Proceedings of the

Fourth Alaska Aquaculture Conference

November 18-21, 1987
Sitka, Alaska USA

Edited by Sue Keller

Alaska Sea Grant Report No. 88-4
University of Alaska
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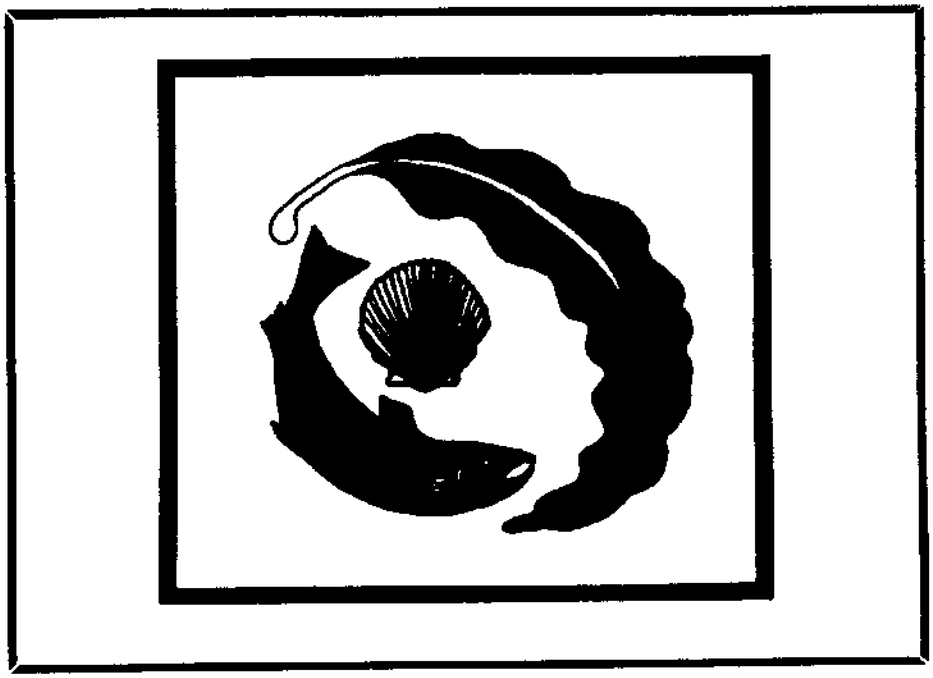

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The Fourth Alaska Aquaculture Conference was coordinated by Brenda Melteff of the Alaska Sea Grant College Program. Members of the program planning committee were Pete Esquiro, Northern Southeast Regional Aquaculture Association; Dolly Garza (Chair), University of Alaska Marine Advisory Program; Rick Harris, Sealaska Corporation; Bill Heard, National Marine Fisheries Service; Mike Kaill, Alaska Department of Fish and Game; Curt Kerns, University of Alaska Marine Advisory Program; Bill Paulick, Alaska Department of Commerce and Economic Development; Brian Paust, University of Alaska Marine Advisory Program; Ray RaLonde, Sheldon Jackson College; Tom Shields, Archipelago Marine Research; and Tom Shirley, University of Alaska, Juneau Center for Fisheries and Ocean Sciences. Virginia Sims summarized the salmonid aquaculture panel discussion. Typesetting for this publication was done by Pamela Orr and the cover design is by Karen Stomberg.

The proceedings of the conference were taped and transcribed by Irene Schuler. Some authors submitted papers to be included in this book, while others edited the transcription of their oral presentation. Questions and answers appearing at the end of the papers may apply to the entire session.

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WELCOME

John Dapcevich, Mayor
Sitka, Alaska

My campaign for election to mayor is very fresh in my memory. The first time I ran for public office here in Sitka was 19 years ago and I had a 19-point platform. One of the points on the platform was to establish fish farming in Southeast Alaska. After 19 years, 18 issues have been addressed; the 19th has not been worked out yet.

My idea is a little different from the mariculture program. In my travels throughout Southeast Alaska (and I've lived here 60 years) I've seen a lot of small streams that don't bear fish. I thought the state could establish a program by a lottery system or a permit system, so that people could obtain fish eggs from a hatchery, and enhance the streams by planting eggs. These people would have the right to harvest the fish, and manage them. If they overharvested, they would only have themselves to blame. I still like that idea, and I think this is an appropriate place to mention it.

What I'm really here for is to welcome you to Sitka. I was hoping our weather would be a little better, but you who live in Southeast Alaska know that this is actually very good weather. We don't have to shovel the rain. Anyway, this is a typical late fall day.

Sitka is a beautiful place to see and there are lots of things you can enjoy here. I understand you will have a boat tour if it is not too rough. That should be very enjoyable.

We hope that you have a very fruitful convention and that you enjoy Sitka. Thank you for coming.

INTRODUCTION

Donald E. Kramer
Program Leader, Marine Advisory Program
Anchorage, Alaska

I'd like to add my welcome to that of the Mayor. He should have mentioned that the weather is very changeable here and probably it's going to change from very good weather to even better in a little while.

This is the Fourth Alaska Aquaculture Conference. The conference is sponsored by the University of Alaska Sea Grant College Program and the University of Alaska Marine Advisory Program.

The first three Alaska Aquaculture Conferences were primarily concerned with salmon hatchery operations, or salmon ranching, although oyster culture and trout rearing were discussed.

The planning for this conference started about four years ago with Curt Kerns, aquaculture specialist for the Marine Advisory Program, and John Doyle, who was at that time leader of the program. For various reasons the conference was postponed several times; we would have preferred an earlier date.

We have two objectives for this conference:

1. To provide basic information on aquaculture for profit (seaweeds, shellfish, and finfish) to Alaskans who are interested in starting an aquaculture business.
2. To provide some information on the pros and cons of finfish aquaculture in Alaska, specifically of salmonid culture.

Both the commercial fishing industry and the subsistence fishery in this state are extremely important, and no one wants to jeopardize them. The recreational fishery in the state is becoming increasingly important, both as recreation for Alaskans and as an industry in the form of charter boat and fishing lodge activities. Certainly, no one wants to jeopardize that fishery, either.

The marine advisory agent in Dillingham is organizing a conference on recreational fisheries as a business for that part of Alaska, and 40 villages are going to participate. This is one example showing the increasing interest in recreational fisheries all over the state.

This conference is going to cover a wide range of species. We will cover seaweeds today, shellfish tomorrow, and finfish Saturday. In addition, there are two very important panels. The first one is on permitting, and that panel starts this evening at 7:00. The other panel is on the pros and cons of salmon aquaculture, which is scheduled for Saturday evening at 7:30. A very important part of these panels is the interaction of the panel participants. I encourage everyone to attend these panels.

My hope for the participants is that you come away with increased information on how you go about setting up an aquaculture business and what are some of the pitfalls. And second, I hope we can get some of this information out to the people of Alaska, since there are going to be some very important decisions made in the next few years, even months, about what direction aquaculture should take in the state.

In closing, I would like to congratulate the program planning committee, especially Dolly Garza who chaired that committee, for preparing an excellent program.

LAMINARIA AQUACULTURE IN BRITISH COLUMBIA

Louis Druehl
Simon Fraser University
Burnaby, British Columbia

This paper is about edible kelp, particularly the *Laminaria* species, which are in great abundance in the Northwest Pacific. Non-edible kelps, harvested by the megaton in California, are used mainly for bulk products such as alginates, which are emulsifiers in such things as salad dressings. Kelp also is used as a feed supplement for cattle and chickens and such. Non-edible kelp usage involves a large amount of material that is not amenable to cultivation at this time.

What is a kelp? A kelp is a large, brown seaweed such as the bull kelp commonly seen on beaches. The word "kelp" is Celtic, and once referred to the ash of large brown seaweeds burned to produce alkalai. As time went by, the word was applied to the seaweeds themselves.

Kelp Life Cycle

The life cycle of a kelp is unlike that of familiar higher plants and very unlike our own reproductive cycle. Kelp plants exist in two generations: sporophyte and gametophyte. The plant of interest as a product is the sporophyte, which can reach many meters in length (Figure 1). The sporophyte has a root-like holdfast, a stem-like stipe, and a leaf-like blade.

Kelp plants (sporophytes) undergo meiosis—reduction division to produce reproductive cells—in very distinct, dark areas on the blades called sori. Flagellated spores released by the sori swim for some period of time and then settle out, growing into microscopic male plants that produce sperm or microscopic female plants that produce eggs. These microscopic plants are called gametophytes.

The sperm fertilizes the egg in situ, on the female. Embryonic sporophytes initiate growth attached to the female gametophyte and thus to the substrate occupied by the female.

KELP AS FOOD

Nutritional Value

I want to compare two of our most popular foods in North America on the basis of some of the features people use when they evaluate food. We have compared the edible kelp, *Laminaria*, and the not-so-edible food, cabbage.

Table 1 shows that kelp has about twice the food energy. The foods have about the same protein content, but there are more carbohydrates and lipids in *Laminaria*. Kelp carbohydrates such as mannitol are, however, indigestible; humans don't have enzymes necessary to break down these compounds. Table 1 shows that kelp far outshines cabbage, at least for its fiber. *Laminaria* also compares favorably to cabbage in an analysis of various elements important to nutrition (Table 2).

There are some problems. Kelp—brown algae in general—are famous for their ability to accumulate heavy metals and a variety of other substances, such as radionucleotides, in concentrations far above what is found in the natural environment. Kelp harvested in an area where there is mercury, copper, zinc, or arsenic in the water will normally concentrate those elements.

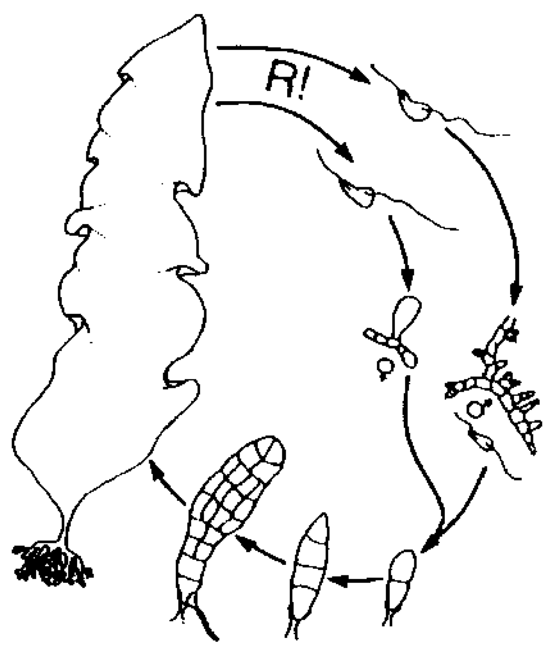

Figure 1. The kelp life cycle. Meiosis (R!) occurs on the large sporophyte giving rise to flagellated spores. The spores grow into microscopic male and female plants.

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Table 1. Some nutritionally important features of *Laminaria* compared to cabbage.

Units per 100 g	dry weight	*Laminaria*	Cabbage
Food Energy	kcal	43	24
Protein	g	1.7	1.2
Lipid	g	0.6	0.2
Carbohydrate[1]	g	9.6	5.4
Fiber	g	1.3	0.8

[1]*Laminaria* carbohydrates are considered indigestible by humans.

Table 2. Concentration of some nutritional elements of *Laminaria* and cabbage.[1]

Mg per 100 g dry weight	*Laminaria*	Cabbage
Calcium	168	47
Iron	2.9	0.6
Magnesium	121	15
Sodium	233	18
Potassium	89	246
Zinc	1.2	0.2
Copper	0.1	0.02
Manganese	0.2	0.2
Phosphorus	42	23

[1]Anon. 1984.

Health Benefits of Kelp

I want to preface this section by saying that all these benefits have been suggested in folk medicine, particularly in the Orient and to a lesser extent, in Europe. And, more recently, by using rat research, it has been found that these benefits might be applicable to human beings. None of these have been proven to benefit humans, but that does not stop people from buying kelp for these reasons:

- Lower cholesterol levels
- Show antitumor activity against sarcoma-180 ascites cells
- Lower blood pressure
- Reduce hypertension
- Chelate radio-strontium
- Prevent thrombosis

Historically, the most important use of kelp has been as a source of iodine. Iodine as an element was first discovered in kelp; kelp concentrates iodine as it does other elements. In fact, kelp has 10,000 to 20,000 times more than ambient levels of iodine. In a bit of dried kelp, up to 1 percent would be iodine.

In Asia, particularly in China, kelp was initially farmed just to supply one billion people with their iodine requirements. The Chinese use kelp as we use iodized salt.

Culinary Uses for Kelp

There are many Japanese dishes that use kelp. I won't list them because the people I work with in British Columbia are not particularly interested in competing for the Japanese market in the kelp business. They're trying to look more to North American tastes.

Here are some of the products on store shelves in North America: candied kelp, pickled kelp, and a variety of soups. In the soups and stews, kelp appears in some combination such as with shrimp. As for pasta, kids who eat spinach noodles can certainly be made to eat kelp noodles. There also are chips and crackers. We have deep-fried the kelp after dipping it in honey, then sprinkled it with sesame seeds. Finally, kelp is sold as a spice. It contains natural monosodium glutamate in a very low quantity. The function of this unique molecule is simply to dilate and sensitize the nerve endings in our mouths—our taste buds—so we are more sensitive to the things we eat.

The larger cities in British Columbia and south have kelp products in health food stores, and to a lesser extent, in Oriental shops. There are few of these Oriental shops around. The reason for this is that the people who grow kelp and market it, particularly the local kelp product, are not professional marketers. And they're lazy in the sense that they don't want to go to town. They like it on the beach where the plants are, so they go to the one place where they know they can make a sale, and that's the health food store. In time, people will break out of that and put some energy into marketing, and sooner or later we'll start to see kelp in the supermarkets. If our food habits have been changed enough so that we eat tofu, we can learn to eat kelp. We have to educate people to like this kind of vegetable.

The retail price of kelp in British Columbia varies from about $35 to $55 (Canadian) per dried kilogram (2.2 pounds). That's quite respectable.

CULTIVATING KELP

Why cultivate kelp, when we know there is a lot of kelp growing out there naturally?

The Ecosystem

Kelp exists in a large, very complex and poorly understood ecosystem. There are little things that live on the plant, like snails, which themselves are food for such things as rockfish. While the snails are eating, they're usually sloppy; they eat something for themselves, and they break off bits. Some of these bits fall down into deeper water to soft bottoms, get eaten by worms and mollusks and so on, which, in turn, get eaten by a lot of our flat fish, halibuts and sole and so on. Other bits of kelp get eaten by shrimp, copepods, etc., which, in turn, are eaten by herring and go up the food chain to the salmon. The sea urchin is a very vigorous kelp eater. It will eat the plant indirectly as dislodged fragments, or in times of limited kelp it will attack the attached plants themselves.

When considering harvesting wild kelp, one realizes that less will be left behind for these other processes. We can't take something away and have it there at the same time.

Some time ago, we did an experiment in which we harvested some *Macrocystis* and then we looked to see what happened afterward. I'm not going to go into detail, but this is an example.

Ulva is sea lettuce. It's a green-bladed plant about a foot tall. After a period of harvesting, we observed that where we had not harvested there was very little sea lettuce on the bottom of the ocean. Where we had either partly or completely harvested *Macrocystis*, we had a lot of *Ulva*. What this means is that we had changed the composition of the other plants in that area. That means, going a step further, that we had changed available food for any animal that might be in that area. Now, that change might be for the better, or for the worse. We looked only at the sea urchins, and when we compared an unharvested area with a harvested area, we found that there was about the same amount of plant material produced, but it came from different sources in the harvested area. It came from some of the smaller plants that increased their growth when the big plants were cut back.

When we harvested the urchins and compared their roe, which is a commercial product in British Columbia (and I believe, in Alaska as well), we found a decided difference, a decrease in both the quantity and the quality. So there is a price to pay, and we can demonstrate in the field that the price is real.

Growth and Harvest

When growing kelp, we are not only growing kelp for ourselves, we are growing kelp for the whole ecosystem.

The plant grows from the bottom. That is where the new tissue is added, so the blade gets longer and longer. Meanwhile at the far end it's eroding away, falling off. There's a point at which the growth at the bottom equals the rate at which the erosion is happening at the far end.

We have calculated, for farm plants, that what the farmer takes off at the end of the year represents roughly half of what that plant produced. The other half has sloughed off and gone into the food chain. We are actually feeding things in that environment with excess vegetable matter we produced and could not harvest. Nature just took its dues.

There have been quite a few studies done in our province on the effects of harvesting *Laminaria* from the beach. In other words, foraging for it at low tide. These studies have shown that it takes about three years for the plant community to return to where it was at the point of harvest. The dominant species in that community is the plant we want to harvest. We can harvest it once every three years, it appears, so that puts a restriction on what we are doing.

People who have attempted to make a business of harvesting wild plants in British Columbia have found that tides restrict when they can harvest. Although SCUBA gear is an alternative, it's cumbersome for handling lots of plant material. Those who harvest wild plants find it difficult to guarantee a regular supply. People are not willing to promote a product if a regular source can't be guaranteed. These are some of the drawbacks to counting on wild stock.

On the other side of the coin, the kelp farmer can harvest whenever he wants to. He does not have to depend on the tides and the weather. Also, plants grown in farms always are much larger—for reasons we don't understand—than anything in adjacent areas growing wild. In *Laminaria groenlandica*, wild plants weighed around 347 wet grams. Cultivated plants were about twice that. In *Cymathere triplicata*, another edible kelp, cultivated plants were not quite double in size, but definitely were bigger. *Macrocystis* shows a considerable difference in size between cultivated and wild plants. The cultivated plants are so large that they are hardly recognizable as the same species.

Kelp in the Northwest Pacific

Why grow or cultivate kelp in the Northwest Pacific, including Alaska? First, nature has told us that this is a good place to grow kelp. We're not going to be competing with people in Mexico or Chile or anywhere else for the varieties of kelp species available for our efforts. In our area, for example, we have 15 genera and 50 species of kelp. This tells us that this is good country for kelp. It is only equaled by Hokkaido, Japan.

Although there are many kelp that are found much farther north and much farther south, there are a lot of kelp that either terminate their southern distribution or their northern distribution in the general area of Vancouver Island. This tells us that this area is very diverse environmentally and supports many species. The diversity of environments is very encouraging to a farmer. That means that he can have greater options in the kinds of products he might be able to raise.

A historical oil painting made near here shows the wealth of kelp early explorers saw when they first came to the coast. I've always been very envious of these people for discovering all these rich kelp beds, all these brand new species. Those explorers made great sacrifices—they preserved the kelp with their wine supplies.

Types of Edible Kelp (Figure 2)

Alaria. This is the closest we have to *Undaria*, which is highly prized by the Japanese as an edible plant.

Laminaria saccharina. Sugar kelp is so named because it has a sweet taste.

Cymathere triplicata. This is the three-ribbed kelp. It is the only kelp species that is consumed in Japan that we share with them.

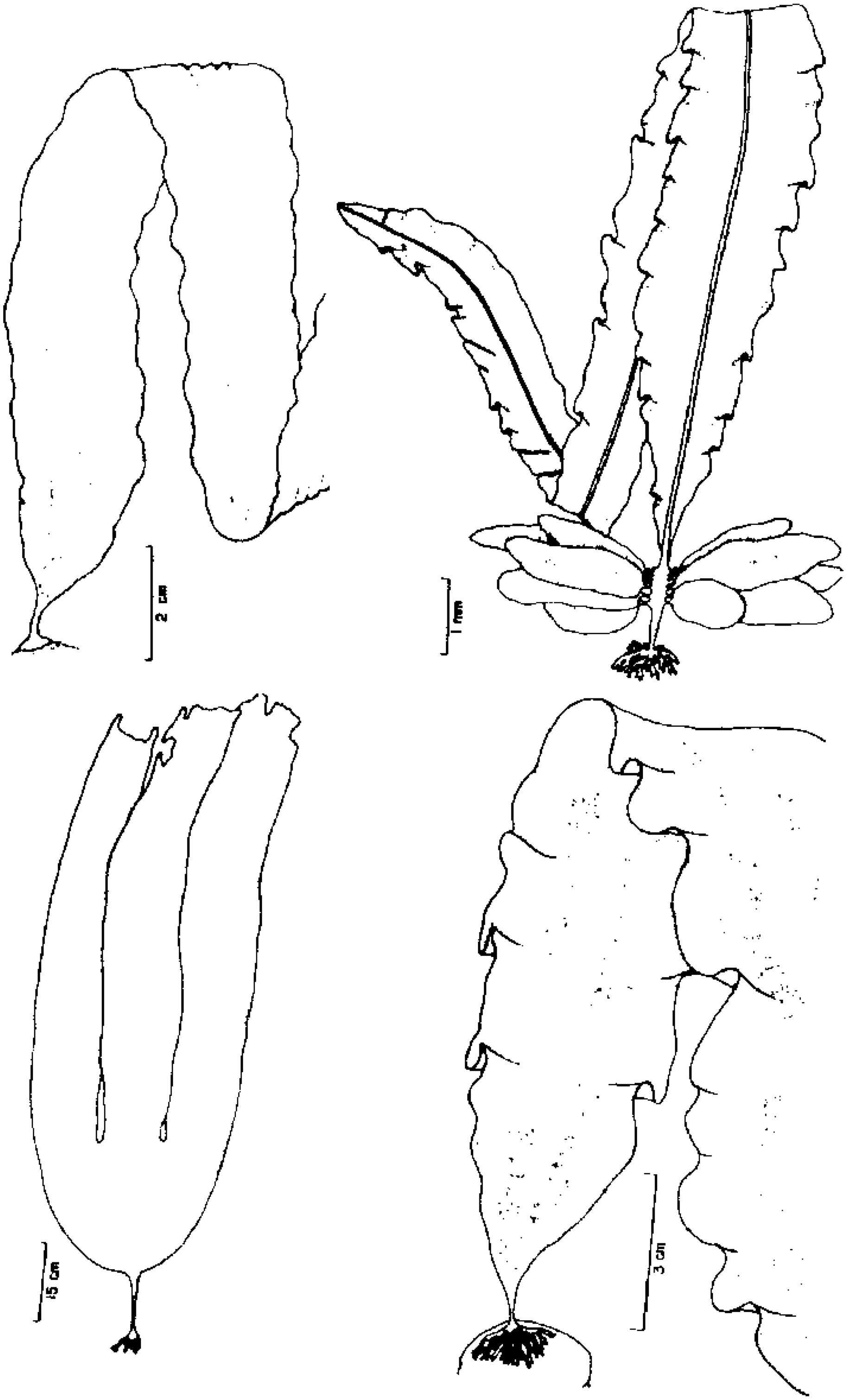

Figure 2. Sketches of *Cymathere triplicata* (top left), *Alaria marginata* (top right), *Laminaria saccharina* (bottom right), and *Laminaria groenlandica* (bottom left). Modified from Scagel 1967.

Laminaria groenlandica. According to the Japanese, and now according to our own experience, this is probably the best plant for aquaculture of seaweeds in this area.

Laminaria japonica. This is the competition, if we are trying to compete with the Japanese. The plants are very long, narrow, and thick. They are up to 10 m long, and often they are no wider than the distance between a thumb and first finger. The Japanese like the thick, dark plant, and this is the king of them all from their perspective.

Growth Cycle

This is the life history—how the plant changes over time—and this is very important to the farmer.

The baby plants created through the sexual process become obvious around March. They're about half an inch tall. They're scattered here and there, including on the beach. They grow rapidly in the spring, starting in March. In the summer, their growth usually is slower than their erosion. They lose tissue faster than they produce it at the bottom. There is a point at which the growth in width and length stops, but the plants continue to become thicker. They also become much more tasty then, which is very important.

They continue with the very slow growth, with lots of erosion. They erode farther and farther back, until the fall, at which time they produce their spores and start the new generation for the next year. The new generation shows up the following March. If the plant is an annual plant, as is the sugar kelp, *Laminaria saccharina*, the erosion takes place until the whole plant is eroded away, and that is the end of that crop. It doesn't matter if it's on a rock or in a farm.

If the kelp is a perennial plant, like *Laminaria groenlandica*, which will live for a few years, then erosion never takes the whole plant away; something overwinters, and then the plant starts active growth in January. This active growth leads to the spring growth.

In the second year of growth, the plants are larger, they are tastier, and they're thicker than at any other time in their life history. That's when they should be harvested. I have described a growth season of about 18 months. The plants actually are growing in response to a changing environment, which results in an unusual growing season.

The growth that we see as the plant enters its second year in January is not in response to light. This is happening in the Arctic Ocean where there is very little light in January. It is growing in response to the high levels of nutrients at this time of year. As the plant enters its second year it is using stored carbohydrates to produce new tissue. It uses this stored carbohydrate and nitrogen to produce new membranes that allow the plant to grow in length, but not in thickness.

In summer when light is good, nutrients often are scarce. As the plant enters the period when the nutrients are scarce, growth can be observed more easily. In the spring it grows 10 cm a day. In the summer it slow down and gets gradually thicker and darker. Chemical analysis shows that it is richer in carbohydrates in the summer. The plant uses the light for a different reason: to produce stored products that will allow it to grow into the fall when more nutrients are available.

But there is more to farming that just leaving the kelp for 18 months, and then harvesting. The trouble is that when the growth has stopped and the plant has thickened, other things become interested in the plant. Things can land on it and grow on it, and these detract from the product.

Adapting Cultivation to the Growth Cycle

Erosion is continually removing the crop. It is frightening to watch a crop erode while waiting for it to mature. We have spent a considerable amount of time figuring out how to beat this plant at this game. This is how we did it.

We plant our little baby plants, not in March as we see it happening in nature, but as early as December. These plants that are started in December grow a little bit and then they say, "Ah, it was great being a first-year plant." In January they start growing like all the other plants, and they are now second-year plants even though they're only a month old. In June or July of that same year, less than a half a year later, we have plants comparable to those we would find in the wild after 18 months, or farmed, simply by manipulating the life cycle.

From spring to fall, carbohydrates increase. Amino acids decrease, but we don't know what to do about that. The ash content decreases, and we kind of like that, because we think the ash content gives the plant a bit of a bitter taste. And the dry weight as a percent of the fresh weight is increasing, and we like that. The final dry weight is about 15 percent of wet weight. So, if we pick 100 pounds, it would be 15 pounds dried.

Techniques for Cultivation

The research I am about to describe was sponsored for three years by the Ministry of Environment and it was then picked up by the British Columbia Science Council for two more years. I had three major research assistants, Kitty Lloyd (who is now a kelp farmer), Ann Lindwall (who is an ex-kelp farmer), and Robin Baird. The work was done at the Bamfield Marine Station and other areas throughout British Columbia. Independent farmers assessed our techniques as far north as Prince Rupert, so their data would be very profitable for anyone who wants to know what to expect in these waters.

When we first started, we went to Japan and we got help from people such as Drs. Y. Sanshonsuga, Y. Hasegawa, and S. Kawashima. Dr. X. Fei, in China, was very helpful, showing some of their techniques, and in Germany, Dr. K. Luening showed us some tricks and helped us cut in half the time it takes to grow a crop

Our research was geared to produce an industry with low capital requirements and could actually be operated as a cottage industry, not massive farms involving tens of thousands of dollars to establish. We envisioned a small farm that could provide all the money for, or help provide money for, people who want to live on the coast.

Seed Production

Seed production involves working with plants from the time they are spores through the sexual phase and sexual conjugation up to the time the plants are about 4 or 5 mm in length, less than 1/4 in. long.

Seed production refers to production of small sporophytes (3-5 mm long) suitable for outplanting on kelp farms. Seed is produced in the laboratory under controlled conditions. Three conditions must be met for the production of optimal seed stock:

1. The parental stock, from which the seed is produced, must have the desired features of the final product, and preferably have demonstrated good growth characteristics under cultivation conditions. The kind of seed we look for is one that grows well on rope, not on rocks. I'll admit, the first time around, the farmer has to take a chance. After that, try to pick the breeding stock from plants from the farm, and be very conscious of what that plant is like. Don't harvest all the best plants and sell them and then use the scrawny ones for your seed for next year. That's not good selection. Make sure you have the right genetic stock when you start your production.
2. The grower should make sure the seed plants are grown in a laboratory environment free of snails and other things that might eat them, and free of other kinds of algae that might compete.
3. The kelp should be as vigorous and as healthy as possible when planted because it's quite a shock leaving the nice warm laboratory, with a little Beethoven in the background, and being chucked out into the cold Pacific Ocean in December. We use a special medium that ensures these plants have all the nutrients they need and every advantage possible. At time of outplanting, the seed must be healthy and in a physiological state that assures competitive success. To meet these conditions, facilities for sterilization and culture media preparation are required. Culture facilities that include access to a sea water system, artificial illumination, and aeration are required.

The three criteria, good stock, no competitors when producing the seed, and good nutrition, are necessary for good vigor of the plants that are going to be set out.

The cycle begins when the plant is picked up in the field, and usually this would happen around October in Alaska. At that time there is a dark patch on the blade called the sorus. The darker that patch, the better. That is where meiosis takes place.

The plant is taken into the laboratory and put in a dark cool place, around 50 degrees, such as the refrigerator. The sorus goes into a plastic bag with some newspaper that has a little fresh seawater on it. This keeps it moist. Twenty-four hours later it should be taken out, and the sorus cut off and put into sterilized seawater. Within 30 minutes, that water will turn cloudy. Look under the microscope to see whether there are huge numbers of swimming spores. If they're not there, throw the sample away. If they are swimming, pour that solution through cheesecloth into a sterile container and let it sit overnight, again keeping it cool and dark. Overnight the swimming spores stay up high in the water column, and the ones that are not healthy plus the diatoms and such sink to the bottom.

Decant the top part, being careful not to stir up the grunge in the bottom, and pour it through some cheesecloth into a container in which there is string and sterilized seawater that's been fortified with a variety of nutrients. Aerate this to keep everything stirred up. The spores get tired of swimming after a while and they settle out, especially on the string.

The string used in kelp culture is hydrophilic nylon and is woven in such a way that when it is cut into little pieces, it doesn't unravel. Leave the string in this situation for another 24 hours, then take it out and put it in a clean container of enriched seawater. That gets rid of all the spores that settled in undesirable places.

Expose the spores on the string to a 16:8 hour light:dark photoperiod for about 45 days. After 45 days, there will be little plants on the string. Cut the string into little bits and insert the string into the warp of the farm rope. Then toss it into the sea. After the rope has been out in the sea for about two months, every place with a piece of string will have a little cluster of plants. After about eight months, it is harvest time. For every meter of growth, with sugar kelp, there are about 8 kg of fresh plant material.

Following that procedure sets the grower up for 18 months of cultivation. To shorten that, follow the seed procedure to the point at which spores settle on the strings, then put them in red light to delay sexual development. After a delay of up to a year, give them blue light, i.e., white light that has blue in it. At that time they will develop sexually and produce seed in the normal way. This means seed can be produced any time of the year.

Farm Location

There are a variety of things that will help you choose where to put a farm. Some of these things are good nutrients, cold water, little runoff, and good water motion. A good indication that an area is suitable for a kelp farm is the presence of healthy stands of wild kelp in the general vicinity. Finally, the site should have a soft bottom suitable for anchoring the farm rope.

Table 3. Production values per meter culture rope for some edible kelp species.

Species	Location	Culture duration (months)	Wet wt (kg/m rope)	References
Laminaria saccharina	Great Britain	6	4.2-28.4	Kain pers. comm.
Laminaria saccharina	B.C. Canada	8	3.0-8.0	Druehl unpubl
Laminaria groenlandica	B.C. Canada	18	9.6-20.5	Druehl unpubl.
Laminaria religiosa	Korea	5	6-9	Chang & Geon 1977
Laminaria japonica	USSR	6	10	Buyankina 1977
Laminaria japonica	China	6	5-20	Fei pers. comm
Laminaria diabolica	Japan	11	8.4-24.0	Kawashima pers. comm.
Laminaria japonica	Japan	20	10.1-15.9	Kawashima pers. comm.
Alaria esculenta	Great Britain	3	7.2-11.9	Kain pers comm.
Undaria pinnatifida	Japan	5	< 5-10	Akiyama & Kurogi 1982

Kelp Farm Structure

The basic farm structure consists of a sturdy, well-anchored rectangle of rope 100 m by 35 m, which is maintained at a constant depth (usually 2-3 m) below the surface. This structure provides the frame to which the culture ropes are attached. The seeded ropes are stuck in there wherever the farmer wants to put them. The grower can harvest the whole rope and take it in at any time.

Kelp Farm Maintenance

Frequent visits to the farm site are required to clean lines of floating debris. This usually consists of free-floating bull kelp and giant kelp. Floating trees and logs are potential hazards too.

Mussels and other sharp-shelled invertebrates may establish themselves on cultivation lines and should be removed. They abrade kelp stipes and will diminish the crop. There are other kelp farm pests, but little is known about them. For example, Barkley Sound Kelp has had a severe herbivorous snail attack.

Harvesting and Drying Farmed Kelp

Culture ropes may be draped across a herring skiff and the plants cut free. Alternatively, the entire culture rope may be retrieved and transported to the drying facilities. The final product influences the drying process to be chosen. If powder or flakes are desired, it is important to be certain that the kelp is thoroughly dry and then sealed from moisture. If, however, sheets of kelp are desired, the kelp is first partially dried, then folded, and then completely dried. Drying may be accomplished in a greenhouse with forced ventilation.

Farming Considerations

The kelp farmer has several options regarding farm operation. The procedures chosen will reflect the species grown, the desired product and the farmer's inclination. During the tenure of our research we explored several options that are reviewed below (see Druehl 1980a, 1980b, 1981 for details). These findings are particular to our situation and may have only limited value elsewhere.

1. Spacing interval of plants along culture ropes. Spacing closer than 30 cm is generally impractical and a greater spacing interval doesn't seem to influence productivity.
2. Thinning plants that arise out of any cluster. Thinning results in larger individual plants but lowers the total productivity of the system.
3. Planting time. If planting takes place in October and the plants are harvested the following June, they are the same size or similar or smaller than plants planted nine months earlier. However, the total harvested crop may be greater for the shorter growing period, as there is a greater survivorship for these younger plants.
4. Planting depth. Kelp are essentially shade plants, which means they grow efficiently at reduced light levels. Depths shallower than 2 m further expose the plants to drifting debris, outboard motors, and fresh water that may mix down from the surface. At greater depths, usually below the thermocline,

Table 4. Production values per hectare kelp farm.

Species	Location	Wet wt (MT per ha)	Reference
Laminaria japonica	USSR	50-60	Buyankina 1977
Laminaria japonica	Japan	49-139	Kawashima pers. comm.
Laminaria diabolica	Japan	59-128	Kawashima pers. comm.
Laminaria japonica	China	55	Fei pers. comm.

more favorable nutrient conditions are encountered. Below 4 m, limited light might cause slower growth.

5. Source of parental stock for seed production. Until genetically superior stock are discovered, we recommend that plants from near the farm site be used for breeding stock. Once a farmed crop has been produced, the kelp farmer should select breeding stock from the farmed plants.

Our production values range from a low of 1.1 to 2.7 wet kg per meter of culture rope for *Cymathere triplicata*, to a high of 2.6 to 20.5 wet kg per meter of culture rope for *Laminaria groenlandica*. These values compare favorably with those obtained elsewhere (Table 3). We have not attempted intense cultivation in British Columbia. However, production values on an area basis are available from the Orient. The values achieved there are very encouraging (Table 4).

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OBSERVATIONS ON LAMINARIA RESOURCES IN SOUTHEAST ALASKA

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This presentation is based on work that Natasha Calvin and I did over several years when we were working for the National Marine Fisheries Service at Auke Bay; much of this work was published and is available. Also, since we did the research there, we've made a lot of personal observations on *Laminaria* throughout Southeast Alaska.

In Alaska, the species that we have been looking at most extensively is *Laminaria groenlandica*. *Laminaria* occurs throughout Alaska to the Pribilofs, and some species of *Laminaria* grow all the way down the coast. *Laminaria groenlandica*, the species most abundant in Southeast, is most likely to be used by aquaculturists. We say this because it is the species that we find we most enjoy eating ourselves. It is most amenable to use by the casual collector, the subsistence-type user. We do have the other major species, *L. saccharina*, the sugar kelp.

ENVIRONMENTAL EFFECTS ON LAMINARIA

We've observed, over the years, that there are environmental factors that determine the species, abundance, distribution, and growth form of *Laminaria*. For instance, the depth distribution of the plant is determined by available light, based on water clarity. In clear areas, we see good-looking *Laminaria groenlandica* down at least to 85 feet. In areas where the water clarity is considerably reduced, such as near the pulp mill, the range of depths for the distribution of *Laminaria groenlandica* is only a foot or two, in contrast to other areas where it goes to about 85 feet.

A fair amount of water movement is necessary to develop a good aquaculture site. We've observed in the wild that this water movement determines the blade shape, its thickness, and the amount of bullation or crinkly texture. In calm waters where there is just a little current, bullate blades will develop on *Laminaria groenlandica*. These blades are fairly fragile and also seem to accumulate more epiphytes such as hydroids and bryozoans. Also there will be more sediment falling on them. This may be the effluent from a glacier-fed stream or other fallout.

In calm water with a slow but continual current, a blade up to 2 meters can develop in *Laminaria groenlandica*. When the blades are that large, they are usually bullate, puckered, and quite delicate. This is a problem in handling the plants because they will crack and break.

In fairly calm water with a good amount of current, another type of plant will be produced—one that is more linear in shape with thick, flat, non-bullate blades. The more agitated the water, the thicker the plant.

In calm water with a lot of current, flat plants will develop with no bullation at all; they will be strap-shaped with parallel sides, and the blades will be quite thick. Under conditions with so much current, the growth of epiphytes, bryozoans and hydroids, is considerably reduced. Epiphytes still occur, but they appear later in the season.

In really rough water *Laminaria groenlandica* will have thick heavy blades with no bullation. They usually split, so the plants are almost digitate in form.

Concurrently with these changes in blade configuration there also are changes in stipe. One of the reasons I'm interested in the stipe form is that the stipes are very flavorful and have a little more texture.

PREDATORS AND PESTS

Natasha and I studied one group of wild *Laminaria* plants at a particular site for several years. We returned monthly, and later we went back weekly to observe them.

One of the things that we observed was a movement of green urchins into and through our study area. This was almost catastrophic for our original study, because these urchins weren't at all hesitant about eating our *Laminaria*. Our *Laminaria* plants, especially those we had tagged for observing growth rates, were particularly attractive to them. They especially went after the plastic survey tapes.

In addition to urchins, we observed another plague in our plants. We looked at this population of plants for 10 years. Over this period, we had just one sweep of urchins through. And in another year, we had a tremendous set of barnacles. These barnacles set so abundantly that they covered everything in our study site, including stipes and blades of vigorously growing *Laminaria*. Eventually, we wound up with casts of *Laminaria* stipes that consisted of barnacles, where the *Laminaria* blade had rotted inside. It totally destroyed all the *Laminaria* on that site. And that was just once in 10 years. Maybe it would be only once in 100 years, but it is a problem we observed.

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The usual hydroids and bryozoans also grew on the blades; this was seasonal. The later in the growing season, the more intense the growth of epiphytes.

Another problem we observed (some people might not view it as a problem) was an infestation of amphipods. In some situations we found a large percentage of plants infested by amphipods. These amphipods burrowed into the blades and the blades responded by growing scar tissue around them. We wound up with amphipods in the *Laminaria* blades and stipes. Now, some people might take advantage of this, for instance in making *Laminaria* and shrimp soup, and use the shrimp that occurs naturally in the *Laminaria*.

After the plague of barnacles occurred, we wondered how extensive it was in the Juneau area. We were able to get a little vessel time and some divers, and we made spot checks over about 100 miles of shoreline. In the 100 miles of shoreline we sampled, we did not find another site with a barnacle infestation.

We did observe areas of 100 yards or so of shoreline where all the plants were very small, 1 or 2 years old. Adjacent to this would be the normal kelp forest. What this told me was that some natural phenomenon, such as a plague of barnacles or sea urchins, was occurring periodically in nature. This is something, therefore, that a grower would have to expect to happen at any one site. Even though a site is a good growing site for several years, it's not always going to be a good site.

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DEVELOPMENT OF MACROCYSTIS CULTURE IN ALASKA

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The topic of this paper is *Macrocystis* biology, culturing methods for *Macrocystis*, and what we have done and are going to do in the immediate future with kelp culture.

MACROCYSTIS BIOLOGY

Macrocystis is the large, brown, canopy-forming seaweed that goes by the common name of giant kelp. At this time, *Macrocystis* has the best potential for mariculture development in Alaska because of its value in the Prince William Sound herring roe-on-kelp fishery.

Macrocystis forms large beds just offshore, growing in depths up to 60 feet. *Macrocystis* is found from Mexico to Alaska on the West Coast. However, the type of *Macrocystis* in California and Mexico is different from the more northern *Macrocystis* found in Alaska. In fact, there are three recognized *Macrocystis* species in the world.

Macrocystis pyrifera is found growing subtidally attached to rocks in exposed coasts along California, South America, and through the southern hemisphere. It grows usually between 30 and 60 feet deep. It extends to the surface forming large canopies. The total lengths of the fronds can be over 120 feet.

Macrocystis angustifolia occurs off of Australia, South America, and perhaps Santa Barbara, California. It is very similar to *M. pyrifera* but grows on sandy bottoms.

Macrocystis integrifolia is found off of South America and from Monterey Bay to north of Sitka. It is a smaller (shorter) plant than *M. pyrifera* and grows closer to shore and in more protected areas. Patches of *M. integrifolia* are usually smaller in size than *M. pyrifera* and grow closer to rocks and reefs. *M. integrifolia* plants do not survive in more exposed coastal areas in Alaska.

There are two other Alaska kelps that form kelp beds with floating canopies and may at first be confused for *Macrocystis*. These are *Nereocystis leutkeana* and *Alaria fistulosa*.

Nereocystis also is known as bullwhip kelp because of its long, whiplike stipe. At the surface the stipe expands into a large bulbous float with many long thin blades protruding from it. This kelp forms extensive beds all over Southeast Alaska, both in inside waters and in exposed coastal areas. It tends to grow in areas of extreme water motion.

The other kelp is rarer in Southeast, but common in the Aleutians, and is the very unusual-looking kelp *Alaria fistulosa*.

It is easy to distinguish *Macrocystis* from the other kelps. *Macrocystis* has many long fronds arising from a large holdfast at its base, which is usually attached to the rocks on the bottom. Each frond has blades coming off at regular intervals all along the frond. The blades themselves are ruffled and serrated along the edge with a small float (pneumatocyst) at the base of the blade The base of the plant may have specialized blades that are called sporophylls. These blades produce microscopic spores for making new *Macrocystis* plants. A *Macrocystis* plant is considered perennial, but individual fronds have relatively short lives.

Macrocystis is a fast-growing plant and can produce a lot of biomass in a small area of the ocean. It is a good species for mariculture because it can be used for a variety of commercial purposes. *Macrocystis* is a source of a variety of chemicals, a source of biomass, and also can serve as a surface for herring roe attachment

Macrocystis contains large amounts of alginates--chemicals that are used in industry as emulsifiers, which are thickening and smoothing agents. *Macrocystis* extracts are found in everything from toothpaste to beer. *Macrocystis* is presently harvested from natural stands in California by large, mowing barges (Figure 1). The Chinese are also very interested in *Macrocystis* and *Laminaria* for chemical extracts and are currently attempting to culture *Macrocystis* on a relatively large scale.

During the oil crises in the 1970s, there was considerable effort expended to show that it would be feasible to convert *Macrocystis* to fuel through fermentation. Large-scale farms were envisioned, and a small, deepwater farm was actually built off the coast of California, but was not successful in growing kelp for any length of time.

At present, the most profitable use for *Macrocystis* in Alaska is associated with the herring roe-on-kelp industry in Canada and Alaska. Alaska has large stocks of herring that spawn on many types of submerged vegetation, but only the brown seaweeds are commercially valuable. In Bristol Bay, the main money species is *Fucus*, an intertidal brown seaweed (Figure 2). It is harvested by hand and sold for 50 cents to $1 a pound. In Prince William Sound, the eggs are harvested attached

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to *Laminaria*, with minor harvests on *Desmarestia* (hair kelp) and *Agarum*. These also are relatively low-value products, selling for $1.50 to $5 a pound.

In Canada, and recently in Prince William Sound, herring roe-on-*Macrocystis* is harvested and sold for as much as $14 per pound (Figure 3). However, there are problems associated with this fishery. In Canada and Alaska, *Macrocystis* beds are often not located close to the spawning herring, and the condition of the beds themselves varies widely from year to year. In Alaska *Macrocystis* beds are in Southeast and the roe-on-kelp fishery is in Prince William Sound over 500 miles away, making logistics difficult. There was at one time a roe-on-kelp harvest in Southeast, but it was closed in 1974.

In both Canada and Alaska, Macrocystis is harvested from natural beds and transported to the fishing grounds where it is used in impoundments. In Alaska, the kelp is taken from areas near Ketchikan and Sitka. To collect *Macrocystis*, a permit is required to both harvest in Southeast and to import to Prince William Sound. *Macrocystis* beds must first be located. Sufficient good quality kelp must then be cut to allow for the wastage that will occur during transport. Once cut, the kelp deteriorates rapidly unless kept in cold seawater. Even so, the kelp must be transported rapidly to preserve its quality.

Figure 2. Freshly deposited herring eggs on the intertidal brown alga *Fucus* in Bristol Bay, Alaska. This type of row-on-kelp is harvested from natural stands of *Fucus* and is worth about $1.00 per lb sold to the on-the-grounds processor. Photo by Michael Stekoll.

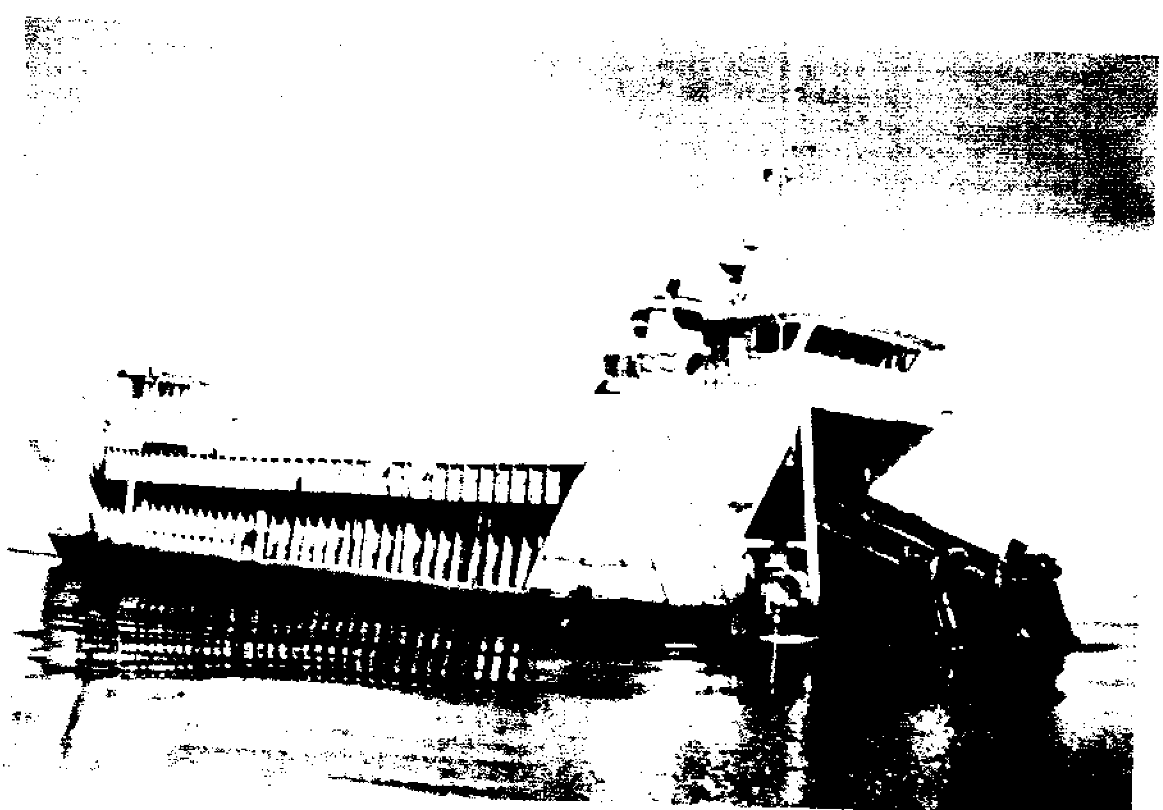

Figure 1. Kelco's *Kelstar* is shown here harvesting *Macrocystis* off of Imperial Beach, California, in January 1986. The harvested giant kelp is processed for a variety of alginate chemicals. Photo by Ron McPeak, Kelco.

Figure 3. Herring spawn on *Macrocystis*. The *M. integrifolia* plants are harvested in Southeast Alaska and transported over 500 miles to the Prince William Sound herring spawning grounds. The plants are trimmed and submerged in impoundments similar to the one in the photo. Ripe herring from purse seines then are introduced into the impoundments and are held there until they spawn. Top grade herring roe-on-*Macrocystis* are worth as much as $14 per lb.

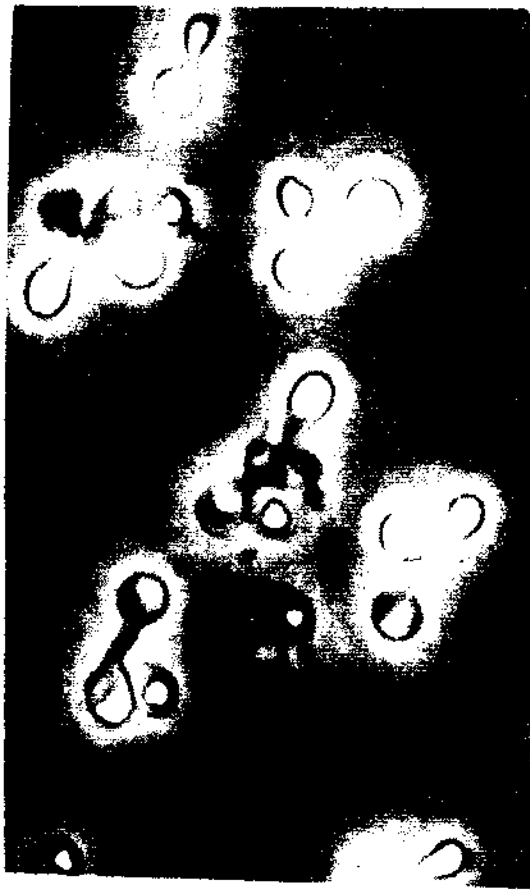

Figure 4. One-day-old cultured *Macrocystis* spores. The ungerminated (round) spores are about 3 microns in diameter. Germinated spores are recognized by the characteristic "dumbell" shape. Normal culture methods provide string as a settling surface on which the spores germinate. Photo by Michael Stekoll.

The impoundment fishery involves preparing an enclosure in which either fronds of *Macrocystis* or *Laminaria* are suspended. Seined herring are transferred to the impoundment and allowed to spawn. The spawn-on-kelp is removed and processed by trimming and packing in boxes. The herring are released and the impoundments left in the water until the remaining eggs hatch.

A major expense with the impoundment method is the cost of collecting and transporting *Macrocystis*. Locating appropriate beds of *Macrocystis* at the proper time may not be trivial. It is thought that mariculture of *Macrocystis* may reduce some problems involved in this fishery. Cultured beds of *Macrocystis* would make available a ready supply of commercial-grade plants. It also is possible that mariculture methods may allow growing adult stages of the plant near impoundments, which would reduce considerably the expense of transporting adult *Macrocystis* over long distances.

MACROCYSTIS CULTURE

I have been involved over the past two years in developing methods for mariculture of giant kelp in Alaska. In order to culture any organism, it is necessary to understand its life history or life cycle. *Macrocystis* has a life history that is essentially the same as that for *Laminaria*.

Macrocystis starts off each new generation by producing microscopic spores from sporophylls made at the base of the giant kelp plant (Figure 4). The swimming spores settle and grow into small, microscopic plants, called gametophytes. Two types are made: male and female. Eventually, when conditions are right, gametes are produced, with the release of sperm and the subsequent fertilization of the egg. The fertilized egg germinates into a small blade that develops a holdfast and finally grows into the mature kelp plant.

All of this normally takes place in the ocean under the kelp canopy. However, as with *Laminaria*, we can carry out most of this life cycle in the lab. To culture *Macrocystis*, sporophylls are collected by SCUBA divers and brought back to the lab. Mature sporophylls can be recognized by the dark, soral patches in the middle of the blade. The sporophylls must be cleaned to remove contaminating organisms and wiped dry to partially desiccate the spore containers (sporangia). Sporophylls are laid on moist paper towels and kept cool for an hour or so, then immersed in warmer seawater and exposed to bright light. This combined temperature, water, and light shock provides the stimuli to release millions of spores into the seawater.

The spores are motile and will swim from a few seconds to a few hours before settling on a suitable surface. At that point they withdraw their flagella, round up, and then secrete an adhesive, gluing themselves to the surface. The settled spores germinate and grow into microscopic, filamentous plants. The female gametophytes are generally about twice as thick in cell diameter as males (Figure 5). These filamentous gametophytes can be kept in this vegetative state indefinitely by keeping them in low light, red light, or by omitting iron from the culture media.

If conditions are right, the plants will form sperm and eggs, fertilize themselves, and produce baby sporophytes. For the large-scale culture of *Macrocystis*, it is easy to provide a surface for settling in the form of string wrapped around a frame of some kind. The Japanese use a special synthetic string called cremona, which does not fray when it is cut, but most synthetic strings are suitable. The gametophytes germinate and grow quite well on the strings and, eventually, after about two weeks, form baby sporophytes (Figure 6). These grow relatively rapidly and are easily visible after four to six weeks.

These "seedling" plants can be outplanted to the ocean directly or can be cultured "provisionally." At the University of California at Santa Barbara, I cut sections of seeded cremona and inserted them into poly

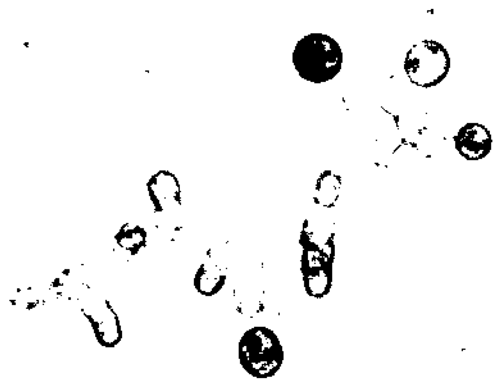

Figure 5. Female gametophytes (1N) of cultured *Macrocystis*. The plants are about 15 days old and have begun to produce eggs. Each mature egg (10-15 microns) is extruded from the mother cell which is left as an empty tube. Each egg will be fertilized by a sperm produced from a similar but smaller gametophytic filament. Photo by Michael Stekoll.

ropes affixed to a section of 2-inch PVC pipe. These were set into special "water broom" tanks in a greenhouse. The plants were grown in seawater for two months until the first dichotomy was visible.

At Sheldon Jackson College in September of last year, the Marine Advisory Program invited me to participate in a *Macrocystis* culture demonstration project. Ray RaLonde, Junzo Abe, and I set up a simple culture lab and were successful in carrying out the first stages of *Macrocystis* culture. However, due to time constraints, we were forced to begin outplanting without provisional culture. The plants on the strings were only about 0.2 mm long. We attached the plants to a rope and sank the ropes with sandbag anchors. Mr. RaLonde reports that no *Macrocystis* were found on the ropes when he examined them several months later.

Mr. Abe also tried a different method for spore release, involving the placing of sporophylls over a net material. The seeded net was then wrapped around a stone and sunk to the bottom. We have not relocated these stones to determine if any plants grew from them.

At Santa Barbara, outplantings were done after provisional culture and allowed to remain in the ocean for seven months. Generally the plants did quite well, growing to over 40 feet in length. The plants were eventual-

Figure 6. Three-week-old cultured juvenile *Macrocystis* sporophytes attached to Japanese "cremona" string. This string is about 2 mm in diameter and will not fray when cut. Each plant is about 200 microns wide and 0.5 to 1.0 cm long. In a few days the plants will be ready for outplanting into the ocean, by cutting the cremona into short lengths and attaching these pieces to a submerged structure. Under optimal conditions, such plants will grow to over 30 m (90 ft) in a single season. Photo by Michael Stekoll.

ly harvested and brought to shore for measurements. The fronds developed normally and blades were normal in size and shape. The holdfasts were generally well developed, but lacked a good surface for attachment. Some of the plants developed to maturity, forming sporophylls. Thus, we were able to grow *Macrocystis* through its complete life cycle.

FUTURE RESEARCH

Plans for additional research in *Macrocystis* mariculture rest with the cooperative agreement between the State of Alaska and the Japan Overseas Fishery Cooperation Foundation (OFCF). According to terms of the agreement, the Japanese will provide supplies, equipment, and technical experts to help establish a feasibility study to demonstrate that *Macrocystis* culture is technically possible in Alaska waters near Sitka. We plan to carry out most aspects of *Macrocystis* culture, from spore release to outplanting and harvesting. The project is scheduled to begin in August 1988.

Artificial culture of *Macrocystis* allows us to bypass many problems the plant faces when growing wild. Early life stages are protected from environmental extremes, disease, predation, and so forth. However, the problems with outplanting remain to be solved. These involve determining the best time of the year for outplanting, the best location and the proper depth, among other factors. The OFCF project will be a major first step in answering some of these questions about kelp culture in Alaska.

THE POTENTIAL AND FEASIBILITY OF MACROCYSTIS AQUACULTURE IN ALASKA

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INTRODUCTION

Macrocystis integrifolia Bory is a large, canopy forming kelp which grows in dense beds along portions of the northwest Pacific coast. *M. integrifolia*, a low intertidal-shallow subtidal kelp, occurs from near Point Conception, California to the Aleutian Islands, Alaska (Druehl 1970). Generally, significant beds of *M. integrifolia* are found along all major sectors of the British Columbia coast except for Johnston Strait, the Strait of Georgia, and Queen Charlotte Sound. In Alaska, significant concentrations of *Macrocystis* are located among the outer islands of the Alexander Archipelago to Sitka.

Many factors are believed to regulate seaweed distributions, including water motion, nutrient concentrations, light, sea water temperature, salinity, and biological interactions. Along the B.C. coast, *M. integrifolia* is found in moderately wave-exposed conditions in coastal waters having either constantly higher salinities or low salinity during the fall and winter. It is not found in areas where there is considerable snow-melt runoff (Druehl 1978).

The biological importance of *Macrocystis* cannot be understated because of its association with many desirable species of fish and shellfish as well as numerous birds and marine mammals. *Macrocystis* also has considerable economic potential. In California *Macrocystis* is harvested and processed as a source of algin, as a mineral supplement for humans and livestock, and as a fertilizer base.

In British Columbia and Alaska the major harvest of marine plants is by the herring spawn-on-kelp fishery. This fishery began in the Prince William Sound area during the 1968 herring season in response to a developing Japanese market for herring roe products. Markets were established for several species of broad-bladed brown kelps which fishermen first gathered using grappling hooks. The fishery has undergone a major transformation during the past 19 years as a result of changes in harvest technology, marketing adjustment, and the development of regulations in response to biological concerns. The development of this fishery has occurred in three phases beginning with the early period in which the fishermen were non-selective due to the use of grappling hooks. The second phase started during the late 1970s when a production quota was established, and the harvesting was restricted to the hand cutting of selected kelps by divers. The third and most recent phase has included the development of a cultured process using herring impoundments. This impoundment fishery has developed rapidly since 1979 in Prince William Sound and has been permitted to expand at the expense of the more traditional fishery, which involves harvesting natural spawn-on-kelp by divers (Randall 1986).

During the 1987 herring season in Prince William Sound, 111 permit holders produced 60.3 tons of roe-on-kelp. The majority of the harvest consisted of *Macrocystis*, and only minor fractions of the total consisted of locally harvested *Laminaria* sp. (J. Brady, personal communication).

Spawn-on-kelp production in British Columbia is restricted to the use of impoundments. Except for localized Native food fisheries, there is no harvesting of spawn on natural marine vegetation in British Columbia. A small spawn-on-kelp fishery directed at Japanese markets was developed in 1975. Today the B.C. fishery is flourishing, with 28 license holders each permitted to produce 6 tons of spawn-on-kelp product (168 tons total). A recent development in British Columbia, termed open-ponding, includes the hanging of *Macrocystis* fronds from rafts which are placed into concentrations of naturally spawning herring. *Macrocystis* is used exclusively by the industry.

The B.C. spawn-on-kelp fishery is likely to expand in the near future. The fishery is presently concentrated along areas of the coast where *Macrocystis* is abundant. When the fishery does expand, fishery managers would like to locate the new permits in areas that support small localized stocks of herring which could be otherwise wiped out if subjected to sac roe net fisheries. Many of these areas are outside of the natural distribution of *Macrocystis*. Season to season fluctuations in the biomass of suitable quality *Macrocystis* has been observed by spawn-on-kelp fishermen (Shields et al. 1985). The apparent decline of *Macrocystis* is probably unrelated to harvesting (L.M. Coon, personal communication). It is more likely that environmental factors, including storms, salinity, temperature, light, and biological interactions affect the quality and abundance of kelp

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Although these declines in kelp stocks may be area specific and cyclical in nature, it is evident that the availability of good quality *Macrocystis* is a limiting constraint to full realization of the B.C. fishery.

The availability of *Macrocystis* is much more of a concern to the Alaskan spawn-on-kelp industry. *Macrocystis* used in the Prince William Sound is harvested from Southeastern Alaska in semi-exposed waters from Ketchikan to Sitka. The kelp has to then be transported some 500 to 900 miles by boat or plane to the herring impoundments. For these reasons it would be useful to the B.C. and Alaska industries to develop the technology to culture *Macrocystis* for use in the spawn-on-kelp fishery.

The successful cultivation of *Macrocystis* in the vicinity of spawn-on-kelp ponds would offer the following major advantages:

1. Resolve many of the logistical problems presently facing this fishery.
2. Provide plant material which is in better condition insofar as it has not been subjected to stress resulting from wild harvest and transportation.
3. The ready supply of quality *Macrocystis* would allow the fishermen to exploit the spawning time of herring in a more efficient manner.

METHODS

Cultivation of Macrocystis

Archipelago Marine Research and Canadian Kelp Resources undertook to develop *Macrocystis* culture techniques for use in the commercial spawn-on-kelp fishery between November 20, 1985 and January 20, 1987. One kelp farm for the cultivation of *Macrocystis* was established near Winter Harbour, on the north coast of Vancouver Island, adjacent to an area where two spawn-on-kelp licensees operate. A second farm was established in Barkley Sound on the west coast of Vancouver Island (Figure 1).

Seed Production

"Seed" refers to small sporophytic plants, usually less than 4 mm long, which are produced in the laboratory for subsequent outplanting to kelp farms. *Macrocystis* seedlings were produced in the laboratory at Bamfield Marine Station, located in Bamfield, British Columbia. Laboratory techniques similar to those used for the commercial production of *Laminaria* seed and described by Dr. Druehl in these proceedings were used. Specifically, laboratory techniques using the culture media of Provasoli as modified by Hsiao and Druehl (1973), and cul-

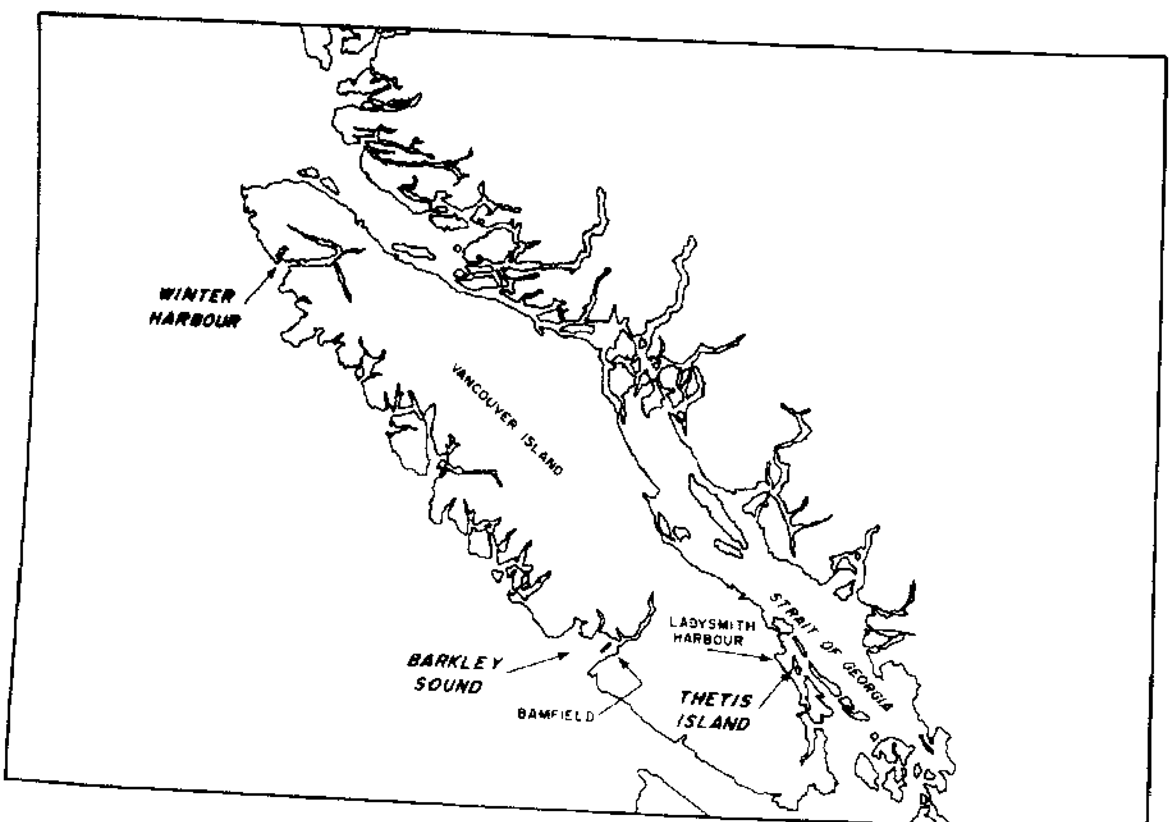


Figure 1. Location of the *Macrocystis* culture sites on Vancouver Island, British Columbia.

ture techniques of Druehl and Hsiao (1969) and Hasegawa (1972) as modified by Druehl (1980) were employed.

Reproductive tissues termed sporophylls (Figure 2) were collected by divers from wild *Macrocystis* plants on three occasions, between November 20, 1985 and December 11, 1986. In all cases sporophylls were packed in sea water moistened paper towel and transported in a cooler to the laboratory.

Outplanting Seed

Seedlings that settled on a hydrophilic, non-fraying string (cremona) were outplanted to the kelp farms once they reached a length of approximately 4 mm (6 weeks) (Figure 3). The seed-bearing string was cut into 2 to 3 cm pieces and inserted into the culture rope at 50-cm intervals and left to grow (Figure 4). The kelp farm in Barkley Sound was constructed in February 1986. Six hundred meters of 0.5 in. (12.7 mm) polypropylene rope was seeded with *Macrocystis*. The farm was arranged into four parallel culture lines of 150 m each. Thirty-five kg anchors were tied every 30 m to the culture lines and the end of each culture line was marked with a surface buoy.

The Barkley Sound kelp farm was placed in 10 to 14 m of water, on a mixture of sand and bedrock substrate. The culture lines were spaced 10 m apart and placed perpendicular to shore. There were a number of individual *Macrocystis* plants growing the area, and a dense bed of *Macrocystis* was present on the opposite shore.

A *Macrocystis* farm was constructed near Winter Harbour in February 1986 using construction methods identical to those used in Barkley Sound. Four 150-m culture lines were placed approximately 1 km outside the mouth of Winter Harbour. Two lines were placed in 3 to 20 m of water on the eastern shore of Forward Inlet. The other two lines were placed in 3 to 20 m of water on the western shore of the inlet. The culture lines were placed on opposite shores of Forward Inlet at the suggestion of one of the commercial spawn-on-kelp operators who intended to use the culture *Macrocystis*. The bottom substrate at both locations consisted of a sand-cobble mixture in the upper 8 m and gradually changed to a sand-mud mixture to a depth of 20 m.

In May 1986, 73 wild *Macrocystis* seedlings measuring 6 to 120 cm in length were collected from nearby kelp beds and attached to 60 m of culture line. The

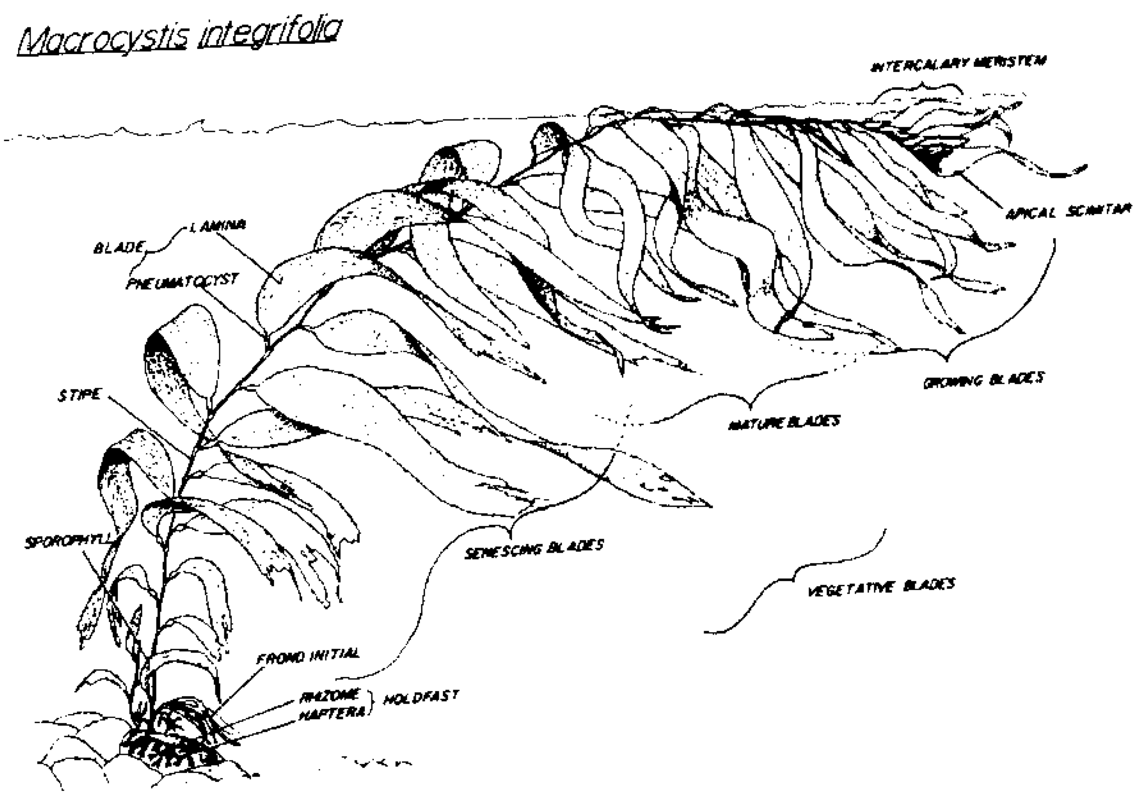
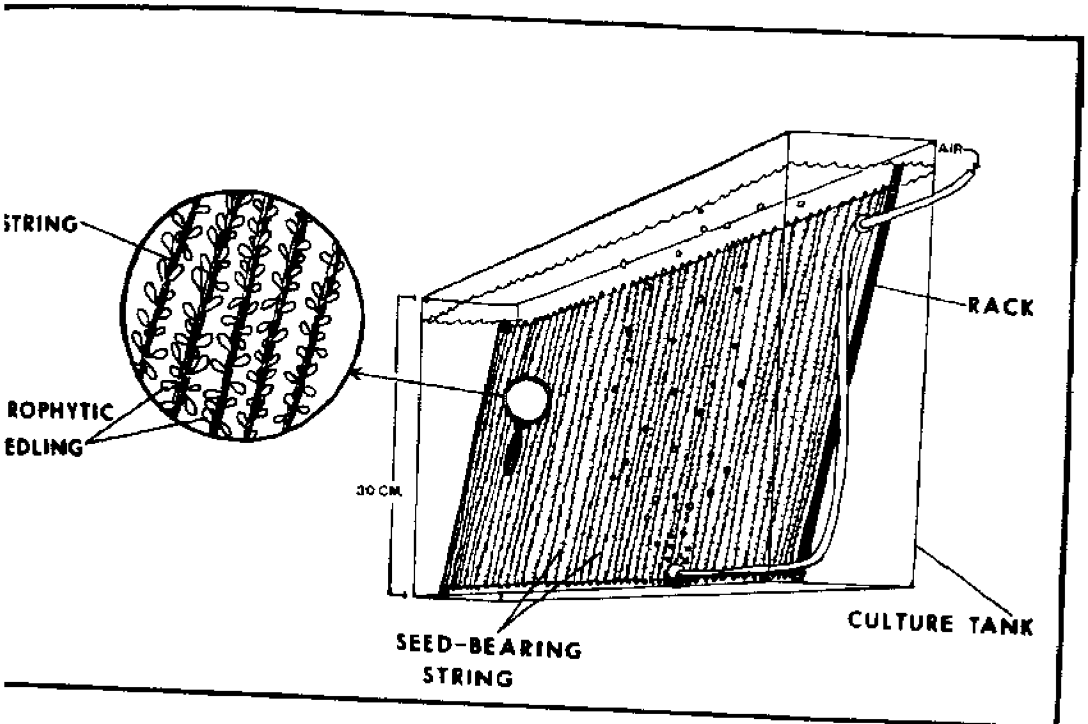
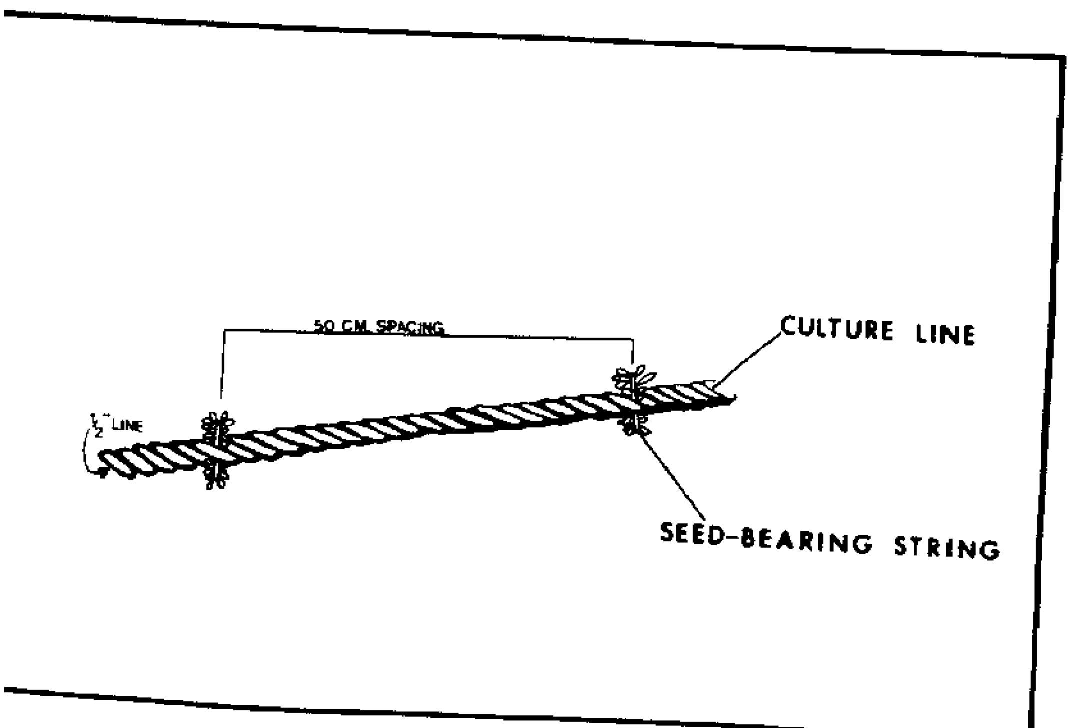


Figure 2. Mature *Macrocystis integrifolia* plant



Seed-bearing string in culture tank.



earing string inserted into polypropylene culture line.

culture line containing the transplants was placed 3 m from the shoreward most culture line on the western shore in 3 to 10 m of water.

Using SCUBA, growth of *Macrocystis* plants on the culture lines was monitored in May, June, and August 1986 in Barkley Sound, and in May and August 1986 in Winter Harbour. On each trip the culture lines were inspected and cleaned of all epiphytes. Also, all *Macrocystis* plants were sampled for total number of fronds and length of the longest frond. A frond was defined as any bladed segment of the plant that had discernible pneumatocysts, including frond initials.

RESULTS AND DISCUSSION

The three seed cultures initiated in the laboratory between November 23 and December 4, 1985, using reproductive tissue from wild *Macrocystis* plants in Winter Harbour, failed to produce any seedlings. The probable cause of the failure was insufficient rinsing of culture equipment after cleaning in an acid bath. Reproductive *Macrocystis* plants were difficult to find in Barkley Sound when the second attempt at seed production was initiated in January 1986. The sporophyll tissue that was used had only small patches of sorus left, as most of the spores had already been released. The resulting cultures produced a sparse crop of young sporophytes, and there were not enough plants on the culture string to allow the culling of the smaller, less vigorous seedlings prior to outplanting. As a result, both the Barkley Sound and Winter Harbour kelp farms were seeded with a less than optimal batch of young seedlings.

The third seed production run (December 11, 1986) was initiated using an abundant supply of sorus-laden sporophyll tissue collected from Barkley Sound *Macrocystis* plants. On January 2 (three weeks' growth) the string bearing the seedlings in both cultures was pale brown, and contained multi-branched male and female gametophytes. On January 11 (four weeks' growth) sporophytes of approximately 10 cells were evident, and these were macroscopically visible in five weeks. Although a healthy crop of juvenile *Macrocystis* seedlings, averaging 5 mm in length, were ready for outplanting to culture lines in six weeks, they were not outplanted due to time constraints in the program.

Survival rates of cultured *Macrocystis* plants in Barkley Sound and Winter Harbour were only 0.5 and 0.6 percent respectively 26 weeks after outplanting. After a 16 week growing period, 32 percent of the wild seedlings transplanted to a culture line in Winter Harbour were still growing.

Wheeler and Druehl (1986) studied the seasonal population dynamics of *M. integrifolia* in Barkley Sound by assessing the structure of a wild population at regular intervals over a two year period and by following the development of cultured plants of similar age and size at two culture sites for 40 months. They determined that the mean number of fronds per wild plant varied between two fronds in the winter and nine fronds in the summer. Number of fronds varied from a low mean of 2 (± 1.6 S.D.) per plant (January to February) at both culture sites to a maximum mean of 6.8 fronds (± 6.2 S.D.) at one culture site and 9.0 (± 9.5 S.D.) at the other. These results compare favorably with mean numbers of fronds observed at our Barkley Sound culture site, 2.9 (± 1.6 S.D.) in June and 8.4 (± 3.5 S.D.) in August. This observed growth of cultured *M. integrifolia*, as determined by mean number of fronds, indicated that *Macrocystis* can be cultured to produce fronds suitable for use in the spawn-on-kelp fishery.

