Rope Culture of the Kelp *Laminaria groenlandica* in Alaska

ROBERT J. ELLIS and NATASHA I. CALVIN

Introduction

The brown seaweed or kelp, *Laminaria groenlandica*, which is abundant in the nearshore subtidal waters of southeastern and central Alaska, may have great potential for aquaculture. In Alaska, naturally occurring *L. groenlandica* is harvested in fisheries of Pacific herring, *Clupea harengus pallasi*, eggs on kelp in Prince William Sound. In British Columbia, *L. groenlandica* and another species of kelp, *Macrocystis integrifolia* (Fuoco, 1980), have been gathered and hung on ropes in ponds with spawning herring to produce herring eggs on kelp. *Laminaria groenlandica* is also a desirable sea vegetable having excellent texture and flavor in various cooked dishes. Similar species are commonly used in Japan and the U.S.S.R.

The use of naturally occurring *L. groenlandica* in herring-roe-on-kelp fisheries or as a vegetable has several disadvantages or limitations: 1) Collection requires much concentrated labor by divers, 2) continued collection poses threats to integrity of natural kelp forests (and herring stocks for roe on kelp), 3) natural kelp forests are limited in extent, and 4) kelp may be of poor quality when needed because of variations in condition of the plants due to age and seasonal changes. Techniques of rope culture have been developed for several seaweeds besides *L. groenlandica*, including other species of *Laminaria* (see Buyankina, 1977), but are intended for large-scale complex operations with seaweeds that have lower economic value than *L. groenlandica*.

As part of biological studies of naturally occurring kelp, we set out rope substrates and observed the *L. groenlandica* that set on the rope. This brief account of our experience could serve as a starting point for anyone interested in raising *L. groenlandica* on rope on a small scale in Alaska.

In this paper, we describe the placement of the ropes, time of first appearance of young *L. groenlandica*, size of the plants at various ages, and other life history features applicable to the use of rope for the culture of seaweeds in Alaska. Culturing of these plants results in more efficient use of labor and increased production of better quality *L. groenlandica* as a vegetable and for herring eggs on kelp. The rope system could be used to grow kelp in deep water by suspending the ropes from rafts and could greatly expand the kelp production in any bay. Additionally, portable substrates with "standardized" growths of young *Laminaria* could prove useful in studies of effects of pollution.

The general technique we describe for using rope as a substrate for raising *Laminaria* is simple. The ropes are seeded with young *Laminaria* by placing the ropes on the bottom near a kelp forest producing spores. The spores settle on the ropes, and eventually young *Laminaria* sporophytes develop. The young *Laminaria* soon attach firmly to the rope, which can then be moved to another site.

Robert J. Ellis and Natasha I. Calvin are with the Auke Bay Laboratory, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, P.O. Box 155, Auke Bay, AK 99821.

Study Area

Our study area is about 17 km north of Juneau, Alaska, at Coghlan Island (Fig. 1) on a north-facing shore exposed to moderate wave action and currents (Calvin and Ellis, In press). At this site, small dense forests of *L. groenlandica* grow on rocky outcrops from about −1 m to −10 m depths on the eastern and western sides of a sand beach and subtidal area.

Methods

We used scuba to install two ropes as substrate on the sand within about 15 m of the kelp forest. The ropes were ⅝-inch (16 mm) diameter nylon; each was 25 m long and, though they had been previously used, appeared to be clean. Flat rocks about 4 m apart held the ropes on the bottom. The ropes were parallel to each other and about 10 cm apart. After the ropes were in place, four 1 m sections of the ropes were marked to represent the four depth zones encompassed by the rope—shallow (−2 m), deep (−8 m), and two intermediate zones (−4 m, −6 m). We installed the ropes in August 1974 and examined them intermittently through March 1980. The abundance and size of *L. groenlandica* were determined to follow survival, growth, and maturation of the plants. Measuring techniques are described in Calvin and Ellis (In press).

Appearance, Growth, and Size of Young-of-the-Year and Yearling Plants

Young-of-the-Year Plants

In February 1975, about 6 months after the ropes were installed, we first saw small, flat, nearly circular brown blades on the ropes. The plants were one to a few millimeters in diameter and emerged on short stipes from a layer of debris, silt, diatoms, and other small algae that covered the ropes. By October 1975, about a year after installation of the ropes, we could plainly see which plants were *Laminaria* though we could not be certain of the species.

