ISSN 0071 - 5638

PROSJEKTRAPPORT

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INSTITUTE OF MARINE RESEARCH

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Distribusjon:
Open

HI-prosjektnr.:
10237

Oppdragsgjevar(ar):
Laboratories Goemar SA

Oppdragsgjevars referanse:

Dato:
14. juni 2004

Program:

Forskingsgruppe:
FG-3

Tal sider totalt:
20

Rapport:
FISKEN OG HAVET

Nr. - År
11 - 2004

Tittel (norsk/engelsk):
Biomassekartlegging av Laminaria digitata i Smøla-området/
Biomass survey of Laminaria digitata in the Smøla area

Forfattar(ar):
Kjersti Sjøtun, Bernt R. Olsen & Sarah F. Eggereide

Samandrag (norsk):
Biomassetettleiken av fingertare (Laminaria digitata) vart undersøkt på tilsaman 28 stasjonar i Smøla-området (Møre og Romsdal). Det vart funne mest fingertare i dei ytre og mest bølge-eksponerte delane av området, der biomassen varierte mellom 10 og 20 kg ferskvekt pr m2. Fingertare-biomassen pr m strandline vart berekna til å vera omlag 40 kg i dei ytre og mest bølge-esponerte områda.
Alder og storleik til fingertare-planter vart undersøkt på to stasjonar. Maksimums-alderen var 5 år, og hovudmengda av plantene var mellom 1 og 3 år gamle.

Summary (English):
The biomass density of Laminaria digitata was examined on a total of 28 stations in the Smøla area (the county of Møre og Romsdalen). The highest abundance of L. digitata was found in the outer-most and most wave-exposed part of the area, where the biomass normally varied between 10 and 20 kg per m2. The biomass per metre shoreline was estimated to around 40 kg i the outer and most wave-exposed areas.
Age and size of plants were examined at two stations. The maximum age recorded was 5 years, and the main part of the plants were 1-3 years old.

Emneord (norsk):	Subject heading (English):
1. Laminaria digitata	**1.** Laminaria digitata
2. Biomassekartlegging	**2.** Biomass survey
3. Populasjonsstruktur	**3.** Population structure

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prosjektleiar

forskingsgruppeleiar

BIOMASS SURVEY OF *LAMINARIA DIGITATA* IN THE SMØLA AREA

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Preface

In 2003 an inquiry was directed from Laboratories Göemar SA (France) to the Institute of Marine Reseach about undertaking a survey of *L. digitata* biomass density in the Smøla area in northwestern part of South-Norway. The main objective of the survey was to give an overview of the *L. digitata* biomass in the area, for the purpose of harvesting. The Göemar project is part of a European Programme; "Development of a new co-extraction process of polymers issuing of seaweed", where utilization of *L. digitata* from Norway is a subject.

Kjersti Sjøtun (senior scientist) and Bernt R. Olsen and Sarah F. Eggereide (master students at the University of Bergen) carried out the field work at Smøla during July and August 2003. We are very grateful for help from John Watten, who helped us with the facilities at Smøla.

Summary and conclusions

The biomass density of *L. digitata* was investigated at a total of 28 stations west and northwest of the Smøla island on the northwestern coast of South-Norway. The stations were situated from the inner and most sheltered area to the outer and most wave-exposed area. The highest occurrences of *L. digitata* in the Smøla area were found in the outer and most wave-exposed parts of the area investigated, where *L. digitata* constituted the dominating vegetation in the lower littoral/upper sublittoral zone. Samples were normally taken from the middle part of the *L. digitata* zone. Biomass density at the stations dominated by *L. digitata* vegetation varied from 4.3 to 20.2 kg per m^2, when sampled in the middle part of the *L. digitata* zone. Except from at four of these stations the recorded biomass varied between 10 and 20 kg per m^2. The amount of *L. digitata* biomass at a site is dependent upon biomass density and width of the *L. digitata* zone. Calculated biomass per metre shoreline at the outer and wave-exposed stations dominated by *L. digitata* vegetation varied between 20 and 81 kg wet weight, and was on average around 40 kg per metre shoreline. However, the length of shoreline with dominating *L. digitata* vegetation is not known.

The *L. digitata* plant density was generally high, and very high at some of the outer and most wave-exposed atations. Age and size (weight) of *L. digitata* were investigated at two stations. Total sampling area for this purpose at each station was 0.75 m^2. Maximum age recorded of *L. digitata* was 5 years, and at both stations young plants (1-3-years-old plants) dominated. At the station with the highest density of large plants the youngest plants were significantly smaller than those of the other station, suggesting suppressed growth. The results indicate that regrowth of *L. digitata* after harvesting will probably be high provided that there is sufficient recruitment.

List of Content

Introduction

Distribution and biology of *Laminaria digitata*

L. digitata (Hudson) J.V. Lamouroux is distributed in the North-Atlantic, from the Arctic (78-79 ^{o}N) in the north to the coast of Brittany (46 ^{o}N) on the eastern side and to Cape cod (41 ^{o}N) on the western side of the North-Atlantic (Lüning 1990). The southward extension of *L. digitata* on the eastern side of the North-Atlantic is probably limited by reduced maturation of gametophytes in winter temperatures higher than 10 ^{o}C, while high summer temperatures limit the southward distribution on the western side of the North-Atlantic (Hoek 1982).

L. digitata has a heteromorph diplohaplontic life cycle with a microscopic gametophyte generation and a macroscopic sporophyte generation. Spores are reported to be produced by the sporophytes during late summer and autumn in the Barents Sea (Schoshina 1998) and twice per year at the French coast, during early summer and late fall (Pérez 1969). Sporophytes up to 10 years old are reported from Iceland (Gunnarsson 1990), and up to 7 years old from Hordaland, western Norway (Olsen et al. in prep.). In mature sporophytes the seasonal growth has been reported to be high during late winter and early summer in Norway and France (Sundene 1964, Pérez 1969), or during spring and summer in Iceland (Gunnarsson et al. 1998), and low during the rest of the year.