Based on production information collected from the commercial spawn-on-kelp fishery (Shields and Kingston 1982, Shields and Watson 1983, and Shields et al. 1985) and on information about the growth and survival of wild *Macrocystis* (Coon and Roland, unpublished data) and cultured kelps (Druehl, unpublished data), it was estimated that 680 plants in March or 493 plants in April would be required to produce enough kelp fronds (estimated 2,175) to fill one 8 ton spawn on kelp permit quota (the quota has since been reduced to 6 tons). Within the first growing season, planted seedlings were expected to have a 34 percent seedling survival.

Culture lines were placed within and adjacent to wild kelp beds because these areas were believed to offer the most suitable growing conditions. It quickly became apparent that culture lines should not be placed within existing kelp beds because the young seedlings will be abraded off the culture lines by larger *Macrocystis* plants. The seedlings on an estimated 200 m of the Winter Harbour culture lines were abraded in this fashion.

Water depth also appears to be critical to the survi val of young *Macrocystis* seedlings. Approximately 130 m of the kelp lines in Winter Harbour were below 10 m. Similarly, a major portion of the Barkley Sound farm was deployed below a depth of 10 m. Most surviving plants in Winter Harbour and Barkley Sound were grow ing between 3 m and 10 m. It is likely that insufficient light is available to young *Macrocystis* plants below that depth.

Another factor that probably contributed to poor seedling survival on both farms was the late seeding dates. By the time the farms were outplanted (late Feb ruary), almost two months of the growing season had passed.

By early May 1986, the errors made in deploying the seeded *Macrocystis* plants were apparent. The culture lines to which the transplanted *Macrocystis* seedlings were attached in Winter Harbour were placed in 3 to 10 m of water outside of a natural kelp bed. The sur vival of those plants after 16 weeks was 43.8 percent and the plants appeared to be as healthy as nearby wild *Macrocystis* plants. The survival of these transplanted *Macrocystis* plants (43.8 percent) demonstrates that *Ma crocystis* will grow successfully on culture lines when proper care is used while placing the kelp farms.

Recommendations

Although we did not culture a sufficient quantity of *Macrocystis* in one growing season to enable us to assess the feasibility of using cultured kelp in the spawn-on-kelp fishery, we did accumulate information that will aid future endeavors to culture *Macrocystis*. Proper timing of the collection of wild sporophylls and careful laboratory techniques are critical to the production of healthy young seedlings. Sporophylls from wild *Macrocystis* plants should be collected during November and December, and the resulting seedlings should be planted no later than mid-January.

The optimal depth for starting young sporophytes is between 3 and 10 meters. Kelp lines should not be placed within existing *M. integrifolia* beds, although a natural *M. integrifolia* bed somewhere in the vicinity will assure the proper conditions for *M. integrifolia* growth.

During the course of the study it became apparent that the seeded kelp lines do not have to be placed along the bottom. It may be advantageous to deploy lines in a fashion similar to that used to culture *Laminaria*. A number of naturally settled *Macrocystis* plants were observed on (Barkley Sound Kelp Co.) commercial kelp lines used to culture *Laminaria*. These plants were healthy, grew rapidly, and did not appear to become entangled. Placing the kelp lines 2 to 3 m below the water surface would eliminate mortality causes including predation, siltation, and abrasion, and facilitate the harvest of kelp fronds during a fishery. Such a system would require more flotation, and more maintenance (i.e., clearing debris from the floats).

During the first six months, it is advisable to conduct dives on the culture lines at monthly intervals. Lines and anchors should be cleaned and checked for abrasion. In addition, the health of young seedlings can be closely monitored and if required, the kelp lines can be moved to a more suitable location.

Feasibility of Macrocystis Culture in Alaska

Based on our experience in British Columbia, we think it is feasible to culture *Macrocystis* in Alaska. As virtually all the *Macrocystis* for the Prince William Sound impoundment spawn-on-kelp fishery comes from Southeastern Alaska, it would be advantageous to industry if *Macrocystis* could be cultured somewhere close to the fishing grounds. Although *Macrocystis* has been known to occur in isolated patches along the Alaskan coast as far north and west as Kodiak (Druehl 1970), it is not fully understood why the northern range of significant beds of *Macrocystis* is somewhere in the vicinity of Sitka. Druehl (1978) suggests that snow-melt runoff and high summer surface temperatures contribute to limiting the distribution of *Macrocystis*. Because of the snow-melt runoff from nearby glaciers and icefields into Prince William Sound, the best approach to culturing *Macrocystis* near the spawn-on-kelp fishery would be to establish a number of kelp farms at various locations within the approaches to the Sound. Site selection should include the following two criteria: exposure to oceanic water from the Gulf of Alaska, and moderate wave exposure or considerable tidal currents. *Macrocystis* seed is readily available from Ms. Kitty Lloyd of Canadian Kelp Resources, Box 25, Bamfield, B.C. V0R 1B0. A 600 m farm should supply enough kelp to produce 6 to 8 tons of spawn-on-kelp product. Although some of the blades will be useable during the first spring following planting, the bulk of useable blades should be available during the second and possibly the third year of growth.

In conclusion, we believe it would be possible to culture *Macrocystis* in Alaska. It would be worth the effort for someone to establish a number of *Macrocystis* farms somewhere in the vicinity of Prince William Sound. A number of kelp farms placed near the area of wild *Macrocystis* harvest in Southeastern Alaska would also be worthy of consideration.

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THE POTENTIAL FOR NORI AQUACULTURE IN ALASKA

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WHAT IS NORI?

Nori is the Japanese name for a species of the red algal genus *Porphyra*. The nori itself is the end product of a long procedure. After *Porphyra* is grown on nets and harvested, it is washed, chopped, made into a slurry, and formed into squares of about 8 inches on mats. It then runs through a dryer, and a 0.1-ounce dried sheet of nori is produced.

Nori is used principally for making sushi, which is a Japanese delicacy that has been gaining popularity in North America, especially on the West Coast. At present, approximately 60 million sheets are imported into the United States annually and, at current values, this is worth over $20 million a year. On the whole, the industry in Japan is worth over $1.5 billion. It is a large industry.

FARMING NORI

Indigenous peoples from around the world traditionally have made nori from selected wild stock. In Southeast Alaska, for example, nori is known as black seaweed, and to this day is collected by the Native Indians who dry it in the sun and use it as snack food and in other traditional dishes.

Japanese actually started farming it three centuries ago. They went from the wild harvest to putting out bamboo branches. They put very tall "shoes" on their feet, which allowed them to walk 3 feet above the ground at the water surface. They walked out and put in the bamboo branches, using digging sticks. The bamboo branches then would catch the natural spores of nori, which float around in the water in late summer and early fall. They were still dependent on wild seedings with this technique.

In this century, a number of technological innovations have turned nori farming into the business that it is today. One of the innovations was the spreading of nets out along the surface of the water to catch the wild spores, instead of using the bamboo branches.

But perhaps the greatest discovery of this century was that of the alternate phase in the life history of *Porphyra*. *Porphyra* is, in a sense, opposite of *Laminaria*. The sporophyte is the large plant in *Laminaria* that is of interest commercially. In the genus *Porphyra*, the gametophyte, or the haploid generation, is the macroscopic plant that is harvested. The microscopic sporophyte was discovered around 1950 by an English woman. She discovered that the alga *Conchocelis*, the reddish spots on shells found at low tide or subtidally on the beach, is actually the alternate phase in the life history of the nori.

The Japanese were very quick to make use of this discovery. They started collecting the spores from the plants they were growing on the nets, inoculating them into shells, and then using those shells to seed nets.

One of their important technological advances was to grow the spores in the laboratory instead of inoculating them into shells immediately. The spores are propagated vegetatively so that a single strain of nori can be reproduced many times. The spores are grown up in flasks, ground up in a blender, and then inoculated over shells under controlled conditions in the laboratory during the winter months. In the shells the *Conchocelis* stage matures during the summer months and produces spores, which grow into the nori plants. Figure 1 shows the *Conchocelis* of *Porphyra torta* growing in oyster shells.

Seeding Methods

There are a number of methods of seeding nori nets from the *Conchocelis* shells. And this is one of the areas where a lot of innovation is going on in Japan.

Hanging Plastic Bags

One of the traditional methods is to put the mature shells in small plastic bags that are hung on bamboo or plastic rods below the nets. Nets are then stretched out on the nursery ground. The morning after the shells are put out, the first bright sunlight will cause the shells to release the spores, which float up to the surface and attach to the nets. About 30 nets are laid on top of each other, so 30 nets are seeded at one time in each set. The entire growing field may be covered with these nets that are being seeded. This procedure is done at the beginning of fall. During the hot Japanese summers the water becomes very warm and if the plants are seeded too early, they will die. The nori farmers have to wait for the temperature to drop below about 72°F before they can begin seeding.

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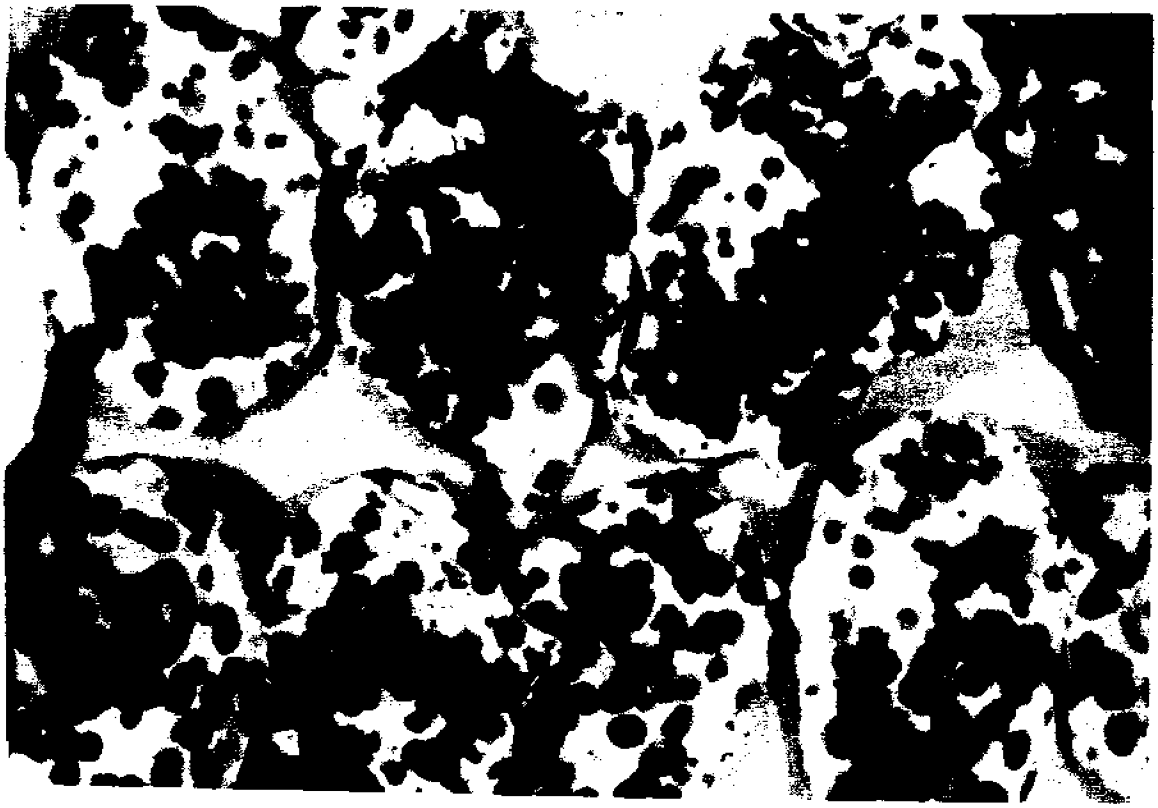

Figure 1. *Conchocelis* of *Porphyra torta* growing in oyster shells. Photo by Sandra Lindstrom.

Plastic Tarp

Another method of seeding involves a plastic tarp which supports a mesh net. The shells with the *Conchocelis* filaments that are ready to release spores are placed upside down inside the seeding net. On top of that are laid the 30 nets to be seeded (Figure 2).

Seeding Wheel

The lower area is enclosed in a tarp and filled with seawater. The nets are wrapped around the wheel. The wheel is then turned by a motor and runs the net through the area that contains the shells that are ready to release, and the nets pick up the spores as they are released.

Another type of seeding wheel has a built-in concrete tank. The shells are placed on bars underneath the net because direct sunlight could damage them.

Long Trough

In this method, bars of shells are laid across a trough and air is bubbled up from the bottom. Nets are fed into the trough, and the spores are released from the shells and attach to the nets. The nets are gathered using a windlass and moved into other tanks where they can be nursery cultured briefly before they go to the ocean for further culturing.

Nursery Culturing

After seeding, or during the process if it's done out in the ocean itself, the nets have to be nursery cultured. In nursery culture the plant grows from a sporeling up to about 1 inch in length, and this takes about a month. Nursery culture is critical for the healthy rearing of the nori plants.

There are a couple of ways in which nursery culture is done. In the southern part of Japan they use bamboo poles with the nets attached to them (Figure 3). When the tide drops to extreme low water the nets are suspended above water level and they will dry off for a certain period each day. This is important for the health of the sporelings because drying kills competitors of the nori plants on the nets. The nori plants themselves can stand a certain amount of drying. It's not particularly good for them—they don't grow when they are in this dry state, but they grow better afterward because the competitors on the net are killed.

In addition to pole culture, there are floating systems in which the nets have to be raised out of the water manually for a certain number of hours each day, and

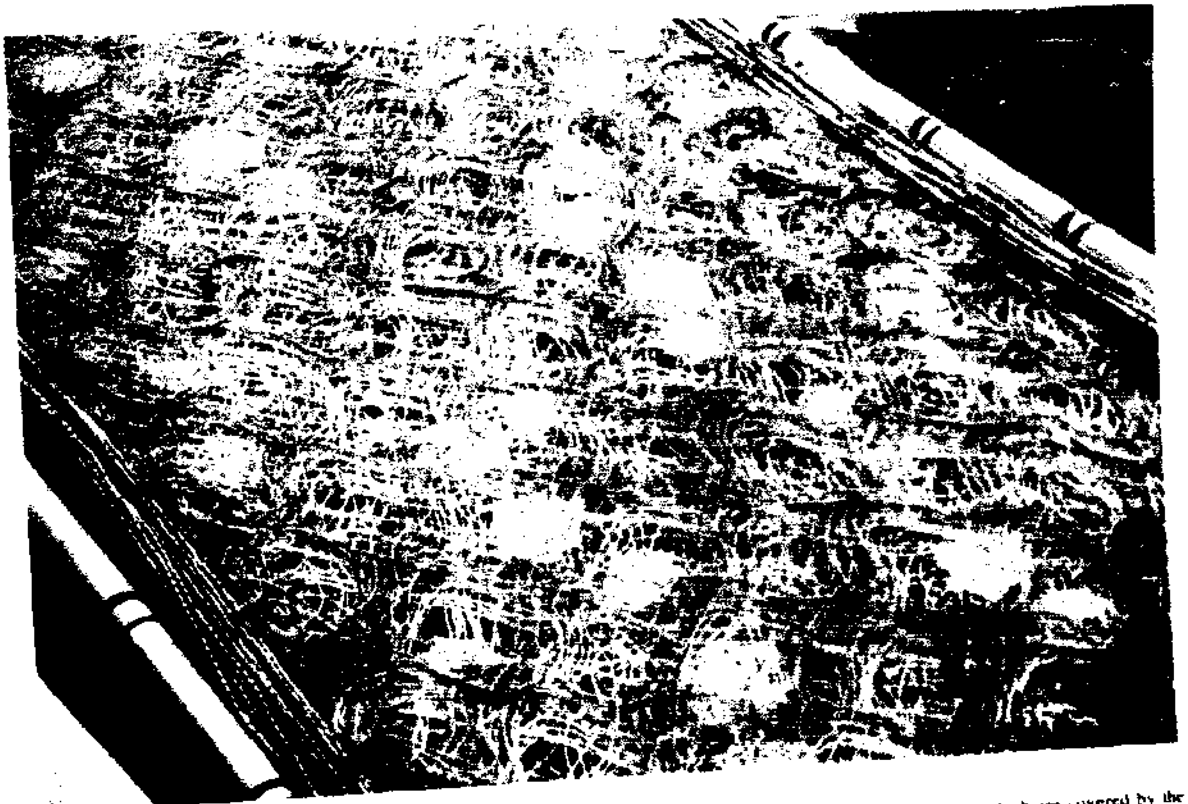

Figure 2. The plastic tarp method of net seeding in Aichi-ken, Japan. Shells are upside down inside seeding nets, which are covered by the nets being seeded. Photo by Sandra Lindstrom.

then put back in the water after they have dried out (Figure 4). Growers in one part of Japan have gone to the trouble of putting in steel pilings to which they attach the ikada, their name for the system that the nursery nets come out on. It's a very expensive method and is not recommended, but because the pilings are in place the growers there still use them.

After the nets are dried they are put in freezer facilities. If the nori has been dried properly, it can be stored at about -20°C (a little below 0°F) for up to a year and sometimes longer. All nursery nets are made in early fall, so that through the winter fresh nets can be brought out and put into production as needed.

Harvesting

In Japan, once the 1-inch nori plants are on the nets it takes six to ten days for them to reach harvestable size of 6-8 inches. The nori is harvested by a number of different methods. In the most common method the net is pulled by hand over an apparatus similar to an upside down lawn mower and the nori is torn or broken off and collected in baskets.

A single nori net, after being harvested once, usually can produce two or three more harvests before it either becomes fouled or no longer produces good quality nori. After that, the net will be taken out and replaced by freezer nets. The growing season continues until good quality nori can be produced no longer. In Japan, this growing season runs from November until February or March, depending on the conditions that year and the problems that they might run into in the spring.

The harvested nori is taken to a factory, which is usually nearby, where it is washed, cut, rinsed, and made into sheets and dried. Then the nori is sold to secondary processors through the Fishermens' Federation Cooperative, which has weekly auctions. The secondary processors dry the nori a second time, toast it, package it, and send it off to market. It might go to Japan, or to the growing market in the United States.

Strain Selection

There has been some strain selection for species or varieties of nori that are grown in Japan. The native species are usually rather small. The preferred shape of the nori is an elongate frond, because more fronds that are elongate (rather than broad) can be packed onto a net, and the net produces greater volume. Therefore rather long narrow blades have been selected

Figure 3. Nursery nets attached to bamboo poles in Ariake Bay, Saga-ken, Japan. Photo by Sandra Lindstrom.

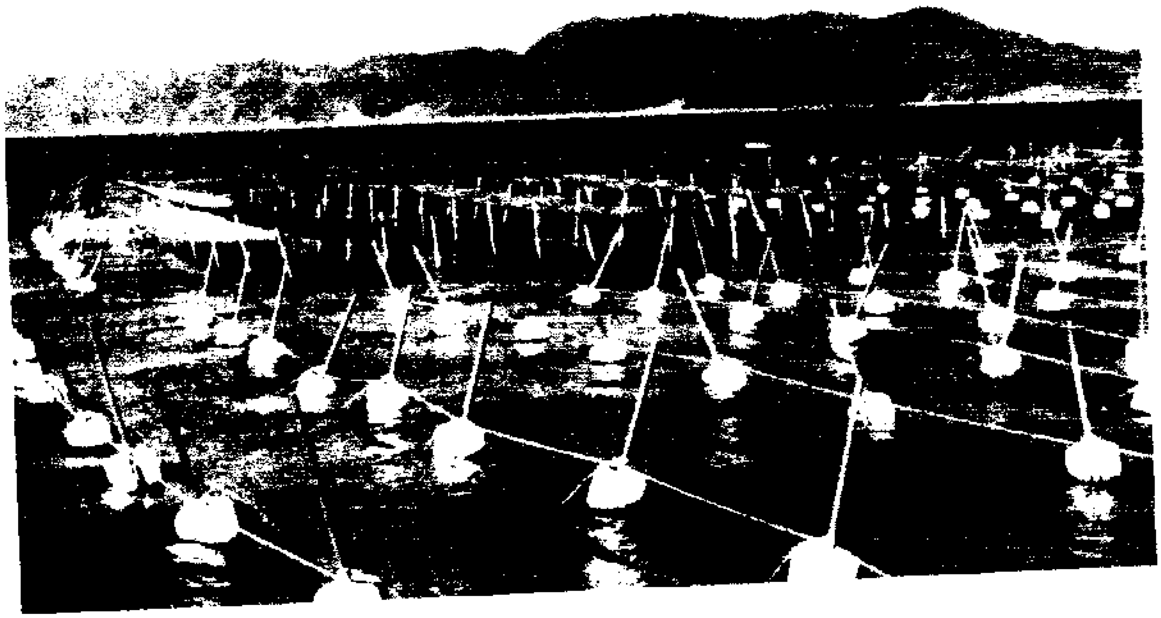

Figure 4. Nursery nets in ikada being lowered back into water after drying, in Chiba-ken, Japan.

Life Cycle Summary

To recap, the life cycle of nori is integral to farming it (Figure 5). The thallose phase, which is the phase that is harvested commercially, becomes reproductive; male and female cells are formed on the same plant, and usually self-fertilization occurs. The fertilized female cell is called the carpospore, and is diploid. It is released and grows into the filamentous *Conchocelis* shell-boring phase that forms the reddish spots inside the shell. Under controlled light and temperature conditions, these filaments eventually mature and release the spores that attach to the nets. These spores are grown on the nets under field conditions in the fall.

One of the important considerations in nursery culture is temperature. During the early phase in the nursery culture young plants produce additional spores in warm water, which then reseed the net. The grower starts out with a relatively low density on the net and the density increases as the monospore production increases. Therefore successive crops are harvested, because the plants are at slightly different stages on the net.

Nori Aquaculture in Alaska--Potential

There are four steps that need to be considered for nori aquaculture in Alaska.

1. Site Selection. Finding areas suitable for the growth of nori is important. The site should be large enough for production. In British Columbia, our 10-15 hectare farm plots are the minimum size for producing nori economically.

   The water depth should be no more than 60 feet for floating culture, and it is likely that this is the culture method that will be used. If the depth is greater than 60 feet, anchoring becomes extremely expensive.

   The bottom should be soft enough for holding anchors. And the water current in the area should be sufficient to bring nutrients to the plants. Nori is sensitive to low salinity, which means that if a site receives a lot of rainwater the plants may become diseased.

   Temperature is important, too, but that comes into the second group of things to be considered, and that is testing and strain selection.

2. Testing and Strain Selection. In Washington and British Columbia where nori is starting to be grown commercially, we are using the Japanese strain. We, in fact, may be straining the ability of that cultivar to grow in our waters because we are more than 10° north of where it is being cultured in Japan.

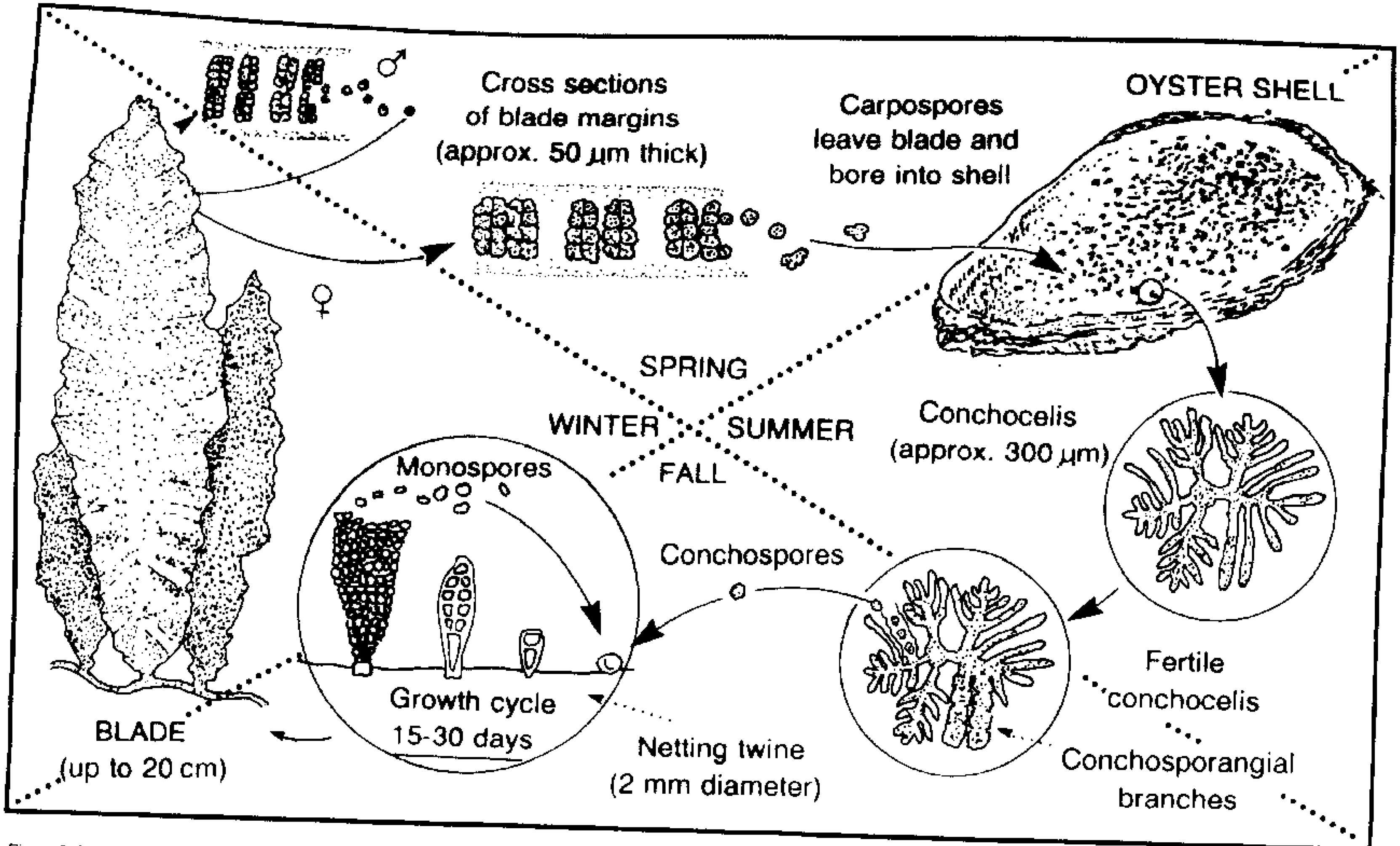

Figure 5. Life cycle of a commercially cultivated *Porphyra*. Adapted from: Programmatic Environmental Impact Statement: Nori Farming and Processing in Washington State, Department of Natural Resources, 1987, p.1.

Southeast Alaska is almost another 10° farther north, where day length and low light intensity may become a problem and the water temperature may be lower for a longer period in the winter. It may be possible to grow the Japanese strain in the Pacific Northwest, including Alaska, but the amount of time it takes to grow and the time of year it can be grown will probably differ from Japan.

Therefore, it is becoming apparent to those involved in nori aquaculture that we must start looking at local strains. We need to do some of the selection work that has been started on kelp and other species that people are interested in growing commercially. We should look for species and strains that are adapted to our local conditions.

3. Access to a Processing Plant. This is where the real money comes in for developing nori aquaculture. The processing equipment is not cheap. Operating the equipment costs a lot too; a great deal of electricity or fuel is required to run the drying machines that dry the nori into sheets.
4. Marketing. There already is a market for nori in North America. And the Chinese, Taiwanese, Koreans, and Japanese all eat nori. There is a growing market worldwide and I understand there are even attempts at introducing nori to the Soviet Union. An important part of the task of finding a market is establishing a means of transporting it. These considerations are critical for people who are seriously interested in growing nori commercially.

At the Conference, Dr. Lindstrom's presentation was followed by a video recording on nori aquaculture made by the Japanese Prefectural Association.

QUESTIONS AND ANSWERS

Q. What is the temperature range for growing nori?

A. The Japanese say for their strain that below 8°C (46°F) it does not grow well.

Q. Should you choose nori sites that are near existing kelp beds?

A. The presence of a kelp forest indicates that kelp grows well in that area, and that's nice to know. But for nori you do want a soft bottom for anchorage, and where there are existing kelp beds you won't have a good anchorage system. If you're asking about competition between domesticated and wild plants, there undoubtedly is some, but we don't know yet how important this is.

Q. Louie Druehl gave us pricing information on dry weight *Laminaria*, and most of the production information is given in wet weight. What would be the conversion?

A. When you are talking to your banker, it's 15 percent, and when you're talking about making a living, it's 10 percent.

Q. What is the current market price for the kelp pounders in Prince William Sound, from Prince of Wales or Sitka Sound—for the *Macrocystis* from Sitka?

A. It costs about $1 a pound by the time it gets to the Sound.

Q. Could you discuss the harvesting and/or drying of *Macrocystis* and *Laminaria*?

A. The harvesting of the farmed plant is done in one of two ways. You can place your rope across a box and cut the plants off so that they fall into the box. Or you can pull out the entire rope with the plants still attached, and then dry it. In British Columbia right now the commercial method uses a greenhouse. You can either hang up individual plants to dry or you can hang up the rope to dry. The drying is an expensive operation because you are removing a lot of water. And you have the same problem here in Southeast Alaska that we have: you don't have very much sunshine.

Q. I'd like to ask a question on the black seaweed. Our native harvest time is limited to about three weeks in late April and very early May. It seems to me the water temperature has no influence on maturing. This is the time we harvest the highest quality black seaweed. Does your process of culturing change that cycle so that they will mature at different times of the year?

A. One part of our process that could prevent the plant from maturing early is cutting them before they have a chance to become reproductively mature. But this is a problem that has to be looked at with any local species you cultivate, because different species do become reproductive at different times of the year. You're correct—maturation is probably not a response to water temperature; it is more likely a response to changes in day length.

What I believe will ultimately happen with nori cultivation in this part of the North Pacific is that you will be growing different species at different times of year, depending on their natural life cycles. So the black seaweed might be one to grow in the early spring up until May, and in the summer we would probably grow a different species.

Q. Louie, it sounded like we were getting something for nothing with your one month appearing to be a year. Were you spawning those sporophytes the previous November and holding them in red light for nine months, so that they still were two year plants, or were you spawning them sometime in April or January?

A. The first year we were restricted to the spores we got in October or November, and we had to wait nine months with the spores in the red light until we planted the next year. Now that we have done that once, we can use the same seed again and again. We keep part of it in the red light all the time, plant it in December, and by January it behaves as a second-year plant. But that first time we had to pay the price of waiting nine months.

SCALLOP CULTURE IN BRITISH COLUMBIA

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INTRODUCTION

Coastal British Columbia extends from 48°20' to 54°40'N latitude. Although the continental shelf area is limited because of the precipitous coastline, there are extensive areas with water depths less than 100 m with good scallop habitat, e.g., Hecate Strait, Queen Charlotte Sound, and off the west coast of Vancouver Island (Figure 1).

Scallops have been caught on longline gear or in otter trawls in finfish fisheries in some of these waters. This has prompted enquiries about the extent of scallop populations and whether a commercial fishery could be supported. Extensive surveys have been undertaken to investigate scallop resources in British Columbia waters. The first was in 1934, and a more comprehensive survey of the entire coast was carried out in 1960 and 1961 (Quayle 1961 and 1963, Bourne 1969). Sporadic surveys have been done since then, particularly in the Gulf Islands region (Bourne, unpublished). Other surveys have been made to assess invertebrate resources in coastal British Columbia (Bernard et al. 1967, 1968, 1970). In addition many tows have been made with otter trawls throughout British Columbia marine waters by both research and commercial vessels.

Results of this work show that 13 species of scallops occur in British Columbia coastal waters (Bernard 1983), (Table 1). Most are rare or small but four species are either large or occur in sufficient abundance to bring up the possibility of establishing a commercial scallop fishery in British Columbia. The four species are: weathervane, *Patinopecten caurinus* Gould; rock, *Crassadoma gigantea* Gray (*Hinnites multirugosus* Gale); pink, *Chlamys rubida* Hinds; and spiny, *Chlamys hastata* Sowerby.

SCALLOP SPECIES AND FISHERIES

Weathervane Scallops

Weathervane scallops are large and can attain a shell height of 23 cm (Bourne 1969). They occur from central California to the northern part of the Gulf of Alaska and west in the Aleutian Islands to Amlia Island in depths of 10 to 200 m, generally on sand or mud bottom (Grau 1959, Quayle 1960, Bernard 1983, Kaiser 1986).

In British Columbia distribution is sporadic and local. The two largest populations are in Dixon Entrance (Figure 1), off the north coast of the Queen Charlotte Islands and in the Gulf Islands region. Small local populations have been reported from a few other locations along the coast.

All populations are small. Estimates made from dragging operations and by direct observations using the underwater submersible *Pisces* indicated the maximum density was about 1 scallop per 65 square meters in the Gulf Islands area. The population in Dixon Entrance is smaller and less dense than the one in the Gulf Islands. Little old shell was caught during dragging work at both locations indicating populations have never been extensive in recent time.

Recruitment in the Gulf Islands population is apparently low. The size distribution of this population has varied little in over 15 years of sampling (Bourne, unpublished). There has been no indication of strong year classes dominating the population.

Sporadic attempts have been made to harvest weathervane scallops commercially from the two main centers of population in British Columbia but they have ended quickly because of low catches.

Rock Scallops

Rock scallops are massive and can attain a shell height of 25 cm (Bourne 1969). The valves are irregular in shape. Until they are 2 to 3 cm shell height they are free swimming and resemble *Chlamys* species. At 2 to 3 cm shell height they attach themselves to a rock by the lower right valve and remain there for life.

Rock scallops occur from Mexico to the Aleutian Islands, 25 to 60°N latitude (Grau 1959, Bernard 1983), from the lower intertidal zone (1.5 m intertidal level) to subtidal depths of 80 m. Rock scallops occur throughout the coastal area but have a patchy distribution and are not particularly abundant in any one location. In British Columbia they appear to be more common on the outer coast than in areas such as the Strait of Georgia. No attempts have been made to estimate population size or density in any area along the coast. Cursory observations show there is a preponderance of older animals in most areas.

Rock scallops do not lend themselves to a dragging type fishery but attempts have been made to harvest them commercially by diving. These have ended in failure be-

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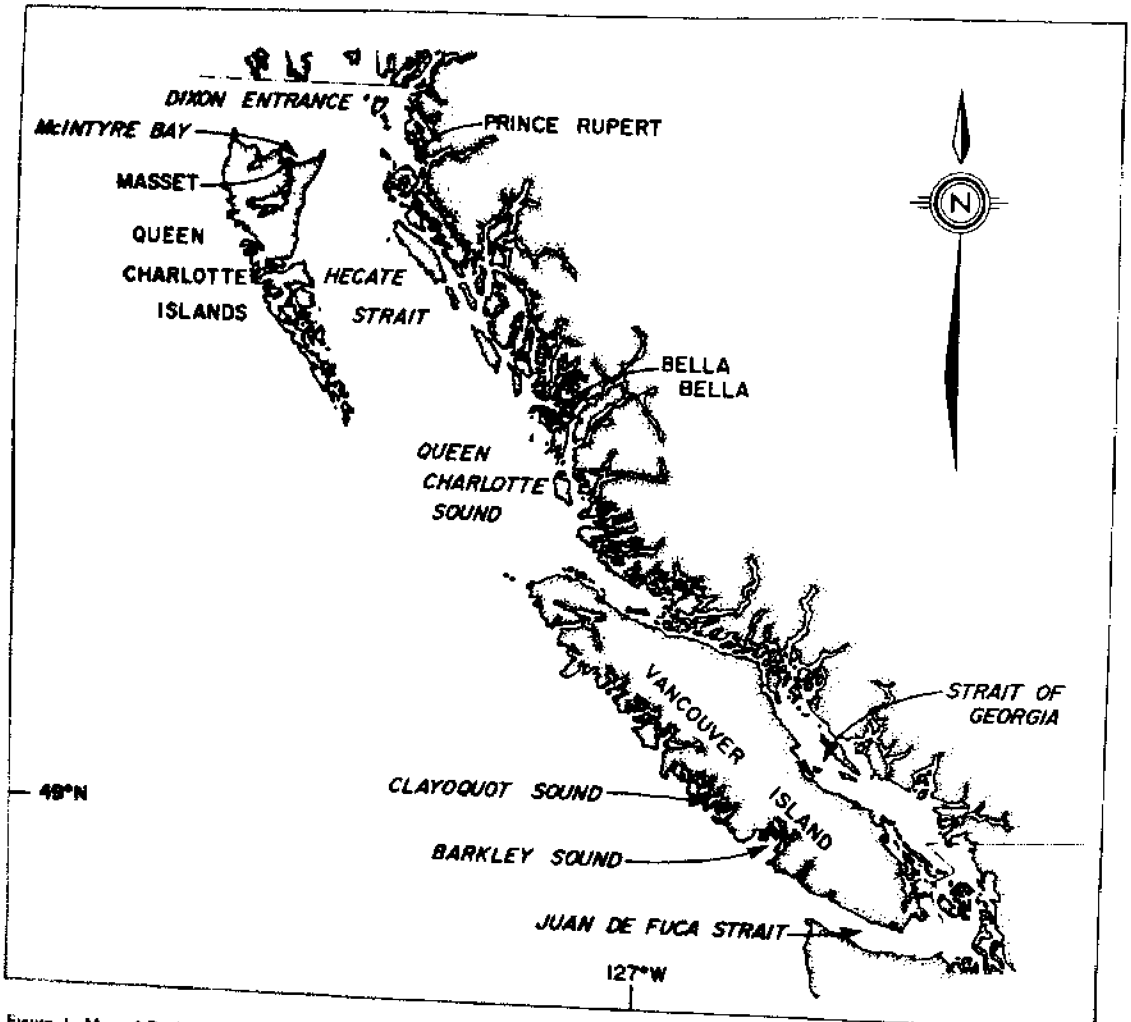

Figure 1 Map of British Columbia waters

cause it is difficult and uneconomical to chisel them off rocks. At present no commercial fishing is permitted for rock scallops in British Columbia but they can be harvested in the recreational fishery where the catch is regulated by a daily bag limit.

Pink and Spiny Scallops

Pink and spiny scallops are small and rarely attain a shell height larger than 80 mm (Bourne 1969). Spiny scallops occur from lower California to the northern part of the Gulf of Alaska, latitude 33 to 60°N; pink scallops have a slightly more restricted range from 33 to 58°N (Bernard 1983). Both species have a discontinuous distribution in British Columbia but can occur in small densely populated beds. Spiny scallops are usually found on firmer bottom, gravel or rock, in areas of strong current. Pink scallops tend to occur in areas of softer bottom. Pink scallops occur in somewhat deeper water than spiny scallops, 5 to 200 m compared to 5 to 160 m (Bernard 1983).

No studies have been made of natural pink and spiny scallop populations in British Columbia but cursory observations of some beds indicate there is a wide spread in sizes of animals indicating that recruitment has been reasonably consistent.

A commercial fishery for both species began in British Columbia in 1981 but landings have been small (Table 2). Traditionally, only the adductor muscle of scallops is eaten in North American markets but the small size of these two species has encouraged development of local markets for whole scallops. The fishery is located in southern British Columbia. Fishing is either by towing small home-made drags or by diving. At present, most of the catch is taken by divers and most of the catch is spiny scallops since diving generally occurs at shallower depths on reefs that have a rocky bottom. Eventual size of the fishery for pink and spiny scallops

Table 1. Species of scallops recorded from British Columbia waters.

Chlamys albida
Chlamys behringiana
Chlamys hastata
Chlamys jordani
Chlamys rubida
Crassadoma gigantea
Cyclopecten argenteus
Cyclopecten carlottensis
Cyclopecten knudseni
Cyclopecten squamiformis
Delectopecten randolphi
Delectopecten vancouverensis
Patinopecten caurinus

Table 2. Landings of pink and spiny scallops in British Columbia, 1982-1986.

Year	Weight (tons)
1982	8.3
1983	11.0
1984	17.9
1985	53.4
1986	71.1

will depend on the extent of scallop populations, size of markets for whole scallops, and the economics of fishing; however, it is doubtful if annual landings will exceed 1,000 tons.

CULTURE

Natural scallop populations in British Columbia are too small to support a large sustainable commercial fishery. If a significant scallop industry is to develop in British Columbia (annual landings of 10,000 tons or more) it will have to rely on culture operations.

In 1981 a program began at the Pacific Biological Station to investigate the feasibility of scallop culture in British Columbia. The program is a joint undertaking of the Federal Department of Fisheries and Oceans, Biological Sciences Branch, Pacific Biological Station and the Provincial Ministry of Agriculture and Fisheries.

Natural Sets

In any culture operation a primary requisite is an abundant, reliable, and inexpensive supply of juveniles (seed). Attempts were made to gather natural sets of juveniles of the four native species mentioned above, using methods similar to those used in Japan (Ventilla 1982).

Attempts to gather natural sets of weathervane scallops in the Gulf Islands area of the Strait of Georgia from 1981 to 1983 were unsuccessful. Ten juveniles were collected in the first year but none in the last two years, probably because of heavy sets of the crab *Cancer oregonensis*.

Some success has been achieved collecting juvenile rock scallops from natural sets. In scallop seed collecting operations in Barkley Sound on the west coast of Vancouver Island numbers of juvenile rock scallops were found in collectors along with juvenile pink and spiny scallops. It was estimated that about 25 percent of the juveniles were rock scallops (G. Lindsay, personal communication). When Pacific oysters, *Crassostrea gigas*, are cultured by the hanging method (Quayle 1971) in various locations in British Columbia, rock scallop juveniles are frequently found on oyster strings indicating widespread settlement of this species. Further research is needed to determine if there are natural breeding areas of rock scallops in British Columbia that could be used to supply seed for a large rock scallop culture operation.

Pink and spiny scallop juveniles can be collected in quantity from natural sets, up to 2,000 juveniles per collector (H. Miller, personal communication). However it is believed these species are too small and too slow growing to support economically viable culture operations.

As a result of this work it was decided to investigate the feasibility of producing large quantities of juvenile scallops in a hatchery, sufficient to support a commercial culture operation. The remainder of this paper is concerned with results of scallop hatchery and culture work at the Pacific Biological Station.

SCALLOP HATCHERY

Scallop Species

An initial consideration in the project was the species that should be investigated. It was decided to work with the four native species, weathervane, rock, pink and spiny, and two exotics, the Japanese scallop, *Patinopecten yessoensis*, and the east coast sea scallop, *Placopecten magellanicus*.

Brood stock of native species was obtained locally. Sexually mature animals were collected and held in the laboratory. Adult Japanese scallops were obtained from Mutsu Bay in northern Japan through the Aquaculture Center of Aomori Prefecture. Sea scallop brood stock was obtained from Passamaquoddy Bay, New Brunswick, through the Biological Station in St. Andrews, New Brunswick. Both exotic species were kept and conditioned under quarantine conditions.

Although work has been done with all six species, most of the work has been with Japanese and rock scallops and in particular with the Japanese scallop. Only results with these two species are discussed here.

Conditioning and Spawning

Only one attempt was made to condition scallops from the spawned-out stage to a ripe condition. In all other instances animals that were sexually ripe were obtained and brought into the lab.

Natural spawning of Japanese scallops begins in mid-March in Mutsu Bay, Japan when water temperatures reach about 8 °C (Ventilla 1982). Sexually ripe scallops were received from Japan in January to February when water temperatures there were about 2 to 4 °C. The gonad condition index (wet weight of gonad over wet weight of total soft parts × 100) was followed closely since it provides a good indication of the sexual ripeness of the animals (Ventilla 1982). Scallops received from Japan had a gonad condition index from 18 to 30 percent. We increased or maintained the condition index from 25 to 30 percent by holding animals in 5 to 7 °C seawater and feeding them as much as possible with cultured algae. After several years experience we are now able to determine whether most animals are in spawning condition by visual observation.

Rock scallops spawn in June in Puget Sound, Washington (Lauren 1982). The exact time of spawning of rock scallops in British Columbia has not been determined but it appears to extend over a period from mid-June to September (Bourne unpublished).

Several methods have been used to spawn scallops. The most successful has been exposure to air followed by thermal shock in seawater. Ripe scallops are kept out of water for up to two hours and then immersed in seawater that is 4 to 6 °C warmer than the holding temperature. The seawater is irradiated with ultraviolet light. If spawning does not begin within two hours the water temperature is raised a further 2 to 3 °C and large quantities of cultured algae and/or sperm suspension added.

Another method that has proven to be successful in inducing spawning is injection of 0.4 ml of a 2 × 10^{-3} M solution of serotonin into the adductor muscle (Matsutani and Nomura 1982, Gibbons and Castagna 1984). Spawning usually occurs in 15 to 30 minutes in males and from 30 to 60 minutes in females.

Spawning can extend over a period of six hours with periods of quiescence interspersed with periods of activity. Spawning can usually be controlled and can be stopped by placing the scallops in chilled seawater (2 to 3 °C), but in a few instances females have spawned out completely. Some individual scallops have been spawned two or three times over a period of three to four weeks. The number of eggs produced at any spawning varies but we usually attempt to produce 20 to 25 million per spawning.

Japanese scallops have been spawned from late February to the end of July, rock scallops from July to January.

Embryonic Development

Seawater in the Pacific Biological Station system ranges in temperature from 7 to 13 °C but the salinity remains fairly constant at 29 part per thousand (ppt) ± 1 ppt throughout the year. According to the Japanese literature these salinities are too low for successful development of *P. yessoensis* embryos and larvae; optimal salinities range from 34 to 38 ppt (Yamamoto 1957).

Experiments were undertaken to investigate the suitability of our sea water system for successful embryonic development of *P. yessoensis*. Four salinities and three temperatures were tested and it was found that embryos held at 19 ppt (ambient salinity) and 15 °C had the best survival (Bourne and Hodgson, unpublished).

Similar experiments were done with *Crassadoma gigantea* embryos under different salinity and temperature regimes. These embryos were more tolerant than *P. yessoensis* embryos and could survive at temperatures of 15 to 18 °C and salinities from 25 to 29 ppt (Bourne and Hodgson, unpublished).

Larval Development

P. yessoensis embryos develop into veliger larvae within 48 to 72 hours at 15 °C. Larvae are raised in a variety of containers ranging from 4 L beakers to tanks 2.5 m (8 ft) in diameter and 1.2 m (4 ft) in height at densities of 1 larva per ml using modifications of standard bivalve larval culture techniques (Loosanoff and Davis 1963, Dupuy et al. 1977, Breese and Malouf 1975). Water used for larval cultures is filtered to 1 micrometer and changed twice weekly. The water is not treated with ultraviolet light or ozone. Larvae are fed daily with cultured algae, the amount depends on size of the larvae.

The effect of temperature and salinity, both singly and in combination, on growth and survival of *P. yessoensis* larvae was determined at three temperatures and four salinities. Optimum growth and survival of larvae occurred at 15 °C and at ambient (29 ppt) salinity (Bourne and Hodgson, unpublished).

Similar experiments were carried out using *C. gigantea* larvae. Maximum growth and survival occurred at a temperature of 18 °C and a salinity of 29 ppt (Bourne and Hodgson, unpublished).

An important consideration in the culture of bivalve larvae is selection of correct algal diets. Much time is devoted to insuring that large quantities of good quality algal foods are available when required. All larval food is raised in our algal culture facility using the batch method of culture. Starter cultures are monitored carefully and changed daily. A variety of algal species have been raised but customarily only three species are used in our work now since they have proven to be good foods for scallop larvae and juveniles and are easily cultured. The three species are: a chrysophyte flagellate, *Isochrysis galbana*, (Tahitian variety) and two diatoms, *Chaetoceros calcitrans* and *Thalassiosira pseudonana*.

Six diets were examined using a single species or a combination of two or three species of algae. Larvae fed only a single species of algae had the poorest growth rates and those fed only *T. pseudonana* did not survive beyond day 28. Larvae fed diets of Tahitian *Isochrysis* and *C. calcitrans* or Tahitian *Isochrysis* and *T. pseudonana* had significantly faster growth rates than larvae fed the other four diets. Larvae grew faster and survived better when fed all three species of algae than when fed only a combination of two species (Bourne and Hodgson, unpublished).

Similar results were found for *C. gigantea* larvae. However, no significant difference in growth rate was found when they were fed three or only two species of algae (Bourne and Hodgson, unpublished).

Considerable research effort has been devoted to determining the nutritional requirements of scallop larvae and juveniles. It is important that larvae, particularly mature larvae prior to metamorphosis, have high energy reserves. The energy content of different algal species in the log and stationary phases of growth and the resulting energy levels in larvae when fed these different algae has been examined (Whyte 1987). Research studies are currently in progress to determine which amino acids, fatty acids, and carbohydrates are necessary to produce good growth and high energy reserves in scallop larvae. Other studies are determining the importance of extracellular compounds and additives to the diet in the nutrition of scallop larvae and juveniles.

Water used in larval cultures is filtered to 1 micrometer but is not sterilized with either ultraviolet or ozone. Periodically mass mortalities of larvae have occurred but the cause of the mortalities is unknown. Samples of moribund larvae have been examined and *Vibrio* sp. bacteria identified (S. Bower, personal communication). It is believed these bacteria are not the cause of mortalities, at least not the primary cause. Cultures have been made of the bacteria and larvae suspended in them. Larvae have shown no ill effects when held in these bacteria cultures even when bacteria concentrations were extremely high (S. Bower, personal communication).

Antibiotics are not customarily used in our larval cultures. Growth and survival of larvae treated with antibiotics, a mixture of streptomycin sulfate and penicillin G, was compared to larvae not treated. There was a significant increase in growth and survival among larvae treated with antibiotics (Bourne and Hodgson, unpublished). In a commercial operation the high cost of antibiotics and the danger of developing a virulent strain of bacteria that is resistant to antibiotics would have to be weighed against the increased growth in larvae.

The larval stage of *P. yessoensis* is 25 to 30 days at 15°C. Larvae have a shell length of 260 to 280 micrometers and an eyespot that has a diameter of 10 micrometers.

Crassadoma gigantea larvae mature when they reach a shell length of 220 micrometers in about 20 days at 18°C. The eyespot is also 10 micrometers in diameter.

Metamorphosis

At maturity scallop larvae begin to settle on substrates, and periods of swimming are interspersed with periods of crawling on a well developed foot. When a suitable substrate is located the larvae undergo metamorphosis, at which time considerable anatomical changes occur within the animal (Cooke 1986). Larval organs such as the velum and the anterior adductor muscle are lost and the soft parts go through a counter-clockwise rotation of 180° (torsion). Gills begin to develop and assume the function of straining out food. After metamorphosis the animal is an early juvenile or spat. Metamorphosis and the period immediately after is a critical stage in the life history of a scallop and heavy mortalities can occur at this time.

Several types of material were tested for their suitability as a setting substrate (cultch) for scallop larvae including: oyster and scallop shell, monofilament line, polypropylene rope, vexar, artificial turf, jute, and sisal. The best material found is an artificial fiber manufactured in Japan called kinran.

Different methods to set metamorphosing scallop larvae have been examined. These have included upwellers, downwellers, raceways, in tanks that have static water and in tanks in which about one-third of the water volume is exchanged each day. The best method is to set the larvae on kinran in tanks with static water and hold them in these tanks for two to three weeks. The water may be exchanged through a filter once or twice a week and the spat are fed daily. After the two to three week period the spat are firmly attached to the substrate and a flow-through water system, run by a recirculating pump, is begun. Food levels are monitored closely and increased as the spat begin to feed heavily which is about four weeks after metamorphosis.

The effect of various stimuli on metamorphosis has been examined. Neurotransmitters, GABA and L-Dopa were tested. Larvae treated with 10^{-5} M gamma amino butyric acid (GABA) or 10^{-4} and 10^{-5} M L-Dopa had a slightly higher rate of metamorphosis than controls but it was not significant (Bourne and Hodgson, unpublished). Sudden temperature shock may induce metamorphosis but results of this work are incomplete.

Optimum density for metamorphosing larvae has also been examined. The highest success at metamorphosis was obtained when larvae were set at 2 larvae per ml or less (Bourne and Hodgson, unpublished).

NURSERY

Culture of most bivalves can be conveniently divided into three stages, a hatchery or breeding stage where animals are spawned, larvae reared to metamorphosis, and set. The next stage is the nursery stage in which spat are grown as quickly as possible to a size where they can be used by a grower. The final stage is growout to commercial size.

Development of a nursery system is an essential part in the culture of most bivalves and particularly with scallops. The goal is to develop technology whereby scallop spat can be grown quickly until it is about 30 mm shell height, at which time it can be grown out to commercial size (10 cm shell height or larger) in the open environment.

Spat have been raised by several methods in the experimental nursery; upwellers, downwellers, in tanks with static water, in tanks with a slow exchange and in raceways. Two methods have proven to be successful. The first is to hold spat in setting tanks using water from the Pacific Biological Station system until they are 3 to 5 mm shell height. A strong water flow is maintained by a recirculating pump and the spat are fed cultured algae. When the spat are 3 to 5 mm shell height they are put in spat bags and suspended in the open environment. Another successful method was to hold spat in tanks with water that was pumped directly from the open environment at a depth of about 3 m through 50 micrometer filter bags. Again a strong water flow was maintained by a circulating pump. Cultured algae was added to the tanks to augment any natural foods available to the spat. When the spat were about 5 mm shell height they were transferred to spat bags and suspended in the open environment.

Spat grew to a shell height of 1 mm in about 30 days and were 1 cm in shell height in about 90 days (Bourne and Hodgson, unpublished).

Heavy mortalities have occurred in the nursery. Mortalities were in highest numbers for spat between 0.4 to 0.6 mm shell height. Cause of the mortalities is unknown but is believed due primarily to poor nutrition. Extensive research work was done in 1987 on the nutrition of scallop spat.

An efficient nursery system that will produce large quantities of juvenile scallops quickly is essential for the establishment of a scallop culture industry. Continuing research is needed to perfect a scallop nursery system.

GROWOUT

Growout studies were done at two sites, Departure Bay near the Pacific Biological Station and Refuge Cove on west Redonda Island at the northern end of the Strait of Georgia. At Departure Bay scallops were held at three depths, 5, 10 and 15 m, at Refuge Cove they were held at four depths, 5, 10, 15 and 20 m. Juveniles were held in pearl nets and later transferred to lantern nets. Juveniles were put out in November 1985 at Departure Bay and in February 1986 at Refuge Cove. The experiment was terminated in February 1987 at Refuge Cove and in May 1987 at Departure Bay.

At Departure Bay mortalities were about 1 to 2 percent per month except in September to November when they were higher. Growth was slowest at 15 m and similar at 5 and 10 m (Bourne and Carolsfeld, unpublished). Heavier fouling was observed at 5 m than at the other depths in May and July and this may account for the slightly slower growth rate at this depth. Fouling may have restricted water flow through the nets and hence restricted food supply.

At Refuge Cove growth was fastest at 5 m and declined with increasing depth. Growth rates were similar to those at similar depths in Departure Bay (Bourne and Carolsfeld, unpublished). Mortalities were low, less than 5 percent during the course of the experiment.

Maximum growth for *P. yessoensis* was 11 cm shell height in 18 months at Departure Bay (from time of spawning). Average growth was 8 to 9 cm in 18 months, 9 to 11 cm in two years. It is possible to produce a commercial size Japanese scallop in southern British Columbia within two years.

Juvenile *P. yessoensis* produced in 1986 are being used in experimental growout studies at seven locations in British Columbia that extend from Prince Rupert in the north to Sanson Narrows in the south.

FUTURE

Considerable progress has been made in our scallop culture program but further work is needed. Nutritional studies of larvae and juveniles are an immediate focus of research work. A comprehensive diet must be developed for larvae and juveniles that will produce rapid growth with minimum mortalities. Nursery methods must also be improved so that large numbers of juvenile scallops can be produced efficiently and with minimum mortalities.

Present growout methods are labor intensive and need to be improved. Growout methods must be developed that are suitable for British Columbia conditions so that juvenile scallops can be grown to commercial size quickly and economically.

Future work should include production of juvenile scallops at a pilot scale commercial level to provide industry with information on the viability of raising juvenile scallops in hatcheries.

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SCALLOP SPAT COLLECTION STUDY IN KODIAK: PRELIMINARY RESULTS

Kodiak Scallop Project Team:
Paul Peyton, Alaska Department of Commerce
Mike Kaill, Alaska Department of Fish and Game
Linda Hornig, Alaska Department of Fish and Game
Bill Osborne, Kodiak Area Native Association

BACKGROUND

Paul Peyton, ADC

The people in the Kodiak area have been interested in mariculture for some time. The wild scallop harvest in the area clearly indicates that there is a resident population.

The Alaska Department of Commerce (ADC) got involved in 1985. We made a field trip in the spring of that year to the Kodiak archipelago at the request of Senator Zharoff and the Kodiak Area Native Association (KANA) to look at fisheries development. This led to the state contacting the Japan Overseas Fishery Cooperation Foundation in 1985. OFCF could be characterized as the Japanese equivalent of a fisheries Peace Corps. Their business is to run fisheries projects worldwide and to promote goodwill for the Japanese fishing industry. They are funded by the Japanese government.

After the initial contacts, a group from OFCF came to Juneau in July of 1985. The ADC and ADF&G (Alaska Department of Fish and Game) held preliminary meetings with the Japanese and drafted a memorandum of agreement on seafood industry, development, and trade. This was finalized and signed in Tokyo by Governor Sheffield and the president of the Japan Fisheries Agency in October of 1985. Technical group meetings followed, to determine what kind of projects we would undertake and how they would be implemented.

The goal from the state's perspective throughout was to focus on high technology and technology transfer projects. We wanted to institutionalize the start-up phase, the difficult part, so that we could teach others how to do this.

For that reason, much of the effort was focused in ADF&G's FRED Division (Fisheries Rehabilitation Enhancement and Development). ADC's role was primarily as facilitators, administrators, and money managers. We haven't been terribly involved in the technical details, but our focus is to make sure that we come up with a commercially viable product.

We undertook three basic projects. One was on-the-job training for personnel for a surimi line. This was a two-part project. The first was the workshop in Kodiak, to develop the text and video for further educational purposes. The second part was a practical workshop in the plants. We brought recognized surimi experts from Japan plus several people from the National Marine Fisheries Service and other experts from the U.S. They put together a very good set of educational materials on surimi manufacture. That was completed in late 1986.

The second project, the Scallop Mariculture Feasibility Project, took place in Kodiak. It was initiated in April of 1987 and will be completed in the fall of 1988. The third project will take place in Sitka and is scheduled to start in the fall of 1988 and be completed in 1990.

The State of Alaska contributes a significant amount of matching funds and the Japanese contribute funds and personnel for these projects.

INTRODUCTION

Mike Kaill, ADF&G

There are a lot of different participants in the Kodiak Project. The state and the agencies such as OFCF do the research and development, and then we turn the project over to the local people and potential developers and go on to other developmental issues.

The overall goal of the project is to test the feasibility of scallop mariculture. The first problem is to find a way to take advantage of a natural resource in terms of collecting wild spat, and then to channel that into a sea farming operation. We want to collect sufficient seed to supply successful farming operations. We also want to find out where the scallops live, what conditions are associated with each population, and how this all relates to collecting spat.

The main source of guidance for the project is the technical advisory committee which is composed of officials from OFCF, KANA, ADF&G, and ADC. The

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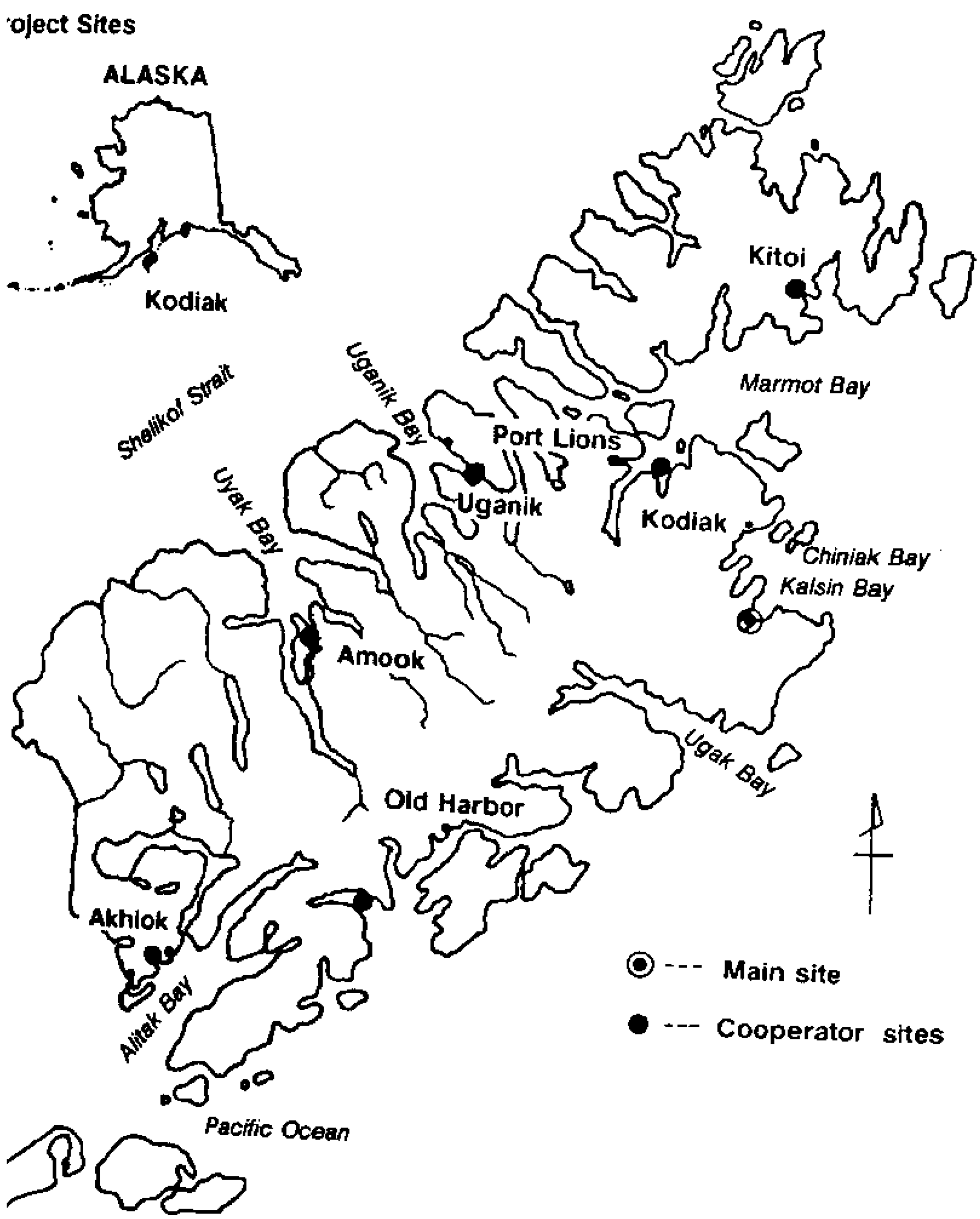


on of main project site (Kalsin Bay) and cooperator project sites around Kodiak Island.

eets in Kodiak and receives general policy : OFCF staff is led by Dr. Iwagishi and ;akishita and Mr. Ishiyama, who is here ntly in Alaska. These people are our resi- represent ADF&G operations in the Ko- roject. We have a biologist located in Kodiak who coordinates things and runs the office. A very active player in this whole project is the KANA, concerned with economic development of the villages of the Kodiak archipelago.

The cooperator people make up the rest of the proj- ect. There are six sites around the island system that have

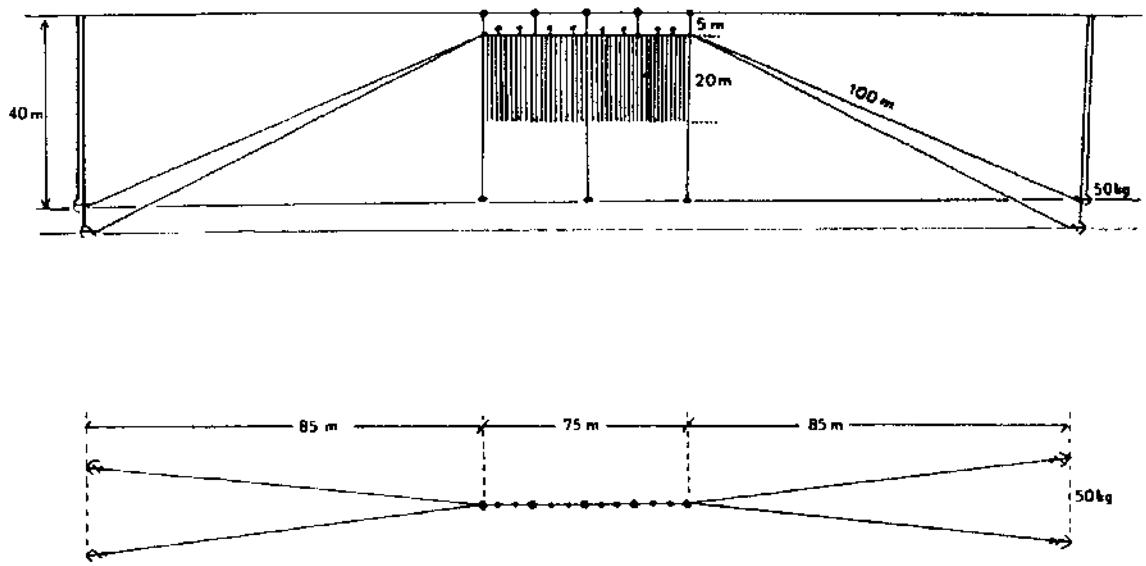


Figure 2. Diagram of Kalsin Bay spat collecting longline (dai).

active participants and they receive support, gear, and equipment from the project. They are fairly evenly distributed around the island. All these people are interested in scallop mariculture, and are interested in continuing as farmers or as spat fishermen during the development phase of the project. We chose the project sites because they are near concentrations of adult scallops, based on commercial harvest data. We do have some very strong scallop beds in Alaska. There is another good source of scallops off Yakutat. We also have deep currents that would carry larvae on shore, and at optimum times. But our scallop beds are not strong enough to sustain a continued economically viable fishery. The weathervane scallop has shown a very consistent and strong price over the years, so we can depend on scallop farmers receiving at least a $4 to $5 ex-vessel price for shucked meats on the market. This is different from other mariculture products, because the price fluctuates on the basis of demand for those other items. But according to data from U.S. Department of Commerce reports, and even with the presence of large catches on the east coast, the price of weathervanes seems to stay stable. Therefore we felt that weathervane scallops were a good candidate for this project.

Another concern for site selection was logistics. Remote locations are an issue in Kodiak. The road system is not very extensive. We have sites that could be more favorable because they are near a large scallop population, but accessibility is still an important criterion.

Another criterion was potential for development. Our concern was a very practical one, that when our phase of the project is over, we leave people who have taken over this project with a high probability of success. Therefore we wanted participation by interested and motivated cooperators. One of the criteria for the cooperators was to get a commitment from these people and then to build on that commitment.

And finally, we wanted to have the sites distributed equally around the island to give the best estimate possible as to the major habitat of the scallops.

METHODS

Linda Hornig, ADF&G

Study Sites

The locations of the main project site and the six cooperating sites are shown in Figure 1. From the north, proceeding counter-clockwise, the sites are as follows: The Kitoi Bay Hatchery, operated by the Alaska Department of Fish and Game, is located near previously fished scallop beds in Izhut Bay. The village of Port Lions has shown strong community support of mariculture, and is located near reported scallop beds in Kizhuyak Bay. Uganik Passage, where commercial set gill net fishermen cooperated with the project, is near a historically dense population of scallops in the upper East Arm of Uganik Bay. Amook Pass, where the operators of a commercial bear guiding camp cooperated with the project, is the meeting point of waters from the outer and inner portions of Uyak Bay. Scallops are currently found in Amook Pass, and have been commercially fished in Uyak Bay. The village of Akhiok was the site of an early scallop culture project in 1980 and is now the focus of KANA's efforts in mariculture. Small numbers of scallops were found in research trawls in Alitak Bay, and a scallop fishery took place outside of Cape Alitak.

The village of Old Harbor is located near previously fished beds of scallops east of Sitkalidak Island, and at the juncture of waters from either side of Sitkalidak Strait where larvae might be concentrated. Kalsin Bay was chosen as the main project site because of major commercial catches of scallops in outer Chiniak and Marmot Bays, and its convenient location near the City of Kodiak.

Gonad Index Study

Gonad index, the ratio of the gonad weight to the soft body weight, is used to quantify the spawning condition of a scallop population. The gonad index slowly increases as the scallops approach spawning condition, and suddenly decreases when spawning occurs and gametes are released. The time of spawning is important information for spat collection, since it indicates when collectors should be placed to catch the spat, which settle approximately 35 days later.

Weathervane scallops harvested by a local commercial scallop fishing vessel were held in pearl and lantern nets hanging from the floating breakwater of the St. Herman boat harbor in Kodiak. Samples of 30 scallops (15 females and 15 males) were taken weekly during the likely spawning period from April 21 to May 26 and also on April 1, June 9, and July 8. In the laboratory, the ages of the scallops were determined by shell observations, and measurements were made of shell height, length, and width. Each scallop was shucked and dissected, and the shell, gonad, muscle mass, and other soft body parts were each weighed separately.

The gonad index was calculated from the following equation

$$\text{Gonad Index} = \frac{\text{gonad weight}}{\text{soft body weight}} \times 100$$

Oceanographic Sampling

Oceanographic surveys were conducted weekly throughout the summer, and twice weekly during the critical period of spat settlement from June 12 to August 13. Regular measurements included temperature, salinity, and transparency. A temperature-depth profile was taken to 30 meters at each station sampled. Water temperature affects the time of spawning, growth rates, and possibly survival of spat and cultured scallops. The depth profile also helps to follow the movements of deeper water masses. A salinity-depth profile to 30 m was taken at each station at the beginning of the summer, and afterward only the surface samples were tested regularly. Scallops have a low tolerance for fresh water, and should not be subjected to salinities below 25 ppt. The depth profiles were done to be sure that underwater springs were not affecting salinity of the deeper waters. A 30 cm diameter white secchi disk was used to determine the transparency of the water, as an estimation of productivity.

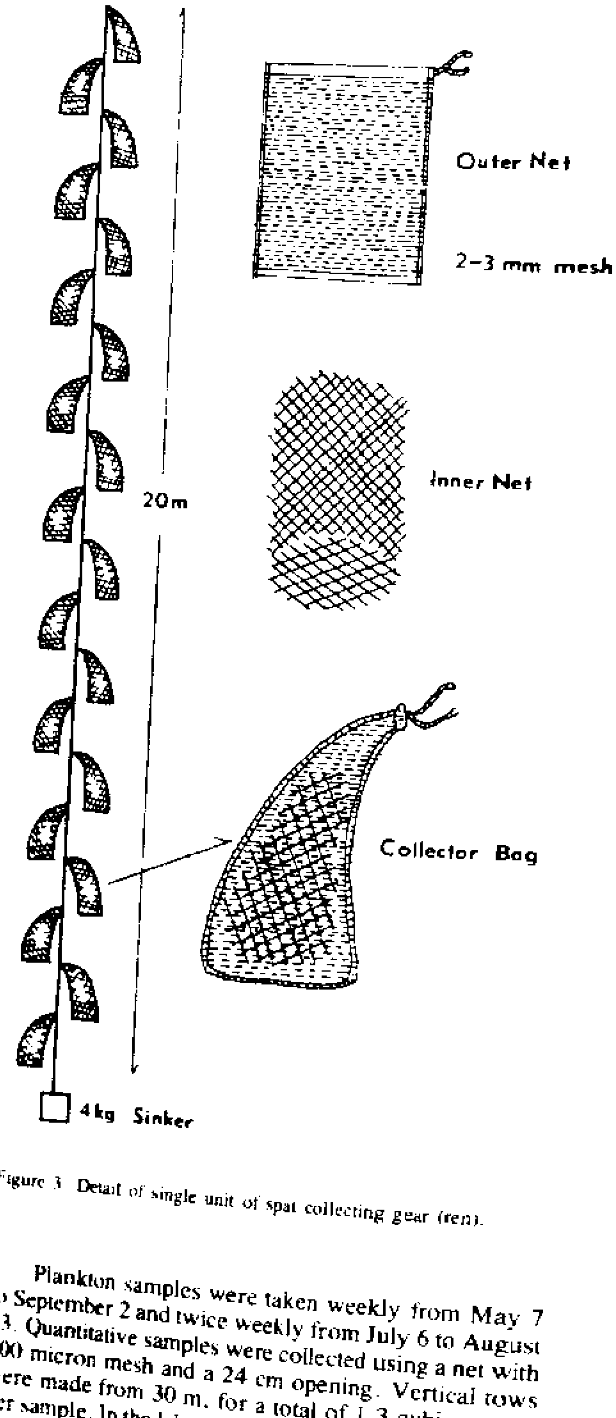


Figure 3. Detail of single unit of spat collecting gear (ren).

Plankton samples were taken weekly from May 7 to September 2 and twice weekly from July 6 to August 13. Quantitative samples were collected using a net with 100 micron mesh and a 24 cm opening. Vertical tows were made from 30 m, for a total of 1.3 cubic meters per sample. In the laboratory the plankton samples were rinsed and concentrated by diluting them, waiting a few moments, and pouring off the top of the sample. Bivalve larvae settle quickly to the bottom and are retained, while phytoplankton and other impurities are removed. This procedure was repeated until only the bivalves (and sometimes a few other organisms such as snail larvae)

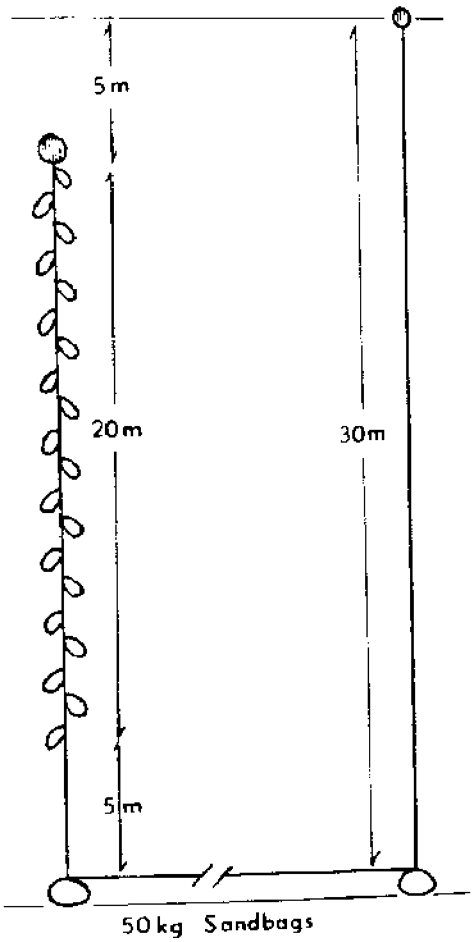


Figure 4. Diagram of cooperator site collecting gear.

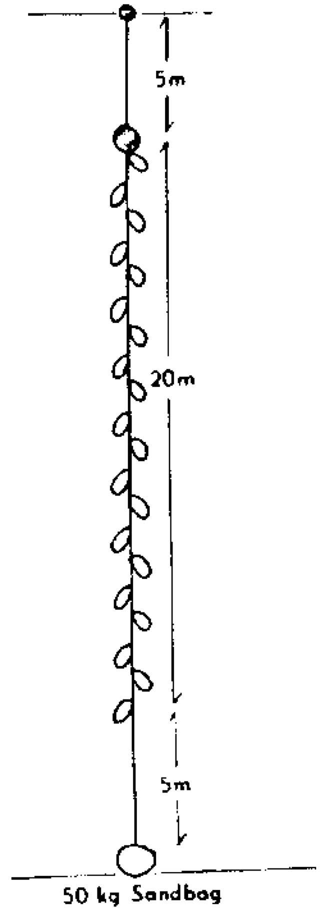


Figure 5. Diagram of pilot collector used near main site longlines.

remained. Similar measurements and samples were taken by project cooperators, as time and weather permitted.

Collection Gear

The main site (Kalsin Bay) spat collecting gear consisted of two separate longlines suspended off the bottom and below the surface of the water. Spat collector bags, attached to dropper lines called rens, were hung off each longline (Figure 2).

Each longline was 75 m long, and anchored in place by four 50 kg kedge anchors. Five 36 cm plastic trawl type floats at the surface and eight 30 cm submerged floats attached close to the longline were used to suspend the longline 5 m below the surface. More floats were attached to the line as needed during the season to prevent the gear from sinking under the growing weight of the attached organisms. A pair of sandbags resting on the bottom was attached to each end and to the middle of the longline to prevent cross-currents from disturbing the longline.

Each ren of collectors consisted of a 20 m length of line with 20 collector bags attached (Figure 3). The bags were 2 mm mesh onion-type bags filled with Netron mesh filler. Fifty rens weighted at the bottom with 4 kg sinkers were spaced evenly along each longline for a total of 1,000 bags per longline. One longline of similar construction with 35 rens was used at the Akhiok cooperator site.

Single ren pilot collectors were used at the cooperator sites (Figure 4). Each consisted of a ren with a 30 cm float attached to the top, anchored with a 50 kg sandbag and enough line so that the float was 5 m below the surface at low tide. A second sandbag was attached to the first, as far apart as the depth of the water. A surface buoy was attached to the second sandbag. This design prevented disturbance of the collectors by surface water movement, and minimized the chance that the ren might become tangled with the surface buoy line. The small size of this gear unit allowed it to be easily set and collected from smaller skiffs.

Simple one-sandbag pilot collectors were used

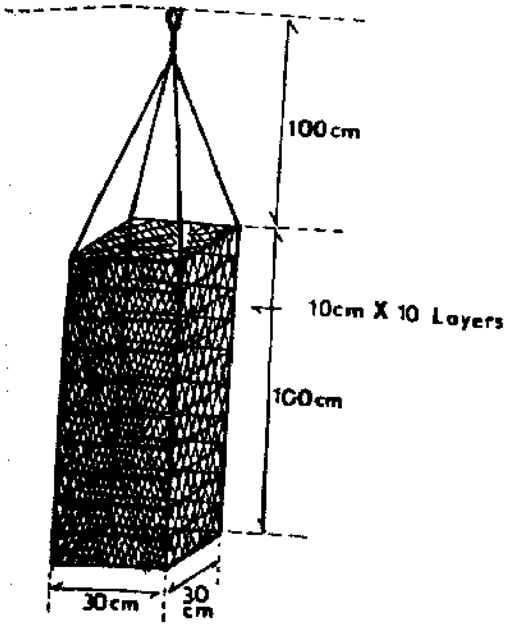


Figure 6. Ten-layer accordion net (tadan-shiki) for use in intermediate culture of spat.

short time intervals in Kalsin Bay to check the timing of spat settlement (Figure 5). These collectors consisted of a ren, anchored by a sandbag, with a float attached to the top 5 m below the surface in the same manner as the other pilot collectors. A small surface buoy was attached directly to the ren float.

