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# THE LAMINARIACEAE OFF NORTH SHAPINSAY, ORKNEY ISLANDS; CHANGES FROM 1947 TO 1955

BY

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## ABSTRACT

Changes in the crops of Laminariaceae over a number of years around Scotland have been investigated. This paper summarises the results of five surveys carried out in 1947, 1951, 1952, 1953 and 1955 in North Shapinsay, Orkney Islands. Considerable losses were found between 1947 and 1952, but thereafter recovery commenced and has continued. Some of the ecological factors are analysed and discussed.

## INTRODUCTION

During the last ten years, 1946 to 1955, an extensive survey of Laminariaceae around Scotland has been in continuous operation. The marine coast of Scotland and of its many islands, 6,700 miles in all, has been photographed through co-operation of the Royal Air Force. With the aid of these aerial stereoscopic photos and with ecological data obtained by methods of quadrat sampling of the seabed (Walker, 1947), it has been possible to assess the Laminariaceae growing around Scotland (Walker, 1954a).

Since 1946, 86 sublittoral surveys, carried out from chartered motor vessels, have been completed, and the data obtained have been statistically analysed. The areas surveyed thus far, totaling 67,000 acres (27,000 hectares), are located off the northeast, northwest, southeast and southwest mainland, off the Orkney Islands, and off the Isle of Skye. Resurveys of many of these areas revealed that considerable changes in abundance in a crop of Laminariaceae occurred over a number of the years.

Of the family Laminariaceae, two species predominated around Scotland: the perennial *Laminaria cloustoni* Edm. (*L. hyperborea* Fosl.) and the annual *L. saccharina* Lamour. While individual plants of *L. saccharina* can grow for two or three years, the majority stand little chance of survival from one year to another.

Part of this ecological programme consisted of surveys of (1) four habitats of *L. cloustoni* in widely separated areas—NE, SE, NE, NW

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mainland of Scotland, and (2) two habitats of *L. saccharina*, one during summer, the other during winter. This paper records the results of five summer surveys of a crop of *L. saccharina* established over an area off Shapinsay, one of the Orkney Islands between the Scottish mainland and the Shetland Islands. Results of the winter surveys of *L. saccharina*, carried out off the Isle of Arran in the Firth of Clyde, have been presented elsewhere (Walker and Richardson, in press).

The survey area off Shapinsay lies between Galt Ness and Sandy Geo, including the extensive Veantrow Bay, North Shapinsay. The surface of the seabed in this area consists of rocks, boulders and sand. Old Red Sandstone is the characteristic geological formation of the Orkney Islands. The mean tidal range is one fathom (1.85 m), and during spring tides the rate of the tidal stream passing the north-west coast of Shapinsay reaches 6 to 7 knots.

The first of the five surveys, carried out in May 1947 before the "May cast," employed quadrat sampling at one-fathom depth intervals from one to six fathoms along transects measured by rangefinder: the transects were 200 yards (185 m) apart (Walker, 1950). The four subsequent surveys took place during July of 1951, 1952, 1953 and 1955 after the "May cast," when random sampling was pursued with an intensity of 250 quadrats per square kilometre between low water and ten fathoms (18.5 m).

Nearly 18,000 quadrats, using calibrated spring grabs, were sampled during these five surveys. All depths were measured to the nearest fathom and were standardised to low water mark at ordinary spring tides. Seaweed density quoted herein represents the mean fresh weight of algae per unit area. The algae were weighed on a spring balance to the nearest half-pound immediately upon being taken from the sea. Seaweed cover is indicated by the number of quadrats which contained Laminariaceae, expressed as a percentage of all quadrats.

During the month of May the lamina (or frond) of the perennial *L. cloustoni* is shed after a new lamina has been partially produced by intercalary growth between the stipe and the mature lamina that was produced in the previous year. The shedding of the old lamina is known as the "May cast," much of which is cast up on the beach though some is carried out to greater depths. Shedding of the old lamina reduces considerably not only the plant weight but the total crop as well. Also, winter storms disrupt the balance of the crop by tearing off larger plants from the seabed; these also may be cast up on beaches or carried out to greater depths.