In the Arctic and on the western side of the North-Atlantic *L. digitata* grows mixed with other kelp species in the sublittoral zone, or it forms monospecific sublittoral kelp beds in wave-exposed areas (Schoschina 1998, Chapman & Johnson 1990). On the eastern side it is mainly limited to a narrow horizontal band in the upper sublittoral and lower littoral zone, normally not exceeding 2 m in the vertical in Norway. However, in France *L. digitata* has been reported to grow to 10 m depth (Gayral 1966 in Briand 1991). The cause of the exclusion of *L. digitata* in the deeper parts of the sublittoral on the eastern side of the North-Atlantic is the dominance of *L. hyperborea*, which outcompetes *L. digitata* (Kain 1979).

In Nova Scotia (Canada) biomass density (standing crop) of *L. digitata* is reported to reach 2-3 kg wet weight per m^2 in the sublittoral (Smith 1985, 1986), while in Iceland biomass densities of up to maxima of around 7 and 15 kg wet weight per m^2 were recorded from two localities respectively (Gunnarsson 1990). *L. digitata* is generally known to have the highest occurrence in relatively wave-exposed areas in Norway, but there is little information of biomass density here. In a study of *L. digitata* in a restricted area on the west coast of South-Norway Olsen et al. (in prep.) found biomass densities of up to 16 kg wet weight per m^2 in the zone of maximum abundance in the littoral/shallow sublittoral zone. Grenager (1964) found up to 38 kg per m^2 in the littoral/shallow sublittoral zone in Mid-Norway.

Utilization and harvesting

L. digitata has been harvested for different purposes in several countries around the North-Atlantic. In EU, about 60 000 tons per year are harvested in France for alginate production (Kaas 1998), while only small amounts are harvested in Ireland for food (Guiry & Hession 1998). In France, it is reported that the annual landings have decreased, in spite of increased harvesting capacities (Arzel 1998 in Billot et al. 2003). This suggests that harvesting of *L. digitata* populations may not be sustainable, perhaps due to lack of sufficient recruitment. A study of genetic differentiation of *L. digitata* populations in the English Channel suggests that spores of *L. digitata* may have a limited range of dispersal, but fertilization is probably random within an area of at least 50 m^2 (Billot et al. 2003).

Outside EU, a small amount of *L. digitata* is harvested for various purposes in Iceland (Gunnarsson et al. 1998). *L. digitata* was earlier utilized for fodder in Norway, and on the western coast of South-Norway it was also harvested for industrial purposes (alginate production) during the 1960ies and 1970ies. It was cut by hand, and harvested along most of the outer parts of the coastline from the county of Rogaland in the south to Sør-Trøndelag in the north. The centralmost area for harvesting was at the northwestern part of South-Norway. Here the coastal landscape is relatively flat and with numerous islands and skerries where *L. digitata* could be harvested in the lowermost part of the littoral zone during low tide. The industrial utilization of *L. digitata* ceased in Norway when the harvesting of *L. hyperborea* for alginate production was intensified during the 1970ies.

Objective of the present investigation

This investigation was carried out in order to undertake a survey of *L. digitata* biomass density in the Smøla area in northwestern part of South-Norway, in case of a possible new upstart of harvesting in this area. The purpose of the survey was to establish in which parts of the area the occurrences of *L. digitata* were at their highest, and the range of biomass densitiy in the area. Also, age and size composition of *L. digitata* populations were to be recorded, and in addition, a study of regrowth was started up in the area. It is necessary to obtain information about age composition and regrowth capacity before regular harvesting can start up, since prompt population restoration of the *L. digitata* vegetation is essential for sustainable harvesting.

Materials and methods

The study area

The examined stations were situated on the western – northwestern side of the Smøla island (63°20' N – 63°30' N) (Figure 1). This is an area with many small islands and skerries, situated in shallow areas separated by channels with deeper water. A biomass survey of *L. digitata* at a total of 28 stations was carried out. The main part of the stations were pre-selected within three subjectively defined areas with different degree of wave-exposure. The innermost area closest to Smøla is most sheltered from wave-exposure, since numerous islands and skerries are situated around Smøla. The outhermost island are most exposed to waves, and the coastline of the intermediate islands and skerries generally is exposed to intermediate degrees of wave-exposure. However, especially in what was defined as the intermediate area the degree of wave-exposure could vary very much, from nearly fully exposed to waves from open sea on one side of an island to nearly fully protected from any wave action on the other.

Field work

The field work was carried out at low water during two periods of spring tide from 25 July to 13 August 2003. The work was done both at morning and afternoon low water. Only stations with solid rocky substratum with an estimated overall slope of not more than 30° were accepted.