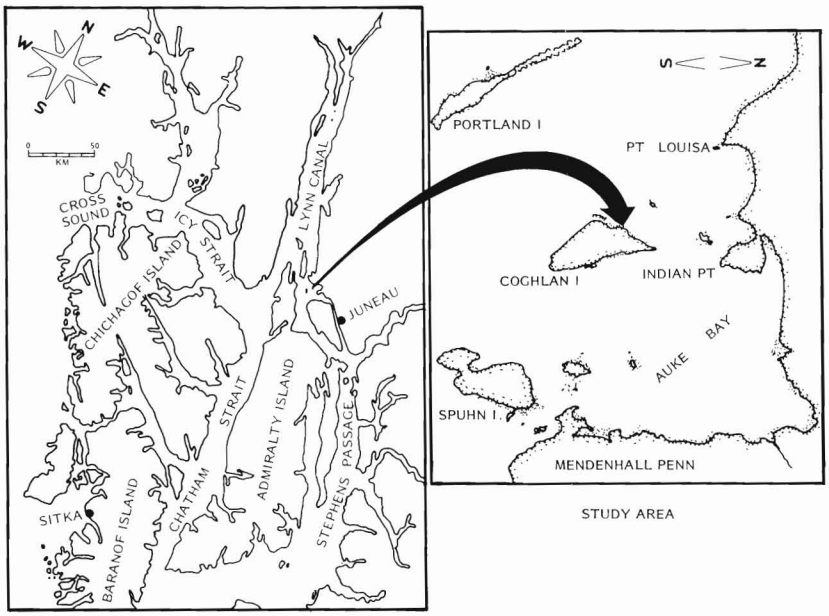

Figure 1. — Map of southeastern Alaska, showing location of kelp study area at Coghlan Island — 17 km north of Juneau.

Table 1. — Dimensions, mean ($\bar{x}$), standard error of the mean ($S_{\bar{x}}$), and range of *Laminaria groenlandica* at the end of their first summer of growth (22 October 1975) over a depth range of −2 to −8 m on a rope substrate in southeastern Alaska. These plants were subjectively selected as typical of their depth area of the rope and were measured in the laboratory.

Sample (shallow to deep)	No. of plants measured	Stipe length (cm)			Blade length (cm)			Blade width (cm)		
		$\bar{x}$	$S_{\bar{x}}$	Range	$\bar{x}$	$S_{\bar{x}}$	Range	$\bar{x}$	$S_{\bar{x}}$	Range
1 (−2 m)	3	0.5	0.0882	0.4-0.7	5.3	0.9018	3.5-6.3	3.0	0.8413	1.3-4.0
2 (−4 m)	8	0.6	0.09150	0.1-1.0	5.2	1.0269	0.3-8.7	2.7	0.6213	0.2-6.3
3 (−6 m)	9	0.8	0.09923	0.3-1.2	4.8	1.0896	1.3-10.3	3.1	0.5034	0.5-5.8
4 (−8 m)	9	0.7	0.1054	0.3-1.0	6.6	1.0776	2.0-11.0	3.3	0.5398	1.2-5.3

Ultimately, we determined that all the *Laminaria* growing on the ropes were *L. groenlandica*.

On 22 October 1975, we collected *Laminaria* from the ropes and measured, in the laboratory, plants that appeared to be typical of the four depth zones of the ropes. At the end of the first season of growth, size varied greatly (Table 1), as expected, probably because of differences in age (original settling of spores could differ by many weeks) and microhabitats on the ropes. Nevertheless, the average sizes of *L. groenlandica* for the four areas of the rope were quite similar — average blade length, for example, was 5.3, 5.2, 4.8, and 6.0 cm (from shallow to the deep end of the ropes).

Yearling Plants

In late winter 1976, the plants were well into their second season (growth begins in midwinter) and were growing rapidly. The plants had survived well and were much closer together on the ropes than plants on the nearby reefs — as many as 200 plants/m were on the ropes where the largest plants were found. There appeared to be a positive relation between large numbers and large size of plants. These yearling plants were growing faster than mixed-age plants on the reef — whether this is a function of age or lack of general shading or competition from older plants is not known. We tagged many individual plants on the ropes in January 1976 and measured them (Fig. 2) on 13 April and 5 May 1976, about the time Pacific herring, *Clupea harengus pallasi*, spawn locally. The sizes of the five largest plants measured each date (Table 2) illustrate the potential sizes obtainable for the date and location. On 14 April 1976, we collected and weighed (wet weight) two large plants — the new growth on the larger plant (from −2 m) weighed 153.5 g (14.3 g stipe, 139.2 g blade) and on the smaller plant (from −3 m) 90.6 g (9.6 g stipe, 81.0 g blade). If growing conditions were improved — for example, by holding ropes off the bottom several meters to prevent plants from lying on the bottom; by placing the ropes in areas of more current; or perhaps with very heavy seeding, by thinning of plants on the ropes — more of the larger plants would be likely.

In May, the yearling plants were still growing rapidly and were clear of most epiphytic plants and animals. The rapidly growing, very smooth surface of the plants is desirable for use as a vegetable but may be a poor surface for adherence of herring eggs.

