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Overgrazing of kelp beds along the coast of Norway

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Abstract

The aim of this study was to better understand the down-grazing of kelp beds by sea urchins (*Strongylocentrotus droebachiensis*) along the coast of Norway. Barren grounds were first observed in sheltered areas along the coast of the counties of Trøndelag, Nordland and Troms in 1974. In the 1980s, the barren grounds spread to areas more heavily exposed to waves. In the 1990s, the kelp beds were re-established in some localities in southern Trøndelag, initially in wave-exposed areas. In the northernmost parts of Norway, i.e. the counties of Troms and Finnmark, the barren ground areas may still be increasing. Crabs (*Cancer pagurus*) and common eiders are the most common predators on urchins. Predation on sea urchins in kelp beds is probably not among the factors that limit the sea urchin populations. Along the coast of Nordland and further north, sea urchins are infected by nematodes, resulting in a low, but significant increase in their mortality. No re-growth of kelp beds has been found in the most infected areas. In the late 1960s and the early 1970s, a high occurrence of echinoderm larvae was observed in deeper waters. This was a period with cold water, which may have caused high recruitment of sea urchins. The bet-hedging life strategy of sea urchins may account for the sudden increase in the size of the populations. In the present paper I propose the hypothesis that higher individual growth rates and higher mortality rates in the south than in the north may explain the decrease in the populations, which may in turn account for the re-growth of kelp in the southern areas.

Introduction

Sea urchin populations are known to increase to such a high level that they overgraze the kelp beds in many temperate areas around the world, with barren grounds as a result. Several theories and critical reviews have been presented to explain why the densities of sea urchins have increased so dramatically (e.g. Lawrence, 1975; Dayton, 1985; Elner & Vadas, 1990; Steneck et al., 2002). One frequently proposed explanation is low predation on sea urchins. High recruitment of sea urchin larvae in combination with favourable hydrographic conditions is another hypothesis (Forman, 1977; Ebert, 1983; Hart & Scheibling, 1988; Wing et al., 1995). Parasites in the sea urchins may also cause large oscillations in the size of the populations (Scheibling & Hennigar, 1997).

Re-growth of kelp beds in barren grounds dominated by sea urchins has been observed in several areas around the world, e.g. California and Nova Scotia (Hawkins & Hartnoll, 1983; Scheibling & Hennigar, 1997, respectively). Will variation in the factors that increase sea urchin populations (e.g. high recruitment, low predation, or low parasite infection) also cause a reduction in the populations? Will other factors such as abnormal weather events and changes in hydrographical conditions affect the populations (Parsons & Lear, 2001; Steneck et al., 2002), or may variation in the parameters related to population dynamics explain the oscillations (Ebert, 1985)?

The cycles from kelp beds to barren grounds and back again to kelp beds may be explained with reference to the life history of the sea urchins, which is characterised by bet-hedging strategies (Ebert, 1982, 1985).

The bet-hedging theory postulates that an extended reproductive life-span, a high rate of adult survival, and low annual reproductive effort are adaptations to compensate for the low and highly variable survival rate of first-year juveniles (Stearns, 1976, Roff, 1992).

The proliferation of barren grounds along the coast of Norway, from Nordmøre and further north to the Russian border, has been reported since the early 1980s (Skadsheim et al., 1995; Sivertsen, 1997a). Barren grounds have previously been observed in the areas around Stavanger by von Düben (1847) and around Tromsø by Döderlein (1900). Re-growth of kelp beds in barren ground areas, observed from the late 1980s, have been recorded in some overgrazed areas in the south, i.e. in Nordmøre, Trøndelag and southern Nordland (Hagen, 1995; Skadsheim et al., 1995; Christie et al., 1995; Sivertsen, 1997a).

The aim of this paper is to get a better understanding of the down-grazing and re-growth of kelp beds by the sea urchin *Strongylocentrotus droebachiensis* (O. F. Müller), in view of both its regional and local distribution on the coast of Norway. The focus will be on predation, parasitism, recruitment, population dynamics and the life history of the sea urchins.

Materials and methods

The area investigated stretches from west of Lindesnes (58°N, the southernmost point of Norway) to the North Cape (71°N, the northernmost point of Norway) and eastwards to the Russian border. This coastline consists of large fjords and an archipelago of hundreds of thousands of large and small islands, some of them at a distance of more than 50 km from the mainland. The archipelago is here divided into three zones. The outer archipelago consists of areas where the swells frequently reach the shores. In the inner archipelago the sea water is influenced by fjord water. In between these zones is the middle archipelago, which is affected by swells and fjord waters to a lesser extent or not at all. This division is suitable for describing the pattern of barren grounds and of sea urchin density and size frequency (Sivertsen, 1997a; 2003). The Norwegian Coastal Current runs northwards along the entire coast.

Laminaria hyperborea (Gunn.) Foslie. dominates the kelp beds in wave-exposed areas, while *L. saccharina* (L.) Lamour. is most common in sheltered areas. *L. saccharina*, with its prostrate stipes and lamina may be easier for sea urchins to graze than *L. hyperborea*, with its stiff erect stipes. During the over-grazing process the kelp and the undergrowth are first grazed. In wave-exposed areas juvenile *Laminaria* sp. were first grazed down, which inhibited their re-growth and left only remainders of canopy individuals, and gradually the canopy kelp disappeared (Sivertsen, 1997a).

An Echinoderm larvae index (EI) was used to estimate the occurrence of Echinoderm larvae, based on unpublished zooplankton samples from 1969–1983 from The Institute of Marine Research (IMR) in Bergen. Plankton hauls were taken in six localities. Three southern localities were at 59°N, 61°N and 63°N respectively, and three northern localities at 68°N, 68°N and 71°N respectively (Figure 1). Two plankton net hauls were performed about twice per month, a shallow one from 50 m depth to the surface and a deep one from 300 m to the surface in each locality. A short-cut method was used to identify dominating plankton species in the samples. The names and stages of the first 100 individuals in sub-samples were identified microscopically, and then the number (N) of Echinoderm larvae out of 100 zooplankton individuals was counted. To estimate the number of Echinoderm larvae in a whole sample, the volume of the sub-sample, or the number and the volume of each identified species, is required (Hjort & Ruud, 1927; Wiborg, 1962). These estimates were not made here. Instead an EI (Echinoderm Index) was made. The Echinoderm larvae were not identified to each species, which brings an element of uncertainty into the data. The net volume (when large individuals such as medusae and large euphausiides were removed) in mL (V) of each sample was measured. The EI used was $EI = N*V$. The average EI from samples taken in March, April and May (zero indices included) was used. Deep and shallow hauls were separated. At the same time temperature and salinity were measured close to the localities where the zooplankton samples were taken. The hydrographic data are stored, and mean values of temperature for March, April and May have been estimated by The Norwegian Oceanographic Datacenter at IMR.

Many species prey on sea urchins. Hooper (1980) lists e.g. *Tealia*, other anemones, small sea stars, *Solaster*, *Leptasterias*, crabs (*Hyas*, *Canser*), lobsters, cod, flounders, wolf-fish and sea-birds as predators on sea urchins in the Newfoundland waters. These groups also occur on the coast of Norway. Predation on sea urchins was estimated from counts of sea birds and landings of fished stocks. Between 1983 and 1986 the sea-bird abundance was estimated in Trøndelag and Helgeland, 63°N–66°N (Follestad et al., 1986), both of which are large areas dominated by barren grounds