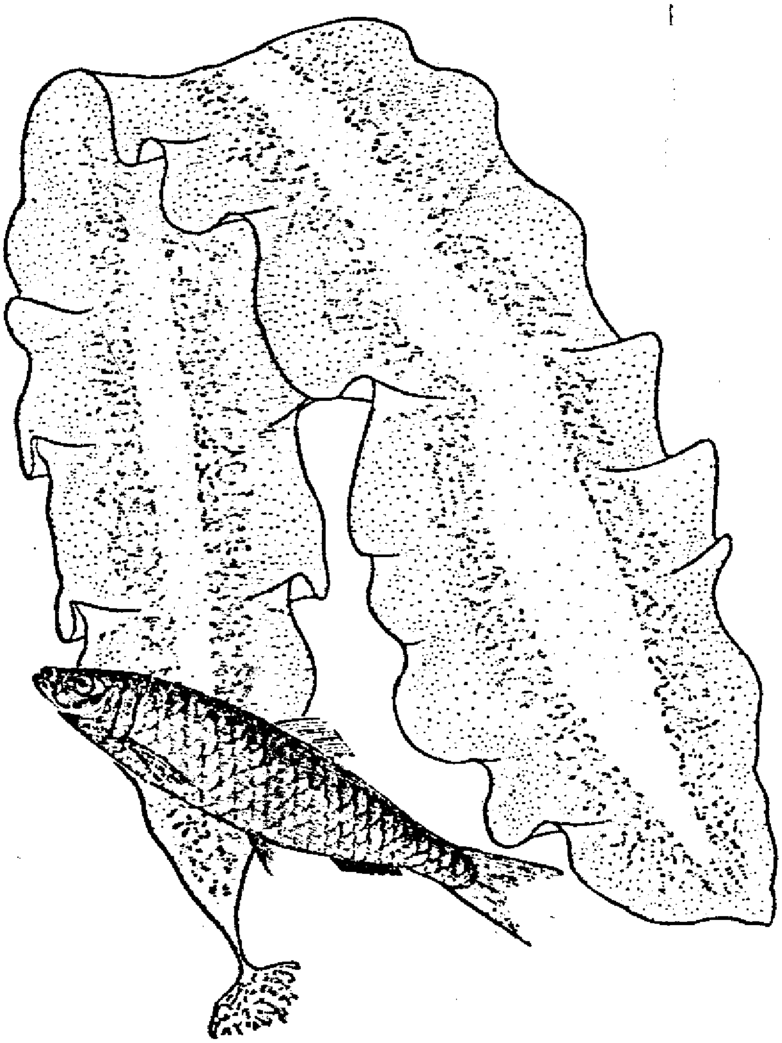
Alaska Sea Grant Program

Proceedings of the Herring Roe on Kelp Workshop



CORDOVA, ALASKA

JANUARY 23 and 24, 1979

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University of Alaska
Fairbanks, Alaska 99701

PROCEEDINGS

of

THE HERRING ROE ON KELP WORKSHOP

Brenda Melteff, Editor

Cordova, Alaska

January 23 and 24, 1979

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ACKNOWLEDGEMENTS

We would like to thank the following people for taking the time to attend the workshop and make their presentations: Ms. Frances Dickson, Canadian Fisheries and Marine Service, on the British Columbia herring roe on kelp fishery, Mr. Richard J. Rosenthal, Alaska Coastal Research, on the Prince William Sound herring/kelp fishery, Ms. Natasha Calvin, National Marine Fisheries Service, on growing kelp, Dr. John N. C. Whyte, Canadian Fisheries and Marine Service, on transporting kelp, Dr. Ronald L. Smith, University of Alaska, on herring biology, and Mr. Pete Fridgen, Alaska Department of Fish and Game, on management implications.

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TABLE OF CONTENTS

INTRODUCTION

The herring roe on kelp fishery in Prince William Sound fell from 417,000 pounds of natural harvest in 1977 to 140,000 pounds in 1978.

The Alaska Sea Grant Program was asked by the Alaska Department of Fish and Game and the fishermen of Cordova to assist in gathering available information on the herring roe on kelp fishery and to assist in the development of research programs to assist this fishery. As a part of this effort, on January 23 and 24, 1979 a workshop on the herring roe on kelp fishery was held in Cordova. A list of participants at the workshop is at the back of this proceedings.

This proceedings is the written account of the presentations from the workshop. There were similarities and dissimilarities identified between the British Columbian and Alaskan fisheries, the most prominent being as follows:

The British Columbian fishery which started in 1972 is being expanded slowly. Of concern was the fact that the Alaska product would compete with and flood the market of the British Columbian product. However, it is now evident that this will not occur. The main reason is that the product exported from British Columbia contains the seaweed *Macrocystis* and is sold for use in gourmet restaurants while the Alaskan product contains *Laminaria* and is sold at fish markets.

The difference in management of the two fisheries is pointed out in that British Columbia determines the total amount of product to be harvested, issues licenses to a number of individuals or cooperatives and divides the total poundage of product by the number of licenses giving each licensee an equal quota. The Alaska regulations call for a total determined poundage of product with licenses being issued to all requestors. Product in excess of the determined weight will be confiscated.

THE BRITISH COLUMBIA FISHERY

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The British Columbia herring roe on kelp fishery began in 1972 as an experimental program. The first permits were issued in 1974 with opposition from those who felt it would interfere with the natural spawning process and with the natural harvest allowed to Indians. Half of the permits were issued to Indians. Actual licenses for the fishery were awarded beginning in 1977.

The number of licenses awarded is determined by the market conditions and each licensee's quota is an equal share of the determined total. Production must be within an enclosure, either a trap or pond. Most fishermen use ponds made of herring seine web or chicken wire which average 60' x 30'. The kelp must be harvested by hand, the spawn must be left two to three days to water harden after which it is brined. All aspects of the fishery are very tightly controlled; a fishery officer must give permission for the product to be removed from the pond to ensure it is not the natural product and must also certify the product for export.

A pond is operated by an average of five people and the time involved in the fishery annually is between three weeks and two months. The variables, of course, are harvesting the kelp, finding and ponding the herring, and getting the herring to spawn at the right time. Future licenses will be given solely to residents of areas where this fishery takes place.

Average costs to participate in the fishery with the exception of the license are as follows:

$1,200	fuel
1,000	materials
600	other
3,100	pond

Average gross income is $65,874.

Summary of Commercial Fishery Production, 1975 - 1978

	1975	1976	1977	1978	1979
No. Licenses	13	21	24	29	29
Tons per license	6	6	10	8	8
Total production (lb.)	32,503	147,617	265,043	300,000	
Price/lb.	$3.07	$3.50	$4.70	$5.52	

Grades of Herring Roe on Kelp

Grade	Description
I	Complete coverage of kelp (90%) with at least three layers of eggs on each side
II	Complete coverage of kelp with eggs with a thin layer on each side or leaf cracked, or covered on one side to a thickness of 3mm
III	Eggs not evenly distributed - broken pieces
IV	Eggs loose

Note: Grades vary according to buyers; often Grades III and IV are combined into Grade III. Product must be clean - free of sand and dirt.