Conclusions

The procedures described here for growing *Laminaria groenlandica* on ropes are simple and require use of divers at only certain stages. The likely steps and considerations in establishing and using rope substrates for kelp production are:

1) A suitable site for seeding the ropes with young kelp plants should be within, or near and downcurrent from, a mature kelp forest.

2) Ropes should be well secured to the bottom in late summer, late in the spore-producing season of the kelp (midsummer to late fall in the vicinity of this study), to reduce competition from other organisms for settling space on the ropes. The depth the ropes

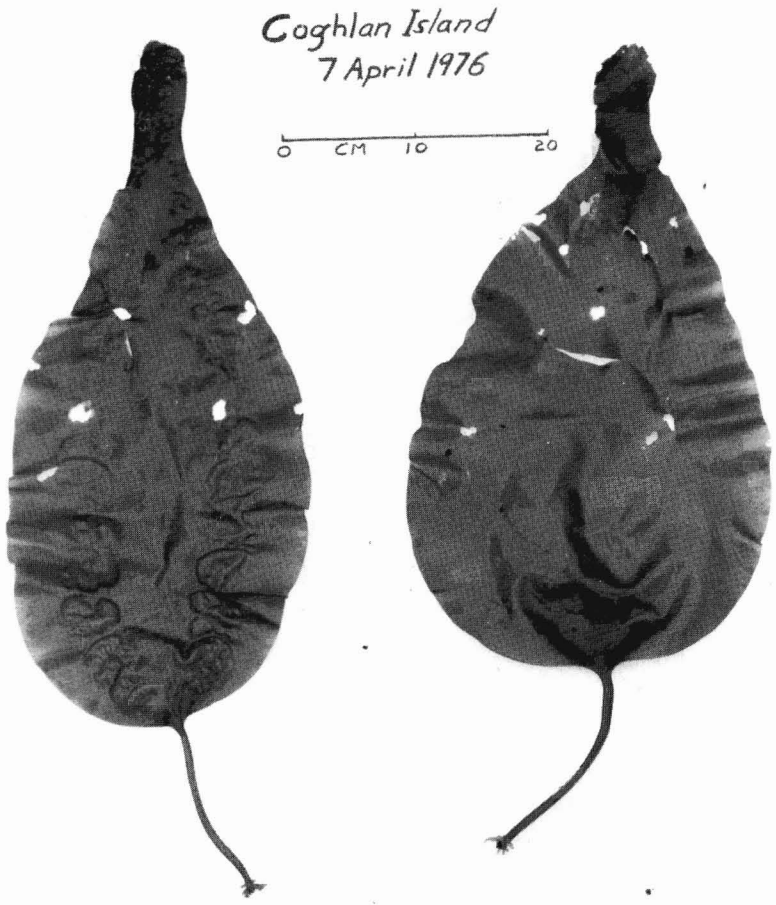

Figure 2.—Typical age 1 *Laminaria groenlandica* from rope substrate at Coghlan Island, 7 April 1976. These plants were growing very rapidly (about 1 cm/day). Pacific herring, *Clupea harengus pallasi*, spawn locally about the first of May.

Table 2.—Sizes of tagged yearling (age 1) *Laminaria groenlandica* on 13 April and 5 May 1976.

	Length of stipe (cm)		Length of new blade (cm)		Width of new blade (cm)		Total length (cm)		Growth of blade length
Tag	13 April	5 May	13 April	5 May	13 April	5 May	13 April	5 May	(cm/day)
Q	6	8	84	95	43	50	90	103	0.5
R	13.5	20	66.5	—	40	48	80	—	—
S	—	21	—	86	—	52	—	107	—
T	10	13	100	126	58	77	110	139	1.2
U	21	23	80	127	65	69	101	150	2.1
W	7.5	9	76.5	91	34	42	84	100	0.7

should be placed for obtaining a seeding of plants is not critical but should be well within the depths occupied by the mature spore-producing plants. However, if the ropes are not to be moved until the kelp is harvested, the ropes should be at the depth of best growth locally.

3) The first spring or summer after the ropes are emplaced, divers should inspect the ropes to determine whether small kelp plants are present.

4) At the end of this first summer, the ropes can be moved to a culture site. The plants should be kept cool and moist with seawater while being moved and should be returned to the water as soon as possible.

5) For use as substrate for roe on kelp, the ropes could be moved to herring ponds at the beginning of the second summer. For use as a vegetable, the plants could be inspected periodically to determine when they are most suitable for harvesting. *Laminaria* cultured on ropes could be used for bioassay at almost any time after the young plants are large enough to be readily counted and measured.

6) Most, if not all, the operations in culturing *Laminaria* on ropes could be done from boats; however, many of the operations could be facilitated by divers.

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