Reproduction of *L. saccharina* occurs in September and of *L. cloustoni* in December, so that by the early part of the year large numbers of small plants are recolonising any suitable and available area of the seabed. Only a small percentage reach maturity.

The Laminariaceae undergo an alternation of generations; zoospores give rise to a heteromorphic generation of microscopic filamentous gametophytes whose ova and sperm on fertilisation grow into macroscopic sporophytes (Walker, 1954b).

## RESULTS

The calculated totals of Laminariaceae, covering 1,040 acres of the sublittoral zone between one and six fathoms for the five surveys, are given in Table I, together with corresponding density and cover. Although samplings in 1951, 1952, 1953 and 1955 were taken to a depth of 10 fathoms, the values in Table I are restricted to a range from one to six fathoms, which were the limits set by economic considerations in the earlier years of the research programme. The standard errors of mean density are calculated by the method of pooled variances for individual depths, based on unit quadrats of one square yard. The sampling was sufficient to cope consistently with the variations within the algal crop of this area. The cover with ratio of species (based on relative fresh weight) and the density are shown diagrammatically in Fig. 1.

TABLE I

Date	Total seaweed; fresh weight (tons)	Seaweed cover (%)	Mean density; fresh weight (ton/acre)	Standard error of mean density (%)
May 1947	33,960	78	32.6	—
July 1951	9,890	52	9.5	2
July 1952	5,830	35	5.6	3
July 1953	6,860	48	6.6	3
July 1955	7,590	52	7.3	3

Cover decreased during the four year interval from 1947 to 1951 and still further from 1951 to 1952; but by 1953 it had increased and continued to do so until the observations were terminated in 1955. *L. saccharina* accounted for most of the change. From 1951 to 1955, changes in the species ratio were more conspicuous in deeper water, where *L. saccharina* gave place to *L. cloustoni*; in shallower water, *L. cloustoni* gave place to *L. digitata* (Fig. 2).