Deployment of Gear

The two longlines in Kalsin Bay were set on June 15 and 18. The 100 rens were attached to the longlines on July 7 and 8, when plankton sample analyses indicated that scallop spat settlement might begin within a week. Five pilot collectors were set near the longlines at the time the rens were attached. Five more pilot collectors were set periodically at later dates until early September in order to determine the exact time of spat settlement.

Each of the cooperator sites was supplied with enough materials for 20 pilot collectors, as well as sampling and laboratory equipment. Pilot collectors were set at the cooperator sites during July and August. The Akhiok longline was set on July 24.

Spat Sampling

Collector bags were sampled weekly from Kalsin Bay starting on July 30. Initially samples were taken from the pilot collectors near the longlines. After September 17, weekly samples continued with rens from the longlines. Two bags were taken from the top, middle, and bottom of the rens. Each pair of bags was placed in a plastic bag and preserved with formalin. On shore the bags were scrubbed by hand to break loose all of the attached organisms. The samples were then rinsed and concentrated in the same manner as the plankton samples, by successively diluting and decanting.

Samples were examined under a microscope and all scallop spat were counted. The first 100 spat from each sample were measured for length and height, and the remainder of the sample was tallied in 250 micron length categories. As the spat became larger and different species types became evident, they were separated by type as well.

One ren from one station at each of the cooperator sites was sampled in October or early November. These samples were processed and measured in the same manner as the Kalsin Bay samples.

Intermediate Culture

Two 60 m longlines have been set for intermediate culture growout, one in Trident Basin near Kodiak on August 25, and one near Akhiok on September 4. These were constructed in the same manner as the spat collecting longlines, but one anchor was used at each end instead of two. Ten-layer accordion cages (tadan-shiki) will be used to hold the spat (Figure 6). Transfer will occur when half of the spat in the collectors is 3 mm or larger. This is the smallest size at which the spat can be handled. Since the mesh in the cages is 6 mm, the spat initially will be placed in 2 mm mesh bags.

RESULTS

Bill Osborne, KANA

Gonad Index

The scallops used for our gonad index study were subjected to the stress of dredging and transportation and to substantially different temperatures from bottom-dwelling scallops, since they were suspended 2 to 5 m below the surface. For these reasons, the sample population did not accurately represent the scallop population likely to produce any spat found in Kalsin Bay. However, these results may provide a guide for predicting the actual time of spawning.

The gonad index of the sampled scallops increased to 20 percent prior to spawning (Figure 7). The sudden decrease in gonad index shown in this graph suggests that these scallops spawned from early to mid-May. Water temperature at 5 m depth was increasing from 6 to 8 °C during this time, although it dropped back to 7.3 by May 26.

The higher temperatures in the surface layer of water at the boat harbor might have induced spawning earlier in the sample population than in the wild population. In comparison with our estimated time of spawning of early to mid-May, previous studies estimated that

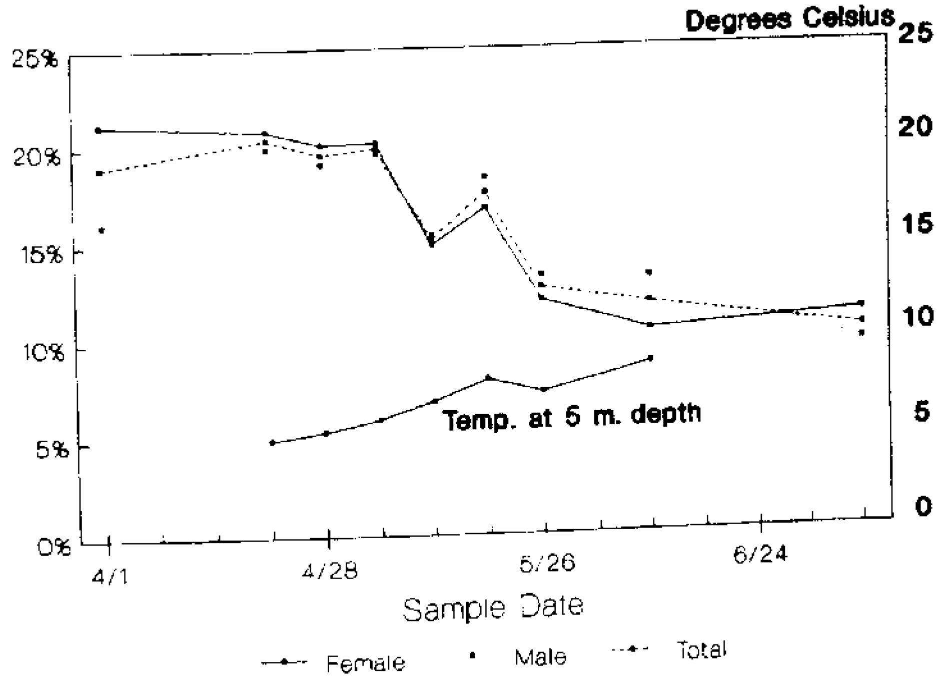


Figure 7. Gonad index for the sample scallop population in 1987, with separate indexes for males, females, and total sample.

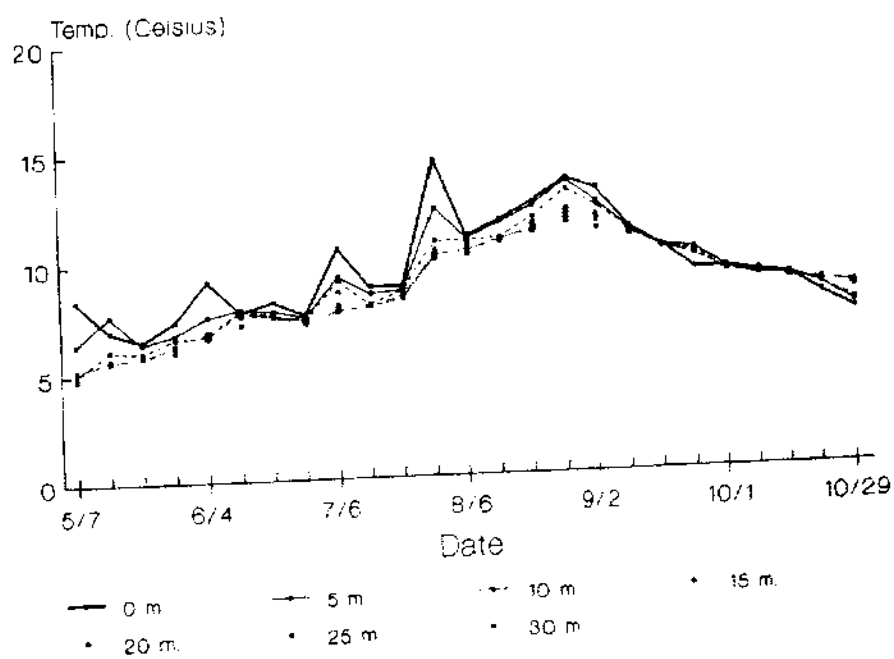


Figure 8. Temperature at depths at Kalsin Bay, Station 1.

weathervane scallops in the Kodiak area spawn in the first half of June.

Oceanographic Studies

The temperature profile of the water column in Kalsin Bay was usually well mixed, with short periods of thermal stratification (Figure 8). When stratification occurred, the temperature of the surface water fluctuated, while temperatures from 10 m to 30 m depth were relatively stable. Of particular interest in this graph is the period of thorough mixing from mid-June to early July. This was a period of severe storms, with an unusually high rainfall. The temperature throughout the water column decreased during this period. In late July the temperature of the entire water column increased, and the temperature at 30 m rose from 7.8 to 8.2 °C in one week. Maximum temperature at the surface was 14.5 on July 30, and at 30 m depth was 11.4 on August 26. Since mid-September, frequent storms have kept the water column well mixed.

Temperature data from Amook show mixing of the water column during the storms in late June and early July and throughout the fall storms (Figure 9). The data suggest considerable variation in temperature not only at the surface, but also at the 25 m depth. Maximum temperature at the surface was 13.2 on July 27, and at 25 m depth was 11.4 on September 14.

Water temperature in Kempff Bay near Akhiok was stable below 10 m depth throughout the study period, with stratification and warming in the surface to 5 m layer from mid-July through August (Figure 10). The highest temperature at the surface was 13.9 on August 2, and at 30 m depth was 10.1 on September 4, over one degree colder than the peak bottom temperature in Kalsin Bay.

Plankton Samples

Plankton samples were taken at all stations in Kalsin Bay in May, but bivalve larvae were only abundant at stations 1, 2, and 3. Sampling effort concentrated at those stations for the rest of the summer. The results presented here are from Station 1 where bivalve larvae were most abundant.

Larval shell shape was used to identify scallops among the bivalve larvae. Examples of scallop and other bivalve larvae are shown in Figure 11. Although there were possibly several species of scallops present (Table 1), no attempt was made to differentiate among them. Scallop larvae are first identifiable at about 120 microns, about one to two weeks after spawning. Larval shells are initially D-shaped, but gradually develop a more rounded appearance until the umbo is completely indistinct at a length of about 200 microns (Figure 12).

Bivalve larvae became abundant in the plankton samples in late May, and reached a peak of 9,267 per cubic meter on May 28, (Figure 13). Scallop larvae were present at stations 1 and 2 in small numbers from June 4 to June 30, with peak abundance of 4 per cubic meter at Station 2 on June 18. Abundance of all bivalve larvae fell to between 72 to 414 per cubic meter during the storms from mid-June to early July, and no scallop larvae were found in early July. Scallop larvae at Station 1 again appeared in samples from July 16 until August 26, with a peak abundance of 136 per cubic meter on July 30. Bivalve larvae were present through the final sample on September 2, and reached a peak abundance of 34,564 per cubic meter on July 27.

Scallop larvae found in the June samples grew at a rate of 2.4 microns per day, calculated by simple regression of the shell length of the largest larvae from each of the four weekly samples. Plankton samples taken each week from early July to August 13 included scallop larvae less than 150 microns in length indicating a prolonged spawning period. Scallop larvae sampled from July 9 to July 30 grew at a rate of 4.2 microns per day, calculated by simple regression of the shell length of the largest larva from each sample.

Bivalve larvae at Amook reached a peak abundance of 4,800 per cubic meter on June 30 (Figure 14). Scallop larvae were found only in the last two plankton samples, taken on August 10 and August 24, respectively.

Bivalve larvae at Akhiok reached a peak abundance of 3,682 per cubic meter on July 30 (Figure 15). Scallop larvae were observed in the July 24, July 30, and August 18 samples, with a peak abundance of 76 per cubic meter on August 18.

Spat Settlement

At the time of settlement, scallop larvae undergo metamorphosis. The larval swimming structure, or velum, is lost. the scallops lose their ability to swim, they begin to feed by means of their gills rather than the velum, an eye spot develops in the middle of each shell, and a foot and byssus gland develop which produce the thread by which the scallop spat attach. After metamorphosis a distinctly different shell is produced. The original larval shell is easily distinguishable from the early spat shell (Figure 16). By measuring the larval shell of young spat, the size at metamorphosis can be determined.

The size at metamorphosis was measured from all spat from the pilot collectors in Kalsin Bay. This size ranged from 200 to 275 microns and averaged 237 microns (Figure 17).

Settlement Timing

Pilot collectors in Kalsin Bay were retrieved from July 30 to September 8. Collectors removed prior to August 13 had few scallop spat or none at all. Collectors set after August 26 likewise had few attached scallop spat. Thus, the major part of the settlement period fell between August 13 and 26 (Table 2).

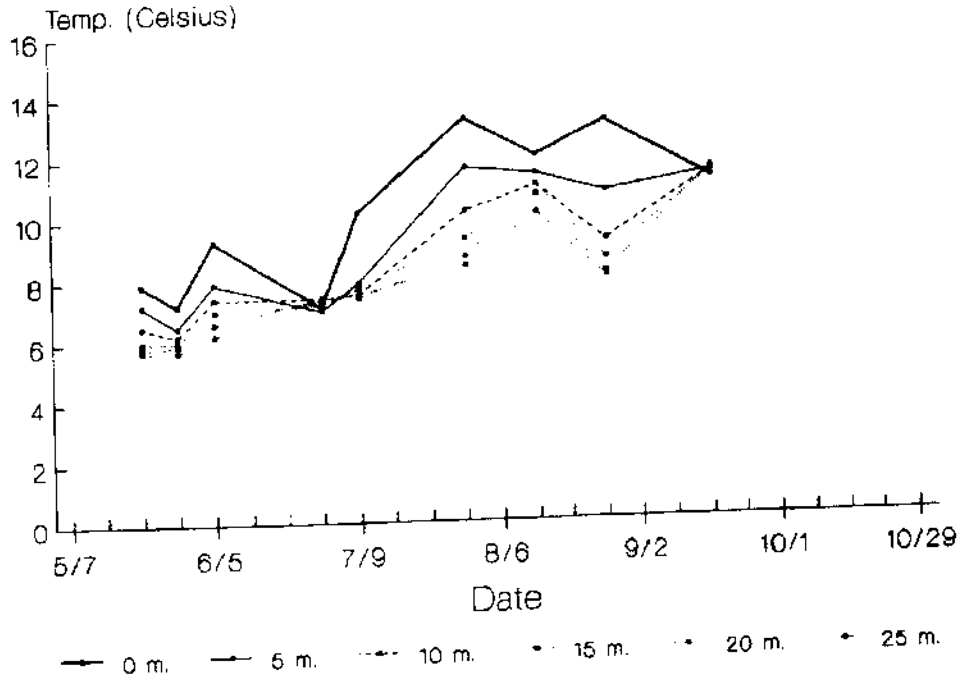


Figure 9. Temperature at depths at the Amook cooperator site, Station 2.

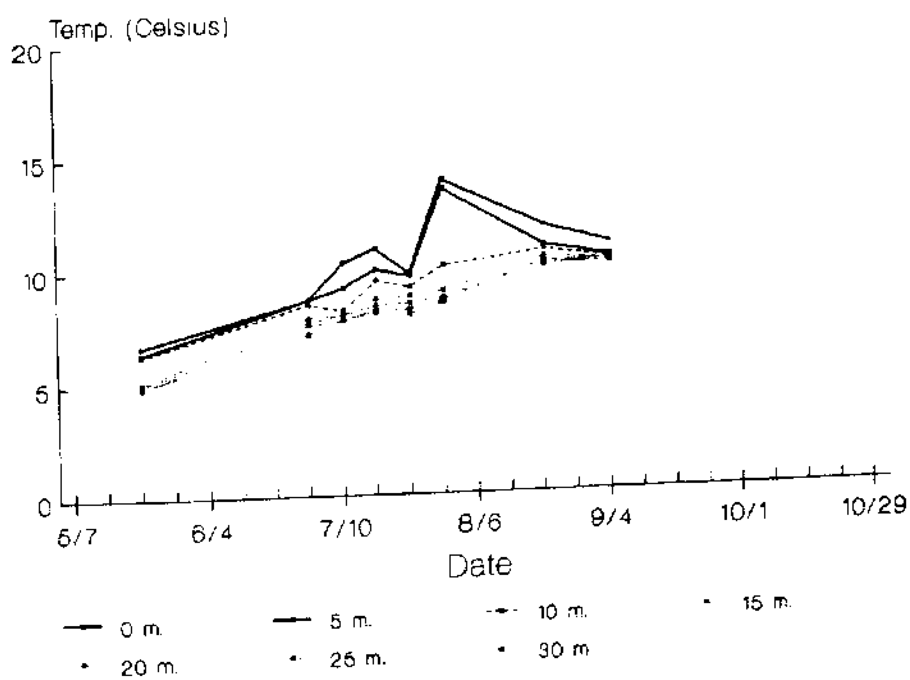


Figure 10. Temperature at depths at the Akhiok cooperator site, Station 1.

Table 1. Species of scallop present in Alaska.

Common name	Scientific name
Weathervane	*Patinopecten caurinus*
Pink	*Chlamys rubida*
Spiny	*Chlamys hastata*
Rock	*Hinnites multirugosus* or *Crassadoma gigantea*
(none)	*Delectopecten* sp.
(none)	*Cyclopecten* sp.

Table 2. Scallop spat settlement in Kalsin Bay, 1987.

Date set	Date pulled	Average no. of spat
7/09	7/30	0
7/09	8/06	0
7/10	8/13	1.0
7/09	8/19	45.8
7/10	8/26	138.6
7/16	8/26	111.0
7/09	9/02	78.0
7/23	9/02	147.3
8/10	9/08	195.6
8/26	9/08	2.0
9/02	9/08	0.3

Spat Growth

On October 1, the scallop spat had an average shell length of 0.6 mm (Figure 18). At this time, different types of spat could be distinguished, so all spat from the next sample were separated into two recognizable shell types, A and B. Spat types were first apparent at around 1 mm shell length. The average length of all scallop spat from October 8 was 0.76 mm (Figure 19). More spat from the October 14 sample were distinguishable into the different types, and the average shell length was 0.82 m (Figure 20). On October 29, most of the spat were distinguishable into types and the average shell length was 1.37 mm (Figure 21). On November 11, the average shell length was 1.36 mm (Figure 22).

One sample was made from the pilot collectors at Amook on October 22. Two bags were sampled from each of the top, middle, and bottom layers. The spat were much smaller than the spat in Kalsin Bay of the same time period, but the same types of scallops were present (Figure 23).

The spat collected from the longline in Akhiok were the smallest of all spat measured at the time of this report. Most spat were unidentifiable, although the same types were present (Figure 24).

Settlement at Depth

On all sample dates and at all sites except Amook, spat settlement was greatest at the 20 to 25 m depth (Table 3). At Amook, the settlement was greatest at the middle depth range. The density of spat settlement was fairly constant in Kalsin Bay, at 180 to 255 spat per bag. Spat settlement was heaviest in Amook Pass, with over 1,000 spat per bag, and lightest near Akhiok with 60 spat per bag.

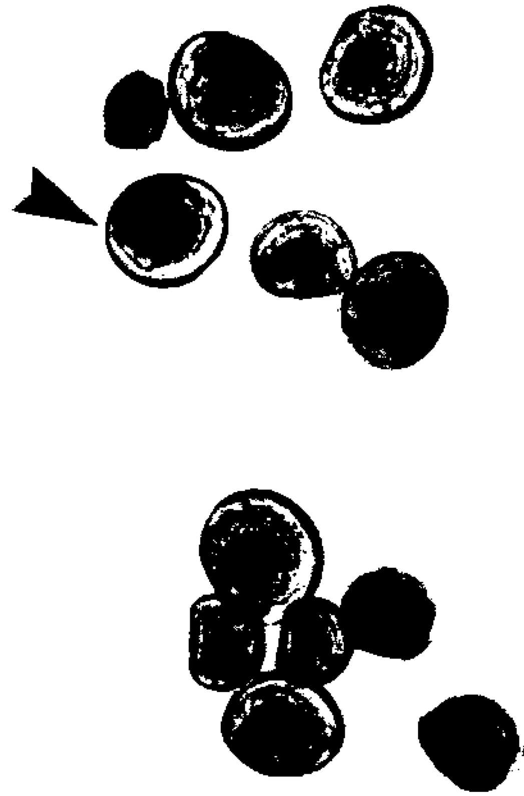


Figure 11. Examples of scallop and other bivalve larvae. Arrow indicates scallop larva. Photo by Yoshio Ishiyama.

Species Identification

Scallop spat from the October 8 sample were first separated into distinguishable types. Spat can be clearly separated into the different types at about 1 mm shell height. Spat called Type A were distinguished by strong ribs visible on spat as small as 750 microns, small spiny projections on the ribs, shell height slightly greater than shell length, and a pink color in spat larger than 1.5 mm (Figures 25 and 26). Spat called Type B were distinguished by weak ribs not noticeable until after a shell height of about 1 mm, large eyes along the mantle margin that are clearly visible through the shell, roughly equal shell height and length, and a speckled color in spat larger than 2 mm (Figures 25 and 26).

There were spat from every sample that were too small to separate into types. The major portion of spat

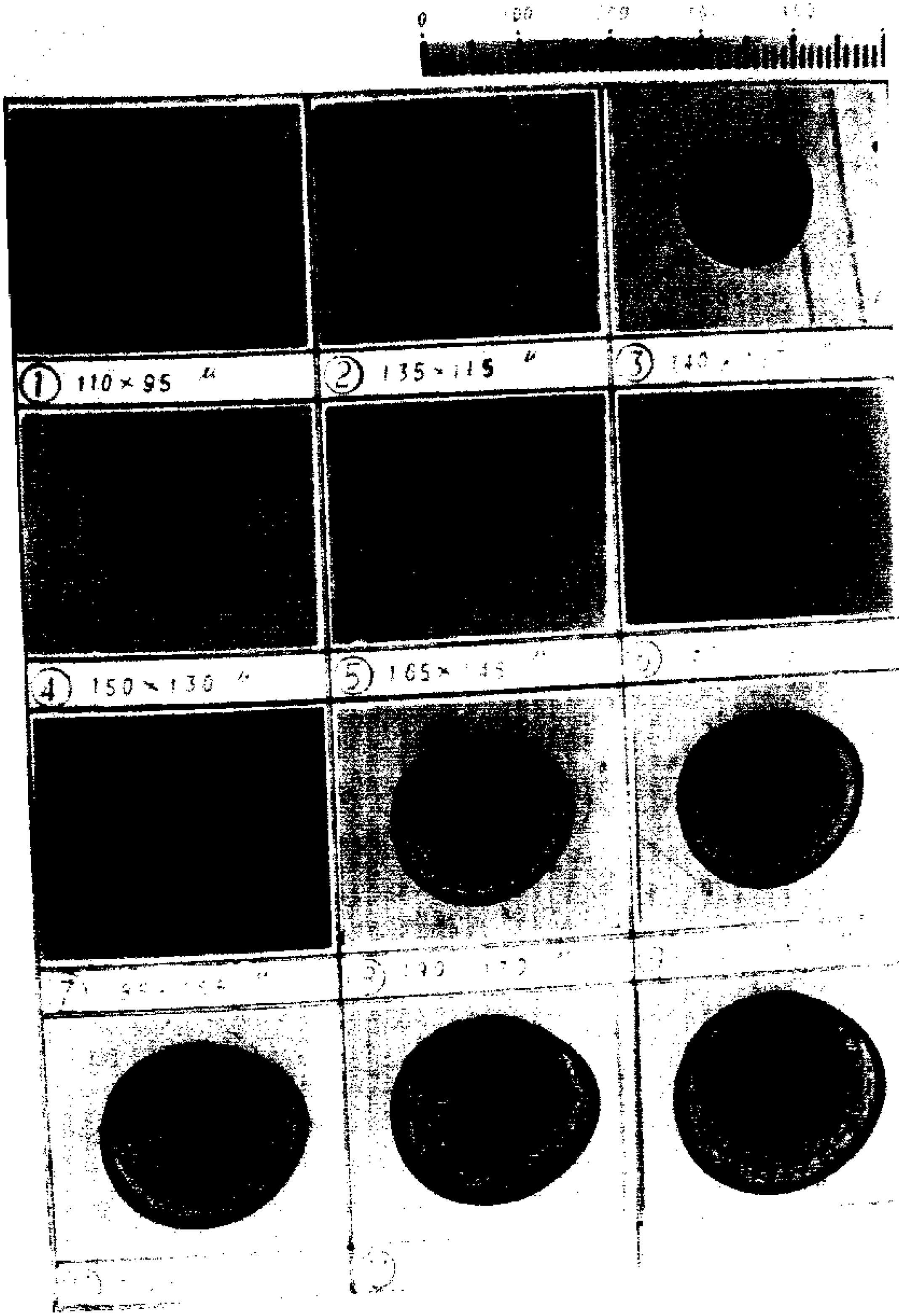


Figure 12. Development of scallop larva shape with growth. Photos by Kyoshi Iwagishi.

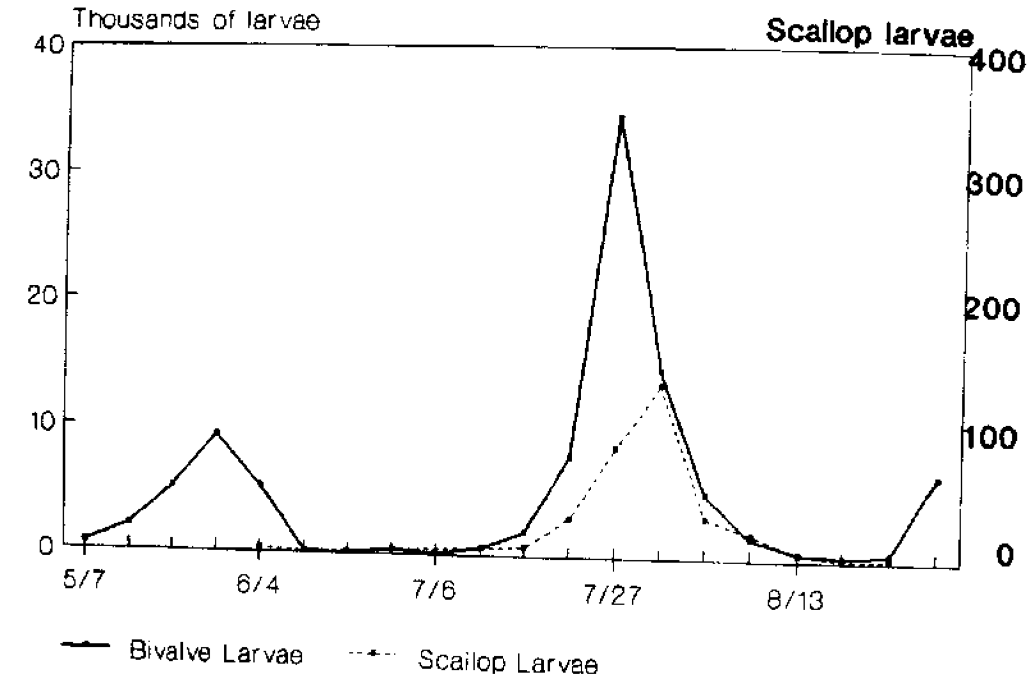


Figure 13. Bivalve larvae from Kalsin Bay, Station 1. Numbers represent larvae per cubic meter of water sampled.

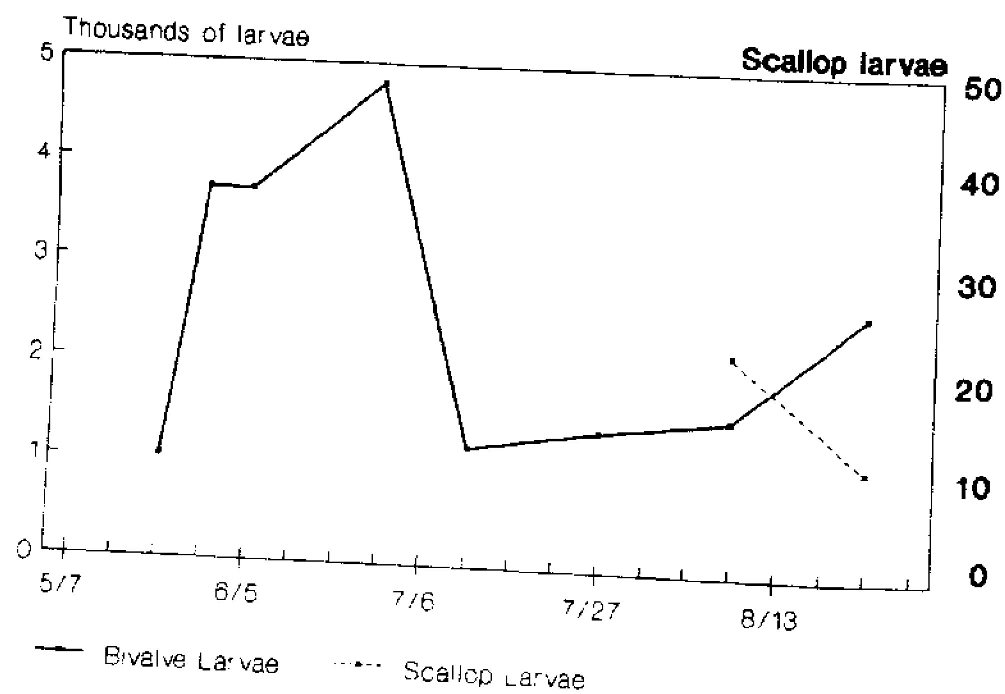


Figure 14. Bivalve larvae from Amook, Station 2. Numbers represent larvae per cubic meter of water sampled.

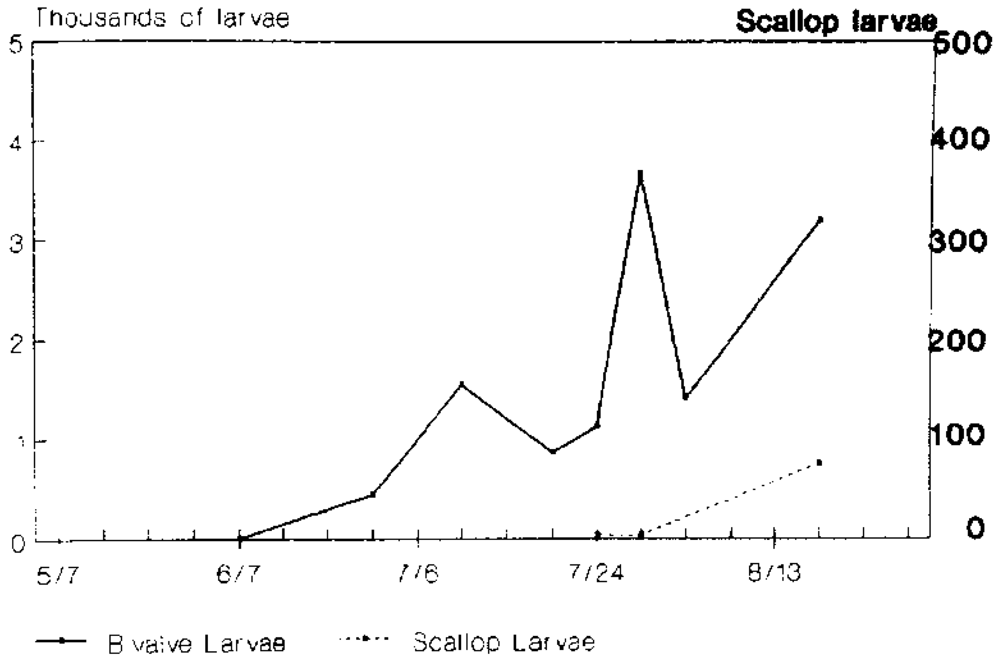


Figure 15. Bivalve larvae per cubic meter at Akhiok, Station 1. Numbers represent larvae per cubic meter of water sampled.

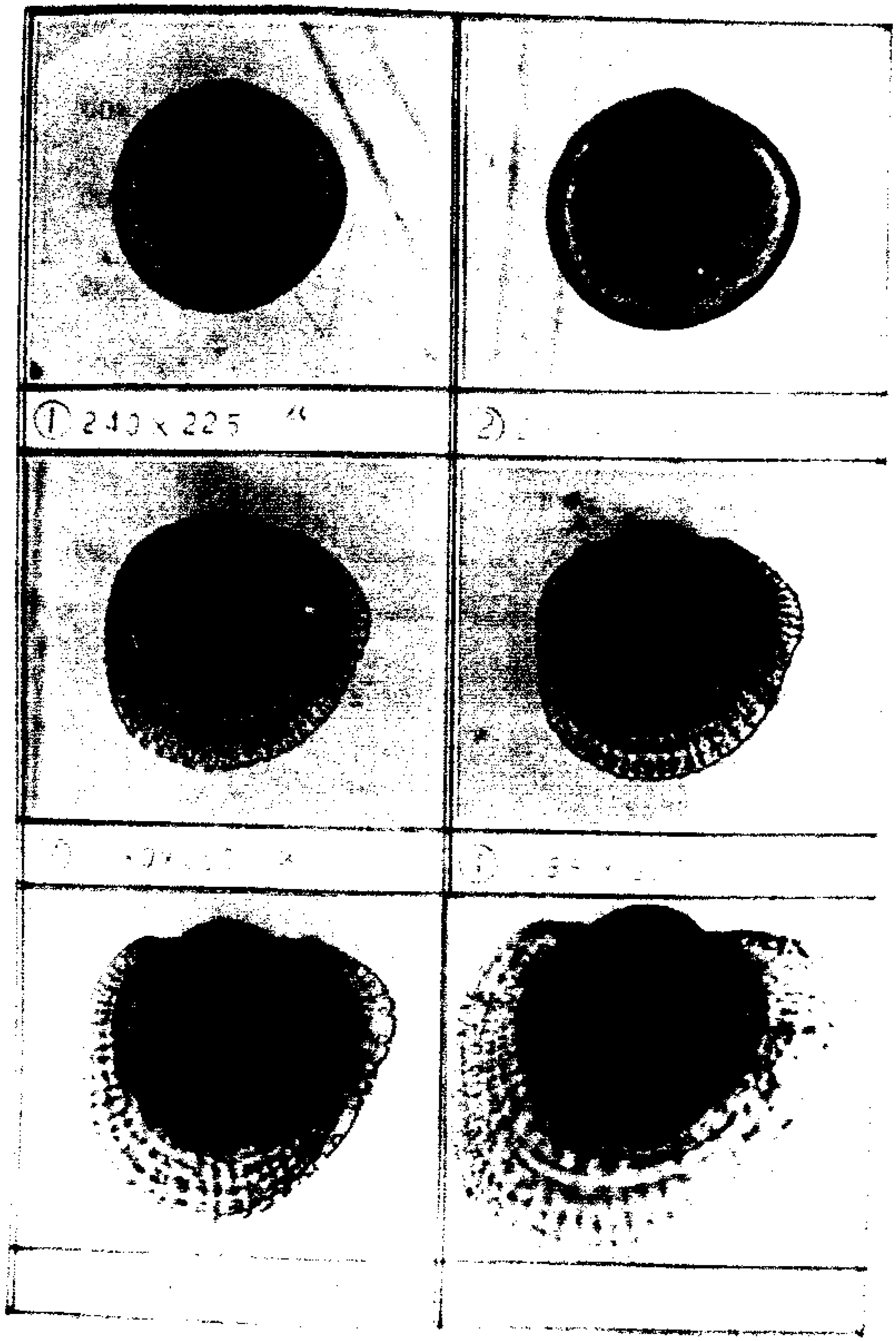
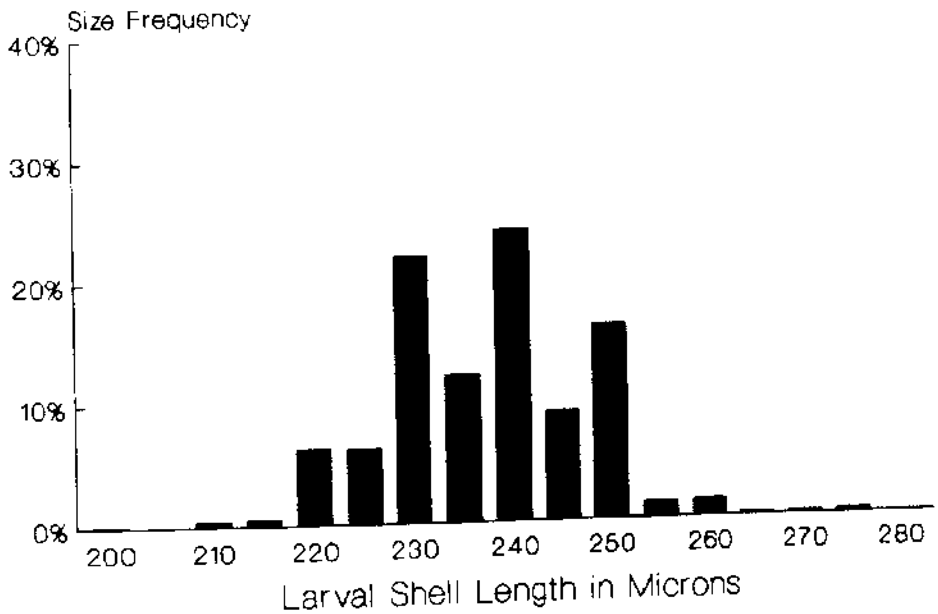


Figure 16. Scallop larvae at time of metamorphosis (1 and 2), and scallop spat soon after metamorphosis (3 to 6). Note the distinct larval shell on metamorphosed spat. Photos by Yoshio Ishiyama and Kioshi Iwagishi.



No. measured: 1906

Figure 17. Distribution of larval shell lengths of spat at time of attachment (Sept. 2, Kalsin Bay sample).

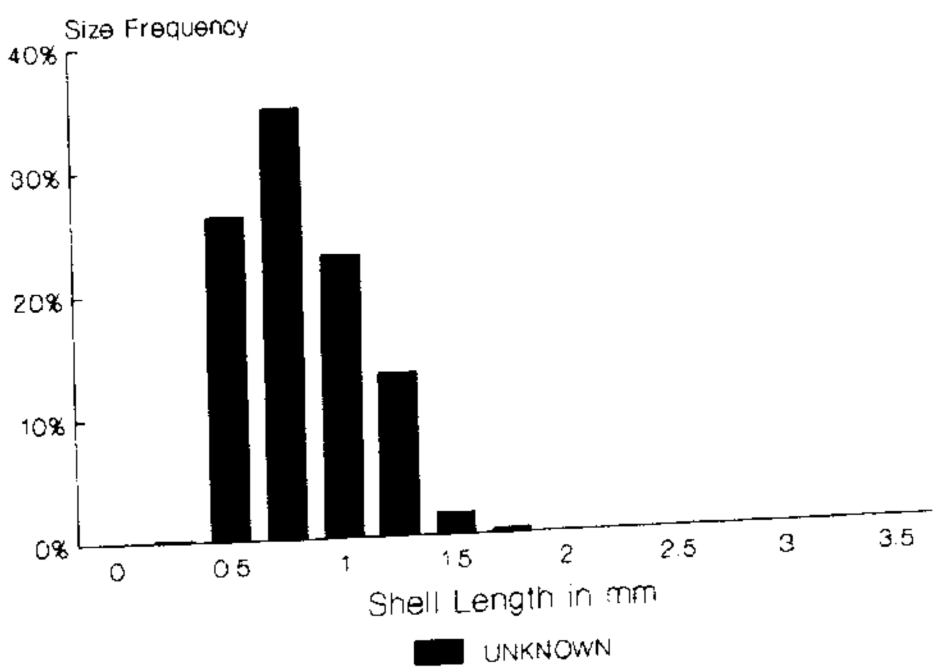


Figure 18. Distribution of shell lengths of Kalsin Bay spat sampled Oct. 1, 1987.

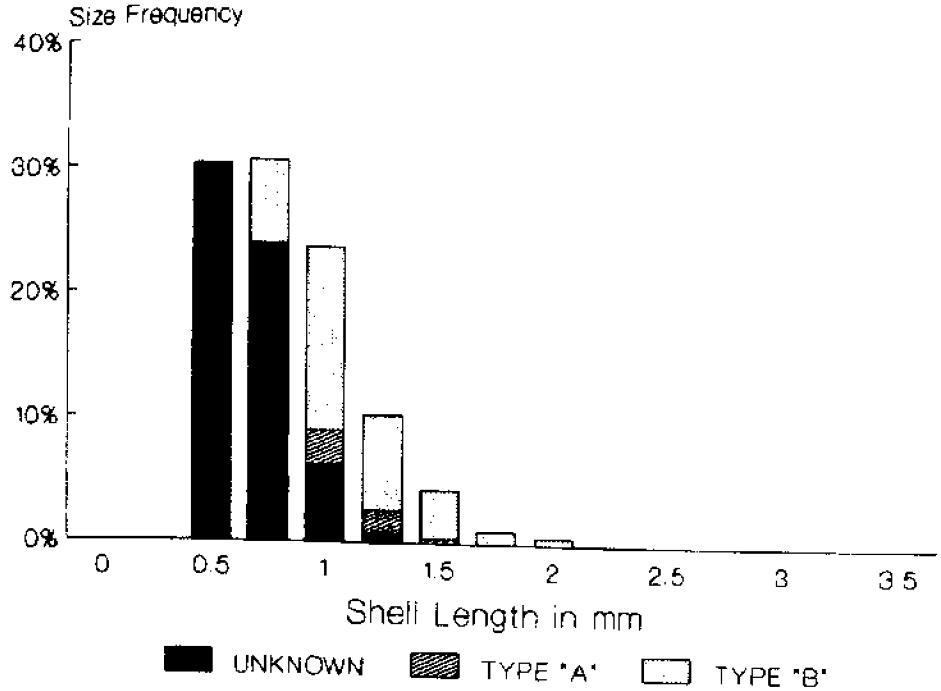


Figure 19. Distribution of shell lengths and type composition of Kalsin Bay spat sampled Oct. 8, 1987.

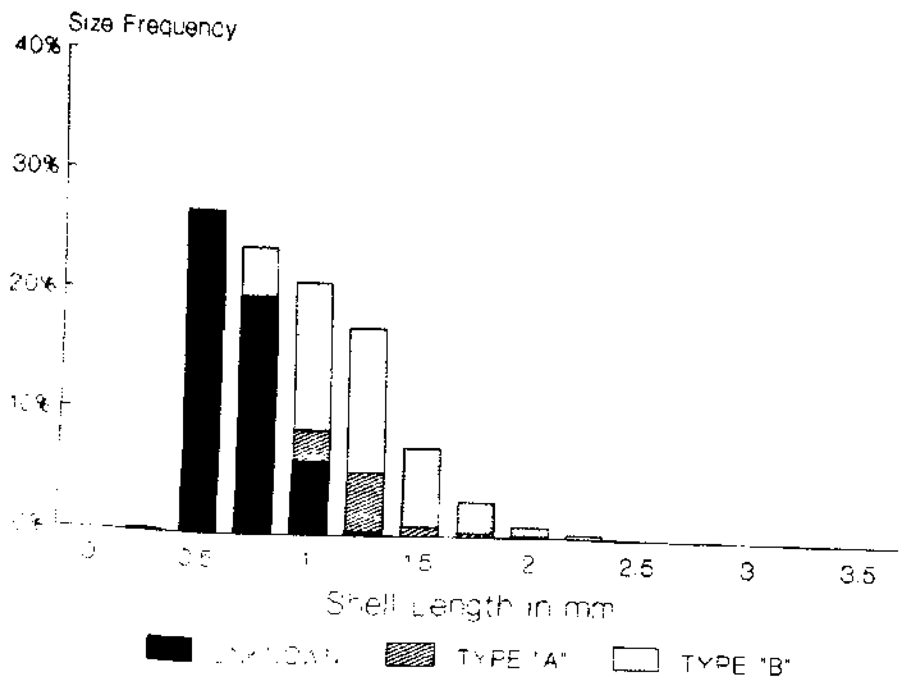


Figure 20. Distribution of shell lengths and type composition of Kalsin Bay spat sampled Oct. 14, 1987.

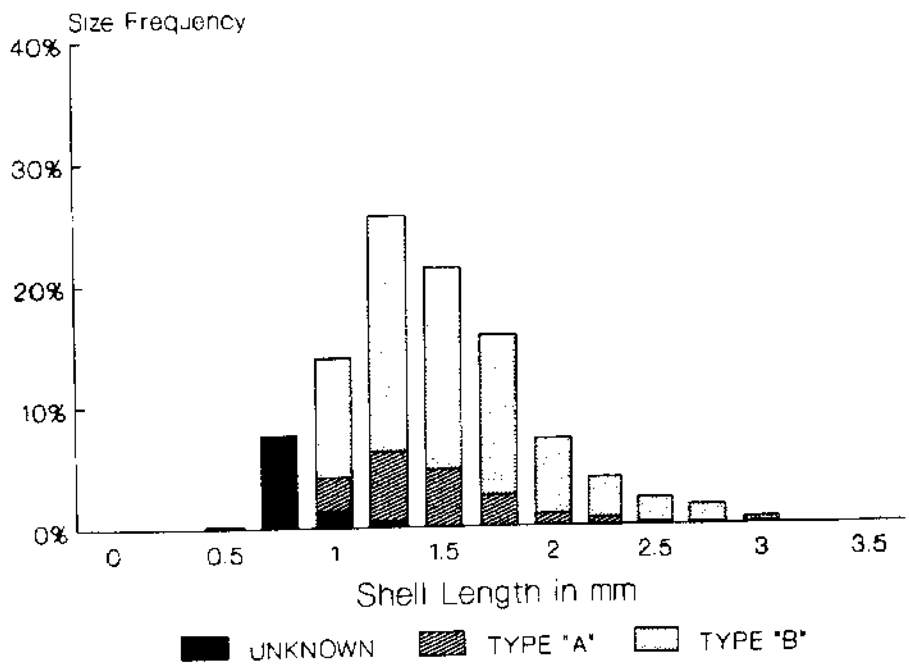


Figure 21. Distribution of shell lengths and type composition of Kalsin Bay spat sampled Oct. 29, 1987.

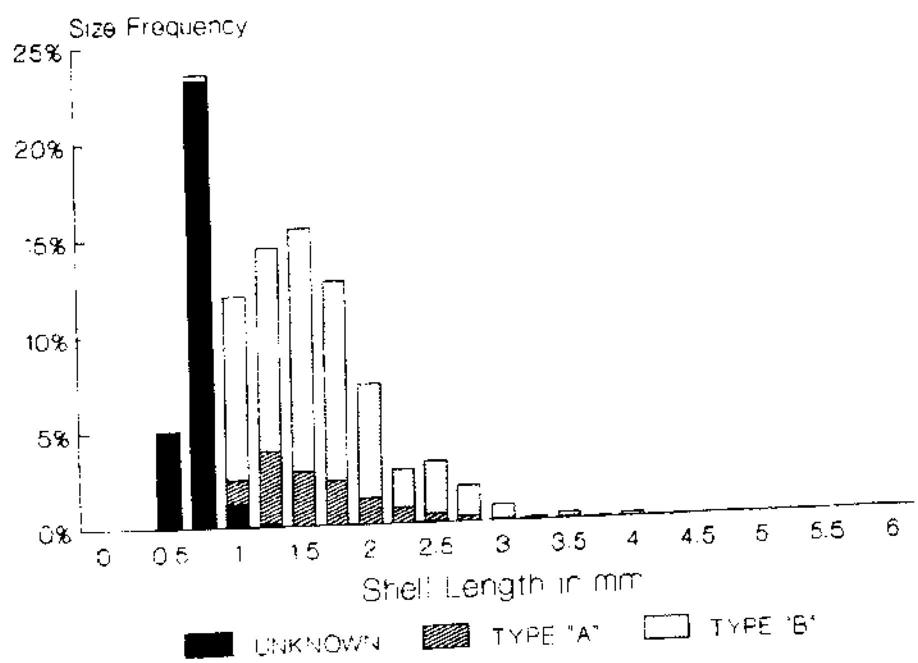


Figure 22. Distribution of shell lengths and type composition of Kalsin Bay spat sampled Nov. 11, 1987.

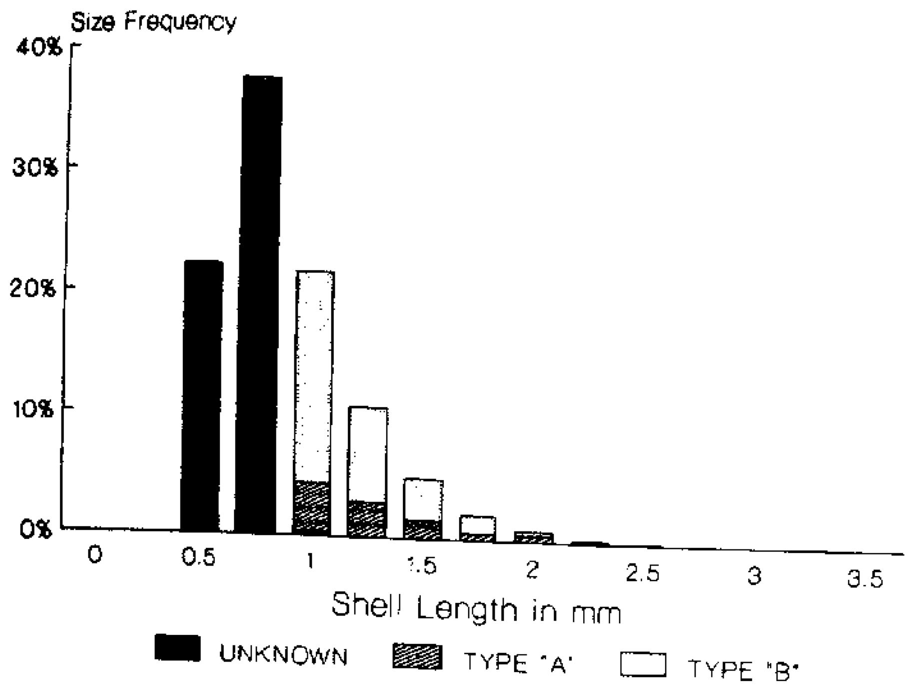


Figure 23. Distribution of shell lengths and type composition of Amook spat sampled Oct. 22, 1987.

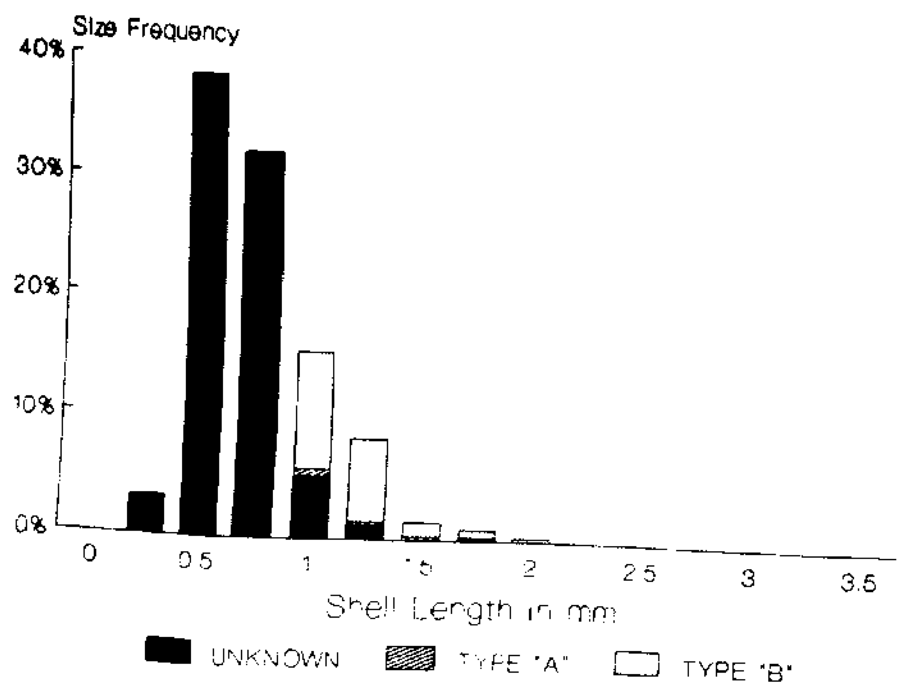


Figure 24. Distribution of shell lengths and type composition of Akhiok spat sampled Nov. 4, 1987.

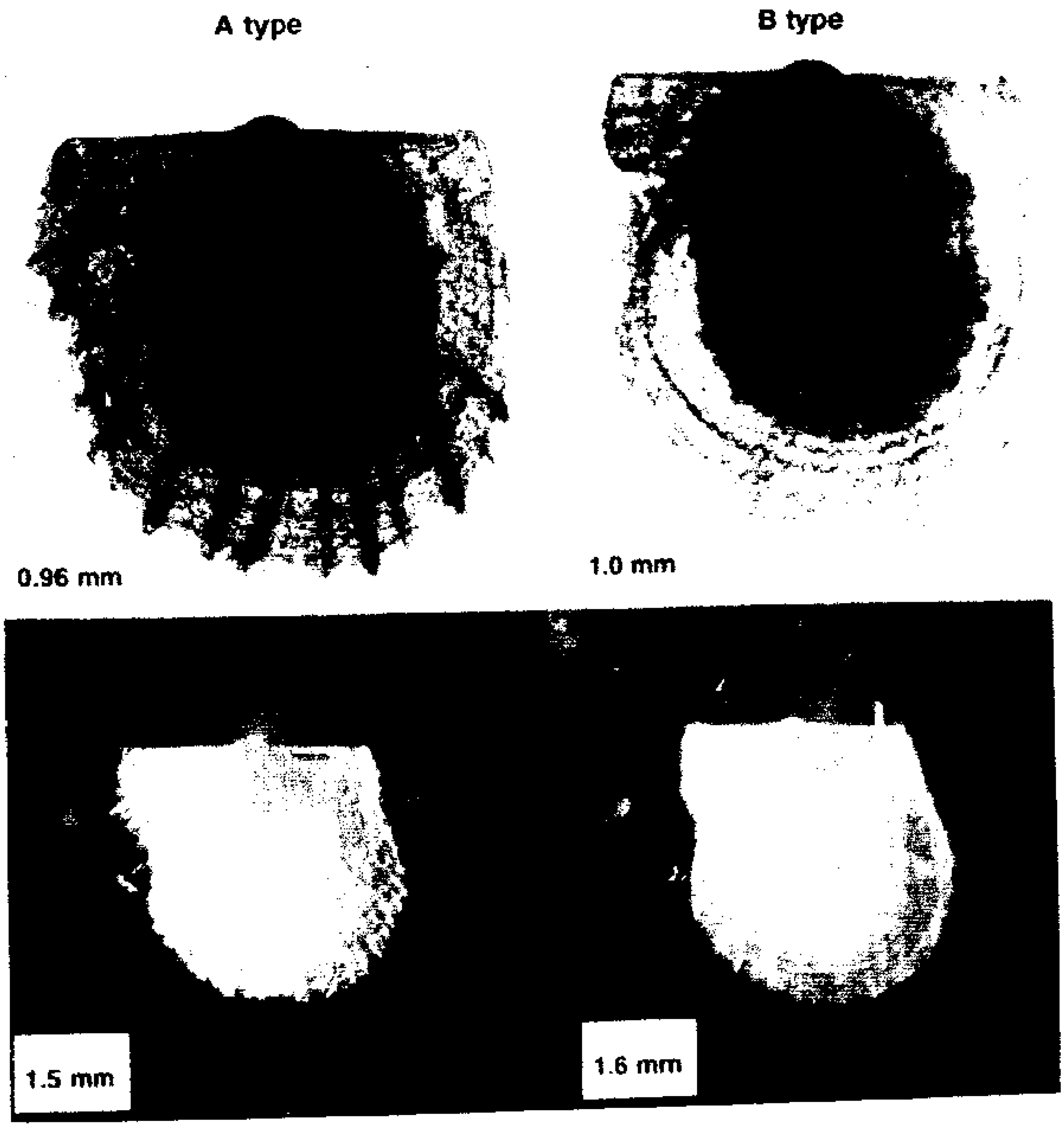


Figure 25. Scallop spat captured from Kalsin Bay. Earliest differentiation between A type and B type occurs at about 1 mm. Photos by Yoshuo Ishiyama.

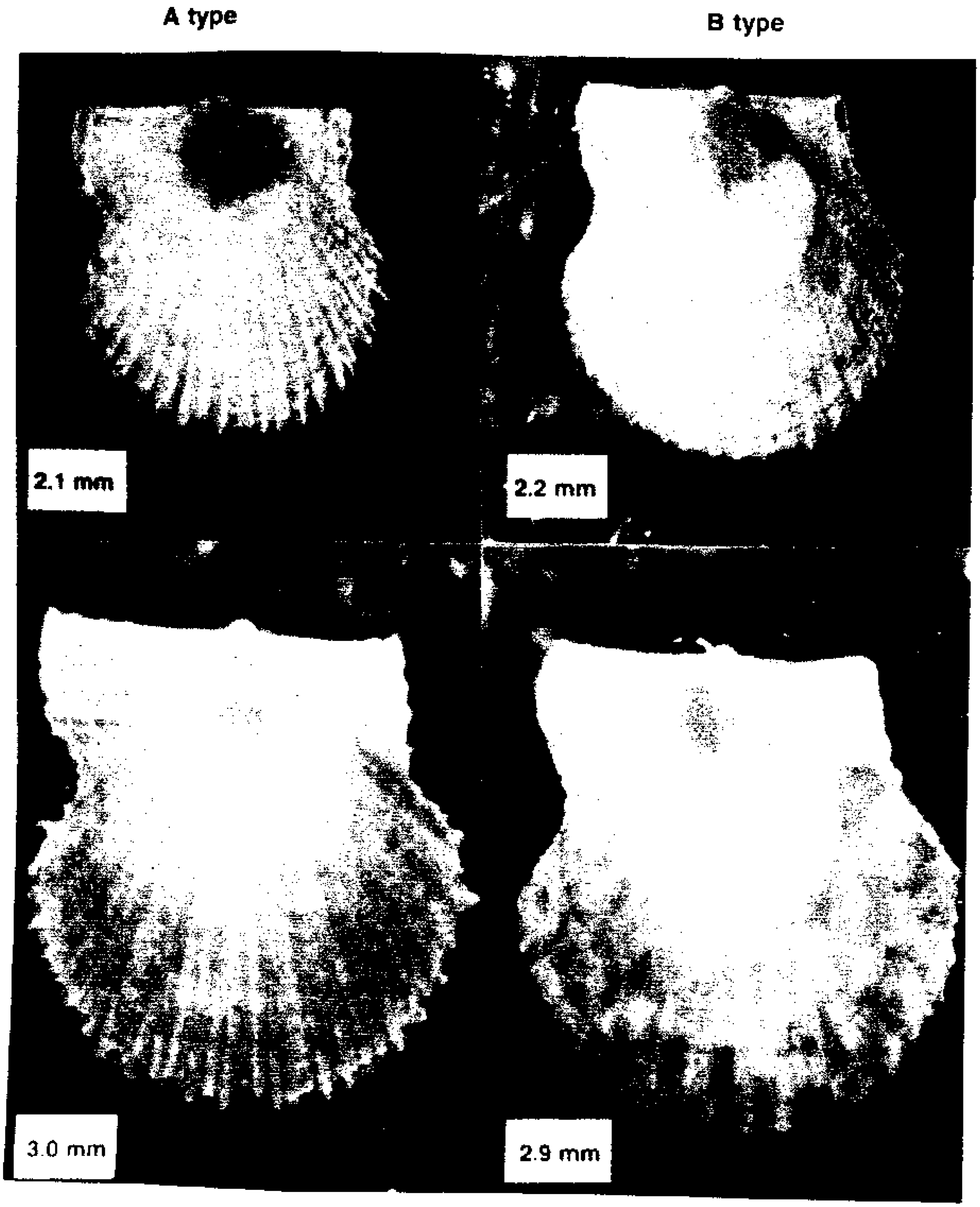


Figure 26. Scallop spat from Kalsin Bay. Differentiation between A type and B type spat becomes clearer as spat grow larger. Photos by Yoshio Ishiyama.

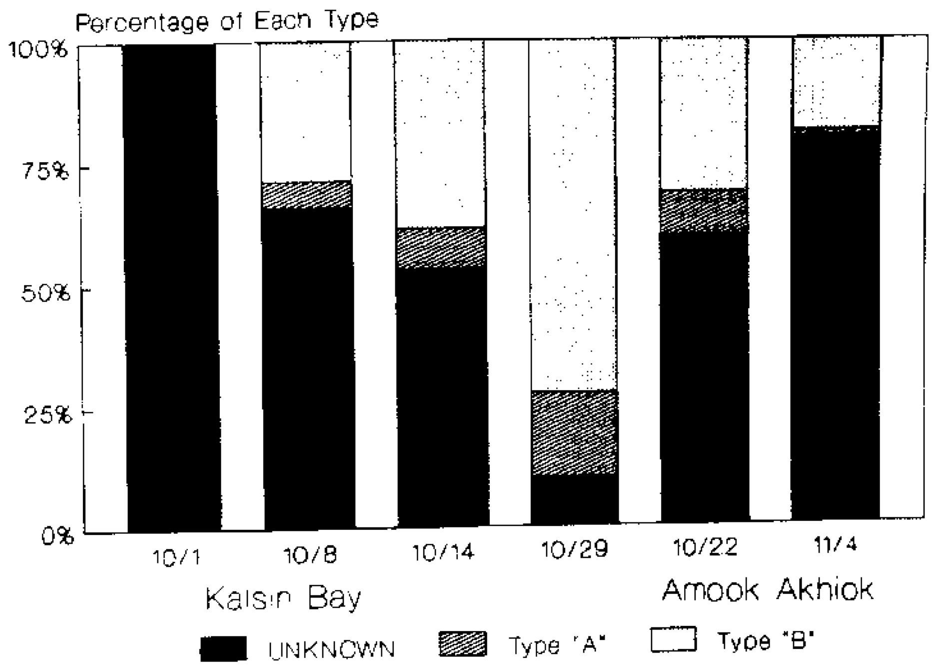


Figure 27. Proportion of different spat types for samples from Kalsin Bay, Amook, and Akhiok.

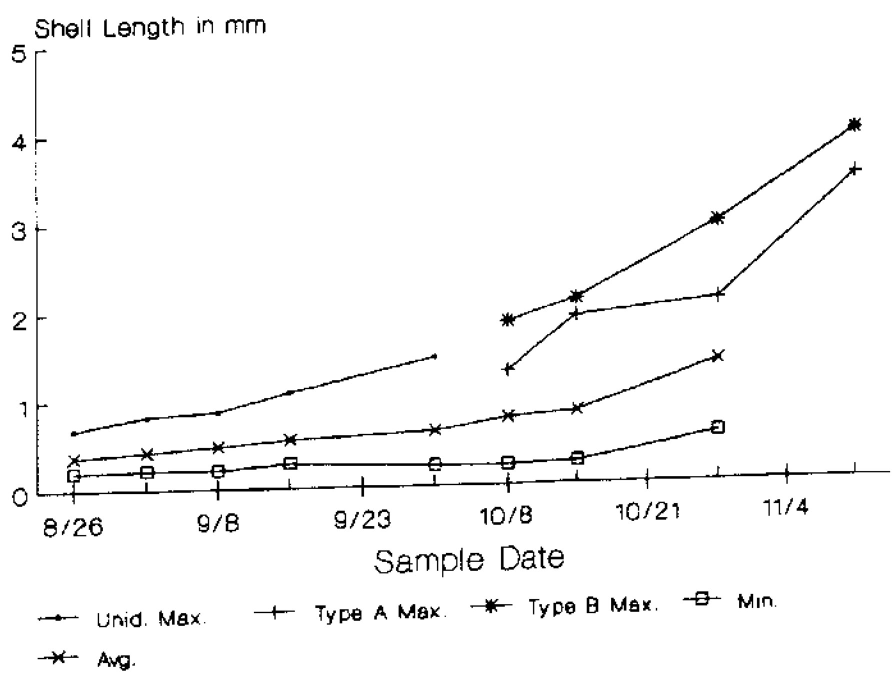


Figure 28. Growth of Kalsin Bay scallop spat.

Table 3. Average number of spat per bag at three settlement depths.

	Kalsin Bay					Amook	Akhiok
Date	10/1	10/8	10/14	10/29	11/11	10/22	11/4
Top (5 m)	32	68	75	60	83	739	10
Middle (15 m)	151	106	120	144	221	1,445	32
Bottom (25 m)	663	422	344	356	638	872	138
Avg. spat/bag	255	199	180	187	314	1,018	60

from every sample were of Type B (Figure 27). About 80 percent of the identifiable spat from each sample from Kalsin Bay were called Type B and the remainder were called Type A. Of the spat from Akhiok and Amook, 94 percent and 78 percent respectively were called Type B, and the remainder were called Type A.

Spat Growth

The growth rates of scallop spat from Kalsin Bay are presented in Figure 28. The upper line on the graph indicates the largest spat found in each sample. Initially, the spat were not separated into types, but after October 8, the largest spat from each sample is of Type B. The largest spat of Type A from each sample is indicated by the next line beginning on October 8. The middle line indicates the average length of spat from each of the samples, and the lowest line indicates the smallest spat from each sample.

Type B spat from October 8 to November 11 had a growth rate of 62 microns per day, and Type A spat from the same time period grew at a rate of 56 microns per day. Throughout the sampling period, small spat less than 250 microns in length were found in almost every sample, indicating either that new spat were continuing to attach to the collectors or that some spat that had attached earlier were not growing.

SUMMARY

Mike Kaill, ADF&G

To date, all of our sample scallop spat are too small to identify, and we have not been able to identify any weathervane scallops. Of the currently unidentifiable scallops, there may be weathervanes, as well as other scallops of possible economic value such as the rock scallop and *Chlamys* species.

This project was not designed as a one-year effort. The uncertainties of weather, location, biological year-class failure, and other factors require a multi-year approach.

We want to emphasize that the technology that OFCF has provided us has already become incorporated into the state's efforts at mariculture. Spat collection effort statewide has benefitted from the insight, gear, and biological information provided to the Kodiak project.

In December this year's results will be evaluated by the project technical committee, made up of OFCF, State, and KANA officials. At that time, a program for the second year of the project will be mapped out. It is anticipated that the following will be identified as work elements:

1. Continue processing of collected spat, sorting and transfer to intermediate growout cages.
2. Continue survey work for location and abundance of scallop populations.
3. Continue gonad index work, to refine estimates of timing of adult scallop populations.
4. Continue oceanographic work, including current measurement, to increase information base of ecology and movement of scallop larvae.
5. Artificial spawning study, for identification of larvae and refinement of timing for setting collectors.

THE ECONOMIC FEASIBILITY OF OYSTER FARMING IN SOUTHEAST ALASKA

Ray RaLonde
Sheldon Jackson College
Sitka, Alaska

Working at Sheldon Jackson College, we frequently receive calls asking for information. Many of those calls in the past few years have concerned oyster farming. The inquiring people ask questions such as, "I have $15,000. Can I start an oyster farm?" And, "What would it take to start an oyster farm—I've got a site here." Or, someone comes into the office with a chart marked at a location on the west coast of Prince of Wales Island, and he says, "Here are four sites. Which one is best?" Our frustration in answering these questions demonstrated that we needed to gather together some information on oyster culture in Alaska, including what it takes to put an oyster farm together.

THE OYSTER FARM MODEL

Our best temporary plan included a computer-simulated model farm. The nice thing about a computer model is that if it does not fit a site, the model can be modified. The major problem encountered during the model development was that there are hundreds of ways to organize an oyster farming business as a small operator, and therefore hundreds of ways to develop and modify a model. We selected some characteristics for a hypothetical farm, and then put in several constraints leading to projections.

The computer model was based upon the best information we could get by visiting farms, writing letters, and searching the literature. One advantage we had in constructing an aquaculture model was the work going on at Sheldon Jackson College's private nonprofit (PNP) hatchery.

Input of information from Alaskans for the oyster farm model was not as complete as that from other states. Survey forms sent to the oyster growers through the Alaska Shellfish Growers Association were not returned. This indicates that (1) there is a real need for the dissemination of information here in Alaska, that (2) oyster growers are either not keeping data or have not been in business long enough to generate much data, or that (3) the growers are not sharing this information.

INITIAL COSTS

An oyster farmer will have initial construction costs for such things as a skiff, cabin, the actual facility, and a dry storage area. The high cost of the site survey alone startles some people—to get tidelands surveyed for the official lease is in the range of $5,000. Permits and data collection previous to site construction are some other up-front expenses, not anticipated by a new shellfish farmer. Shipping cost for equipment may increase its delivered cost by 50 percent; $100 worth of pipe may cost $150 by the time it arrives at the site. A grower may be able to transport equipment to a remote site by chartering a local boat for $800 or $1,000 a day.

Rearing Structures

Oysters, cultured for the half shell market, are reared in two primary systems: suspended, tiered lantern nets and surface trays. Models with both of these types of structures were developed.

Lantern Net Model

Lantern nets are tubular structures 6 feet long and divided into 10 compartments. The nets are held in position initially by an anchor and supported by floats. The floats are attached on one another as a longline. Lantern nets at present are a very expensive option for rearing oysters, because they must be imported from Japan. A 10-tier lantern net sells for about $34 (although I understand lower prices are now avalable) for only an 18- or 24-inch diameter 10-tier net, which is not nearly as efficient for oysters as a surface tray. With the lantern net facility, I estimated that an oyster farmer would have to produce more than 200,000 spat per year to make the farm economically feasible; feasibility means pay back of facility cost and operation within 15 years.

Surface Tray Model

A surface tray model is made of a log or plastic pipe rectangle flotation about 15 feet long by 4 feet wide. It has a mesh screen attached to the bottom of the flotation to form a chamber in which the oysters are suspended. Two types of surface tray facilities—one that used log flotation and one that used plastic flotation—were modeled to determine whether the log flotation was cheaper in the long run than plastic flotation.

An economic analysis of both culture facilities determined that even though log flotation costs less initially, logs in the long term are more expensive. With a 200,000 spat-a-year facility, about every third or fourth

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year approximately 6,500 feet of logs will need to be replaced. (I was talking to Don Nicholson, however, and he says there is a way to extend the life span of the logs to five years or longer.)

One source of logs is from the U.S. Forest Service which allows cutting on Forest Service property at a cost of $0.51 per linear foot. Their policy is to mark the trees themselves for cutting, and these trees would not be on the beach and therefore would not be accessible. The trees then would have to be cut, limbed, taken to the beach, and then transported to the site.

The cost for the logs, net, surface tray, anchors, etc. would be about $50 a tray. It appears that a grower wouldn't save much by using that system. If you are considering using the logs as a flotation device, you should ask yourself if it is worth the trouble.

Plastic flotation is less troublesome in the long term since the useful life of the facility is longer. In the model, a 200,000 spat facility could be paid back in 10 to 12 years.

OPERATING COSTS

An important operating cost is salary. The computer model assumes that it takes three years to get a marketable oyster, based upon some of the cold water conditions in Alaska. Thus an operator would have living expenses for three years on the site, or someone would need to be hired to stay at the site to supervise and guard the product. Salaries are a major expense in operations, and to have a person living at a remote site for three years in a cabin could cost as much as $100,000.

In addition to salaries, employee wages, personal transportation, boat fuel, and maintenance of materials must be considered. Equipment maintenance should go into the budget; if equipment is not maintained, operational problems could become serious, especially in a remote site. Equipment depreciation should be part of operations cost since capital must be available to replace equipment and facility structures to continue in operation.

Our models contain a maintenance requirement of 1 percent of equipment cost annually, and 10 percent depreciation of facility annually for reconstruction. The cost for the seed for the oysters is relatively low—about $11.00 per 1,000.

The more difficult expense to project is tidelands lease, because the tidelands lease policy is so unclear. The lease cost may be based upon the most valuable economic use of the property, or it may be as low as $50.00 per acre.

Marketing and product transport expenses were put into the computer model. Marketing cost should include travel and communication to find the market and negotiate the deals, including contracting expenses and possible legal fees. The marketing costs might be as much as 10 percent of the market value of the product.

Insurance on the product is a necessity. Lloyds of London is an example of a carrier that might be willing to insure the product as a percent of the market value.

Shipping containers and freight costs must be considered. With a perishable product a reliable way to get the oysters to market quickly is necessary. Air freight will be required if the market is not close by. By the way, Alaska Marine Highway ferries don't ship—they made it very clear to me. They're not a shipping agency; they are a highway system.

USING THE MODEL

For the model, I was looking toward producing approximately 200,000 oysters a year. With surface tray plastic flotation, the operating and construction costs for 200,000 spat are approximately $115,000 during the first year. Once the material is in place the operating costs are about $60,000 per year. Income from sales, projected after the fourth year at the beginning harvest is around $72,000 a year above expenses of $12,000. At this rate, the oyster farm can pay itself off in 10 to 12 years.

The oyster farm models described here are included in more detail in the *Alaska Oyster Grower's Manual* (University of Alaska Sea Grant, Marine Advisory Bulletin 17, available from Alaska Department of Commerce and Economic Development, P.O. D, Juneau, Alaska 99811). Feedback is welcome.

QUESTIONS AND ANSWERS

Q. You said $72,000 was the gross sales. What was that based on?

A. I had 50 cents an oyster and 200,000 spat a year with mortalities over a three-year period.

OYSTER AQUACULTURE IN THE PACIFIC NORTHWEST

Kenneth K. Chew
University of Washington
Seattle, Washington

INTRODUCTION

I have been involved with oyster research and education for approximately 25 years, and will note that many exciting things have been happening in oyster aquaculture in the Pacific Northwest during the last ten years. The person following me, Jim Donaldson, will open your eyes to major improvements that have taken place in oyster culture. Most of the information I have to present to you is based on the oyster industry in the Pacific Northwest, but I will apply what I can to Alaska.

Figure 1 shows two principal species grown in the Pacific Northwest; the Japanese or Pacific oyster (*Crassostrea gigas*) and the smaller native or Olympia oyster (*Ostrea lurida*). The Pacific oyster is a species introduced from Japan after the decline of the native oyster fishery during the turn of this century in Washington State. If it were not for the Pacific oyster, we would probably not have an oyster fishery on the U.S. Pacific coast. The native oyster production is slowly coming back in southern Puget Sound, but will never reach appreciable levels as in the past because of the domination by the Pacific oyster.

PRODUCTION LEVELS

The main area for oyster production on the West Coast is in the state of Washington (Figure 2). There was good oyster production in the 1950s because of large shipments of the Japanese seed. Production went into a slump during the 1970s and there is a general increase now in the 1980s.

During the 1960s and 1970s Maryland, which borders the Chesapeake Bay, was the number one oyster growing state, Louisiana along the Gulf of Mexico was the second largest, and Washington in the Pacific Northwest was third. As of 1986, the American oyster (*Crassostrea virginica*) fishery in the Chesapeake Bay area has fallen below Louisiana and Washington. Pollution and disease have contributed to the demise of the oyster fishery not only in Chesapeake Bay but Delaware Bay also.

As a result of the decline of the East Coast oyster fishery, the Pacific coast oyster producers are beginning to ship oysters to the eastern seaboard to fill the market demands. Because of these demands the West Coast production scheme has also changed as the growers harvest their crops earlier instead of waiting three or four years to let the oysters get larger.

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POTENTIAL FOR ALASKA

There is good potential for an oyster industry in Alaska. I saw some excellent oyster-growing areas in Wrangell. The Pacific oyster grown there has a great flavor. Apparently one of the biggest problems for Alaska is lack of seed now. At least four or five years ago I advised Robin Larsson of the Alaska Shellfish Growers Association it would be good to start an oyster hatchery in southeast Alaska, or to get certification to allow eyed larvae to be shipped for remote setting in this area. I will comment further on remote setting later. Alaskans have to get moving on this quickly.

Assuming that you get adequate seed supply from your hatchery, and/or via remote setting, there are several culture techniques for growout you could use. I will discuss some of these techniques. If you want more detail, you can contact the Alaska Sea Grant College Program in Fairbanks at (907) 474-7086 or the Marine Advisory Program in Anchorage at (907) 274-9691 for specific information.

OYSTER GROWING METHODS

Intertidal Bottom Culture

The historical way of growing oysters is to spread them as seed on the oyster bed and grow them. Over 90 percent of the oysters on the West Coast are grown this way. However, in Washington and California for example, those who are currently getting into the business generally must grow the oysters off the bottom since only second and third class tidelands are available to them. The first class or best tidelands with firm ground, good for growing oysters or clams, are all in use or unavailable. Second class intertidal tidelands are in many cases marginal, with only small acreage now available for lease. Mostly third class tidelands are available for lease to oyster farmers, but such tidelands generally are soft or muddy bottom which will not allow for bottom culture where oysters can sink or get buried when laid on top of the substrate. Thus prospects are for off-bottom culture only.

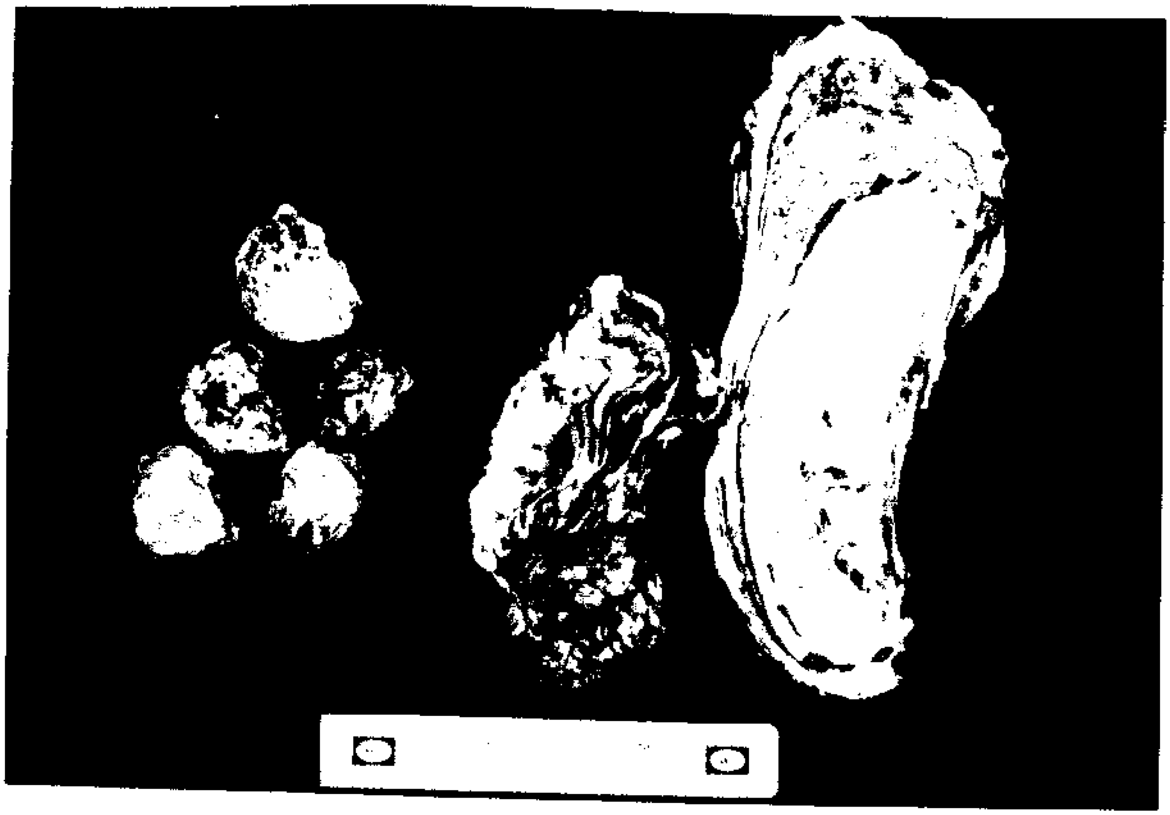

Figure 1. The native or Olympia oyster (*Ostrea lurida*) on the left and the Japanese or Pacific oyster (*Crassostrea gigas*) on the right.