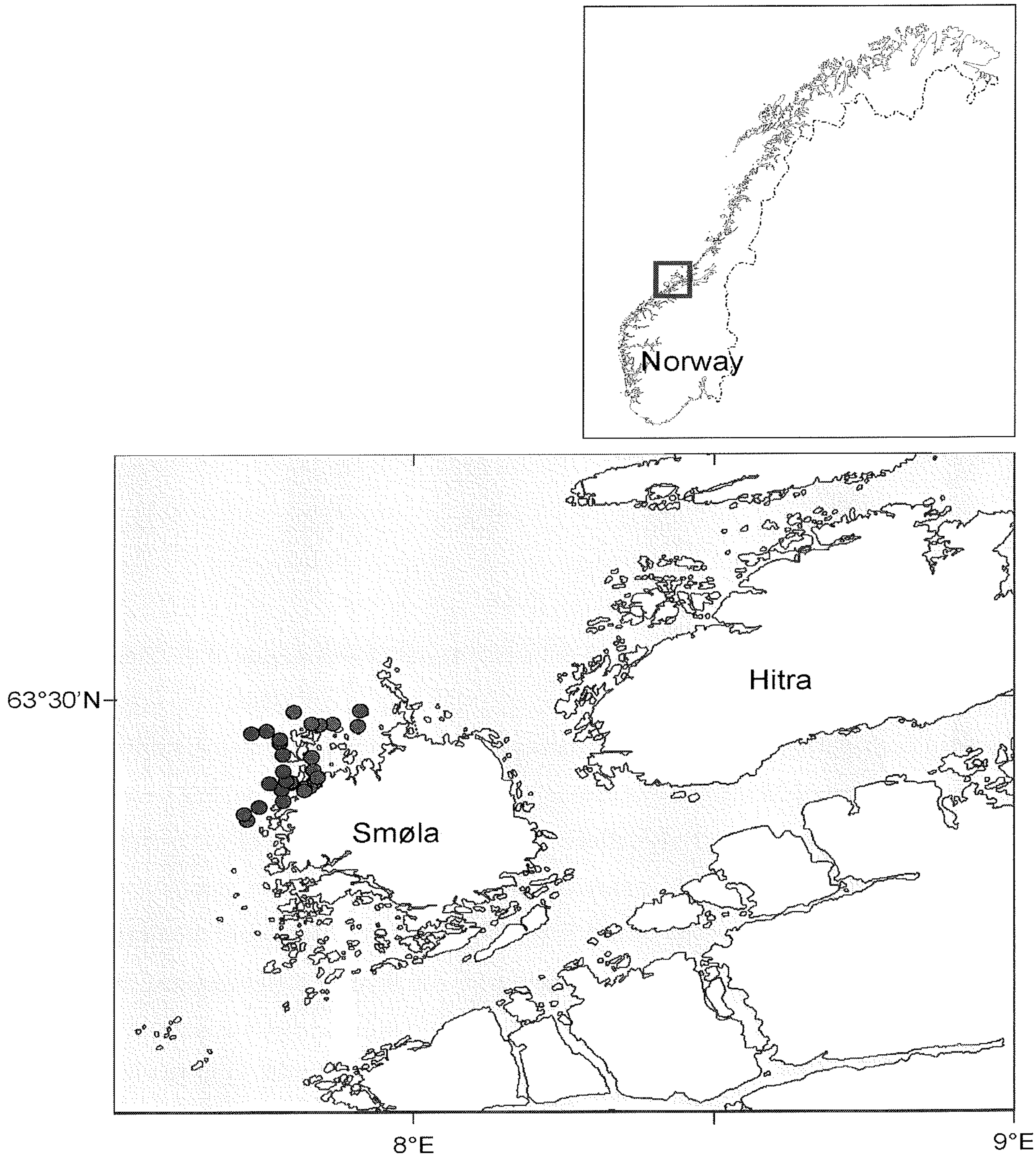

Figure 1. The location of the 28 stations included in the biomass survey northwest of Smøla, Norway.

The position of each station along the shore was defined by a rope, 20 m long, placed parallel to the shoreline in the middle part of the littoral zone. The dominating vegetation of large, brown algae in the lower part of the littoral zone was recorded. The width of the *L. digitata* zone, if a clear zone was present, was measured at three points along the rope, at each end and in the middle. The average of the three measurements was registered. On sheltered or semi-exposed stations there was normally no distinct *L. digitata* zone at all. The rope was marked every second metre, and samples of the *L. digitata* vegetation were taken by placing a sampling square (0.25 m^2) under each mark along the rope within the *L. digitata* vegetation, comprising a total of 10 samples per station. The extent of the submerged area with *L. digitata* vegetation at low tide varied much from station to station, and depended to a great extent on the degree of wave-exposure. At semi-exposed stations dominated by *F. serratus* all sampling was normally done from the sea-side, by using skin-diving equipment. At the most exposed stations most of the zone was above the low tide level, and sampling was done from the shore. The sample squares were in either case placed around the middle level of the *L. digitata* zone or the area where *L. digitata* grew, except from at three stations (Stns. 8, 18 and 26). At these stations the main part of the zone was submerged at low water, but the sampling was done from land, and consequently the samples were taken in the upper part of the zone.

All *L. digitata* plants with the more than half of the hapteron attached to the rock within each of the sampling squares were removed, by cutting the stipes with a knife above the haptera. All plants from each sample square were collected in a bag, weighted to the nearest 50 g wet weight by using a spring balance, and counted on the shore. All plants longer than about 5 cm were removed in the sample squares.

At two stations (Stations 19 and 24) samples was collected for age determination. All *L. digitata* plants collected in three randomly chosen sample squares of 0.25 m^2 per station were examined. Each plant was weighted to the nearest g wet weight by using an electronic scales, and age determined by counting growth rings of the stipe.

At three stations (close to Station 11, Station 12 and Station 26) the *L. digitata* zone was cleared in strips along the shore. All large *L. digitata* plants down to about 10 cm length were removed in the cleared strips. Occasionally some larger plants may have been left in the cleared strips. Other large brown algae occurring within the *L. digitata* zone, e.g. *Fucus serratus* and *Alaria esculenta*, were not systematically removed. The length of the cleared strip varied. It was about 20 m at Station 26, about 50 m at the station close to Station 11, and about 60 m at station 12. The purpose of the clearing of the *L. digitata* zone was to provide an opportunity to examine the regrowth of the *L. digitata* vegetation. By sampling the regrowth vegetation at regular intervals along the cleared strip, and at various distances from the unharvested and spore-producing *L. digitata* vegetation at the edges, it can be examined if the rate of regrowth is dependent on the distance to the unharvested and spore-producing *L. digitata* vegetation.

Results

Biomass estimates

A view of two selected Stations is shown in Figur 2. The uppermost picture in Figur 2 shows Station 6, which is dominated by *Fucus serratus* vegetation in the littoral zone, and the lowermost picture shows Station 15, which is dominated by *L. digitata* vegetation.

