Subtidal algal colonization following the removal of *Echinus*

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KURZFASSUNG: **Algenkolonisation im untergetauchten Gezeitenbereich nach Entfernung von *Echinus*.** An der Seeseite des Port Erin Wellenbrecherdammes kommen keine größeren Algen im Bereich der unteren 3 m vor. Hier herrscht eine große Besiedlungsdichte des Seeigels *Echinus esculentus* (3,6 Individuen pro m²). Über eine Zeitspanne von 3 Jahren wurden nun sämtliche *E. esculentus* von einem 10 m breiten und 12 m langen Felsstreifen allmonatlich entfernt; insgesamt wurden dabei etwa 3000 Individuen abgesammelt. Ein Jahr nach Beginn des Absammelns betrug die mittlere Siedlungsdichte der jungen *Laminaria hyperborea* auf dem von Seeigeln freigehaltenen Felsstreifen 22,7/m². In den folgenden Jahren wurden zwei- und dreijährige *L. hyperborea* nur auf diesem Felsstreifen oder in der Nähe seiner Begrenzungen gefunden. Andere Algenarten reagierten in ähnlicher Weise. Aus den Befunden wird gefolgert, daß die untere Verbreitungsgrenze von *L. hyperborea* zumindest zum Teil durch Seeigelfraß bestimmt wird, und daß *E. esculentus* die Siedlungsdichte der anderen Algenarten beeinflußt.

INTRODUCTION

The ruined breakwater at Port Erin is composed of concrete blocks and boulders and forms a suitable substratum for algae from mid-tide level down to 11 m below extreme low water springs, where it meets the sandy bottom. On the seaward face *Laminaria hyperborea* (GUNN.) FOSL. forms a forest from ELWS (extreme low water springs) to 6 m below but larger algae are normally absent from about 8 to 11 m depth and smaller species are sparsely distributed on the blocks and boulders. Not far away, however, where there is deeper rock, *L. hyperborea* extends down to 15 m or more (KAIN 1962).

A possible reason for the absence of *L. hyperborea* from the lower part of the breakwater is the grazing pressure exerted by the sea urchin *Echinus esculentus* L. This animal is present all over the breakwater but appears to congregate on the lower parts near the sand. It was therefore decided to clear the *Echinus* from a strip down a profile of the rock, to maintain the strip relatively clear, and to observe the effects on the growth of algae.

There are several other records of the effects of grazing by echinoids. NEUSHUL (1958) reported that NORTH had observed that following the wreck of an oil tanker off Baja California there was heavy mortality among sea urchins and other

grazers. This resulted in the colonization by *Macrocystis* and other algae of a number of small areas where they had previously been scarce. LEIGHTON, JONES & NORTH (1966) discussed the effects of grazing by sea urchins and stated that seaweeds invariably reappeared after urchin numbers were reduced sufficiently. Experimental destruction of sea urchins with quicklime showed that algal reestablishment took place when *Strongylocentrotus franciscanus* (AGASSIZ) was reduced to 1 individual per m^2, *S. purpuratus* (STIMPSON) to 10 per m^2, and *Lytechinus anamesus* CLARK to 10 per m^2. KITCHING & EBLING (1961), working at Lough Ine, Ireland, induced a rich growth of *Enteromorpha* and other algae by the removal of large numbers of *Paracentrotus lividus* (LAMARCK) from certain rocky areas in shallow water. NEILL & LARKUM (1966) removed *Arbacia lixula* LOVEN and *Paracentrotus lividus* from squares with 5 m sides and observed that a thick fur of algal sporelings had developed after a month.

METHODS

The seaward face of the ruined breakwater at Port Erin is about 200 m long. A wire rope was laid out at right angles to the line of the breakwater, a little way north from the base, from low water mark down to the sand at 11 m and fixed at either end. In July 1963 all individuals of *Echinus esculentus* were removed from squares of 5 m side alongside the wire successively from above downwards. The *Echinus* from each square were placed in a bag and counted in the laboratory. Later a further strip was cleared on the north side of the wire at its lower end, and an area 12 m long by 10 m wide has been subsequently cleared at intervals of about four weeks until the present.