Off-Bottom Culture

Efforts are now going into developing and/or refining new methods of off-bottom culture. When we say off-bottom we are talking about structures that are used to hold oysters off the bottom for cultivation. Briefly, the off-bottom culture techniques used along the West Coast of United States are longline, stake, rack, floating raft, and pearl or lantern net cultures. These are briefly described as follows:

Longline culture system involves using mother shell (containing attached oyster seed) inserted between the braided polypropylene fibers and cinched tight on the line, spaced six to eight inches apart and grown intertidally (see bottom diagram of Figure 3). Figure 4 shows Pacific oysters grown in Japan by longline floating buoy culture. This is hanging string of mother shell with seed vertically in the water column along the longline between the buoys.

Stake culture is another off-bottom technique where seed on a mother shell is attached to the end of a cedar stake and inserted into the substrate on the beach (Figure 5).

Another stake method requires a 1/8 in. diameter galvanized wire with a plastic coffee can lid and plastic spacers in between the mother shells as shown in Figure 6. The plastic lid serves to keep the wire stake from sinking down into the mud. This culture method is used primarily in California, and tried in Grays Harbor and Willapa Bay in the state of Washington.

Rack culture uses racks that are built on the intertidal zone with poles or 2x4 wooden (cedar) studs as shown in the middle diagram of Figure 3. The mother shells with oyster seed are put on wires between spacers in most cases (braided polypropylene lines are also used). The rack is exposed during low tide, and the oysters are grown off the bottom.

Raft-culture is similar to floating longline culture. The difference is using a floating raft to hang vertical strings of oysters as opposed to a series of oyster strings along a line between floating buoys. If the oysters are hung in the water column continuously, market-sized oysters can be grown from seed in usually less than 20 months in northwest waters; beyond 20 months they may be too big. When Pacific oysters grow too fast, their shells may become brittle or fragile. In some cases, one may get around this problem by taking the strings of oysters off the raft and laying them on the intertidal zone. This will allow the oyster to be exposed to air and the shell to grow thicker and heavier to retain water for

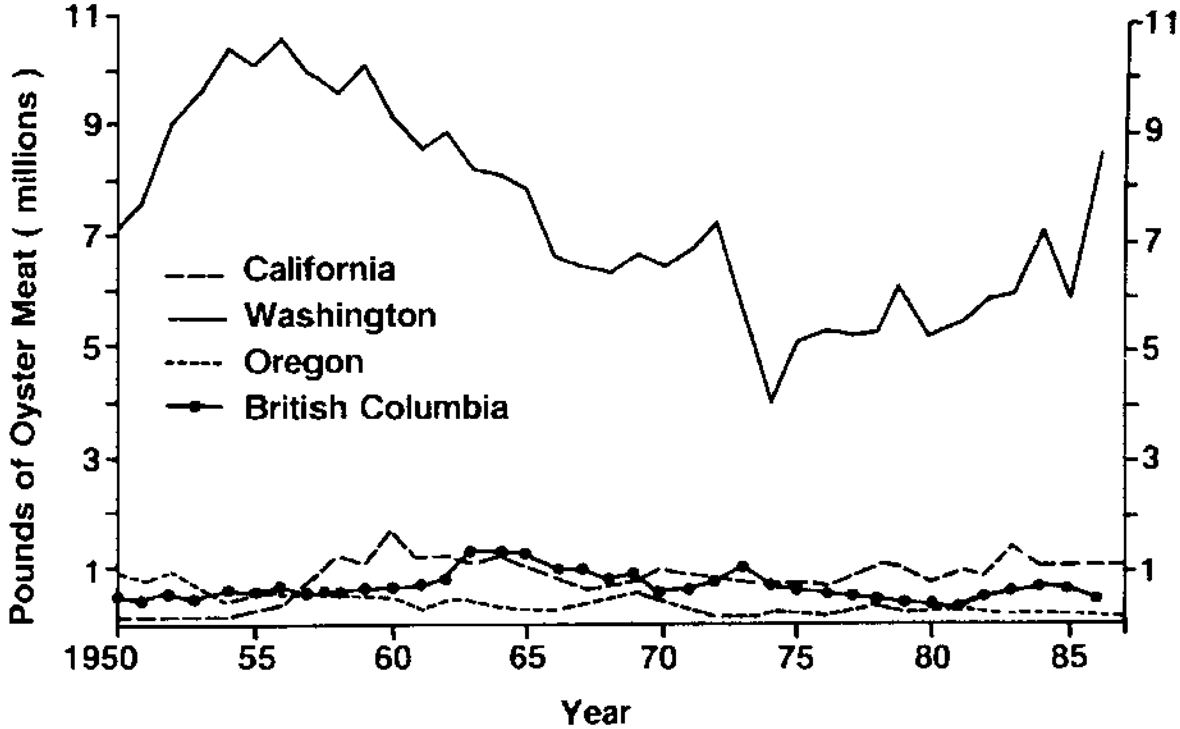

Figure 2. Production of Pacific oysters in California, Washington, Oregon, and British Columbia.

longer periods. Also, the shell is made easier to open by the shuckers.

I should mention off-bottom culture, in which the oysters are grown continuously in the water column. This is not a panacea, because of fouling problems. Figure 7 shows starfish ravaging the oysters on a line. Mussels can also attach to the strings as well as other sedentary organisms that interfere with survival and growth of oysters.

Pearl nets and *lantern nets* are hung in the water column to grow the single oyster. The pyramid shaped pearl nets are usually used to handle the younger and smaller seed to juvenile or larger (25 cm) oysters before being grown to market size in lantern nets.

Twenty-five years ago there were few restaurants in the Northwest with an oyster bar selling the raw half-shell oyster. Any of the finer restaurants now have oyster bars because of people's acceptance of eating oysters on the half shell as appetizers.

Intertidal trays are used to grow the Pacific oysters off-bottom, with regular sorting to separate the larger and faster growing oysters from the slower growing ones. The method utilized is taken from the French technique using plastic trays as shown in Figure 8. This culture method is used to grow single oysters for the raw half-shell trade.

OYSTER SEED SOURCE

It is very important to get a reliable source of seed. The original source of Pacific oyster seed came from Japan. These same stocks adapted to growth and reproduction in two locations in Washington (Willapa Bay and North Hood Canal) and one major location in British Columbia (Pendrell Sound). It is usually possible to predict when the larvae will settle, metamorphose, and attach to a substrate (cultch) material. Knowing this, the oystermen would tow the shell cultch (in nylon mesh bags) to seed catching locations and anchor to catch the natural seed. This method has been superceded to a large extent by remote seed setting of eyed larvae of Pacific oysters from the hatchery. Further information on remote setting will be provided next.

Remote Setting of Seed

Over 85 percent of the Pacific oysters grown on the West Coast come from hatcheries. The oyster hatchery at the right location and with the right water quality can

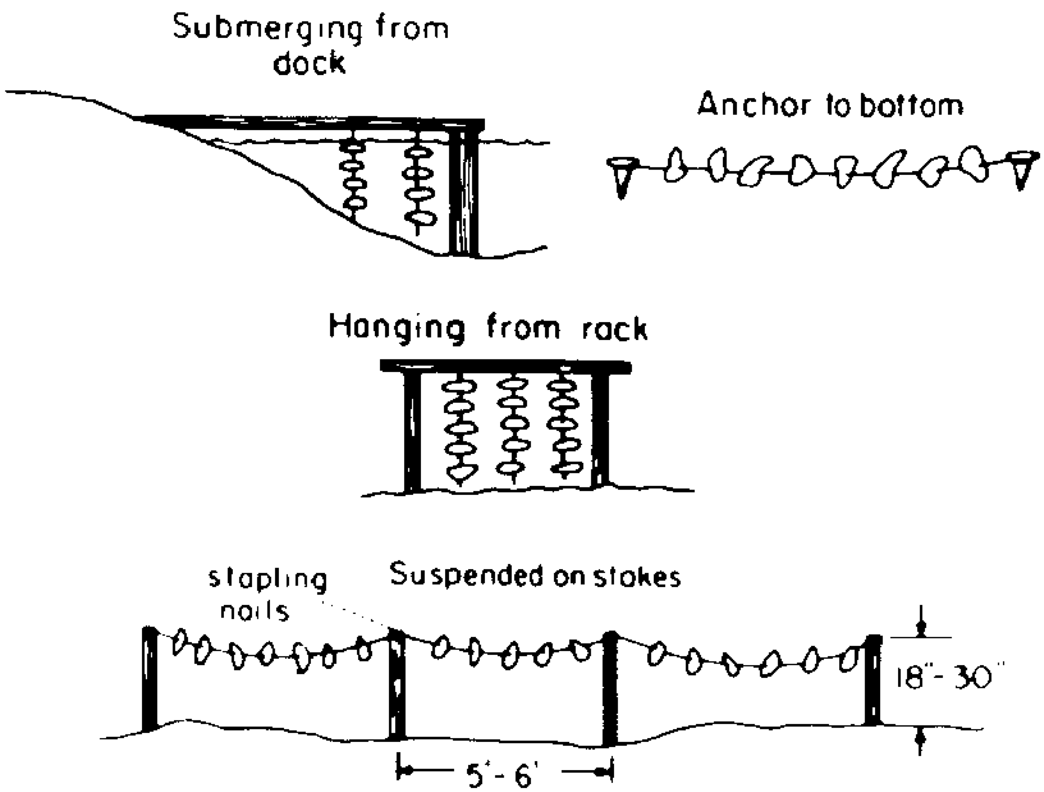

Figure 3. Off-bottom culture methods for growing Pacific oysters on mother shell. Techniques from top to bottom are: submerging from dock, anchored to bottom, hanging from rack, and suspended on stakes in a longline system. Diagrams provided by Terry Nosho.

produce oyster larvae. When the larvae have reached the eyed stage (about 280 microns in size), they are filtered from the culture tank. Seven to eight million larvae can be held in a gauze bag the size of a tennis ball. The larvae can then be shipped in a small styrofoam cooler (5 to 8 °C) to an oyster grower. In the past the hatchery has grown the larvae and sold the seed caught on the shell at the hatchery facility. This is a major expense for the hatchery and proved uneconomical when at times the seed could not be sold. With remote setting the eyed larvae is shipped to the growers to catch the oyster seed in their own tanks at the oyster farm. The element of risk is taken by the oysterman who must catch his own seed. Hatcheries such as Coast Oyster Hatchery in Quilcene, Washington and Whiskey Creek Hatchery in Oregon can economically produce all the needed eyed larvae for all oyster growers on the West Coast.

An example of cement tanks for hanging the shell cultch material for catching the eyed larvae is shown in Figure 9. Another way to catch seed is to use clean shell in nylon mesh bags. These are carefully stacked in the tank with good aeration and the water raised to the right temperature (20+ °C) before the eyed larvae are placed inside (Figure 10).

An oysterman can generally, but not always, regulate the number of seed he wants to have settle on each oyster shell in remote setting. Ten to twenty-five seeds are ideal, but higher numbers can be expected. If the average number of seed on the shell exceeds 75-100 the grower normally breaks the mother shell with seed into smaller pieces or waits until the oysters have grown a year before breaking to smaller clusters.

There were 18 oyster farmers catching their own seed via remote setting in 1983. Latest counts along the Pacific coast including British Columbia show there are over 60 farmers catching their own seed through this technique. Seed catch from Pacific oysters is no longer a problem for the West Coast.

Figure 11 shows the importation of the Pacific oyster seed from Japan into Washington State, which peaked about 1955-56. Each case is equivalent to 15,000 to 20,000 oyster seed on shell. After that the number of cases of seed dropped, and 1977 was the last year the Japanese shipped seed to us. The domestic Hood Canal catches of seed were prominent in 1964, 1969, and 1970. But it failed in 1975 and 1976, and the shellfish growers began to realize that they would need hatcheries for a consistent supply of seed. When you

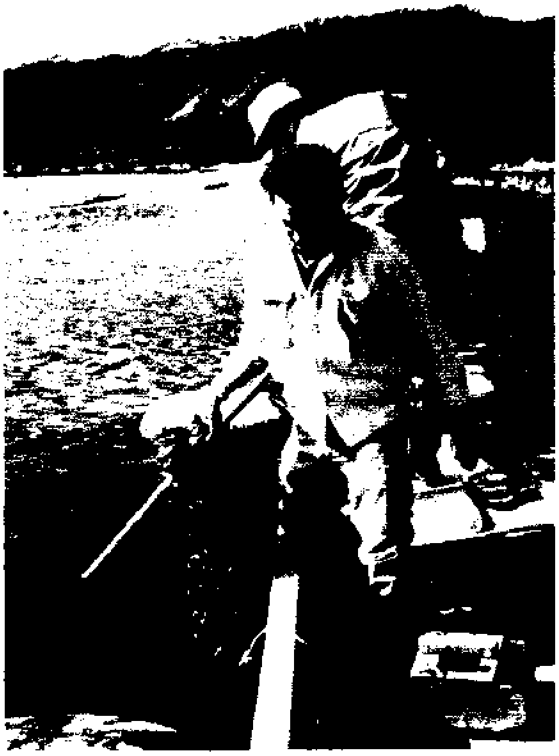

Figure 4. Pacific oysters growing on a longline floating buoy culture system in Japan. The strings of mother shell with oyster seed are hung vertically in the water column along the longline between the buoys.

are in the business to produce oysters for sales, you cannot afford to have a couple of years with no seed available.

Figure 11 also shows that 1977 and 1978 were the years when the concept of remote setting started to take hold. Remote setting has revolutionized seed production for the West Coast with an estimate of over 80,000 cases of seed now produced from this process in Washington State alone. Although not shown in Figure 11, the 1986 figure is estimated as going over 100,000 cases.

GENETIC STUDIES

We started genetic studies at the University of Washington as a result of problems related to summer Pacific oyster mortalities. Throughout the 1960s and early 1970s there were catastrophic summer mortalities in select bays in Washington and California. With U.S. National Sea Grant support we began to monitor this phenomenon and looked for the disease organism. In the course of the study, extensive histological examination of oyster tissues revealed no pathogen as causing the mortality. It was noted the Japanese had studied similar summer mass mortalities in the 1950s in some of the

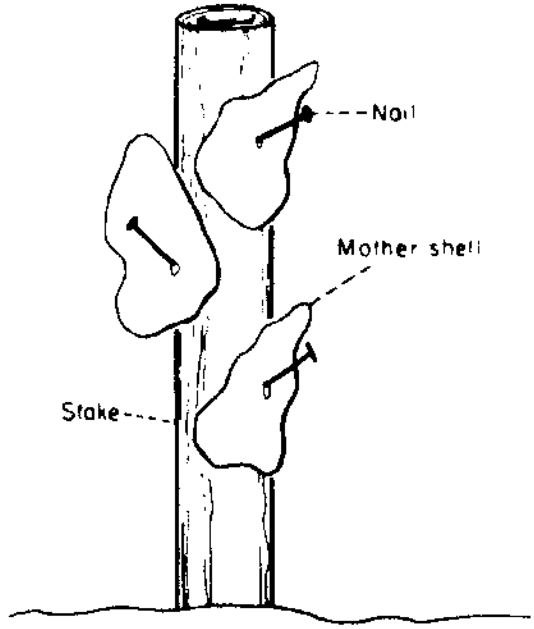

Figure 5. Stake culture method. Mother shells with seed Pacific oysters are attached to the end of the cedar stake and inserted into the substrate on the beach. Diagram provided by Terry Nosho.

Figure 6. Stake culture method using galvanized wire with a plastic coffee can lid and plastic spacers in between the mother shells.

Figure 7. Fouling problems on a string of oysters grown from a float. Note starfish which preys upon the oysters and naturally caught mussels on the string.

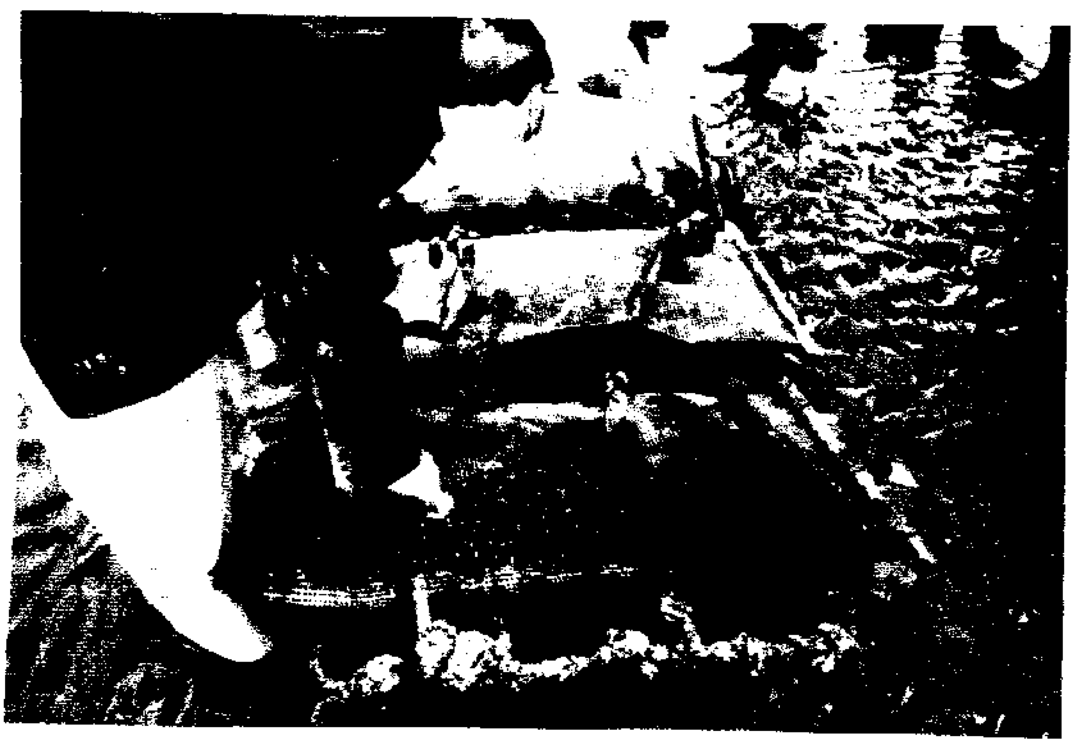

Figure 8. Intertidal tray culture of Pacific oysters in Willapa Bay, Washington. This method is taken from the French culture technique.

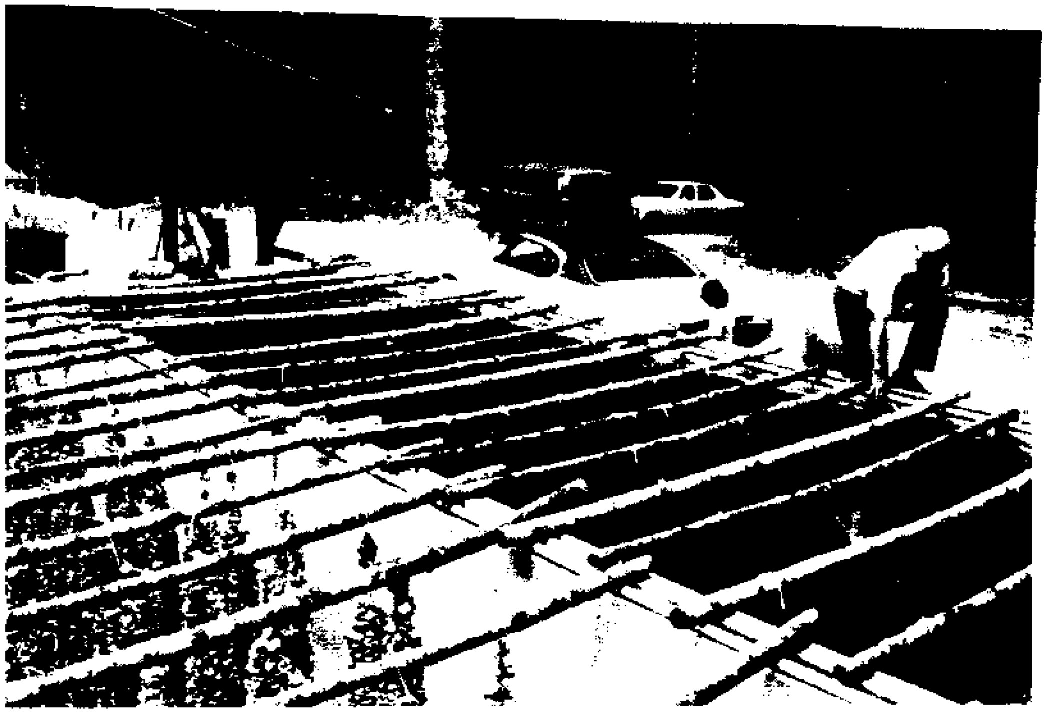

Figure 9. Cement tanks used for hanging the shell cultch material for catching the eyed Pacific oyster larvae

Figure 10. Cleaned oyster shells in nylon mesh bag placed in a tank in preparation for remote setting of eyed Pacific oyster larvae

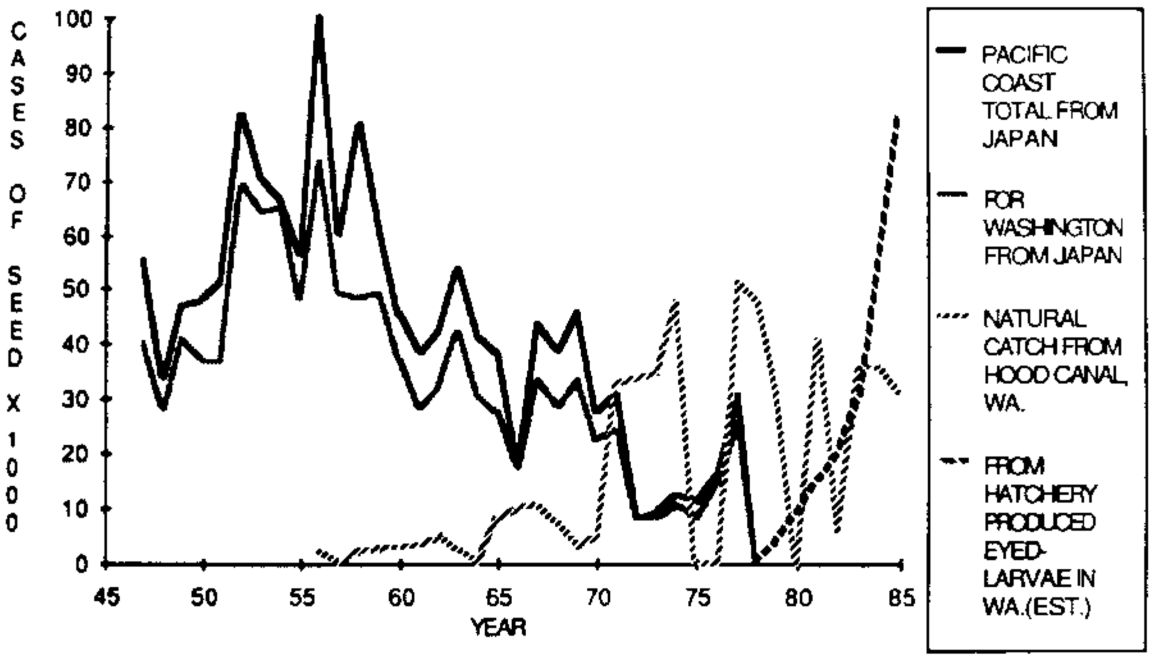

Figure 11. Total cases of Pacific seed from Japan for the Pacific coast; cases from Japan, planted in the state of Washington; equivalent cases of natural seed produced in Hood Canal, Washington; and equivalent cases using hatchery produced eyed larvae in Washington.

areas where the seed originated, but they were unable to find any disease organism either. They did mention that all the oysters that died were heavy with spawn in the warmer months, and they concluded that the problem was related to physiological stress.

We then started looking at the reproductive physiology of the animal which involved some breeding studies in the hatchery to determine if a resistant stock of oysters could be developed to this summer mortality. With further testing it was found that the oysters that survived the die-off had higher glycogen reserves; glycogen is a stored carbohydrate resource important for sustaining life. One of my students, Dr. James Perdue, was able to show that in a time of high mortality, the families of oysters with the lowest glycogen reserves are the ones most susceptible to summer mortalities.

Pacific oysters are noted for high egg and sperm production during the summer. Almost all the energy they take in is shunted toward the production of eggs and sperm, at the expense of simple living apparently. We were able to relate the glycogen cycle to the reproductive cycle and concluded the need to breed oysters that have higher glycogen reserves in mid-summer when reproduction was most active.

Success was attained in producing oysters with higher glycogen levels but, as is often the case with genetic studies, these oysters retained an undesirable trait. They had good survival rates, but they grew much slower than the regular oyster. Thus, research is continuing to produce a summer high glycogen and fast growing oyster.

In the early phase of the University of Washington mortality studies, mature oysters were brought into the laboratory during the late spring and early summer. These oysters were placed in a static water system with 20+ °C temperature water for testing. In 16-17 days, 70-80 percent mortality was realized, especially if the water received a nutrient additive (peptone, yeast, and glucose additives). The surviving adults were spawned and we raised the progeny for further testing in the field.

TRIPLOID OYSTERS

The four-season oyster, all-season oyster, or triploid oyster is being produced commercially in the Northwest. Triploid means that instead of two sets of chromosomes there are three sets. Details on how to produce the triploid oyster can be obtained from the Division of Aquaculture, School of Fisheries, University of Washington, Seattle, WA 98195.

Figure 12 shows a normal oyster and triploid oyster. The normal oyster is cream colored and full of spawn, while the triploid oyster has little spawn. During summer the normal oysters are usually milky and full of eggs or sperm. Esthetically, this is not pleasing for the market. In some cases, shipments are returned to the producer. Because of the cooler temperatures in Alaska, the Pacific oyster should not develop the heavy spawn as in the state of Washington.

Figure 12. The left is a normal diploid oyster and the right is a triploid oyster. Note that the normal diploid oyster is full of spawn while the triploid oyster has little spawn. Photo taken during the middle of the spawning season in July, by Stan Allen.

SUMMARY

There is much activity taking place on the West Coast of the United States now. The focus of attention for innovative methods related to oyster culture has swung from the East Coast to the West Coast. Much of this has been due to the open-mindedness of the oystermen on our coast and the desire to try new things. Further, a combination of disastrous events on the East Coast related to disease and pollution of oysters has created further appreciation for what is taking place with the Pacific oysters. Production levels are beginning to climb again for our coast and one should be able to anticipate the state of Alaska becoming involved in a significant way in production soon.

It might be noted that prime first class tidelands are not available for the entrepreneur who wants to get into the oyster business for the state of Washington. We have limited second and third class tidelands left and in general, some of these are still good for bottom or off-bottom cultivation of the Pacific oyster. Various techniques for off-bottom cultivation have been discussed and some of these techniques could be applied in the state of Alaska.

One of the problems we have in Washington is the permitting system. In Alaska you have permit problems too, but I would venture a guess that it is not as excruciating as down in Washington, Oregon, or California. Almost all bays in the state of Washington have people living along the shoreline and there is a reluctance by many of these inhabitants to accept floating structures in front of their property in the bay. Education is the key to indicate to them that certain types of aquaculture operations are compatible.

In Washington we are having some problems with decertification of shellfish beds because of pollution. Several bays that have been producing oysters in the past were taken out of production because of pollution. Your problems in this area may not be as great yet, but this is something that needs to be carefully looked at before it happens.

Perhaps the most important point I can make as part of my summary is that the Alaska oyster fishery needs a hatchery system, whether it is private or state operated. The hatcheries are here to stay. I have heard several people tell me they could not get Pacific oyster seed to grow in Alaska. This scarcity of seed apparently relates to only one source from the state of Washington which is allowed to come in. Every effort should be made to either clear other hatcheries in Oregon or Washington to ship seed up to Alaska or build your own hatchery system to produce the eyed larvae for remote setting.

Finally, I have given an abbreviated picture on some of the various techniques for culture and research work that we have been involved with at the University of Washington. Our studies are for the most part related to the development of genetic strains for better growth and survival traits, as well as triploid oysters. I hope these comments are worthwhile for you, and if you have

any questions concerning any aspect of what I have said, I would welcome a letter from you.

COMMENTS ON WEST COAST REGIONAL AQUACULTURE CENTER

As Brian Paust mentioned, the concept of regional aquaculture centers in the United States originated with the Department of Agriculture, under the U.S. Farm Bill. Regional centers are to be established to promote research, development, and demonstration projects. The five centers have now been established, and one is located on the West Coast under the name of Western Regional Aquaculture Consortium (WRAC). The Administrative Center for WRAC, of which I am director, is located at the University of Washington School of Fisheries.

Presently the five institutions involved in WRAC are the University of Alaska, the University of Idaho, Oregon State University, University of California at Davis, and the University of Washington. Institutions from other western states will participate in the near future.

One of the requirements for WRAC is that all funded research and extension projects must be regional and cooperative between states. As an example, we are going to be funding an IHN project, which is a serious virus disease in the salmonid culture fisheries, and it will involve Alaska, Oregon, Washington, and Idaho researchers.

One method of developing a budget for this type of project is the use of subcontracting. The funds from the Department of Agriculture for each of the regional centers goes to one institution in their region, such as the WRAC Administrative Center at the University of Washington. The University of Washington then has the fiscal responsibility of contracting out to the units that are handling the specific projects in other states.

We look at WRAC as a permanent entity. We are starting out with $3.5 million for all five centers this fiscal year, and we hope that in the years to come, the funding will increase.

For you Alaskans, Dr. Ole Mathisen of the University of Alaska in Juneau is the person to contact if you are interested in information on any of the WRAC research projects. He is on the WRAC Board of Directors.

COMMENTS ON SCALLOP CULTURE

There are a lot of decisions being made now concerning Alaskan scallop operations. These decisions are going to help you a great deal in implementing some type of culture in the future.

One thing that I want to make you aware of is that if we get scallop culture going, the eating habits of the people of North America are going to have to change. Right now most of us consider eating only the scallop muscle. But those who are investigating the project realize that unless we condition the people of North America to eat the whole scallop rather than just the muscle, it's going to be kind of tough, economically speaking.

In China, scallops are eaten whole. I have just returned from there, where I reviewed the progress of one of the Chinese fisheries programs. In 1982 I helped make arrangements to ship about 150 bay scallops from Virginia to the Institute of Oceanography, Academia Sinica in China. These East Coast scallops normally grow close to shore, to about 3 inches, and their life cycle takes about 18 months. All of the first 150 died, so I arranged to have another 150 shipped. The second batch were smaller scallops from Connecticut, and 22 survived.

During my visit this past summer the Chinese made a point of showing me what they had done with the surviving scallops—a very impressive operation involving an extensive longline culture system. They estimated that they were going to produce between 6,000 and 7,000 tons of bay scallops in 1987, all from those original 22 bay scallops.

I am well aware of the fact that introducing exotic species can lead to lots of problems. Canadians and Alaskans might want to think about this more carefully and weigh the prospects for safe introduction against potential economic benefits. Alaskans wouldn't be able to use all of the Chinese culture methods because of regulations in Alaska, but the Chinese do have a successful operation and much can be learned from them.

OVERVIEW OF AN OPERATING OYSTER HATCHERY

Jim Donaldson
Coast Oyster Company
Quilcene, Washington

INTRODUCTION

I'm going to concentrate primarily on what's happening inside the hatchery at the Coast Oyster Company. We've been around the block a few times, starting in the early 1940s, so we're a well-established oyster company. In fact, we have the largest hatchery in the world. We have four remote setting sites: Quilcene; Willapa Bay; southern Puget Sound; and Humboldt Bay, California.

Our production, combined with one other hatchery in Oregon, supplies 70 to 80 percent of all the oyster needs on the West Coast, from California to British Columbia.

Coast Oyster Company has approximately 20,000 acres of primarily intertidal oyster ground. Most of that is owned, and some is leased (by subtidal lease) from the Department of Natural Resources. We use only 2,500 to 3,000 acres of that, or 15 percent, to cultivate and propagate our oysters. A lot of that ground could be brought into production by using alternative methods, but a good part of it is held for buffer.

The hatchery system started in 1974 to supply Pacific oyster seed on a regular basis. At the time we weren't thinking about triploids, other species of oysters, or clams. We started the hatchery at Willapa Bay, Washington. Willapa Bay is the main growing area on the West Coast; approximately half the oysters on the West Coast are grown there. An old cannery building located there was handy to most of our growing grounds. This was converted easily into our first hatchery building.

We operated there for about four years and didn't make a very good go of it. The first couple of years we had virtually no production. The next couple of years we did have some production, but it wasn't at the rate we needed. Willapa Bay is very productive for algae, which is not good for a hatchery. What is best for a hatchery system is a very low productivity area, without much algae bloom. In a high productivity area the situation can be uncontrolled and unstable, which often results in poor larvae performance.

SPECIES CULTURED

We've worked with many species over the years. The Kumamoto oyster is one of our primary oysters. It was brought in from southern Japan in the 1970s. We started working with a few hundred individuals and this year we produced over a billion eyed larvae. It is now one of our primary species.

We also have crossbred the Kumamoto oyster, which is subtropical, with the Pacific oyster. We wanted to produce an individual with the summer oyster qualities of the tropical oyster, to grow in the Northwest. In other words, it would be fat and it wouldn't be soft. But the resulting hybrid has a tremendous array of sizes, and the product is not uniform enough to be marketable.

We also grow European flat oysters commercially. We imported them from Maine, and they were originally from a stock grown in France.

We have produced Olympia oysters at the hatchery in the past, but we found that we can't make money on them. People will buy shucked Olympia oysters for $250 a gallon, which is too little for a profit for us.

We've grown Manila clams in a fairly sizable quantity. Over the years we found an abundance of clams associated with our oyster beds, so we began harvesting them. We are now looking at replenishing those supplies which have been harvested and depleted. This last year we planted approximately 10 million seed clams. We have worked with several other clams, including quahogs, geoducks, native littlenecks, and rock scallops. But for various reasons their production has been discontinued.

Most recently, we've gone to Pacific oyster triploids and Kumamoto triploids, which right now form the basis for our production. We have invested over a quarter of a million dollars in the triploid research program to produce the Pacific triploid oyster. We've produced triploids for about four years. The first two years we had virtually no production; high mortality rates of the larvae were common and the percentage of triploids was extremely low.

Last year we made tremendous improvements. We were able to produce almost 3 billion triploids, with most groups over 70 percent triploid. For Pacific oysters, normal spawning in a hatchery results in about 75 percent survival of the larvae to 24 hours. With our triploids, the first couple of years we had from 0 to 5 percent. Last year we were in the 15 to 20 percent range for survival to 24 hours, and we expect our percentages of triploids to go higher as we refine our techniques.

We limit ourselves to four or five products. As a commercial operation we don't find it profitable to raise many different kinds of animals. The Pacific oyster, *Crassostrea gigas*, has formed the basis of our produc-

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tion over the years and it will continue to do so in the future.

HATCHERY DEVELOPMENT

In 1978, we moved the hatchery from Willapa Bay up to Quilcene. At that point there was a dramatic improvement in our operation. Quilcene Bay supports the slow growth of oysters, to market size. However, it has a naturally reproducing wild population of Pacific oysters. Even though the water is very warm (up to 20° to 22°C in summer), it is not very rich. There is not much nutrient input and it is a very deep body of water; this makes it ideal for a hatchery. When the hatchery was started there in 1978 it was very small, with two tanks. We then expanded dramatically for several years, sometimes with a 25 to 50 tank expansion in a year. We had a couple of billion larvae the first year, and we're now up to an annual production of 21 billion larvae total. The majority of that is oysters.

One of the reasons that we set up the hatchery was the inconsistent supply of oyster larvae. We had a good supply of seed back in the 1950s and 1960s, with most of this from Japan. Then it declined because the Japanese started shipping seed to France and prices in the U.S. began to rise. We began getting seed from Dabob Bay in Washington and Pendrell Sound in British Columbia, but this was inconsistent. The supply from all sources was declining, and the cost was going up. Only in a good year could we get an ample supply of seed. A small oyster company, under 200 acres, can spread a small supply of seed out over a couple of years. They put it into a high intertidal area, grow it very slowly, and then plant it the next year. But with a large oyster company that method will not work.

West Coast hatchery production has gone up dramatically, especially this last year. Again, only two hatcheries are involved. In 1986 we produced 12 billion larvae and the other hatchery produced 4 to 5 billion, for a total of 17 billion. This year we're at 21 billion and the other hatchery is 5 billion; within the last year we've gone almost entirely to remote setting of larvae as a seed supply. We've gone from 17 billion up to 26 billion in the past year. In the next three or four years there will be an increase in production of harvestable oysters in our company and in a lot of other companies.

FACILITIES

Quilcene Bay is on the west side of Puget Sound and has a depth of about 500 feet, which is very deep. Quilcene and Dabob bays are very productive natural oyster reproducing areas; most of the natural oyster catch in the state occurs there every year. There is a fairly good set in the bay, but most people don't go after the natural catch any more because it is less expensive to buy eyed larvae from hatcheries than to put shells out for the natural catch.

Our hatchery facility is at the shallow end of the bay. We have 33 tanks outside the hatchery that are 10 feet in diameter and 4 feet deep. They serve as brood stock tanks as well as setting tanks.

We have a research laboratory adjacent to the hatchery production facility. We do research there on a small scale, and as soon as we find something that works we immediately apply it to the large hatchery. We try to move that research into production as quickly as possible.

GROWING ALGAE

We have a greenhouse where we grow our algae. We had a lot to learn about algae when we were first setting up the hatchery at the Willapa Bay site. No one knew much about growing algae in 1974. We started with a rapid-growth system that requires maximum light penetration into the algae cultures. For this we use translucent fiberglass tanks, with 1/16-inch walls. The system requires carbon dioxide, a water filter, and added nutrients. It only takes a couple of days to grow a 700-liter cylinder of algae. That small amount is adequate for a laboratory.

To increase the volume, different methods of lighting and water treatment are required. First we tried fluorescent lights contained within a plastic sheath, and this was fairly good for growing algae rapidly. To increase the growth rate even more, we put wall-to-wall fluorescent lights above the tanks. But we found that we could fill the tanks only half way in order to get proper light penetration down in them. After trying a lot of different systems, we found that the best was the high-intensity discharge metal halide lamp suspended over an open tank. We first tried it outside, because the hatchery wasn't large enough to add a scaled-up algae system at the time. The natural sunlight combined with the metal halide lamps worked very well. We could grow lots of algae out there. But we had a problem with low temperatures and insects in the tanks. So we covered the system with a greenhouse. Now we are using 4,000-liter tanks, each with one lamp, as intermediate growing vessels, and 18,000-liter tanks fitted with three lamps each for final algae growout.

We pour a carboy of algae into a 4,000-liter tank and it grows up to maximum density in about two days, to a very dark, root beer color. Then it is transferred into the 1,000-liter algae tanks. We introduce a 1-liter flask of algae into our system and in eight days that liter of algae gives us 10,000 gallons of algae ready to feed.

Most of that algae is pumped over into our oyster growing systems. Some goes into the larvae system, some goes into the brood stock, and most of it goes into our seed. All of those systems are monitored for growth rate and health to make sure that we are introducing sufficient quantities of algae.

Recently, we've found that we can concentrate the algae down until it's a heavy paste the consistency of toothpaste. With a centrifuge we can concentrate 5,000 gallons of algae down to 1 quart that can be stored in the refrigerator. Then we feed it into our tanks on demand. It stays alive in our refrigerator for a couple of days, and is good for feeding for at least a couple of weeks. We are working with some preservatives now that could extend the shelf life for several months. Now we can ship eyed larvae to different areas of the world and provide the concentrated algae to feed them.

If we sell someone 10 million oysters, we supply them with the equivalent of a 5,000-gallon tank full of algae. Feed cost will be about $100. That will keep the oysters alive for four or five days. It will get the oysters set and grown up, and then the grower can put the seed out in the bay and have very good survival.

GROWING LARVAE

Inside the hatchery we have 39 tanks for growing larvae. Most of these tanks are 10 feet high and 14 feet across. We grow larvae in all of these, and the larvae are all in different stages of development from egg stage to setting size. For Pacific oysters it takes 20 to 21 days to reach setting size. In one of these tanks we grow from 50 to 100 million oyster larvae.

In order to grade the larvae, we first siphon them out of the tank. Working with about 50 million larvae at a time, we run them through a series of screens and separate them into three or four groups. We often grade several tanks at a time, and we end up with groups of larvae that are fairly narrow in size range. Grading improves growth rate.

Screening also allows us to eliminate the smaller, slower-growing oysters, and to save the fastest growing ones. If we want to do any genetic work on them and screen out the 5 or 10 percent fast growers, then we can isolate those in separate groups.

SHIPPING LARVAE

Aqua Foods in British Columbia called us last summer and requested bundles of about 3.25 million larvae, and we were able to send them exactly what they wanted. We also send whatever algae supplies people request. And we're consultants too; if somebody calls up and says, "We want larvae, but what do we do with them?" We help them out with that. We give them the algae and divide the larvae into whatever quantities they want, to match their tank size, etc.

The larvae bundles can be shipped anywhere in the world, as long as they are kept in moist paper towels, and kept at 50°F in a cooler. They should not be kept too cool, and if they are kept too warm they will spoil. Normally we package a shipment of larvae in a small styrofoam ice chest and put some blue ice in it. It can be shipped anywhere, as long as it reaches its destination within 48 hours. Last year we made several shipments to Japan and Korea in this form, and they had good luck setting the larvae there.

SETTING SYSTEM

Once the larvae are received they are ready to set. They have been screened and graded; oysters that are ready to set have been separated from the ones that aren't. When we screen 50 million larvae, we might get 5 or 10 million that are actually ready, and the others are a day or two away. These can be placed back in the rearing system to be drained and regraded another day.

We put the setting size larvae in an aerated tank with shells, and by the next morning there will be lots of seed there attached to the shells. If they're good larvae, they should set within 12 hours in the summer season. If the larvae take two or three days to set, then they are not ready and should have been back in the larvae tank. We like to set about 50 oysters per shell.

Setting Enhancers

We use some tricks when we're setting. We use setting enhancers, such as L-dopa and epinephrine. L-dopa is a neurotransmitter used to treat Parkinson's disease, but oyster larvae also like it. It triggers their searching behavior. When larvae have eye spots, they are ready to settle down to the substrate. Each larva has a foot at that time, and it begins to crawl when it settles. L-dopa stimulates the crawling behavior. We use L-dopa for all of our setting, and we have done this for a couple of years.

Another drug that can be used is epinephrine, which is a synthetic adrenalin. Epinephrine eliminates the searching behavior, and causes the oyster larvae to secrete cement and go into metamorphosis. The result is single, unattached oysters. We normally use epinephrine for clams, which do not produce permanent type cement as oysters do. We get a high percent metamorphosis in clams when we use epinephrine.

Normally we grow the larvae for two or three days after setting during the summer months, and longer during cooler times of the year. Our system is set up with heaters and aeration. We keep the larvae warm and feed them algae during that time, before we put them out into the bay.

The bags of shells are then taken out of the tanks with cranes and tractors. They are put onto a float system and towed out into the bay where they are kept in a nursery system. We can unload a tank and load the floats up on a tide without any problem, and when the tide comes in we tow the system out.

Our system uses all creosoted logs. They were built about ten years ago and so far we haven't had any problems with them. There hasn't been any rot. We've replaced the styrofoam around the edges, but that's about all.

SINGLE OYSTERS AND CLAMS

The other method I mentioned is to set single oysters or single clams. We treat the larvae with epinephrine and set them in a system with seawater flowing up from the bottom of the tank. We have about an inch of water over the substrate, which forces the oyster larvae or clams down to the substrate. For clams we use clean washed sand for the substrate, and for oysters we use ground oyster shell. The ground up oyster shell is graded so that the shell particles are the same size as the oyster larvae, about 300 microns. An individual oyster will attach to a piece of ground up shell. After it is grown out, the shells that are not set are screened out and we end up with individual oysters.

The individual oysters or clams can be grown on a tray for a month, but normally they're put into the upwell system. In the upwell system we concentrate the seed. We siphon or pump water out of the tank. The water flows through the bottom of the screen on its way out of the tank. The screen will then be 3 or 4 inches deep with solid seed, several thousand to several hundred thousand individual oyster or clam seed. This is a very popular system in many hatcheries all over the world.

The seed is grown up to about 4 or 5 millimeters, and then it is put into a screen or tray to continue to grow. The seed does not do very well beyond about 5 millimeters in an upwell system.

French Pipes

An alternative system that we use for single oysters is to set them on French pipes. These ½-inch PVC pipes have about 30 small longitudinal striations or grooves. When the oysters set, first they come in contact with the pipe and then they crawl along a groove and attach themselves. We try to get about 1,000 seed oysters attached to each 1-meter pipe.

We treat the plastic pipe before exposing it to the oysters. Most plastic needs to be aged for six months before it is used in any kind of system. It needs to be leached. It should sit in salt water for at least two weeks, and during that time algae and bacteria build up on the surface. This way a more natural environment is created, which the larvae respond to positively.

After the pipes are set and have grown to about ¼ inch in the nursery, we break the bundles apart and grow them up on racks. Each pipe is laid horizontally across ropes and strapped to them, about a foot off the bottom. We get very good survival and very good growth rate that way. French pipes can also be grown suspended below a floating raft.

Before the oysters are marketed, they are stripped off the pipes. They can be stripped off very easily when they are about 3 inches long. They are put on the bottom and held there for about six months, and then they are marketed.

French Bags

The methods that we're using experimentally, and that many others in Washington have gone to recently, is the French method of growing single oysters in bags. Normal production is 100 oysters in each 2 x 3 foot bag. We start out with about 800 oysters that are 5 to 6 millimeters. They should be thinned three times. The final thinning is done when they are about 2 to 2½ years old yielding 100 oysters per bag.

Plastic Strips

Another system that is commonly used is similar to the pipe, but is a flat piece of plastic that has grooves in it. This may be a much better system to grow single oysters than the pipe system. Because of its flexibility, when the oysters are about ¼ inch we can twist it and run a knife from one end to the other. One strip can yield about 1,000 oyster seed.

SHELL STOCK PRODUCTION

Longline

Coast has recently begun using the longline method. We put the bare shells on the rope before we put any seed on them. Then 100 feet of rope that has an oyster shell every 6 inches is put into a bag. That bag is put into our setting systems. We get a higher percent set when we space the shells on the rope than when we just put the shells in the bag. With a longline system, the advantage is more than the high growth rate and the quality of the product; the oysters are kept away from predators. These roped seed shells can be grown suspended from a raft or from string between poles on a beach.

We have oyster drill problems in Quilcene Bay and in many of the bays in Washington. Oysters that grow on the bottom have a very high mortality rate from oyster drills. Also, crabs get to them on the bottom. Crabs and oyster drills are probably the two main predators of oysters in Washington. We find that when we get them up off the bottom, we have a much higher survival rate. For one shell with 50 oysters, normally we get 50 to 75 percent survival. Our survival rate is so high that we are decreasing the number that we put on each shell.

Quilcene Bay is not a productive growout area. Normally it takes 4 to 5 years to grow an oyster in Quilcene Bay. If we put these same oyster longlines into Humboldt Bay, we can do the same thing in about 18 months. Its disadvantage is the amount of labor involved in farming.

Stake Culture

Stake culture results in very high survival rate, with a good quality, very good flavor oyster. And it is essentially free of predators.

Traditional Oyster Beds

Of course, the traditional way of growing oysters is on an oyster bed. As Dr. Chew mentioned, 90 percent of the oysters that are grown in Washington are grown by this method. But many of the other methods allow us to control the number of oysters on different types of substrates. We can produce single oysters with a hatchery. We can produce oysters that we could not produce otherwise, such as Kumamotos and triploids. The traditional method is going to continue, but we think that by growing on longlines, or by using the French bag method, we can make one or two acres of oyster-growing plots two to three times more productive, and produce a high quality product as well.

CONCLUSION

There are innovations that have occurred in hatchery systems in the last couple of years. Remote setting has been established over a 10 to 15 year period, and it is a very reliable method. Anyone can purchase eyed larvae from a hatchery and have very good success.

A more recent innovation is the availability of algae concentrate. Now growers don't have to raise their own algae. And there are now setting enhancers to improve the setting.

And in the last year or two triploids have become available. We've reached the point now where we're not experimenting with triploids any more; we're doing it commercially. Next year triploid production will be 20 to 25 percent of our overall production. This year it was 10 to 15 percent. We will gather more information about triploids as they begin to be harvested this year. Our expectation at this time is for a gradually increasing percentage of our production over the next several years. The next major endeavor in commercial shellfish research probably will be genetic engineering. Perhaps within a few years we will catch up to the state of the art techniques in agriculture and livestock breeding.

OYSTER AQUACULTURE IN ALASKA

Don Nicholson
Canoe Lagoon Oyster Co.
Coffman Cove, Alaska

I represent a rare and endangered species—the Alaska oyster farmers. I believe my experiences with growing oysters in Southeast Alaska are of value to potential farmers, so I am relating some of them here. Specifics about site selection, types of gear available, etc., are listed in the *Alaska Oyster Grower's Manual*, which is available from the Alaska Department of Commerce and Economic Development in Juneau.

HISTORY

Oyster farming in Alaska began in the early 1940s, but the harsh environmental conditions prevented immediate success. In the early 1970s, because of new technology, some people in Wrangell had a wild idea that they might be successful at growing oysters in Alaska. The movement was spearheaded by Robin Larsson. He started the legalization process for importing the spat and culturing oysters in Alaska, and it took him six years. Now, thanks to his efforts, a permit can be obtained in six months.

SITE SELECTION

When I first looked at my site, I was faced with the most critical decisions of the entire process of starting an oyster farm. Unfortunately, these decisions came at a time when I had the least amount of knowledge and experience. As I considered the different variables, I saw that the permit procedures required serious investigation. I learned about paralytic shellfish poisoning, or PSP, and found out about the agencies involved in securing an oyster lease. It is important that the farmer has navigable waters or anchorages, examines competing uses such as log storage or recreation, and finds out about upland owners. It would be unfortunate to start building a house and then have to leave because someone from another state owns the property.

I also looked at the biological and physical aspects I wanted in a site. The site should satisfy the requirements for the oyster, such as supplying the necessary nutrients. The physical location and the special features about a site dictate what the biology is going to be and how that will affect the oysters. Therefore the biological and physical aspects cannot be separated.

I needed several supporting physical characteristics, based on the type of culture I was going to use: suitable beaches for building trays and drying structures, a site for a home and storage buildings, access to logs, and access to supplies and markets. After considering all these details for about a year, I chose a site and began to find out how to grow oysters.

CULTURING OYSTERS

The nurturing of oysters is called culturing. That involves buying the seed and growing them to market size. The successful culturing of oysters is a balance among the site, the selection of gear, and the operator. The site provides the basic needs of the oyster. The gear provides an artificial habitat. The farmer is the conductor and orchestrates how all these things work together to create a balance.

As I looked into kinds of gear and methods I wanted to use to grow oysters, the goal I had in mind was to maximize the growth rate of the oysters. I found this to be very important, because the longer it takes the oysters to mature to selling size, the more it costs.

We start with a large spat size, between 14 and 20 millimeters (20 millimeters is the legal size allowed in Alaska). This reduces the handling time and mortality at this stage in the oyster's life, which is very important. We try to time our plantings early in the spring and later in the summer, in order to miss the spawning cycle of most of the fouling organisms.

The nursery gear we use for these plantings are 2 x 2 foot stacking trays that are 3 inches deep, and we stack the trays six deep in the water column (Figure 1). Each tray is stocked to a density of about 600 oysters, which is 3,600 per stack. In three to four weeks up to six weeks, depending on the temperature of the water, the oysters are thinned to about 400 per tray.

After four to six weeks or a total of eight to ten weeks from planting the oysters, which are about 1½ inches in diameter, are sorted into clean surface trays. Our trays are ¾ inch vexar attached between two logs for flotation (Figure 2). This is a crude method of growing oysters on the surface of the water. The animals at this point have a density of approximately 3,000 per 20 lineal feet of tray space. Using these figures, it's easy to figure how many trays are needed for a certain number of oysters. From this point on, during the growout, our job is to keep the trays clean and flushed to allow the oysters the cleanest environment possible. Figure 3 shows one of our early experiment with a growout technique.

For our surface trays we use two logs, which cost

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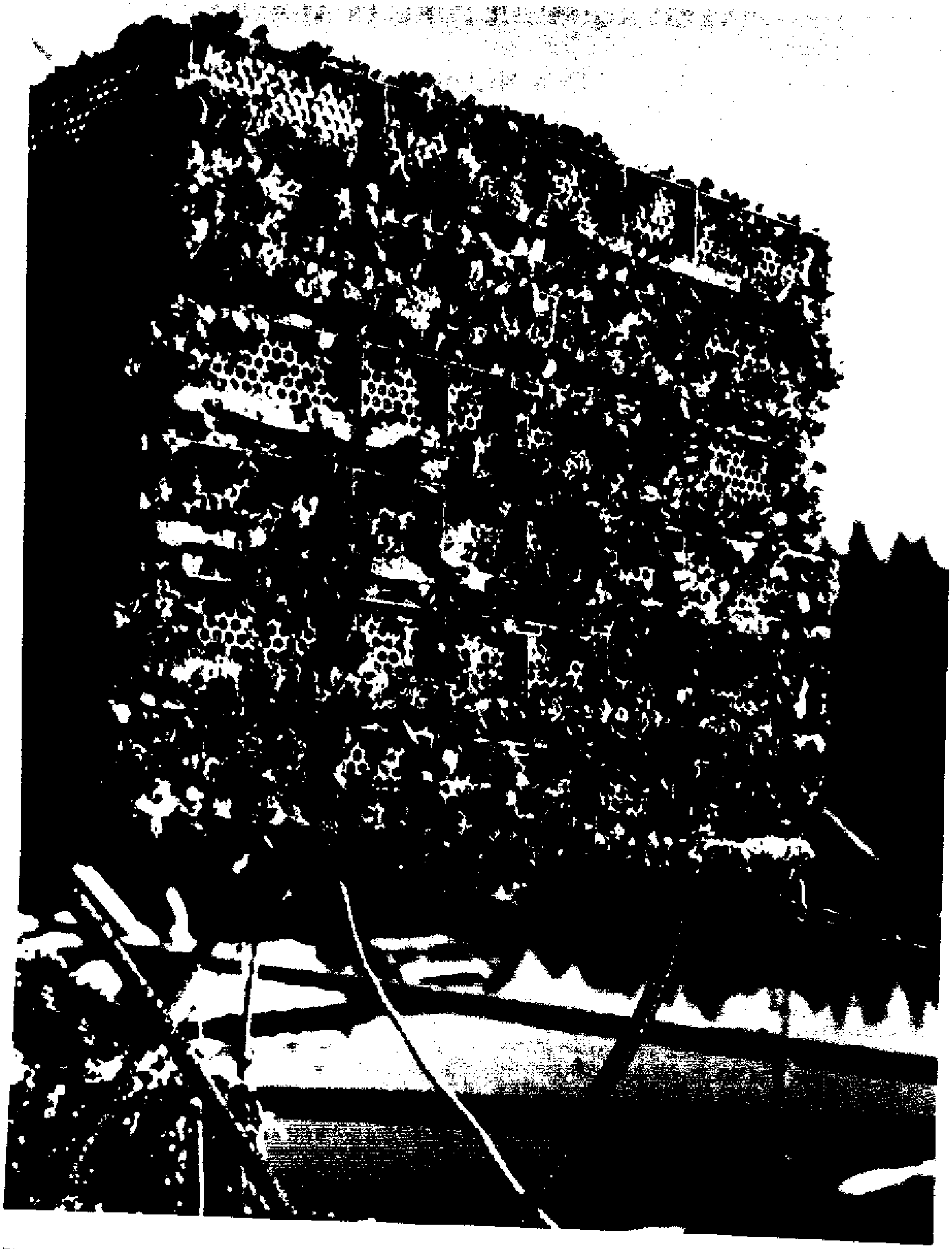

Figure 1. Stacking nursery trays for oysters in Southeast Alaska, with fouling—the accumulation of intertidal and subtidal organisms. Photo by John Church.

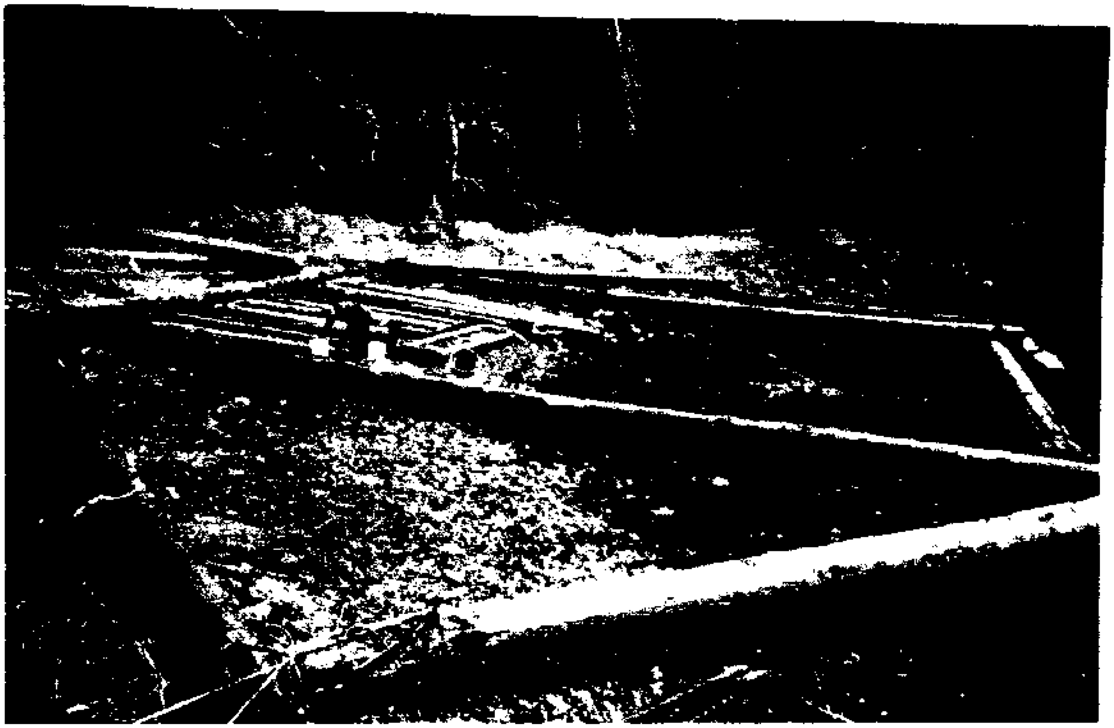

Figure 2. Beached surface trays for oysters in Southeast Alaska. The boom sticks provide protection from wave action when the trays are in the water. Beaching periodically is a way of controlling fouling. Photo by John Church.

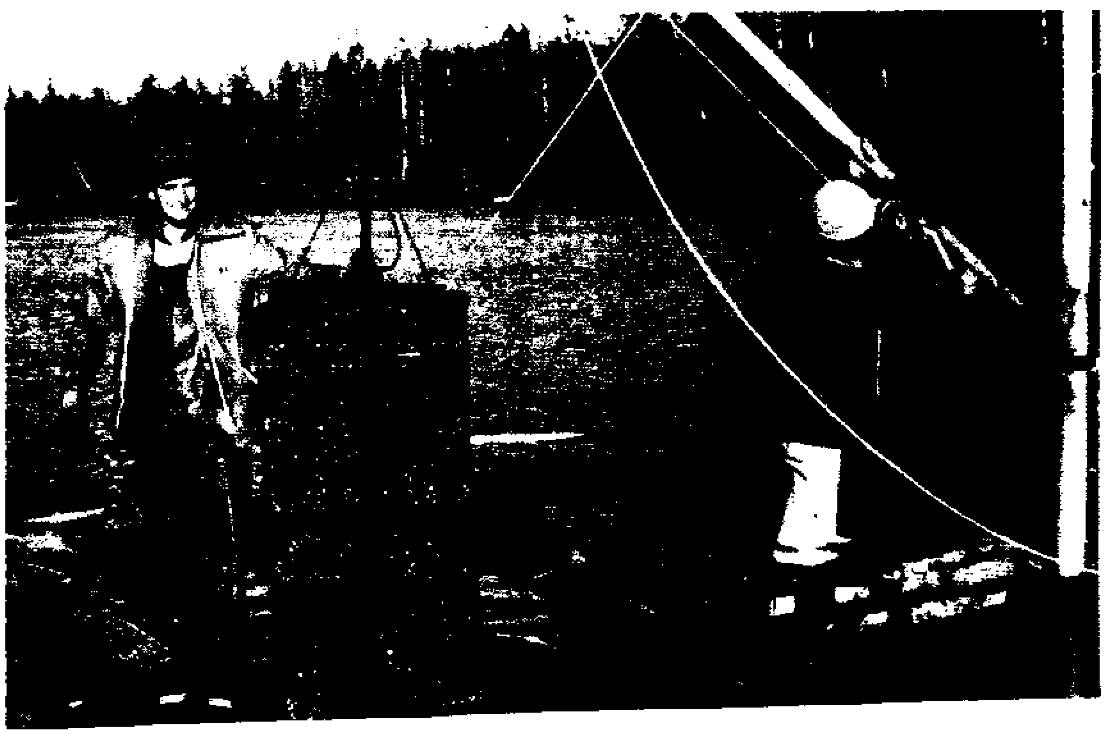

Figure 3. Experimenting with growout systems in Southeast Alaska. Photo by John Church

virtually nothing. The oysters are close to the surface where most of the nutrients and the food is available throughout the year. With the surface trays the oysters will grow 12 months a year, except during extreme cold spells. Slow growth in the winter, a problem in other areas, seems to be counteracted by these surface trays.

It takes about eight months from the time of the last thinning to grow the first harvestable product. When the oysters have been in the water 12 to 18 months, we can harvest about 20 to 30 percent of the oysters in each tray (Figure 4). During harvesting, the fouling is removed, misshapen oysters are sorted out, and those that are too small are cleaned and placed into a clean surface tray for further growth. Oysters all grow at different rates, just like any other animal, and we find that by removing the largest oysters, we make more room and more food available for their smaller brothers and sisters. This helps them to grow as quickly as possible.

FOULING

Fouling control is a key process in the successful cultivation of oysters. Here in Alaska our waters are fairly pristine, which means that we have a very large array of intertidal and subtidal organisms that attach to gear and oysters (Figure 5). The control of this fouling consumes 40 percent of the total energy and time required to grow oysters to market size. If fouling is not controlled, growth rates decrease.

Fouling will cause deformation of the shell. We are growing primarily half-shell oysters for our market and the shape is important to the consumer. As the fouling increases, the oysters compete for the food supply; the fouling can actually kill the oysters by suffocation. Fouling will reduce water circulation and will cause destruction of logs and other floating gear.

To control fouling, we have learned to beach gear at some time during the growing season, such as before spring or after summer (see Figure 2). We also have surplus gear on hand if we need it to help control fouling. Another method of control of fouling is that we pick the barnacles and mussels and the other types of subtidal fouling off the oysters every time we handle them. I can't stress enough the importance of controlling the fouling. We've found that as long as the fouling is removed before the fouling organisms reach sexual maturity, we can keep some control over it.

HARVESTING

The oysters that are planted in April or May have the fastest growth. By the following April or May after their second successive growing season, we begin to harvest the first oysters in that crop. These oysters weigh about 2 pounds per dozen; they are fat, healthy oysters.

PREPARING OYSTERS FOR MARKET

Before a farmer can sell oysters, a shellfish processor's permit must be obtained from the Department of Environmental Conservation.

The next step is to prepare the oysters for market. This consists of hardening them, which is to strengthen the adductor muscles to keep the shell closed. To accomplish this, we place the oysters within the intertidal zone. This procedure increases the shelf life.

Before any oyster can be sold in Alaska, testing for PSP is required. Before PSP testing we remove a batch of oysters from the water. In order to keep the oysters cool, or to keep them from freezing, we store them in a refrigerator. We shuck six 100-gram samples of oyster meat and then send them to the testing lab in Palmer, Alaska, for PSP testing. This procedure takes a minimum of three days if everything goes right—if the float planes fly and the jets make it through to their destination.

Once the meat is tested and found to have less than 60 micrograms of poison per 100-gram sample, then the lot is released for sale. The lot is the batch of oysters that has been removed from the water. At that point, we box the oysters, label them, and send them on their way.

Right now it costs us about 35 cents per oyster to produce and market. That is a very high figure. The cost is high because we still have many logistics and problems to work out. We haven't started producing on a scale yet that will allow that price to come down, but we are selling them for 50 cents apiece right now, which does help overcome those costs.

So far our customers are very pleased with our product. The oysters are plump and fat. They have a very sweet taste and are comparable with oysters grown anywhere in the world.

PROBLEMS

Our oysters do tend to have somewhat brittle shells. Possibly more hand weighing or beaching for a period of time would alleviate that problem.

Last summer we experienced what is called summer die-off. It was devastating. We hadn't experienced anything like it before. It was a dry, hot summer, with surface temperatures of 70° for several days in July. This created a stress condition in the oysters. Several factors were involved in this stress condition:

1. The oysters were probably getting excited about spawning. Spawning produces psychological problems and the oysters may have become upset. If they had spawned it would probably be the first time in Alaska in recent historic times.

2. Another explanation has just come up during this conference: It is possible that we had a terrific bloom of algae early in the spring, and the oysters grew exceptionally fast and had very high glycogen counts. As the water warmed up, their metabolism rate continued to increase. Meanwhile the food supply began to drop off, which often hap-

Figure 4. Sorting and harvesting oysters from beached surface tray in Southeast Alaska. Photo by John Church

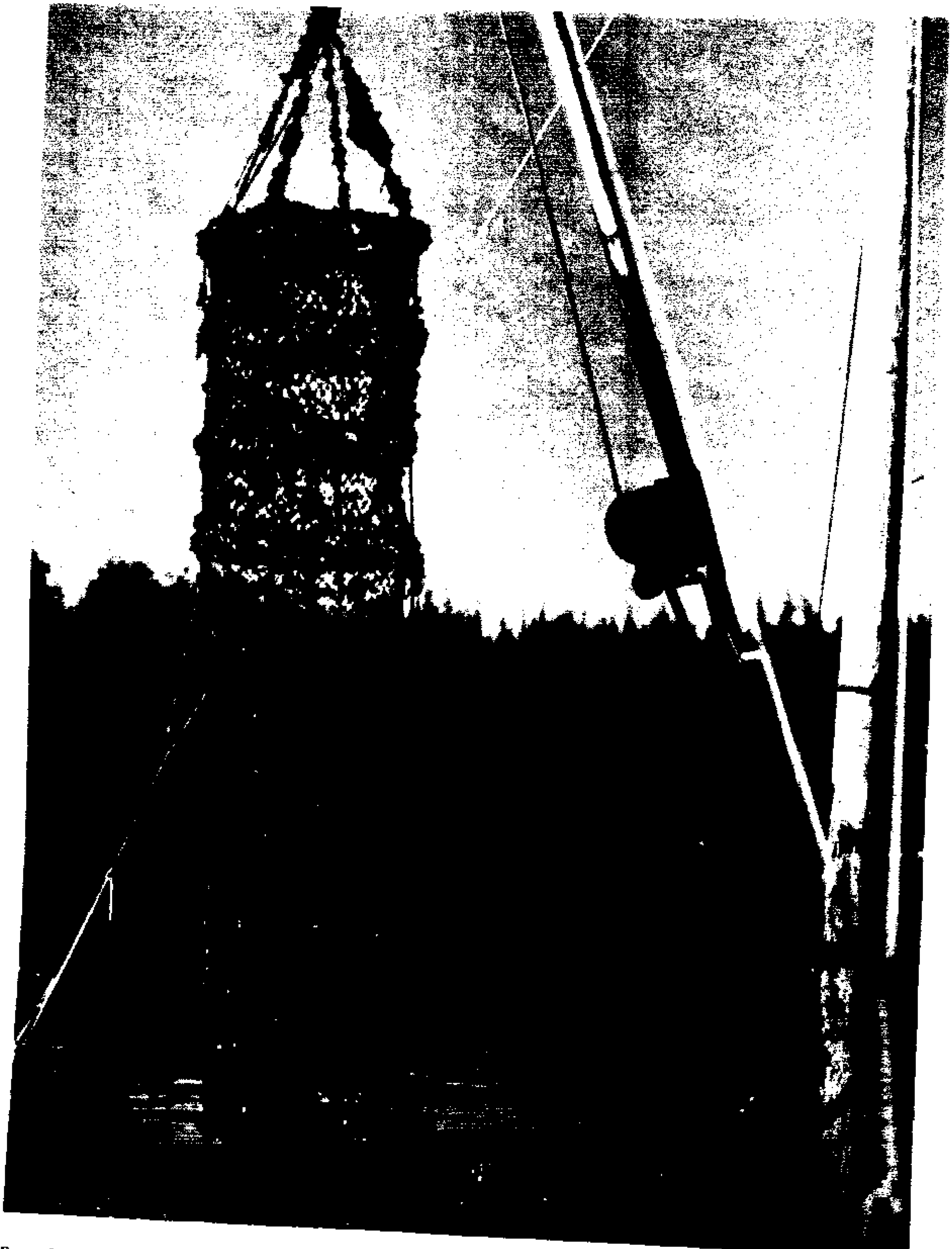

Figure 5 Oyster lantern net with heavy mussel set, in Southeast Alaska. Photo by John Church.

pens in the summer when the nutrients get used up by all the organisms.

We sent some oyster samples to the Division of Fisheries Rehabilitation Enhancement and Development lab (FRED) in Juneau, to Ted Meyers, and he was very helpful. He was quick about sending results back. He said the oysters were stressed. I did a bit of research so that I now understand more about what causes the stress and the summer die-off.

We really appreciate the concern and effort expressed by the FRED division. It's a very comforting feeling to know that we have all this expertise in the state that is backing us, and any time we need help or information, they are there. This was a good example of how risky this business of sea farming is.

It seems that in raising oysters there is an unusually high number of variables involved in their survival. But no matter how much research is conducted, the productivity of the farmed oyster will be determined by how well the farmer can key into the oyster's needs. And this principle applies in looking for a site as well as marketing the oysters. It's very important to try to understand the oyster's requirements to survive.

CHANGES FOR THE FUTURE

Our current Alaska oyster business is just the tip of the iceberg. What I foresee in the near future is that the oyster industry will really take off in Southeast Alaska.

Getting a farm going takes a long time; there are many things that have to be worked out in detail. We can't necessarily take information from British Columbia and Washington and apply it directly to our conditions here in Alaska. I foresee problems with the permit and regulation structures. Without interactions between farmers and state agencies, the industry may never become viable or profitable. We need to streamline the procedures to get our state permits, which would make the industry look viable and feasible for making a profit. Right now, an oyster farmer doesn't have a very secure feeling about the tidelands permit or the shore facilities. Until this situation is improved, the industry is just going to stagger along.

In the near future, financial assistance is not necessarily what we need to give us a boost. What would really assist us are policies that would safeguard not only a healthy environment for people in Alaska, but also a healthy environment for growing oysters. If oysters have a healthy environment, then that means the rest of the environment is doing okay.

We need to know what the carrying capacities are of each site. We need to establish with the Department of Natural Resources criteria defining a minimum (or maximum) size oyster farm. There have been problems in other areas of the world that have too many animals growing in small bodies of water. One of the results of these conditions was an increase in PSP. And that we don't need at all.

One aspect of creating a sensible market climate in Southeast is that we need to work with the Department of Environmental Conservation (DEC) to regulate and conduct testing for PSP. We need to streamline the testing so that it is more compatible with the marketing requirements of the oysters. We have looked at how other states conduct their tests and we think that with more data, and more oysters being sold, we will be able to make recommendations. The DEC has been very cooperative and supportive all through the process. We feel they should stress the importance of conducting PSP tests to anyone who thinks they want to grow oysters. Before planting a single oyster, a farmer should be sure that the area does not have the potential for the PSP organisms. Just one PSP incident and a business is lost for a long period of time. We saw this happen with salmon.

ACKNOWLEDGMENTS

I wish to acknowledge at this time the huge effort of Dolly Garza, Brian Paust, Ray RaLonde, and many other people who put a lot of effort into this conference. I also would like to thank the Sea Grant people who helped this conference to materialize. And I wish to thank my partner, Ann Caldwell, who supported my participation here.

QUESTIONS AND ANSWERS

Q. Have you experienced a problem with oysters milking during the summer? Do you have marketing problems like the Washington oyster farmers have?

A. (Mr. Nicholson) No, we didn't get to that point with the oysters. They were producing gonads, but the meat still had a firm texture. A yellowish mass was beginning to form, and if the water continued in the 70° range, we would have had milkshakes.

Q. What was the incidence of PSP, or have you had any that stopped sales?

A. (Mr. Nicholson) No, we have not had any problems with any sales being called back. If the test shows more than 60 micrograms, then its considered a positive test and that means you can't sell your oysters. We have always had very low PSP readings in the oysters, even though sites nearby have shown PSP amounts well above the minimum level allowed. We also test other shellfish—mussels and clams. It takes a certain mechanism to release the PSP cyst that lives in the mud, and in the calm waters near our oyster site we don't have those conditions. We did have one count of 58 this fall, which is the highest we've ever had.

Q. Jim Donaldson, can you talk more about why you gave up on rock scallops and what you think the outlook is for that species?

A. (Mr. Donaldson) Rock scallops definitely have some potential. The reason we gave up on them was that we had trouble with survival of the seed after it was set. We had no trouble growing the larvae, but we had a great deal of trouble after that stage. We were working with a lot of different species at the time so we just decided to abandon the rock scallop. The important thing is that once you have the hatchery system and you have the tanks and you have the algae supply, you have what it takes to grow mollusks. Basically all the systems are similar. There are just subtle differences, and most of these have to do with management, the way you grow the different species.

Q. We have the advantage that the Alaskan oysters don't become sexually mature during the summer. At what point might we expect to have significant competition from the triploid oysters?

A. (Mr. Donaldson) We have grown some triploid oysters to market size, but there aren't significant quantities in the marketplace. With the 3 billion oysters that we produced this year, we expect to have large quantities in three years and we'll be gearing up. Next year, we'll have some and the year after we'll have siginificant quantities. I'd say we're about three years away from very large quantities. The preliminary results of the tests with the triploids look very good for the growout. The market quality looks every bit as good as what we've seen before.

Q. What are the cells per milliliter in your algae?

A. (Mr. Donaldson) In any of those culture systems, whether its a carboy, a 1,000 gallon tank, or a 5,000 gallon tank, densities are around 3 million cells per milliliter maximum.

Q. What species are those?

A. That's for *Thalassiosira pseudonana* (clone 3H), *Chaetoceros calcitrans*, and *Skeletonema* sp. All three of them are about the same. You can grow them much denser, but we've found that it adds a few more days to your growth and if you add a few more days, you need more tanks and you need more floor space.

Q. How are we going to compete in the market if we're selling oysters for 50 cents apiece?

A. (Mr. Donaldson) For the last couple of years we've been able to produce lots of oysters and sell every one without any problems. The vast majority of the oysters that we produce are sold on the East Coast. The oyster growers in Washington and Oregon supply most of the markets on the West Coast.

The decline of the Chesapeake Bay fishery will definitely continue, while the decline of the Gulf of Mexico fishery may be turning around. Supply and demand goes in cycles, but there's still a lot of demand out there.

Q. What is the oyster price now?

A. We haven't set that yet. Most of these triploids will be marketed in July, August, and September. Triploid oysters that are grown and harvested from October through June aren't much different from regular oysters. There's no point in selling a product that we have put a lot of money into for the same price as a Pacific oyster.

Q. But right now it looks like in Alaska we're going to have to compete in this market. It appears that we're going to have to concentrate on staying here rather than concentrate on selling in other areas.

A. (Dr. Chew) There is one thing I'd like to mention, and that is that I get, on the average, about one call a month from people in the Midwest. Apparently the business of half-shell oysters is really picking up. I know growers here have been trying to get into that market, and there's a big market out there in Iowa, Wisconsin, Chicago, all through this area. So I send them over to Coast Oyster Company or some of the other farmers.

Q. I would like to ask Jim Donaldson, since Coast Oyster is kind of controlling the eyed larvae market, what kind of price schedule do you anticipate?

A. (Mr. Donaldson) The price for eyed larvae right now is $100 per million. I don't expect that to change significantly. The price for the algae concentrate that I showed you is $12.50 per 100 grams. You can grow a million larvae for three or four days with 100 grams of algae, and get some good seed out of it. It would cost you $112.50, a reasonable deal. So if you consider the cost of producing your own eyed larvae and then successfully setting them, you're going to spend a lot more money compared to just purchasing them.

We've gone through 13 years of a hatchery system and any new hatchery that starts up is probably looking at three to four years of settle-out period.

Q. Alaska growers have experienced quite a high variation in the growth rates of the seed they get from down south. What about adapting a few generations of oysters to the Alaska conditions to get a more uniform product?

A. You could possibly do that over several generations if your desired traits were heritable. You would select the fastest growing oysters from the group grown in colder waters. I wouldn't commit myself to say that we'll do that at this point, but it's certainly possible.

Q. I'm wondering about the viability of Whiskey Creek? Are they still in business?

A. The last I heard they were still in business.

OPERATING AND MARKETING A MUSSEL FARM

Peter Jefferds
Penn Cove Mussels, Inc.
Coupeville, Washington

GENESIS

When Penn Cove Mussels was established in 1975 it was the second mussel culturing operation in the United States; the first had been established in Maine less than a year earlier. No mussels were being sold in the Seattle area, because the quality of those that had come earlier from the East Coast was so bad that there were no repeat orders. However, market research indicated that the French and continental cuisine restaurants were interested in a quality product. The first sale of mussels, 10 months after the farm was started, were used at a cooking seminar for Seattle chefs. The French master chef's parting comments were published in a column in the *Seattle Post-Intelligencer*, "The butter in Washington is too watery but the mussels from Coupeville are first rate." This comment got an immediate response from restaurants. We were very lucky that our mussel company was able to take advantage of it.

SITE

Our site search consisted of boating from cove to cove in north Puget Sound, pulling up buoy lines and looking at pilings for evidence of a good population of large, fat mussels. Penn Cove was selected for that reason, plus Whidbey Island had both a ferry and a bridge for easy access to the market. The site is on the south side of the cove, sheltered from the prevailing winds by a high bluff. At the time it was chosen, the site was not visible from any homes. The waters of the cove benefit from the distant runoff from Skagit Flats, a rich agricultural area. Mussels consistently grow to 2 inches in 8 to 10 months.

RAFTS

The initial rafts were built from 40-foot cedar poles lashed parallel to each other with spacers in between. This provided a stable platform but one that was very difficult to work on. There wasn't enough room between the logs to easily pull out the mussel lines, and the logs were too large to pass the lines under them to the outside. The most serious problem was that boring worms ruined the buoyancy.

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The present generation of rafts is made of two styrofoam logs 3 x 3 x 40 feet held apart by a tubular steel frame that also supports a grid of 40-foot parallel poles. The mussel lines are suspended from the latter. This makes it easy to pass a line of mussels to the outside of the raft for pick-up.