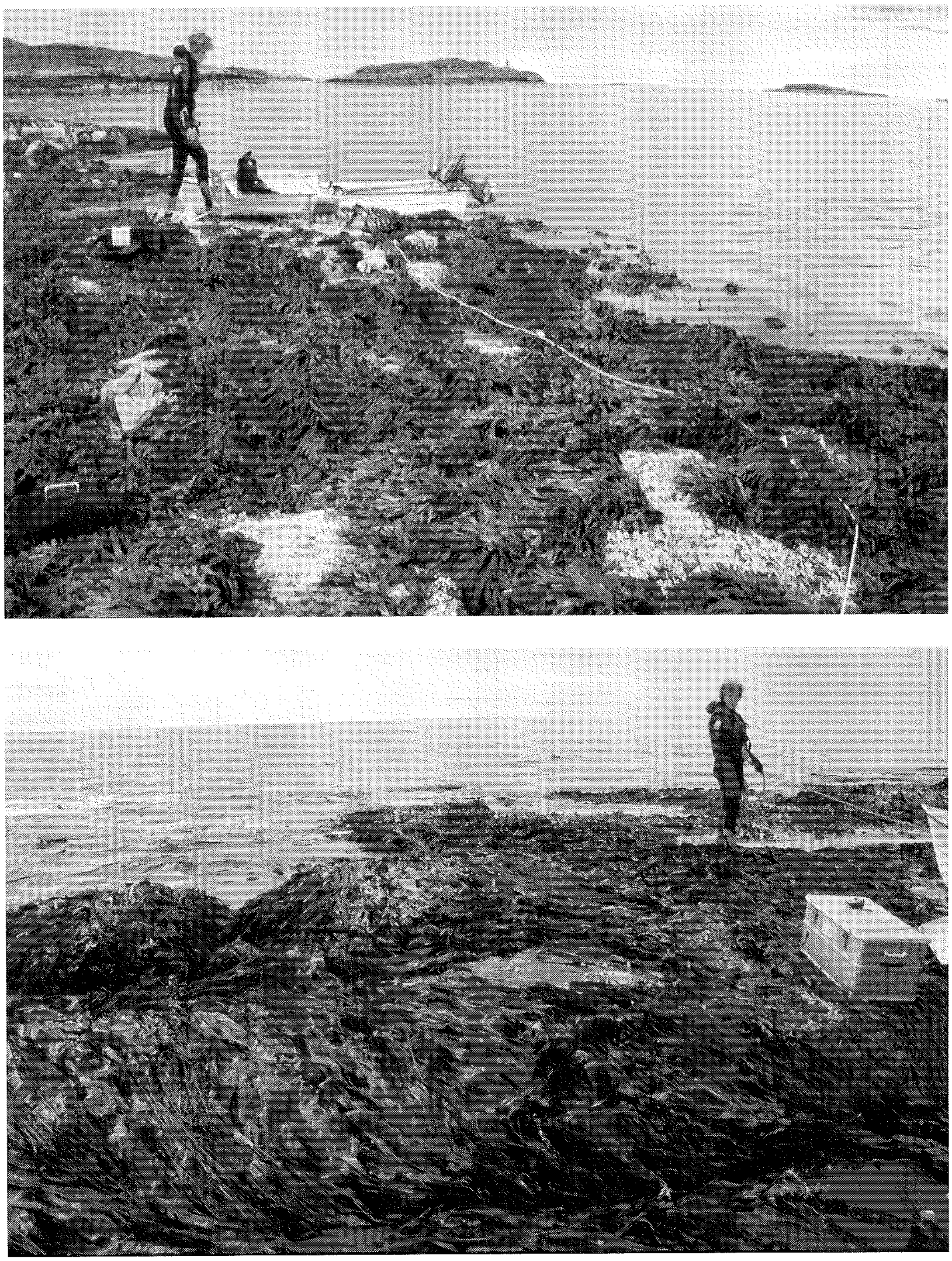

Figure 2. A view of Station 6 (uppermost picture) and Station 15 (lowermost picture).

Table1. Position (°N and E) of Stations 1-28, average biomass (kg wet weight) per m², standard deviation (n=10) and width of *L. digitata* zone in m (- not measured or no zone). Dominating vegetation in lower part of littoral zone: 1 *Ascophyllum nodosum*, 2 *Fucus serratus* with patchy occurrence of *L. digitata*, 3 *L. digitata* with patchy occurrence of *Fucus serratus*, 4 *L. digitata* with patchy occurrence of *Alaria esculenta*. Main direction towards the seaside is given for each station.

Position (N/E)	Station no	Biomass ($kg*m^{-2}$)	Standard deviation	Width of zone (m)	Dominating vegetation	Direction
63 25.7/ 07 47.7	1	6.32	5.44	1	2	SW
63 25.7/ 07 47.7	2	5.32	4.30	-	2	W
63 26.3/ 07 50.0	3	0.76	1.29	-	1	W
63 27.0/ 07 49.8	4	0	0	-	1	W
63 23.8/ 07 43.4	5	19.8	15.10	1.5	4	NE
63 24.8/ 07 47.0	6	8.84	6.06	-	2	W
63 25.4/ 07 46.8	7	5.48	6.61	-	2	W
63 25.7/ 07 45.6	8	14.12	6.41	2	4	SW
63 25.8/ 07 47.3	9	11.04	8.62	-	2	SW
63 26.3/ 07 47.0	10	12.88	11.38	-	3	SW
63 28.7 /07 51.9	11	14.4	9.78	4	4	N
63 28.6/ 07 50.6	12	20.24	10.83	4	4	N
63 28.3/ 07 45.3	13	4.28	2.85	5	4	W
63 28.2/ 07 43.8	14	8.44	5.99	5	4	W
63 27.7/ 07 46.6	15	10.08	7.43	2	4	S
63 27.9/ 07 46.6	16	10.52	10.68	3	4	W
63 29.3/ 07 48.0	17	6.36	5.21	6	4	S
63 29.3/ 07 54.7	18	10.44	7.69	2	4	W
63 28.6/ 07 54.4	19	12.12	10.69	-	4	W
63 25.7/ 07 50.0	20	0	0	-	1	E
63 25.5/ 07 49.6	21	0	0	-	1	W
63 25.4/ 07 49.1	22	0	0	-	1	W
63 25.3/ 07 49.1	23	0	0	-	1	W
63 28.7/ 07 49.8	24	19.2	9.30	4	4	S
63 26.0/ 07 50.4	25	0	0	-	1	W
63 27.1/ 07 46.9	26	18.4	10.82	3	3	NW
63 24.1/ 07 43.1	27	5.96	3.34	10	4	W
63 24.5/ 07 44.6	28	10	11.05	2	2	E