RESULTS

The strip, when first cleared, was covered from low water to about 7 m depth, for a distance of about 22 m horizontally, by a forest of *Laminaria hyperborea* with occasional plants of *Saccorhiza polyschides* (LIGHTF.) BATT. and a few *Laminaria saccharina* (L.) LAMOUR (Fig. 1). From about 7 to 9 m depth there were only occasional *L. hyperborea* and more *Saccorhiza*, and below this a zone bare of larger algae with only occasional smaller specimens. Figure 1 also shows the density of *Echinus* on the strip in July 1963 and the density on a transect some distance to the north of the strip in July 1965. In both cases there was a considerably greater concentration of these animals on the lower boulders near the sand of up to 5 per m^2 compared with a maximum of 2 per m^2 higher up. *Echinus* does not normally move from rock to sand and this aggregation, which is noticeable along the whole length of the breakwater, may be caused by random movement and the presence of a barrier in one direction. That this is probably the explanation is borne out by the fact that at the northern tip of the breakwater, where there is a sand barrier in two directions, the density of *Echinus* near the sand is much higher still. The density at the lower end is a good deal higher than that found by FORSTER (1959) near Plymouth and approaches

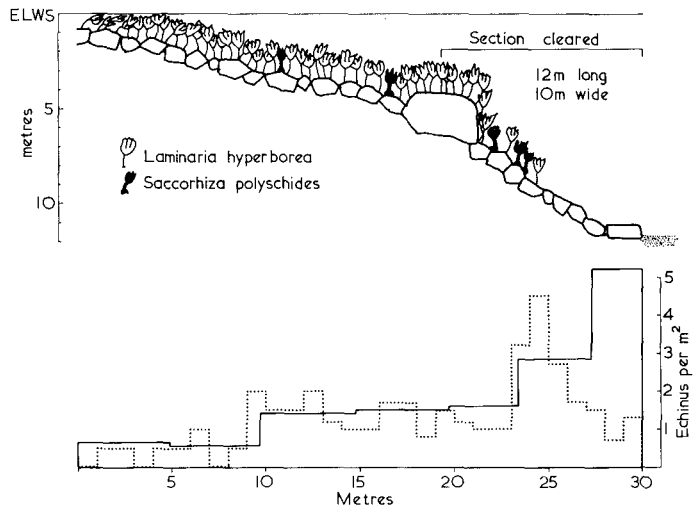

Fig. 1: Upper section – diagrammatic representation of a transect through the cleared strip on the outer face of Port Erin breakwater before clearing. Lower section – the density of the sea urchin *Echinus esculentus* along the transect shown above in July 1963 (solid line) and along a transect about 150 m north of the strip in July 1965 (dotted line). ELWS: level of extreme lowwater springs

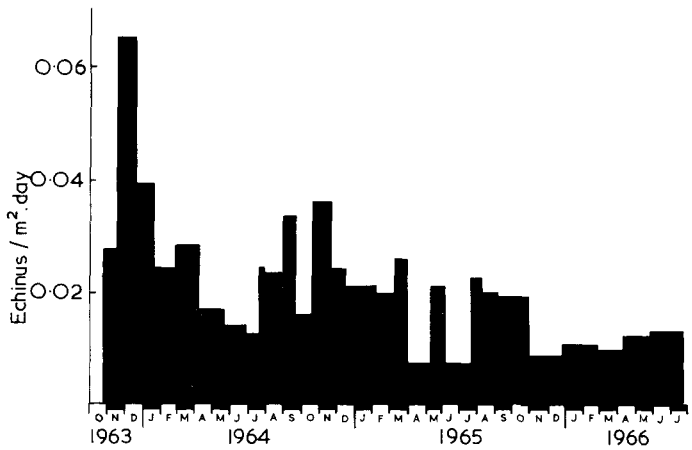

Fig. 2: Mean density per day of *Echinus esculentus* on the cleared strip through three years after the original clearance

that found for *Paracentrotus* in Lough Ine. FORSTER observed grazing rates in *Echinus*, and using his data, at the average density at the lower edge of Port Erin breakwater the whole rock surface could be scoured every three months when the animals are active. It is likely that this would have a considerable effect on the algae.

The variations in numbers of individuals of *Echinus* removed from the strip at each clearing is shown in Figure 2. The number per m^2 has been divided by the number of days since the last clearance to give a mean number per day. There seems to have been a peak in the amount of movement during the late autumn and this may be connected with the amount of food available or with the breeding cycle and water temperature. There was a slow decline in the numbers entering the strip, so the surrounding areas must have been slowly depleted, but this has been arrested during the third year. The number of urchins removed originally from the bottom 12 m of the strip was 340, and the total subsequently removed during the following three years was about 2320. The average density on the strip at the time of each clearing was about 25 % of the original. Thus, although grazing was not eliminated, it was reduced substantially, particularly near the centre of the strip.

By July 1964, a year after the initial clearing, the effect was obvious. There was a rich growth of small algae on the boulders normally bare, over an area a little narrower than that cleared of *Echinus*. *Saccorhiza* plants, which grow quickly, were conspicuous, but *Laminaria hyperborea* and *L. saccharina* sporelings could be found by close examination. Much of the cover of small algae disappeared in the autumn but reappeared in the succeeding summers (Table 1). In July 1965 the following species were present 30 m north of the strip: *Cutleria multifida* (gametophyte and sporophyte), *Saccorhiza polyschides* (sporeling), *Antithamnion* sp., *Bonnemaisonia hamifera* (sporophyte).