The growing lines are of a synthetic material with a fairly rough surface. Initially these lines are doubled up to collect seed, since the best collecting is near the surface. Once set, the lines are opened and held straight with a weight. The weight can be half a brick or a sack of gravel. The length of the growing lines is determined by the depth of the water and how well it is mixed.

The rule of thumb for seeding is that too few are better than too many. Too many mussels will elbow each other away from the line, where they hold onto other mussels rather than the line. In that position they are apt to fall off, either prior to or as they are being harvested. Lines that are too full must be thinned at least once. Seed that has been removed can be put into special net tubes or can be held to a growing rope until they reattach themselves. The mussels can be held to the rope by tying, wrapping with a gauze, or merely inserting into the opened warp of the rope.

LONGLINES

Longlines were tried but are not being used because they cannot be effectively protected from predators. There is much to be said for the method, however. The lines are accessible for working and offer more feeding area to the mussels. Our system was copied from the New Zealanders, and they probably copied it from the Japanese. It consisted of an anchor at each end, anchor lines to the surface, and parallel surface lines 300 feet long with two-handled floats tied between them. The anchors were a spade type with 20 feet of chain to a 55-gallon drum of cement with a poly anchor line. Anchors set without the drum would move. The number of floats used depends upon the weight of the growing lines.

PROBLEMS

Red Tide

Red tide is the most serious of all problems. Newspaper articles about even nontoxic red tides such as the highly visible *Noctiluca* can put an end to shellfish sales

The state of Washington has a testing program that requires samples every two weeks from April through October. If there is any sign of toxin, the testing is increased to every week. The cutoff for harvesting is a count of 80 micrograms per 100-gram sample. The samples are delivered to the state laboratory in Seattle and the results are ready usually the same afternoon. For this service our mussel company pays $125 per year.

PSP

Prior to 1978, the state published a paper that said paralytic shellfish poisoning (PSP) was not a problem in Puget Sound east of Dungeness Spit, near Port Angeles. In that same year a random sample from Penn Cove Mussels came up with a count of 325 micrograms, shutting us down. Immediate follow-up samples showed 750 micrograms. Shortly after that, I ate three small mussels believing there must be some mistake. Within 1½ hours, my lips and tongue were numb. By 2½ hours my teeth felt like they were floating and my fingertips were numb. Shortly after that the sensation was gone. Extrapolating, we figured that the count on the mussels that I had eaten was about 2,000 micrograms. Dr. Richard Névé, who came down from Alaska as an expert, had seen counts as high as 5,000. The count at Penn Cove got up to 22,000. It was six months before the toxin got low enough for the state to permit Penn Cove Mussels to harvest.

Tidal Action

If you build in an open area with a lot of tidal change, think well on your anchoring system. Until 1982 our rafts were held by one anchor on each end. During the heavy tides of June a damaged anchor line broke while we were next to it. That extra strain caused the other line to fail also. As we watched, the raft drifted onto another raft downstream and the entire mass went out into the pass. A local dragger could not move the mass against the tide because of the sail effect of the hundreds of mussel lines below the rafts. A tug took 16 hours to get the rafts back into Penn Cove. Those rafts now have three anchors upstream and two downstream.

Predators

Predators that cause a serious problem are scoter ducks. Scoters take advantage of a free lunch, and on the West Coast mussel farmers provide it. The scoters dive as deep as the mussels grow and they will swallow mussels as big as 2 inches. Once they find the mussels, they will come in ever increasing numbers. The *Avilarm* used by eastern fruit farmers proved effective for only three days and was irritating to the people living nearby. The same sound pumped through a transducer was expensive and no more effective. When we used a propane cannon, also used by fruit farmers, the sheriff came out after four shots. The only reasonable system that we were able to come up with was to shoot with a .22 rifle during the periods the crew wasn't working. A few close shots would frighten the flock outside the perimeter of the farm and another shot every 20 to 30 minutes would keep them there. After a couple of days we could take a few days off, as they were conditioned to stay away. Unfortunately some local residents believed that we must be killing ducks and they persuaded the county authorities to stop our shooting. This has been a serious problem for longlines, but we can put nets around the rafts to keep the scoters out. The mesh is just smaller than the ducks, is visible, and goes to the depth of the lines.

MUSSEL CULTURE IN OTHER PLACES

Spain

One of the benefits of having a business is that we can justify trips to see how the other guys are doing it. Spain was a good place for us to find out if the idea was practical for Washington. In 1974, Spanish growers had rafts made from anything that would float, from old wooden ships with grids to the grids on small oil tanks. Today, they build large fiberglass systems that cost up to $100,000 each. The mussels are grown as they are here, but are harvested at a much larger size. The seed are attached by bandaging them to the line with a rayon gauze that dissolves within a few weeks. They harvest an entire raft of mussels at one time. The lines are pulled from the water by means of a balancing basket. This basket is lowered on two lines, the mussel line is centered over it, and the basket is raised collecting the mussel line as it comes up. Without the basket the mussels would not have the strength to hang on as they come out of the water. In water, they weigh 1/4 to 1/5 their weight on land.

Mussels that are to be sold fresh must be depurated. This is done by holding them for 24 hours in tanks of water that has been sterilized by chlorine and ultraviolet light. Once depurated, they are packed in yellow bags to signify their purity.

Italy

Mussels are primarily raised in two areas of Italy, Chioggia, which is south of Venice, and Trieste, which is near the Yugoslavian border. At Chioggia the waters are shallow and the tidal change small. Mussel growing lines there are hung from wires stretched between wooden racks driven into the bottom. At the time of first thinning the seed clumps are put into a net tube that has a mesh small enough to hold clumps but large enough for individual mussels to migrate out. As they migrate out they essentially turn the tube into a rope. This thinning takes place two or three times, each time with a larger mesh. At Trieste the growers go through the same thinning process as at Chioggia, but longlines are used instead of racks.

As in Spain, the Italians produce a large mussel. Unlike Spain, which exports mussels, Italy doesn't produce enough even for their own use.

Korea

At the southern tip of Korea, mussels are longlined below glass or plastic floats in an area that has been declared a national water park. This park designation is rigidly guarded to protect the U.S. Department of Agriculture's approval of the products that are raised there, since a large part of the harvest is shipped to the United States. The majority of the canned smoked mussels sold in the U.S. are Korean. The mussels as they grow have very few fouling organisms on them. They appear the same as ours except that the meats tend to be orange rather than white. The rafts in that area are supported by styrofoam cylinders with fitted nylon covers. It is imperative that the styrofoam be protected with a cover to keep it from eroding away.

France

France has the most unique method of raising mussels. The majority come from the North Brittany coast where the tidal flats go out for miles. At low tide a raft would squash the crop and at high tide the rough seas would destroy the system. Their method is to raise the crop intertidally on poles called bouchots. These are made of oak and are driven about 4 feet into the sand. Seed is collected on natural fiber ropes stretched on low racks in the so-called parc.

The seeded rope is cut to length and tacked in a spiral to the bouchot. As the seed grows it migrates from the rope to the wood, eventually covering it where the mussels grow to maturity. All work is done on foot when the tide is out, or from small boats as it comes in. At full tide the facilities are not visible. The parc that I visited had 11,000 bouchots. In spite of large production, France imports mussels from Spain, Holland, and Ireland. I was very impressed to see fleets of mussel trucks delivering mussels in Brussels where they were the feature item in restaurants.

Holland

In Holland mussels are dredged from the muddy bottom of northern inland seas where they have set. As the mussels are picked up they ingest silt that must be purged before they are saleable. To accomplish this the mussel fishermen transport shiploads to seas in the southwest that have firmer bottoms. Tracts for harvesting and holding are alloted by the government. From these holding areas the mussels are harvested as needed. This is a big business, with product being moved in semi truck loads. Holland shuts down harvesting from the end of April to June. I assume that this is to prevent sale of a less desirable spawny product but it also permits the fisherman-farmer time to attend to matters other than harvesting. This system, on a smaller scale, is being used on the northeast coast of the United States.

New Zealand

Mussel farming in New Zealand is entirely by longline. The mussel is not *Mytilus edulis*, as in other places that I visited, but *Perna canaliculus*, the green lipped mussel. Perna grows rapidly and to a large size. While it is good, it is just not the same as our blue bay mussel. New Zealand is another place that processes most of its product. Much is either frozen on the half shell or as meats. Some is pickled or smoked. A limited amount is air freighted out fresh. New Zealand has opened Japan as a market, even though the Japanese traditionally have not eaten mussels. This was accomplished by calling the product perna or kiwi clams.

The annual production in New Zealand is large, and farming, harvesting, processing, and sales have all become specialized operations. It has progressed beyond our stage of having one company do the whole operation.

Prince Edward Island, Canada

While Prince Edward Islanders longline mussels in a conventional way, their harvesting in winter is most unconventional. Just prior to freezing of the bays, the longlines are sunk to just below the surface by shortening anchor lines to the floats. This continues to keep the mussels suspended above the bottom but protects the float from being carried away with the ice. To harvest, a diver is sent down to cut the longline loose from the anchors. It is then winched through the hole in the ice with a tractor or some other device, and the mussel lines are removed and trucked to a processing plant on shore. This industry that began a few years ago as a cooperative of a few farmers is now a giant corporation of many farmers, and is a major economic factor in British Columbia.

Northeastern United States

The majority of the mussels harvested from Rhode Island to Maine are dredged, but a few companies use longlines. Blue Gold Seafoods was established near Newport, Rhode Island, as the third or fourth mussel culturing operation in the United States. Blue Gold found that in spite of being well funded they had a unique problem that made marketing their longlined mussels almost impossible—they had pea crabs. These crabs live symbiotically inside the shell. The crabs were in about 30 percent of the mussels. They don't appear to hurt the mussel, but they were a turn-off on the market. When consumers ate the mussels, they got a crunch instead of the soft texture they expected. This was unappetizing to them. Blue Gold was thus forced into the dredging business even though they had hundreds of thousands of pounds of unusable cultured product. A change came a few years ago when an adman offered to sell the cul tured oysters. His artistic advertisement in trade journals showed the twin catch, a cooked mussel with a small chowder crab. The ad implied that the consumer would be fortunate to find one of these delicacies, as only 10 percent of the mussels had them. The ad was a success and the crop was sold.

QUESTIONS AND ANSWERS

Q. Do you think new permits will be issued in your area in the future?

A. At present there are two more years to go on a three year moratorium on aquaculture in Island County, Washington. Upland owners are organized against having anything intrude on their views. They promote a fear of the unknown. At present the heat is on the salmon farmers. One thing that we point out is that rather than upsetting the local ecology, aquaculture can enhance it. A raft of mussels is rather like an upside-down kelp bed. It is full of other growing things such as acidians, anemones, shrimp, crabs, little fish, and the larger fish that prey on them.

Q. What is the shelf life of your product?

A. One thing to remember about shellfish, and mussels in particular, is that they are not like wine—they don't improve with age. They should be eaten as soon as possible. All the time they are out of the water they are living and generating waste. Therefore we deliver to most markets two times a week.

Q. What size do you sell your mussels?

A. We say that 2-3 inches is just about right. Customers want something that they can take in one bite. It's sweeter at that size. Also, why let the mussels grow for two years if they can be sold in one?

Q. Apparently there are some mass mortalities in mussel farms in British Columbia. Have you had a problem with that?

A. I'll tell you about mass mortalities. The first year that we saw the effects of El Niño we lost about 80 percent of the mature crop. The next two years we lost about 95 percent. That is 80 and 95 percent of the crop remaining, beginning around July. Surprisingly, the seed grew remarkably fast. Those years we started harvesting 2-inch mussels in six months.

Q. How warm was the water at that time?

A. Maybe it was a half degree warmer than normal. No one knows, we didn't have any baseline data. I don't think that anyone really knows the causes.

Q. Where do you get your net tubes?

A. Initially we bought them from Italy. Later, we bought them from a Maryland sales representative. Now we buy from Ralph Schley of Norplex, Inc., Kent, Washington. He will make most any kind of extruded net product that we want.

MUSSEL AQUACULTURE IN ALASKA

James E. Hemming
Otter Sea Farms
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Mussel culture is not new. It began more than 750 years ago in France when an Irish sailor put a fish trap made of wooden poles on the tide flats. Instead of fish, he caught blue mussels when spat settled in great abundance on his poles. Mussels proved to be an easily obtainable food source in France and the Irishman's discovery eventually led to a culture system called the bouchot system, which is still in use in France.

Blue mussels are grown in Washington on Puget Sound. They are also grown commercially along the New England coast, and on oil rigs in the Santa Barbara channel of southern California. Each of these areas has chronic water quality problems.

Alaska has innumerable fiords and protected bays with excellent water quality that should provide suitable sites for shellfish culture. With good planning, technical support, and protective regulations, Alaska could easily become the mariculture center of North America.

Blue mussels are filter feeders, which collect food by straining microscopic organisms from the water they live in. In the wild, mussels occur in the intertidal zone, where they are uncovered part of each day by the tide. This means that they can feed only about half of each day. Because they must filter algae and plankton from the water, they do best in areas with relatively strong currents and good circulation. Wild mussels grow slowly in intertidal zones because they can feed only during high tide. Cultured mussels reach commercial size in 12 to 18 months, whereas wild mussels may require five years or more to reach an equivalent size. If you compare wild versus raft-grown mussels of the same shell length, you will find that the raft-grown mussels yield 40 to 50 percent more meat than their wild cousins, i.e., they are fatter.

Wild mussels attach themselves to rocks and old shell debris on the bottom where they are constantly scoured by sand and gravel moved by tidal currents. If sand grains become embedded in soft tissues, they form tiny pearls or grit that are unpalatable to patrons of fine restaurants. The use of raft or longline culture systems keeps mussels off the bottom, which reduces the hazard of pearl development, and in the water column where they can feed and grow continuously.

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CONSIDERATIONS FOR STARTING A BLUE MUSSEL FARM

The attributes for an ideal mussel farm include:

1. Protection from weather.
2. Excellent water quality.
3. An abundant supply of food organisms and nutrients in the water column.
4. Ice-free conditions.
5. Limited human settlement or development (minimum pollution).
6. Abundant wild mussels for seed stock.
7. Low incidence of paralytic shellfish poisoning (PSP).

Shelter

A suitable site must have some protection from seasonal storms that may cause damage and make harvesting impossible. Sturdy rafts and longline systems can be used in bays that are not facing directly into the open sea. It is important to define the worst possible wave conditions for the site under consideration before making final decisions to establish a sea farm. On the more exposed sites, longline systems may prove the most practical.

Depth

A minimum depth of 8 to 10 fathoms is required for raft or longline systems, because net tubes containing young mussels are usually 10 to 20 feet in length and the dropper lines must be kept off the bottom to avoid predation from starfish. There also is an advantage to establishing raft or longline systems in areas with water depths greater than those normally used by feeding sea ducks; deep water sites would significantly reduce the risk of sea duck predation on young mussels. Our system is anchored at a depth of 20 fathoms.

Sea Bed Type

The best type of bottom for holding moorings is firm mud or clay. Sand bottoms can also be used but may require burying anchors with diver assistance.

Salinity

Blue mussels can exist in salinities as low as 5 parts per thousand (ppt) but will grow well in salinities of 17 ppt or greater. At our site, summer salinities averaged 26.6 ppt at the surface and 24.5 ppt at 10 feet below the surface. Ocean water is usually considered to be 35 ppt.

Temperature

Mussels survive in temperatures ranging from -4° to 80°F (-20° to 27°C). Mussel growth rates will increase as temperature increases up to about 68° (20°C) provided that sufficient food is available. Temperatures at our location in Halibut Cove Lagoon range between 34°F and 55°F (near 0° to 12.5°C). Summer temperatures averaged 53°F (11.6°C).

Water Quality

It is important to select sites that are free of industrial or sewage pollution. Sewage pollution can be remedied by using depuration, but this is costly. Depuration is the process of moving live mussels from the harvest site to tanks containing sterilized seawater, and holding them there until they are free of coliform bacteria and chemical pollutants. It is necessary to depurate commercially harvested mussels and clams from many locations on the East Coast, and it is a common practice in Europe. In Alaska, we have a great advantage over other locations because most areas are still pollution-free. Alaska regulations require that water samples be taken several times a year from shellfish growing areas.

Water Exchange and Currents

Tidal action and circulation should be adequate to replenish food organisms and to keep the water well oxygenated and to dilute toxic products released by the shellfish themselves. Most sites with moderate currents are suitable for growing mussels except those at the heads of bays where currents may be very slow and where food availability may be limited. If longline systems are used in areas with very strong currents it may be difficult to work the lines.

Feeding Conditions

Mussels feed on runoff from land as well as on the microscopic plants and animals that occur naturally in the water column. The best feeding conditions are usually found adjacent to steep-sided fiords, and poorer conditions occur adjacent to flat or low-lying coastlines.

Growth

In many parts of the world, commercial-sized mussels (1 ½ to 2 inches in length) can be produced within 18 months from spat fall, except in places where salinity is so low that it hinders feeding. At our site, mussels reach commercial size in approximately 12 months.

Seed Supply

Mussel farm sites should be selected close to good natural populations of wild mussels, where wild seed can be collected or spat collectors can be used. Another option would be to purchase spat from a commercial or state-operated hatchery. There seems to be good potential for economic production of spat for purchase by shellfish growers at facilities such as Sheldon Jackson College in Sitka. I think all of the shellfish growers in Alaska would welcome a hatchery and it would probably pay for itself.

Fouling

This includes competitor organisms such as barnacles, tube worms, sea squirts, and kelp. The presence of fouling organisms results in higher maintenance costs. If they affect the appearance of mussels, they may result in lowered market value. However, the presence of plant materials such as kelp increase the organic matter available for mussel feeding. In some parts of the world, kelp culture is an integral part of mussel culture. Finfish farmers and oyster farmers would probably consider mussels vermin. They are one of the chief fouling organisms for various types of three-dimensional aquaculture.

Predators

Common scoters and other sea ducks feed heavily on blue mussels. If they discover a mussel farm, special remedies such as scarecrows or protective netting will be required around the rafts. As mentioned earlier, we found that by setting our rafts in parts of the fiord where our anchors are at depths much greater than the normal feeding range of sea ducks, we have no problem with predation. It is important to understand the natural feeding patterns of sea ducks in a potential sea farm site, so feeding areas can be avoided. If predators discover the rafts, it probably will be necessary to hang nets around raft boundaries. This will increase the level of maintenance labor required to regularly clean fouling organisms from the netting.

Parasites and Diseases

Suspended mussel culture minimizes infection by parasites such as pea crabs and red worms (red worms are actually copepods). It also avoids production of pearl-like particles in the flesh, which are often found in wild mussels as a reaction to both sand bombardment and trematode worm infections. Another problem requiring special attention is related to paralytic shellfish poisoning. This problem is caused by plankton blooms made up of toxic organisms that are ingested by the mussels. The mussels become dangerous to humans for several days or weeks. As a result, it is required by permit to test each shipment of blue mussels before they can be approved for commercial sale. In selecting sites, it also is important to collect background information on natural levels of PSP in hard-shell clams, cockles, and mussels to be sure that the site is free of problems. At present, the only PSP testing facility is the state laboratory in Palmer. Because of its location, it is time consuming and sometimes costly to obtain test results in a timely manner. Meanwhile, harvested shellfish must be held out of water and artificially chilled. Increased facilities at more convenient locations on the coast would ensure delivery of higher quality product and reduce costs.

Use Conflicts

In selecting a site, careful attention must be paid to other users of the area. These may include commercial fishing operations, gear storage, recreational traffic areas, etc. Such use patterns may not always be obvious and it is important to check with local fisherman and residents before finalizing site selection. As a shellfish grower in Maine puts it, "Musseling in at the expense of traditional communities can only lead to hostility."

We also have learned that mussel farming is compatible with special upland classifications such as state parks and wilderness areas because both parks and shellfish farms have a long-term interest in maintaining very high quality water. Usually this is assured only by restricting upland development and settlement. For example, our operation is within park waters in Kachemak Bay State Park and requires a special land use permit from the State Division of Parks rather than the usual Land and Water Resources Division permit from the Department of Natural Resources. Consider the long-term use potential of your site carefully before making a capital investment.

Access

Shellfish farms should be located close to good commercial transportation. Site feasibility assessments should include the cost of transporting products to market and the distance from reliable road or air transportation.

Permits

Once a suitable site has been found, permits and licenses must be obtained. An Alaska business license is the first step, followed by a tidelands lease, water quality certification, coastal management consistency determination, Corps of Engineers Section 10 Permit for structures in navigable waters, Commercial Fisheries Entry Commission permit, a shucker-shipper permit from the Department of Environmental Conservation, and soon a shellfish farm permit from the Alaska Department of Fish and Game (ADF&G). If the sea farmer plans to do anything beyond harvesting and shipping live mussels to market, other permits may be required as well.

At present, it is possible to apply for a shellfish farm permit at any location on the coast. However, there has been no planning by the state to identify areas that are both suitable for shellfish culture and have minimum conflicts with other users. Because of this, we are seeing a flood of applications for shellfish farms in the small lagoon where our farm is located because people don't know where else to go. There will probably be serious conflicts at our site in the very near future.

Before we go much farther with regulations and permits for other species, the state should do a coastal survey to identify areas that are suitable for mariculture and that do not have serious conflicts with other users. This is not difficult to do and would not be very expensive.

Once a survey is done, areas should be zoned for mariculture so new business can have the long term support needed to assure financing as well as the potential for successful farm operation.

The farm regulations proposed by ADF&G may also create problems, because they would restrict permits to those of us with prior experience in sea farming. This would be good for me but not for newcomers.

There is no specified time limit on ADF&G permits or provisions for removal of facilities such as rafts or longlines when a permit is dropped. This means a flaky operator could abandon his system, leaving the state with the liability for cleaning up the mess. By having a set permit period requiring periodic reviews and by placing the liability for removal of facilities with the permittee, we would see the development of a much more responsible mariculture industry.

Draft regulations also seem to mix finfish culture with shellfish culture, and I don't think the shellfish farmers want their permits tied to the tail of salmon farmers or vice versa. There needs to be a clear definition of what is meant by shellfish.

Regulations also need to require that cultured shellfish seed stocks not endemic to Alaska be certified disease-free before they are introduced into Alaska waters. We don't want to be shut down because someone brings in diseased spat.

If we are going to start a new industry, we need to do it right to assure success.

LITTLENECK CLAM AQUACULTURE IN THE PACIFIC NORTHWEST

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INTRODUCTION

Early records show the Japanese enhancing clam culture by putting bamboo or brush on the intertidal zone to break up the currents to form eddies. This causes the larvae to get concentrated into current pockets for settlement. In fact, the Japanese are still doing this to encourage clam set.

Before we get into details about how the littleneck clam is cultured in Washington, as well as how it might be cultured in southeastern Alaska, I should mention some of the other species that are being cultured in the Pacific Northwest.

A variety of commercial and recreational clams are sought in the Puget Sound region, and several of these species also occur in southeastern Alaska. A few of these are cockles (*Clinocardium nutallii*), native littleneck (*Venerupis staminea*), butter (*Saxidomus giganteus*), and horse (*Tresus* sp.) clams. For several years hatchery spawning and culture attempts on the native and butter clam species were made. Thus far there has been no success.

Three Washington species of clams spawned in the hatchery with moderate to good success are the razor (*Siliqua patula*), geoduck (*Panope generosa*) and the Manila (*Venerupis japonica*) clams. These will be discussed individually with more extensive discussions on the Manila clam.

SPECIES CULTURED IN WASHINGTON

Razor Clam. Until recently, the razor clam was spawned and the larvae developed to metamorphosis (settlement) by the Washington Department of Fisheries. The hatchery was developed to cultivate the larvae and subsequently the juveniles in the nursery system to a size for planting. This came as a result of declining populations on the beaches and it was felt something should be done. The hatchery is now closed.

Geoduck Clam. The geoduck culture is quite successful now. Through funds to the Washington Department of Natural Resources from leases of geoduck tracks, money is fed back into the Fisheries Department for operating a hatchery to produce the juvenile clams for planting on commercial and recreation beds. More information can be obtained from the Washington Department of Fisheries Shellfish Laboratory in Brinnon about this successful program.

Manila Littleneck Clam. The Manila or Japanese littleneck clam (Figure 1) was an accidental introduction when Pacific or Japanese oyster seed (*Crassostrea gigas*) was shipped from Japan. Thus many areas of British Columbia, Washington, Oregon, and California now have naturally producing stocks of Manilas. The small clams were settled on old mother shells with oyster seed when shipped to the United States.

As shown in Figure 2, the Manila clam is having a major impact on commercial clam harvest in Washington State. It started out slowly in the 1950s and has built to a production level of over four million pounds by 1986. The native littleneck clam production dropped below the Manila clam in the mid-1970s.

Aside from commercial harvest of the geoduck clam, Manila clam production has taken over the other hard clam species. There are perhaps several reasons for this. First, it was consumer acceptance of the darker color of the shell. Second, the shelf life of the Manila clam appears to be slightly better than the common native littleneck clam. Third, people have begun to develop a taste for the Manila clam, although at first they thought it was a much stronger flavor than the native littleneck species. These are only presented as my own impressions.

In Puget Sound, Washington, clam growers have in the past used the Japanese technique for enhancing the settlement of littleneck clams by staking brush in the intertidal area where natural sets could be caught. This was not found to be a reliable way to catch seed.

Some beaches that have historically produced good quantities of native littleneck or Manila clams have dropped in production. One could speculate at length on reasons why this happens. Over-harvesting is one possible reason. Lack of seed set is another. Once the pelagic egg is fertilized, it takes two to three weeks for larval development in the water column before settlement. The source of set may be adult populations two or three miles up the bay. Thus, if the adult population is over-harvested or meets with a major mortality, larvae from this population which normally are available will be gone. This applies not only to Manila clams but to all clam species.

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Figure 1. The Manila or Japanese littleneck clam (*Venerupis japonica*). Photo by Greg Anderson.

CULTURE METHODS

The following describes the experimental techniques tested to enhance Manila clam culture in Puget Sound by the University of Washington School of Fisheries between 1970 and 1982:

Raking. One of the first studies conducted was raking the intertidal ground and planting the Manila clam seed. Hatchery seed of 4 to 6 mm was used. One week after raking and planting, none of the planted clams could be found. From diving observations, it was discovered that as soon as the clam seed was planted, fish swam onto the planted bed and preyed on the seed, even though they were dug in. Raking the beach served to release odors that attracted the fish.

Planting without Raking. Next, seed was planted into the gravel without raking. There was some success, but clam recovery was very low. Apparently the clam seed could move out of the planted plot. Fish predation was also a problem on open plots.

Graveling. The Washington State Department of Fisheries (WDF) has experimented with graveling the beach to attract clams. Some beaches have a tendency to get muddy, so in several areas WDF tested the prospect of graveling. They did this several years ago, primarily to attract Manila clams. This method has been used successfully in the past to attract natural sets of native littleneck clams. Hatchery seed Manila clams can also be planted on newly graveled beaches.

Netting. All of the previous methods described have had moderate or poor success compared to some type of netting. One of the most promising type of netting was ¼ in. mesh Vexar car cover, a type of netting used on fruit trees to keep away birds. When laying the car cover, a trench is dug along the perimeter of the netting. We lay the netting down on the beach, and we stake it in the middle and at the edges (in the trench). Gravel is then pushed back over the edge of the netting to assist in holding it in place.

Clam seeds are usually planted on the incoming tide. If they are 2 to 4 millimeter size clams, planting density (by scattering) is 800 per square meter. But if they are 10 millimeters we plant 400 to 500. Results show that if 2 to 4 millimeter clams are planted at a density of 1,000 to 1,500 per square meter, the recovery rate after one year will almost be the same as if we had planted about 800 per square meter.

It is important to be able to distinguish planted clams from the natural set when experiments are conducted. The WDF has developed a method of air drying the seed clams and spraying them lightly with flame red fluorescent surveyor's paint. Spraying too heavily causes the clam shells to stick together. The technique is to spray a thin coating on the seed, allow to dry 30 seconds, shift them around and spray again. When these sprayed painted clams are harvested later, they can be distinguished from the natural set. Even after a couple of years, when they are approximately 2 inches long, a black ultraviolet light will pick up the tiniest fleck of paint at the hinge or umbone area.

Planting marked clam seed with paint provided a separation between hatchery and natural stocks of Manila clams on the beach. Best results observed using car cover netting was 70 to 80 percent recovery of planted clams. In comparison, six months after planting painted clams in the open plots without car cover, very low or zero recovery was noted.

Sand and gravel inside a car cover plot will build up over a period of a few months. The dynamics of a beach is such that sand and gravel shifts constantly, depending on current flow, storms, etc. Gravel keeps falling between the mesh of the netting, and the bed starts to build up like a tabletop. The net gets tight, but it is flexible as the sand and gravel fills. When the netting is pulled off, the clams are near the surface of the substrate and in many cases, only a rake is needed to harvest.

CLAM CULTURE IN FRANCE

France is moving quickly into Manila clam culture now because of the demand. About 10 years ago, before they went into culture of this species, they were requesting 10,000 to 20,000 pounds of steamer clams from

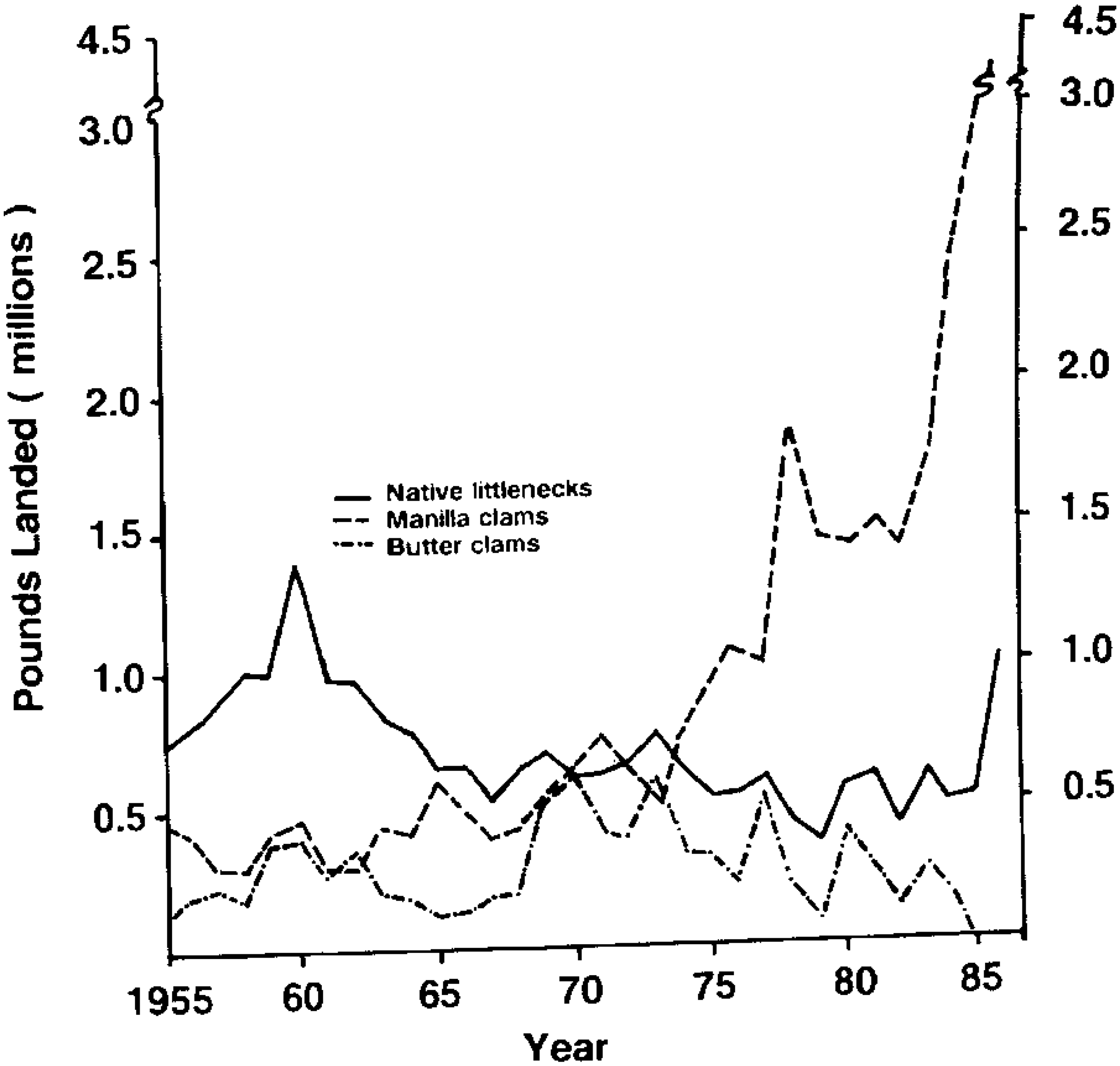

Figure 2. The Washington State native littleneck (*Venerupis staminea*), Manila (*V. japonica*), and butter (*Saxidomus giganteus*) clam production from 1955 to 1986.

Washington State to be shipped air freight to France. The requests were given to clam growers, and at the time they did not have enough clams among them to fill the orders they already had. Since then, growers in France started developing techniques for planting clams on their own beaches. Culture has expanded to Spain.

One of the techniques the French use involves a plastic mesh tray that is completely enclosed by mesh. With a shovel they dig a rectangular shaped indentation about 2 inches deep in the intertidal zone. They set the tray into the indentation with small seed clams on the inside (seed larger than mesh size of basket). Natural movement of the substrate will cause the sand and gravel to work through the mesh into baskets. These same trays are now being tried in southern Puget Sound.

According to Jim Donaldson, the French growers are also using a special netting technique. They put the netting in a row on the beach just wide enough so the wheels of a street sweeper will run along the edges and not disturb the center. They plant the seed in the center under the net, and periodically roll the specialized street sweeper over the planted netting and sweep the netting clear of algae and debris. The use of a street sweeper as part of a clam operation is an unusual idea.

PREDATION ON MANILA CLAMS

Moon Snail (*Polinices lewisi*). The moon snail will drill a hole usually near the hinge on the umbone in most species of clams. A new Puget Sound clam farmer who has experimented with several techniques to culture Manila clams indicated one of the best ways to counter the moon snail was to use double Vexar car cover netting. With a bulldozer he pushes several inches of gravel off his beach, and puts down one layer of netting. He then pushes the gravel back on top and rakes and levels it off. Then he puts another layer of netting on top of this before planting the Manila clam seed. Apparently this will keep the larger moon snail from getting into the planted clams.

Fish. Rock sole (*Lepidopsetta bilineata*), pile perch (*Rhacochilis vacca*), and several other species of fish feed on Manila clams. The worst time for fish predation is right after the planting of seed. Although dug in, the seeds are very near the surface where they are easy prey.

Crabs. Under Vexar car cover netting, in studies we conducted, the red rock crab (*Cancer productus*) can feed on the clams and grow to a size where they cannot get out of the netting.

Birds. Scoter ducks (*Melanitta* sp.) are known to swallow clams whole. Using the Vexar netting can deter the ducks' effort to prey on the clams.

SUMMARY

It is obvious that the potential for a grower is great because the demand for clams is great for the West Coast of the United States. I get requests regularly from southern California—from Los Angeles to San Diego. That market has increased at least 500 percent over what it was even five years ago. This is partly because the large Asian segment of the population is very fond of Manila clams. I have passed on the requests to local clam growers in Washington, but often the growers cannot supply all the clams that are requested.

Introducing the Manila clam to Alaska may be difficult, because it would be a new species for the regulators to make a decision on. The native littleneck clam would be a good one to try, but the seed simply is not available. If you plan to go into clam culture of littlenecks, it would have to be the Manilas, because of the availability of juvenile seed clams.

The technique for growing the Manila clam seed is not complicated, provided you have the right intertidal beach conditions and water quality. I think southeastern Alaska can support Manila clams if they are allowed in.

The Manila clam harvest in the state of Washington alone is around 5 million pounds now. Our growers in Puget Sound, Willapa Bay, and Grays Harbor estimate that in two or three years their production will be close to 7 to 8 million pounds.

QUESTIONS AND ANSWERS

Q. Do you think the Manila clams would spawn naturally up here?

A. I don't think it's warm enough. I heard someone here mention Pacific oysters getting ripe and that's the first time I heard of that. In Puget Sound the Manila clam only spawns once, at the last part of July. In Japan, they spawn twice because of the warm temperature. Here in Alaska I don't know if it gets warm enough for even one spawning.

Q. Do the larvae require the warm water to survive?

A. Yes.

Q. Is there any aquaculture going on with Manila clams?

A. In a sense there is. Manila clam seed is being produced in hatcheries and sold to clam growers for planting into their beaches for growout. This is a type of extensive culture. Intensive type culture where the clam is watched over or cared for continuously is difficult. A grower in Willapa Bay has tried this with a flow-through system, but he is not in business anymore. Also the open-tray system has been tried near Olympia. The Manila clam is the only clam I know of that can grow to market size in a tray without any gravel to keep the shell closed. The butter clam, the native littleneck, and most other species of clam will not grow out of the sand or substrate. One of the problems with growing Manila clams out of gravel or trays is that barnacles and other organisms grow on the shell, and the clams therefore are not as appealing.

ABALONE AQUACULTURE ON THE PACIFIC COAST AND ITS APPLICABILITY TO ALASKA

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Pacific Trident has been in the abalone business since 1964. We have been culturing abalone for the last seven years, with the first five of those seven years mainly in research. We have been doing well the last two years, building an inventory up to a satisfactory level. The techniques that we have developed would adapt to Alaska as well. *Haliotis kamtschatkana* is the local British Columbia species of abalone; it is the same one that occurs in the kelp beds up here in Alaska.

In 1977 British Columbia produced close to a million pounds of abalone. Since 1983, we've been on an equal quota system of 104,000 pounds. The 26 licensed harvesters get 4,000 pounds apiece. It's interesting to note that if we could harvest at the 1977-78 levels, it would be an $8 million industry. But right now it's an $800,000 industry. Our harvesting size for native abalone in British Columbia is 4 inches. We get 43 to 45 percent edible meat out of the abalone. Abalone is the most expensive shellfish in British Columbia.

CULTURING ABALONE

At our sea water lab we have a spawning area. Our conditioning tanks have 25 to 30 wild harvest animals in them, with artificial light. It takes about a month to mature the adults and induce them to spawn and fertilize the eggs. We use the spawning method developed by Dr. Morse at the Scripps Institute in San Diego. We separate the males from the females. Three hours (plus or minus 10 minutes) after we add the animals to the chemical mixture containing hydrogen peroxide, they start to spawn. A female abalone between 3.5 and 4 inches will release between 3 and 5 million eggs. We try to save about 2 million eggs.

Next we put a layer of eggs into a small container that holds about 200,000 eggs. The water level is about 2 inches up from the bottom. We pour in a concentration of sperm and let it sit for two minutes. And then we fill the container with ultraviolet-treated seawater that is filtered down to 5 microns. The eggs settle to the bottom and then we decant the water off and fill it back up again. We do this four or five times, to rinse the excess sperm from the egg.

Our larvae culture and hatchout system involves putting the fertilized eggs in buckets with a very fine flow of water over the top of the bucket. The water flow, which is through a small air tube, doesn't disturb the bottom section where the eggs are lying. When the larva hatches it is attracted to the light and swims to the surface. There it is caught up in the current and flows into small chambers.

Ours is a very good system—we get 80 percent recovery compared to the 20 to 25 percent we used to get. We average about 60,000 larvae in each of the little chambers. We have a 40 micron screen in the bottom. The larvae are removed from the chambers on a daily basis, the chambers are sterilized, and the healthy larvae are separated from the poor ones.

About eight days after spawning, the larvae are ready to settle. During that time we are growing diatoms for feed for the newly settled larvae. The Japanese system for growing diatoms uses a small (16 inch square) corrugated polyvinyl chloride (PVC) plate. We put 10 of these plates in a container and then while the larvae are going through their development stage, we're growing diatoms on the plates. Direct sunlight causes very good diatom growth. It takes about 8 days. We've got it coordinated so the diatoms are grown at about the same time as settlement.

We put about 300 of the PVC diatom plates in our settlement tanks, in a horizontal position. We get 1,500 to 2,000 larvae to the plate. We mix them up to have them evenly distributed. Sometimes we use gamma-amino butyric acid (GABA) to induce settling. We've gotten away from that by relying on mucus from 1-year-old juveniles to attract the larvae to the plates. Those juveniles are actually working for us in the settlement tank. Abalone are nocturnal after the metamorphosis, so at night they come out and eat the diatoms on the PVC plates. In about three days 1-year-old juveniles can graze a plate down; they eat off the first layer of diatoms. The second diatom growth is a small, very stable layer that's suitable for the larvae to feed on. The juveniles leave a mucous trail on the plate, and that mucus helps to attract the larvae. It works out very well.

The plates sit in the horizontal position for 3 days and then we stack them up in a vertical position. They stay in settlement tanks for about a week, after which they are placed in outdoor raceways. The abalone are two to three weeks of age when they are put into the outdoor raceways.

The abalone stay in the intermediate growout area for one year. During their growout time the abalone feed

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strictly on benthic diatoms; we rear benthic diatoms continually for food. After a year, we feed the abalone both benthic diatoms and kelp for the final growout, which takes two years. We feed the abalone twice a week; with fresh kelp. The sun that shines in the tank sets diatom growth, and we also feed them kelp. Therefore they get a good mixture of diet. The entire culture time is three years, with a growth rate of approximately ¾ inch per year.

We have eight raceways. There are four lower ones and four upper ones, 60 feet long. We shade them from direct sunlight to keep the diatom growth down. On a daily basis we have to inspect the plates to make sure there are enough but not too many diatoms. In the winter we have artificial lighting.

There is very little oxygen transfer in the water, so we aerate. We exchange the water once every 2 to 2½ hours. That keeps the oxygen level up in the tank itself. We also use the aeration mechanism to keep the water agitated, so there are no dead spots in the tank.

Normally abalone have a blue shell. The shell is blue with continued diatom feeding and green with kelp feeding. When we put the abalone in the growout baskets we add some chopped *Nereocystis* kelp for them to feed on. After about two months of eating kelp they turn an emerald green. This emerald green stays true in our hatchery abalone providing we give them kelp. We can switch between kelp and diatoms and actually change the color as we want to by the feed itself. The abalone we market are emerald green, and are about 2¾ inches. They go about 12 to 14 to the pound, although we sell them by the individual. We transport them live.

We had a lot of trouble the first five years of our enterprise, and we have tried various methods for culturing abalone. We have tried a system developed at Morro Bay, California, using concrete raceways and we like that very much. Right now we're building 50 concrete raceways for our 1-year-old abalone.

JAPANESE METHODS

In Japan, most of the hatcheries are owned and operated by the government. They grow abalone for one or two years and then they sell them to the fishermen's cooperatives. The fishermen then transplant them to the seabed. In Japan, a lot of small abalone are available from the Japanese producers.

The Japanese pay quite a high price for abalone in a sushi bar, or sauteed in butter in a restaurant. They are very, very delicious. The American delicacy is the fried abalone steak.

OVERVIEW OF SABLEFISH MARICULTURE AND ITS POTENTIAL FOR INDUSTRY

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INTRODUCTION

Sablefish or blackcod (*Anoplopoma fimbria* Pallas) range around the entire North Pacific Ocean, from northern Mexico to the Gulf of Alaska and the Aleutian Islands, and along the continental shelf of the Bering Sea to the coasts of Siberia, Kamchatka, and northern Japan. The largest concentrations in North American waters occur in the Gulf of Alaska, between Queen Charlotte Sound, British Columbia and the Shumigan Islands, Alaska. Adult sablefish are abundant along the entire coast of British Columbia in depths exceeding 200 m. Consistently high commercial catches are taken at depths exceeding 600 m (McFarlane and Beamish 1983).

Sablefish spawn from January to March along the continental slope at depths exceeding 300 m. Maximum spawning activity occurs in early February (Mason et al. 1983). Mean length and age at 50 percent maturity were estimated at 58.3 cm and 5.2 y for females, and 52.8 cm and 4.8 y for males.

Full utilization of sablefish stocks by the Canadian domestic fleet (annual catch stabilized at approximately 4,000 tons), and increasing demand in Japan and North America for a quality product have stimulated interest in developing a sablefish mariculture industry. The potential for such an industry was first identified by Kennedy (1972, 1974).

Preliminary efforts at sablefish culture were based on short-term growout operations using impounded second year juveniles from wild stocks. However, both the population dynamics of sablefish and the economic feasibility of live capture and transport preclude this as a means of establishing a mariculture operation.

Research to date has indicated that sablefish are amenable to culture in terms of hardiness and food conversion efficiency. Nevertheless, to achieve viable commercial production, further information on other aspects of their culture will be required, particularly: induced spawning, egg incubation, larval and juvenile rearing, and development of cost-effective diets.

This paper describes preliminary results of studies conducted at the Pacific Biological Station, Nanaimo, British Columbia over the last few years. Areas of study include the capture and transport of all life history stages of sablefish, techniques for induced ovulation and spermiation, techniques for fertilization and determination of optimal conditions for incubation of eggs and yolk-sac larvae, and laboratory studies on rearing of wild captive larvae and juveniles.

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MATERIALS AND METHODS

Study Design

The multidisciplinary study was developed as a five year, three phase design consisting of the following components:

Phase I. Controlled maturation, egg incubation, and larval rearing, 1986–1988.

Project 1. Capture and transport. To determine optimum conditions for capture and transport of larval, juvenile, and adult sablefish from the field to the laboratory in a healthy condition.

Project 2. Maturation and induced spawning.

a. To determine those environmental conditions that promote sexual maturation in adult sablefish.
b. To develop techniques for the control of maturation and ovulation or spermiation in adult sablefish.

Project 3. Fertilization and egg incubation.

a. To develop laboratory fertilization techniques.
b. To develop optimum conditions of salinity and temperature for survival and development of eggs.

Project 4. Larval rearing.

a. To determine optimal conditions of salinity and temperature for survival and development of yolk-sac larvae.
b. To determine food organisms, particle size and density and time of presentation of these organisms, that are required to bring larvae successfully to the early juvenile stage (40 mm).
c. To determine optimal stocking densities for growth.

Phase II. Growth, nutrition, and health, 1986–1989.

Project 5. Juvenile growth. To determine density and temperature optima or optimal ranges for growth of juvenile sablefish.

Project 6. Nutrition and diets. To determine nutritional requirements and develop diets for optimum growth of sablefish, with emphasis on development of an inexpensive grower diet which can be stored at ambient temperatures.

Project 7. Fish health.

a. To describe the microscopic anatomy of sablefish tissues as reference data to allow distinction of normal from abnormal changes at various growth and developmental stages.
b. To provide baseline data to assist future recognition of disease problems that may occur during rearing of sablefish.

Project 8. Sablefish energetics. To determine the balanced energy equation relating food intake, maintenance, growth, activity and excretion for various size-classes of sablefish.

Phase III. Pilot farm (joint Department of Fisheries and Oceans-industry project) 1989–1990. Upon successful completion of Phases I and II (anticipated to be late 1989), a pilot farm will be established to develop the necessary technology for a commercial-scale operation.

In particular, results of Phase I and II will be used to develop:

a. Site selection criteria.
b. Techniques for on-site handling of stock.
c. Techniques for large-scale manufacture and storage of feed at ambient temperatures (dry, silage, etc.).
d. Farm technology, i.e., net pen design and construction.
e. Market development, particularly for domestic markets.

Capture and Transport

Sablefish larvae were captured off the west coast of Vancouver Island during a survey to determine their distribution and relative abundance (Shaw et al. 1985). All larvae were captured at night, using a modification of the Sameoto neuston sampler (Sameoto and Jaroszynski 1969). Tows were made for a duration of 10 min at a speed of 3 knots. Once on board, live larvae were immediately placed in 1-L jars contained in a water bath supplied with continuously flowing seawater. Larvae were held for up to 10 days prior to transport to the Pacific Biological Station (PBS) via truck. At PBS, larvae were held in a 300-L aquarium supplied with flowing seawater at ambient temperature.

Juvenile sablefish were captured off the west coast of Vancouver Island, Queen Charlotte Sound, and Hecate Strait. Fish were caught with a bottom trawl, equipped with a 4 cm mesh cod end liner. On board, the fish were placed in 3,000-L oval holding tanks; dead fish were removed every 2 h. Only fish healthy in appearance with no obvious physical damage were selected for transport to PBS. Fish were transported via truck using a 2,700-L transport tank supplied with an oxygen aeration system. At PBS, juveniles were held in 3,550-L holding tanks.

Adult sablefish were captured annually off the west coast of Vancouver Island by the charter vessel, M/V *Victor F*, using conical Korean traps (1.5-m base diameter and 73 cm high). Captured fish were held on board in an oval 3,000-L holding tank supplied with a continuous flow-through of seawater. Healthy fish were transported to PBS in 2,700-L aerated transport tanks. At PBS, the adult fish were held in either 3,550-L fiberglass or 10,500-L wooden tanks provided with continuously flowing seawater.

Procurement of Gametes

Stripping of Wild Fish

Spawning sablefish were captured in conical Korean traps off the west coast of Vancouver Island in February of 1986 and 1987 by chartered commercial fishing vessels. On board the vessel, spawning fish with visibly running sperm or eggs were separated out. These fish then were blotted dry with paper towels, particularly around the cloacal region. As the fish were held in an upright position, a hand was slid along the ventral surface from the head to the cloacal region while applying a gentle pressure. At this time the tail was bent slightly away from the cloacal region. This process was repeated until the eggs or sperm flowed freely. The first few milliliters of eggs or sperm were wiped away to remove any bile or other secretions from the genital pore. Eggs were collected in 1-L plastic containers (one-third filled) ensuring that no water came in contact with them; while 15-ml aliquots of sperm were placed directly into Whirl-pak bags and closed to contain a large pocket of air to promote spermatozoa respiration. All fish were then measured for fork length and otoliths were removed for later age determinations (Beamish and Chilton 1982).

Gametes were packed into a cooler (maintained at 3°C with freezer paks), sealed with tape and then immediately transported to PBS via boat and truck.

Inducement

Adult sablefish brood stock were captured as described above, transported to PBS, and held in 10-cubic-meter holding tanks. The fish were maintained in either dark or dim light conditions at 8.7 ± 0.5°C and fed every 2 days on a diet of chopped squid, herring, and shrimp.

The inducement techniques were carried out according to Solar et al. (1987). Brood stock were alternately injected with partially purified salmon gonadotropin (SG-G100) and synthetic analogues of gonadotropin-releasing hormone (GnRHa). Doses of these hormones were scaled to the weight of the fish at: 1.0 mg per kilogram and 0.2 mg per kilogram for SG-G100 and GnRHa (D-ala^{6}, des-gly^{10}-LHRH ethlyamide), respectively. All injection volumes were based on 0.4-ml hormone solution per kilogram body weight. In the 1987 trials, some fish were injected with GnRHa as in 1986, some re-

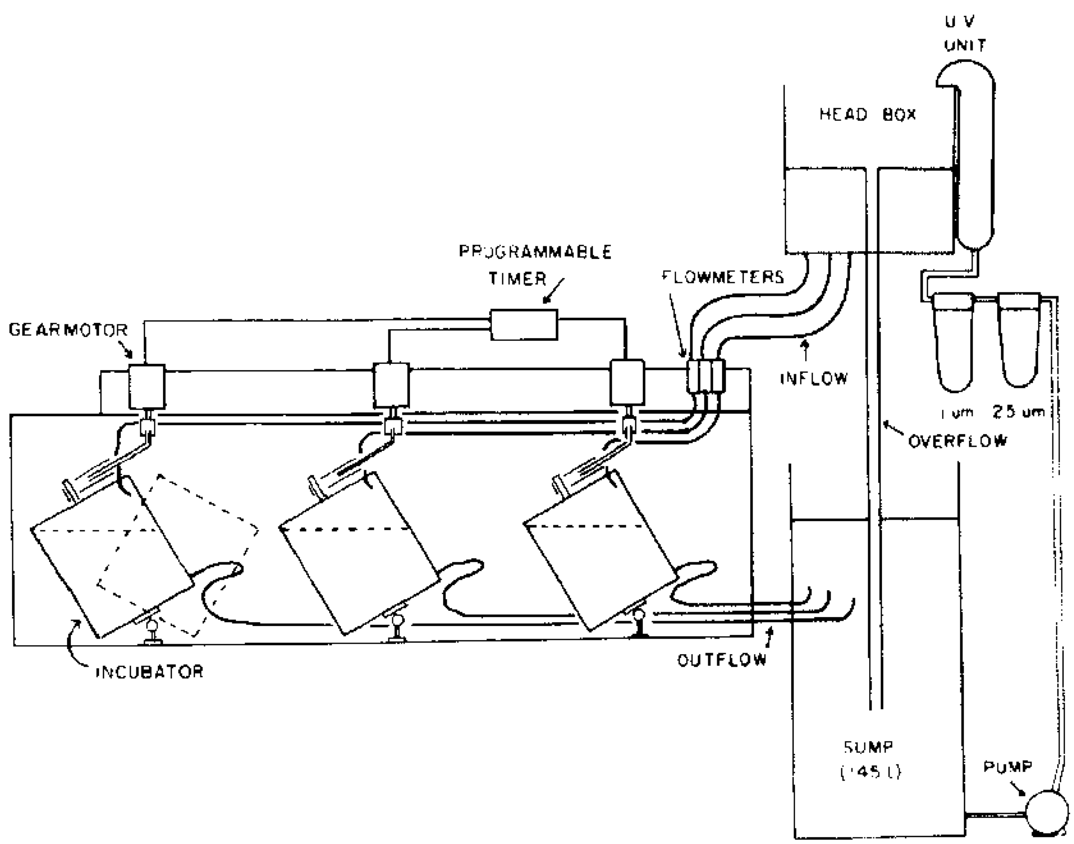


Figure 1. Diagram of three incubators in operating position (remaining three incubators to right of sump not shown). Slow exchange of incubator water occurs through the metered (50 to 100 ml per min) inflow. The outflow is sized (larger) so that the water level in the incubators is very near that in the sump. Water enters the head box via a pump (10 to 12 L per min), two filters (1 and 25 micrometers), and an ultraviolet sterilizing unit. The overflow returns to the sump. Incubator motion through the gear motors is controlled by a programmable timer (from Alderdice et al., in press).

ceived injections of GnRHa combined with 5 mg per kilogram domperidone (dopamine receptor antagonist), and some received an injection of domperidone only. In a second experiment, single hormone analogues (GnRHa); 0.47 to 0.54 mg per kilogram D-trp^6-LHRH, 0.1 mg per kilogram D-ala^{6}LHRH ethylamide, and 0.1 mg per kilogram D-arg^6-salmon GnRH ethylamide were administered to 10 other females. Prior to injection the fish were anesthetized with MS 222 (Tricaine methane sulfonate). The injections were made into the peritonial cavity, posterior to the base of the left pelvic fin.

Brood stock were initially inspected 7 days after injection. Thereafter, fish were inspected daily. Gametes were obtained from ripe fish by gentle abdominal pressure and collected into 2-L plastic containers (ova), or 200-ml Whirl-pak bags (sperm). Gametes were stored at 3°C in a cooler for 2 to 270 h before fertilization.

Fertilization and Egg Incubation

Eggs were fertilized and rinsed as described by Alderdice et al. (1988). In this method milt was added to eggs at a ratio of 1 ml per 210 ml eggs in a dry container. The eggs and sperm were stirred for 30 s and allowed to stand for 3 min, after which a large column of 35 ppt seawater was added. Live fertilized eggs remained at the surface while dead eggs sank. Live eggs were removed from the container, rinsed with 35 ppt seawater, and placed into the incubators.

Fertilized eggs were incubated in six rotating 11-L capacity units (Figure 1) designed by Alderdice et al (in press). Incubation was at 5.3 ± 0.07°C, 35 ppt salinity, and in darkness. After hatching, the larvae were maintained in the same incubation containers until eye

Table 1. Composition of two test silage-based diets employed for culturing sablefish at the Pacific Biological Station for a period of 106 days (Experiment 1).

Ingredients (g/kg as fed)	Diet[1] A	Diet[1] B
Steam-processed whole herring meal	304.8	255.2
Dried whey	50.0	38.2
Freeze-dried euphausids	40.0	—
Blood flour	—	50.0
Corn distillers dried solubles	40.0	40.0
Soybean meal	—	100.0
Corn starch	28.4	—
Vitamin-mineral supplement	43.5	42.6
Alginate binder (AG-66)	20.0	20.0
Pollock silage[2]	450.0	450.0
Herring oil (stabilized)	18.8	29.5
Vitamin C	1.3	1.3
Choline chloride (60 percent)	3.2	3.2

[1] Sablefish were fed by hand each of the diets to satiation once every second day.

[2] A total of 3 percent (W/W) acid was added to minced whole pollock of which 1.5 percent was concentrated sulfuric acid and 1.5 percent was concentrated formic acid. Also, 200 ppm of liquid ethoxyquin was added to prevent lipid oxidation.

pigmentation was formed and approximately 50 percent of the yolk sac was utilized.

Larval Rearing

Yolk-Sac Larvae

Larvae at the 50 percent yolk-sac stage were transferred from the incubators to 8-L glass battery jars equipped with airlift pumps for circulation, designed after Kinne (1976). These jars were immersed in water baths which regulated the temperature at 6.0 ± 1.0°C. Salinity was maintained at 35 ppt with the addition of sea salts to the ambient seawater (approximately 28 ppt), and light was kept at low levels (1 to 2 klux) on a 16:8 h light:dark photoperiod. Dead larvae and debris were siphoned out of the jars, and ⅓ to ½ of the culture water exchanged daily. Phytoplankton, *Isochrysis* aff. *galbana* Green (Clone T-ISO) and/or *Tetraselmis suecica* Kylin, were added to the culture water to aid in water quality maintenance and serve as a potential first diet for the larvae.

Measurements of total length, notochord length, snout to anal length, and yolk dimensions were made every 3 to 5 days on subsamples of the larvae. A detailed description and photographic record of larval development was made throughout the larval stage.

Feeding

Isochrysis galbana and *Tetraselmis suecica* were cultured in 20-L carboys by the method of Whyte (1987). *Chlorella saccharophila* var. *saccharophila* Kruger also was cultured (SISFFA 1964) as a primary food source for the marine rotifer *Brachionus plicatilis* Muller. Both warm- and cold-water strains of this rotifer were cultured by the methods of Nagata (1985). *Artemia* nauplii also were hatched out from cysts and fortified with lipids and vitamins (Watanabe 1982).

Brachionis plicatilis was provided as the initial major exogenous food source to the sablefish larvae. This rotifer was provided to the larvae from 50 percent to past 100 percent yolk utilization. After this time the larvae were fed on *Artemia* nauplii and/or wild plankton collected by tows. Later stage larvae were also fed on a salmonid diet (P-10), formulated by Higgs et al. (1985).

Early Juvenile Rearing

Captured wild juvenile sablefish 1.5 to 3.2 cm (average 2.0 cm) in length were divided into five groups of 8 fish, and fed at 3, 5, 10, and 20 percent body weight per day. A control group was starved. These fish were originally fed on live *Artemia* nauplii, then weaned onto frozen *Artemia*, frozen euphausids, P-10 diet, and frozen herring, in that order as fish size increased. The experiment was terminated when a length of 60 cm was reached.

Diet Development

Dry Diets

Two dry diet types, (1) a practical dry diet and (2) a purified diet, were formulated. Both diets were high in protein (57 percent) and lipid (17 percent), with a moisture content of 10 to 30 percent. In the practical dry diet, steam-dried herring and walleye pollock meal provided the principal protein sources, while casein and gelatin supplied this in the purified diet. The major lipid source was herring oil in both diets. Later formulations

Table 2. Capture and transport mortalities of larval, juvenile, and adult sablefish.

Stage	Number captured	Onboard mortalities	Transport mortalities	Number remaining
Larvae	117	53	19	45
Juveniles	47	47[1]	—	0
Juveniles	188	103[1]	4	81
Juveniles	30	0	2	28
Juveniles	224	20	84[2]	120
Juveniles	141	7	0	134
Adults	27	0	0	27
Adults	35	0	0	35
Adults	55	0	0	55

[1] Caught together with dogfish or rockfish. [2] Transported to PBS via charter vessel.

of both diets also included whole frozen euphausids in their formulation.

In each feeding trial, 25 juvenile sablefish (about 45 cm in length) were placed into six experimental tanks. Two randomly selected tanks were fed on each of the two test diets, while two control tanks received a diet of chopped raw fish (60 percent herring, 25 percent walleye pollock, and 15 percent squid or shrimp). The fish were fed to satiation every 2 days and the total weight of food consumed was recorded after each feeding. Fish length and weight were measured every 2 weeks for a 4-month period.

Silage Diets

Two silage-based test diets were formulated according to Higgs and McFarlane (personal communication, D.A. Higgs, Dept. of Fisheries and Oceans, West Vancouver, B.C.). Whole minced pollock was treated with a mixture of concentrated sulfuric and nitric acids to a total of 3 percent (W/W). This was combined with two binder formulations to yield test diets A and B (Table 1). A control diet was composed of chopped whole herring (75 percent) and squid (25 percent). Each diet was fed to a test group of 26 sablefish, with a mean weight of about 1,100 g. The fish were fed by hand to satiation every 2 days, over a 106-day test period. Weight of the sablefish was measured four times over the experimental period.

Late Juvenile and Adult Rearing

As part of a study to assess tag loss and tagging mortality and the effects of oxytetracycline on growth, juvenile and adult sablefish were held in a 92,000-L tank after tagging (OTC injection). The fish were fed to satiation twice weekly on a diet of chopped fish, and measurements of length and weight were taken every 3 months for a period of 24 months.

Fish Health

One- to six-year-old sablefish were caught off the west coast of Vancouver Island, as previously described. Immediately after the fish were discharged onto the deck, small tissue samples were excised into at least 10 volumes of Bouins' fluid for fixation. Tissues were embedded, sectioned at 5 micrometers, and processed for histological observations by the methods of Yasutake and Wales (1983).

Energetics

Immature juvenile sablefish weighing approximately 1 kg were caught off the west coast of Vancouver Island, as previously described. The fish were then adapted to captive conditions of 8.5 to 9.5°C and a 12:12 h light:dark photoperiod over a 6-month period, receiving a diet of chopped herring at rations of 50 g every 4, 7, and 14 days. Two control groups were starved for 2 months. Metabolic rates, ammonia excretion, and activity of groups of five fish were measured before, during, and after acclimation to the different feeding regimes. All measurements were carried out in a 4,000-L mass respirometer equipped with an activity meter. Estimates of total metabolism, activity, and feeding rates were coupled with caloric analyses of the food to estimate protein and lipid conversion efficiencies.

RESULTS

Capture and Transport

The mortality rates of larval, juvenile, and adult sablefish resulting from capture and transport are presented in Table 2. Of the 117 larvae held on board for 1–4 days, 53 died on board and 19 died during transport to PBS. Mortalities of sablefish during transport to PBS were low for the juveniles and absent in the adults. However, onboard mortalities were high for juvenile sablefish when caught together with dogfish or rockfish.

Procurement of Gametes

Stripping

Gametes were stripped from a total of four females and eight males in 1986, and three females and five

Table 3. Chronological sequence of major developmental stages of eggs and larvae of Anoplopoma fimbria at 6°C.

Stage or major feature	Time from fertilization (days)
2-cell	0.24[1]
16-cell	0.63[1]
64-cell	0.96[1]
Germ ring formed	3.5
Yolk plug closure	6.5
Heart beating	11.5
Beginning of hatch	12.4
50 percent hatch	13.4
Eye pigmentation	20.4
Pigmentation of alimentary canal	25.0
50 percent yolk-sac utilization	29.0
Pigmentation of head and nape of neck	30.0
Algal cells in gut	32.0
Ingestion of rotifers	37.0
100 percent yolk-sac utilization	57.0
Ingestion of *Artemia*	58.0

[1] From Alderdice et al. 1988.

males in 1987, and transported to the Pacific Biological Station. Females ranged in length from 65 to 98 cm, while males ranged from 57 to 73 cm in length. Approximately 100,000 to 200,000 eggs were obtained from each female. Transport time to PBS from time of stripping ranged from 24 to 30 h. Bad weather during the spawning period and the high cost of boat charters appear to be the greatest barriers to obtaining gametes by this method. Also the period during which sablefish eggs show maximum fertilizability is extremely short, placing further constraints on the sampling period.

Induction

A total of 30 fish in 1986 and 29 fish (19 in Experiment 1, and 10 in Experiment 2) in 1987 received hormonal injections, as described previously. In 1986, seven (23 percent) fish were males which spermiated prior to injection, twelve (40 percent) were females which ovulated after one injection, three (10 percent) were females which ovulated after a second injection, and eight (27 percent) neither ovulated nor spermiated (Solar et al. 1987). No ovulation occurred in the control fish, which did not receive hormonal treatment.

In 1987 (Experiment 1), six fish (32 percent) were males which spermiated independent of injection, seven (36 percent) were females which ovulated within one week of injection, and six (32 percent) neither ovulated nor spermiated (Solar, personal communication). In the second experiment, seven out of ten injected fish ovulated within 1 to 3 weeks. None of the eggs obtained in the 1986 trials survived past the late blastoderm cap stage (42 h). In 1987, one out of twelve test fertilizations from Experiment 1, and three out of ten test fertilizations from Experiment 2, resulted in successful hatching. However, due to the limited capacity of the egg incubation system, it was not possible to incubate all the eggs from successful fertilizations. Therefore, it is probable that some of the remaining eggs could have been successfully hatched.

Fertilization and Egg Incubation

Results of fertilization and egg incubation of both wild and induced gametes are reported by Alderdice et al. (1988, in press). In summary, fertilization success for gametes from stripped wild adults was 67 to 90 percent. Fertilization success for induced gametes was 0 to 24 percent in 1986, and in 1987 was 72 percent. After 48 h of storage at 3°C, gametes appear to lose 50 percent of their fertilization potential. Maximum survival of fertilized eggs to hatching was 24 percent. Most egg mortality (61 percent) occurred during the first 6 days of incubation, prior to yolk-plug closure. The eggs were also found to be very fragile with a bursting pressure of 1 to 2 g. Complex changes in egg density were also found to occur throughout development (Alderdice et al. 1988). Initially, neutral buoyancy of the eggs was approximately 32.5 ppt, which increased gradually to 34 ppt. Just prior to hatching (24 h) there was a substantial increase in density to over 37 ppt. At incubation temperatures ranging from 4 to 6°C, hatching occurred in 12 to 15 days. Table 3 shows the time from fertilization for various stages of egg and larval development.

Larval Rearing

Table 3 also lists major developmental features of sablefish larvae in a temporal sequence from time of hatching until full yolk-sac utilization, at 6.0°C, while Figure 2a-f shows a photographic record of these major developmental events. Yolk-sac larvae ranged from 4.2 to 5.8 mm at hatching. The embryo floats head down suspended under the yolk-sac near the surface of the water column. Newly hatched larvae were extremely primitive with the mouth unformed and nonfunctional, and possessed no pigmentation on the head and body. Eye pigmentation was observed 6 days after hatching, followed, respectively, by alimentary canal, head, and body pigmentation at 5-day intervals.

Algae were first observed in the larval guts 19 days after hatching, while ingestion of rotifers was first observed 24 days after hatching. *Artemia* were first ingested 45 days after hatching. Both the rotifers and *Artemia* nauplii were readily attacked by the larvae from an S shaped striking curve, as described by Rosenthal (1969) for larvae of the herring *Clupea harengus* L.

Growth of post-hatch larvae was linear throughout the yolk-sac stage. Larvae reared at 4.5, 6.0, and 7.5°C increased in length approximately 0.90, 1.03, and 1.17

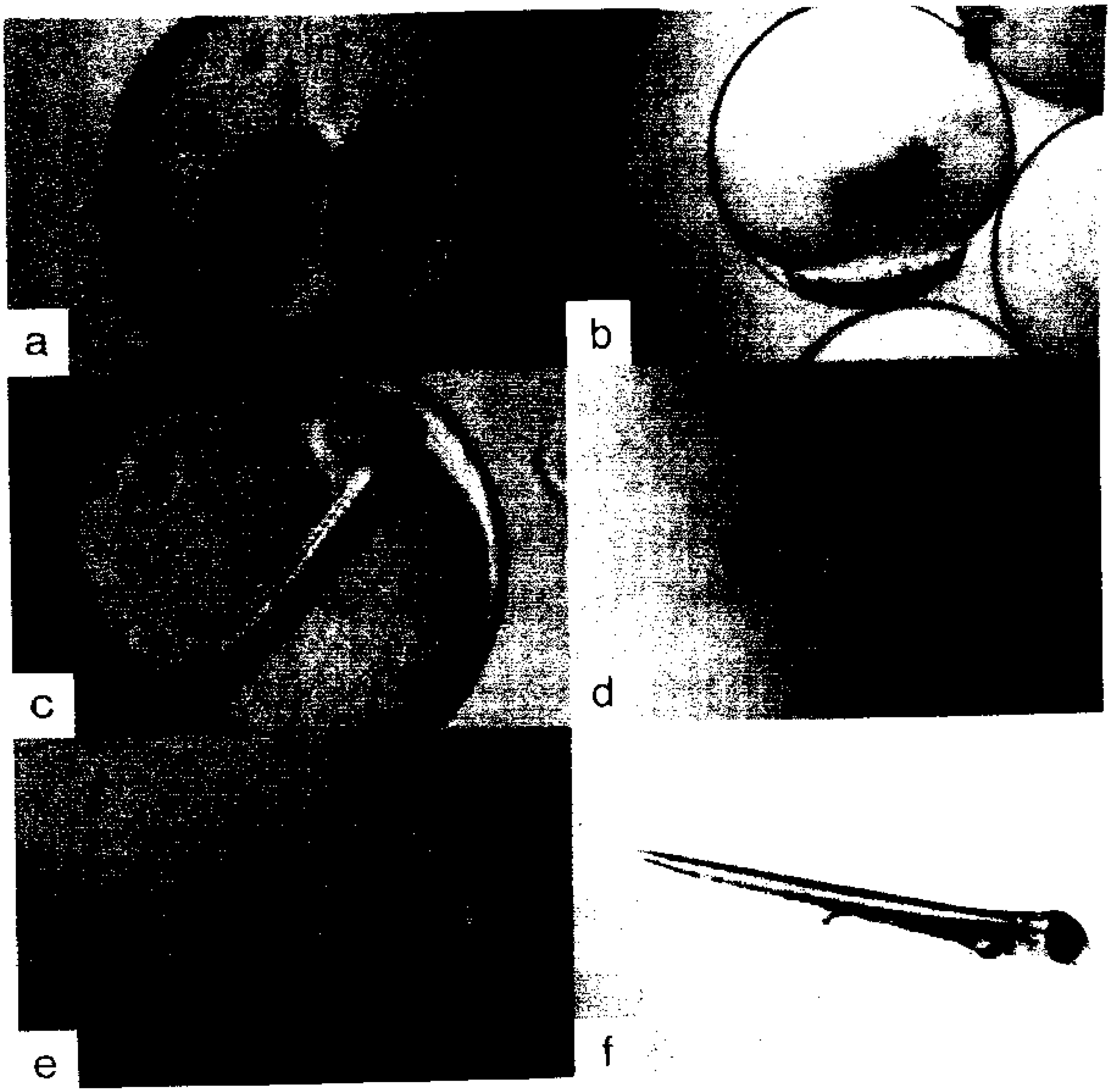


Figure 2. Developmental stages of (*Anoplopoma fimbria*) larvae from hatching to the early post-larval stage. (a) Two-cell stage. (b) Late morula stage. (c) Yolk-plug closure. (d) Newly hatched (note head still on yolk; no pigmentation, mouth not functioning). (e) Half yolk-sac utilization (note pigmentation of eyes and alimentary canal). (f) Full yolk-sac utilization (note heavy pigmentation, functional mouth and rotifers in gut).

percent per day, respectively. Figure 3 shows a typical growth curve of sablefish larvae from hatching to full yolk-sac utilization at 6°C. In the 1987 experiments, growth was greatly reduced after a length of 12 mm was attained; and all larvae died during the post-larval stage (40 to 70 days from hatching). The cause of mortality is not known. Future experiments are designed to examine more closely the nutritional requirements of the larvae at this stage.

Figure 4 shows the effect of ration on the growth and survival of sablefish larvae through yolk-sac utilization. Although all experimental groups exhibited similar growth curves (Figure 4, length), a definite ration dependence is seen in the survivorship curves. A ration of 10 to 20 rotifers per ml appears to be an optimal level for feeding larvae during this stage.

Juvenile Rearing

Early juvenile captive sablefish, fed at five ration levels, exhibited wide variations in growth in both length and weight (Figures 5a and 5b). Starved fish died within 2 to 16 days. Growth of the four experimental groups was directly related to ration level. The best growth rate

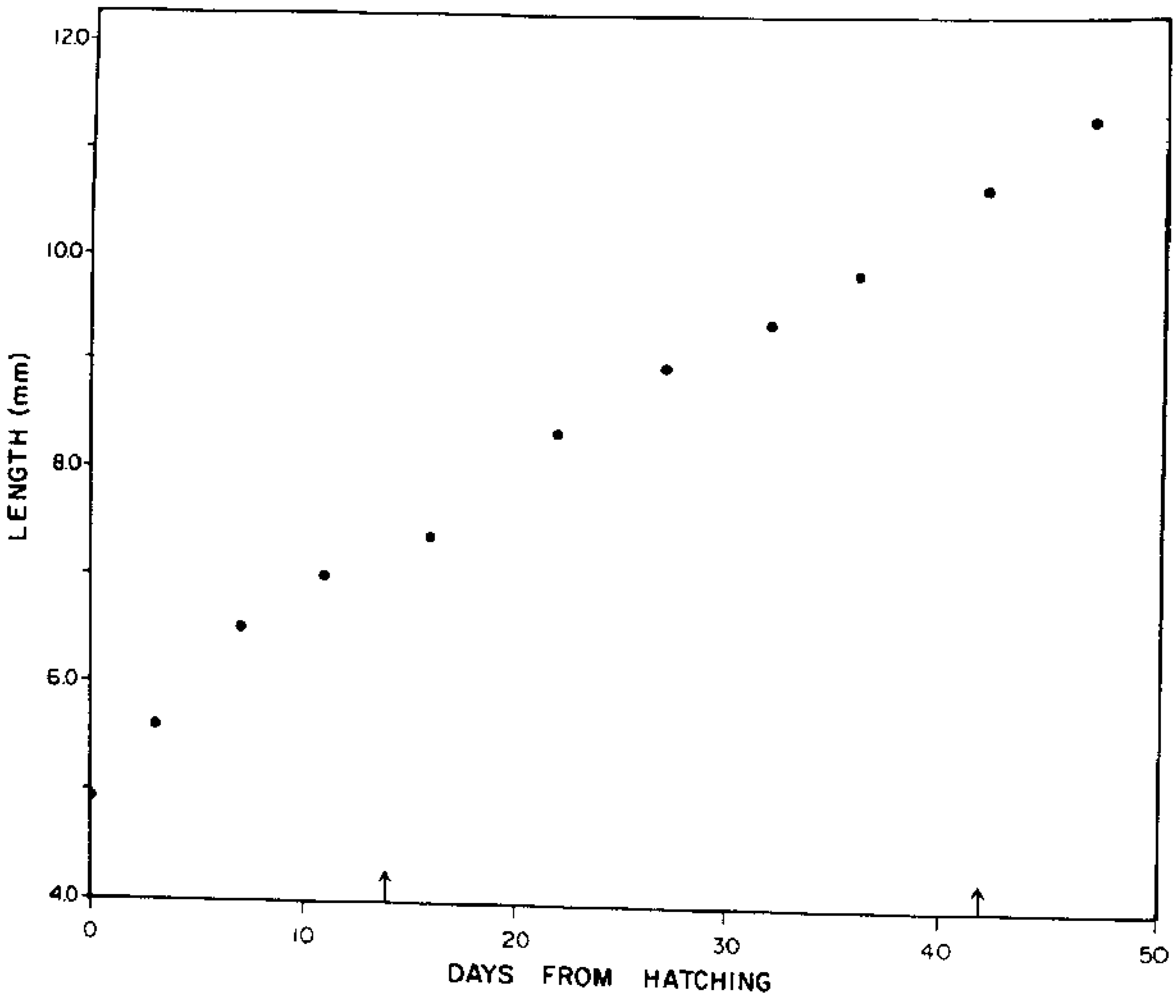


Figure 3. Growth curve of (*Anoplopoma fimbria*) larvae from hatching to the post-larval stage at 6°C. Arrows indicate 50 percent and 100 percent yolk-sac resorption, respectively.

was achieved at a ration level of 10 percent (dry weight food divided by dry body weight). Figure 6 shows the relative body size of fish from the four ration levels after 6 months of rearing.

Diet Development

Dry Diets

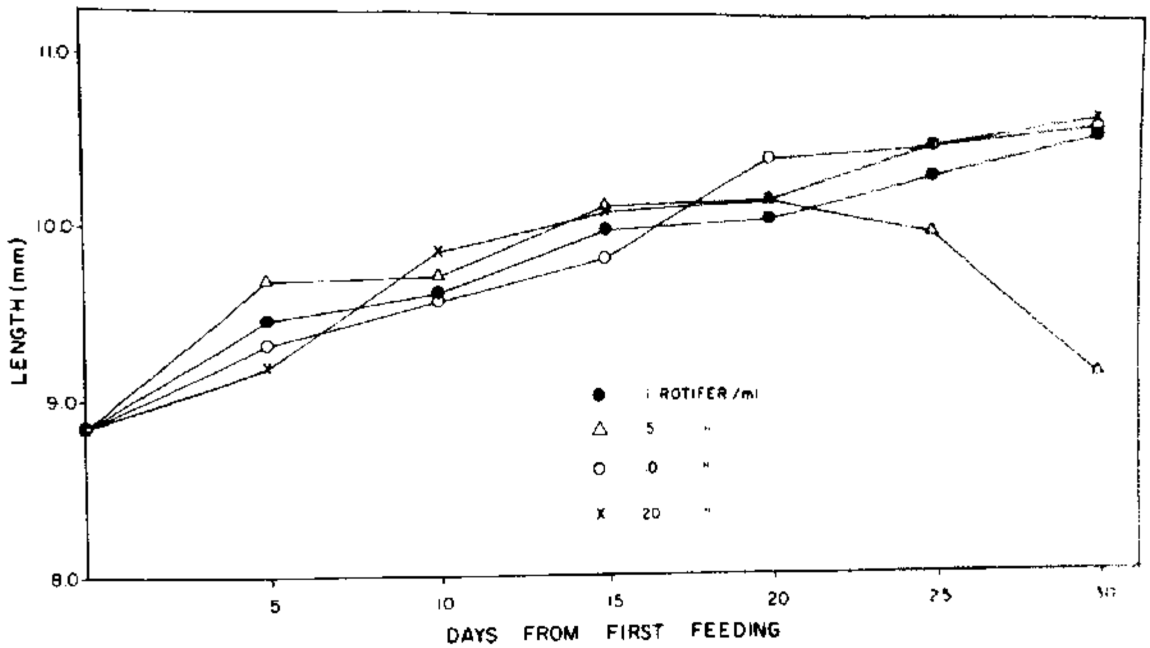
Growth in weight of juvenile sablefish fed the dry diets was greatly reduced compared to fish fed the control diet (Figure 7). This reduced growth was a reflection of the acceptability of the diets. Following 10 weeks of initial feeding, moisture content of the diets was increased from 10 to 20 percent. Introduction of higher moisture content diets resulted in increased growth rates of the experimental fish to a rate almost identical to that of the control fish.