The position of each investigated station and an overview of the biomass results are shown in Table 1. Average biomass of *L. digitata* at the stations varied between 0 and 20.3 kg per m². The results show that the standard deviation was also quite extensive at most of the localities with *L. digitata* vegetation. Since there is a well-known connection between the degree of wave-exposure and the resulting dominating littoral fucoid community on European shores, the stations were categorized according to the recorded dominating vegetation of large, brown algae in the lower part of the littoral zone (Table 1). Four of the stations (Stations 20, 21, 22 and 23) with dominating *Ascophyllum nodosum* vegetation were situated in what was originally selected as the innermost area, and three stations (Stations 3, 4 and 25) in the middle area. The stations with dominating *Fucus serratus* vegetation were situated in the middle area (stations 1, 2 and 6) and the outermost area (Stations 7, 9 and 28). At these stations *L. digitata* was normally not present in a distinct zone, but appeared in patches within the *F. serratus* vegetation. Of the remaining stations with dominating *L. digitata* vegetation in the littoral zone, one station (station 19) was situated in the middle area, while the others (Stations 5, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 24, 26 and 27) were all situated in what was originally defined as the outer and most wave-exposed area.

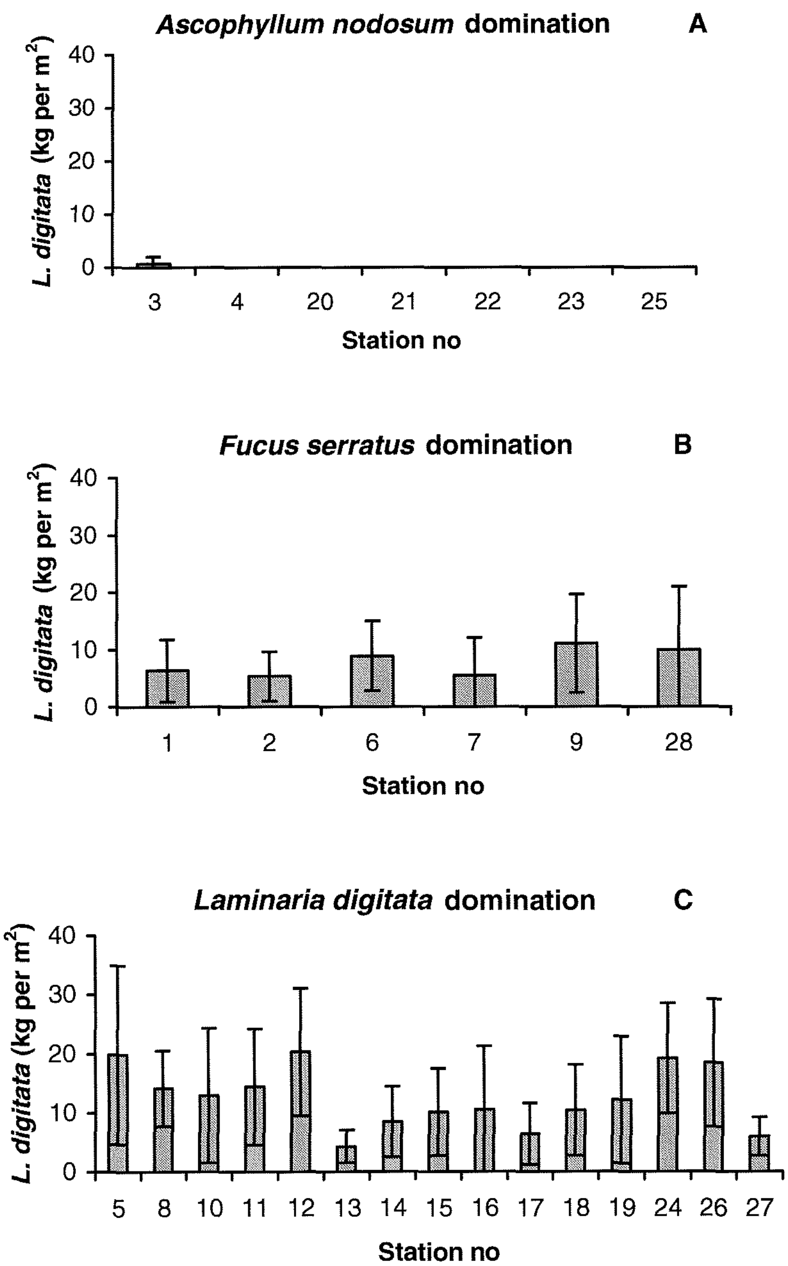

Figure 3. Average biomass of *L. digitata* (kg wet weight per m^2) with standard deviation (n=10) at the examined stations. A: Stations dominated by *Ascophyllum nodosum*, B: Stations dominated by *Fucus serratus*, C: Stations dominated by *L. digitata*.