Table 1

Algal species present in samples scraped from boulders near the sand on the strip in July 1965

Cutleria multifida (Sm.) Grev. gametophyte and sporophyte	*Chylocladia verticillata* (Lightf.) Bliding
Dictyota dichotoma (Huds.) Lamour.	*Cystoclonium purpureum* (Huds.) Batt.
Laminaria hyperborea (Gunn.) Fosl.	*Delesseria sanguinea* (Huds.) Lamour.
L. saccharina (L.) Lamour.	*Halarachnion ligulatum* (Woodw.) Kütz.
Saccorhiza polyschides (Lightf.) Batt.	*Hypoglossum woodwardii* Kütz.
Antithamnion sp.	*Lomentaria clavellosa* (Turn.) Gaill.
Bonnemaisonia asparagoides (Woodw.) C. Ag.	*Plocamium vulgare* Lamour.
B. hamifera Hariot sporophyte	*Polysiphonia elongata* (Huds.) Grev. ex Harv. in Hook.
Brongniartella byssoides (Good. et Woodw.) Schm.	*Pterosiphonia parasitica* (Huds.) Falkenb.

Counts were made of *Laminaria* sporelings on each boulder adjacent to the sand across the strip and for a further 20 m northwards towards the end of the breakwater (Fig. 3). By July 1964, well away from the strip, there were some boulders with sporelings on them and some without but on the strip not only were there some higher densities but there were no bare boulders. By November 1964 none of the sporelings subjected to full *Echinus* grazing had survived except on a single boulder whereas all the boulders near the centre of the strip still bore sporelings.

In July 1965 second year plants were entirely confined to the strip, and in July 1966 third year plants were found only on the strip but second year plants were also

found at and just outside its northern edge, possibly as a result of the depletion of the *Echinus* population near the strip.

There was, of course, a new crop of sporelings in each of the years 1965 and 1966 but these were not counted except as second year plants in 1966. It is clear that even

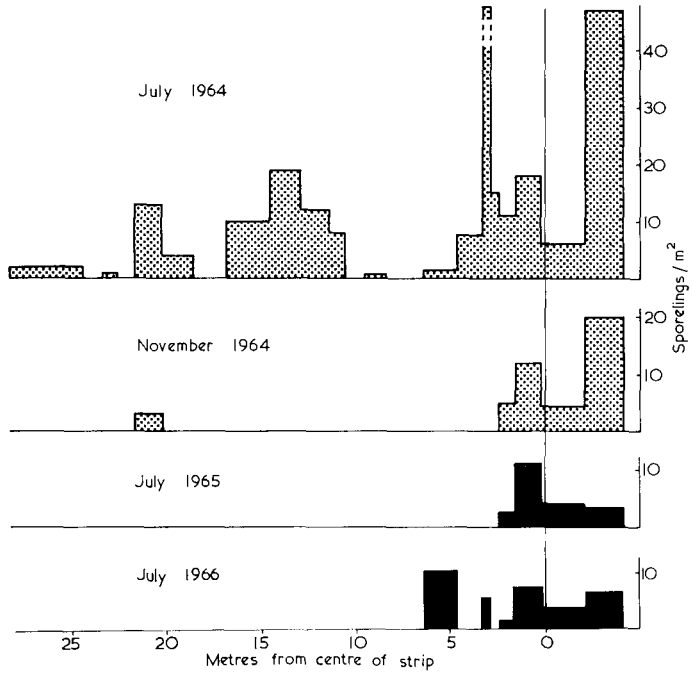

Fig. 3: Density of sporelings of *Laminaria* spp. on boulders adjacent to the sand at 11 m depth below ELWS across the cleared strip and for 20 m to the north of it. July and November 1964 – first year sporelings of *L. hyperborea* and *L. saccharina* together; July 1965 – second year plants of *L. hyperborea* only; July 1966 – second and third year plants of *L. hyperborea*

on the strip mortality was fairly great but this is to be expected in the first year and it may be some time before a forest is formed because growth conditions are not optimal at the bottom end of the strip as light is probably limiting.

Figure 4 shows the numbers of plants of *Laminaria hyperborea, L. saccharina* and *Saccorhiza polyschides* more than a year old along three transects 4 m wide counted in May 1965, along the centre line of the strip and parallel to it at positions 20 and 40 m northwards respectively. On the strip some plants more than two years old, present before the strip was cleared of *Echinus,* were found down to about 9 m depth but below this two-year-olds only were found, these having been allowed to grow because of the slackening in grazing pressure. On the two transects away from the strip no two-year-old plants were found below 9 depth. All three species of algae seem to be affected similarly, though *Laminaria saccharina* was only present in small numbers.