Silage diets

Sablefish fed the silage diets also initially exhibited reduced growth rates when compared to fish fed on the control diet (Figure 8). After 4 weeks, the experimental groups accepted the silage diets, and their rates of growth became similar to those of the control fish.

Late Juvenile and Adult Rearing

Large juvenile and adult sablefish reared for a period of 24 months also exhibited accelerated growth when compared to wild fish (McFarlane and Beamish 1983) (Figure 9). Fish increased in length from 48 to 72 cm, with a corresponding weight increase of 1.6 to 4.8 kg over the 24 month period. This is four to five times the growth rate of similar-sized wild fish.



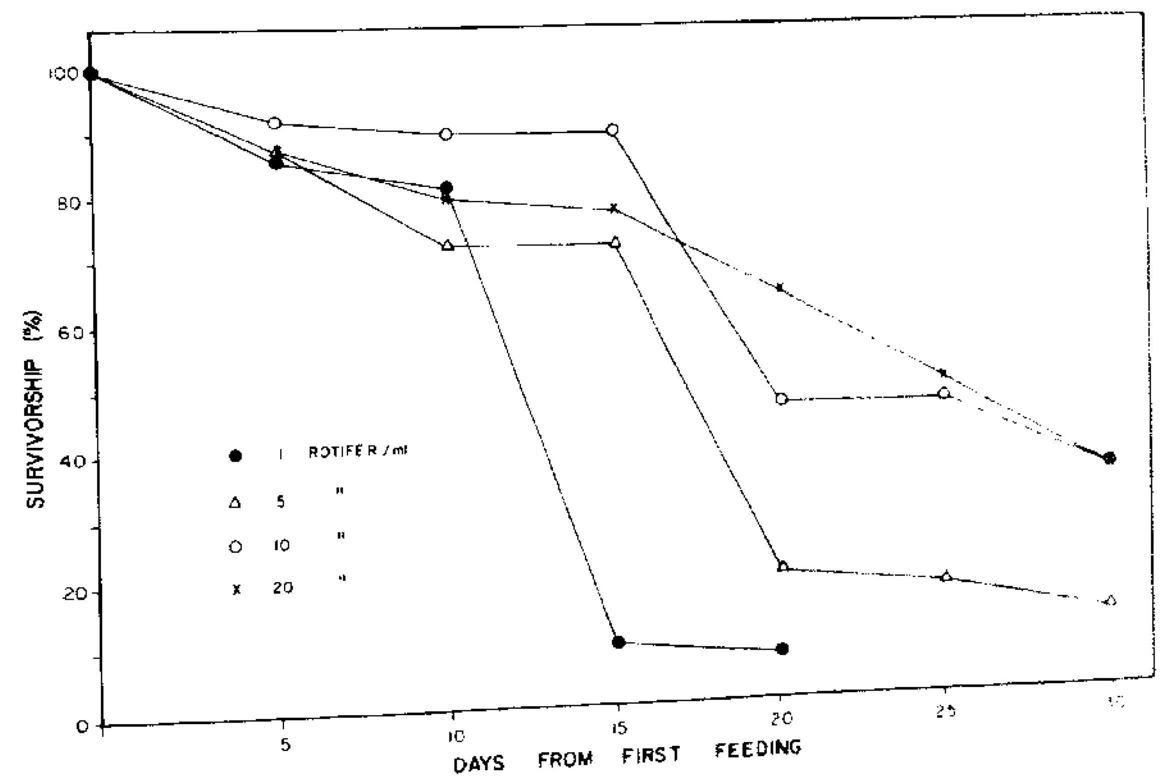


Figure 4. Growth (length) and survivorship curves of (*Anoplopoma fimbria*) larvae from first feeding to the post-larval stage at various ration levels.

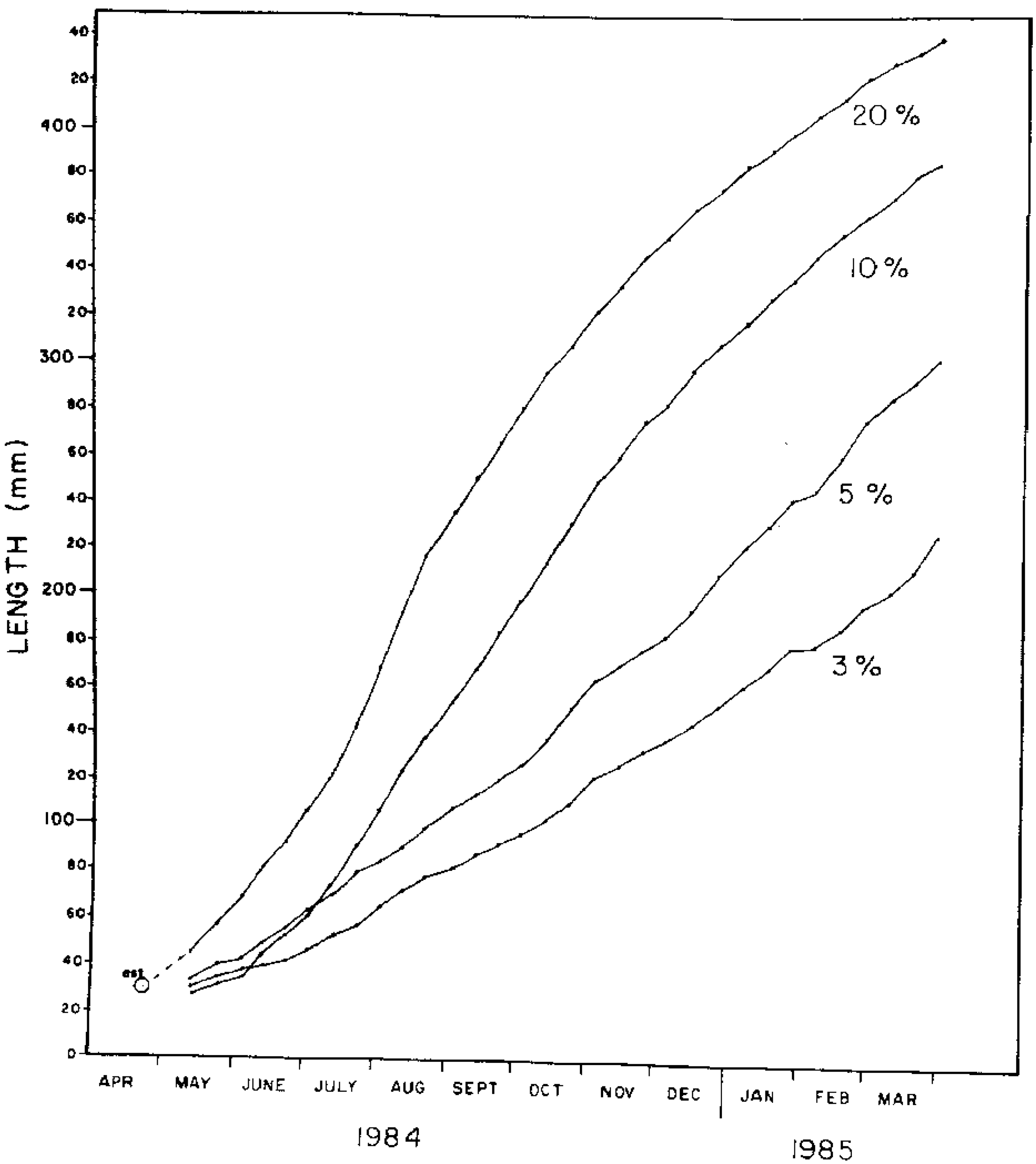


Figure 5a. Growth of captive juvenile sablefish in length fed at various ration levels.

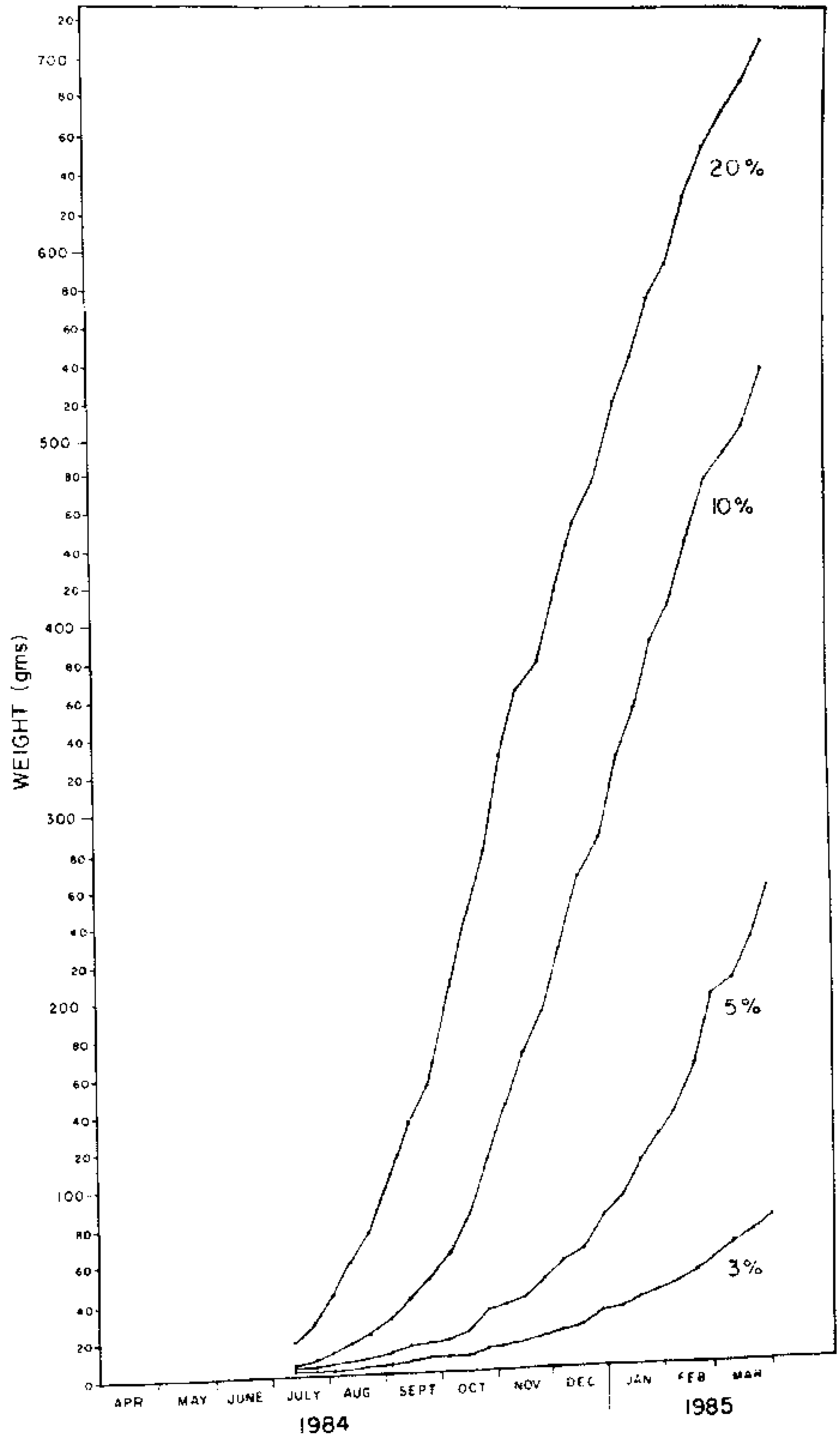


Figure 5b. Growth of captive juvenile sablefish in weight fed at various ration levels.

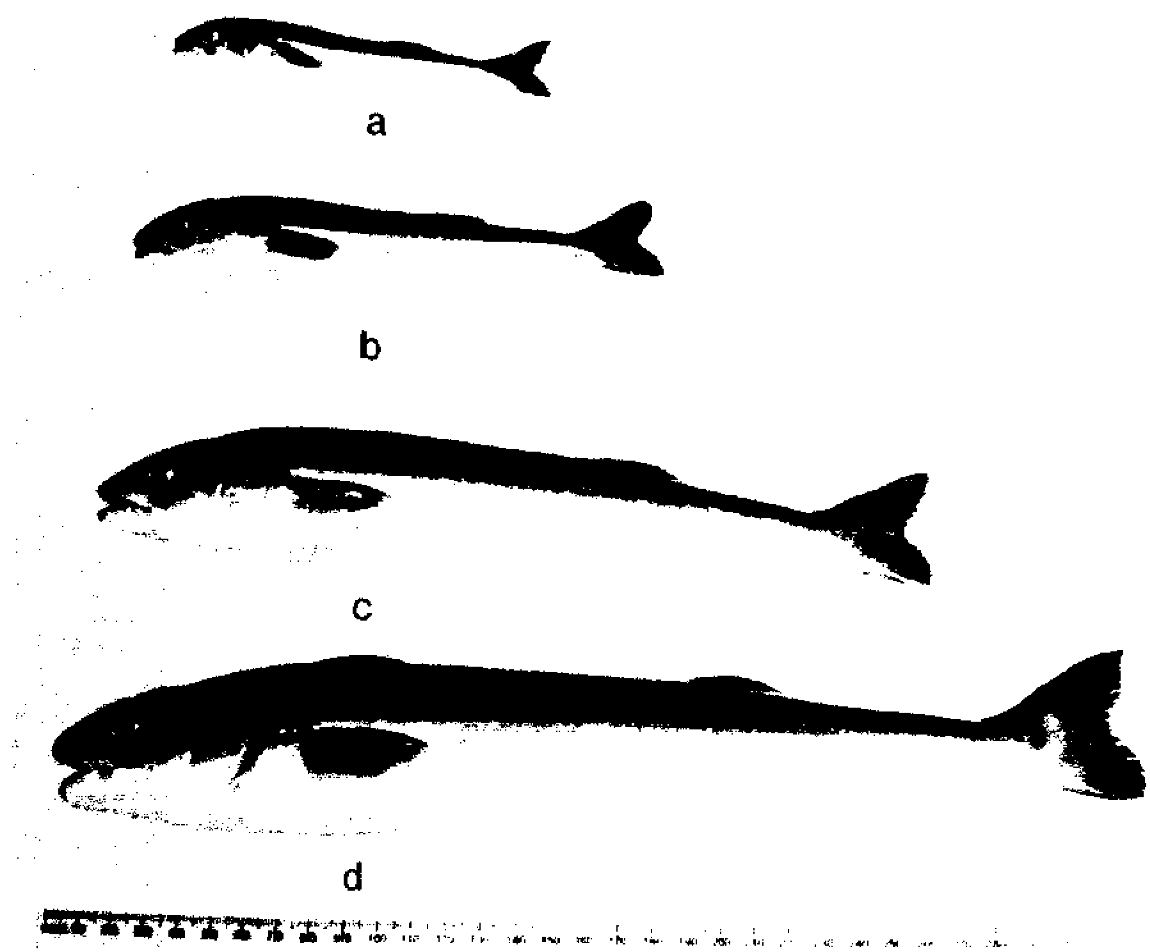


Figure 6. Variation in body size of captive juvenile sablefish fed at various ration levels. (a) = 3 percent; (b) = 5 percent; (c) = 10 percent, (d) = 20 percent (expressed as percentage of dry body weight).

Fish Health

A compiled atlas of sablefish histology has been published by Bell et al. (1986). This atlas contains concise histological plates of all soft tissues of adult sablefish. Thus, an excellent reference guide of histology prepared from healthy wild sablefish is available for future studies on pathology of this species.

Energetics

It was found that swimming energy expenditures and standard metabolism are sigmoid functions of ration frequency. The lowest metabolic rates were associated with the most frequent meals. At the most frequent meal interval (i.e., 4 days) conversion efficiency on a caloric basis was 30 percent for proteins and 98 percent for lipids. Trends indicated that greater protein conversion efficiency could be expected with more frequent feeding.

When the fish were spontaneously active in the respirometer, the activity component of metabolism was generally less than 25 percent of the standard metabolic rate. When swimming spontaneously, the sablefish moved at a single, probably optimal velocity regardless of ration history. Fish in the experiments were active most of the day despite the low contribution of the activity component to total metabolism.

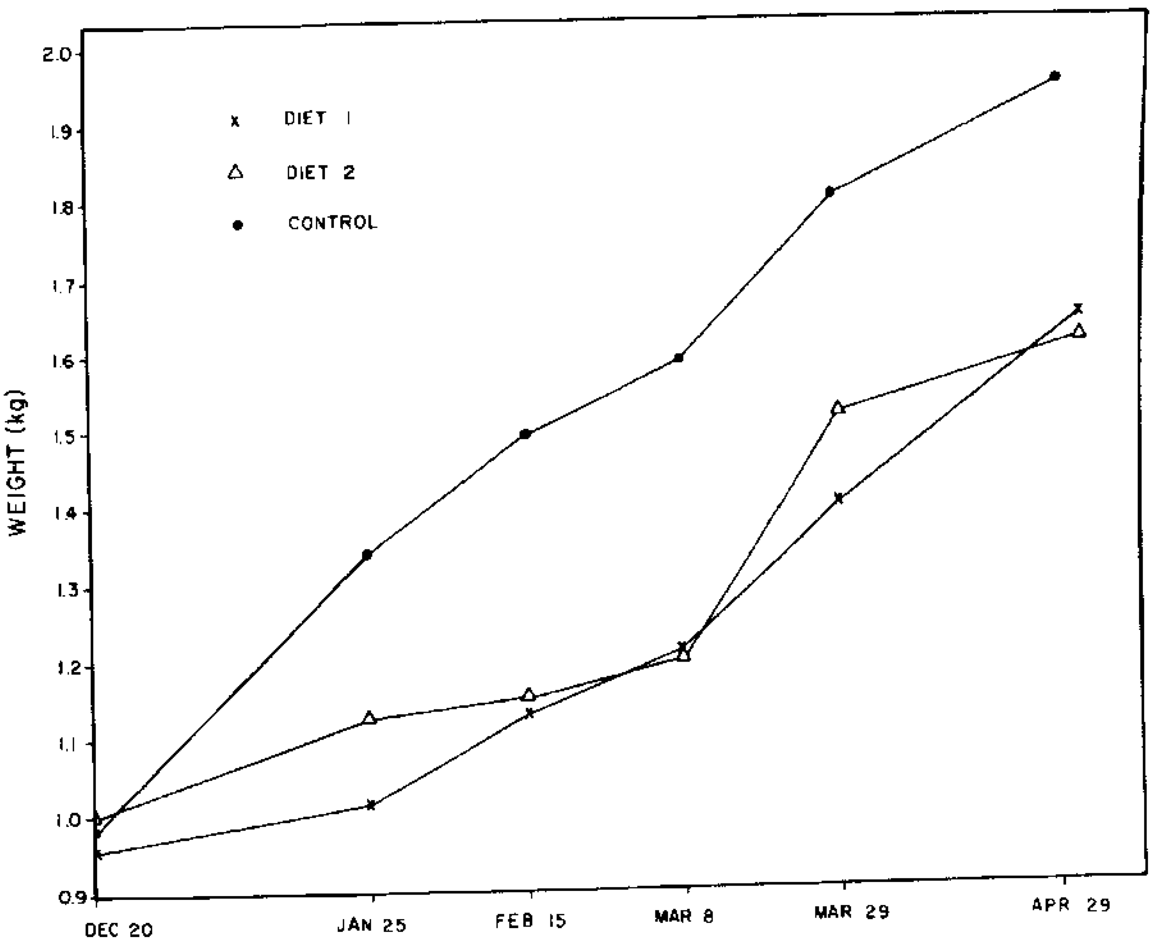


Figure 7. Growth in weight of adult sablefish fed on formulated dry diets. Diet 1 = practical dry diet; Diet 2 = purified dry diet. Control = minced fish.

DISCUSSION

In this paper we have presented an overview of sablefish mariculture studies currently under way at the Pacific Biological Station. Success has been achieved in a number of areas: developing techniques for the capture and transport of all life history stages of sablefish, including procurement of gametes from the field; developing techniques for induced ovulation and spermiation of sablefish using hormonal treatments; developing fertilization and incubation techniques for both wild and induced gametes; determining optimal salinity and temperature conditions for incubation of eggs and yolk-sac larvae; and determining food organisms, their particle sizes and densities, and time of presentation, that are required to bring larvae successfully to the post-larval stage. In addition, studies have also focused on optimum growth conditions for post-larval and juvenile sablefish; determining nutritional requirements and development of diets for juvenile and adult sablefish; and determining baseline fish health data from wild stocks to assist in the recognition of disease problems that could occur during rearing.

The results from the energetics study indicate that sablefish have excellent food conversion capabilities, even on modest diets. They also appear to have an adaptable physiology which is plastic enough to compensate for the changing metabolic needs associated with a variable food supply.

In our opinion, the biological feasibility of sablefish mariculture has been demonstrated by the results of these studies. Prior to the establishment of commercial scale farms, further research will be directed to some critical areas. First, the determination of the nutritional requirements of post-larval sablefish and the development of diets to successfully rear larvae through this stage will be a priority in future rearing trials. Wild post-larvae were successfully reared to adults with little mortality;

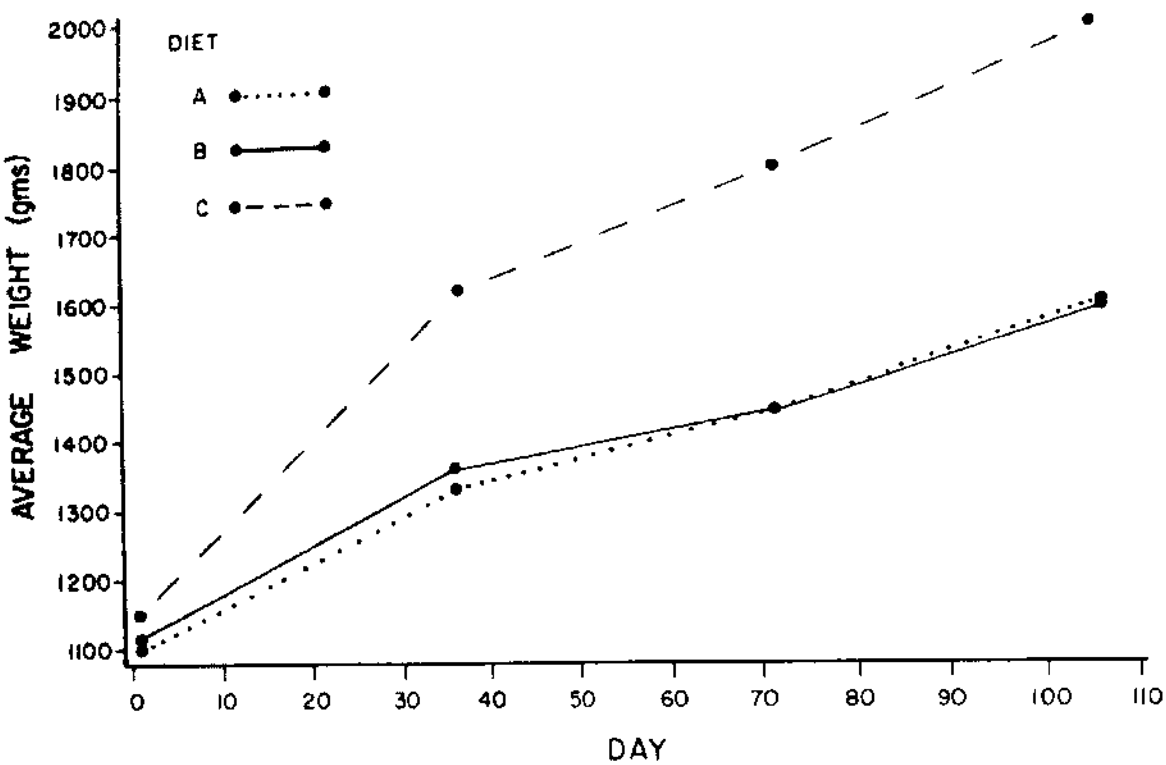


Figure 1. Growth in weight of adult sablefish fed on formulated silage-based diets. Diets A and B are silage; C is a control.

however, cultured post-larvae all died within 1 to 4 weeks following full yolk-sac resorption. Second, modification of incubators and rearing tanks to accommodate larger numbers of eggs and larvae will be essential for the scale-up to commercial production. Third, further development of brood stock techniques will preclude the necessity of capturing and transporting adult fish for gamete production. This would also eliminate the need for the costly process of gamete stripping in the field.

In addition to the biological requirements outlined in this paper, development of sablefish mariculture methodology at the commercial level will be required. For example, developmental requirements such as: site selection (i.e., criteria for), farm technology, on-site handling, predator control, feeding schedules, food supply, transport (supplies and product), fish health, etc., must all be considered prior to establishment of a commercial farm operation.

Last, the economics of sablefish mariculture have not been addressed to date. Although it is beyond the scope of this paper to undertake economic and marketing analyses, we feel a few points are pertinent to review here. Rearing wild-caught juveniles in the late 1960s and early 1970s, Kennedy (1972, 1974) concluded that sablefish were biologically suitable for farming. However, he pointed out that the market value of sablefish at that time made such a venture uneconomical.

With the advent of the 200-mile fishery conservation zones and subsequent quotas on commercially caught sablefish, market prices have increased substantially. Today, most sablefish are marketed in Japan as a dressed frozen product. At present, the demand for quality sablefish is greater than the supply, which is directly reflected in the price increases of recent years. Since commercially caught sablefish are under quota, it is doubtful that the increasing demand for this product can be met by the commercial fishery.

Preliminary studies (J. Richards and Barkley Sea Farms, personal communication) indicate that, at current ex vessel prices, sablefish farming is economically attractive. This is particularly true since farmed fish of other species yield a premium price (approximately 40 percent more than wild fish) in the market place. In addition, new domestic markets would increase the value placed on a steady supply of fresh fish of uniform size and quality.

In summary, sablefish mariculture has the potential of becoming a valuable new industry. We anticipate that the biological constraints will be resolved within 2 years, and that the transfer of the necessary technology to industry will follow immediately.

ACKNOWLEDGMENTS

Many people participated in the various components of this study. In particular we thank Dr. E.M. Donaldson

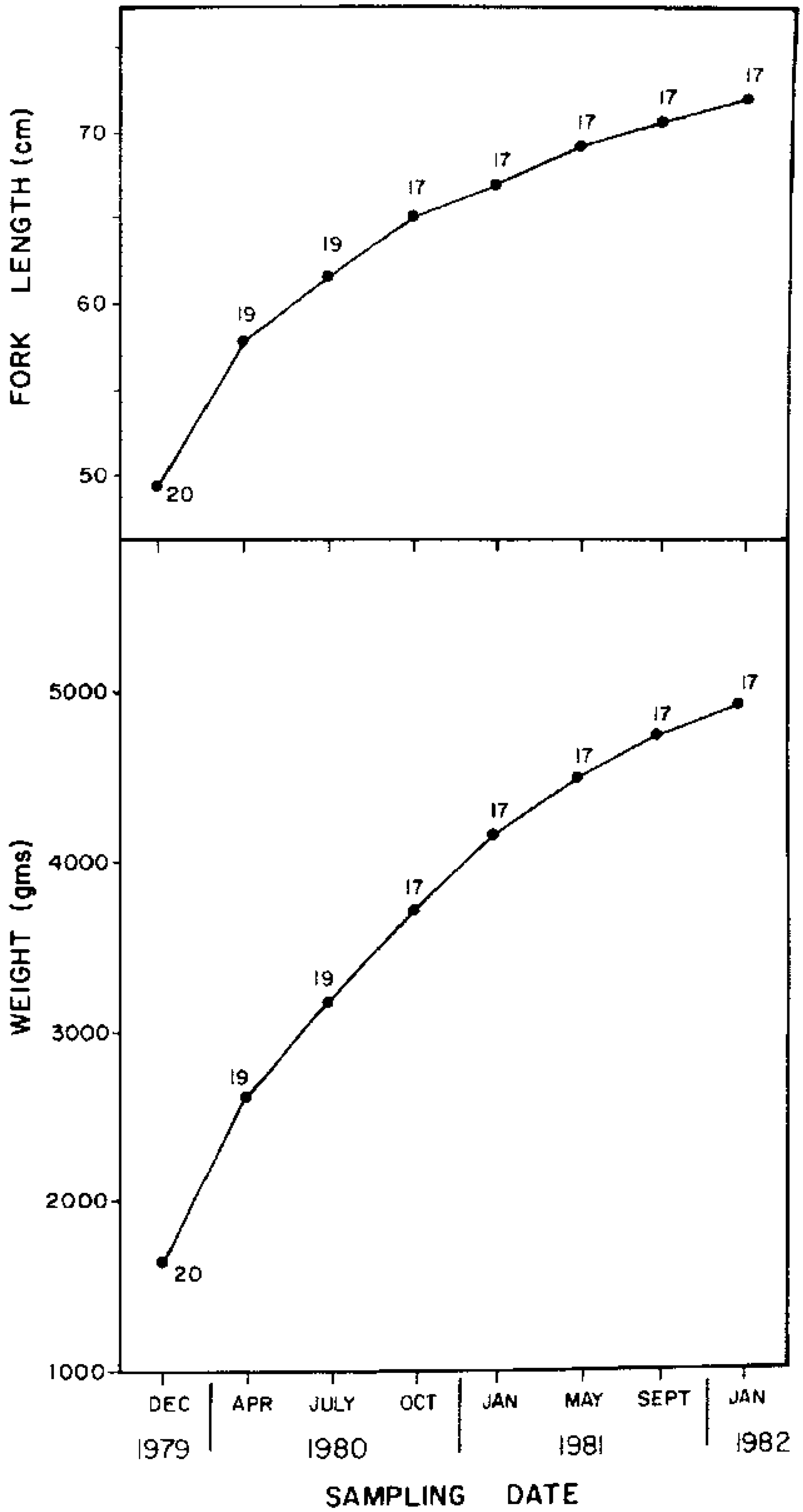


Figure 9. Growth of captive late juvenile and adult sablefish in length and weight over a 24-month period.

and I. Solar, who allowed us to present information on their 1987 induction studies; Dr. D.F. Alderdice, J.O.T. Jensen, and F.J. Velsen, for recent information on gamete fertilization and egg incubation; Dr. D.A. Higgs for information on diet development; and Dr. D. Furnell for information from his energetics studies. We also thank W.T. Andrews, R. Scarsbrook, and M.S. Smith for their participation in the capture and transport and larval rearing studies.

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NUTRITIONAL REQUIREMENTS OF FARMED FINFISH

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HISTORY

Nutrition of farmed finfish is a very young field of study; worldwide there are fewer than 250 active researchers in this area. The first reported nutrition study was done by Embody (1918). He fed diets of only vegetable or animal meals to trout, and the trout died. Vitamins were being discovered at that time, and Embody concluded that the problem with these types of feeds must be their lack of vitamins.

In the 1920s, the main feeds for hatchery-reared fish were what we call wet feeds. These contained slaughterhouse by-products, cottage cheese, or anything available. The fish were fed wet, milky, small-particle feeds with high levels of suspended material in the rearing water. It was very poor quality feed by today's standards, but it did grow fish.

In the 1930s hatchery production increased and the supply of locally available slaughterhouse by-products could not meet the needs of hatchery production. Consequently, fish farmers extended the wet feed with dry soybean meal or cottonseed meal. The farmers mixed them together, dropped them into a fan, and then fed the particles. This was the standard fare for many years.

In 1947 McLaren et al. in Wisconsin developed the first semi-purified diet to which researchers could add or delete individual nutrients. A semi-purified diet is a diet made of highly refined ingredients. Unfortunately, in 1947 the refining techniques used to manufacture these materials were insufficient to make them completely nutrient free. Nevertheless, this was the first approach to scientific fish feeding.

Grassl (1956) was the first to feed a dry pelleted diet. He was able to feed the diet to his fish for seven months. However, he still had to feed once a week with chopped liver to avoid nutritional deficiencies.

Halver (1957) developed the first complete semi-purified diet. This was a major breakthrough and the test diet has been the foundation of nutritional work with fish feeds. Nearly everything we know about nutrient requirements of fish has been discovered in the last 30 years.

The Oregon moist pellet was a major milestone in practical hatchery rearing and feed development. The Oregon moist pellet was developed primarily to eradicate fish tuberculosis. Before its development in the late 1950s, hatcheries fed diets containing chopped, frozen salmon from the previous year's spawners. Unbeknownst to them, they were perpetuating a disease called fish tuberculosis.

The Oregon moist pellet (Table 1) contained pasteurized fish waste and was made by centralized manufacturers, which took fish diet production out of the hatcheries for the first time. This gave all hatchery-reared fish the same diet and created the foundation for the tremendous boom in hatcheries that occurred in the 1960s and 1970s.

A successful dry diet was developed later by Phillips et al. (1964). In the 1970s, the major event in practical fish feeding was the development of dry extruded diets. These diets were made by an extrusion process that results in a pellet that will float or slowly sink. In 1971 the Abernathy dry diet (Table 2) was developed for salmon (Fowler and Burrows 1971).

FEED REQUIREMENTS

Embody and Gordon (1924) were the first to publish the results of a study on fish nutrition. They caught wild trout and examined the stomach contents. They counted the insects in the stomachs and calculated the proportions of insect groups. Embody and Gordon calculated the proximate composition of the wild trout diet to be: protein 49 percent, fat 15-16 percent, fiber 8 percent, and ash 10 percent. It is interesting that this is very similar to the proximate composition of feeds used today.

Fish require the following nutrients:

1. Ten essential amino acids.
2. A group of lipids called omega-3 fatty acids.
3. Dietary energy, which determines the amount of food they eat.
4. Fourteen essential vitamins.
5. Approximately 10 minerals in their diet. These requirements vary under different conditions; fish can obtain certain minerals from the water in which they are reared.
6. Carotenoid pigments, apparently in very low levels. These pigments produce the flesh and egg color in salmon, but the biological role is not clearly understood.

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Table 1. Oregon moist pellet specifications.

Ingredients	Mash	OP-4	OP-2
Herring meal	49.9	47.5	28.0
Wheat germ meal	10.0	remainder	remainder
Cottonseed meal (48.8% Pro)	—	—	15.0
Dried whey	8.0	4.0	5.0
Corn dis. dried solids	---	—	4.0
Sodium bentonite	—	3.0	--
Trace mineral pre-mix	0.1	0.1	0.1
Vitamin pre-mix	1.5	1.5	1.5
Choline Chloride (70%)	0.5	0.5	0.5
Wet fish hydrolysate	20.0	30.0	30.0
Fish oil	10.0	7.0	6.75

Table 2. Abernathy dry salmon diet specifications.

Ingredients	Percent in Diet		
	Starter	Crumble	Pellets
Herring meal	58	55	50
Dried whey	5	5	5
Blood flour	10	10	10
Condensed fish solubles or poultry byproduct meal	3	3	3
Wheat germ meal	—	5	5
Wheat mids, mill-run, or shorts	remainder	remainder	remainder
Vitamin pre-mix	1.5	1.5	1.5
Choline chloride (60%)	0.58	0.58	0.58
Ascorbic acid	0.1	0.1	0.1
Trace mineral pre-mix	0.05	0.05	0.05
Lignon sulfonate (binder)	2.0	2.0	2.0
Fish oil or soybean lecithin (max. 2%)	12.0	9.0	9.0

Protein

The protein requirement is a highly variable entity, but it basically is an amino acid requirement (Table 3). Juveniles require less protein than fry, and post-juveniles require even less (Table 4).

Fatty Acids

Fatty acids that are essential for salmon have a double bond at the 3 position counting from the omega end. The non-essential fatty acids do not have a double bond at the 3 position. Individual fatty acids are written in shorthand as C14:0 or C18:2, for example. The first number is the carbon count in the fatty acid and the second number is the double bond count in the molecule.

Herring oil is the standard lipid used in salmon diets and contains about 12 percent omega-3 fatty acids. Salmon oil has 23 percent omega-3 fatty acids. Menhaden is a good source of omega-3 fatty acids, with 31 percent. Pollock would be a good source of oil for use in salmon diets.

The quantitative requirement for essential fatty acids in fish diets is not clear. The tentative requirement was established by feeding very highly purified esters, which are single fatty acids. The oils fed to fish are fed as triglycerides, which are three fatty acids joined together with a glycerol molecule. Apparently, triglycerides and free fatty acids may have differing nutritional value. In other words, feeding a diet containing highly refined esters produces different results from a diet containing triglycerides with the same fatty acid profile in oils. When esters are used, the requirement for omega-3 fatty acids is about one percent of the diet.

Energy

Energy can be derived from dietary protein, fat, or carbohydrates. Generally diets are formulated so that energy comes from lipids or carbohydrates rather than protein. Since protein is expensive, we prefer that dietary protein is used for tissue growth by the fish.

Gross energy is the total energy in the diet (Figure 1). In animals, a certain amount is excreted in the feces, in the urine, and through the gills. What we're left with after that loss is called metabolizable energy. There is a small loss for metabolism, and we are left with net energy. That is what we have to work with to support standard basal metabolism, voluntary activity, growth, and reproduction. Roughly 65-75 percent of the gross

Table 3. Essential amino acids for salmonids.

Amino acid	Dietary requirement: % of diet	Dietary requirement: % of protein in diet
Arginine	2.4	6.0
Histidine	0.7	1.8
Isoleucine	0.9	2.2
Leucine	1.6	3.9
Lysine	2.0	5.0
Methionine[1]	1.6	4.0
Phenylalanine[2]	2.1	6.0
Threonine	0.9	2.2
Tryptophan	0.2	0.5
Valine	1.3	3.2

[1] Without cysteine.
[2] Without tyrosine.

Table 4. Dietary protein requirement of salmonids.

Stage of rearing	Dietary protein (%)
Fry	48-52
Juvenile (up to smolt)	44-48
Post-juvenile (in seawater)	42-45
Maturing salmon	45

dietary energy is available as net energy, and of that approximately half is available for growth and reproduction.

A different way of looking at energy balance is to consider feeding level versus energy level. The maintenance feeding level is a level at which fish receive enough energy to stay alive and maintain weight. Below maintenance feeding level, fish lose weight, and above that level fish gain weight. At a normal feeding level, the energy used for growth and sexual reproduction (in reproductively mature fish) is about 35-40 percent of the net energy.

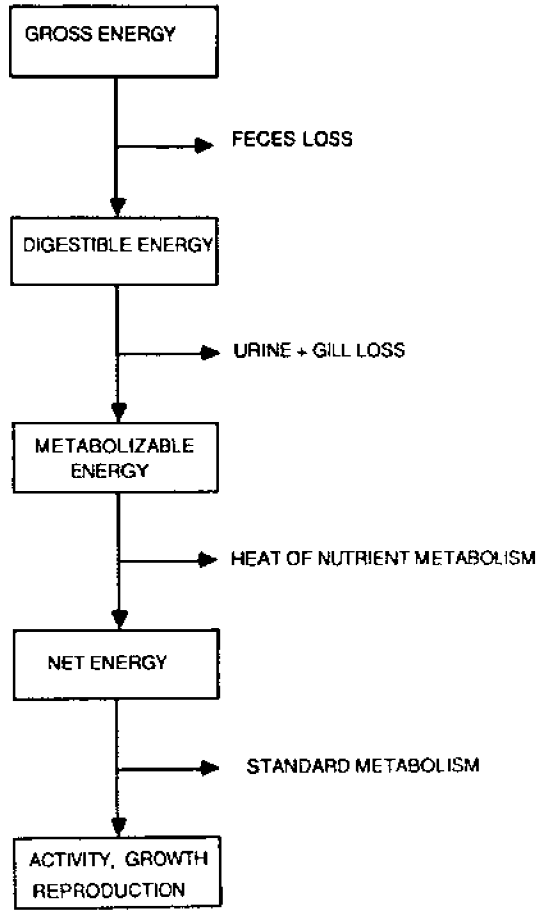

Figure 1. Fate of dietary energy in fish.

Vitamins

The primary functions of the required vitamins in fish are the same as their functions in other animals (Table 5). For the most part, B vitamins are required for metabolism of carbohydrates, fats, and amino acids, and the fat-soluble vitamins A, D, and K have other specific metabolic functions. Ascorbic acid, or vitamin C, is required by fish. Inositol and choline are structural components of tissue, and folic acid is required for specific metabolic reactions.

The deficiency signs of these vitamins in fish reflect their role in metabolism. When the fish are fed a vitamin-deficient diet, the first observable change is reduced growth. This sign is nonspecific and thus of little use in determining which vitamin is deficient in the diet. Some vitamins have specific deficiency signs (Table 6). Thiamin deficiency causes convulsive behavior or hyperirritability, because neurological tissue is affected. On the other hand, a vitamin B_{12} deficiency does not show specific clinical signs.

When practical diets are made, a pre-mix is added to more than satisfy the National Research Council (NRC) recommended levels of essential vitamins for salmonids (Table 7). With few exceptions, all of the levels are higher than NRC recommendations. Since the recommendations were made six years ago, research has been conducted to show that the recommended level of riboflavin is too high. Rarely in commercial production diets do we encounter a vitamin deficiency. However, vitamin deficiencies are sometimes seen in feeds made by fish farmers on site.

In fish feeds, some vitamins are more stable than others (Table 8). Alpha-tocopherol (vitamin E) and vitamin C are the main vitamins that are lost during manufacture and storage in most commercial feed. Thiamin can be destroyed by the enzyme thiaminase, which often is present in diets made from fish.

Table 5. Primary functions of vitamins.

Vitamin	Primary function
Vitamin A	Vision, normal skin
Vitamin D_3	Calcium metabolism, bone formation
Vitamin E	Maintain cell membranes
Vitamin K	Blood clotting
Thiamin	Cell metabolism of carbohydrates
Riboflavin	Cell metabolism of carbohydrates, fats, amino acids
Pyridoxine	Cell metabolism of amino acids
Pantothenic acid	Cell metabolism of carbohydrates, fats, amino acids
Niacin	Cell metabolism of carbohydrates, fats, amino acids
Biotin	Cell metabolism of carbohydrates, fats, amino acids
Vitamin B_{12}	Cell synthesis of nucleotides
Ascorbic acid	Needed for collagen synthesis, many other things
Myo-inositol	Structural component of cell membranes
Folic acid	Cell synthesis of nucleotides
Choline	Structural component of cell membrane

Table 6. Vitamin deficiency signs in salmonids.

	Primary deficiency signs	
Vitamin	Poor appetite & growth	Other
Vitamin A	Yes	Eye problems (pop-eye)
Vitamin D	Yes	Weak bones
Vitamin E	Yes	Anemia, ascites, death
Vitamin K	No	Anemia, prolonged blood clotting
Thiamin	Yes	Hyperirritability, convulsions
Riboflavin	Yes	Lens cataract
Pyridoxine	Yes	Convulsions, erratic swimming
Pantothenic acid	Yes	Clubbed gills
Niacin	Yes	Skin lesions
Biotin	Yes	?
Folic acid	Yes	Blood cell disorders
Vitamin B_{12}	No	Anemia
Myo-inositol	Yes	
Ascorbic acid	Yes	Lordosis, scoliosis, hemorrhage, anemia

Minerals

Minerals are classified as macrominerals or microminerals (Table 9). Macrominerals are required in gram-per-kilogram amounts and microminerals are required in milligram-per-kilogram amounts. Calcium, phosphorus, potassium, sodium, chlorine, magnesium, sulfur, and zinc are all required macrominerals. All of these minerals have metabolic functions (Table 9). Calcium, phosphorus, and magnesium are essential for bone formation. Zinc deficiency causes cataracts in fish. We've had tremendous problems when using high-ash fish meals that reduce the availability of zinc in the diet.

We determine mineral status in the laboratory by measuring the whole-body concentrations of fish. Fish regulate the minerals in the body within a fairly narrow range. So with fish fed a deficient diet, we can detect the mineral shortage before there are signs of clinical deficiency simply by grinding up the fish and analyzing it.

Carotenoids

Salmonid fishes have pink to red colored flesh. Farm-raised fish often have an orange tint in their flesh. This is caused by feeding a diet containing synthetic carotenoid pigment called canthaxanthin. Canthaxanthin is not the major carotenoid found in wild salmon, but it is very similar. Until recently, it has been the primary carotenoid added to farmed salmon diets.

The other primary pigment, which we extract from wild fish, is called astaxanthin. Fish cannot synthesize either of these compounds; they must get them in the diet. In nature they get the pigments primarily from eating crustaceans or other fish that have ingested algae.

There is very little chemical difference between astaxanthin and canthaxanthin, although astaxanthin is the more effective pigment. Both of these compounds have been synthesized commercially and are available for use in salmon feeds. At present, the industry in Europe and in Canada is switching from the use of canthaxanthin

Table 7. Vitamin pre-mix specifications (mg/kg).

Vitamin (form)	NRC recommendations	OMP	Pre-mix[1]
Vitamin A (palmitate or acetate)	2,500	110,229	(1,654)
Vitamin D_3	2,400		
Vitamin E (tocopherol acetate)	30	33,510	(503)
Vitamin K (menadione sodium bisulfite complex) 33% active	10	1,201	(18)
Thiamin (mononitrate) 92% active	10	3,086	(46)
Riboflavin	20	3,527	(53)
Pyridoxine (HCl) 83.3% active	10	2,504	(38.6)
Pantothenic acid 92% active	40	7,668	(115)
Niacin	150	14,770	(222)
Biotin	1	39.7	(0.6)
Vitamin B_{12}	0.02	3.97	(0.6)
Ascorbic acid	100	59,523	(893)
Myo inositol	400	18,818	(132)
Folic acid	5	1,102	(16.5)

[1] Values in parentheses are levels present in diet.

Table 8. Stability of vitamins in fish feed.

	Primary factors affecting stability			
Vitamin	Heat	Acid	Oxidizing fats	Natural enzymes
Vitamin A	S	S	U	S
Vitamin D_3	S	S	U	S
Vitamin E				
(Alpha-tocopherol)	S	S	Very U	S
(Alpha-tocopherol acetate)	U	S	S	S
Vitamin K	S	S	S	S
Thiamin	S at low pH		S	U*
Riboflavin	S	S	S	S
Pyridoxine (vitamin B_6)	S	S	S	S
Ca-pantothenic acid	U in sol'n	S	S	S
Niacin	S	S	S	S
Biotin	S	S	S	S
Vitamin B_{12}	S	S	**	S
Ascorbic acid	U	U	Very U	S
Myo-inositol	S	S	S	S
Folic acid	S	S	S	S
Choline	S	S	S	S

S = stable.
U = unstable.
* = thiaminase.
** = destroyed by oxidizing agents

to astaxanthin. Both pigments are very expensive; they cost close to $1,000 per kilogram. Canthaxanthin is available as a 10 percent active product, and about one pound per ton is added to feed. This adds about $50 per ton to the price of the feed. The commercial product contains only 5 percent astaxanthin.

When salmonids are fed diets containing carotenoids over a period of time, only about 4 percent of the carotenoids are retained in the body. Carotenoids are dietary components and are absorbed in the intestine. Then they show up in the liver, where they can be stored and used to make lipoproteins, or they can be excreted from the body. They are transported in the blood and deposited in the muscle. During reproduction, carotenoids are transported from the muscle to the ovaries or to the skin.

Visual numerical scores have been assigned to concentrations of the pigment in the flesh. In the low ranges the color difference is easy to see, but in the high ranges the eye can hardly detect a difference. It is not difficult to achieve very high levels in the flesh by feeding more pigment. Nevertheless, no further economic benefit will result from increasing the pigmentation level beyond the 5 to 7 value.

Worldwide, about 6,000 kg of carotenoids (at $1,000 per kg) are being fed to salmon. Our projections show that with increased production, 14,000 to 15,000 kg will be used. The amount of money that would be saved (in U.S. dollars) by increasing carotenoid retention from 4 to 5 percent would be $4 to $5 million. Increasing the retention to 10 percent would save $10

Table 9. Metabolic functions of the minerals and approximate recommended dietary levels.

Macrominerals	Recommended dietary levels mg/kg	Major metabolic functions
Calcium	5,000-10,000	Bone formation, muscle function
Phosphorus	8,000	Bone formation
Sodium	Not known	Extracellular cation
Potassium	5,000	Intracellular cation
Chlorine	Not known	Extra- and intracellular anion, digestive juices
Magnesium	500-1,000	Bone formation, co-factor for enzymes, nerve and muscle function
Sulfur	Not known	Part of sulfur-containing amino acids
Microminerals		
Iron	500-100	Present in hemoglobin, myoglobin, cytochromes
Manganese	20-50	Co-factor for some enzyme systems, male fertility
Copper	1-4	Co-factor for some enzyme systems
Zinc	20-120*	Essential for insulin function, co factor
Cobalt	0.003-0.10**	Part of vitamin B_{12}
Selenium	0.030-0.1**	Interrelated with vitamin E
Iodine	0.1-0.3	Required for thyroxine formation in thyroid
Chromium	———	Required for normal insulin systems
Molybdenum	———	Co-factor for some enzyme systems

* Depends upon other dietary components.
** Estimate.

million. Considering these figures, it seems worthwhile to do some research on how to increase carotenoid retention!

A combination of canthaxanthin and astaxanthin appears to pigment salmon more efficiently that either pigment alone. Somewhere between a 30:70 and 50:50 combination of canthaxanthin and astaxanthin is most effective.

GROWTH

Growth occurs when the maintenance feeding level is exceeded (Figure 2). Above the maintenance feeding level are the optimum and maximum feeding levels. At maintenance feeding level, the feed conversion ratio is infinite because there is no growth occurring. At the optimum feeding level, feed conversion is most efficient and at maximum feeding level it is less efficient.

Diet preparation is the process of combining the ingredients in a mixture that will meet specific goals for production (Figure 3). These goals may be very different, depending on whether we are feeding fry or smolts, whether we want to get smolts to release size by a certain time, or whether we are in business to make money. Another concern in diet preparation is hatchery effluent, particularly nitrogen and phosphorus. In commercial farming, enhanced organoleptic quality is a concern. In research, we may be interested in creating a vitamin deficiency or the establishment of a dietary requirement.

The first decision in feed manufacture is what we are going to feed. And in a production diet, that feed must meet these criteria: It must be economical to manufacture, easy to handle, and easy to feed. The fish have to eat it. And of course it must be nutritionally complete, which includes both the chemical analysis and the available nutrients.

In feed formulation, we first choose the ingredients for the feed, and then decide where to establish maximum and minimum levels of the ingredients. The diet of course must be palatable and nutritionally complete. One method to determine amounts of each ingredient in a feed is trial and error. Levels of each ingredient are increased until a mixture with sufficient protein, energy, and required nutrients is achieved. This can be done with a personal computer spreadsheet, simultaneous equations, or least cost computer programs. Least cost computer programs are very nice, but there are two assumptions associated with their use that people don't always understand. The first assumption is that nutrients from ingredients are interchangeable, which may or may not be true. And the other assumption is that there is an ideal feed formulation; in fact the number of acceptable combinations is infinite.

The Oregon moist pellet formulation (Table 1) has different compositions for different size fish. Generally it contains 50 to 52 percent protein on a dry weight basis and about 18 percent fat. The feeds contain about 28 to 32 percent moisture, so they must be kept frozen until they are used. In contrast, the Abernathy dry diet (Table 2) does not require refrigeration, and its proximate composition is almost the same. The semi-purified diet formulations that are used in research are based on casein, gelatin, and dextrin, which are highly refined ingredients.

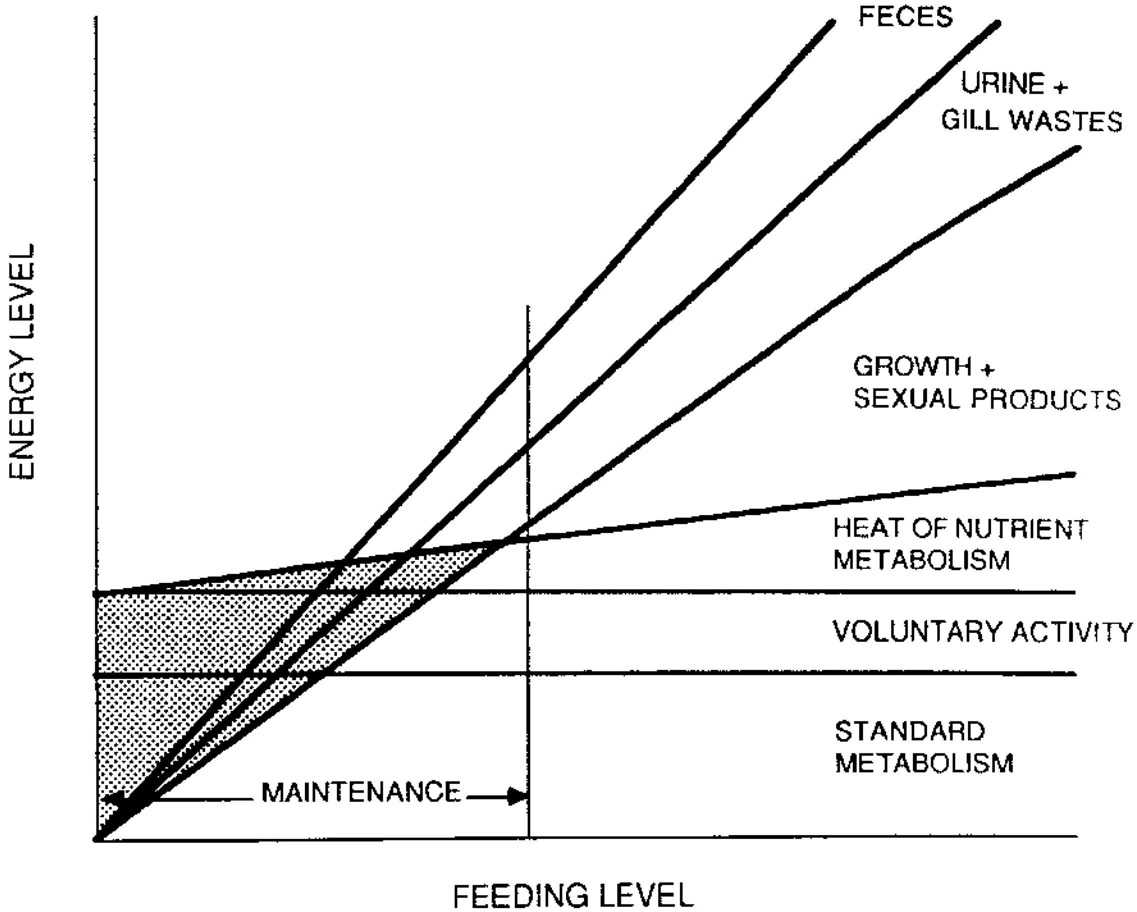

Figure 2. Distribution of feed energy at various feeding levels.

RESEARCH IN OUR LABORATORY

Fish Silage and Liquified Fish

We do research in many different areas of fish nutrition. One area that we work in is the utilization of fish processing wastes. We have examined fish silage in great detail. Silage has some advantages, particularly in places such as Alaska. Silage is very easy to manufacture, and equipment requirements are minimal. Almost any starting material can be used. The product is highly stable when it's made correctly, and environmental problems are minimized. The disadvantages are that it has a high water content, it is very bulky, and it is expensive to ship. It is not commonly used; there are very few people who know how to use it properly. The nutritional data available on fish silage are insufficient for most applications.

Fish silage can be any type of material; for example, under-sized fish or processing waste. After being ground, the fish waste is mixed with acids. Formic acid or mineral acids can be used. After the acids are added, the natural enzymes in the fish product or fish waste digest the material. The purpose of the acid is to inhibit microbial spoilage. The material becomes liquified, which may take a couple of weeks at a cold temperature, or one day if it is heated. Then it can be separated into three parts: oil, sludge, and liquid phase.

Fish waste can be made into a second kind of hydrolysate product called liquified fish protein. This is a similar process to ensilaging, except that we heat the material after it is ground and before the acid is added. We heat it from 30 to 60°C to accelerate the enzymatic digestion, which occurs in about an hour. After the enzymatic digestion, the liquid is heated to 85°C for about 15 minutes. This reduces microbial load and also inac-

Diet Preparation: The process of combining feed ingredients to form a mixture that will meet specific goals of production.

Examples of goals of production

- Rapid growth
- Inexpensive growth
- Successful reproduction
- Reduced hatchery effluent (N_2 or P)
- Enhanced organoleptic quality
- Induction of a vitamin deficiency
- Establishment of a minimum dietary requirement

Considerations in formulating a production diet

- Economical to manufacture
- Easy to ship
- Easy to store
- Easy to feed
- Palatable to fish
- Water stable
- Nutritionally complete

Figure 3. Fish feed formulation and manufacture.

tivates proteolytic enzymes to prevent further digestion of the material. At that point, it can be screened to remove bones and then stored following acidification to pH 4.0. One of the main advantages of liquification of processing waste is that the bone content (ash) in the product can be reduced.

Several options for use of hydrolysates in aquaculture feeds exist. Liquified fish and fish silage are about 75 percent moisture, which is too high for salmon feed. In Norway, the liquified products are combined with a binder meal and vitamins in a 40:60 mixture, to end up with a 45 percent moisture pellet. This very moist pellet is too fragile to be shipped. Generally, this form of pellet is made by a fish farmer on site and fed within one or two days.

Another option is to concentrate the liquid to about 50 percent moisture. This is not too difficult, because the energy required to remove the first half of the water is fairly low compared to that required to remove the second half of the water. The material that is 50 percent moisture is combined with other dry ingredients to make a pellet similar to the Oregon moist pellet. The final option is to dry the product to 10 percent or less moisture and use it in place of fish meal.

There are many factors that influence the nutritional value of products made from fish processing waste. These include neutralization of the acidified material, degree of hydrolysis, the comparative value of products made from whole fish or fillet scrap as starting material, and removal of bones.

Shearer and Hardy (1987) made a study to evaluate the nutritional value of salmonid diets containing whole fish meal, a meal made from fillet scrap as the major source of dietary protein. Fish that were fed the various diets all grew the same amounts during weeks 1 through 18. However, after 18 weeks of feeding, the fish that were fed the deboned fillet scrap stopped growing.

Whole-body mineral composition was used as an index of mineral status. After only four weeks of feeding there were differences in whole-body calcium, phosphorus, and magnesium levels between fish fed the diet containing the deboned scrap and fish fed the other diets. After 20 weeks, the group of fish fed the diet containing deboned product was split into two groups. One group was continued on this diet, while the other group was fed the same diet supplemented with sodium phosphate. Within a month the phosphorus, calcium, and magnesium levels in the fish fed the supplemental diet increased to normal.

Hormones

A study was conducted to test the effects of naturally occurring androgenic steroids found in low temperature dried fish meals from spawned salmon. For the first meal we removed the gonads from the males; for the second one we left the gonads in; and for the third meal we added the gonads that had been removed from the first meal to make a double gonad batch. The results after 18 weeks of feeding to salmon fry showed that growth was enhanced by the presence of naturally occurring hormones in the diet. The concentrations of steroids in these diets were in the nanogram-per-gram range, much lower than the concentrations that other researchers have added to diets to stimulate growth. In our study, the presence of other steroids in the natural meals may be the reason growth was increased at such low concentrations.

Vitamins

We are developing microchemical tests to measure the vitamin status of post-juvenile fish. These tests are much more sensitive than existing tests and can detect deficiencies of some vitamins weeks before clinical signs are observed in the fish. This allows dietary treatment to be used before the fish are so sick that they won't eat.

We measured nutritional status for the vitamins biotin and pantothenic acid. We developed a very sensitive radioassay which directly measures levels of biotin in the plasma. We found differences in the plasma of fish after 32 weeks of a diet with no biotin, 16 weeks before the appearance of clinical signs. I think we can develop this into a method that will allow us not only to identify deficiencies, but also to establish the correct dietary level for fish.

We also developed a test to measure enzyme levels in the liver, which reflect pantothenic acid stores. After only four weeks we can see a difference between fish fed a complete diet and fish fed a pantothenic acid-deficient diet. In this study, fish did not exhibit clinical signs of a shortage until 9 to 12 weeks of feeding a pantothenic acid-deficient diet.

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QUESTIONS AND ANSWERS

Q. Did you say that salmon do not synthesize omega-3 fatty acids?

A. They do not synthesize them; they have to get them in their diet.

Q. How do omega-3 fatty acids in farmed salmon compare to omega-3 fatty acids in wild salmon?

A. That's an excellent question. In the farmed salmon, the total omega-3 levels are about 15-16 percent compared to a level of 23-24 percent in troll-caught coho salmon. However, in our laboratory we have increased the levels of omega-3 in farmed salmon to the same as wild salmon by feeding different fish oils, such as menhaden oil.

Q. What about farmed fish like catfish; do they have much omega-3?

A. They do not have much omega-3, and with catfish if you increase the level of oil in the diet, you get a product that's greasy. No one wants greasy fish.

THE RELATION OF FEED COSTS TO FINFISH FARMING

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Today, fish farming is still as much of an art as it is a science. This makes it difficult to give specific information on feed costs in finfish farming. For Swecker Salmon Farms, Inc. this is complicated by the fact that our operation is highly diversified. Historically we have been involved in innovation in facility design and rearing strategy development. Perhaps the easiest way to explain all this is to give you a little bit of our history.

HISTORY

My wife Debby and I started our operation in 1974, raising coho salmon smolts in two dirt ponds in our back yard. Today we are currently installing nineteen more. In the beginning we raised coho and chinook smolts for saltwater pen growers and ocean ranchers. By 1980, it was becoming apparent that our markets for smolts were drying up. Most of the people we raised fish for had developed their own freshwater facilities to produce smolts. At that time we decided to diversify and began producing pansize salmon in fresh water. Until that time it had primarily been done in saltwater net pens. We had to develop freshwater facilities and new rearing strategies as well as a processing operation to supply deboned pansize salmon to markets all over the United States.

In 1982 we were contacted by a Norwegian company and asked to begin raising Atlantic salmon smolts for an emerging net pen industry in Puget Sound. This again required dramatic changes in facilities and technology as well as the management strategies for a new species. One thing we learned very early is that Atlantics are about ten times as hard to raise as coho. We have spent the last five years perfecting the production of Atlantic salmon and integrating this production with the other activities in our facility to maximize effectiveness and efficiency. There is another factor that has added a level of complexity to our operation. Because we do not have access to salt water, we do not have our own brood stock for any of these programs, so each year we face problems associated with egg quality and stock variation.

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FEED COSTS

With this in mind we can turn our attention to the relation of feed costs to finfish farming. For salmon, lower feed costs do not necessarily mean more profits. This statement is much more true for salmon than it is for the trout industry. Given the products currently available, trout in most conditions do well on the majority of commercial diets with small variations in feed efficiency. This is definitely not the case with salmon. Salmon react much more radically to variation in level of protein, quality of protein, feed sizes, and palatability. Without a doubt, a poor choice in feeding strategy can result in massive impacts on the overall productivity of an operation.

There are three options available currently in commercial manufactured feed: dry, semi-moist, and moist.

Dry Feed

The major advantage to dry feed is that it can be stored at room temperature for several months without significant deterioration in product quality. It usually contains about 10 percent moisture and is the cheapest of the three options. The disadvantages of dry feed are that it is less palatable to the fish, and less of the nutritional value of the components such as proteins are retained once the product has been dried.

Another characteristic of dry feed is that the fish use the water from their surrounding environment to build body tissue, which results in better conversion rates. However, if there are disease organisms in that environment, the fish are more likely to be affected by those organisms. The palatability problem also can result in a nutritional deficit in the fish simply because they won't eat it. This will make them more susceptible to disease.

Salmon tend to feed less vigorously on dry feed, therefore they must be fed more often and more of the feed is spit out or ignored by the fish. This feed can accumulate on the bottom and can be an expensive waste. Salmon do better on dry feeds at temperatures above 10°C. In surface water facilities where temperatures vary depending on the time of year, a marketing and production strategy should be adopted that will accommodate low growth levels during the colder months. On the other hand, it may still be very cost effective to use dry feeds because of the high conversions seen during the warm months. I know one pansize grower who uses exactly this strategy and puts out some of the best fish in the industry. He just doesn't produce very many pounds in the winter.

Semi-Moist Feed

This incorporates some of the advantages of both dry and moist feed. The big advantage is that it does not have to be refrigerated until after the bag is opened. If it is used quickly enough it need not be refrigerated at all. The major disadvantage is that it is the most expensive feed; it is commonly about twice as expensive as dry feed. Even though it is somewhat more palatable to the fish, in production trials with Atlantic salmon, we had better luck with frozen, moist feed than with semi-moist. I think palatability was still a major factor. I also believe that quality does deteriorate more in semi-moist feed, particularly the vitamins which tend to oxidize more quickly. Nevertheless, where refrigeration is not economical, semi-moist feed may be the best bet.

Moist Feed

Of the commercially prepared pelleted diets available, moist feed is probably closest to what salmon eat in their natural environment. It has many advantages. Because of its palatability, salmon accept moist feed much more readily. If the feed has been stored properly we see fewer nutritional problems and less disease. With more aggressive feeding behavior, labor costs for feeding and cleaning ponds are much lower. In a saltwater environment the fish use the fresh water in the feed instead of salt water to build tissue. This reduces the physiological stress on the fish because it doesn't have to work as hard to regulate the salt level in the blood.

Moist feed requires the least amount of processing by the manufacturer, therefore the quality of the raw materials is preserved. They have not been deteriorated by heating and drying. We should be careful not to confuse moist feed with wet feed which is primarily ground fish. The largest single component in wet feed is water. Moist feed contains no more than 30 percent moisture and usually contains over 40 percent protein plus grain binders, vitamins, and fish oil. The obvious disadvantage of moist feed is that it must be shipped and stored in a frozen state. Moist feed can range in price from 30 percent more than dry feed to nearly as expensive as semi-moist. For Pacific salmon weighing over 10 grams, the lower cost generic OMP (Oregon moist pellet) formulations perform as well as any other feed.

Choosing Feed

Smaller fish require higher quality feed. Of the feeds produced in North America, I would recommend moist or semi-moist for salmon under 10 grams. It is my understanding that in Europe growers experience considerable success starting their fish out on dry feeds. I believe there are several reasons for this. First, the raw materials (fish proteins) they use are higher quality than those we have access to here. They have a special fishery and rigid handling requirements for the fish that are converted into fish meal for their feeds. Because they start with a higher quality product the extra heating and drying does not reduce protein quality below acceptable levels. Most of the fish meals we use in this country are a by-product of other industries and vary widely in product quality, levels of ash, and freshness. Another reason to opt for a more expensive high quality feed at the start is that early nutrition deficiencies can result in poor growth performance throughout the rest of the life cycle of the fish.

Inexperienced farmers should select higher quality feed. Unfortunately, many farmers starting out try to use the less expensive options because cash flow is so critical in the early years. I can tell you from experience that this is penny wise and pound foolish. A good quality feed can compensate for many management errors that eventually are eliminated with experience.

Some types of errors commonly experienced include overcrowding, inadequate flow rates, poor pond cleaning, and facility design errors. Other errors include overfeeding, underfeeding, and poor grading.

Grading Practices

Grading is a critical factor that I want to discuss a little more in depth. By grading I mean sorting the fish by size. Most people conceptualize fish growth in terms of a uniform population. One example of this would be the farm pond concept used for trout growing in Idaho. In this scenario small trout fingerlings, 2 to 3 inches in length, are placed in a pond and fed for four to six months. At the end of this time all the trout in this pond are harvested because 95 percent of them are in the correct size range. Apparently this concept works well with trout. It does not work well with salmon. Salmon are picky eaters easily intimidated by their brothers and sisters.

If you take a group of salmon at 4 to 5 inches, place them in a pond, and begin feeding them, the following things will occur. The first month most of the fish will grow. The second month maybe only 60 percent will grow. And the third month perhaps only 30 percent will grow. After that only the largest, most aggressive eaters will get much feed at all. By this time 30 to 60 percent of the fish are in nutritional deficit, and it is doubtful many will recover. There will still be fish in the pond as small as 4 to 5 inches. Feed pellets of a size consumable by the smallest fish must be used, so they will get at least some feed. But this small feed size cannot be eaten efficiently by the large fish, and many pellets go to the bottom and are wasted. As a result there is wasted feed, bottom accumulation, water quality problems, nutritional deficits, disease problems, and possible cannibalism or (as we commonly refer to it) "mysterious disappearance."

There is only one way to avoid this problem of non-uniformity, and that is to grade a minimum of every two months. I mention this problem in the context of feed costs because not only is it important what you feed but also that you do everything you can to insure the fish have a chance to eat it. Any management strategy, no matter how good, can be ruined by poor grading.

Hand Feeding

Something else that is as important as the quality of the feed is the quality of the feeder. The person who goes out and looks into those ponds each day will make or break the operation. This person must be aware of the general condition of the fish, their behavior, and any warning signs that suggest an alternate course of action should be taken. The feeder must understand that many factors affect how much feed a group of fish will take at a time. Some of these factors include the length of day; time of day; hunger of the fish; how aggressively the fish feed as a group; and feed characteristics such as oil content, smell, and palatability. If the fish behave differently from what the feeder expects, it is usually one of the first signs that something is wrong.

Automatic Feeding

Automatic feeders are not necessarily a substitute for hand feeding. We have tried both. In small Atlantic salmon, automatic feeders work very well and contribute to much higher survivals at first feeding. This is because first-feeding Atlantics need to be fed about every 5 minutes during daylight hours. Feed is wasted at this stage by overfeeding, but the fish are so small that the wasted feed is not cost prohibitive. The tanks must be cleaned daily.

All of the other fish in our facility are fed by hand. This is because the fish eat different amounts at different times of the day, and we found that when we used the automatic feeders we had to supplement them by hand feeding. I have seen more automatic feeding systems abandoned than I have seen used effectively.

SUMMARY

To summarize, I recommend you keep it simple. Start out using the highest quality feed to which you have access. It is particularly important to consider moist or semi-moist feeds in colder water and for smaller fish. Feed by hand to get a feel for the fish in the beginning. Experiment with automatic feeding systems before you make a large expenditure on this kind of equipment. And finally, the person on the pond or pen is still the most important ingredient in your formula.

A BRITISH COLUMBIA PERSPECTIVE ON SALMON FARMING

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I welcome the opportunity to discuss a British Columbia perspective on salmon farming. I welcome it for two reasons: first, because it offers me my first visit to Alaska, and second, because it allows me to discuss a most interesting subject, one that has undergone rapid changes in perspective since 1976, the year salmon farming was first introduced to British Columbia. Since that time the viewpoints have become more structured, more articulated, and most important, more convergent with one another. This paper will move quickly through the early expectations of salmon farming in British Columbia to the present, and many of the recent, positive occurrences that are leading to an increasing consensus of viewpoint will be discussed. A review of some outstanding issues that require resolution will also be considered. Finally, a prognosis for the future will be offered.

At this point, the perspective for salmon farming in British Columbia is extremely bullish. Having said that, let me back up and begin by answering a question that may be on one or two tongues: "What does a fellow from a private laboratory know about salmon farming?" Syndel Laboratories has been on the leading edge of aquaculture technology, providing fish health services, research and development backup, and consulting services to the industry for the past 10 years. I have seen the industry grow from a single farm to the present 100 or so, depending upon who you are talking to. During this time I have been privy to many of the farm problems and successes during and after their developmental stages. I have followed the growth of this new industry with keen interest from birth, through adolescence, and now almost to adulthood.

THE PAST

Let us look at some of the historical viewpoints of salmon farming in British Columbia.

Salmon farming in British Columbia was largely unheard of during the 1970s. Those farms that were operating maintained a low profile. The appeal of fish farming was more for personal grounds than financial reward. The life style offered by fish farming was a significant drawing card. Neighbors, if there were any, looked upon the farmer as a bit eccentric. Government departments, and there were many of them, looked upon the farmer as just another business to regulate.

By the early 1980s the Norwegians appeared. They had been farming in Norway in earnest since 1971. What they saw in British Columbia was the potential of farming closer to their intended market, i.e., the United States. The Norwegians had already proven to themselves that salmon could be cultured profitably—very profitably. British Columbia's coastline was ideal. They invested quietly at first, then with a rush. Their enthusiasm triggered local entrepreneurs into action to the degree that by 1985 a gold-rush mentality pervaded the industry. The provincial government was not prepared for it, but certainly encouraged the development. The province needed a positive and encouraging issue to escape the effects of the recession.

The farms were established in remote areas for the most part, but with at least some access to the transportation route. Thus the Sunshine Coast (see Figure 1) became the first major area of development. The surge continued, spreading out to west Vancouver Island and the Campbell River-Quadra Island areas, and even up to Prince Rupert until mid-1986.

Newspaper and magazine captions echoed the development: "modern day gold rush," "Overstaking questioned," "Whose bay is this anyway?" "Aquaculture, another Klondike?" "A long way to go," "Too much salmon," or, "Angling for profitability," "overwhelming potential," "Net profits," "Lucrative potential." These and other divergent viewpoints quickly developed into the hype and hysteria that reached its peak just prior to the Gillespie Inquiry in mid-1986.

This inquiry could not have come at a better time. Polarization had developed to such a level that if it were not defused, there could have been many serious altercations between farmers and fishermen. Many good points were raised at the inquiry by both sides, and it is to the credit of Mr. Gillespie that his 52 recommendations were adopted intact by the government. Subsequent to the inquiry, the perspectives seemed to shift. There no longer appeared to be the viewpoints that dominated the media prior to mid-1986. People got back to doing what they did best, farming and fishing.

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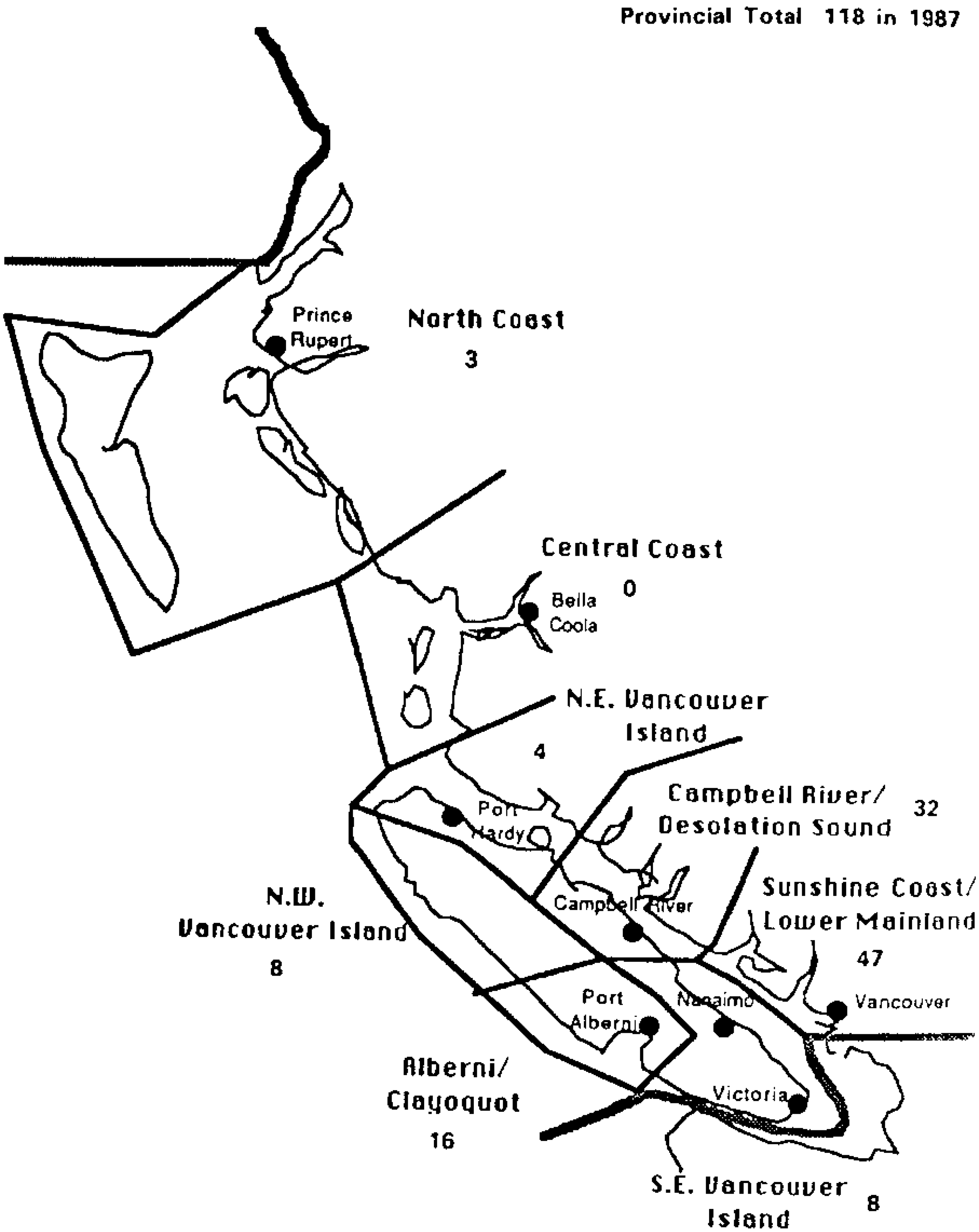

Figure 1. Distribution of salmon farms operating in British Columbia, November 30, 1987. Courtesy B.C. Ministry of Agriculture and Fisheries.