Management

All product is produced within impoundments; harvest from the beach is strictly prohibited except by native Indians for their personal food consumption. Herring roe on kelp license holders cannot also hold herring roe licenses. All product must be processed in a registered plant which meets Fish Inspection requirements.

The kelp used is primarily Macrocystis integrifolia (giant kelp); it may not be cut less than five feet from the base of the plant.

License holders apply for an area in which they would like to operate. The herring used in the herring spawn on kelp fishery is deducted from the total herring roe quota for the British Columbia coast.

Approximately 60 to 100 tons of herring are used to produce eight tons of herring spawn on kelp product.

AN INVESTIGATION OF THE HERRING EGG ON SEAWEED FISHERY IN PRINCE WILLIAM SOUND, ALASKA: ESTIMATES OF STANDING CROP, GROWTH RATES OF KELPS AND PATTERNS OF RECOLONIZATION IN HARVESTED AREAS

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Editor's Note: Mr. Rosenthal's report was prepared for the Alaska Department of Fish and Game. Printed here are the Introduction and Abstract sections. For copies of the full report, contact the Alaska Department of Fish and Game.

INTRODUCTION

The herring egg-on-seaweed fishery takes place in Prince William Sound, Alaska during spring. Each year, since the inception of the fishery in 1969, commercial harvesters and processors have gathered at specific sites in the Sound to collect seaweeds that are laden with the spawn of the Pacific herring, Clupea harengus pallasi Valenciennes.

The macroscopic seaweeds and seagrasses (macrophytes) form a conspicuous band along the shores of Prince William Sound. The extensive, crenulated shoreline supports large standing crops of marine plants. The submerged plants usually become a major target for the spawning herring, seemingly because of overlaps in vertical distribution and because the eggs adhere to such a wide variety of vegetative substrates.

This paper presents the results of our investigation of the fishery. It deals mostly with the biology of the seaweeds that are currently harvested. The potential adverse effects of this activity are also being examined so that resource management recommendations, both for regulation and future studies, can be formulated.

ABSTRACT

Prince William Sound is an important spawning area for the Pacific herring, *Clupea harengus pallasi* in Alaska. The herring move into the shallow waters of the Sound each spring to deposit their adhesive eggs on intertidal and shallow subtidal marine vegetation. Concurrent with these spawning activities is the commercial take of the eggs and brown algae by divers who harvest the spawn-laden seaweeds during April and May. The harvest has ranged from 2.7 tons in 1969 to 458.5 tons in 1975; estimates place the first value of the fishery at between $400,000 and $500,000. Currently, less than 5 percent of the shoreline in the Sound's northeastern quadrant is affected by the fishery. Although more of the beachline is utilized by the herring an appreciable amount of spawn usually ends up on inorganic substratum and/or undesirable species of plant life. Concern for the herring stocks and heavy exploitation of the kelp resource in specific areas necessitated the adoption of more stringent regulations concerning method of take, and in some instances required the closure of historic spawning areas to insure a sustained kelp harvest on an annual basis.

Diver-biologists studied the seaweed assemblages of northeastern Prince William Sound from 1975-1978. The investigation was directed at the commercially valuable species that grew in the 2-15 m depth range. The width of the vegetative band varied from less than 100 m to almost 2 km depending on the steepness of the shoreline. Estimates of total biomass or standing crop values ranged from 0.5-5.3 kg fresh weight/m^2, typically there was a marked drop in standing crop below 15 m. The dominant algae were the broad-leafed

kelps *Laminaria* spp. and *Agarum cribrosum*, which formed moderate to dense canopies in the rocky sublittoral zone.

Experimental harvests of small areas (24 m^2) were conducted during spring to test the effects of hand-cutting the kelps versus clearing areas by totally removing the plants from the substratum. Survivorship of hand-cut *Laminaria* was high, however the partially debladed *Agarum* suffered a 60 percent reduction in density over a 1.5 year time period. The effects of partial removal of blades on growth was studied from May to August. Partially debladed kelps averaged between 0.03 and 0.05 cm/day of blade elongation, as compared to undisturbed control plants which averaged between 0.12 and 0.37 cm/day. Despite the recorded growth, there was usually a net loss in the length of the blade during late summer, presumably because the rate of erosion was greater than the rate of growth.

Recolonization of both commercial and experimental harvest areas was monitored over the same time frame. The intensity of harvest or extent of areal disturbance seems to be critical to kelp recruitment and subsequent replacement of lost canopies. Intensely cleared areas returned to a harvestable stage after five years, whereas kelp germination and recruitment in small experimental clearing occurred during the first year, and should be ready for reharvest in about three years.

A SUGGESTION FOR A SIMPLE METHOD OF OBTAINING HIGH QUALITY KELP PLANTS (LAMINARIA) FOR HERRING SPAWNING IN IMPOUNDMENTS

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LIFE HISTORY

Figure 1 provides a brief summary of the life history of _Laminaria_. The plant arises from a microscopic filament which grows from a spore which will have settled at the spot several months before the plant first becomes apparent. The blade is replaced each year. Most of the growth occurs at the juncture of the stipe and the blade. The plant grows only a few inches in its first season of growth, and then really puts on size in the second year, provided it has sufficient light. Dickson reports that herring eggs do not adhere well to the very young plant. A plant will probably live at least four years, producing spores three of those years. The time of spore production varies with the species and with the location so if spore is to be collected you have to check the timing at each place. Spore release is usually late summer or early fall. The spores cannot travel very far through the water. Hasegawa measured the distance they could swim in standing water before settling as about 3 meters. Of course, currents would carry them further, and would also determine the direction of drift. In general, they will still settle fairly close to their point of origin.

Figure 2 shows the seasonal growth of _Laminaria_. Most of the plant's annual growth in size takes place in the early spring. In Nova Scotia, Chapman and Craigie have experimented with forcing the plant to continue to grow fast throughout the summer by fertilizing with nitrates. The plants grew large