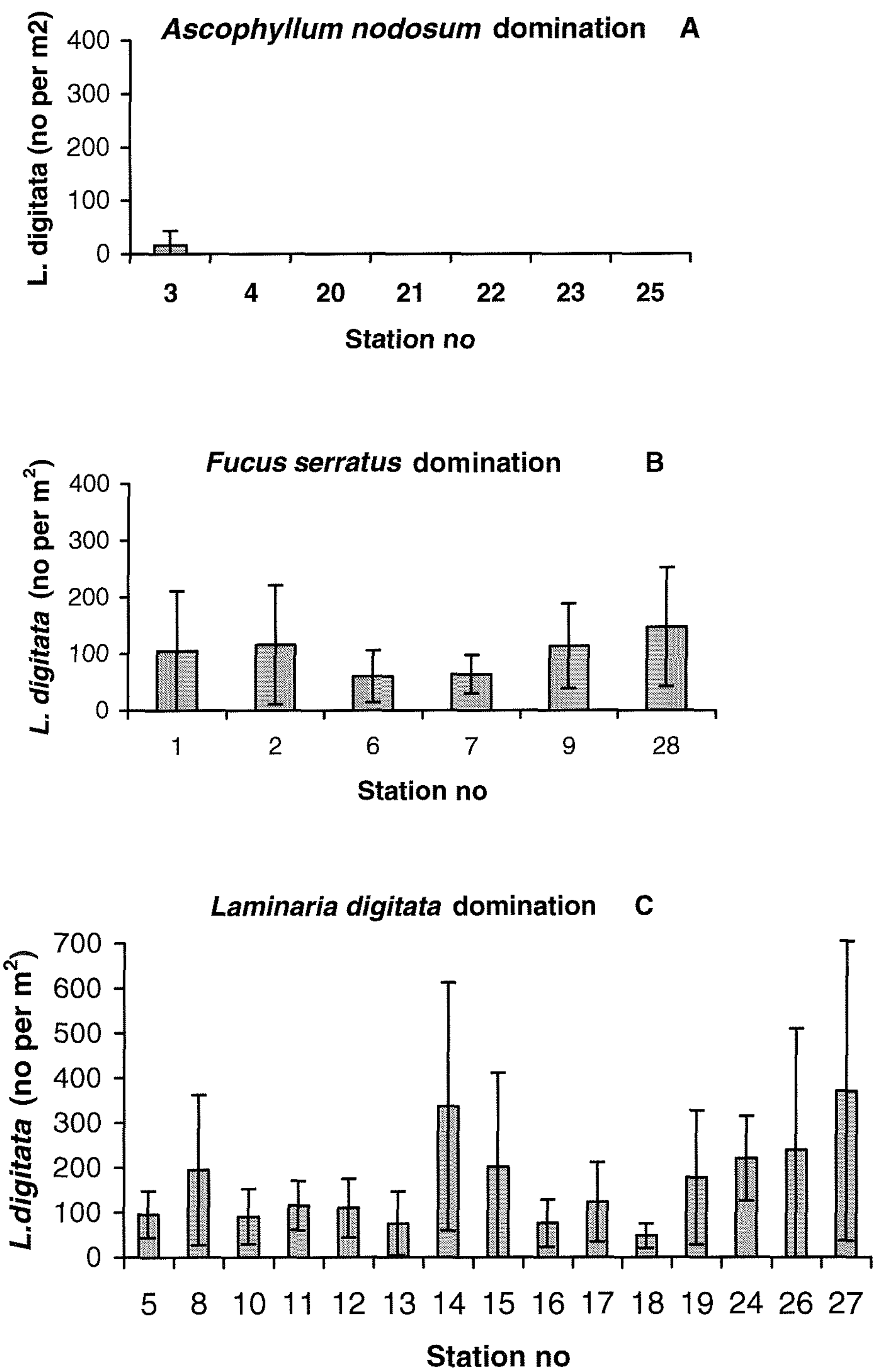

Figure 4. Average density of *L. digitata* (no per m^2) with standard deviation (n=10) at the examined stations. A: Stations dominated by *Ascophyllum nodosum*, B: Stations dominated by *Fucus serratus*, C: Stations dominated by *L. digitata* (note the different scale of y-axis in C).

The average biomass values of *L. digitata* (kg wet weight per m^2) at the stations are shown in Figure 3. The stations are grouped according to the dominating vegetation of large, brown algae. No or very little *L. digitata* was recorded at the stations dominated by *Ascophyllum nodosum* (Figure 3A). At the stations dominated by *Fucus serratus* between 5 and 11 kg *L. digitata* per m^2 was recorded in the zone with most *L. digitata* (Figure 3B) However, at these stations there was no clear zone with *L. digitata*, or if a zone could be detected, it was only 1-2 m wide (Table 1). At the stations dominated by *L. digitata* the recorded biomass of *L. digitata* in the middle part of the *L. digitata* zone varied between 4 and 20 kg per m^2 (Figure 3C). However, only four of these stations had *L. digitata* biomasses lower than 10 kg per m^2, and at the rest (11 stations) the biomass varied between 10 and 20 kg per m^2. The width of the *L. digitata* zone varied between 1.5 and 10 m at the stations in this category.

Average density of *L. digitata* plants (with lengths more than 5 cm) at the examined stations is shown in Figure 4. The stations are grouped according to dominating vegetation in the same way as in Figure 3. The plant density is around 100 plants per m^2 in most localities with *Fucus serratus* domination and *L digitata* domination (Figure 4B and C), but higher at some of the localities with *L. digitata* domination, where an average density of between 300 and 400 plants per m^2 were recorded at two stations (Station 14 and 27) (Figure 4C).

Age and size composition

At two of the localities dominated by *L. digitata* vegetation (Stations 19 and 24) age and size composition of *L. digitata* sampled from the middle part of the zone were recorded. Maximum age recorded was 4 years at Station 19 and 5 years at Station 24 (Figure 5). At Station 19 a total of 84 plants were age determined, comprising seven 0-year-old plants, 41 1-year-old-plants, 21 2 year-old-plants, ten 3 year-old-plants and five 4 year-old-plants. At station 24 a total of 171 plants were age determined, and the results showed nine 0-year-old plants, 42 1-year-old plants, 55 2-year-old plants, 48 3-year-old plants, 15 4-year-old plants and two 5-year-old plants. The size of the sample area was 0.75 m^2 at both stations. At Station 19 the 1-year-old plants was thus the dominating age group, and constituted about 50 % of the plants in the sample. At Station 24 a more even-aged *L. digitata* population was recorded . Here, the sample was dominated by about similar amounts of 1 – 3-year-old plants (Figure 5).