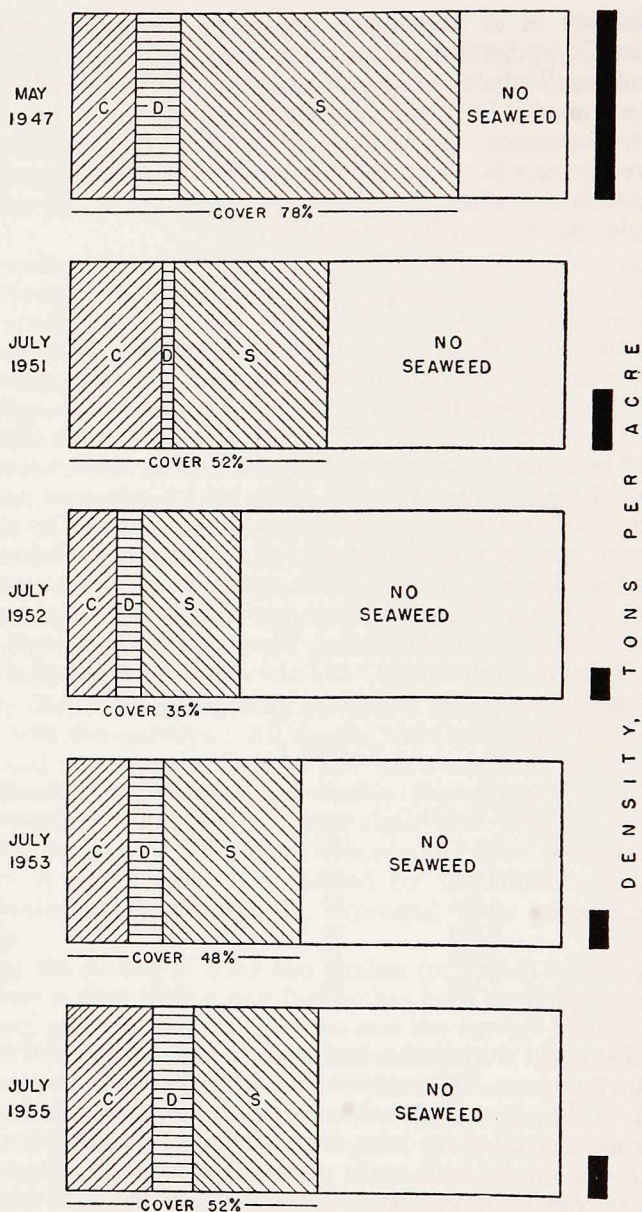


Figure 1

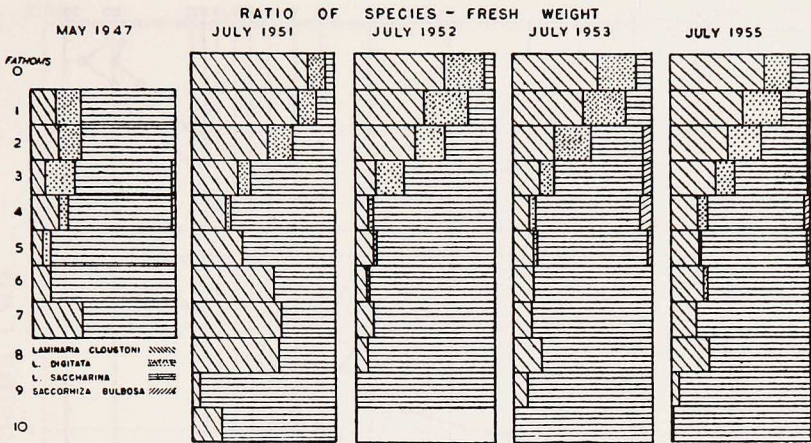


Figure 2

Fig. 3 gives plots of the mean values of seaweed density (on  $\log^{10}$  scale) of Laminariaceae against fathom intervals of depths, calculated from all quadrats and from only those quadrats containing Laminariaceae. There is fair approximation to straight-line log regression with increasing depth, as might be expected where photosynthesis occurs with light transmitted through water.

It has been found that there is a relationship between density, cover and depth at which the Laminariaceae grow around Scotland (Walker, 1950, 1954a). This relationship may be expressed as follows:

$$\sqrt{\frac{d}{C}} = k - \gamma f \quad ,$$

where  $d$  is mean density based on total quadrats for a particular depth (lb/sq yd),  $C$  the corresponding cover (%),  $k$  a constant for the survey,  $\gamma$  the coefficient of regression, and  $f$  the depth in fathoms. The values for  $\sqrt{d/c}$  for the five surveys, over a range from 1 to 6 fathoms, are plotted in Fig. 4. The movement of the graphs is not progressive with time; this would be unlikely, since the area must be recolonised by young plants after any violent disruption of the crop.

It is possible to recognise three fairly distinct phases (listed below), each of which is directly influenced by (a) the number of plants per unit area, (b) the mean weight per plant, and (c) the algal cover of an area. The product of these three factors gives the total weight of the crop.