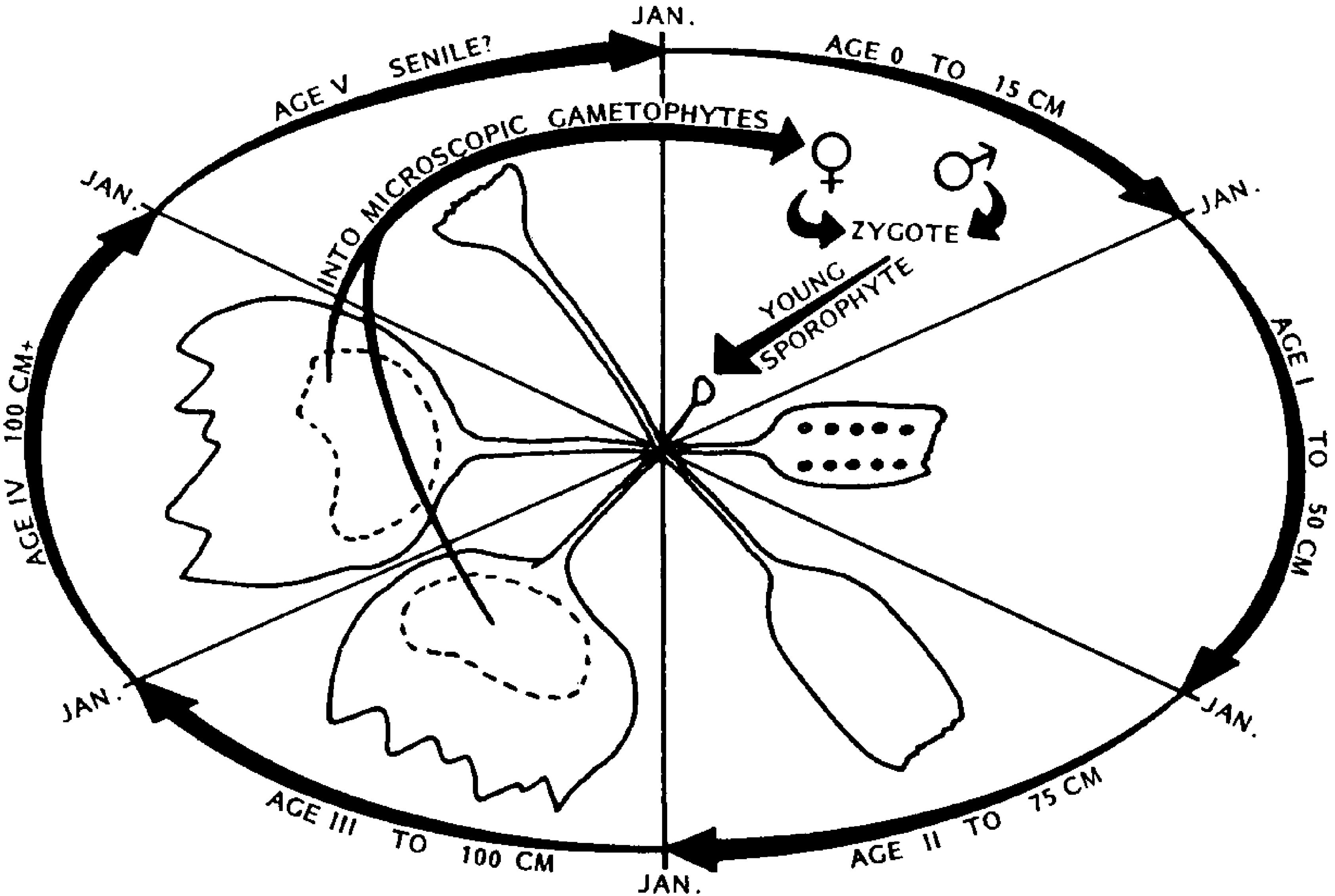

FIGURE 1. Probable life history of Laminaria groenlandica in shallow water at Coghlan Island study site.

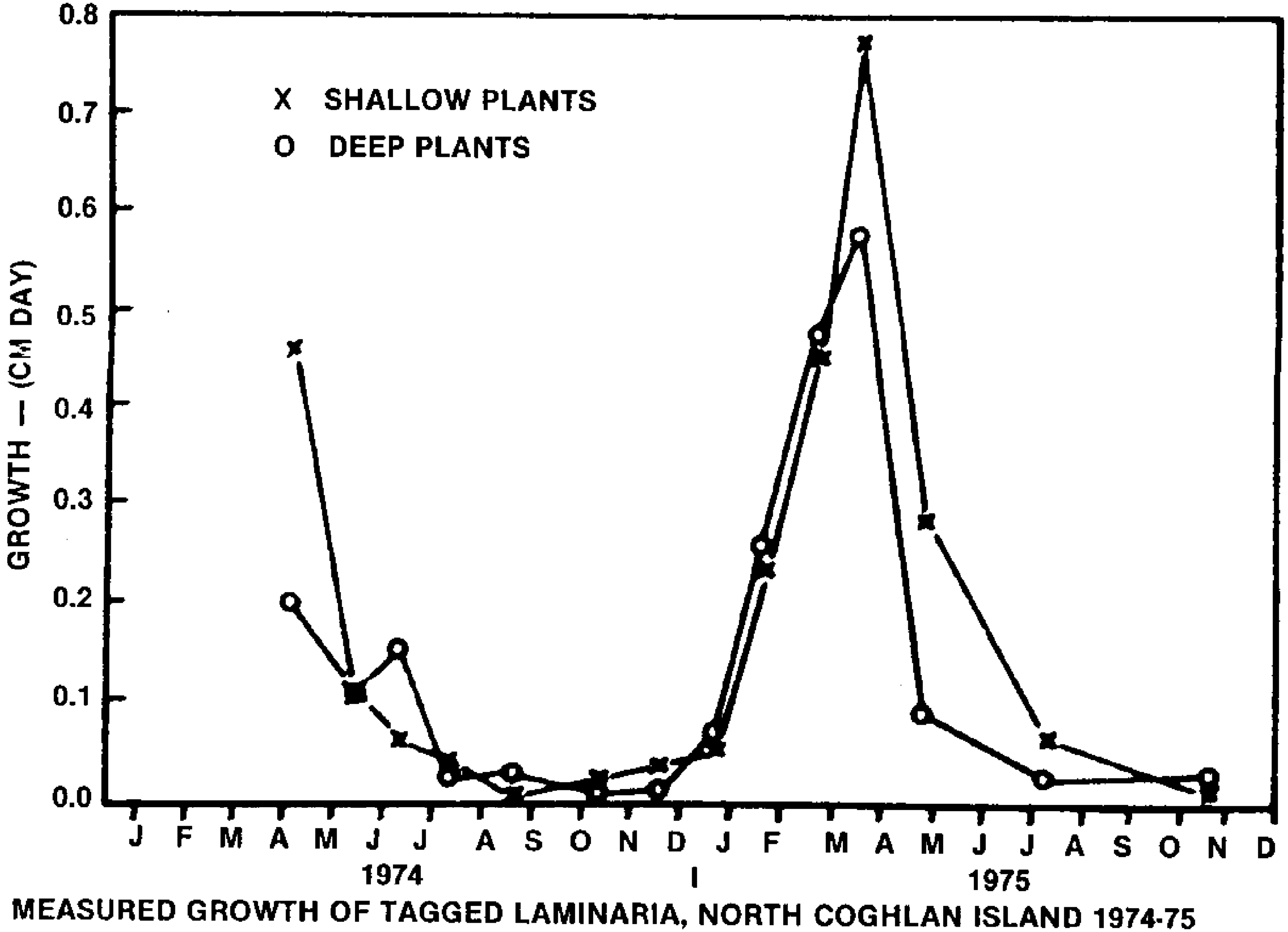

FIGURE 2. Seasonal growth in length of _Laminaria groenlandica_ blades at Coghlan Island study site March 1974 to December 1975.

but had little stored energy to start the next season's growth with. Since the herring spawn in the early summer, it would seem the fertilization technique would not be useful.