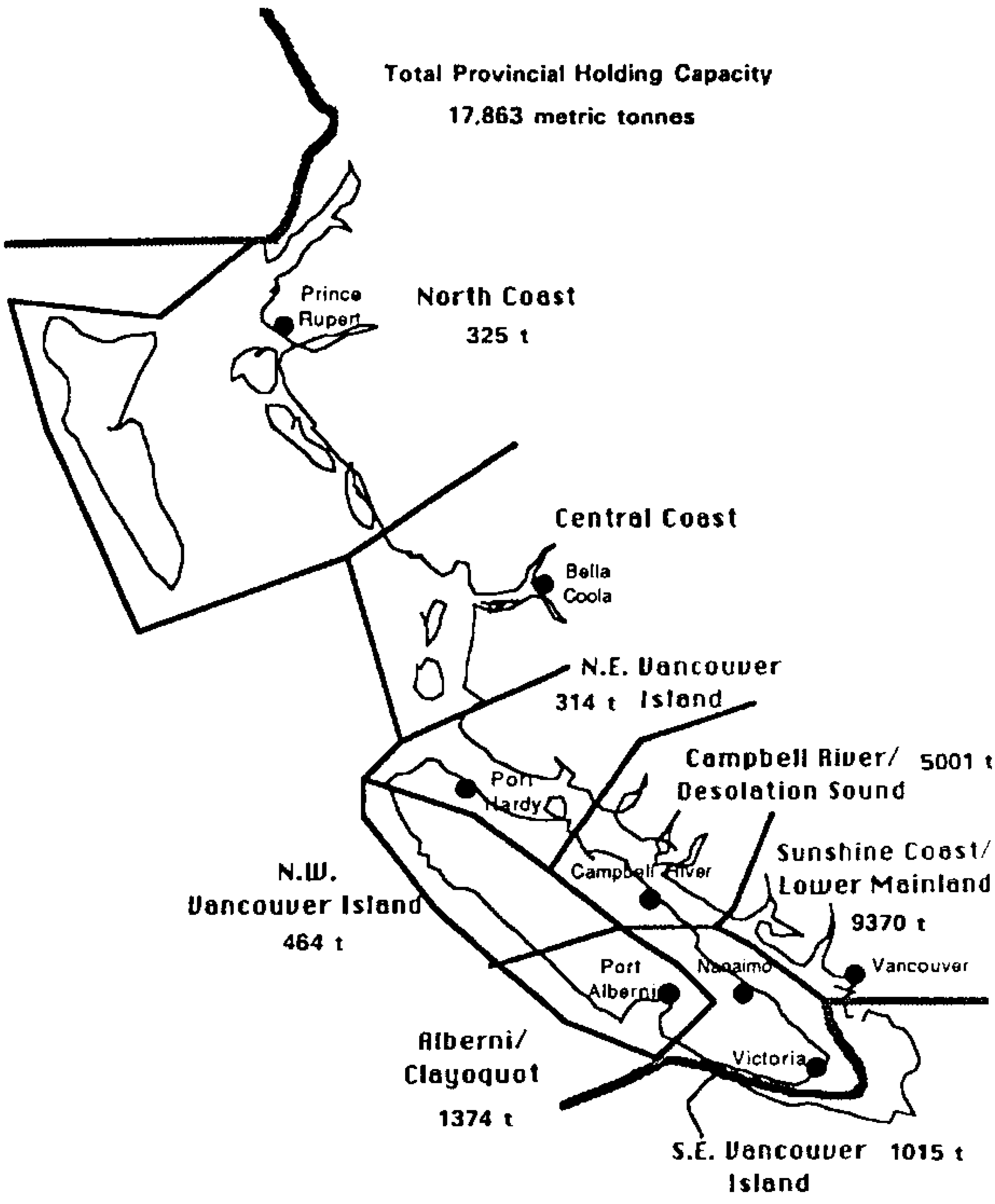

Figure 2. Regional totals of net cage holding capacity for salmon farms in B.C. These are based on an average stocking density of 8 kg per cubic meter. Courtesy B.C. Ministry of Agriculture and Fisheries.

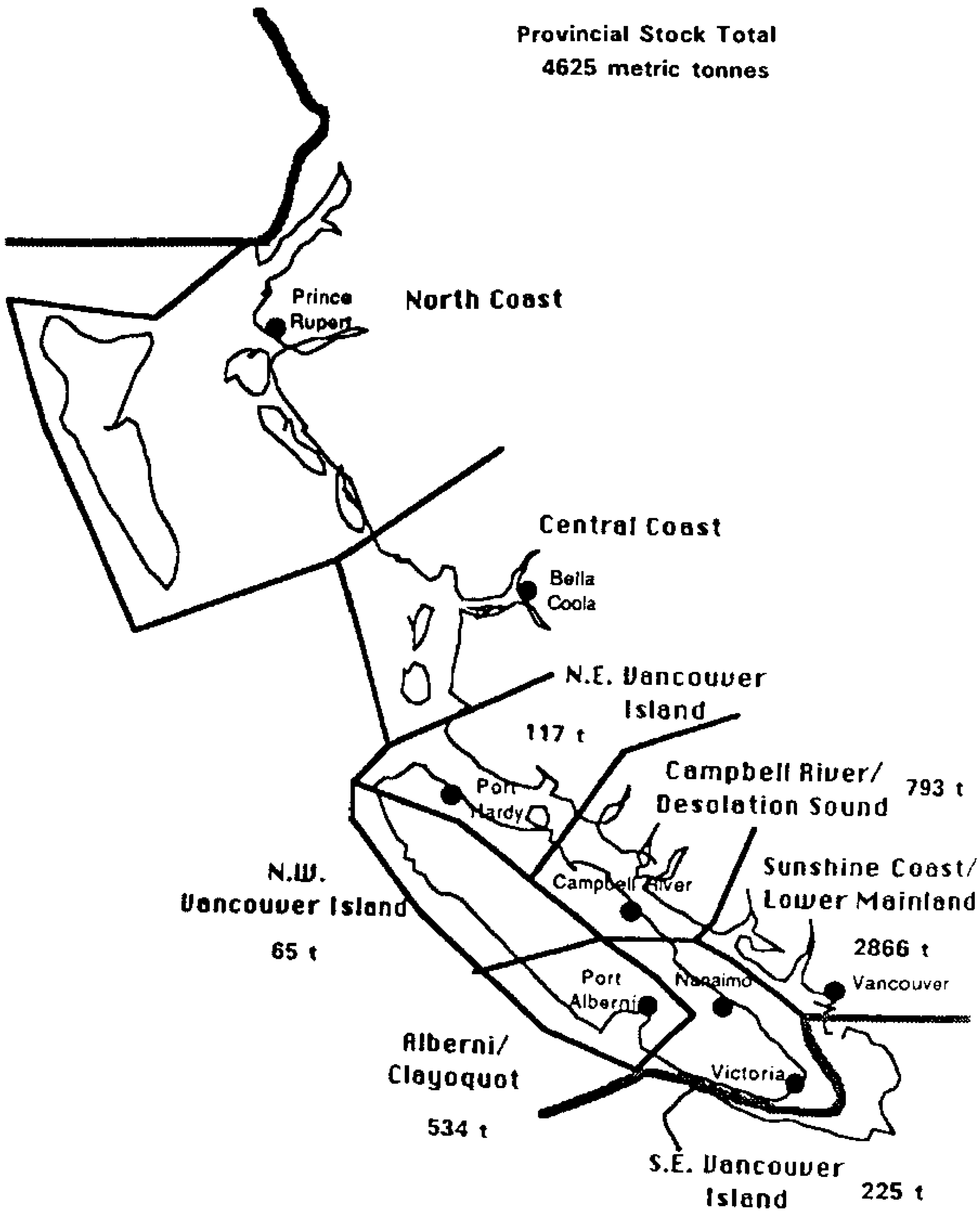

Figure 3. Summary of stock on hand for most regions for B.C. salmon farms. November 30, 1987. Courtesy B.C. Ministry of Agriculture and Fisheries.

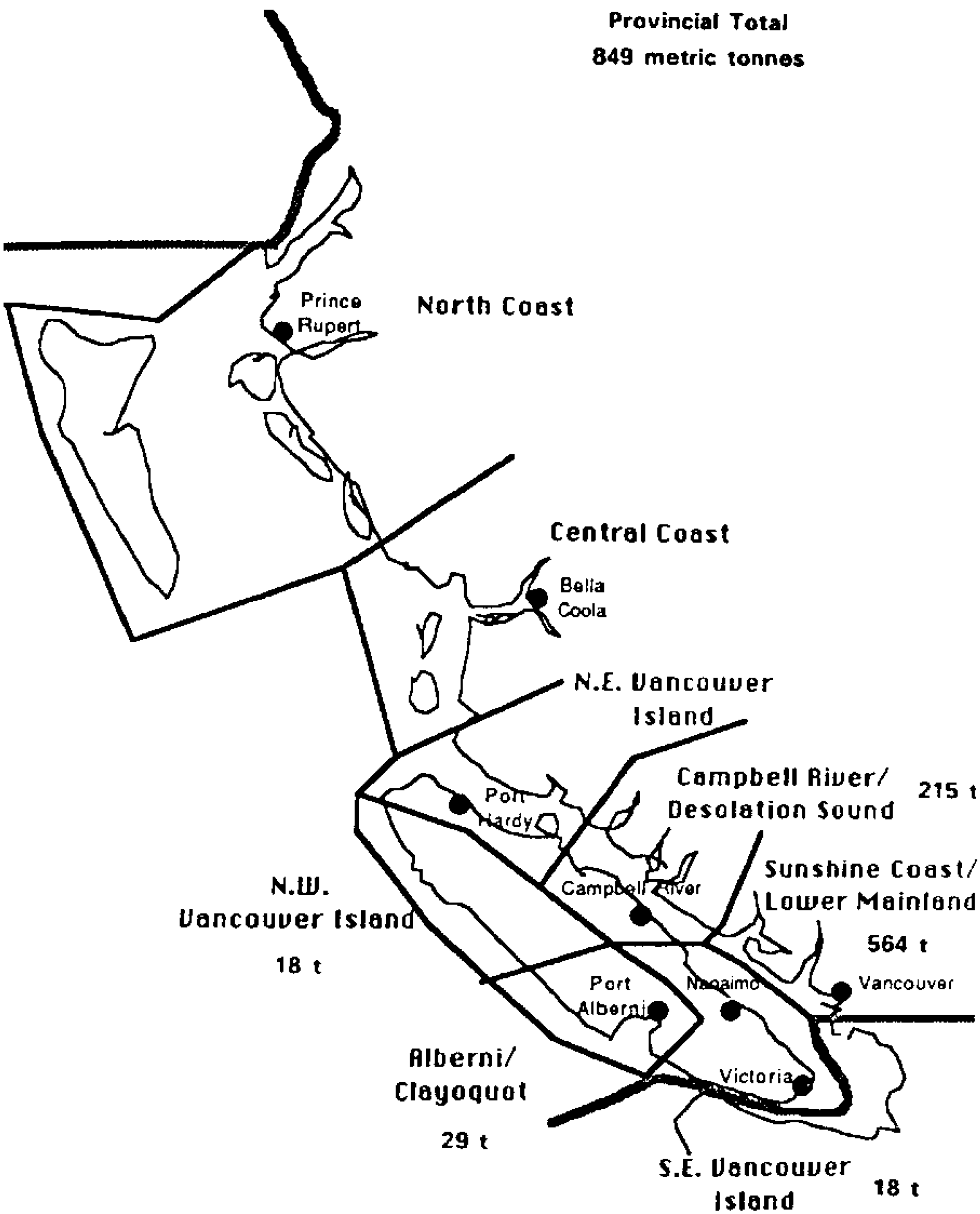

Figure 4. Harvest reports from most regions for B.C. salmon farms, November 30, 1987. Courtesy B.C. Ministry of Agriculture and Fisheries.

THE PRESENT

Figures 1 through 4 show distribution and size of salmon farms in British Columbia. Presently, the industry is more confident and is more responsibly managed than it was earlier. This has not come without a lot of hard work. Improved management with better business focus has been key to many of the critical decisions that had to be made over the past 18 months. The huge financial requirements to keep the farms going until there were positive cash flows were underestimated, and novel approaches to raising funds were necessary. Although this fundamental problem has not been completely overcome, the quality and depth of management has improved immensely. This has had a very positive effect on investor confidence, to say nothing about internal confidence.

Many farms chose to use the Vancouver Stock Exchange as a means of raising capital. They did so during a time of unprecedented investment in equity stocks, and fared very well. My conservative estimate is that approximately $30 million was raised this way. As part of their prospectus requirements, the farming of salmon had to be explained, markets had to be identified, and the length of time required before profits could be realized had to be stated. This was part of the story that was poorly told or missing altogether during the earlier period of hype. Not only were the investors getting better information, but the public now had an opportunity through the media to become better informed. A better informed public can develop its own viewpoints, rather than merely echo earlier rhetoric.

Another positive move within the industry happened through advancements in the British Columbia Salmon Farmers Association. This association was formed in 1984, but had little strength or influence among its members until early 1987. Realizing that it had a monstrous task of coordinating egg screening and distribution, assessing research and development requirements and building a marketing strategy, the association hired two additional professionals to handle research and development and marketing. The activities of these two people, along with the executive, have assisted greatly in consolidating the farmers into team effort with a focus. Although this move may not have influenced the general public's expectations of the industry, it did bind the industry together for the first time. Workshops on such topics as disease and nutrition were conducted. Guidelines were set for minimum standards, ranging from end product quality to on-farm ethics.

Within the industry, few, if any, needed to be convinced of the potential salmon farming held for them. The farmers' perspective has always been one of high expectations. However, the advances made over the past 18 months, or at least since the clarification of issues by the Gillespie Inquiry, have instilled an even greater determination to achieve those expectations.

Perhaps, though, the most significant change in viewpoint has been experienced by the general public, and no group has been affected more than the support sector.

The following categories of infrastructure build-up have profoundly influenced the perspective of those in the support side as well as those peripherally connected, such as in housing and staples:

- Transportation
- Feed manufacture
- Diagnostic services
- Nets and pen manufacturers
- Publications
- Insurance
- Boat building
- Processing and general equipment of local manufacture

A brief look at the results of a study recently completed by the Salmon Farmers Association titled "Salmon Farming in B.C.: Economic Impact on the Supply and Service Sector" has the following objectives:

1. To quantify and classify companies now in the supply and service sector of the salmon farming industry.
2. To determine the total level of employment in the supply and service sector and the wages and benefits generated by it.
3. To determine total sales and capital expenditures.

Ten classifications of support activity were identified and surveyed. These were

1. Cage suppliers and manufacturers
2. Feed producers
3. Pharmaceutical, laboratory, research and development
4. Nets, ropes, and seine
5. Construction and marine supplies
6. Transportation
7. Auxiliary goods and equipment
8. Consulting and professional services
9. Fish processors
10. Diversified aquaculture service companies

By referring to Table 1 the following two projections are worth noting. Example 1: Wages and benefits for 1987 of $8,850,000 indicate a substantial employment picture. However, by 1990, that figure could exceed $35,000,000. Example 2: The anticipated number of new person-years created in fish processing plants by 1990 is 283, compared to the present number of 17. For comparison, the number of plant worker person-years for 1985-1986 in British Columbia fish processing plants has been estimated at 4,800, which includes processing of all groundfish as well as salmon. Therefore, processing of farmed salmon may very well add an extra 10 percent to the existing and mainly unionized positions—a fact that should not be lost on any of us.

The confidence of two major international fish feed producers in the success of British Columbia's salmon farming future is evident in their significant capital investments. B.P. Nutrition, through their ownership in

Table 1. Employment in the supply and service sector of B.C. salmon farming industry in 1987.

Company classification	1987 Person years of employment (total)	Total wages generated (1987)	Anticipated full-time positions created by 1990 by salmon farms
Cage suppliers/manufacturers	62.4	1,700,000	213
Feed producers	39.9	930,000	60
Pharmaceutical/laboratory/R&D	29.4	1,180,000	77
Nets, ropes, twines	63.4	1,360,000	34
Construction & marine supplies	27.0	710,000	26
Auxiliary goods & equipment	32.4	850,000	153
Transportation			
Air	1.3	30,000	3
Sea	1.0	20,000	70
Consulting & professional services	29.3	1,000,000	53
Fish processors	17.0	400,000	283
Diversified aquaculture service companies	22.9	670,000	74
Total	326.0	8,850,000	1,046

Courtesy B.C. Salmon Farmers Association

Moore-Clark, recently completed a new plant in Vancouver. The Finnish company, EWOS, purchased and refurbished an existing poultry feed producer in the Fraser Valley. In Nanaimo, a division of the Prince Rupert Fisherman's Coop, White Crest Mills, is also producing salmon feed in a new plant and is reported to be running at or near capacity already.

Another benefit being realized as a direct result of salmon farming in British Columbia is the effect it is having on many coastal communities. We only have to look at the Sunshine Coast for a shining example of coastal community revival. Before salmon farming, this community of some 17,000 was plagued with an unemployment level exceeding 12 percent. Many businesses were on the verge of bankruptcy. A regional district study recommended two possible solutions to improve the economic health of the community: promote tourism or encourage salmon farming. They chose the latter. With over 25 farm sites now active in this region the business atmosphere is healthy. The ripple effect to the community has been profound. Viewpoints on the Sunshine Coast are divided only by politics, otherwise the community is solidly behind salmon farming and what it has done for the community.

A major external force that is driving the whole industry is the unprecedented increase in demand for seafood. Health concerns, new eating habits, and new evidence of cholesterol reduction from eating foods rich in omega-3 fatty acids have all turned the consumer on. Salmon is a major source of omega-3 fatty acids. Not only that, the consumer has very high expectations of salmon farming. They want quality, they want it fresh, and they want it year-round. Only salmon farming provides that.

Last, but by no means least, the provincial government attitude is positive. Encouragement is offered wherever possible, although little or no money is being pumped into the industry directly. There are funding incentive programs for aquaculturists and sales tax concessions on equipment, material, and supplies. The Ministry of Agriculture and Fisheries has assumed the lead role in the province for aquaculture. Heavy-handed regulations have been minimal, and the Gillespie Inquiry sorted out many of the inconsistencies and almost everyone now knows how to play the game. The federal government role is still ambiguous, although they are tenuously holding on through their traditionally strong expertise in research and development.

Although the preceding may sound rosy, there still are some risks and uncertainties. It is unlikely that these uncertainties will change the perspective; indeed they may only enhance it once the uncertainties are resolved. The major uncertainties to which I refer are

1. Undercapitalization
2. Egg scarcity
3. Health
4. Technology gaps
5. Suspicious fishermen
6. Bank temerity

Undercapitalization

Despite the stock exchange successes, there is still a scramble for working capital. It is a perennial problem for most public and private farms, and the October 19 stock market crash has not made it any easier for them, regardless of whether they are public or private.

The programmed harvest period for British Columbia farmed fish is between December and May, a period during which fresh wild harvested fish is unavailable. Usually at other times of the year the salmon farmer would have to compete unfavorably in price with the wild caught fish. However, this year the fishery was much below expectation, and many farms did harvest early. Prices ranged from CAD $4.20 to $4.50 per pound for chinook and coho, an unseasonally high price. Obviously this improved many a farm's cash flow this year, and in some cases may have saved their bacon. Nevertheless, there is still some sorting out taking place, and ownership changes will continue to occur.

Egg Shortage

This year's egg collection from the wild fishery, at time of writing, was much below expectation. Everything seemed to be late this year. If the numbers come close to a quarter of the expected amount, as has been suggested, the anticipated farmed harvest for 1989-90 will be seriously affected.

Health

Farms must still institute proper health management programs. Although maintaining healthy fish is a prime objective, the approach to handling disease has been largely reactive, not productive.

Technology Gaps

British Columbia is farming two salmon species, the chinook (predominantly) and the coho. They are mainly brought in from the wild. Several years will be required to produce a stock that is domesticated and that has many desirable traits for culturing. In addition, there is a paucity of understanding in such subjects as nutrition, stress tolerances and disease control.

Suspicious Fishermen

Fishermen are still suspicious of farming fish as opposed to hunting them. There is no easy answer. Both sides must recognize that it is a market-driven industry. The market today is not being satisfied, nor will it be for some time to come. Farming has introduced a new element to seafood supply—consistent quality on a year-round basis. 'We don't fight over prices,'' say the chefs. The industry still has to achieve consistent supply, but this should serve to enhance the dockside price for wild caught fish. In the final analysis, the farmer and fisherman will complement one another, not compete.

Bank Temerity

Canadian chartered banks have been slow on providing working capital to salmon farmers. Perhaps when the Bank Act is amended through present lobbying efforts to allow chartered banks to use inventory in the water as collateral, there may be greater interest. Fish will be treated in the same manner as other agriculture products, a status it does not have at the present. A more positive viewpoint by the chartered banks is necessary. Salmon farming is a business, and therefore it must use and have the support of all the components of the financial community.

THE FUTURE

Salmon farming in British Columbia is a reality. It has come a long way in the past five years, and even in the past 12 months. There is a mood of confidence, pride and achievement that transcends any dissenting viewpoint. Aquaculture International, to be held in Vancouver, September 1988 is a clear indication of the enthusiasm and commitment British Columbia has for aquaculture. Within 3 to 5 years this industry will become an adult. As we have read in the *Canadian Aquaculture Magazine*, ''. . . there is not time for puberty and adolescence.''

INSURING FARMED SALMONID STOCKS

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I thank the organizers of the Fourth Alaska Aquaculture Conference for inviting me to participate. This report will deal with stock mortality insurance, and is divided into two sections. First, I'll discuss some underlying principles of insurance and second, mortality insurance, including the proposal forms and insured perils.

INSURANCE PRINCIPLES

The principle behind the conduct of insurance is that the whole industry sharing the individual's misfortunes is the least painful way of handling the misfortunes. It is the underwriter's job, which he does for a profit, to assess the risk surrounding the various insurance interests and then decide on the way the risk can be defined and how the risks can be accommodated into the general portfolio of the insurance community.

The underwriter must strive for a perfect balance if he is to successfully carry out his task of fair and equitable spread of risk. He must charge more premium for the high-risk exposure than for low-risk interest. He must even restrict or reject some business if the risks are too high or if there is a moral hazard involved.

The basic function of insurance is to spread risk. The fundamental legal principles underlying insurance are:

1. Insurable interest. Any party wishing to take out insurance must have an interest in the property or liability for which coverage is required.
2. Utmost good faith. The duty of utmost good faith is duty to disclose material facts and is required of both parties to an insurance contract. The full facts relating to a risk are usually known or should be known by the prospective insured, whereas they are not known by the insurer.
3. Material facts. These facts would affect the judgment of an underwriter in considering whether he would enter into the contract of insurance and at what price.

Material facts are not just those provided in answer to questions in a proposal form. Materiality does not depend on the opinion of the prospective insured. Whether or not a fact is material must be for a court to decide. That is usually done after a policy has been issued and a claim made. The problem for the fish farmer is to decide what is material fact and what is not in completing the proposal form. Material facts include

   A. Facts that tend to render the risk proposed for insurance greater than normal. But in the aquaculture industry, where no two risks are alike and the state of its science is somewhat primitive, what is normal? It might be said that we know 75 percent of the biology of human beings and 50 percent of the biology of chickens, cows, and pigs, but our knowledge of the biology of aquatic creatures we are farming probably ranges from a maximum of 20 percent for the better-known creatures to well below 5 percent for the lesser-known ones.
   B. Facts that are suggestive of some special motive for insurance; for example, a farmer may wish to insure certain species and not others.
   C. Facts necessary to explain the exceptional nature of a risk where, in their absence, the underwriter would justifiably believe the risk to be normal.
   D. Facts showing that the proproser, himself, is in some sense abnormal. For example, the lack of experience with certain species or an unfortunate claims experience, such as the declination of risk by a previous insurer.

4. Indemnity. The principle of indemnity is that an insured should, as far as possible, be placed in such a position following a loss as he would have been had the loss not occurred. This is difficult in the fish farming industry because of lack of replacement fish available year-round.
5. Proof of loss. The burden of proving that a loss is caused by an insured peril rests upon the insured. To comply with the need to provide proof of loss following a claim, the policy-holder should keep written stock control records, keep close track of events as they develop in a claims situation, and make every effort to see that causes and actions taken are well documented.

RISK MANAGEMENT

A natural adjunct to the insurance is the control and management of pure risk, otherwise known as risk management. The object of risk management is to reduce

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or, if possible, eliminate wasteful risks and hazards. It has to be done on a cost-effective basis. We, in the insurance industry, are not experts on keeping fish alive, but we are experts at looking objectively at the peripheral risks of situations and we do give advice to clients on how to manage some of the risk in their situation. The overall survival rates in aquaculture could be improved significantly if personal attention were paid to each fish, but of course that is totally impractical. Somewhere between personal attention to each creature and throwing them in to get on with it lies an optimum point where effort to improve health and prevent disease is rewarded by extra profit. Both the underwriter who stands to pay for the loss, and the insured farmer whose profitability is reduced by waste, stand to gain if risk management techniques are employed.

The study of risk management developed initially in the United States in the 1950s, when many universities set up insurance departments. Academics began to realize that the best and cheapest insurance cover was not necessarily the key. In other words, insurance is only one way of handling the risks and hazards of the business. *Risk management* can be defined as the identification, measurement, and economic control of risks that threaten the assets and earnings of a business. *Risk identification* involves attempting to pinpoint all the risks that can threaten a business. *Risk measurement* is the art of placing some degree of magnitude and probability of occurrence on the risks identified. *Risk control* involves attempting to determine the best way of guarding against identified risks. *Risk financing* is the economic control of risk and attempts to find the best way of dealing with potential losses from a financial point of view. An example of this would be to prevent fish from jumping out of nets or preventing predators from getting in by buying nets to cover the pens. Similarly, it is logical to improve security to prevent intruders from gaining access to equipment or polluting water or feed stuff. The magnitude and probable occurrence of such risks is thus lessened though it is still worth channeling finance into insurance against such perils.

It is only through adopting a formal risk management approach that some hazards can be identified and seen to have enormous potential for loss. For example, it is a good idea to look at dependency of a business on suppliers of equipment or raw materials. How dependent are fish farmers on suppliers of fish food, or on suppliers of smolts or fingerlings? Are there alternative suppliers? What are their delivery schedules? Are the fish farm suppliers dependent on other suppliers?

It is not presently the case that banks are pulling out of lending money (yet!). But it is the case that some insurance companies are actually considering withdrawing from the field. Were they to do so, it would coincide with an increased requirement for insurance underwriting capacity, brought about by the greater demands of banks that their fish farm clients be insured and by the ever-increasing aggregation of values that are developing all over the fish farming world.

The insurance industry's attitude toward aquaculture provides another clue to the inherent risk level. If insurers, the most skilled assessors in society, are considering getting out of aquaculture insurance, or if they are seeking to restrict the cover that they give to fish farms, then surely that is a warning to everyone. It is a fact that many insurers have lost substantial amounts of money through insuring fish farm stock over the last few years. The only conclusion that can be drawn is that risks to the aquaculture venture are very high.

The role of insurance as the principal tool for offloading the risk exposure of the aquaculture venture is an important one. Insurance is already the established tool for managing the risks of many aquaculture operations. If, for some reason, the insurance market for aquaculture risks were to collapse, what would be the effect on banks and investors? Would they continue or would they pull out?

There is a limit of capacity in the insurance market for aquaculture risks. A long-term insurance market must be based on profitability to the underwriters. It must be realized that there would be no long-term insurance market unless underwriters make a profit from spreading risks and hazards. History shows many examples of how the insurance industry has met and solved the problems of insuring industries founded on new and often high-risk technologies.

STOCK MORTALITY INSURANCE

Fish farming is a very unbalanced business for the insurers, with high values concentrated in a relatively small number of units, with high risk of total loss from diseases, and with the risk of accumulation of several farms within one geographical area being hit by the same type of loss. Far better results (on a worldwide basis) are required in order to accumulate technical reserves for this type of risk, which could be termed adequate from an actuarial point of view. The aquaculture industry on the Pacific Coast is still very much in an infancy stage. The insurance industry has very few statistics on which to base their judgment. There is a need to coordinate all kinds of risk-related information, of which the following are only a few general examples:

1. The average and extreme of various catastrophic and subcatastrophic diseases.
2. The average and extreme of various environmental factors.
3. The basic parameters for mooring cages and rafts in the marine environment.
4. The incidence of plankton blooms, the extent of the area they cover, and the way in which they can be handled.
5. Advisable stocking densities.
6. Acceptable alarm systems.
7. The effectiveness of vaccines.
8. Working conditions in aquaculture.

There are special insurance needs for commercial aquaculture. At the heart of every aquaculture operation are the species, to whose health and growth a company's entire expenditure of effort and capital is completely devoted and upon which its profitability entirely depends. If anything prevents the product from reaching its market, then all effort and expense is wasted. It is clear then, that the most important insurance policies in the portfolio of any commercial aquaculture operation are those that protect the loss of stock.

People in, and associated with, aquaculture are the first to admit it is a high risk business. There are few other stocks that suffer losses from so many varied causes. The dependence of stocks on water adds a totally new dimension to livestock insurance and creates a whole series of problems that are different from those problems associated with the air-breathing creatures.

A very detailed proposal form for stock insurance is required because of the relative inaccessibility of sites and lack of sources of information generally available. The proposal forms should be completed in a most comprehensive manner. Generally speaking, terms are more favorable when good, detailed information is submitted.

When an underwriter first completes insuring a particular farm, he does so at two levels: first, he looks at the overall risk level involved and then at the premium he needs to cover it; next, he looks to see if there is any way the risk level can be improved.

A reasonably sized deductible has been placed over the self-retained amount. This percentage deductible is called a franchise and it must be exceeded before a claim can be made. The insurance is intended for catastrophe and not the everyday, casual loss to be expected in this kind of operation.

The insured must maintain regular, monthly, written stock records. The monthly inventory does not have to be backed up by a full-scale stock take; however, monthly reports of values must be submitted, based on stock reports kept. These records must be based on full counts or random weight samplings carried out when suitable. Mortality numbers must be kept and incorporated into the stock records. It is clear that to prove any loss, the fish farmer must maintain his records carefully.

REVIEW OF PROPOSAL FORM

I will review the proposal form before discussing the insured perils. Bear in mind that the proposal form becomes part of the insurance contract.

1. The first section deals with general information on the company applying for insurance: the name, location of sites, species to be farmed, and resumes of key employees.
2. Information is required concerning the physical characteristics of the holding system on the following:
   - Marine chart
   - Farm plan
   - Photograph
   - Construction details of pens, net size, anchoring or mooring arrangements
3. There are several biophysical characteristics of the site:
   - Extreme ranges of tide
   - Current speed
   - Salinity
   - Temperature
   - Wave height
   - Wind speed
   - Minimum depths below cages
   - Frequency cages are checked under water
   - Use of mechanical device for aeration
4. Stocking density. Wild Pacific salmon, in our experience, do not survive in high densities. As the fish become domesticated, densities perhaps can be increased.
5. Details of precautions used to avoid or minimize losses due to net rupture or predation.
6. Details of diseases known to exist at the site or in the vicinity, together with information on the availability of drugs to treat diseases.
7. Details of previous loss experience.
8. Details of alarm or security procedures.
9. Details of potential catastrophes, i.e., hurricane, earthquake, tidal waters, extreme hot or cold water.
10. Details of any potential pollution, including plankton blooms.
11. Anticipated maximum value per cage and on the site.

After all these questions are answered, we still ask for details of any other material facts which may help assess the risk.

Aquaculture stock is open to loss or loss of value from a great number of very different perils, which may broadly be listed as follows:

- Predation
- Pollution
- Disease
- Slaughter made necessary by disease
- Food poisoning
- Failure of water supply from natural causes and climate conditions, blockage, or breakage
- Breakdown of equipment and machinery
- Net rupture and cage failure
- Flood
- Cold weather
- Power failure
- Theft and pilferage
- Negligence
- Fire
- Explosion
- Earthquake
- Impact
- Aircraft
- Malicious damage

Many of the previously listed perils are interrelated. Therefore, while it is common practice in other branches of insurance to provide what is called named-perils coverage (i.e., insurance against certain listed perils only), the danger to the aquaculture operator of insuring his stock on a named-perils basis is very great due to the likelihood of misinterpretation by either or both parties to an insurance contract. The difficulty in insuring the individual named perils can be illustrated by pollution cover. To pollute means to destroy the purity of, to make foul or filthy. It would not be the intention of insurers, in granting pollution coverage, to cover disease risk. For example, it is possible for a polluting substance to pass through a fish farm without causing death to stock immediately, but causing injury to fish which later die from injury-induced disease. The cause of loss would appear to be disease and would, therefore, be excluded under the policy. The insured would have to prove the disease was a direct result of the injurious substance. Under an all-risks policy, the onus is transferred to insurers to prove that a particular loss is inadmissible because a specific peril that caused the loss is excluded.

Following are standard exclusions under all risk mortality insurance policy:

- Sonic bang
- Radioactive contamination
- Mysterious disappearance
- Normal trade mortality
- Disloyalty of employees
- Intentional slaughter

Predation

In many underwriters' opinions, predation is a subject with which they feel they should not be involved. The cormorant or blue heron that gets into a cage is not a peril against which farmers should look to their insurers for protection. However, insurers must provide farmers with protection against much greater damage done by killer whales, sea lions, seals, or sharks.

Pollution

Farmers are inclined to say, "Oh yes, we can recover from polluters—no need to waste money on insurance premiums for this risk." That is all very well if you can trace the source of the pollutant, and if you manage to convince a court that a third party is guilty, and if you can then recover your money. In practice, underwriters usually have been able to trace the third party responsible for any pollution and, after a considerable period of time and legal expense, recovered their money. A fish farmer should continue to produce his fish while insurers worry about recovering losses from third parties.

Plankton Blooms

The problem of plankton blooms appears to be of major significance. If there is a likelihood that a loss can occur every 50 years, then a premium of 2 percent has to be levied to cover that. Plankton blooms can kill the fish in five major ways:

1. Through the release of toxin by live animals.
2. Through the release of toxin by dead animals.
3. Through the reduction in oxygen levels as a result of high demand of live animals.
4. Through the reduction on oxygen levels resulting from the high demands of decomposing animals.
5. By mechanical clogging of gills.

Underwriters have been looking at the problems of plankton blooms for some years now. They have plotted reports of these blooms on a worldwide basis. It is their opinion that it is unrealistic for mariculturists to say these occur elsewhere "But not on my site." The fact some farms have not experienced plankton blooms does not mean they cannot occur. In the opinion of a large London underwriter, the plankton bloom is the major problem that marine farming faces. One plankton bloom off the East Coast of the United States was approximately 86 km long by 60 km wide. It ranged from the top to the bottom of the water column. Evidence suggests that the spores of the creatures that can do the damage may rest on the sea bed, like little time bombs, waiting for the right conditions to cause a bloom.

One is dealing with thousands of different creatures, and since the cause of a bloom will undoubtedly vary from one plankton species to another, finding the cause may take considerable time. One of the major questions, from an underwriter's point of view, is what maximum and average area can a plankton bloom cover? The answer to this question will tell the underwriter whether he is exposed to claims from several farms as a result of the effects of one single bloom covering a large area.

It would appear that warm spring, summer, and autumn months are probably the dangerous periods for plankton blooms. Two relevant questions in relation to risk management concern the length of the time over which they occur and the frequency of occurrence of blooms at individual sites. There is a need for more information on these blooms. The attitude of insurers is to exclude plankton blooms but to add them back into the insurance coverage—for a price. The price is based on the insurance industry's estimate of what a particular site is exposed to.

Disease

Disease outbreaks have plagued fish farmers through the years. The ability to detect trouble quickly, or better yet, anticipate the trouble before it breaks out, is a valuable asset in keeping losses to a minimum and to obtaining insurance cover for diseases. Underwriters are very concerned over the ability of new fish farmers to spot diseases and treat them. There is a need for practical technical training. Some fish diseases seem to be here to stay. Farmers should be aware of the pattern of diseases that could occur at their farms—the time of year, the size, age, and type of fish involved. Recording these factors will help farmers anticipate the necessary corrective measures. The principle behind insurance of diseases is that the disease be diagnosed and treated, and the sound health of the fish restored. The losses due to disease could then be subject to an insurance claim.

But what about untreatable diseases? Underwriters are not going to allow a disease claim to be made in the first month of a policy and then have the policy respond to 11 months of a disease. There will be time restrictions put on policies for untreatable diseases.

The Hitra disease in Norway has been the most frequent cause of loss there. It appears to be a recurring event. The insurance industry in Norway has posed the question of whether this disease is an insurable risk or whether the losses caused by the disease should be regarded as a normal calculable operating expense that should be excluded by the insurance industry. (This thinking parallels that of underwriters concerning bacterial kidney disease [BKD] in British Columbia.) The losses in Norway due to Hitra disease were enormous last year. Losses due to the disease and early slaughter could be as high as 8,000 tons or US $45,000,000.00. There is a need for a network of veterinary services and disease testing facilities to be developed. A database has to be developed and maintained to identify precise reasons why projects have failed. There is a need to apply existing knowledge from the federal and state fisheries and oceans departments, and from universities. The technology transfer from these groups can shorten the learning curve for fish farmers.

Running Down

Is damage caused by third party vessels colliding with cages? Once again, in theory, losses are recoverable from a guilty third party, but the actual incident must be witnessed and the third party identified. If damages are levied, the same problems concerning the ability of the third party to pay must be faced.

Theft

Theft is occuring more frequently. Vessels can come alongside cages and those on board can steal a considerable amount of fish.

Vandalism and Malicious Damage

It is surprisingly difficult to cause a serious loss to a marine farm—more difficult than just shutting off a valve or blocking a pipe on an onshore facility. It is quite difficult to pollute a marine cage. Proof of this can be seen when an attempt is made to spread a drug throughout a cage.

Drifting Debris

This can cause considerable losses. There are one or two good precautions. One is to surround the cage site with a floating boom to deflect surface debris. Some arrangement of large mesh netting below the surface may provide additional protection. It is good practice to inspect the shores near your farm on a regular basis, especially before seasonal high tides.

Equipment Failure

If a piece of equipment is built and that equipment does not perform as it should, and somebody loses out as a result, then that party has the right to recover from the manufacturer. I have no doubt that eventually underwriters will attempt to recover from a cage manufacturer or a net producer or other manufacturers or suppliers to the industry.

Storm Damage

This is called heavy weather damage in the marine insurance industry. A great deal can be done to reduce the risks, thereby keeping premiums down and profits of cage producers and underwriters up.

Just about everywhere cage culture is carried on, boating of some form or another also is carried on. It may range from large-scale commercial marine movements to passing by of pleasure boats. A major part of the boat traffic will be insured and almost certainly there will be companies who specialize in marine surveys and safety checks for underwriters. These companies offer the cage farmer a readily available source of risk management advice founded on a wealth of practical local experience. The experience covers the mooring of yachts and fishing boats, which is not unlike that of cages, and the surveying of docks and wharves and other marine structures. There is a great variation in the nature and effect of tides, winds, and waves.

Very few sites are perfect on all points when it comes to heavy weather. Another point is that a comprehensive marine survey report may well make the difference between affordable and nonaffordable rates, between getting or not getting insurance cover. There are two more points on marine surveyors:

1. Cage farms are expanding—it is good practice to call on the surveyor once a year or to consult with him before any major change in site configuration or changes in marine equipment.
2. Find out the surveyor's recommendations for maintenance procedures, for lighting and navigation warning procedures, and for safety equipment.

PRODUCT LIABILITY

An area of potential problem for the insurance industry is product liability. It remains to be seen how the liability exposures of aquaculture develop. The treatment of nets with tributyltin oxide (TBTO) based paints, to prevent their being fouled, provides a clear example of how careful the industry must be in the future if it is to steer clear of damaging liability claims arising either between different branches of the industry or from the general public.

The damaging effects of botulism must never be underestimated in an industry that is made up of so many individual producers. Only one careless producer selling infected fish can tarnish the image of the industry. The liability exposure can be measured and the consequential effect on markets can be devastating. One need only look at the canned salmon industry as an example. Liability exposures will develop as the industry grows. There are several areas to be watched:

1. Liability of the vendor of fish for the transfer of diseases to the purchaser.
2. Liability for environmental damage by fish farms.
3. Liability of system designers and builders whose systems do not meet specifications.
4. Liability of others for polluting fish farms.
5. Liability to the general public.

Most of the clarification is likely to arise out of legal activity in the coming years.

CONCLUSION

I hope I have given you an insight into the trials and tribulations of the aquaculture insurance business. I stress that any fish farmer would be very unwise to accept an insurance quotation offered to him without receiving a copy of the terms and conditions being offered. He must carefully consider whether or not those terms and conditions accurately express what he, himself, understands will be covered by the policy he is purchasing.

MARKETING OF BRITISH COLUMBIA FARMED SALMON

Al Archibald
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Three areas will be covered here. The first aim is to provide an overview of the markets for farmed salmon and some of the features of those markets. The second topic is how British Columbia farmed salmon is marketed, the market performance to date, how the market went in the last year, and more detail about the kind of product that's coming out of British Columbia. And the third area to cover is the issue about farmed vs. wild salmon, and whether they complement or compete in the market.

BRITISH COLUMBIA SALMON FARMERS ASSOCIATION

The British Columbia Salmon Farmers Association is a producers association and we represent over 95 percent of the 80 or so salmon farmers in British Columbia. We've got people doing a variety of different things from egg allocation to liaison with the government.

We have three major areas of involvement. We are involved in generic promotion, which means promoting British Columbia farmed salmon to the marketplace as opposed to the production of any one farm. The second thing we're working on is quality assurance and control. We have a number of programs in that area, such as developing grade standards and working on quality control handbooks, manuals, instructional materials, and support materials. And the third thing we're working on is market research. We try to keep abreast of what's happening in the marketplace and provide useful information to our members so that they can make informed decisions about marketing the product.

THE MARKET FOR FARMED SALMON

Markets for salmon are very much a function of the product form that we are dealing with. When we are talking about farmed salmon we mean fresh and frozen salmon as opposed to total salmon consumption, which would include canned, for example.

When we started a research project for the British Columbia Salmon Farmers Association about two years ago, one of the first things that we did was look at consumption trends of fresh and frozen salmon worldwide. We wanted to identify the most reasonable markets for the British Columbia farmed salmon. The results of that are relevant to the consideration of farmed salmon in Alaska.

In Japan, the 1983 consumption of fresh and frozen salmon was 273,000 tons, or five times the American consumption. So generally farmed salmon marketers look at Japan as having a huge potential, more in the medium to long term than in the short term. There is some imported farmed salmon being consumed in Japan right now, about 1,500 tons. This is in addition to their own production. There is definitely a potential market in Japan, but there are lots of barriers to be overcome.

But what really bodes well for British Columbia farmed salmon is the size of North American consumption relative to European consumption. The 1983 European consumption was about 50,000 tons, and the North American market about 65,000 tons and growing. British Columbia has competitive advantages in the North American market over the other major producers, such as Norway.

There are two major markets for fresh and frozen salmon in North America: food service and retail. Food service is restaurants or away-from-home consumption. Retail is basically food that is purchased and then consumed in the home. For fresh and frozen salmon, particularly fresh salmon, the majority is consumed in a restaurant. The retail segment is the one that people look to as having the greatest potential for growth—supermarkets and specialty stores.

British Columbia Salmon Farmers Association research has shown that farmed salmon has a tremendous market potential when its product characteristics are compared to what buyers consider important. We wanted to identify those attributes or characteristics that consumers considered important. The consumers in this case were the people in the restaurants, the restaurant chefs, the buyers, and the retailers. There were a number of interesting findings that came out of that. The first one was size—the market ideally wanted a salmon over 6 pounds, but something over 4 pounds was acceptable. As long as that criterion was met, there was nothing that said that Atlantics were necessarily superior to Pacifics. So that was very encouraging with regard to what species to rear. From a marketing standpoint, that was comforting information to find out.

There is clearly a strong preference for fresh salmon, as opposed to frozen. Fresh salmon, and fresh seafood in general, is very well liked these days, and this was confirmed by the research that we did. Also, quali-

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ty was an extremely important element in seafood consumption.

Another thing we found out was that in some of the markets that we looked at, especially in restaurants, they were very much in favor of the pre-cut steak or filleted product as opposed to a whole, head-on product. Definitely continuity of supply is one of the key features that farmed salmon has to offer. That was an interesting finding.

All of those criteria ranked higher than the actual price for the product, so there is a tendency to put the price further down in the priorities behind things like quality and consistency.

Today we have about 110 sites developed with fish in the water. Production for the year ending December 1987 will likely be 1,600 tons, and is predicted to rise to 3,000-5,000 tons next year. I think that sites of fish in the water is probably the most telling statistic about where the industry is going. We're still waiting for the production from those sites to get going. For 1989 the production estimates are 12,000-15,000 tons. It really is difficult to make production forecasts because there is no reliable system for reporting changes in the inventory on hand, and there are varying survival rates and weights at time of harvest among producers.

The primary species reared in British Columbia are Pacific chinook and coho (also called kings and silvers). There is some activity with trout and Atlantics, but they're not the prominent species, primarily because we've been dependent upon wild stocks for a source of eggs.

Of chinook and coho salmon, there is more interest in chinook. Chinooks seem to have a lot better features both from a production point of view and a market point of view. There is a strong move away from coho right now.

The fish we are marketing are small—about 4 pounds. And there are reasons for that. Part of the reason relates to basic biological characteristics. Also, a lot of people have been selling fish as soon as they reach 4 pounds to raise needed capital. But the most important reason, especially with our coho species, is the difficulty in getting them over the 4 pound limit before they mature. If we somehow postpone or delay the onset of maturity through one of a variety of different ways, the fish don't perform nearly as well. So as long as we raise coho and as long as we're dependent upon wild stocks for our smolts, we will have a lot of small fish.

Ninety percent of our product is going to the fresh market, with the main marketing occurring between November and May. There's a domestic market in and around Vancouver because production in the wild has been low. We've also been looking at eastern Canada as well as south of the border.

Farmed chinook and coho have lighter flesh color and milder flavor, with delicate flesh and high fat content. The farmed fish doesn't have the same degree of firmness as the wild stocks, and sometimes people refer to delicate or soft flesh in less than favorable terms. These fish have to be carefully handled. We think flesh texture will improve over time, but soft flesh seems to be associated with farmed salmon generally. To color the flesh the orange shade typically found in the wild stocks, it is possible to use synthetic pigment. The mild flavor tends to be associated with the diet. Recent research indicates that the typical fish meal based feeds used in the industry produce salmon with the same omega-3 fatty acid content levels as wild salmon, and the potential to manipulate to even higher levels if required. Fish are what they eat and if they are fed diets that are high in herring meal and other products, the omega-3 fatty acid levels will be similar to what you'd find in wild stock.

THE MARKET FOR B.C. SALMON

There are certain competitive advantages that British Columbia salmon farmers have in selling to some nearby marketplaces. Transportation is the obvious one. The cost to air freight fish from Norway to mainland United States is over $2 per kilogram or over $1 per pound. We can truck British Columbia salmon to California for $0.15 per pound, and we can fly it to other parts of the United States at significantly reduced rates.

British Columbia has good growing conditions. We also have a good inspection program in British Columbia, and that has given us a positive image.

The exchange rate is important as well in that our dollar tends to follow the U.S. dollar. Lately the U.S. dollar has been falling relative to some of the European currencies, for example, and that prices the European product much higher in the United States.

We also have some disadvantages. The first one is high production costs. That largely stems from the newness of the industry—the capital intensity of the industry. We won't be producing inexpensive fish, at least initially.

Second, with the quick growth of the industry there was a tremendous concern for getting organized quickly and for getting fish in the water and therefore some decisions were made that weren't necessarily to our credit. We hope that will be corrected over time.

Figure 1 shows the harvesting and processing options for farmed fish. The channels by which fish move from the net pens to the marketplace in British Columbia are similar to those that Alaskan farmers and processors would use.

There is some integration between the wild sector and the farmed sector in British Columbia. Many of the fish packer vessels are being converted to handle live haul of farmed salmon to processing plants during off-season. Farmed fish can be sold fresh in the winter; the vessels can be utilized during a season when they would normally be idle.

The live haul method tends to be more popular around the Sunshine Coast, in the southern coastal area of British Columbia. Some of the main processing companies have facilities in Vancouver. The companies go out to net pens and pump or brail fish live out of the pens and transport them to the processing plants. This

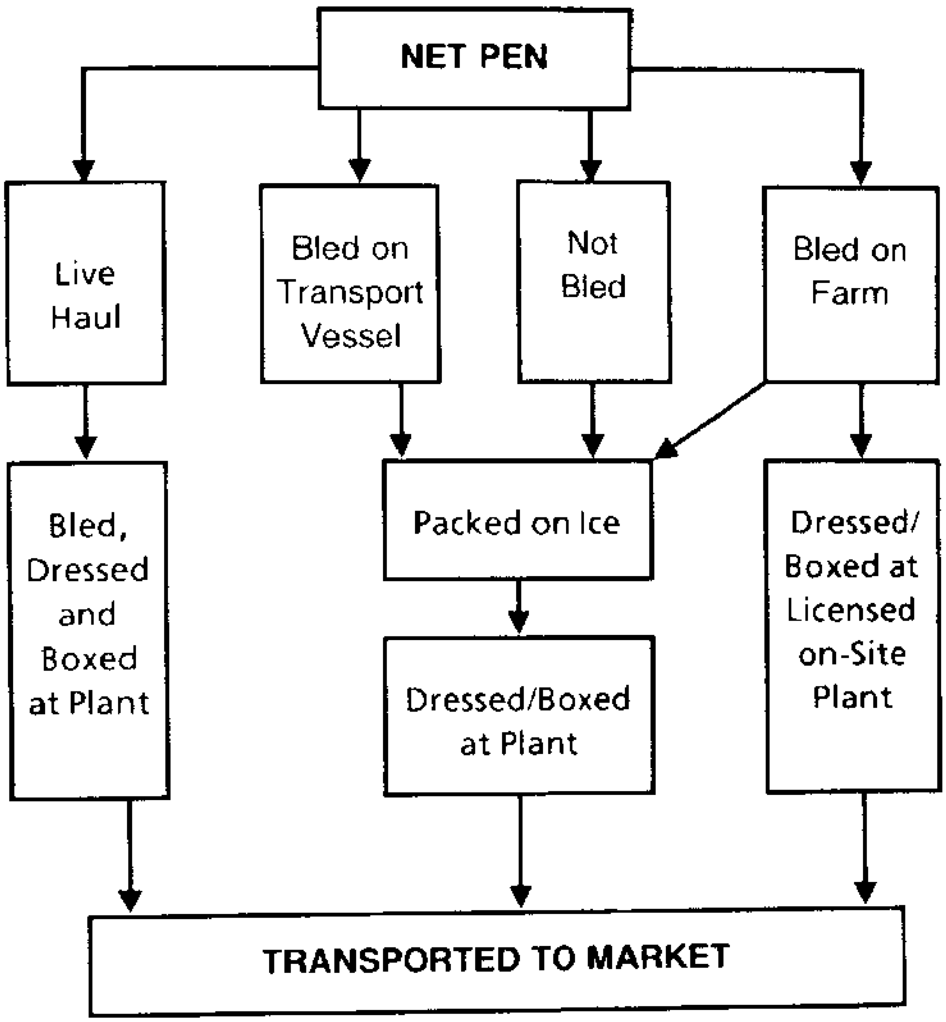

Figure 1. Harvesting and processing options for farmed fish.

technology has grown rather quickly. In November 1986 operators had not yet successfully completed a live haul transfer of market-size fish, but by March 1987 it had become standard practice. There are still some problems to be overcome and some issues to be resolved, but live haul is becoming an important means of moving fish from net pens on their way toward processing plants.

A method that is becoming common in the Campbell River area involves a transport vessel that moves the fish to a processing plant where it's dressed and boxed. The fish are slaughtered at the site, but processed at a plant off the site. There are three or four operations that have net pen sites and are themselves registered licensed processing plants.

There is quite a lot of variation in shipping a product, as shown in Figure 2. It ranges from the fisherman or farmer selling directly to a consumer to very complex channels. There are various middlemen or intermediaries involved in moving farmed salmon. This is true for any seafood product and many other food products as well. We find that as production grows and as farm units grow, more middle people are involved in the selling function.

There are five major selling options for British Columbia farmed salmon. About 10 percent is direct selling, where a farmer takes his fish to a specialty seafood shop or a restaurant. This typically involves a domestic sale in the Vancouver area and British Columbia. If volumes are low, direct selling is common, but with high production this changes.

Thirty to forty percent of sales are through traditional fishing companies. The processors of wild fish live-haul salmon to their plants in Vancouver. They use their existing sales force to sell an added item to their product line. They are becoming more aggressive about getting out to the farmed salmon supplies. This is at-

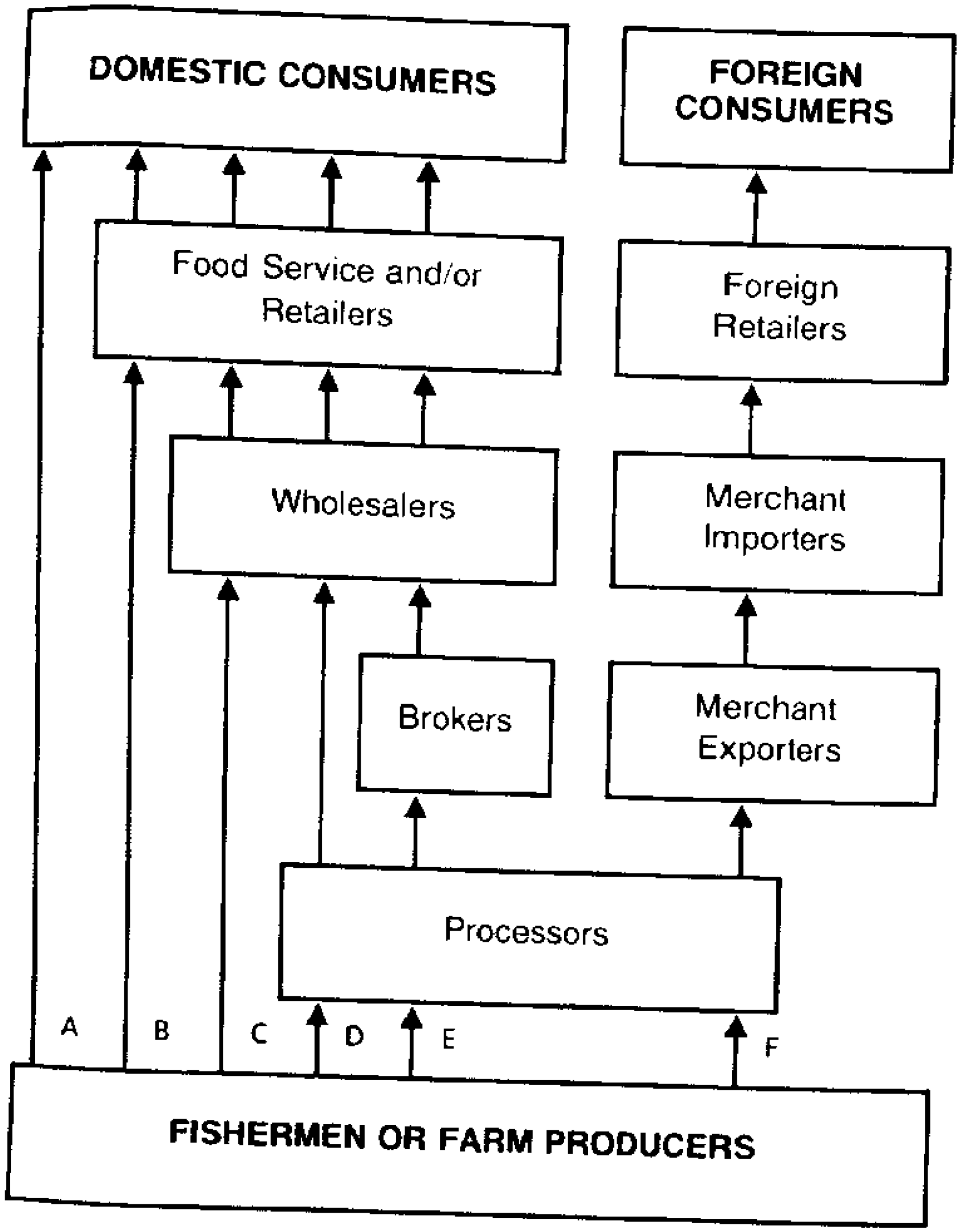

Figure 2. Distribution channels for fish.

tractive to many farmers because they have capital constraints and are tied down to their farming, and many would rather not have to worry about the steps beyond that stage.

About 15 percent of sales are through the large, oftentimes publicly funded, aquaculture companies in British Columbia. Some of them have links with existing processors. Others have established their own marketing arms and groups. We're finding that they also are trying to attract supply from the small farmers. So the aquaculture companies are becoming an important means by which farmers can sell their product.

Norwegian export companies account for 25 percent of sales. They are primarily looking at a North American marketplace. There are many Norwegian companies who have links in the U.S. marketplace and are selling Norwegian salmon. These companies are beginning to add British Columbia farmed salmon as a product line and are some of the biggest movers of farmed salmon in the northwest.

Table 1. Pricing structure for British Columbia farmed salmon, per pound.

	U.S.$	Canadian $
Price to farmer (88% recovery)		3.10
Price to farmer (dressed)	2.70	3.50
Processing costs (including box and ice)		0.45
Transport to processor		0.15
Total price F.O.B processing plant		4.10
Transport to market		0.15
Market commission (8%)		0.35
Total price to wholesaler	3.50	4.60

Smaller export-import and trading companies account for about 10 percent of the sales. Our resources industry already has a strong link with the Japanese market, and several firms are trying to get access to the Japanese market.

We have a host of brokers and wholesalers serving the wild fishery who are trying to buy farmed salmon. When we have a demand outstripping supply, the farmer has no problem finding potential buyers. The problem is sorting out good buyers from the bad ones.

Table 1 shows the pricing structure for British Columbia farmed salmon. It gives some indication of cost and returns that exist from the farmer to the wholesaler. These are illustrative prices based on the situation that existed last year. This should give the reader a feeling for how the price to the farmer gets translated into the price for the wholesaler. In British Columbia, a rough rule of thumb is that the price to the wholesaler F.O.B. Vancouver is roughly $1.10 to $1.15 higher than the price to the farmer for a dressed product at the farm gate. This varies depending on where the farm is located and how far it is from the market, and particularly what kind of link the farmer might have to the marketplace. The $1.10 excess includes processing costs at the processing plant, transportation costs to the processor and from the processor to the marketplace, and a brokerage or commission. Many of these standard processors are working on a commission sales sort of basis, so that's an average that seems to be appearing in the industry. The US $3.50 F.O.B. Vancouver price is not bad for the middle of the season last year.

The information in Table 2 is from *Seafood Price-Current*, March 21, 1987, published by Urner, Barry Ltd. This twice-weekly publication has started to list farmed salmon prices, and is a fairly good indicator. Last year we had a lot of farm-raised Canadian coho in the 2 to 4 pound range, which is considered a no-no. There was a feeling that the amount of salmon we had in that small size was pulling down the prices in the entire species of fish. But I mentioned earlier that the price was US $3.50 F.O.B. Vancouver. That's close to the price on the table—US $3.30 to US $3.40 for 4 to 6 pounds last year.

Also, the chinook (or king) prices were higher than coho. It is unclear whether that's due to the nature of the beast, the fact that it is a more premium fish even in the wild markets, or the fact that average size tends to be bigger.

British Columbia farmed coho salmon traded fairly close to the price of the Chilean coho last year, and roughly $1.00 less than the Atlantics. The latter is a trend that is continuing, and we feel that's a problem that will remain with us as long as we're producing smaller fish on an inconsistent basis.

Prices from last week were up quite a lot—$4.50+ for 4 to 6 pound Canadian coho. Fish is pretty short right now. That gives an indication of the volatility in the fresh salmon markets. It demonstrates the law of supply and demand.

CHALLENGES FACING THE INDUSTRY

Small Fish

The first challenge is small fish. There is no doubt that the smallness of the fish we're producing is causing some significant problems. It means that the prices we're receiving are lower, in many cases, than those that were forecast in business plans.

The small size narrows the market segment to which we can sell our product. The Norwegian imports and the larger salmon have typically been sold in the white

Table 2. Fresh farmed salmon prices, F.O.B. Seattle, March 1987.

Weight	Canadian coho	Canadian king	New Zealand king	Chilean coho	Scottish Atlantic	Norwegian Atlantic
2-4 lbs	3.20-3.25					
4-6 lbs	3.30-3.25	3.80-3.85	3.75	3.40-3.45		
6-9 lbs	3.60-3.70	4.00-4.05	4.00	3.60-3.70		
9 lbs +			4.25			4.30-4.40
2-3 kg					4.45-4.55	4.35-4.45
3-4 kg					4.55-4.65	4.45-4.55
4-5 kg						4.55-4.65
5-6 kg						

tablecloth restaurant marketplace. What we're finding is that a lot of our product is moving in the retail outlets. It's just not a product that's big enough to be sold in restaurants. That may change over time, but not for the next two or three years.

Quality

The second area of challenge is quality. Because the industry has grown so quickly, there are a lot of people out there who are new at the business and there is considerable variability in the quality. That will definitely change over time. It's something that we're working on at the association, but as it stands now, there is considerable variability.

Consistency of Supply

The third challenge is achieving consistency in supply. There's definitely potential for farmed salmon to be sold on a year-round basis, but we are far from that now. The primary marketing season is November through May. Unfortunately, a lot of our coho that haven't been neutered or otherwise modified, mature at the same time as the wild coho. Therefore they tend to be sold in a very short time period in August and September and at that time they're just getting up to about 4 pounds. With chinook, we're finding that to achieve that 4 pound minimum for the best prices in the marketplace, and to get our product in before the wild season starts, we sell in February through the end of May.

Last year the wild season wasn't as promising as it had been in previous years and there were people who were marketing farmed fish through the summer and getting good prices for them. Right now the production strategies are geared toward getting most of the year class out before May and June. But this is just a three or four month window unless we want to sell smaller fish, which is what happens too often. But this is expected to change. Farmers compare this year's class with the equivalent age class last year and they say they are ahead in weight gain and everything else.

Production Coordination

Production coordination is the fourth challenge. This is related to the growth of the industry. The main producers are moving 40 to 50 percent of the product. We still have lots of sellers. One of the advantages of farmed salmon is to be able to coordinate production and bring the fish along consistently over a long period of time. That's very difficult to do if there are a lot of small sellers with small production. This kind of production coordination will be very important as the industry moves forward in successfully marketing their product. Right now, there is some cooperative selling and there are still a lot of small sellers out there.

WILD VERSUS FARMED SALMON INTERESTS

Wild vs. farmed salmon is a very complicated issue and it needs a lot of analysis. But the impact of the conflict is exaggerated. The markets are complicated for salmon and so much depends on what species we are talking about, how it's caught, what product form it's going into, and finally, what market segment we are selling in.

When it comes to farmed salmon, I think the following points should be made. First of all products do not compete unless they are substitutes for each other. Canned salmon doesn't compete with troll-caught salmon, but the issue gets a little fuzzier as you consider other products.

The market for Alaska troll-caught salmon primarily has been in Europe, for smoking, whereas fresh salmon from British Columbia is sold fresh in the U.S. marketplace. Therefore there isn't a conflict between the markets that these products are serving.

With regard to the product form, fresh vs. frozen, there are some interesting issues that should be raised. Research that's being proposed will address these things. The buyer for a white tablecloth restaurant usually will not substitute frozen salmon when fresh is not available; he will buy another kind of fresh fish. Clearly, our competitors for fresh salmon are other fresh seafoods as opposed to the frozen variety.

Consideration of differences among market segments and among markets in foreign countries is important in the farmed vs. wild salmon debate. The white tablecloth market has different criteria and different buying characteristics from the smoked one. And, similarly, the situation in the United States is a lot different from Europe. So to determine the extent of competition between wild and farmed salmon, one has to examine the degree of interaction in each distinct market.

There is a lot of room for growth in the North American marketplace, which is what British Columbia farmed salmon is going to be using for the majority of its sales. This growth can't just come from domestic sources. Already 65 to 70 percent of the seafood that's consumed in the United States is coming from outside the United States. Clearly, to fill the demand for seafood, we wholesalers are going to have to look outside the United States for supply sources.

Analysis of data suggests there is lots of room for U.S. seafood consumption growth. The overall growth in seafood consumption per capita in the United States between 1982 and 1986 was 20 percent. However, seafood consumption for fresh and frozen products other than shrimp has gone up only 6.3 percent between 1982 and 1986. I believe growth has been low because of a lack of supply. That is why prices and demand are high and that is why consumption is not growing at the rate we would expect. The problem is the non-availability of the product. One of the most important things to keep in mind is that our research indicates there is a lot of potential demand out there. North Americans want to consume more seafood. There is room for growth for farmed salmon and there is room for growth for wild salmon.

With our wild catches near or exceeding their maximum sustainable yields, aquaculture is one of the major ways in which the need for increased supplies can be met. Farmed salmon has the ability to fill the gap between the amount of salmon North American consumers are prepared to buy, and the amount that will be available from the wild fishery in the future. In such an expanding market, there is clearly room for both sources of product.

One last point is that it has been demonstrated that higher quality farmed salmon can command higher prices. That is important because for a long time much seafood has been traded as a commodity, and efforts to improve quality in the wild fishery haven't necessarily translated into higher prices. So this development actually improves the market prospects and returns to fishermen who produce a high quality wild salmon.

I would like to express my thanks to the conference organizers for inviting me to give my talk.

QUESTIONS AND ANSWERS

Q. You made the statement that your egg supply comes from wild stocks. But don't the eggs, in fact, come from enhancement hatchery surpluses?

A. Right. The point that I was making was that the eggs are not domesticated in any way. The eggs do not come from fish that have spent their whole life in pens in a domesticated situation.

Q. There is one producer whose fish spend their entire life cycle in net pens. For those of us who have labored long and hard in the enhancement program to hear him refer to hatchery eggs as "wild" eggs is something that warms the cockles of the heart.

ECONOMIC EVALUATION OF THE CULTURE OF ALL-FEMALE PACIFIC SALMON

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The work that I do is not entirely new. The techniques of chromosome set manipulations have been around for a number of years and right now several workers in many different countries are trying to identify some economic advantages to some of the chromosome work that has been done for academic and scientific purposes. This is the British Columbia work that has promoted sex control techniques in salmon. The British have monopolized the technique to the point that the majority of the farmed trout in Great Britain are sex control forms.

A report was written just last year that was the result of polling the fish farms in Great Britain. At that time only 17 percent of the fish in Great Britain that were farmed were mixed sex fish; 53 percent were farmed using the techniques of sex control and 30 percent were produced using the triploidization of females to form sterile all-female populations.

INDUCED POLYPLOIDY TECHNIQUES

This paper is a review of one of the most exciting and newly emerging aspects of genetics and salmonid set manipulation, termed induced polyploidy; it produces superior attributes in cultured stocks. Coast Oyster and the University of Washington have made promising progress with triploid oysters. I will briefly discuss the techniques used with salmonids and present some of my results with triploid hybrids, with an emphasis on the benefits of using these techniques to control the proportion of females in hatchery populations. Sex ratios in salmonids can easily be controlled with the use of hormones; however, the chromosome technique produces an all female population without administering hormones to fish.

Chromosome set manipulations are possible because at the time of fertilization, salmonids have two sets of chromosomes, one in the nucleus and one in what is called the second polar body. Within 45 minutes of fertilization, the second polar body is shed from the egg and a normal diploid embryo is formed. If we heat shock the egg during that 45 minute period, the polar body fuses with the egg nucleus and a triploid embryo (three sets of chromosomes) is formed. In most cases, these are completely sterile.

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The first step in the production of all females is to go through this same process except to inactivate the sperm chromosomes with UV light. This produces a gynogen—all of these individuals will have two maternal sets of chromosomes and be XX females. Both of these manipulations are done with a simple heat shock. A 29 °C water bath for 10 minutes works well with most species.

Key to this process is that sex is not fixed in salmonids until a few months after hatch. Hormone treatments at this time enable the reversal of sex of these XX individuals to males which will only produce female progeny for culture.

One of the most promising applications of triploidy in salmon is the production of triploid hybrids. Triploid hybrids survive much better and frequently grow faster than diploid hybrids, and we are currently testing a number of combinations to identify if any have desirable attributes.

Diploid hybrids often suffer from a number of genetically caused abnormalities. If we triploidize the hybrids, frequently those abnormalities completely disappear as a consequence of there being two sets of chromosomes in one species, which allow that individual to have all the genes it needs to be a good fish. It's got an extra set of chromosomes from the male parent. That will confer some of the characteristics of the male species on top of that already healthy species, but reduce the abnormalities that are present in the diploid form.

Some of the early work in salmonids was done by Washington State University researchers. They took the knowledge that had been gathered by many other people and applied it to the production of brown trout, brook trout, and hybrids called tiger trout. They found they could increase the survival rate of diploid tiger trout by about sixfold by making triploids. And, in addition, the triploid fish grew faster than the parent species or diploid hybrids.

Our initial work in hybrids was done testing the viability of three species in combination as hybrids—chum salmon, coho salmon, and chinook salmon. We got a variety of different results and survival and two of the positive findings we found were that the coho-chinook diploid hybrids expressed poor survival rate and uniformity of form. When we triploidized them, the survival rate stayed about the same, but the deformities were completely removed.

One of the most exciting things that I've been working with lately is the chum-chinook hybrid. The diploid hybrids were completely inviable. We've never been able to get one to hatch in our process in Washington and Idaho. The triploid hybrids hatched nearly at control levels, nearly at the level that the chum-mother-fertilized-with-chum-sperm progeny would hatch. We had about a standard 10 percent handling mortality in the laboratory, and in the field we've seen this mortality increase up to as high as 50 percent. We don't feel that makes this hybrid any less useful; the cost of chum eggs is very low and if we need to take two eggs to make one good pen farming hybrid, we think that that's an acceptable cost.

UTILITY OF GYNOGENESIS

The gynogenesis process that I described earlier generates production amounts of all-female progeny. The advantages of raising all females are many. The first thing that comes to mind is that for someone raising all females, a lot of eggs are necessary to rapidly increase a brood stock. And the other is the potential increase in value of a commercial roe fishery.

Europeans and trout farmers in Washington accomplish the production of all females by maintaining a captive male brood stock on the side. The male brood stock is formed by using induced gynogenesis to first produce the inbred all females. The individuals are sex reversed (which is very easy in salmonids) into males. Those males will produce only female progeny. The sperm from those males is used to fertilize the eggs from the outbred population. Those will all be females, and if raised to maturity, will all produce eggs. The eggs from the maturing production fish then can be sex reversed again to perpetuate the captive male brood stock. And in that way, after gynogenesis, there is no additional chromosome set manipulation; the population of all females will be self-perpetuating.

I'm not completely certain that these techniques will be universally applicable in ocean ranching or net pen farming situations, but I think there are a number of cases in which that will be possible. There are advantages to ocean ranching, both public hatcheries and private, regional association-type hatcheries. The benefits are threefold. First, there is an increased price to the fisherman, but in addition there's a reduced requirement for brood stock which makes processing at the hatchery level a lot easier and eliminates the problem of precocious males.

A poll was made of Southeast Alaska processors to get a general sense of the price they would be willing to pay for progeny that were mostly female—not all female, but mostly female. The results of the poll were striking. The prices in 1987 apparently were at a high, because fish were at a premium. The numbers were about $0.31 a pound for pink salmon and $0.55 a pound for chum salmon in 1987. And the processors as a whole said that had the sex ratio been 4:1, females to males, they would have increased the price to $0.37 for pink and $0.69 for chum.

After talking with the same processors at length, the general sense was that in years when the price for pink and chum in the terminal fishery is extremely low, the price for populations that are skewed toward mostly females would nearly double. It would be nearly 100 percent additional value because of the presence of eggs. And in years like 1987 when fish are at a premium, the increase in value is not nearly so much.

The additional benefits to the fishing community that I had not even thought about were the fact that the increased value in price of these mostly female populations would greatly accelerate the debt service for regional associations and that acceleration of debt service would immediately put more fish into the common property fishery.

NET PEN FARMING

The work that I've done toward net pen farming fish production is primarily with the hybrids. But obviously there is a potential utility for this sex control technology in net pens primarily because farmers have the relatively easy option of maintaining the captive male brood stock.

The advantages of pen farming operations are the same as for ocean ranching operations, except for the greater impact of loss due to maturing males in net pens. As I understand it, aside from disease and nutrition, one of the biggest problems or concerns of net pen farmers is loss due to precociously maturing males.

The trout farmers in southern Idaho have found that by rearing female-only populations, the groups of females in a raceway tend to grow at rates similar to one another more so than the groups of mixed-sex fish. And as a consequence, they do not have to handle and grade them quite so much. And they also have found that the females grow to their small size (that is the pan size) in about 11 months, whereas the mixed-sex, with the handling and the grading, take about 13 months. So that's one additional advantage of the one-sex culture over mixed-sex culture.

These advantages don't come without some costs. And the costs are similar to what they are in adapting to any new stocks and new situations. Fortunately, now the governments in the United States and British Columbia are paying for a substantial portion of those adaptation costs. The real cost is the cost of maintaining the the captive male brood stocks. And for farmers who maintain a captive mail brood stock already, it's not an additional cost at all.

To summarize, some of the advantages are: (1) the increased value of the harvest, (2) the increase in the allowable rate of harvest in the public hatchery sector, and (3) the potential to increase the profit for all kinds of private aquaculture.

Again, the technologies that we're talking about are innovative and are not restricted to Idaho or Washington or Alaska. The Japanese, the English, the French, and (unfortunately a little late) the North Americans, now are taking a look at what we can do with simple chromosome set manipulations. And most of it can be accomplished in a bucket of hot water.

ACKNOWLEDGEMENT

I would like to say thanks to Rick Harris. He has been a real help in getting me to realign my thinking to look for economic benefits in the exciting scientific results that we've been getting in the lab.

QUESTIONS AND ANSWERS

Q. Over lunch we worked out what the difference was in the pink salmon harvest. What were the numbers for Prince William Sound if they were all females?

A. Somebody mentioned to me that there were about 27 million pink salmon at 4 pounds apiece that were harvested in Prince William Sound, and if you multiply that by a dime apiece, you come up with an increased revenue to the individual fishermen of $20,000 apiece. So we're not talking about small dollars. And that's with 1987 prices.

Q. There has been some speculation about the environmental or ecological hazards of straying fish. Would you guess what the likelihood is of those kinds of things happening?

A. I think that the ecological hazards are primarily going to be associated with ocean ranching. Right now we're only working with hybrids in a net pen situation. The concern that a lot of people have is what would happen if these hybrid fish would stray and try to spawn with the natural population. Part of the funding that is supporting the research is for looking at that very question. I wouldn't advocate the wholesale use of hybrids. On the other hand, this all-female phenomenon is completely different. When you're working with native stocks and you're producing all females, those females have an identical genetic component with all other females in the population. All we've done is eliminate the males. And none of the fish that we produce for either pen culture, raceway culture, or release would be in any way different. They are identical to the native stocks.

Q. Can you eliminate freshwater rearing of hybrids?

A. Absolutely. The sea water chums that I did were started at the 0.5 gram stage and I took them up through a gram or so over a 3-week period. My findings so far are that the mean plasma sodium level in the hybrids is identical to the plasma level in the chum salmon, at the 0.5 to 1 gram stage. The commercial farmer who is growing them in seawater took that into account in raising them to 2 grams before transfer and had no problems at all.

Q. Would the chum-chinook hybrids mature?

A. That's what we're studying right now. The evidence is that the females won't. There is a possibility that the males will. If the males did mature, they would still be sterile but they might take on the secondary sexual characteristics of a normal male and try to spawn. Therefore we're trying to find that out before we do any wholesale releases.

Q. But they would be sterile. There would be no genetic intermingling.

A. Right. That's the way fruit flies are controlled. I'm really excited about these techniques, but we're not advocating that every hatchery install a bucket of hot water and dip everything in it. I'm really impressed with the way people in Alaska are approaching these new techniques, because there are a number of really high quality experiments going on in Anchorage, Ketchikan, Little Port Walter, etc., who are investigating the utility. There is a good chance that sometime in the future you will see these techniques applied.

Q. If only hatchery space were needed, and no rearing pond space, how much would a farmer save in production costs to be able to immediately put the fish into salt water?

A. I haven't worked that out, but I know that the growers with whom I'm working are really excited about it because they're also raising steelhead, chinook, coho, and Atlantic salmon. They're paying (depending on the species) up to a dollar a smolt. And these hybrid smolts conceivably would cost a few pennies apiece.

Q. If a population of females only got mixed in with natural stocks and as they matured they produced more females only, wouldn't that eventually cause a loss of the male ability to reproduce, because male population would be lost?

A. No, because if normal males fertilize the eggs from the female-only individuals, the ratio of the offspring would be normal. That's the real delight of this system. The production of all females in this is in no way altering the genetic integrity of the locally adapted fish. These are basically wild fish. All we've done is eliminate the male component in the hatchery. If those fish stray and spawn with other fish in the same area, then they are the same as native females.

Q. What possible change could occur in the wild with the hybrid chums and kings?

A. Only one thing could happen. If some of these males did take on secondary sexual characteristics and return to their native stream, or return to below the stream, they might try to spawn with a native female. These males are sterile, and if they did compete with the king males or chum males, they would be shooting blanks and the spawn from that female would be zero.

Q. What would that female be likely to go after, pinks or chums?

A. That's really speculative. They might try to go after brook trout, but I don't know.

Q. I know that chums in net pens are very susceptible to vibrio. Do you have any experience with vibrio with your production of the hybrids or were they vaccinated?

A. Yes, they were vaccinated. My understanding is that the water in South Sound is a little bit warmer than it is elsewhere and that vibrio is a problem with all fish down there. It has been speculated that the hybrids are more disease free than either kings or chums. I don't know if that's true or not, but it is certainly something that we should look at.

Some of the legitimate concerns that have come out deal with what might happen if these fish stray. It turns out that nothing will happen if they stray. I think there will be a tremendous way to enhance sport and troll fisheries. They're a vigorous, good-looking, fast-growing fish.

Q. I'm new to this game, but isn't the number of brood stock and the male:female ratio important to maintain as large an intact pool as possible? And if this decreases the number of brood stocks, are we not watering down the pool?

A. The only time that really is a factor is if you're dealing with the California condor where you have only a few of them anyway. In terms of salmonid hatcheries, where you're dealing with hundreds (if not thousands) of parents, you can maintain the genetic variability by using as few as 200 of the least common parent; in this case, males. I understand that about 200 of each sex is the recommended minimum in the state of Alaska's genetic policy. The kind of thing we're advocating here is certainly not going to reduce the genetic variability.

DISEASES OF SEAWATER REARED SALMON IN WASHINGTON STATE

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Net-pen rearing of salmon is well established in Norway and Scotland, but large-scale production by this method is relatively new in North America. Coho salmon (*Oncorhynchus kisutch*) and Atlantic salmon (*Salmo salar*) are the species most commonly reared commercially in seawater net pens in Washington State. Chinook salmon (*O. tschawytscha*) are reared by the National Marine Fisheries Service, Manchester, Washington for mitigation and research purposes, and this species is becoming more popular in commercial net pen operations. The Battelle/Marine Research Laboratory provides diagnostic services to fish farmers in the state. We have observed new pathological conditions in pen-reared salmon in Washington in addition to diseases that previously have occurred in European pen culture. Reported here is a summary of diseases observed in pen-reared salmon from 1985 to 1987.

METAZOAN PARASITES

Although helminths were occasionally observed in the guts of moribund fish at necropsy, we have observed only external copepods (*Lepeophtheirus salmonis*) in sufficient intensities to consider them significant pathogens. *Lepeophtheirus salmonis*, commonly called the salmon louse, is a cosmopolitan parasite that has been reported to cause epizootics in pen-reared salmon in Scotland (Wootten et al. 1977). Moderate infestations were associated with dermal ulcerations on both coho and Atlantic salmon reared in Washington, but severe epizootic episodes such as those seen with heavy infestations as reported in Europe have not been observed.

PROTOZOANS

Epizootic diseases due to protozoan parasites are common in aquaculture, and several are significant pathogens in pen-reared salmon. We have detected *Parvicapsula* sp. (Myxosporea: Myxozoa) in kidneys of coho salmon. The parasite sporulates in the epithelium and lumen of the kidney tubules, causing tubular degeneration and kidney hypertrophy (Hoffman 1984; Johnstone 1984).