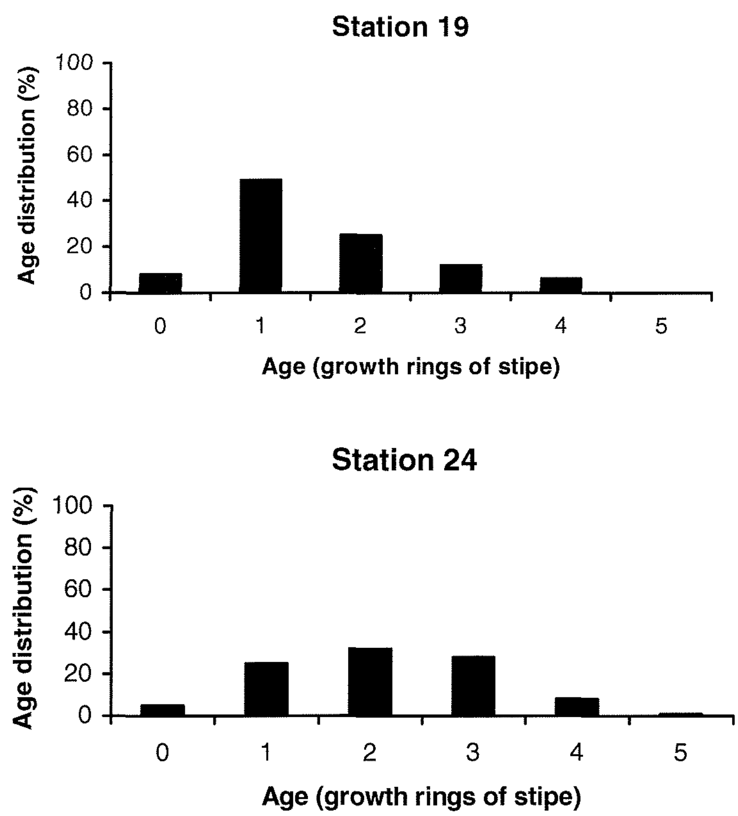

Figure 5. Age distribution (age determined by counting growth rings of stipes) of *L. digitata* samples from Station 19 and 24.

The size composition of the different age groups at the two stations is shown in Figure 6. An average maximum weight of between 250 and 300 g wet weight of 4-year-old plants was recorded at both stations. The results from Station 19 show a nearly linear weight increase with increasing age, while at Station 24 the average weights of 1- and 2-year-old plants are lower than in similar age groups at Station 19 (Figure 6), resulting in a slightly more sigmoidal curve of weight development with increasing age at this station. At Station 19 the average weight of 2-year-old plants was around 100 g wet weight, while 2-year-old plants from Station 24 were around 60 g on average. Comparisons between the two stations of 1-year-old plants and 2-year-old plants in a students *t*-test showed that average weight of both 1- and 2-year-old plants were significantly lower at Station 24 that at Station 19 ($p<0.05$).

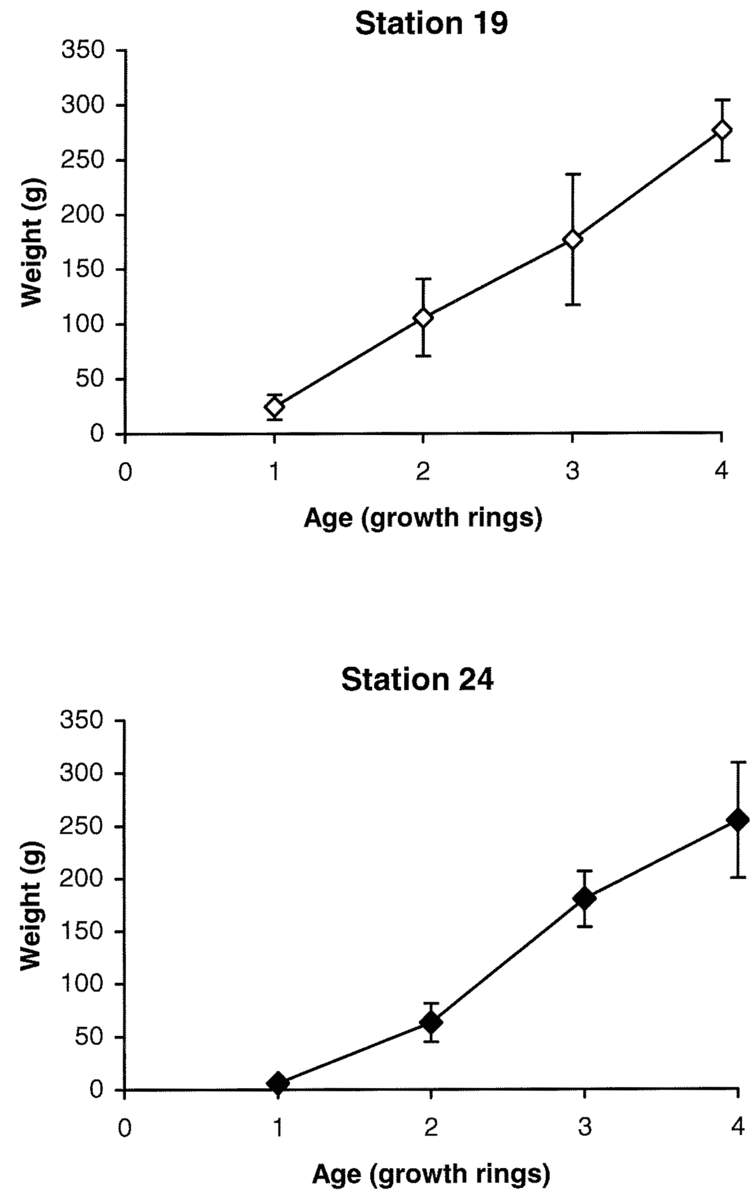

Figure 6. Average wet weight (g) with ± 95 % confidence limits of *L. digitata* samples from Station 19 and 24 in the age groups 1-4 years old.