OUR STUDY

I would like to describe an experiment we did with growing kelp on an artificial substrate at a moderately exposed site in Auke Bay. Then I would like to draw from what we learned in addition to some personal observations to suggest a relatively simple method of obtaining high quality kelp (*Laminaria*) plants for use in the herring impoundments.

In the course of a growth rate study on *Laminaria*, we had noticed a big difference between the shallower and the deeper plants on a rock reef, (Figure 3).

The mature plants were so different from each other that we thought they might even be different species. We wondered if the plants could be the same genetically, with the differences caused by depth.

To test the same genetic theory, we set out two parallel 9/16 inch stiff nylon lines near the reef, running from the shore outward so as to cover a depth range of about minus 4 to minus 25 feet. These depths seemed to be the optimum range for *Laminaria* in the area. We fastened the lines securely to cement blocks. Since most of the plants in the area are fertile in September, we placed the lines in August (1974) in hopes of a good set.

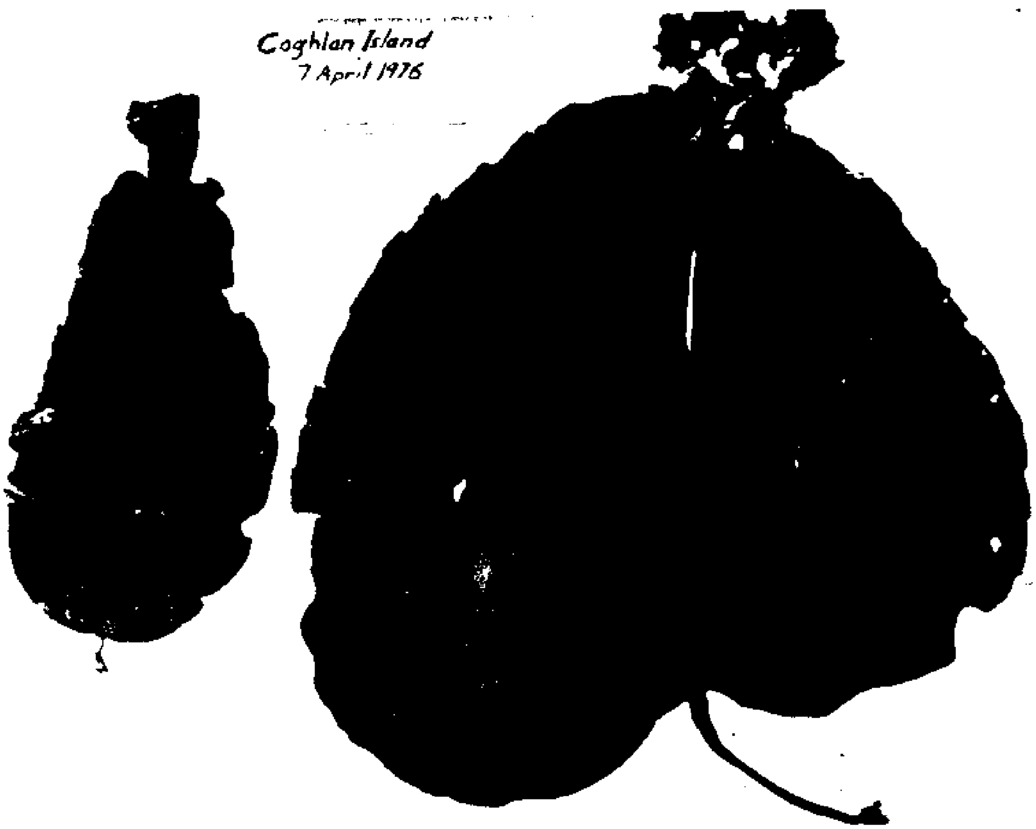

FIGURE 3. Typical examples of the two types of Laminaria groenlandica found at the Coghlan Island study site.

By the following April (1975), small Laminaria plants were appearing on the line in addition to a number of other species, espceially Alaria. By June, the Alaria were mature. Notice the "grunge" all over the line in Figure 3. At the same time we counted a maximum of about 200 Laminaria plants in a half meter length of the line at the optimum depth, and a minimum of about 5 plants in a half meter in the shallower area.

The plants eventually thinned themselves naturally. However, ultimately the large mature plants were much closer to each other on the line than they would grow on the reef. Apparently the lack of competition from the sides allowed this.

We made no attempt to clear the other species off the line; not only because we wanted to see what would happen naturally, but also because at this stage the hold of the Laminaria on the line was very tenuous. Any attempt to remove other species would have dislodged them.

In November of 1975, before the next season's growth began, we moved one of the lines below the other, running from a depth of about minus 25 to minus 65 feet, (see Figure 4).

We placed the lines on soft substrate near the reef so as to be within the range of spore fall. We had some success with getting a good set of Laminaria on our lines. As a result, others decided to lay polypropylene lines out on the west side of the other reef in late September of 1976. The depth range of their line was about minus 15 to minus 45 feet. They also had a good set of plants. This line was placed lower than the first

