Growth of amputated and dark-exposed individuals of the brown alga *Laminaria hyperborea*

K. Lüning

Biologische Anstalt Helgoland (Meeresstation); Helgoland, Germany (FRG)

**Abstract**

The seasonal growth of the brown alga *Laminaria hyperborea* (Gunn.) Foslie, which forms dense forests in the sublittoral zone of Helgoland, a rocky island in the Southern North Sea, was investigated by transplanting specimens of the littoral zone of Helgoland, a rocky island in the Southern borea (Gn-FOSFLE, which forms dense forests in the sub...}

**Introduction**

The mode of seasonal growth of *Laminaria hyperborea* (Gunn.) Foslie, has been described by Kain (1963). Fast primary and secondary growth is confined to the first half of the year, very slow growth to the second half. During the darkest time of the year — December and January — the alga begins to produce a new frond; this process takes place even in complete darkness, as will be shown below. Thus the equation "growth equals gross assimilation minus respiration" cannot be correct for the time at which the growth of the new frond begins. According to Black (1950) the frond of *Laminaria hyperborea* is rich in laminaran and mannitol in the autumn and contains minimum amounts of carbohydrates in spring. It seems possible that the carbohydrates are used up during the dark winter period not only by respiration, but also in the process of synthesizing proteins (Black and Dewar, 1949). Such seasonal changes imply that the old frond contributes considerably to the growth of the young frond. With the brown alga *Macrocystis* it has been found that the growth of young fronds is supported by assimilates synthesized by older blades (Sargent and Lanthrop, 1952; CLENDENNING, 1961; PARKER, 1963).

Growth studies on sub-tidal algae in situ have now become possible by advancements of SCUBA diving techniques. Subtidal growth stations have been installed by SCUBA divers, and "planted" with *Macrocystis* (North, 1961; Neushul and Hako, 1963). Similar techniques have been used in the present 2-year study on the growth of normal, amputated, and dark-exposed specimens of *Laminaria hyperborea*. This alga forms dense forests at the depths between 1 and 4 m in the sublittoral zone of Helgoland.

**Material and methods**

Entire individuals of *Laminaria hyperborea*, growing 2.5 m below mean low water of spring tides (M.L.W.S.), were carefully removed from the rock by a diver who took care to damage the haptera as little as possible. The haptera were then partially covered with a plastic network and fastened with rubber bands to wooden or PVC plates (8 × 15 cm; Fig. 1).

Fig. 2 shows the holdfast of an alga mounted on a PVC plate in February and photographed in the following August. The alga, at first kept in place only by the rubber bands, attaches itself to the plate by outgrowths of the old haptera (visible beneath the plastic network), as well as by new haptera (above the plastic network) which may even grow around the edges of the plate. Outgrowths of the old haptera occur after about 2 months in plants transplanted in winter as well as in July or August. They fix the algae firmly to wooden plates so that plastic network and rubber bands can be removed before the appearance of new haptera.

Since wooden plates are soon destroyed by woodboring organisms, the majority of algae were transplanted to PVC plates. *Laminaria hyperborea* attaches itself to this material mainly by new haptera growing around the plate edges; the proliferations of the old haptera adhere only slightly to the smooth PVC surface. A similar method of transplantation has been used by Sundene (1962, 1964) who offered concrete blocks to *Alaria esculenta* and *Laminaria digitata*, and studied their growth in the upper sublittoral without employing SCUBA diving.

Series of 40 *Laminaria hyperborea*, attached to individual PVC plates mounted on iron frames (2 × 1 m), were submerged near the rocks from which the algae had previously been removed. Whenever possible, the algae were surfaced and photographed on board the diver boat every 2 weeks during the first half of the year, every 4 weeks during the second half. From these photographs, measurements were taken of frond areas using a polar planimeter. The only difference between *Laminaria hyperborea* (growing at
similar population densities) on natural rock, and the transplanted specimens, is the substrate and the fact that the latter had to re-attach themselves. It is, therefore, assumed that growth rates are comparable.

In order to study the effects of amputation and darkness on growth rates of *Laminaria hyperborea*, the increase in surface area of the new fronds has been recorded in the following experimental groups (see Fig. 4):

(A) Normal algae with stipe and old frond (stipe lengths between 50 and 80 cm)

(B) Algae with their old fronds amputated by the end of February (stipe lengths between 50 and 80 cm)

(C) Isolated new fronds from which the old frond and most of the stipe had been amputated by the end of February; the remaining 8 cm of the stipe was used to fasten the new frond with plastic network and rubber bands on a PVC plate

(D) Dark-exposed algae (stipe lengths between 6 and 55 cm) placed into "dark chambers" in December 1967; the "dark chambers" were submerged in a large, out-door, sea-water tank supplied with running sea water direct from the sea.

Experimentals of groups A, B and C grew in situ at a depth of 2.5 m below M.L.W.S. on PVC plates mounted on submerged frames.

In 1967, the experiments began with 10 individuals of each group (A, B and C). In 1968, the experiments were repeated with 20 individuals of each group. Individuals showing damage of their fronds due to grazing by animals (mainly the snail *Gibbula* spp.) were excluded from growth rate calculations. The number of algae of each experimental group included in growth rate calculations are presented in Table 1. Since the pressure of the rubber bands on the remaining stipe piece used for attachment of new fronds caused fouling, losses were heaviest in experiments with isolated new fronds.

### Table 1. Number of *Laminaria hyperborea* included in growth rate calculations

<table>
<thead>
<tr>
<th>Year</th>
<th>Normal algae</th>
<th>Algae without old frond</th>
<th>Isolated new fronds</th>
<th>Dark-exposed algae</th>
</tr>
</thead>
<tbody>
<tr>
<td>1967</td>
<td>5</td>
<td>6</td>
<td>2</td>
<td>—</td>
</tr>
<tr>
<td>1968</td>
<td>13</td>
<td>14</td>
<td>13, 14</td>
<td>—</td>
</tr>
</tbody>
</table>

**Results and discussion**

The growth records of a specimen of *Laminaria hyperborea* obtained from 1966 to 1968 are illustrated in Fig. 3. In October 1966, the specimen in question had a frond area of 4.5 dm². During the period of fast growth, i.e. from January to June 1967, the alga produced a new frond of 9 dm²; this area was reduced by about one half in the following period of slow growth, i.e. from July to December 1967. During the next period of fast growth—from January to June 1968—a new frond of 14 dm² was produced. The increase in stipe length from 5 cm in October 1966 to