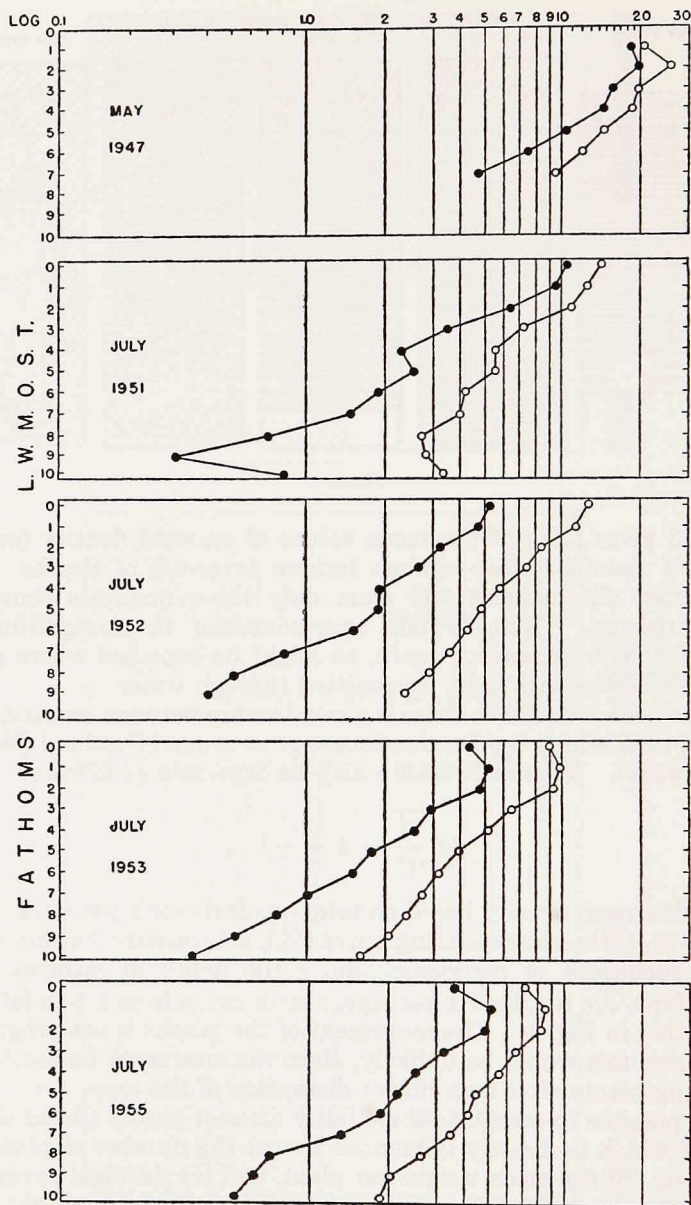


Figure 3

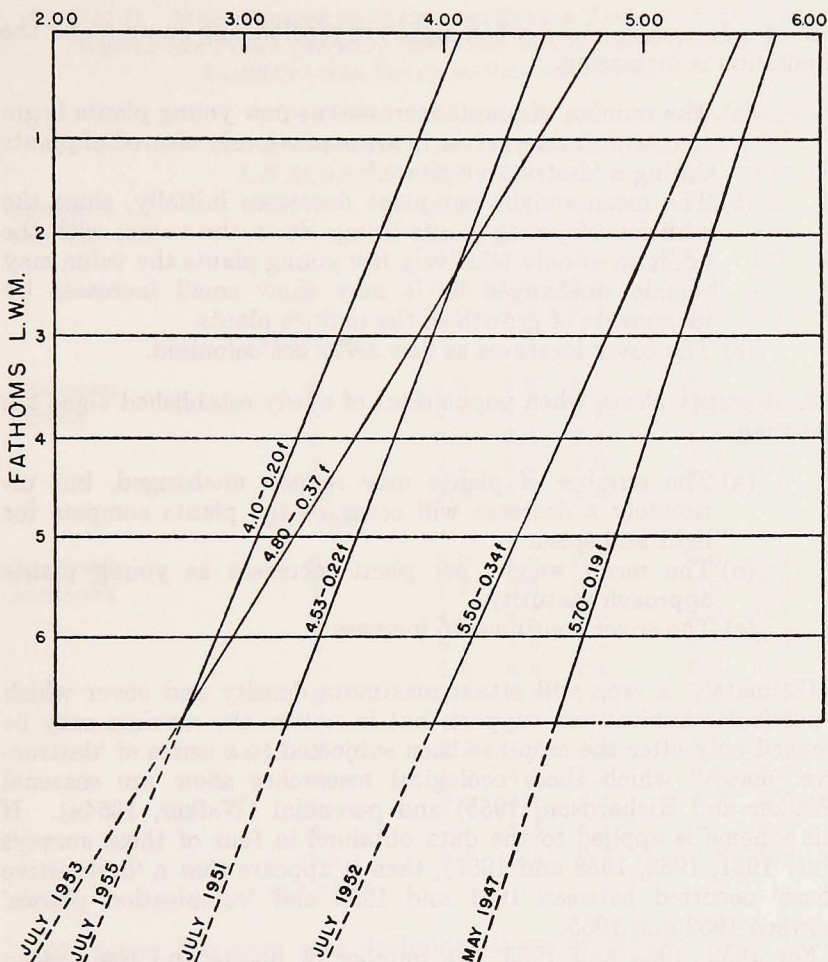


Figure 4

1. A *destructive phase* is marked by a decrease in the population, as for example after 'strong gales,' when large quantities of seaweed are cast.

- (a) The number of plants decreases.
- (b) The *mean* weight per plant decreases because the larger plants are most vulnerable during strong gales.
- (c) The cover decreases.



2. A *colonization phase*, when algae are recolonising an area and the population is increasing.

- (a) The number of plants increases as new young plants begin to establish themselves in areas previously cleared of plants during a 'destructive phase.'
- (b) The mean weight per plant decreases initially, since the addition of young plants brings down the value; with the addition of only relatively few young plants the value may remain unchanged or it may show small increases by increments of growth of the mature plants.
- (c) The cover increases as new areas are colonised.

3. A *growth phase*, when populations of newly established algae are maturing.

- (a) The number of plants may remain unchanged, but ultimately a decrease will occur as the plants compete for light and space.
- (b) The mean weight per plant increases as young plants approach maturity.
- (c) The cover continues to increase.