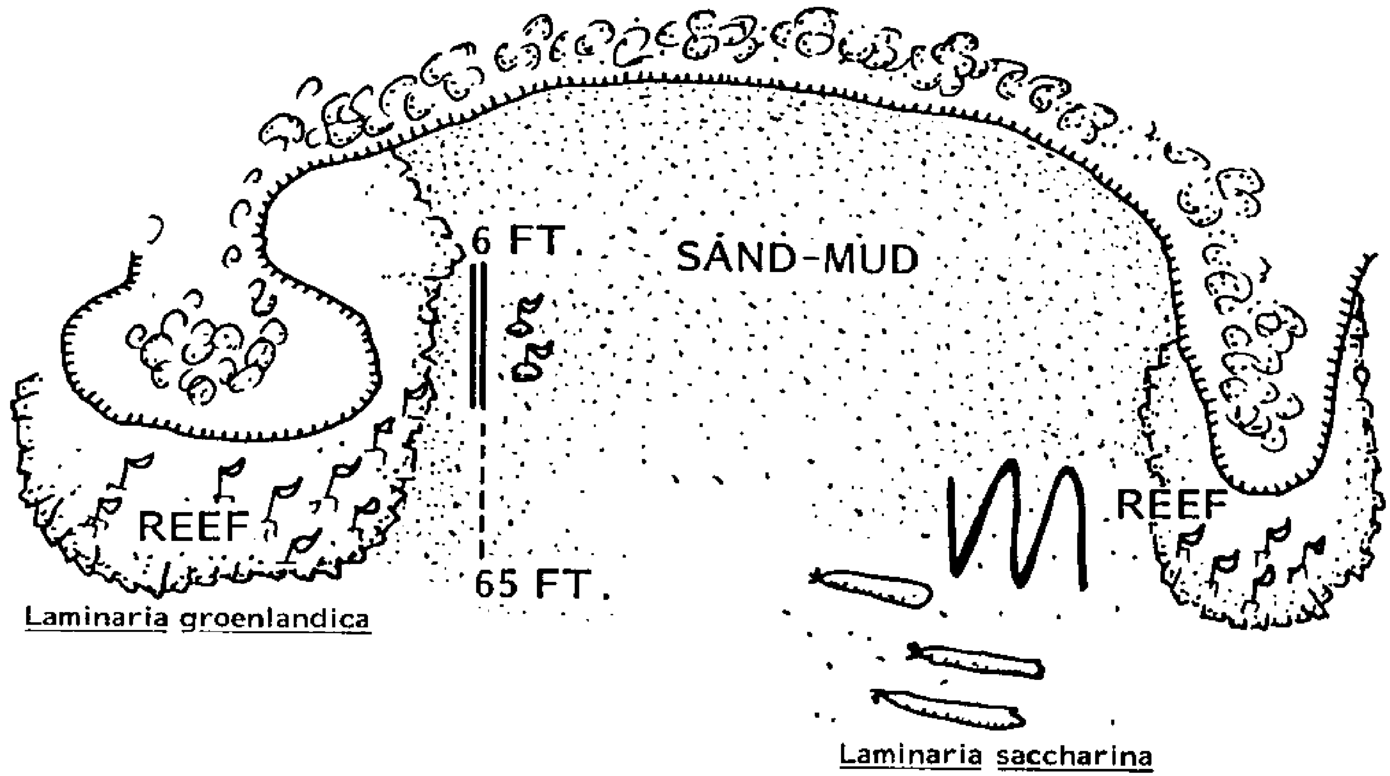

FIGURE 4. Site of placement of substrate lines near Auke Bay for growth of *Laminaria*.

one, so they missed the heavy set at the 12-foot level, but they did pick up some L. saccharina at the lower depths, which we had not. There is a population of that species on soft substrate there at about minus 40 feet.

On April 7, 1976, near the middle of the period of rapid growth, we measured the plants within the meter lengths we had marked. Plants on the shallow line ranged in maximum size from 13 cm at the shallowest, to 94 cm at the optimum depth, about 12 feet. The average large plants were about 40 cm long. Plants on the deep line ranged in maximum size from 2 to 14 cm. They had been suppressed in their growth. The numbers of plants on the shallow and deep lines were the same: A total of 114 plants on four 1/4-meter sections on each line. At the optimum depth, (12 feet), the plants were largest and most abundant.

SUGGESTED METHOD

I believe that in Alaska we do not need to maintain laboratories to produce kelp, as is being done in Japan. As long as our waters are clean and our management practices are sensible, we can rely on the natural system to produce as much kelp as we can use.

For the purposes of herring impoundment and obtaining high quality kelp for spawning, I propose that we leave the natural system intact, using it as a source of "seed", or spores. By using the substrate line method, we can even grow kelp over soft bottoms where it would not normally grow. Or, after seeding, the lines could possibly be hung at their optimum depth under float structures.

There would be several advantages to the substrate line approach:

1. You could choose your species, and control growth to produce a uniform product.
2. It is simple, being less labor consuming than cutting and pinning on by hand. Once a system was established, it could be operated with very little work by divers.
3. You could choose your time for doing most of the work.
4. It should have little impact, if any, on natural kelp stocks.
5. There would be no expensive laboratory procedures as you use natural seeding.
6. Kelp can be grown over soft substrate where it would not have grown otherwise.

Figure 5 gives an idea of the schedule involved. On the upper portion of the figure is what the plants are doing. The lower portion shows what the herring impounder would do.

SUGGESTED PROCEDURE

1. Choose the species of kelp to be grown.
2. Choose a seeding site. It should be near or in a natural stand of kelp. If it's on soft substrate beside a reef, such as ours was, check for plants of the species you want on scattered rocks nearby, to be sure the currents are in the right direction for seeding your lines.
3. Check the depth range of best plant growth in the area, particularly if you are going to leave your ropes _in situ_ until the plants mature. The optimum depth range will vary from site to site.

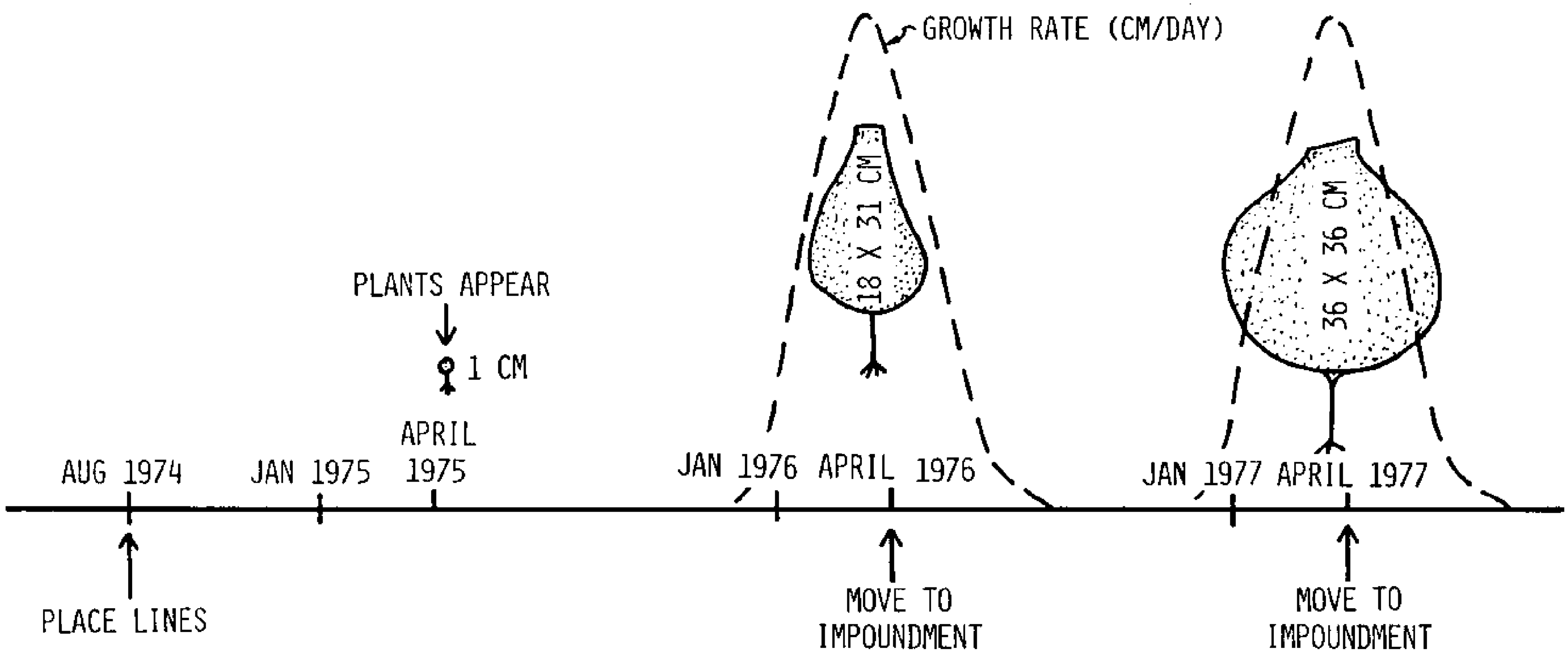

FIGURE 5. Timing for placing lines for seeding of *Laminaria*, growth of plants, and moving lines to herring impoundments.