Discussion

Biomass estimates

In the most sheltered areas *L. digitata* specimens with morphological features typically of plants growing in sheltered areas (wide, fragile lamina and short stipe) occasionally could be observed among other members of the *Laminaria* spp. in the sublittoral zone. However, the highest occurrence of *L. digitata* in the area was observed in the lower littoral zone – upper sublittoral zone. A clear connection between abundance of and degree of wave-exposure was found. In the most sheltered areas very little *L. digitata* was found, while the highest biomass densities were recorded at the stations situated in the outer and most exposed areas. Here, up to 20 kg per m^2 could be found in the lower littoral zone – upper sublittoral zone. Low abundance of *L. digitata* in sheltered areas in Norway have been reported earlier (e.g. Kain 1971).

Overall density of *L. digitata* per metre shoreline will depend on biomass density per area and width of the *L. digitata* zone. The width of the zone is in turn dependent on the vertical extension of the *L. digitata* vegetation, and there was a tendency of an increasing vertical extension of the *L. digitata* zone with increasing degree of wave-exposure. However, the width of the zone is also strongly dependent on the local sloping of the landscape, which varied considerably both between the stations and locally at some of the stations. The average width of the *L. digitata* zone at the wave-exposed stations dominated by *L. digitata* vegetation varied from 1.5 to 10 m, and the average biomass density of *L. digitata* at these stations varied from 4.3 to 20.2 kg per m^2. Based on the figures from Table 1 the estimated biomass per shoreline varied between 20 and 81 kg per m shoreline at the investigated stations where *L. digitata* dominated in the lower part of the littoral, with an average of about 43 kg per shoreline. In a survey from Tustna (south of Smøla) Grenager (1954) recorded biomass densities of *L. digitata* from 5.6 to 30 kg per m^2. In a survey from Froan, some distance north of the Smøla area, Grenager (1964) found *L. digitata* densities of between 13 and 39 kg per m^2. The *L. digitata* biomass per shore metre was calculated to vary between 14 and 81 kg (Grenager 1964), which is in the same range as calculated from the Smøla area in the present investigation.

The *L. digitata* resource is thus estimated to be about 40 kg per shore meter in the outer and wave-exposed areas dominated by *L. digitata* in the Smøla area. The total length of shoreline dominated by *L. digitata* in the lower littoral zone in the Smøla area is not known. However, these calculations are based on biomass recordings mainly taken in the middle part of the *L. digitata* zone, and there may be variations in biomass density from upper to lower level within the zone. This will be a subject of further investigation. At three of the stations (Stations 8, 18 and 26) the samples were taken from the upper part of the zone, but the recordings did not vary substantially from those of the other stations, where the samples were taken in the middle part of the zone.

At most stations with *L. digitata* vegetation the biomass values were much higher than the biomass density reported for *L. digitata* in the sublittoral in Canada (Smith 1986). However, within the *L. digitata* zone at Smøla there were only minor amounts of other kelps, whereas in Canada *L. digitata* mostly grow together with *L. longicruris*. Competition with *L. longicruris* can partly explain why *L. digitata* occurred in lower biomass densities in Canada compared to this investigation, but we can not rule out that *L. digitata* may in general grow denser or better in the lower littoral/upper sublittoral zone than in the deeper waters. On the other hand *L. digitata* often occurred in relatively low densities when it grew together with *Fucus serratus* at the localities, and it can not be ruled out that lower biomass values at these stations are due to competition between *L. digitata* and *F. serratus*.

Age and size composition

The maximum age recorded in the sample from two stations was 5 years. Olsen et al. (in prep) found *L. digitata* up to 7 years old further south on the western coast of South-Norway. This suggests that *L. digitata* will normally not grow older than 5 – 7 years in this area. However, since we only have samples from the middle of the zone, we can not rule out that the vegetation has a different age composition in the upper and lower part of the zone.

The density of *L. digitata* plants, when present, was high at most localities in the present investigation, and it was very high at some of the localities where *L. digitata* dominated the vegetation in the lower littoral/upper sublittoral zone. The samples from the two stations with age and size investigations of *L. digitata* plants show that 1-3-year-old plants will normally dominate the vegetation in the middle part of the zone. In harvested *L. digitata* kelp beds in Nova Scotia Smith (1985) recorded pre-harvest biomass densities after two years. Regrowth after harvesting will probably be high also in Norway, provided that there is sufficiant recruitment, and biomass should be restored about 2-3 years after harvesting. Little is known about degree of recruitment of *L. digitata* in Norway. Printz (1959) noted that recruitment of *L. digitata* could vary substantially, and was particularly low during a warm and dry summer.

At the *L. hyperborea* fields it is demonstrated that the productivity increases after harvesting, since the large plants are shading the small understorey plants. After removal of the large *L. hyperborea* plants the understory plants increase their growth (Sjøtun et al. 1998). The results from the present study suggest that growth of small *L. digitata* plants may also be suppressed when growing under a dense layer of large plants, since 1- and 2-year-old plants from the station with the highest overall biomass density and density of large plants (3- and 4-year-old) (Station 24) were smaller than those from Station 19. This has earlier been demonstrated in an experimental study of *L. digitata* (Creed et al. 1998).

The low percentage of 0-year-old plants at both stations is probably due to the fact that the main part of the 0-year-old plants are too small to be sampled in the present study. It is also possible that some 1-year-old plants may have been left out of the samples, especially at Station 24 where the average size of the 1 year-old-plants was low.

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