Ultimately, a crop will attain maximum density and cover which a particular habitat can support, but in nature the maxima may be reached only after the crop has been subjected to a series of 'destructive phases,' which these ecological researches show are seasonal (Walker and Richardson, 1955) and perennial (Walker, 1954a). If this scheme is applied to the data obtained in four of these surveys (July 1951, 1952, 1953 and 1955), then it appears that a 'destructive phase' occurred between 1951 and 1952 and 'colonisation phases' between 1952 and 1955.

For 1952, 1953 and 1955, the number of plants and their mean weight are given in Table II. In the case of *L. saccharina*, the predominant species, the number of plants increased as the mean weight per plant decreased, indicating a period of recolonisation from 1952 to 1955. Only those quadrats which contained a single species of *Laminaria* (75%) were used to compile this table.

The coefficient of variability is a useful statistic for comparing the behaviour of a crop growing under a complex set of ecological factors, each subject to change. Such coefficients for the 1951, 1952, 1953 and 1955 surveys are shown in Fig. 5.

It will be seen that the 'outsiders' occur in 1951 and 1955. During

TABLE II. MEAN NUMBER OF PLANTS PER SQUARE YARD AND MEAN FRESH WEIGHT PER PLANT (WITHOUT HOLDFAST) OF THE CHIEF SPECIES OF LAMINARIACEAE FOUND AT VARIOUS DEPTHS