4. Install the ropes, in this depth range, securing them well, preferrably at a time when most of the naturally growing plants in the area are covered with fertile tissue.
5. Wait a year.
6. If the ropes are less than 2 feet apart, move them to about 6 feet apart in a year, checking growth at the same time. Perhaps you'll want to thin the plants to promote growth. If you move them much before a year, you will lose quite a few plants.
7. At the second spring, transfer the ropes to the impoundments at the desired time. Harvest the kelp and spawn.
8. Replace the line at the seeding site for the next crop.

FUTURE RESEARCH

1. Test different types of line. Polypropylene lines used in our experiment received a good set, but they tend to float, which complicates the operation.
2. Try various methods of fastening lines to the bottom and to the impoundments.
3. Try different areas for seeding and growing; high current areas, suspended from floats, and so forth.
4. Try fertilizing to see if you can get larger plants sooner.

THE QUALITY, HANDLING, AND TRANSPLANTING OF KELP FOR KOMOCHI KOMBU PRODUCTION

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Macrocystis integrifolia is the principal brown alga used as a substrate for culture of komochi kombu in sea impoundments. In the past, Indians of the Pacific Northeast have harvested herring roe on seaweed from beaches and from herring bait ponds implanted with kelp fronds. In addition, the commercial fishery in Alaska has harvested about 400,000 pounds annually of the wild stock of roe on kelp for shipment to Japan. This product is prized as a food delicacy particularly at New Year festivities. Pond cultivation of komochi kombu in Canada started in 1975 when it was realized that the potential market of this highly priced product in Japan reflected the limited local production caused by shortage of herring in that portion of the Pacific.

Other species of brown seaweed used as substrates have included *Nemacystis decipiens* in Japan and *Laminaria groenlandica*, *L. saccharina* and *Agarum fimbriatum* to a limited extent in Canada. The physical nature of the latter three recumbent algae has provided inferior products relative to that incorporating *Macrocystis*. *L. groenlandica* fronds have a smooth surface which tends to prevent firm adhesion of the roe, whereas the convoluted surface of *Macrocystis* fronds effectively locks-in the roe such that it resists sloughing-off. Both *L. saccharina* and *Agarum fimbriatum* have thinner laminae than *L. groenlandica* and *Macrocystis* and are subject to tearing when the product is recovered from the ponds. In addition, divers have trouble finding premium quality plants in early spring when the algae are damaged by predation, encrustation and wave action throughout the winter months. Macrocystis, as a perennial floating kelp, therefore affords distinct advantages relative to the subtidal, recumbent kelps.

Of crucial importance in pond cultivation of komochi kombu is the quality of Macrocystis fronds. This alga is subject to epiphytization with encrusting calcareous bryozoan Hippothoa hyalina and/or Membranipora membranacea, the moss-like Obelia longissima, the calcareous polychaete Spirorbis spirrillum, together with diatoms of the Melosira, Cocconeis and Fragilaria spp. Growing algal tissue generally prevents fouling by sloughing off superficial layers or producing chemical anti-fouling agents which inhibit settlement or growth of epiphytes. Occasionally, however, epiphytism can be so intense that the anti-fouling mechanism cannot cope and senescence occurs by the reduction in incident light and decreased exchange at the surface of the fronds. It has been noted that although season, habitat and environmental conditions influence the degree to which a kelp is subjected to epiphytes, some kelp beds appear less susceptible than others and only by reconnaissance prior to the time of production can these healthy beds be identified.

Collection of Macrocystis at low tide provides access to lower mature fronds and eliminates the need for divers. Either mature fronds removed from the stipe or the top 4 feet of the complete plant can be used in the ponds. However, the use of mature fronds (6 inches wide x 2.5 feet long) strung individually in the ponds normally yields a superior product to that obtained when the entire top portion of the plant is used. Young immature fronds at the growing tip of Macrocystis exude polysaccharides which prevent secure attachment of the roe.

Ideally the location of the kelp bed and the impoundment should be sufficiently close to ensure that the Macrocystis fronds collected are positioned in the ponds within hours of cutting; however, this is not always possible. Nevertheless our research has shown that Macrocystis can be collected, drained and transported at low temperature (5-10^{o}C) for up to 24 hours without adverse effects and on reimmersion in seawater will continue to thrive as a living, free-floating entity for at least a further four week period. Containment for longer periods tends to result in diatom smothering and resultant senescence. It should be noted that normally a cut Macrocystis plant will float when impounded, however if pneumatocysts (air bladders) on some fronds are damaged, the buoyancy of the plant is upset thus a catchment net under the kelp may be prudent.

Wave action normally prevents rain water from affecting exposed portions of the alga, but in still, calm water rain-washed tissue rapidly undergoes disintegration. Exposed portions of Macrocystis floating calmly in fish tanks irrigated with seawater were subjected to a heavy rainfall and within 24 hours these portions had completely decomposed. One fisherman in B.C. who had his kelp enclosure in calm water adjacent to his home overcame this problem by pumping seawater as a spray over the surface mat of kelp.

Care should be taken when handling and transporting the kelp to minimize perforations or surface abrasions which are sites for bacterial attack and subsequent deterioration. Damaged fronds also exude protective polysaccharides which prevent attachment of the roe. The overnight temperatures during this roe season are often below $0^{o}C$ thus it is essential to ensure that the seaweed collected is prevented from freezing as the ruptured cellular tissue succumbs to biodeterioration.

Final products lacking seaweed between the roe sandwich have been observed and conclusions reached that the original fronds were in a state of partial decomposition prior to roe attachment. Even after brining, the process of decomposition continues and leaching ultimately leads to a product devoid of seaweed and limited commercial value.

Herring will often spawn in areas of low salinity yet this is an environment detrimental to the fresh water intolerate Macrocystis. A compromise must be reached between locating a pond in a freshwater fed bay to stimulate spawning and the viable longevity of the seaweed located in the pond. This intolerance to reduced salinity is a major contributing factor to the absence of Macrocystis integrifolia in the Strait of Georgia.

As part of our research, whole Macrocystis plants were collected in late January at Sooke, Strait of Juan de Fuca, and transplanted in cool, moist condition to English Bay, Strait of Georgia. Time out of water was about 16 hours prior to reimmersion to a depth of 12 feet. Initially the plants grew well with no apparent signs of stress but by April all the mature fronds had decayed and only discoloured basal portions remained by June. Water salinity and temperature in English Bay varies from $28^{o}/oo$ to $24^{o}/oo$ and 7^{o} to $16^{o}C$ from winter to summer, whereas $31^{\circ}/oo$ and 7° to $11^{\circ}C$ are values recorded in the Strait of Juan de Fuca. Obviously the combination of decreased salinity and increased temperature in the Strait of Georgia during the summer months were conditions intolerable to *Macrocystis integrifolia*.