It seems clear that at this site and probably others *Laminaria hyperborea* has its lower limit determined at least partly by the grazing pressure of *Echinus esculentus,*

although slower growth due to reduced light may be a contributory factor. Evidently it is not only the gametophytes that are held in check; young sporophytes can be produced in this zone but they do not survive for more than a year. The sea urchins certainly exercise an important control over the numbers of other algal species.

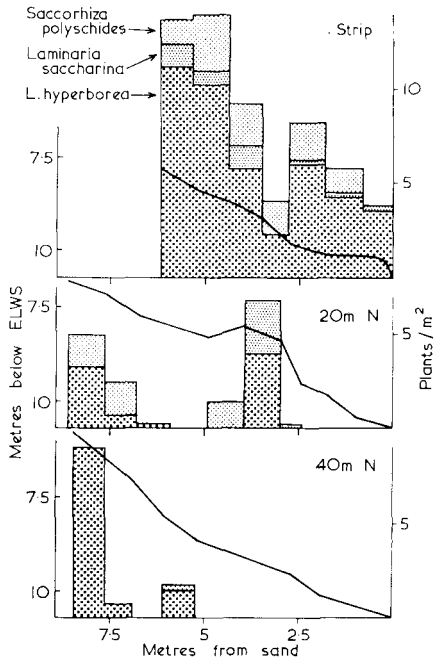

Fig. 4: Density of plants more than one year old of Laminariaceae in May 1965 along transects through the cleared strip and at positions 20 and 40 m north of it. The heavy black line represents the profile of the transect at each position

SUMMARY

1. On the seaward face of Port Erin breakwater large algae do not occur on the lowest three metres. Here the density of *Echinus esculentus* is high.
2. Over a three year period all *Echinus* were removed from a 10 m wide strip at about monthly intervals. The total number of individuals removed approached 3000.
3. One year after initial clearance the mean density of *Laminaria hyperborea* sporelings on the strip was 22.7/m² and 5.1/m² to one side of it. By the winter these had almost disappeared outside the strip and in the succeeding years second and third year plants were found only on the strip or close to its edge. Other algae were similarly affected.
4. It is concluded that the lower limit of *L. hyperborea* is determined at least in part by the grazing pressure of *Echinus* and that the urchins exercise some control over the numbers of other algae.

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LITERATURE CITED

FORSTER, G. R., 1959. The ecology of *Echinus esculentus* L. Quantitative distribution and rate of feeding. *J. mar. biol. Ass. U.K.* **38**, 361–368.

KAIN, J. M., 1962. *Aspects* of the biology of *Laminaria hyperborea*. 1. Vertical distribution. *J. mar. biol. Ass. U.K.* **42**, 377–386.

KITCHING, J. A. & EBLING, F. J., 1961. The ecology of Lough Ine. 11. The control of algae by *Paracentrotus lividus* (Echinoidea). *J. anim. Ecol.* **30**, 373–384.

LEIGHTON, D. L., JONES, L. G. & NORTH, W. J., 1966. Ecological relationships between giant kelp and sea urchins in Southern California. *Int. Seaweed Symp.* **5** *(Halifax, N.S.)*, 141–153.

NEILL, S. R. ST. J. & LARKUM, H., 1966. Ecology of some echinoderms in Maltese waters. *In:* Symposium of the Underwater Association for Malta 1965, 51–55.

NEUSHUL, M., 1958. Studies on the growth and reproduction of *Macrocystis*. *Q. Prog. Rep. (Kelp Inv. Prog.) Univ. Calif. Inst. mar. Res.* **58–10** (IMR Ref.), 4–24.

Discussion following the paper by JONES & KAIN

MONNIOT: La disposition des *Laminaria* près de Roscoff est analogue à celle que vous avez observé. Dans ces stations il n'y a que peu d'Oursins mais le Mollusque brouteur *Haliotis tuberculata* est très abondant. Peut-il s'agir d'une action similaire?

JONES: Yes, I think that it would affect the algae.

MACFARLANE: What is the upper level of the occurrence of *Echinus* in the seaweed beds? Can you tell us what factors determine their upper limit?

JONES: In Port Erin we find *Echinus* from the low water mark downwards, but we have only watched their movements at the lower edge of the breakwater after the initial clearance. I know that in some places *Echinus* seems to migrate upwards in the spring, but I am not convinced that this takes place in Port Erin.

MACFARLANE: Have you ever used lime to eliminate *Echinus?*

JONES: We did not use quicklime because we wanted to leave the area outside the strip as undisturbed as possible.

GAGE: What precautions can one take to avoid possible interference in these ecological experiments. I am thinking particularly of people who might collect *Echinus*.

JONES: At Port Erin we can bring some pressure to bear on amateur divers as a condition of filling their bottles, but I do not know how one overcomes this problem in general.