Species	Depth (fathoms)	Mean number of plants per sq yd			Mean weight per plant (lb)			
		L.W.M.O.S.T.	1952	1953	1955	1952	1953	1955
<i>Laminaria cloustoni</i>	0		6.1	7.1	6.1	2.2	1.2	1.2
	1		5.6	7.6	8.0	2.0	1.2	1.3
	2		4.6	10.6	9.1	2.5	1.0	1.4
	3		5.3	7.9	8.2	2.3	1.3	1.3
	0-3 as a whole		5.5	8.1	7.5	2.2	1.1	1.3
<i>Laminaria digitata</i>	0		4.0	5.0	5.1	2.3	1.1	1.0
	1		4.9	4.9	4.5	2.1	2.0	1.5
	2		6.0	5.4	7.1	1.8	2.1	1.6
	3		7.3	5.3	2.0	2.0	2.7	1.0
	0-3 as a whole		5.5	5.1	5.8	2.0	1.9	1.4
<i>Laminaria saccharina</i>	0		8.0	4.9	6.2	1.0	0.6	0.5
	1		7.8	5.0	6.9	1.0	0.6	0.4
	2		4.8	6.7	7.6	1.0	0.7	0.6
	3		6.3	7.5	7.2	0.9	0.6	0.6
	4		6.5	6.8	7.4	0.8	0.6	0.6
	5		5.6	6.3	7.0	0.8	0.5	0.5
	6		4.9	5.7	6.6	0.8	0.5	0.5
	7		3.8	4.7	5.6	0.8	0.5	0.6
	8		3.3	4.2	5.1	0.8	0.5	0.4
	9		2.9	4.1	4.6	0.8	0.5	0.4
	10		—	3.5	4.1	—	0.6	0.5
0-9 as a whole		5.3	5.9	6.7	0.8	0.6	0.5	

1951, when the crop was declining, these coefficients were of less value, whereas during 1955, when the crop was recovering, they were of greater value. A declining laminarian crop also loses its variability while a recolonising crop gains variability as more generations appear. These crop changes fit into the ecological pattern found around Scotland during the last ten years, the general trend of which indicates an eleven-year cycle with logarithmic annual change; this cycle coincides with that of the sun-spot activity (Walker, 1956).

The seaweed cover of the above surveys and the incidence of strong gales in the Orkney-Shetland area have been found to be related mathematically; this may serve as a pointer in future research.

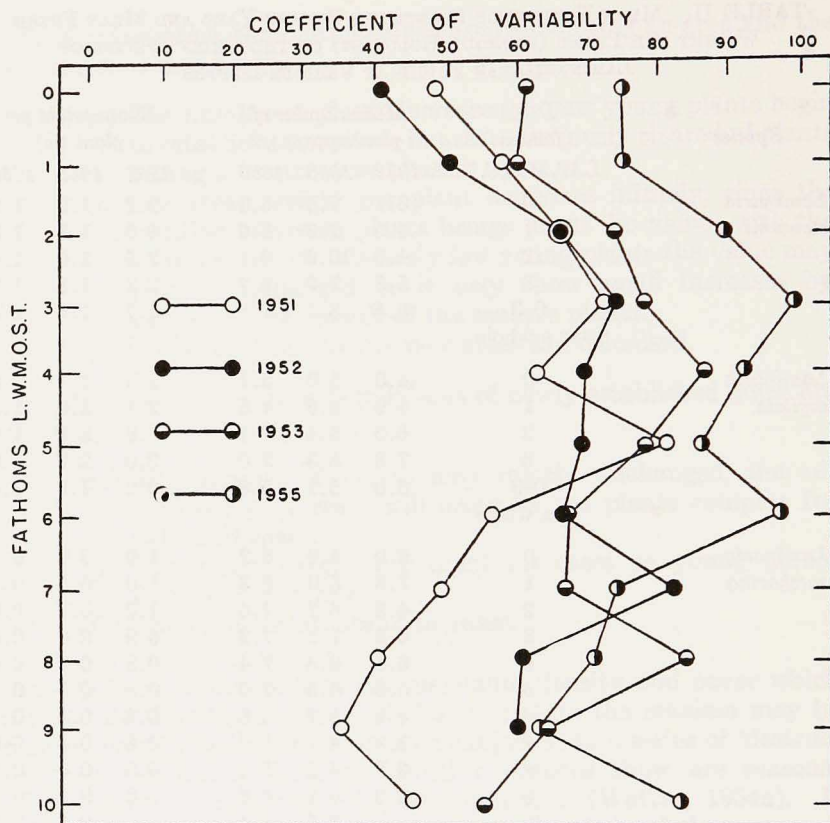


Figure 5

### ACKNOWLEDGMENTS

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