Factors influencing the success of transplanting kelp to barren areas include (a) salinity and temperature tolerances - pertaining to macrophyte and spore survival, (b) location - dictated by nutrient availability by appropriate currents, (c) substrate - changes with season pertaining to spore viability with possible silting problems, (d) predation - the red sea urchin *Strongylocentrotus franciscanus* dictates the lower distribution of kelp in B.C., and (e) genotypic variants - parameters for survival may differ. These factors, and probably more, have to be satisfied before transplanting kelp would succeed. Transplanting should therefore be considered as a long term option with the existing resource being transported to meet the immediate demands for komochi kombu production.

SOME REMARKS ON HERRING BIOLOGY

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I will discuss herring biology centering on the herring embryonic stage since that is the stage that is being harvested in the industry. First, a brief summary of adult herring biology. Herring are planktonic feeding organisms. As juveniles, herring feed heavily on copepods and other planktonic organisms. As they grow to adulthood, they shift to larger planktonic organisms such as euphausiids. The adult herring can and do feed on larval fishes and are probably somewhat opportunistic. When herring get in shallow water they are probably feeding on organisms that are not typically planktonic.

Adult herring are definitely a schooling species and they occur in large aggregations at a particular place and time. The integrity of a particular school is a complete mystery to me. I do not know what keeps a school intact and I am not sure anybody knows whether schools are always mutually exclusive or if they sometimes come together to form larger schools. In any event, schools do move considerable distances. Adult herring are preyed upon by a number of different organisms in the marine environment over and above human predation in the form of commercial harvesting. They are probably preyed upon by quite a number of fishes. Adult herring are preyed upon by salmon, and when near the bottom they are liable to become flatfish food. Large sized pollock are fish eaters and they also have been shown to ingest herring. I'm not sure about marine mammals but I suspect that sea lions also feed on herring.

There are a number of factors of the herring biology and physiology that fluctuate on a seasonal basis. Obviously, gonad weights and the condition of the gonads fluctuate considerably on a seasonal basis. Early reports in the literature which followed seasonal gonad development of Washington State and British Columbia herring stocks, indicate that the development of the ovaries is a long process with the gradual accumulation of mass leading up to the full size gonads that are in evidence by spawning time.

The spawning activities, as reported in the literature, are restricted to the upper 20 meters of the water column for Pacific herring. There may be some exceptional cases that I do not know about or that have not been reported in the literature. This is one of the classic differences between Atlantic herring and Pacific herring. Atlantic herring apparently spawn down to as deep as 100 meters or 200 meters making their potential spawning area anywhere on the continental shelf. Their spawning is not as restricted compared to that of the Pacific herring.

Spawning time is correlated with geographic location. Spawning populations of Pacific herring occur from as far south as San Diego, all the way up the Pacific coast and into the Beaufort Sea. There are also Asian stocks of Pacific herring as well. A sampling of spawning times indicates spawning in San Francisco Bay takes place or has taken place as early in the spring as November. November does not sound like spring but most likely it is some temperature trigger mechanism causing these herring to spawn. The spawning temperature in San Francisco Bay was about 15°C. Washington State populations have been reported to spawn in February and Prince William Sound late April or early May. In the Bering Sea, spawning times are in June. Spawning in Bristol Bay is around the same time as Prince William Sound. Norton Sound is still later in the year. I do not know of any information on spawning times in the Beaufort but I am sure that they are later still. Spawning temperatures in Prince William Sound are probably around 5.5^{O}C.

There are separate stocks along the Pacific coast and it is logical to assume that the herring populations off Southern California are going to have to exist and tolerate higher temperatures than found in Prince William Sound. Stocks probably adapted over time to match their abilities to whatever they face in the environment.

Herring move into suitable habitat (sometimes not so suitable habitat) to deposit their spawn. The females have been observed to actually brush their vents against the substratum, the algal fronds or rock or piling in the boat harbor or whatever. The brushing is an apparent behavioral releaser that allows them to deposit the eggs. They are not broadcasting their eggs into the water column to have them settle on a substratum but rather they are brushing the eggs onto the substratum. They are very deliberate about it. Males in the vicinity are shedding milt to fertilize these eggs and the fertilization rate is extremely high based on field observations. It is easy to pick out unfertilized eggs from developing embryos a short time after this spawn deposition has taken place.

The developmental sequence, once the fertilization takes place, depends on a number of factors. The length of embryonic development is temperature dependent, higher temperatures lead to shorter developmental times. In other words, the embryos hatch out quicker. There is a trend as we move up the coast in lengthing of the hatching times. There is probably some adaptation to temperature but not totally. In Prince William Sound, based on my studies, embryonic development takes from 15 to 25 days. Environmental temperatures do fluctuate depending on what the weather is like, how much cloud cover there is, how much sunshine there is, what the wind pattern is and a number of other factors.

The hatching success from experimental and natural studies has been shown to vary considerably. The hatching success depends on salinity fluctuations. Experimental studies have shown that low salinities, really low salinities, adversely affect hatching. Very low salinities kill the embryos. Although there is confusion in the literature it looks like below salinity $15^{o}/oo$ is detrimental to developing embryos. One study I read indicated that $20^{o}/oo$ was not detrimental to embryo development. Embryos can tolerate a fair range in salinities during developmental sequence. One of the reasons is that the egg membrane is basically impermeable to salts so they're not being that much affected by osmotic changes.

The percentage of hatching successes has been shown to be affected by air exposure and by temperature fluctuations. Temperature fluctuations may be rather extreme during the air exposure portion of the tidal cycle for the herring spawn deposited above the mean low water. If you get extremely cold temperatures while the tide is out, you get a drastic effect on the herring eggs that are developing above low tide.

Herring eggs are a really significant nutrient source of the intertidal and shallow sub-tidal environments in which they are deposited. Everything that is around that can get the herring eggs in their mouth are eating them. That includes shore invertebrates, fishes that are inshore at the time, and water fowl that come migrating through. There is a substantial number of water fowl that feed upon the eggs at one time or another. Shore birds may take a toll on the intertidal eggs and perhaps, although I don't have any confirming information, terrestrial mammals as well can wade out into the intertidal at low tides and take advantage of this rich nutrient source.

In addition, pollutant stress has an important impact on embryonic development and hatching success. Pollutants could include pulp waste products; water soluble aromatic hydrocarbons; or simply the water soluble fractions of gasoline, kerosene, or diesel fuel that may incidentally spill from the very vessels that are attempting to harvest the eggs. The larval existence, once the hatching takes place, is a little bit of a mystery to me. Once hatching takes place, the larvae in Prince William Sound tend to average about 8 millimeters in total length. Normal herring hatch with a residuum of yolk material in the yolk sac, they utilize that material until it is gone. At that point they must be able to switch to active feeding and accumulate enough food reserves to grow and metamorphose into juveniles. This metamorphosis in Washington State waters apparently takes about 4 to 6 weeks. While they are larvae, they are undoubtedly feeding on small plankton organisms and in turn being fed on by larger organisms. Whether the larvae hatching from a particular algae bed or kelp bed school together is unknown.

