin (*Strongylocentrotus polycanthus*) characteristics in habitats of varying environmental conditions. At Shemya Island, Alaska, three habitat types [dense kelp beds, intermediate kelp beds, and algal barrens (low to no foliose algal cover)] were monitored seasonally from September 1995 to August 1996, for live and drift foliose algae. In general, drift algal abundance was greater in areas with more attached kelp, but this varied with season. Along with drift algae, sea urchin density, test size diameter, gonad and nutrition indices, and mobility were seasonally sampled within each habitat. Densities were highest in the algal barrens and lowest in the kelp beds. Seasonally, densities varied between summer/fall, and winter/spring, with lower numbers in the winter/spring. Test size was largest in the kelp habitats when compared to the intermediate or barren sites. Test size was seasonally consistent in the kelp habitats but not in the intermediate or barren sites. Here, test size did vary depending on season (larger urchins were found in winter). The gonad index showed much seasonal variation at the kelp and intermediate kelp sites, but was relatively more stable over time in the barren habitats. Between habitats, gonad and nutrition indices were larger in areas with kelp. Urchin movement varied seasonally between habitats, with more overall movement and variation in barren habitats. These results illustrate the importance of small-scale temporal and spatial variation. Monitoring for 1 year demonstrated that certain parameters varied more in areas of higher foliose algal cover (gonad indices), while other parameters varied more in low kelp areas (test size and movement). These results suggest that studies involving urchins should consider both time of year and overall algal community composition when conducting any type of experimental or monitoring work.

**Introduction**

Previous work examining temporal changes in community structure have sought to elucidate patterns of long-term variation. Much of this work has focused on large-scale episodic events (i.e. El Nino Southern Oscillation events; Dayton and Tegner 1984; Harris et al. 1984; Ebeling et al. 1985). To date, little work has directly addressed the role of seasonal change in community functioning (live and drift algal composition and abundance and their effects on the abundance, fitness and mobility of the dominant herbivore) within marine systems. Those studies that have addressed this issue have been on a longer temporal scale than the transitional effects of seasons (Paine and Levin 1981). Understanding short-term changes in communities is necessary to realistically understand how they function. Just as ecology has increasingly come to emphasize the importance of spatial variation, it is crucial to recognize short-term temporal variation in the absence of major episodic events. Short-term variation will influence the results found in many ecological studies (i.e. a winter study will give results that will differ from a summer study; likewise a summer monitoring program may not be representative of the entire year). This is especially true in subarctic populations where seasonal winter storms can be severe and play a major role in structuring communities. Because of this, it is necessary to know the extent of typical, annual variation within these communities. The purpose of this study, then, was to evaluate short-term fluctuations in a dominant herbivore’s population characteristics in habitats of varying macroalgal cover.

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Dominant herbivores are important in structuring communities because of their role as habitat modifiers (Bertness et al. 1999). Sea urchins, in particular, have been shown to structure algal communities by their grazing behavior (Breen and Mann 1976; Dean et al. 1984; Andrew and Underwood 1993; Scheibling et al. 1994; Hagen 1995; Leinaas and Christie 1996; Konar 2000). Certain urchin characteristics (defined here as density, test diameter, gonad and nutrition indices, and mobility), along with attached live and unattached drift algal composition and abundance, have been used to describe communities. Both urchin and algal characteristics can vary naturally among seasons. In northern Pacific marine systems, there are two primary factors that can cause the seasonal variation that will alter these community characteristics. First, storms will vary in strength and duration with the largest storms in the winter. Second, the algal community composition will vary, with more annual algae present in the summer compared to the winter. These two main factors will have multiple direct and indirect effects on the community interactions of algal producers and their herbivores.

Winter storms can cause direct changes in adult algal populations by causing differential mortality in the less resistant algal species and the less healthy individuals within a population. This disruption in the algal community can indirectly cause an increase in the abundance of the drift algae available to herbivores (Himmelman 1984; Harrold and Reed 1985). Although numerous herbivores feed on algae, sea urchins have been shown to be potentially the most important grazers in terms of the frequency and severity of destructive grazing (Harrold and Reed 1985; Estes and Duggins 1995; Konar 1998). Urchins are also a group whose behavior and community importance are strongly tied to drift algae; in areas with abundant drift algae, sea urchins are sedentary and spend less time searching for food. Storms may also remove drift algae from the system (Ebeling et al. 1985). This decrease can cause sea urchins to become mobile and actively graze for food (Harrold and Reed 1985). Independent of available drift algae, seasonal storms may also deter general invertebrate movement (Feare 1971; Pace 1976; Lissner 1980). Habitat structure can also change as a direct result of winter storms. The general disruption of the substrate can open space for algal and invertebrate settlement (see Pickett and White 1985 for review on physical disturbances). In some communities, intense storms may change habitat structure by clearing overstory algae, thereby increasing the bottom light (Reed and Foster 1984) and providing additional drift algae, which in turn influence sea urchin mobility.

Another way that communities directly change with season is in the production of annual algae in the summer. The extent of the seasonal variation in annual algal cover can correspond to the total amount of foliose macroalgal cover in the community. This variation in annual algal cover will influence the amount and composition of drift algae available in the summer and fall, which in turn will influence the mobility of herbivores (Harrold and Reed 1985; Macia 2000). Increases in annual algae in the summer can also cause changes in herbivore feeding preferences. Himmelman (1980) found that feeding behavior of sea urchins can switch from eating primarily perennial algae to annual algae such as *Monostronia* and *Desmarestia* when they become available. The influence that both winter storms and summer increases in annual algal cover can have on a community may depend on habitat structure (particularly the overall amount of foliose algal cover).

Although much is known about kelp bed and barren ground community ecology, few studies have evaluated short-term seasonal fluctuations in algal community and sea urchin population structure in areas that differ in the composition of the community but not in physical properties (wave exposure and substrate). The purpose of this study was to evaluate short-term fluctuations in subarctic algal communities in conjunction with certain sea urchin population characteristics (density, test diameter, and gonad and nutrition indices) and behaviors (mobility). The results of monitoring macroalgal and sea urchin communities in three types of habitats (kelp, intermediate and barren) are presented in this paper. This study demonstrates which sea urchin population characteristics are most seasonally variable and dependent on algal community structure. The area chosen for this study was Shemya Island, Alaska, because habitats ranging from dense kelp beds to barren grounds can be found in close proximity (<2 km). This area also has only one dominant herbivore, the sea urchin, *Strongylocentrotus polyacanthus*. This is the first study to examine nearshore seasonal community fluctuations in a North Pacific/Bering Sea system.

**Study areas**

Shemya Island is located in the western Aleutian archipelago (Fig. 1). Shemya is highly exposed to swell and wave action from the Bering Sea to the north, and the Pacific Ocean to the south. Due to its latitude and geographic position, this island is subject to extreme seasonality in both photoperiod and weather conditions.

The kelp communities around Shemya contain the perennial brown algae, *Agarum cribosum*, *Thalassiphylum clathrus*, *Laminaria dentigera* and *L. yezoensis*, the annual brown algae, *Desmarestia viridis* and *D. ligulata*, and the canopy-forming annual kelp, *Alaria fistulosa* (Dayton 1975). Relatively few foliose red and green algae are found within these kelp communities. The barren communities have very few foliose algae. This community type is dominated by encrusting (non-genculate) coralline algae.

Study areas were selected on the north and south side of Shemya Island because they represent the range of kelp bed densities commonly found in the Aleutian archipelago. Study sites were segregated into dense kelp, intermediate kelp, and barren ground, depending on the average amount of foliose algae present in the summer.