I have more information about Prince William Sound females. In comparison with the data in the scientific literature, it looks as though for a particular length of herring, Prince William Sound females have fewer eggs than similarly sized British Columbia or Washington State herring. That is, for a 150 or

175 millimeter fish from all three geographic locations, the Prince William Sound fish have fewer eggs. However, this appears to be somewhat offset by the fact that the Prince William Sound fish seem to have a higher mean fecundity value per spawner in the spawning population than either the British Columbia or Washington State populations. A study I did at Green Island indicates that each adult female spawner had about 22,000 eggs.

Question: What was your sample size?

Answer: About 160 fish. I realize that is small. That is about as big or bigger than anybody else's sample size that have looked at the fecundity problem.

MANAGEMENT IMPLICATIONS OF HERRING POUND SPAWN ON KELP FISHERY

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In order to present any management implication of the herring pound, spawn on kelp fishery, it is necessary to briefly discuss or summarize the historical background of the present Prince William Sound spawn on wild kelp fishery.

The herring spawn on kelp fishery of the Prince William Sound Area began in 1969. In this initial fishery three permits were issued and 2.7 tons of spawn on wild kelp were harvested. Since that initial fishery as many as 1,100 permits have been issued in any one year, and as much as 458.5 tons of spawn on kelp harvested. The average annual harvest, excluding the first and last year of this fishery is approximately 220 tons.

Since the first year of the fishery some regulation changes have occurred. Although various kelping areas have been opened and closed by emergency order from year to year, the most significant regulation change has been the change in harvest method from grappling hook to hand cutting of kelp fronds four inches above the stipe or stem. Studies initiated in 1975 indicated that the grappling hook was destructive to the various kelp communities, and in 1977 the hand cutting method of harvest was adopted by the Board of Fisheries.

Since this regulation more or less restricted the participation in this fishery to those individuals with some diving experience, the annual number of permits issued immediately decreased as did the annual tonnage harvested. With the regulation change the diver/harvesters were more selective in taking spawn laden fronds, fewer plants were dislodged from the substrates and hand cutting four inches above the stipe allowed for a faster regrowth or recruitment of the kelp beds.

In 1977 the Board of Fisheries passed a more restrictive regulation which imposed a 60 ton spawn on kelp guideline harvest level. This regulation was later reconsidered by the Board at the request of fishermen and processors, and 10 days prior to the season the guideline harvest level was raised to 165 tons. Due to the lateness of this regulation reconsideration, processors were unable to contact or procure divers, and coupled with poor spawn desposition on desired kelp species, only 70 tons of spawn on kelp was harvested.

At the most recent Board of Fisheries meeting held in December, the Board promulgated regulations raising the guideline harvest level to 200 tons of spawn on kelp. Harvest areas will be determined by kelp recruitment and spawning densities as indicated by pre-season underwater surveys, and a more intensive rotation system of regulating the kelp harvest, based on Rick Rosenthal's investigation of the spawn on seaweed fishery, will be initiated.

Along with the guideline harvest level change, the Board of Fisheies adopted regulations allowing for the development of a new spawn on kelp fishery by the impoundment of herring and the introduction of kelp into these pounds.

Since this fishery was more or less developed as a pilot or experimental project, the new regulation contained the following conditions: 1) the guideline harvest level for the production of herring spawn on kelp by pounding is 8 tons; 2) herring pound operators must obtain a permit issued by the Commissioner with the area of operation specified on the permit; 3) herring must be released after spawning, and pounds must stay in place until the herring eggs attached to the pound structure have hatched; 4) the size of each pound must be specified by the permit; 5) the method of capture and retainment, and other guidelines determined by the Commissioner, in his direction to be necessary for the conservation, management, and public health, safety and general welfare, may be specified by the permit; and 6) the permit must specify locations from which kelp may be taken or transplanted for use in a pound as a substrate for the production of herring spawn on kelp.

The possible implications of the impoundment technique of a spawn on kelp fishery has raised some concern by both wild kelp harvesters, and to a lesser extent, by management biologists. The areas of concern, which I hope will stimulate some discussion after this presentation, are as follows:

1. Herring captured for impounding will be taken from areas close to natural kelp communities, and, therefore, will decrease egg densities on the wild kelp stands which would be available to the diver/harvesters.

2. If seining is used as a capture method for obtaining the herring to be impounded, and allowed to be conducted near or in natural spawning areas, physical damage to kelp beds would occur, or bottom sediments dislodged by the seines will settle on kelp stands making the plants unmarketable after spawning has occurred.

3. Harvesters of spawn on kelp voiced their concern of the possible disruption of herring schools caused by seining as a capture method for pounding. The feeling here was that larger schools of spawning herring would possibly be broken up into smaller schools which would spawn over a larger area causing less than desirable egg cover, thereby lowering the quality of the product available for harvest.

These concerns, as voiced by the harvesters of wild kelp, have identified the areas of conflict between the two user groups. If the impoundment project is to be successful, studies conducted in British Columbia have indicated that the herring should be captured as near to spawning maturity as possible which would mean that capture should take place when the herring schools are on or near the spawning grounds.

Also, for the success of this project, approximately 80 to 100 tons of herring are required for impoundment to produce 8 tons of spawn on kelp.

When the pounding regulation was reviewed by the Board of Fisheries, the Assitant Attorney General, acting as consultant to the Board, informed Board members that under existing state law anyone applying for and meeting the conditions of the permit, as outlined by the Board, would lawfully be entitled to a permit. At this time, interest has been shown locally by three parties, and we anticipate more interest to be shown when the application dates for filing of permits is advertised. I would expect that three or more permits will be issued. Since the Board has imposed an 8 ton guideline harvest level for the production of spawn on kelp from pounds, the question most often asked is which pound operator (if more than one) receives the benefit of the harvest? At this time the question still remains unanswered, but it was suggested that the operator harvesting his product first would be the "winner", while the "losers" would have to leave their product in the impoundment until the eggs had hatched.

Presently, four user groups are involved in the utilization of the Prince William Sound herring resource. We have a spring sac roe fishery that operates under a 5,000 ton guideline harvest level; a newly developed fall and winter bait fishery which we anticipate will harvest approximately 1,500 tons of bait herring by the end of February when that season will close; and the two spawn on kelp fisheries presented in this report.

Due to a very limited budget, herring research in Prince William Sound consists of some hydroacoustical assessment work on overwintering herring stocks which has met with limited success; a research project, on the spawn on kelp fishery conducted by Rick Rosenthal in which he has investigated the growth rates, recruitment and recolonization of kelps in harvested areas; and ongoing programs of biological sampling of the commercial catch for age-weight-length and sex structures of harvested populations to assess overall condition and recruitment of herring into the commercial fishery.

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