Paramoeba pemaquidensis (Amoebida: Paramoebidae) was also observed on the gills of coho salmon after seawater transfer. Intense infections have occurred in the fall and winter months, particularly in 1985, and affected fish showed severe epithelial hyperplasia of the gill, which resulted in fusion of the secondary lamellae. Though other *Paramoeba* sp. are parasites of invertebrates (Sprague et al. 1969, Jones 1985), *P. pemaquidensis* is normally free living, and this is the first report of *Paramoeba* infecting fish.

A similar amoeba has been associated with gill disease in seawater reared salmonids in Tasmania (Munday et al. 1988). External parasites such as these gill amoebae are easily eradicated when fish are maintained in confined ponds or raceways by applying chemotherapeutics to the water. This is difficult when fish are reared in net pens, which have a constant water exchange. Formalin and other chemotherapeutics were ineffective in controlling amoebae (Munday et al. 1988). However, the parasite is apparently a strict marine organism and a reduction in salinity eradicated the parasite from coho salmon maintained in seawater tanks (R.P. Hedrick, University of California, Davis, personal communication). We are maintaining the organism in culture, and it will be useful for drug sensitivity tests and transmission studies.

We have also detected a microsporidian similar to *Loma salmonae* (Microspora) in the gills of coho salmon. The parasite is a recognized pathogen of chinook salmon, *O. tschawytscha* (Hauck 1984), but this is the first time it has been reported to cause disease in coho. In contrast to chinook salmon infections in fresh water, the parasite caused severe interstitial hyperplasia in the gills of coho after they were transferred to seawater. Fish become infected in fresh water, and initial observations indicate it is not spread in seawater pens. Therefore, the disease can be controlled by preventing infections in salmon during their freshwater phase of development.

Two interesting protozoan pathogens have been observed in chinook salmon maintained in net pens by the National Marine Fisheries Service. A microsporidium infected the nuclei of hemoblast cells of the spleen and kidney in three-year-old chinook and was associated with severe anemia (Elston et al. 1987). Also identified in three-year-old chinook was an obligate intracellular protistan parasite of undetermined taxonomic status, commonly called the rosette agent (Elston et al. 1986, Harrell et al. 1986). This parasite infected inflammatory cells of the spleen and kidney and was associated with enlargement of these organs. Over 80 percent mortality

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occurred in groups of salmon infected with the parasite during an eight-month period in 1983 and 1984.

BACTERIA

Renibacterium salmoninarum, the causative agent of bacterial kidney disease of salmonids, was detected in both coho and Atlantic salmon. The bacterium typically causes a chronic inflammation of the kidney interstitium, spleen, heart, and other organs (Fryer and Sanders 1981). It can be transmitted either horizontally or vertically within eggs (Evelyn et al. 1984), and the disease is often exacerbated after infected fish are transferred to seawater. Bacterial kidney disease has occurred in seawater net pens in Europe, and it is widespread in net pens in Washington and British Columbia. Coho and chinook salmon apparently are affected more severely than Atlantic salmon, and the disease is prevalent through the spring and summer. No consistently effective drug has been identified to control BKD, and the pathogen is considered by many to be the most significant cause of disease and mortality in pen-reared *Oncorhynchus* spp. in the Pacific Northwest.

Vibriosis, caused by *Vibrio anguillarum* and *V. ordalii*, is a cosmopolitan disease which infects salmonids and other species cultured in seawater (Novotny 1978). The bacteria cause septicemia, and the disease is exacerbated at higher temperatures. We have isolated *V. anguillarum* from coho during the summer, but it may have been a secondary invader, because most of these fish were also infected with *Renibacterium salmoninarum*. We have also isolated *Vibrio* spp. from Atlantic salmon that exhibited visceral hemorrhages. These isolates were serologically distinct from *V. anguillarum* and *V. ordalii*, and their role in the disease is unknown.

Furunculosis, caused by *Aeromonas salmonicida*, often causes severe disease in freshwater fishes. As the culture of fish in seawater has increased, this bacterium has been recognized as a pathogen in seawater as well (Novotny 1978), and we have observed epizootics due to this pathogen in net pens in Washington. As with *Renibacterium*, epizootics may occur in salmon with latent infections following transfer to seawater (Cox et al. 1986, Smith et al. 1982). Although the bacterium often originates in fresh water, it apparently can survive and spread in seawater (Scott 1968). In addition, infections have been reported that are restricted to marine waters (Morrison et al. 1984).

We have isolated a marine *Cytophaga* sp. from skin and muscle lesions in Atlantic salmon (Kent et al. 1988a). *Cytophaga psychrophila* and a related bacterium, *Flexibacter columnaris*, are well-recognized surface pathogens of freshwater fishes (Anderson and Conroy 1969), but the taxonomy of members of these genera which are associated with disease in seawater-reared fishes is poorly understood. Only *C. maritimus*, which causes disease in cultured sea bream in Japan, is well-described (Wakabayashi et al. 1986). Shortly after seawater introduction, the *Cytophaga* sp. which we have observed in Atlantic salmon caused skin lesions that ultimately developed into large ulcers extending into the muscle. The ulcers were focalized in the posterior region of the fish and were particularly prevalent in fish introduced in the spring of 1985, 1986 and 1987. Wet mounts and histological sections of the lesions revealed massive numbers of *Cytophaga*-like bacteria. In 1987, we isolated a *Cytophaga* sp. from these lesions that is serologically and biochemically distinct from the other known *Cytophaga* or *Flexibacter* pathogens of fish. We were able to induce the skin and muscle lesions in fish exposed to this bacterial isolate in the laboratory, which indicates that is it the etiological agent of the disease.

IDIOPATHIC DISEASES

We have observed a condition similar to pancreas disease in Atlantic salmon reared in Washington (Kent and Elston 1987). Pancreas disease is a syndrome that affects Atlantic salmon reared in Europe during their first year in seawater. Fish become emaciated, and histological examination reveals diffuse necrosis and atrophy of the exocrine pancreas. The cause is unknown and researchers in Scotland have proposed various etiologies; Ferguson et al. (1986) suggested that the condition may be related to vitamin E and selenium deficiencies, whereas Munro et al. (1984) reported epizootiological evidence consistent with an infectious etiology.

Toxicopathic liver disease was observed in Atlantic salmon maintained in net pens in Port Townsend Bay, Washington (Kent et al. 1988b). Severe diffuse necrosis was observed approximately three months after smolts were introduced to seawater in 1986 and again in 1987. Examination of surviving fish revealed basophilic foci of regenerating hepatocytes, intermixed with cells undergoing hydropic degeneration, and parenchymal cells with nuclear inclusion and enlarged nuclei. The latter is similar to megalocytic hepatosis of flatfish from polluted waters in Puget Sound (Myers et al. 1987). Ultrastructural examination of the nuclear inclusions revealed that they originated from cytoplasmic invaginations, and no viruses were detected. The disease is likely caused by a waterborne toxicant, rather than the feed, because Atlantic salmon fed the same diet and maintained at Port Angeles never exhibited the liver lesions.

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SITE SELECTION CRITERIA FOR FINFISH FARMING IN ALASKA

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The information in this paper has been garnered during my involvement with salmon ranching at the University of Alaska over the last ten years. Also, for the past three years I have been involved in a study of the selection and effects of a salmon farming site, located in British Columbia.

The matter of selecting a site is absolutely critical. It is a decision that a farmer lives with for the rest of the time he operates the farm. Don Nicholson shared an important insight when he said that the worst time to look for a farm is before we have operated one, because we have the least amount of knowledge about the process, organisms, and the important characteristics that make a farm viable.

There are numerous criteria that need to be used in choosing a site. The physical priorities that appear in articles on site selection are reasonably straightforward. Even though a particular site may not fit within the range of values given, it is possible to make adjustments for shortcomings if you have enough capital and if reduced profitability is acceptable.

There are many farms in British Columbia that have been successful. Criteria are being developed that indicate the general range for a site, particularly in physical matters such as those listed in Table 1. The main factors include water temperature, dissolved oxygen, water depth, salinity, the absence of pollution, current velocity, hydrology of the area, predators, marine plants, winds, and wave heights. At the end of this article are further references on the subject.

The most important step in choosing a site is to take stock of your abilities that will be directly involved with the operation of the farms. Ask yourself what you are capable of, what you are comfortable with. Some individuals use a skiff, a 40-ft long or 100-ft long boat, as readily as others use a pickup truck. If your spouse, like mine, really would not prefer to spend the next ten years in a remote location, you had better look for sites that are quite accessible.

You may wish to join in with others. Are you comfortable with the complex world of finance? Of fisheries biology? If not, you may wish to team up with persons who are.

Next decide what your objectives are. Do you wish to amass capital and build a large company? Or are you looking primarily to implement a life-style?

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A system of weighing factors is suggested. You may look at a large number of prospective sites. Assign points on some arbitrary scale to each of the physical, biological, and cultural factors. For example, a 0 would mean rejection, a 5 means so-so, and a 10 is perfect.

One of the difficulties is that there are really very few hard and fast rules. Factors such as landslides, large numbers of naturally spawning salmon, deep glacial waters, and large fluctuations in salinity and temperature are difficult to overcome, but values outside of the optimum ranges for other criteria can be dealt with. For example, water depth should ideally exceed 150 feet; however, a site with 30 feet can be made to work for rainbow trout. But you should not select a site that is too far out of the suggested range, since you may not succeed if just one species can be cultured. British Columbia has had two devastating algae blooms, and rainbow trout were hit the hardest.

Once you define what is really wanted and what the objectives are, and you have researched the physical and biological characteristics, the next step is to go to a good library. The ones at the National Marine Fisheries Service Laboratory in Auke Bay, the Resource Library in the Federal Building in Anchorage, the various University of Alaska and state libraries, or even the fisheries library at the University of Washington are recommended. Seek information on physical oceanography, weather patterns, and transportation networks. (Transportation is quite important and should be closely looked at as it is necessary to move a large quantity of material into and away from a farm.) There is a lot of time and money you can save by going to the library first.

Once you have selected an area that looks appealing, contact the local residents and make sure they would welcome a farm. Starting a salmon farm is a difficult proposition. I would not start one with neighbors who do not want one nearby. It is very easy to sabotage a farm. You will have quite enough challenge to make the farm successful even with the full support of those close by.

Find out just which permits you will be required to have. Securing one or more approvals only to find out that the next one or even last one is unattainable is a very expensive and time consuming process. Consequently before applying for the first permit, talk to all the major players in the regulatory process. During the initial contact it is not necessary to go into great detail. It is important to get an idea of what the agencies think and what their objections might be. At an early stage

Table 1. Summary of Biophysical Criteria

Factor		Good	Medium	Poor
Temperature	Summer	10 - 15 °C	16 - 21 °C	> 21 °C
	Winter	7 °C	5 - 7 °C	< 4 °C
Dissolved Oxygen	Minimum Conc.:	8.1 mg/L	6.2 mg/L	4.5 mg/L
	Minimum Sat.:	100%	79%	57%
Salinity	Long Term:	24 ppt	15 - 24 ppt	< 15 ppt
	Fluctuations:	3 ppt change	3 - 5 ppt	> 5 ppt
Plankton		No record of harmful blooms	Infrequent harmful blooms	Frequent lethal blooms
Pollution		No nearby sources	Nearby low level sources	Within areas of high pollution sources
Currents	At slack water:	10 - 15 cm/s	10 - 2 cm/s	< 2 cm/s
	At peak flows:	10 - 15 cm/s	10 - 100 cm/s	100 - 200 cm/s
Depth	At low tide:	> 50 m	2 - 49 m	10 - 19 m
Geomorphology & Substrate		> 30° slope; rock, sand or gravel	15 - 30° slope; sand, mixed rock	< 15° slope; mud or organic ooze
Hydrology—Freshwater lens depth of:		< 1 m	1 - 4 m	> 4 m
Predators		No nearby sea lion haulouts; small avian & mammalian predators	Sea lion haulouts within 80 km; avian & mammalian predators	Nearby sea lion rookeries & haulouts; problem predators; orcas
Marine Plants & Fouling Organisms		Low levels of fouling organisms; no kelp	Moderate levels of fouling organisms; kelp nearby	High levels of fouling organisms; kelp onsite
Wind & Waves		Sheltered site; wave height < 0.6 m	Partially exposed; wave height 0.6 - 1.2 m	Exposed; wave height > 1.2 m

it is easy to change direction and to alter what you have in mind to better meet regulations and statutes. Agency personnel have to do their job too. And they can be quite helpful if approached in a reasonable manner. If they are not helpful, move up the chain of command.

After you have spoken with the major regulatory agencies and found no major problems, you can begin a second level of planning, much more detailed—and consequently more expensive.

Salmon farming had its first real beginnings in the Pacific Northwest at the Manchester Field Station of the National Marine Fisheries Service, in conjunction with the University of Washington Sea Grant Program and a private company. But we are just beginning to understand it. The consensus among farmers in British Columbia two years ago, and in some cases just a year ago, is not what the consensus is today.

There is one additional matter. If at all possible work on a farm first. Volunteer if you must. But at least visit several farms and plan on spending some time on each. Ask a lot of questions. If you can, get prior permission to arrive during periods of activity. Do not be surprised if the workers ask you to help out while you are there. Salmon farming is very hard physical work. If you don't like working hard, you don't want to become a salmon farmer.

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ENVIRONMENTAL EFFECTS OF FINFISH CAGE CULTURE

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Marine finfish aquaculture in Alaska has with one exception involved ocean ranching of salmon. The associated marine habitat impacts have been limited to the effects of short-term smolt feeding in net pens anchored in estuaries and bays. In the past few years debate has arisen on the issue of for-profit commercial aquaculture, including the pen rearing of fish to market size. Papers that have explored various technical, economic, and legal aspects of finfish cage culture in the Pacific Northwest include Alaska Mariculture Technical Work Group (1976), Huguenin and Ansuini (1978), Kerns (1986), Lindgren et al. (1985), Logan and Weddleton (1987), Pierce (1987), and Weston (1986).

The decision to allow or disallow pen rearing centers around potentially controversial issues related to market, environmental, socioeconomic, and regulatory impacts. The purpose of this paper is to describe the potential environmental impacts of long-term marine pen rearing, related literature, and suggestions for minimizing those impacts.

PHYSICAL IMPACTS OF CAGE CULTURE

Water Flow and Currents

Cages or net pens can affect local currents and thereby alter sediment transport and deposition patterns, oxygen supply and removal of waste metabolites, and the supply of planktonic food.

Beveridge (1984) summarized the drag forces affecting the flow of water through enclosures. The reduction in flow is dependent upon a number of variables including flow rate and density of water, enclosure size and shape, mesh type (knotted or knotless, diamond or square) and material, degree of fouling, and stocking density.

Inoue (1972) noted the current velocity inside a large (20 x 20 x 6 meter) cage of 5 cm mesh size, stocked with fish at 1.6 kg/m^3 fell to only 35 percent of the current speed recorded outside the cage. He also demonstrated that when cages were located parallel to the direction of current, flow rate in successive cages fell. Webb (1975) noted the presence of cages acted as a breakwater creating still water to their lee.

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CONCEPTS OF SELF POLLUTION

The major impact of cage culture activities is self-pollution, which can create unfavorable environmental conditions through accumulation of organic wastes beyond the carrying capacity of the effluent-receiving environment. These conditions could have a detrimental effect on animal health, production, and natural ecosystem surrounding the facility.

Hall and Holby (1985) documented the environmental impact of a rainbow trout fish cage farm in the marine environment (on the west coast of Sweden). The most obvious changes were increased sedimentation rate, increased sediment oxygen uptake, increased benthic release of phosphates during oxygenated conditions, and increased concentrations of carbon and nitrogen in the sediment and of phosphate and ammonium in the interstitial water.

Average daily amounts of sediments deposited from a sea bream farm were 33.8 g/m^2, and 23.0 g/m^2 for a yellowtail farm compared to 14.6 g/m^2 for a non-culture area (Kadowaki et al. 1980). Sediments were related to the type and amount of foods supplied and water depth. In addition, natural sedimentation rates can be affected by placement of cage structures and their effect on water current and velocity (Phillips and Beveridge 1986, Webb 1975, Weston 1986). The degree of self pollution is dependent on several factors:

1. *Site Selection*. Factors that affect water quality and resulting self-pollution are related to water retention time and bottom conditions. These include site exposure, bottom topography, water depth, presence or absence of an underwater sill, frequency and patterns of water exchange, number and volume of areas with no circulation, locations for accumulation of dead fish, and organic waste (Moller 1976, Webb 1975).

   Coastlines with areas of accumulation act as pollutant and sediment traps or purification plants for the open water. They are not suitable sites for cage cultivation as material deposited from the cages will be accumulated on the bottom and result in undesirable local effects. Erosion-bottoms indicate a good water exchange which consequently will disperse the discharge over large areas (Ackefors 1986). Barr (1973) fortuitously observed a temporary anoxic condition in Little Port Walter on southern Baranof Island, Alaska. In a restricted area near a sill and below a depth of 12 meters, divers observed numerous animal carcasses on the bottom; most of them were shrimp, but there were also numerous chitons, limpets, clams, anemones, sea stars, crabs, and a few fish. Subsequent measurements documented the existence of only minimal dissolved oxygen concentrations. The mass of anoxic water was flushed out of the bay three days later coincident with extreme tides. Two features common to anoxic situations in fiords were present—a shallow sill and an adjacent pycnoline.

2. *Method of Culture*. (Beveridge 1984, Braaten [no date], Huguenin and Ansuini 1978, Moller 1976). Four types of aquaculture structures include

   A. *Cage Culture*. Beveridge (1984) uses the term cage culture for a totally floating device with all sides but the top covered with mesh or netting. Variations of cage culture are closed cages, which are floating pens with flexible solid walls into which seawater is pumped and discharged, and submersible cages. Cages can be designed for mobility and open ocean locations.

   B. *Pen Culture* is defined as a construction with the bottom formed by the lake or sea bottom. Experimental barriers such as electric fences are being considered for some situations.

   C. *Enclosure Culture* is the name for projects that take advantage of natural enclosures such as lakes. (Intensive feeding and fertilization coupled with limited circulation makes this category very susceptible to accumulation of organic waste and reduced oxygen levels.)

   D. *Raceway and Tank Culture* are containment structures into which water is pumped and drained. Until recently they were only land-based techniques; they are now being explored for floating tanks.

   The closer the cage is to the bottom the greater the proportion of wastes that are likely to become sediment directly under the cages. Where prevailing currents are low, few of the wastes—especially the larger, denser waste feed particles—will be carried away. Anchoring cages on single-point moorings will result in the distribution of wastes over a much greater area and hence reduce the real rate of waste accumulation (Beveridge 1987b).

3. *Environmental Conditions at the Site*. Environmental conditions combine to affect individual sites: wave and storm patterns, tidal currents, water temperatures, solar exposure, salinity, biofouling rates and types, and natural predators present (Huguenin and Ansuini 1978, Milne 1976).

   Consideration should also be given to long- and short-term climatic conditions and seasonal influences.

4. *Species Cultivated*. The species most likely to be cultivated in marine waters of Alaska are rainbow trout and Atlantic, chinook, or coho salmon. The production species, in part, determines how long fish will be held, rate of restocking with new smolts, and feeding schedules. Further, the density of fish held in cages and the amount of buffer area between cages are important in terms of water availability for absorbing and diluting the discharges.

5. *Applied Technique or Experiences of the Operator*. An entire spectrum of effects can be placed under this category. Differences will result depending on the particular method and choice of feeds, application of medications or other chemicals, frequency of structure cleaning, length of time fish are held, lapse time between crops, and slaughter wastes disposal. The slaughter and various processes involving filleting, freezing, and packaging might also exert a change in the environment. Suspended matter in the processing water could result in a heavy organic loading that causes higher oxygen consumption as the substances are decomposed. The influence of these variables might be balanced by adapting the environment (Ackefors 1986).

   Since artificial culture of finfish to market size has not been allowed in Alaska, except in a limited research situation, we draw most of our knowledge from the experience gained by Canadians, Norwegians, and others. Developers of the industry in Alaska are faced with isolated sites; a low population base; a lack of historical public acceptance or support; special transportation and marketing considerations; and perhaps most importantly, relatively pristine, sensitive, and threatening environmental conditions. For example, the effect of toxic algae blooms on a future Alaskan industry are relatively unknown at this time, but are likely to be a consideration to the farmers.

   The main source of pollution in fish farming is excess feed and feces. Overfeeding has been a continuous problem in intensive fish farming and is mainly caused by two factors: the use of the wrong type of food and lack of knowledge of how to feed correctly (Braaten et al. 1986). The feed waste in percentage by using dry feed is estimated to be 1 to 5 percent and corresponding figures for semi-moist feed and wet feed (minced fish) are 5 to 10 percent and 10 to 30 percent respectively (Ackefors 1986).

6. *Size of Production*. The size of the production unit will play a crucial role in whether self-pollution is likely to occur. The threshold size of a production unit in marine waters of Alaska remains un-

known. Though not directly applicable, Karlgren (1981) estimated that a surface area of at least 30 ha is required in oligotrophic lakes for every ton of fish farmed in order to avoid undesirable effects from the added nutrients. The National Swedish Environment Protection Board and the National Swedish Fisheries Board (Anon. 1983) recommend a lake area of 15 to 30 ha for each ton of produced fish.

EFFECTS OF SELF-POLLUTION

The effects of self-pollution are most serious at or near the facility. Heavy pollution loading may have an effect on the wild flora and fauna at the site, and if it does, it represents an even more serious threat to the caged fish themselves (Webb 1975). Possible indications of self-pollution are reduced fish growth or an increasing mortality rate. Moller (1985) discussed occurrence of fish diseases in relation to polluted waters. Braaten et al. (1986) said self-pollution can be concluded from the following symptoms:

1. Accumulation of waste material which results in the formation of toxic gases and metabolites.
2. A drastic reduction in the oxygen content of the water.
3. Accumulation of dead fish due to sudden mortality.
4. Local eutrophication.
5. Occurrence of pathogenic bacteria, viruses and parasites, some of which may be resistant to antibiotics due to an extensive use of antibacterial agents.

Eutrophication resulting from release of sludge and oxygen-consuming matter (food particles, feces, and ammonia) can also increase the chances of toxic algae blooms (red tide), which in turn die and result in further sedimentation. As a result of high eutrophication levels, large areas in protected coastal areas can be exposed to reduced oxygen conditions during summer and autumn (Ackefors et al. 1984, Rosenthal 1983, Hirata 1985) and increased nitrogen compounds. Highly eutrophic lakes have regular kills through deoxygenation of the water following the collapse of algae blooms (Beveridge 1984). Accumulation of organic matter on the bottom creates anaerobic conditions in the immediate vicinity and also large areas with depleted oxygen levels (Phillips et al. 1985b). Such conditions can have devastating effects on the shellfish industry (Rosenthal 1983) and alter the bottom flora and fauna.

IMPACTS ON NATURAL FISH HABITAT

There are additional risks or considerations associated with coexistence of the natural fish and shellfish industry with the potential Alaskan cage culture industry. These are (1) risks of spreading diseases between farms and to wild fish populations, (2) risks of establishment of nonindigenous species and stocks in natural habitats, and (3) release of antibiotics and chemicals used to combat disease and stress. Each is further described below.

1. There are five main groups of organisms which cause disease in fishes: ectoparasites and fungi, endoparasites, bacteria, viruses, and organisms which produce toxins leading to fish deaths (Sarig 1979).

   The Alaska Mariculture Technical Work Group (1986) expressed the opinion, "Future mariculture practices would produce no further risk to wild stocks than practices currently employed. Certain disease agents are already ubiquitous in the environment and opportunistic, infecting fish only when they are crowded or stressed artificially by aquaculture practices. Other disease agents which are obligate pathogens could possibly transmit from cultured finfish/shellfish to wild stocks. Although this would be undesirable, most generally, clinical disease or catastrophic mortalities do not result in the receiving wild populations due to lack of stress factors and wide environmental dispersion of host animals." This general opinion was supported by Beveridge 1984, Phillips et al. 1985a, and Weston 1986.

2. Wreckage of cages and release of contents will occur from time to time. Cages can be constructed with outside barrier nets to minimize susceptibility to damage from predators. Release of domestic fish could occur via deliberate means, however, as well as damage to the netting, marine mammal and four-legged creature interference, and even accidental loss during harvest or stocking.

   The effect on wild stocks, if domestic species become established, is largely speculative. Practically there could be competition for spawning and rearing grounds, and possibly interbreeding and a change in genetic makeup of the wild stock. There are many records of the impacts of escaped or deliberately transplanted fishes on indigenous fish stocks, and these include the extermination of local fishes through predation or competition, interbreeding, habitat destruction, and outbreaks of disease epidemics (Rosenthal 1983, Phillips et al. 1985a). Actual impact on the habitat due to establishment of domestic stocks of salmonids would be very subtle since organisms of that type presently use the habitat.

3. Possible release of antibiotics and chemicals into the water to combat disease and stress in the caged fish could affect local invertebrate, vertebrate, and planktonic populations. If open net cages are in use, then it follows that whatever is put in the water could disperse and affect water quality beyond the immediate vicinity of the cage. The The Alaska Mariculture Technical Work Group (1986) expressed the opinion that, "Risks of environmental contamination from drug applications

is negligible because: (1) The great magnitude of dilution of such drugs on the water column would make the final exposure concentration so far below efficacious levels that natural fauna and flora should be unaffected, (2) Infrequency of use would prevent chronic exposure of natural flora, (3) In most cases, a systemic chemotherapeutant is the only practical method to treat disease in thousands of captive fish. Consequently, the drug is administered in the diet. . ." Beveridge (1984) described treatment as ". . . costly and difficult due to water flow through the enclosures which can rapidly dilute the chemical used, and render treatment ineffective. The addition of large quantities of chemicals to compensate can make treatment too costly. To minimize expense, many farmers enclose cages in polyethylene sheeting to try and reduce the flow rate or transfer diseased fish to a specially modified enclosure or tank, thus minimizing waste (i.e. loss to the environment) of chemicals."

Though the above statements appear logical in explanation, Braaten et al. (1986) listed several hazards connected with use of therapeutics in fish farms.

1. Development and proliferation of bacterial strains which are resistant to the most common antibiotics.
2. Spread of foreign substances in the environment that create adverse effects on microbiological processes, e.g., degradation of organic matter, which secondarily affects the fish farm itself.

IMPACTS FROM INFRASTRUCTURE

Related development such as roads, residences, and market routes (possibly just air transport) could result in a separate form of environmental impact. Ackefors et al. (1984) discussed the development trends of aquaculture production units. They explained that areas generally suitable for aquaculture production could hardly be developed on an economic basis if the necessary infrastructure (transportation, roads, supplies, and markets) is largely lacking.

Fouling of net pens and barrier nets is a continual problem. Fouling makes the nets heavier, increases drag in current, and prevents the exchange of water in the pen. Additional infrastructure needs may be required for a net washing area. A method suggested in the *Alaska Oyster Grower's Manual* (Else 1985) is to place empty trays on the beach at half tide and allow fouling organisms to be eaten off. This may work with nets as well.

There are basically three choices for collection or production of stock for cage culture: (1) import egg or brood stock, (2) collect natural runs of wild stock spawn and incubate eggs, and (3) purchase smolt from state-run or private nonprofit hatcheries. Environmental effects would result from use of water and land for buildings, incubators, housing, docks, etc., which are needed to support the ancillary aquacultural industries.

ACCESS IMPACTS

Access issues, though not environmental issues per se, are potential areas for conflict with other users such as recreational and commercial fishermen. The amount of area needed to contain the facility and that needed as a buffer is worth distinguishing. Concepts of property protection from theft, damage, or pollution will require that distance be maintained between other water users and cages.

NOAA (1977) published an aquaculture plan that recognized the development of aquaculture as being in the national interest and called for protection of coastal and estuarine environments so that aquatic foods can be produced in these areas. The plan stated the objective of NOAA programs will be to provide the scientific, technical, legal, and institutional base needed for development of aquaculture and to facilitate early application of research results by information dissemination and extension activities.

As the aquaculture industry grows, the National Marine Fisheries Service will reconsider this objective in order to balance aquaculture needs with the needs of the commercial and recreational fishing industry.

PREDATION

Cages of fish are known to attract a wide range of fish-eating vertebrates: fish (Webb 1975), birds (Beveridge 1987a), marine mammals, furbearers, and humans. This can result in loss of stock, damage to nets, transfer of disease and parasites from predators to prey, and a higher level of predation on wild stock in the area.

If the potential predator is a marine mammal, additional coordination and preventive measures will be required. Special consideration of all marine mammals is provided for under the Marine Mammal Protection Act (MMPA). Federal responsibility for these species is placed under the Department of Commerce, National Marine Fisheries Service (NMFS), and the Department of Interior, U.S. Fish and Wildlife Service. The MMPA protects marine mammals from takings. The term take means to harass, hunt, capture, or kill or attempt to harass, hunt, capture, or kill any marine mammal. Evidence of harrassment has been described as a change in behavior or activity brought on by a certain action.

Supporting regulations of the MMPA allow the Department of Commerce, through the NMFS, to issue permits for the taking of small numbers of marine mammals for certain purposes if the taking will have a negligible impact on the affected species or stock. For the NMFS to consider allowing an incidental take, a written request for regulations must be submitted in accordance with 50 CFR Section 228.4. The request must contain detailed information on the activity in general and impacts of the total potential take. It may be submitted by those conducting the activity, such as the Alaska Mariculture Association, or by a federal agency that regulates the activity. If NMFS makes certain findings, specific regulations will be issued which, among other things, establish a permissible method of taking and requirements for monitoring and reporting. Once appropriate regulations are in place, a letter of authorization is required to conduct the activity (50 CFR Section 228.6).

POSSIBLE MITIGATIVE MEASURES

There is a variety of means that may be partially effective in minimizing the impacts discussed above. Briefly these are

1. Use of pumps to aerate water locally deficient in oxygen.
2. Rotate or move cages or pens to clean locations periodically to allow naturally occurring communities to restore themselves. (Preapproval of more than one site may be required initially.)
3. Taking care in the methods of disposal and treatment of diseased stock to protect wild stocks from exposure and possible contraction of the disease.
4. Experimentation with use of self feeders because they may use less feed.
5. Use of floating feeds; these are newly available and are applied by releasing the feed subsurface. What particles the fish do not eat float to the surface and can be skimmed off.
6. Placement of shellfish mariculture facilities in close proximity to finfish cage culture facilities to offset the elevated nutrient levels by added filtering organisms (Wallace 1980).
7. Release of domestic fish cannot be prevented completely, but it may be minimized through sanctions, penalties, and regulations. The initial choice of site and structure can be evaluated according to likelihood of successful containment. Requirement of a net around a cage surrounding a group of cages, to form a second barrier prior to release into the open marine environment could function as a safety factor in reducing accidental releases of domestic fish. Further, the relative location of cage culture activities to important wild stock habitats can be used to minimize chances of successful establishment by escaped domestic stocks.
8. After harvest, trawling of the bottom to accelerate the remineralization process of the settled organic material. A process used in Japan in association with culture of clam, oysters, and other mollusks (Ackefors et al. 1984).
9. To minimize release of therapeutic antibiotics and chemicals, safeguards could be recommended for transport, storage, and application of such drugs.

INFORMATION NEEDS

There is limited information of a practical nature for southeast Alaska salmonid cage culture. For example, if known sizes of pens were placed in known areas, stocked with known amounts of fish, and fed known amounts of feed, what would be the expected change in sedimentation and oxygen levels around the pens?

Regulatory experience and perhaps modification may be required to limit rate or amounts of discharges of waste feed and fecal waste in specific areas.

We need experience with minimizing feed waste. Feeding less at a time but more frequently may result in less waste and higher consumption rates. Use of floating pellets are a potential waste saver.

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PANEL DISCUSSION ON THE PROS AND CONS OF PRIVATE-FOR-PROFIT SALMONID AQUACULTURE IN ALASKA

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Brian Allee, Alaska Department of Fish and Game
Sen. Richard Eliason, Alaska State Legislature
Sen. Fred Zharoff, Alaska State Legislature
Rodger Painter, Alaska Mariculture Association
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Bill Heard, National Marine Fisheries Service
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The Fourth Alaska Aquaculture Conference wound down to its final session with a panel discussion on the question of whether private-for-profit salmon aquaculture projects should be allowed in Alaska.

Such projects would be similar to those in other parts of the world, mainly Norway, where salmon are raised to full maturity in pens and then shipped out to provide fresh fish for the off-season winter market.

The concept differs markedly from the familiar public nonprofit aquaculture ventures that have proven so successful over the years in helping build back depleted salmon runs in Alaska. This is a system of ocean ranching where juvenile salmon are released into streams, go to sea, and then return at the end of their cycles to be harvested by fishermen. With private salmon aquaculture, however, the fish are harvested and sold directly by the farmer-owner.

With seafood consumption growing in the United States, the ability to supply fresh fish on a year-round basis has proven to be a real money-maker. Imports of foreign pen-reared finfish have soared in recent years to the point where the United States had a seafood deficit of $3.5 billion in 1986.

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Alaskans hate to see a good market go by default. So last year a bill (CSSB106) was introduced in the legislature, which would set up a comprehensive state policy to allow private-for-profit mariculture of seaweeds, shellfish, and finfish. Although a few shellfish farms already are operating in the state, the idea of salmon mariculture raised so much controversy that a moratorium was placed on all commercial finfish farming until July 1, 1988, for further hearings and studies.

State Sen. Fred Zharoff, D-Kodiak, the primary sponsor of the bill, told the panel he introduced the legislation mainly to get people thinking about the idea. He said his district, where preliminary studies are well under way toward a scallop farming venture, has no problem with seaweed and shellfish ranching. But he admitted that many coastal communities do not like the idea of finfish farming. "I have mixed feelings about it myself," he said. "But we're looking at pen-reared salmon the world can produce when we're not operating because the wild salmon aren't available during the winter months. However, I think we should assess the whole situation very carefully and decide what's best for Alaska. Whatever we do, it should be in our own self-interest."

State Sen. Richard Eliason, R-Sitka, a commercial fisherman himself, pointed out that other states and foreign countries developed salmon farming because their natural stocks were declining. On the other hand, he said, Alaska's wild stocks are among the healthiest and most abundant in the world. "There are apprehensions about what effects pen-reared salmon might have on natural stocks—concerns about the transmission of disease and possible water pollution from the farms," he said. "We're talking about public resources here—not just the fish, but water use and site and land selections. And we're talking about impact—not just on commercial fishing, but on sports and subsistence fishing as well. In some areas, commercial fishing and mariculture might be compatible, but in other areas, probably not." He added that the biggest impact would probably be in his Southeast Alaska district where there is a limited winter troll fishery.

Eliason said interim hearings on the proposed legislation, held by the Senate resources subcommittee of which he is chairman, revealed much apprehension throughout the state on the idea of pen-reared salmon. "The only place we found people to be largely in favor of it was downtown Anchorage," he said.

Rodger Painter of Juneau, executive director of the Alaska Mariculture Association (AMA), described pen-rearing of salmon as simply a logical extension of the seafood industry and an opportunity for great economic development in Alaska. "We want to displace foreign salmon with a year-round total product on the marketplace," he said. "We could benefit from numerous side industries as well, such as smolt production and fishfood production. And once the new industry got going, it would provide a year-round product for the state's fish processors, now mostly idle during the winter months."

He said diseases are not transmitted from farmed salmon to wild stocks because the fish are never released from their pens. And he foresaw little impact on the prices paid for commercially caught salmon. "Research has shown that there is very little overlap on the markets for wild salmon and pen-reared salmon," he said. "As a matter of fact, pen-reared fish cost more to raise so the farmers can't let prices sink too low."

Eliason asked Painter if his organization would support legislation providing for the development of seaweed and shellfish farming but putting off finfish mariculture for the time being.

Painter said he would have to consult with the AMA board of directors before going on record to support separate legislation. "Actually, we support all forms of mariculture," he said, adding that the AMA was concerned about splitting the issue and "subjecting each species to a political litmus test."

Brian Allee of the Alaska Department of Fish and Game's Fisheries Rehabilitation Enhancement and Development (FRED) Division traced the successes of Alaska's public nonprofit aquaculture projects since their development began in the early 1970s. "In Prince William Sound last season, fishermen harvested a record catch of more than 25 million pink salmon," he said. "Of that number, 73 percent were attributed to releases from the four hatcheries on the sound and only about 27 percent came from wild stocks." The pink salmon catch alone brought nearly $40 million to area fishermen.

Whether Alaska should allow private-for-profit salmon ranching is a question for the legislature to decide, he said. But he warned that if it is undertaken, the law should insure that a number of standards be met. Among other things, mariculture must

1. Be developed in an orderly fashion so that it is a stable industry.
2. Benefit Alaskans and not compete with commercial fishermen.
3. Pay for itself.
4. Provide for protection of wild stocks and environmental safeguards.
5. Insure access to uplands.
6. Provide a fair system of allocation of permits and sites to mariculture farmers.

A statement from the Alaska Trollers Association, presented by Eric King of Juneau, raised no objections to seaweed and shellfish farming, but strongly opposed finfish farming. The trollers saw pen-reared salmon not only as a threat to wild salmon stocks, but as competition in the marketplace and as a drain on already limited state funds for management and regulation of wild stocks. Furthermore, they feel Alaska doesn't need private salmon farming.

"We should first consider that Alaska produces 90 percent of all salmon landings in the United States or 43 percent of the world's landings from wild natural runs of salmon. Our current fishing industry already employs approximately 50,000 people directly, and that doesn't include employment in associated support industries in all segments of our economy. Our wild salmon runs are the second largest revenue generator in this state and are proving to be Alaska's true permanent fund. No one can say for certain no harm will come to them from pen-reared fish, and it doesn't make good economic sense to gamble with our future."

King said the troll fishermen are disturbed by the fact that the bill now before the legislature places management authority for the private-for-profit mariculture projects under the State Department of Economic Development rather than the Department of Fish and Game.

"Pen-reared fish do escape, no matter how stringent the protections are, and we are concerned that management of this prospective industry would be given to an agency with little experience in the biological and technical bases needed to protect our wild stocks," King said.

Still another concern is that state funds to manage and regulate fish farming would cut into programs now used to enhance wild stocks. "To many, a fish is a fish, and it's a safe bet that the funds to manage the new industry will come out of current fish management programs." King said that so far as prices to commercial fishermen are concerned, there is only one market for fish in the world, and as the supply increases the prices will decline.

Bill Heard of the National Marine Fisheries Service at Auke Bay said research has shown that king salmon can be raised to commercial size in pens. "There is nothing to indicate that salmon farming in Alaska is not biologically feasible—whether it is economically feasible is another question."

He said most of the regulations required for the protection of natural stocks, such as the ban against importation of foreign (exotic) stocks from outside Alaska, are already in place. But he emphasized that maintaining the habitat and environment for wild stocks is critical. And he had a suggestion: "If you do allow salmon farming in Alaska, I propose that the Alaska trollers be given the first permits. Then let them concentrate on year-round quality."

Kate Graham, executive director of the United Fishermen of Alaska, said her group would go along with seaweed and shellfish farming, despite fears that site allocations for such projects might provide a head start for future finfish farms. But she said fisheries people still consider salmon farming "way too risky," and too costly. "It's the state's obligation to protect the public and the environment, and the salmon farmers certainly won't be able to regulate themselves," she said.

She explained that would mean in these times of economic downturn and tight budgets that the money for the new industry would probably come out of current fish management programs which already are suffering cutbacks.

"It's a myth that salmon ranching will pay its own way," she said. "Fishermen more than pay their own way because our taxes are attached to sales. But the salmon farms won't be taxed until they start making a profit and it will take two or three years before they even start making sales. Meanwhile, the state just doesn't have any extra money to throw around."

The nagging question of who would own the fish farms, how much they would cost, and how they would be financed was a recurring topic throughout the discussion.

Zharoff said one of his chief reasons for introducing the mariculture legislation is to provide a possible source of new income for rural areas of the state. "Village fishermen in their small skiffs can't compete with the big commercial fishing fleets off their shores," he said. "But a mariculture project under local control would be a very good thing for small communities." He said that in Norway finfish farms in small coastal villages have helped slow the tide of young people leaving home to find jobs in the big cities.

Eliason agreed that jobs in rural areas are an important priority. But he was doubtful about the feasibility of small mariculture ventures. He said that judging from what he saw on a trip to Norway last summer, the so-called "Ma and Pa operation" can survive only if Ma and Pa happen to have a couple of million dollars.

But panelist John Forster of Seafarm Norway, a private-for-profit finfish farm in Port Angeles, Washington, described mariculture as an industry "whose time has come." He said Alaska has an ideal environment for salmon farming and should be able to compete with the world. "And it doesn't necessarily take megabucks," he insisted. A person could start a small farm with a few pens and make money raising fish as a side income.

But Graham said the cost of establishing a salmon farm would probably be much more than most expect, and she expressed fears that finfish mariculture would wind up as a "private club" which few Alaskans could afford. She said the idea of small owner-operator projects is being promoted to open the door for the big well-financed investors like those who have taken over mariculture operations in other countries.

Earlier the conference attendees had heard from economists and bankers about potential difficulties in obtaining start-up money for relatively untested ventures such as private-for-profit mariculture projects. Canada gave its early salmon farmers a boost by providing interest-free loans of up to $100,000 with no payback for two years. Other foreign countries, such as Norway, provide generous government subsidies. And governmental aid can come in the form of vital support services such as communication and transportation links between salmon farming areas and their markets.

After the panel had its say, the discussion was open to questions and remarks from the large audience in attendance. Sitka is a fishing community, and the reaction to the idea of private-for-profit salmon farming was mostly wary.

Some felt small coastal villages might benefit from locally owned mariculture operations. But others remembered too well the hated fish traps of the early days, owned largely by outside fishing interests. The fish traps were outlawed in 1959 by an ordinance approved by the voters in the same election during which the constitution of the new state of Alaska was adopted.

Sitka resident Mark Jacobs Jr. told the panel the Alaska Native Brotherhood has passed a resolution opposing mariculture. "Do you think big business would tolerate the little fellow for long?" he asked. "We would just be squeezed out." And he added: "We fear another fish trap era."

At the conclusion, Moderator John Doyle of the Marine Advisory Program summed up the private-for-profit salmon farming dilemma with the observation: "It is obvious that the social problems are more difficult to solve than the economic and scientific problems."

SETTING UP A SMALL AQUACULTURE BUSINESS

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The Alaska Economic Development Center, University of Alaska Southeast, is a public service of the university funded by the U.S. Department of Commerce, Economic Development Administration, and the State of Alaska, Department of Commerce and Economic Development, Division of Business Development.

Our role is to extend resources of the university to communities of Southeast Alaska, and we do that by making presentations and providing technical assistance in two different areas.

My program provides technical assistance to communities and community organizations, to arms of the state, federal and local governments, and to nonprofit organizations. And, according to mandate of the Economic Development Administration, to Alaska Native Claims Settlement Act corporations.

This presentation is on setting up a small aquaculture business in Alaska. I'd like to emphasize the use of the word small. I'm not talking about a large corporate farm. I'm not talking about a shore-based facility that requires a very large investment in capital and a large operating staff. What I'm talking about is the small, family-owned, individual-owned, partnership or corporation-owned business that might be operating in the half-million to $1 million a year range in sales.

The definition of small business used by the U.S. Department of Commerce extends to anything with less than $5 million annual in sales. And that encompasses almost every business we deal with in Southeast Alaska, with minor exceptions. I'm talking about small businesses that are handled by a couple of active working partners and a number of full-time and part-time employees.

I want to stress that I am talking as if I am addressing a group of neophytes, people who might have some experience in the field, for example, but who have not set up and operated a small business. A lot of what I am talking about is, plainly and simply, common sense. But this common sense seems harder earned by a lot of individuals who are in small business. They will tell you that with the pressures of putting together a business—pressures caused by financing, general worries, lack of time—they haven't had time to learn some of the things that I'm talking about.

I am breaking the talk into two phases: organizing an aquaculture business and assembling a business plan for potential investors. At the end, I'll briefly discuss resources available to help you get started.

ORGANIZING AN AQUACULTURE BUSINESS

During this phase, you are doing a number of things. You are assessing the business environment: political, financial, and community. And you are making a personal decision about whether you actually have the personality to be involved in small business.

I've heard a number of jokes about small businesses. One of the ones that I found more humorous was that the small successful business operator is lucky to end up only having to work half-days. That is, 12 hours out of every 24, seven days a week. And that's close to the truth. Many people I know in small business, whose business may be earning less than $200,000 a year in gross sales, put in that much time.

You need to determine whether you have the personality that a small business owner must have. You need to know if you have the technical skills involved in a small business. Some businesses require a good retailing background; some, good marketing. Others are more technically oriented where you're actually manufacturing a product or where you're farming or growing a product. That's a question that needs to be asked.

In my work over the past two years, I've definitely found that with decline of oil revenues in the state and the change in state spending, entrepreneurship is changing the face of Alaska. Every week I read new articles about people who want to continue to live in Alaska; they plan a business opportunity, learn all they can about that opportunity, and then go out and realize it.

Right now, we are in greater numbers involved in manufacturing, building, brewing, growing, and harvesting things of all kinds. Those of you who live in Juneau know that beer is being brewed in the state. Mattresses and car batteries are being made in Fairbanks. I was surprised to find out that aluminum boats are being fabricated in Unalakleet. Of course, we are all aware of wild berry jams and smoked salmon. Potato chips are being made in the Matanuska Valley. We've had milk for quite a while. And there are furniture builders. Alaska sausage is famous. And, surprisingly enough, paint is being manufactured in Alaska. These business opportunities are available for the bold and venturesome. They are not for someone with a weak heart. And not for someone who likes a lot of comfort.

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Aquaculture is one of those new opportunities that I believe is headed for a boom. We have all the natural and necessary resources for aquaculture. What remains in order to open up the field is resolution of a number of economic policy questions on the state level. I'm sure that, attending this conference, you already are aware of what those debates are, or else you soon will become aware.

I'm not going to cover permitting and financing, because my preliminary copy of the agenda indicated that those subjects would be covered separately from mine.

As with any small business, in aquaculture it's going to be your responsibility to make a profit to survive. Now, that's an easy concept to put on paper. You take your costs, both operating and administrative, which are generally broken down on a financial statement, and you try to make sure that those are less than the price that you receive for your product. The difference will be your profit. That's an easy concept to put down on paper, but it's a very difficult one to carry out. In order to make that profit, you're going to have to have people to produce that product for you, you're going to have to turn out an excellent product, you're going to have to turn it out at the right time, and you're going to have to have a market for it.

Now, look at the plight of the regular American farmer these days. I'm sure that you've seen, as I have, many times the foreclosure sales on the evening news, and the anger of farmers who are the best producers of farm products in the world. They are the most efficient, they produce at the lowest price. They have very good capital equipment and machinery, and they are right at the peak of technology. I'm amazed at the technology that some of these farmers use. And yet, because the world is oversupplied with some of the products they are dealing with, and because of certain changes in consumption patterns of their preliminary markets, a lot of these farmers are hurting. Many of them have not adapted to changes.

What I'm telling you is that if you go into an aquaculture business, it's going to be a never-ending battle, a continuous battle, to make sure that you maintain all the elements of a successful small business.

I want to make it clear that, as part of the university, I'm passing no judgment on political debates about aquaculture that are taking place right now. They went on during the last session, and I suspect they will be going on again this session. I paid a small amount of attention to what was going on. I do read a number of the major fishing periodicals and am somewhat familiar with the debate, but I want to let you know I am not an expert in aquaculture. What I am telling you about is based on my training in what it will take for you to start a small business. It should be made very clear, however, that if you plan to start an aquaculture business, you should pay attention to that political debate, you should understand what is behind both sides of the argument, because that will affect your ability to maneuver in whatever community in which you choose to live. And it will probably affect you for years to come.

Evaluating Skills and Expertise

The first question I think you need to ask yourself is, do I have the technical skills that are required for this particular business? And I'm talking about any business, really. If you are going to go into manufacturing wood products of some sort, you need some basic skills in that area. If you're going into aquaculture and you have selected a particular product, the first hard question that you ask is, am I able to raise that product? Am I familiar enough with all the requirements that go into establishing a business, that is, the support structure around raising that product?

Most farmers and most small business people are jacks of all trades, and I've heard the phrase, "master of none." We all tend to know a little bit about a lot of things, and some of you may know a lot about one thing. But most small business owners know a little bit of everything and not a whole lot about any one thing. But they tend to gain that expertise as they work in the business.

These are several technical skills that you might need in a small business. If you have to construct a facility, do you have the technical skills to do so? Also, you need to know a little bit about site location. If water quality and water temperature are important to you, do you know how to measure that quality and temperature and do you know the requirements of the product that you want to grow? Do you have to protect your aquaculture product from predators? Will that require a certain type of facility? Do you know what type of feeding facilities are going to be required for your business? Storage space is important to consider. You will have a harvest and you will need space to keep your harvest until it can be transported. If your product needs primary processing, you will have facilities available for that. Of course, office and administrative space are important also.

Lots of this expertise you can hire out to consultants through various state programs, or you can hire design professionals and construction professionals. But you still need to know what your requirements are in order to converse with the various professionals with whom you deal. Otherwise, you're going to get yourself an expensive education, and that's money you could put into the actual establishment of the business.

Once you have the facility constructed, you will need to operate it on a day-to-day basis. Do you have the skills, administratively, to take care of the bookkeeping and accounting departments? It's a sad commentary, but many small businesses in Alaska and elsewhere fail because they cannot do the bookkeeping. Their owners don't understand the concepts of cash flow, of budgeting; they cannot, at any given time, put their finger on what they have in the business. They figure if the money's coming in and they can pay the bills, they're doing all right. Well, in a way they are doing all right, until circumstances start to catch up with them.

Your corporation will have significant amounts of necessary maintenance and state and federal reporting requirements. Depending on the type of business you select, they can be rather onerous.

You'll need to look into feed procurement. You'll need to look into whether you have a brood or a seed stock available for your use. You'll need to have operating supplies. You'll have to provide for maintenance and care of the product that you've selected, whatever that requires, such as disease control. There will be waste management questions that you'll have to think about. Personnel management will be extremely important. There isn't a small business around that does not survive on the talents of the people it hires. And you'll have to look at shipping, marketing, and transportation.

Each of these small elements requires some skill on the part of the small business owner. You need to assess whether you either have that skill, whether you can hire it, or whether you are willing to learn it. And I have to add, if you are willing to learn it, you have to look at the amount of time that you'll be putting into a small business, and consider if you have time to learn it.

You will work with a number of administrative requirements. You will work with bankers, you will work with other financiers, you'll work with people who are interested in buying your product, you'll work with suppliers. By the time you get home at the end of the day, you won't be willing to do much more than kick off your shoes and hit the couch. And that's the time you will need for picking up the various skills I've talked about.

Potential Obstacles

The second thing you need to look at is whether there are any constraints on the type of business you are considering. As I mentioned, political constraints will inevitably affect your decision to start an aquaculture business in Alaska today.

The debate over finfish farming has affected permitting. There are questions of ulterior motives if you're looking at tidewater sites for an oyster farm. There will be suspicions about your motives, whether you're actually locking up the site for the future for finfish farming. You're going to be suspect no matter what you do.

That's a constraint you need to look at and consider in your own discussions about whether you have the references to establish the business you want.

And those are not the only political considerations. There will be other considerations, depending on the community you select. This is not peculiar to aquaculture farmers alone. I am sure that if you were trying to locate a chemical plant in a community, there would be a substantial body of opposition to a chemical plant. An industrial plant that belches out a lot of black smoke also would attract opposition. This is a standard part of doing business in all communities. You may have all the requisites for locating that business in the community, but you will meet community opposition that will generally attack the establishment of your business through permitting or zoning procedures and through site location decisions, which are generally zoning decisions. That is a constraint you need to consider.

Growth cycles for the various types of aquaculture products are lengthy and if you expend a couple of years getting the site you want in addition to a couple of years of construction and going through problems, you may be looking at four, five, six, maybe seven years before you have a product to put out to market. You may in the meantime be holding down a job to pay the bills and cash can get pretty scarce when you have capital that's essentially unproductive.

As I understand it, too, an important consideration to address now is location and source of brood or seed stock for the product you're going to grow. Some are not available, some are available at high cost. We don't have a well-established business or industry in aquaculture in Alaska right now, so you don't find an existing support structure. That support structure will grow up around you, but if you're one of the first in the business, it's not very comforting when you have to spend a great deal of your time going out and looking for various types of stocks that you need.

Feed is another item you have to examine. As I understand it, feed is produced in the state of Alaska, but that's only enough for the ocean ranching hatcheries right now, and the capacity would have to increase if the type of stock that you choose to raise requires feed.

As for finfish, again as I understand it, a supply of the eggs or what is delivered to you is not available in the state of Alaska right now. That will have to be investigated and you'll have to locate a source for that.

And then, of course, in Alaska, one of the problems we always deal with is transportation. If you're not using a shore-based facility, if you're using tideland somewhere, generally it will be away from the community and you'll need to look at your access to that facility—docks, highways or other sorts of transportation.

You have to consider your employees as well. The farther away you get from a source of employees, the more difficult your logistical problems. The Greens Creek Mine on Admiralty Island is transporting its employees from Juneau to Hawk Inlet and that certainly is a considerable expense.

Financing a Small Business

The third organized question you need to ask is the one we hear most often in our small business assistance program: Where do I get the money? And I really don't know how to answer that one for you. Most small business owners typically have money from their own resources such as from savings, family, friends, and relatives. They beg, borrow, steal, and hustle. I can almost assure you that if you are going to start a small business and you don't have the money to hire immediately all the resources that you need, you're going to have a very difficult time getting any bank, particularly banks in Alaska, to finance the business for you.

You'll have two strikes against you. The first strike is the fact that Alaska banks do not deal with aquaculture businesses. The second strike will be that almost every bank in the United States does not deal with small businesses that are startup, almost bar none, unless you happen to have the collateral that will over-collateralize the loan that you're going after.

In other words, if you have to borrow a half million dollars and you have a million dollars worth of real estate, you'll probably get the loan. If you need to borrow a half million dollars and your home mortgage is greater than the remaining value of your house, you're not going to get the loan. I can pretty much assure you of that.

Many federal programs require, as part of your participation in that program, that you get a turndown from two commercial banks. And those are very easy to get when you're starting up a small business. That's the least of your difficulties.

You can look at forming a limited partnership or a corporation to gain some of your money. The Tax Reform Act of 1986 has affected your ability to do that. Both limited partnerships and corporations have been used to lure in passive investors, people who have $5,000 or $10,000 to lend and who are interested in investing in businesses that are local. The same is true of corporations, where instead of becoming a limited partnership, they become actual shareholders of the corporation and have a say in the management.

Using either form will be relatively expensive for you. I would suggest strongly that if you are considering a limited partnership and corporation, you should contact a CPA who has a strong tax practice, and an attorney who's involved in organizing small businesses.

There will be some foreign interests that might be willing to finance. I recall that the Norwegian delegation conducted a program in Juneau not long ago. I know that the United Kingdom and Japan and some of the Scandinavian countries have investments outside of their own countries in the aquaculture business. I'm not very familiar with that. That might provide financing for some small aquaculture businesses in Alaska.

And this is a guess, a conjecture on my part, but I would suspect that after the state legislature and administration resolve ongoing debates about aquaculture, you may find some programs available from the state, whether loan guarantee programs, or actual loan programs, I'm not sure. But my suspicion is that there will probably be some sort of support for the aquaculture industry. As I understand it, financing will be talked about right after I'm done with my presentation.

Knowing Your Market

Another question to consider is where are your markets? What do they want? If you have any product to sell, you need to know where you can sell it and who you're competing against. Many products will compete against similar products. Pork will compete against beef, chicken will compete against fish. You need to know what will substitute for your product. That's in addition to the direct competition. Scallops will compete against scallops. Salmon will compete against salmon. That's the marketplace for you.

What buyers typically are looking for is a good deal, and not only a good deal, but a product of consistent quality and one that will be produced and supplied consistently. So the quality needs to be consistent and the supply needs to be consistent. And price often is a factor of that. If you take extra care of your products, it may cost you a little more, but suppliers generally are willing to pay a little more for quality. If you're dealing with another small business, a restaurant, for example, they will be interested in consistent supply. They're not interested in hearing excuses, because then they have to repeat that excuse to someone who orders it off the menu.

Foreign interests will provide part of your major competition. Aquaculture products in Alaska should be relatively fairly positioned to compete against foreign interests in U.S. markets, because we don't have the various barriers that are set up to import products into this country. If you're going from Alaska to Washington with your product, you have an easier time taking the product there than if you were a foreign interest. Where you have a more difficult time is competing on price because of the low cost of foreign labor.

You need to be award of what the world market is doing. Just like the American farmer in the Midwest, someone in aquaculture is an extremely small part of a much larger picture. And you need to know if world supply is soon to exceed demand. Right now, as I understand it, world demand is great enough so that new supply can be accommodated, but if that equation ever changes, then you must replace other products or compete against them on price in order to sell your own. By economic tradition, there is a set price at which you should be able to sell most of your product until you get down to the point where you're giving it away. If you have to move your price down below the cost of producing your product, then you're out of business. You should be aware of market threats that face your business and be ready to meet them.

You also need to consider what it will take to market your product and who will actually be marketing it. Will you hire a broker to market it? Will it have to be stored for any length of time? And if it has to be stored, where will you store it? If it's a fresh product, you're going to have to move that real quickly. If you freeze it, chances are that you're going to lose a bit of the premium that goes with the appellation "fresh."

If you will be trading on international markets, you will have a whole new language to learn. Most of that language has to do with the requirements for shipping in international trade, and dealing with import/export restrictions and financing terms. And again, in Alaska, we may well have to deal with out-of-state banks that typically have the expertise and who are set up to deal with international finance. Alaska banks have some capabilities, but they are limited by their limited experience in international finance. Their capabilities could increase as we have more and more involvement.

PLANNING AND PRESENTING YOUR BUSINESS

Writing a Business Plan

Now that you've considered all the elements of organizing your business, how are you going to operate it? If you're going to find financing, if you're going to be lining up partners, if you're going to be talking to people and trying to encourage them to work for you, the best suggestion I can make for you is to have—and participate in writing—a business plan for this venture. A business plan is actually a written document that outlines a number of points. Worksheet No.1, which is in the Appendix to this paper, sets out an outline of a sample business plan.

After making your plan, you should have accomplished two things. You will have learned an awful lot about your business and how you plan to operate it and how you plan to implement your policies. You also will have a document that reflects all of the thought process that has gone into it and that you can use to go out and get involved in the hard work of starting your business.

A business plan comes essentially in four sections: policy, financial data, financial proposal, and supporting documents.

Policy

Very simply, a question of policy has to do with how you plan to operate within a certain segment of your business. A statement of policy, for example, would be "I plan to raise such-and-such a product. I have selected a product and I'm going to channel my skills and my resources into growing that particular product." And what you've said to potential investors and other people potentially involved with your business is that you have thought through what it is you're going to grow and you shouldn't change your mind in the future.

There are other items of policy you need to discuss. A description of the business is one. You need to discuss the market, as we've talked about. The market is crucial to you. You need to discuss your competition. In most small producing businesses, the area of competition can be extremely large. For certain aquaculture products, you'll be dealing with Norway, with Chile, with Japan, with British Columbia, with Washington state, and maybe with Oregon. You need to be aware of the competition. Some businesses will be dealing with local competition. If you're a clothing retailer, you'll be concerned only with clothing stores in your location. In an aquaculture business, you'll be dealing with a rather wide group of producers that will be your major competition. And they will be producing essentially the same product as you. There are differences in their product, too. That will be your competition. And, although in most circumstances a small business owner will not affect either world demand or supply for that product, you should be aware of the world market, because it will influence what you do. And your policy statement should reflect what it is you plan to do. If you foresee fairly high start-up costs and a fairly high cost of production up front, but you're able to reduce the cost of production a little farther down the line, then that would be a part of your strategy. If you produce a quality product at a good price, you should do all right. But you need to monitor that price and know your competition.

Another part of your policy statement should be your business location. I mentioned earlier that you probably won't be right near a community. You might not be able to drive to your facility. You might have to have a boat. You might have to have living facilities at the site that you've chosen. That should be noted.

And, of course, you'll have to transport your product once it's harvested, and you should deal with that in a policy statement as well.

The primary reason for failure of that small business is poor management. Now, I'm not talking about fraud. I'm not talking about malfeasance. I'm talking about plain ignorance and bad management—people who don't understand what is involved in putting together a product and selling it.

It's very important, when looking for financing and for people to be involved in your business, that you look at the resources that you have available as part of your management team. If you intend to be the primary manager, your skills will need to be noted and presented in a supplement to the business plan, probably with a real dynamite resume. If you have partners, or if you have other people who are going to be involved, you should list what their resources are. If you don't have those resources, your policy statement should refer to the resources that you have in mind to use. If you can, you should get a statement from those resources that they are available, and that they have the expertise to help you. Management will be a continuing concern of just about everyone you're dealing with, from suppliers to consumers to employees. Everyone will be interested in good management.

Thus, another policy section should be how you plan to deal with that very precious commodity we've talked about: whatever money you have managed to scrape up. You will want a certain type of facility, but you will end up with another type, I can assure you. Instead of a Cadillac, you may end up with a U-Haul. But many small businesses start out that way, and you shouldn't be embarrassed about that. These funds are very precious and your policy should deal with what you are planning to buy, how you're planning to use it. What you also should do is look at why you need it. Can you do it cheaper another way? What will the equipment you're planning to buy return to you? If you can buy a $5,000 boat or a $20,000 boat, and they both accomplish the same thing, maybe you should go with the $5,000 boat. If you're going to buy an automatic feeder, maybe you should compare what it saves you in labor costs and what it costs you in any other areas.

When considering policy, in Alaska, you should be aware that quality is important. We do not yet have a large enough population to have skilled trained personnel in all of the repair fields that you're going to have to deal with. If you've ever lived on Prince of Wales Island and tried to get someone to repair your copy machine, or in Angoon or in Haines, you know what I'm talking about. It's very difficult to get skilled personnel to perform certain kinds of repairs, so quality is important. Even though it might not be top-of-the line in terms of all the whistles and bells, it should be of very good quality.

Financial Data

After you have taken care of the policy section, then you need to deal in very, very fine detail with the financial data. Think of the presentation of the financial data you develop as showing how you will actually manage the business. Cash is the key to any small business. You have to have it, you have to keep it coming in, you have to stop it going out as fast as it comes in. You also need to know how to hold on to it without offending those you've been keeping it from. It's a fact of business that if you have 45 days to pay an account, you should hang on to it for 45 days and then pay it on the last day. You need that cash. You might not have it in; you're expecting it from someone else who is holding on to their cash for 45 days until they pay you. But you'll need to know how you plan to use your cash, you'll need to know in all phases of business how it's actually being used, and for those occasions when you need more of it, and it's not coming in from sales, you'll need to know how to talk to bankers or whoever's going to finance your business.

The very first step you need to look at in establishing this finance plan is to make sure you understand bookkeeping, that you have a bookkeeping system set up, and you have someone to operate and maintain it. You can set up your bookkeeping system by doing it in-house, if someone has the skills. Or you can have a trained professional do it for you and train you to use it, or you can do a combination of both.

There are essentially five control documents you will use in assembling your financing data:

1. Balance sheet—This shows the assets and liabilities of your business. It is taken periodically from your bookkeeping system. You can take a look, at any given time, at what you have.
2. Income statement—This is sometimes referred to as a profit and loss statement.
3. Break-even analysis—You'll need this to figure out the price of your product. It will tell you, at different levels of profit, what can you sell, and for what price, in order to break even.
4. Pro-forma—This is just a fancy name for a cash flow projection that shows on a monthly basis when you expect cash to come in and what you expect to go out. This document will also serve as a budget.
5. Deviation analysis—If you monitor your business and you budget carefully, you can do a deviation analysis, which essentially shows the difference between what you have budgeted and what you have actually spent. That helps you budget for subsequent periods.

There are samples of each of these documents in the Appendix. And there are resources to help you fill those out. I said earlier that I think it's important if you are planning to start a small business, that you actually be involved in writing the business plan, that you do most of the work yourself. And I say that because it's very important for you to become familiar with the resources that are available to you and the constraints that are going to be confronting you. And doing the worksheets with someone who is more experienced is one way to become familiar rapidly. It also helps you to be able to monitor the business on an ongoing basis. If you sit down, for example, at the end of every month for three or four hours and perform your deviation analysis, you'll know where you're doing well. It may alert you to a problem in the operations side of your business that you can correct before your business hemorrhages so much that it can't be saved.

One of the problems our Small Business Assistance Center encounters frequently is that people will not pay attention to finances until there are external signs of trouble, such as attorneys or credit companies chasing you or your supply being cut off for nonpayment. Once you reach that stage, it's very difficult for you to resurrect your business. And I'd be very concerned about any business that reaches that stage.

By performing the deviation analysis, sticking to your budget and paying attention to the finances, you're going to be a lot happier and a lot healthier.

Financial Proposal

The third part of a business plan is putting together the financial proposal. If you plan to borrow money or if you're going out for a limited partnership, you should say what you're looking for. If you want 20 limited partners at $5,000 each, or 10 at $10,000, what can limited partners expect in return for their investment?

The rest of the plan should show how you plan to implement the business, how you plan to grow, and the skills and the expertise that you have to make that business grow. Those investors are going to be looking three, four, five years down the road to see if you have the capability to carry out what you have planned.

Your financial proposal also should discuss how you're planning to run the business, what cash you're putting in, what debt you're going to be contracting for, and what equity you're going to be trying to attract from the limited partners or shareholders.

It's also important to set out what it is that you're going to buy, what you have to invest in, such as buildings, capital facilities, and other expenses and equipment. Everything that you plan to spend should be fairly well detailed.

Supporting Documents

In the final section, we deal with supporting documents. You may already have a site location. You might have worked on the permitting process so that you are relatively assured of it. And perhaps you have a map of the location. That's a supporting document. You may have resumes of the principal people who are going to be involved in your firm. You will probably have sales quotations from capital equipment that you plan to buy. You may have already contacted buyers and from those buyers you will want to have a letter of intent to buy. You will want to have letters from brokers indicating that they can move your product, and some indication that they are successful brokers. You will probably want letters of reference testifying to your good character and to your long-standing position in the community. If you have already leased a site, or if you are leasing equipment, you should use that lease as a supporting document. If you have incorporated, the incorporation papers, the by-laws, that created that corporation, should be available.

RESOURCES

It sounds like a lot of work, and small business is a lot of work. It's a never-ending process. Successful small businesses, after five or six years, can afford to hire people for management, to take some of that burden off, but during the start-up phase, if you are not well heeled, and you can't afford those resources, you're going to be doing a lot of work yourself.

These are resources available to you. This conference is one. And some of the individual organizations involved are technical resources you can turn to.

The Small Business Development Center in Alaska, located in Juneau, Anchorage, and Fairbanks, with satellite offices in other cities, will provide small business assistance and help you put together a business plan. Cooperative Extension, Marine Advisory Program, and Sea Grant Program have resources available for your use.

In addition to state resources, there are plenty of private consultants. At the end of the Appendix you will find a list of technical assistance providers in Southeast Alaska that I have distributed in the past, and a couple of documents to which I refer.

There is a publication by the Alaska Department of Commerce and Economic Development called *Business Planning Guide*, which might also be helpful. They are selling it for $7, and it has a lot of information on how to start a small business.

APPENDIX

Setting Up A Small Aquaculture Business in Alaska

Patrick M. Anderson, J.D.
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November, 1987

The Alaska Economic Development Center is a public service offered by the University of Alaska Southeast. Funding is provided in part through the United States Department of Commerce, Economic Development Administration, and the Division of Business Development, Alaska Department of Commerce and Economic Development

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SETTING UP A SMALL AQUACULTURE BUSINESS IN ALASKA

A. ORGANIZING YOUR AQUACULTURE BUSINESS

1. Do you have the technical skills required to operate the business?
   - Can you install a seafood farming facility?
   - Are you capable of operating the facility?
   - If not, are the resources readily available?
     - Construction contractor with skills
     - Operating foreman
     - Laboratory facilities
   - Disease control is important, can you handle it?

   If not, are you willing to acquire the technical skills?

2. Are there constraints on establishing the business you want?
   - Is the type of business politically possible?
     -Salmon, black cod are not currently possible.
     -Scallops, Oysters, Mussels, Abalone, Little Neck Clams and seaweeds are potentially possible.
   - Are locations available (need salt water/sheltered)
   - Is there a source of brood/seed stock available?
   - Is a source of feed readily available, if necessary?
   - Can you get the necessary permits
   - Are there any environmental operating restraints (waste?)
   - Will you have good transportation access for supply and delivery

3. Where is your financing going to come from?
   - Banks are not a likely source
   - Personal resources, friends, investors
   - Limited partnerships, corporations, as fund raising vehicles
   - Joint ventures with foreign interests
   - State programs (AIDA), Federal Programs (EDA, SBA)
   - Foreign financing (Norwegian, Japanese, Etc.)

4. Have you considered where your markets are and what they want?
    - What product is your primary competitor
    - Is demand growing
    - Are there other sources of supply or competitive products?
    - Who will sell your product for you and who can you sell to?
    - Are brokers important in your business?
    - What about transportation to markets?
    - Is storage required? If so, where?

5. Will you be trading in international markets?
    - Must learn about export requirements?
    - Export financing is different, are there banks you can rely on?

B. OPERATING YOUR BUSINESS

6. Do you have a business plan?
    - Describe the business and why you feel you can succeed in it
    - Forecast profitability
    - Forecast cash flow
    - Prepare an operating strategy
    - Form of organization
    - Establish a marketing plan
    - Are the personnel available or will they have to be trained?
    - Market analysis and marketing plan

7. What resources can you turn to for help?
    - State of Alaska Division of Business Development
    - Office of International Trade
    - University of Alaska Southeast
        - Cooperative Extension Service
        - Marine Advisory Program
        - Small Business Development Center
        - Alaska Economic Development Center

INTRODUCTION

Entrepreneurship is changing the face of Alaska. Alaskans in ever greater numbers are starting to manufacture, build, brew, grow, harvest, produce and sell all kinds of products and services. Paint, beer, mattresses, car batteries, boats, wild berry jams, smoked salmon, potato chips, milk, furniture, sausage and numerous other products are made in and are available for sale in Alaska. Business opportunities are available for the bold and venturesome (who have a little bit of capital). One new business opportunity being investigated by many entrepreneurs is the field of aquaculture. Although aquaculture enterprises currently exist in Alaska, they are on a small scale and are small in number. Yet the potential for a business explosion in Alaskan aquaculture is real. We have all of the necessary resources - tidelands, capital, labor and transportation. All that remains in order to open up the field is for a number of economic development policy questions to be answered.

You might be one of the entrepreneurs currently investigating aquaculture as a business. If so, I hope to give you a little bit of advice on how to start exploring the potential of aquaculture. Other topics such as permitting and financing are being covered by other speakers.

Aquaculture is a business and as with any business, you must make a profit to survive. Making a profit is a simple concept to put on paper. You make sure that your total costs (operating and administrative) for producing the aquaculture product you have chosen to raise, are less than the price you can receive for your product. The difference is your profit. In order to make that profit, you must work to produce an excellent product in saleable quantity while holding your costs down, and at the same time find markets in which to sell your products for a price that covers both your costs of production and the profit you hope to make. Look at the plight of farmers in the United States. They are the most productive farmers in the world. However, because of oversupply and competition from foreign producers, they have come upon hard times. As a small producer, you must realize that you are vulnerable to world supply and demand. The demand is favorable right now to new supply. It will be a continuous battle for you to maintain your position should you choose to enter the aquaculture business.

Part of the continuous battle has to do with the political environment. I pass no judgment on the political battle currently being fought over finfish. What the successful entrepreneur will do is monitor the debate and be prepared to move to establish the business if or when the debate is settled. This presentation is being made to advise you on how to do that.

Before starting your business, it helps if you begin by taking a personal assessment of your skills and abilities. Section A of the outline asks many of the same questions you must ask of yourself about what it takes to successfully start and operate the business. If you lack any of the skills outlined, don't despair. Most small business owners end up learning a great deal about their business after they enter into it.

Another type of assessment you need to consider doing is whether you have the entrepreneur personality. What you must assess of your personality is whether you are motivated to learn and to work very hard. It has been said many times that small business owners are lucky - they get to work just half days to be successful- only twelve out of the twenty four hours in a day. Security, vacations, a regular dinner hour, time with the family: all take a back seat to the successful business.

You also need to undertake an assessment of the political, business and community environments in which you will be operating. The political environment regarding aquaculture is very charged in Alaska at present, with the major debate taking place on the question of finfish farming. You need to monitor this debate if you intend to participate in any finfish farming allowed in the future. If you intend to try a different type of aquaculture, you can start the process today. The business environment is another important part of your assessment. If the economy is healthy, many of the goods and services you will need should be available. As I mention later, availability of brood/seed stock, feed, labor, and other items are limited in places in Alaska. Finally, the community environment is important. You need community support in order to survive. A hostile environment can hurt your chances of success. Talking to political leaders, business leaders and community leaders will help your chances for success.

In this presentation, Section A leads you through many of the steps you will undertake in planning and organizing an aquaculture business. The questions you must ask and answer are listed. Section B will discuss the concepts behind preparing a business plan and getting started to operate the business.

A. ORGANIZING YOUR AQUACULTURE BUSINESS

1. Do You have the technical skills required?

As with any small business, you must either have the skills necessary to start and operate the business, be willing to learn the skills yourself, or hire someone who already has them.

Any farmer is a jack of all trades (except for the large corporate farms). Someone starting an aquaculture business will need to locate a site and construct a facility with holding pens (if necessary), protection from predators, feeding facilities, storage space, harvesting and processing space, office and administrative space, and other requirements. The expertise to accomplish this phase of starting the business can generally be contracted for through design and construction professionals, although there is a substantial cost to do so. Some new aquaculture farmers can, and will, do much of the work themselves. The advantage to doing the work is that capital costs will be held down. The disadvantage may be an inadequate facility if it is not properly planned.

You will also need to operate the facility. Constant day to day administrative duties will have to be met, including bookkeeping and accounting, federal and state reporting, procurement of feed, brood/seed stock and operating supplies, regular care and feeding of the product, disease control, waste management, personnel management, harvesting and processing, shipping and marketing, among others. Each task involves skills that will have to be available, if you don't have them or do not have the time to do the tasks yourself.

Like all small business, you will be dealing with a number of administrative requirements. Production will have to be scheduled in order to meet demand. Cash will have to be managed (since you will turn out a product and get paid only when it is harvested). Good will with both brokers and customers will have to be nurtured. The indeterminate number of small problems that can grow into big ones rapidly will also have to be handled. As the owner, you may not have time to do them all and run the actual farm.

With finfish, disease control is an important part of managing an aquaculture farm. Fish need to be vaccinated and tested for disease. Small operations cannot afford the cost of a separate laboratory, so you will need to rely on the state laboratories in Anchorage and Juneau. Fish also need regular monitoring for efficient utilization of feed, or fish husbandry.

2. Are there constraints on establishing the business you want?

Political considerations will inevitably impact your decision to start an aquaculture business in Alaska for the near future. You should be aware of the significant public policy debate occurring on the question of whether finfish farming should be allowed in Alaska. Finfish farming is currently not allowed. As a potential aquaculture farmer, you should become familiar with the arguments being made both pro and con. Until the debate is resolved, there are some species other than salmon and other finfish that you can look at to be farmed, such as oysters, mussels and sea vegetables.

In addition to finfish restrictions, other political considerations will be involved in whether you can start any aquaculture business, namely, the site acquisition and permitting processes. Since most tidelands are controlled by the State of Alaska, a state policy on leases for tidelands for seafood farming will need to be adopted. As for permits, there are a number of them that will have to be acquired, both state and federal, and other requirements that must be met. Depending on your location, some opposition to your business may be expected. This opposition will generally attack the establishment of your business through the site location and permitting processes.

An extremely important consideration to address now, and certainly early in your planning process, is location of a source of brood/seed stock for the business. If you will be growing oysters, you will need a supply of oyster spat to set in your farm. If you will grow salmon, trout, steelhead or other finfish, you will need a source of brood stock (in the fry stage) to grow to maturity. There are no Atlantic salmon stocks currently available in Alaska, so your ability to grow Atlantic Salmon will be limited unless you can order the supply from outside the state. This will be difficult because of a fear of disease transmission and the fact that importation of eggs or fry is not presently permitted. As for raising wild stocks of Pacific Salmon species such as coho or king, it may take some time before a suitable supply of brood stock becomes available. You may, in fact, have to spend a few fish generations experimenting in order to develop suitable stocks for your use. Think of this process as similar to domesticating wild animals such as the buffalo for ranching.

Once you have managed to resolve the political questions and the brood/seed stock requirements, you will then need to feed any stock you raise. For finfish, dry or semi-dry feed will be required, in substantial quantities. There is limited production of such feed in Alaska today, and the feed produced is being used for existing fish hatcheries. Feed costs represent a substantial portion of your cost of producing finfish, so a low cost supply is important. Just as important is a reliable source of feed, since losing stock because of a lack of feed is expensive. Other types of aquaculture products may not need feed.

Finally, transportation problems must be solved. Most aquaculture farms will be located away from highways, docks and other transportation facilities. Employees will not generally live within traditional commuting distances unless measured by boat miles. Weather will be a factor when water transportation is involved. You need to solve these problems for your sit. Some security will be required as well. This may require living quarters at the site.

3. Where is your financing going to come from?

As with almost all small businesses, financing will be a source of frustration. The majority of small business starts with financing provided by the owner(s), friends, and people who have small sums to invest and are interested in both local economic development and a good return on their investment. In any aquaculture business, you will not be generating any cash flow until you have fully grown product to sell. For Atlantic salmon, the growth cycle is approximately 18 months. Other aquaculture products have long cycles to maturity. The expenses will require operating capital for an extended period before payback can begin. The only suggestion I can make here is to hustle and locate the money where you can, in the quantities you can. You should do your best to budget adequately in order to know what your cash requirements are.

Banks are not a likely source for finding financing. In particular, Alaska banks are not going to be familiar with the aquaculture business, and therefore will have a reluctance to loan funds for an unknown business in addition to their traditional unwillingness to loan to small businesses.

Forming corporations or limited partnerships are means of attracting funds, but will require a well written business plan, and in some cases will have to meet other requirements. You should consult an attomey and tax professional to explore these options.

Some foreign aquaculture interests and foreign banks may be interested in investing in an Alaska aquaculture business. The Norwegians hosted an aquaculture conference in Juneau during the fall of 1987 and have invested in aquaculture businesses in British Columbia and Washington State. The United Kingdom and Japan also have aquaculture investments in foreign countries.

After the aquaculture policy questions are resolved by the State of Alaska, financing programs could be started. Otherwise, the traditional new enterprise funding through the United States Department of Commerce, Economic Development Administration and Small Business Administration loan guarantees might be a source to check out.

The topic of financing an aquaculture business is being discussed by another speaker at this conference.

4. Have you considered where your markets are and what they want?

If you have a product to sell, you need to know where you can sell it and who and what you are competing against. You notice that I added "what" you are competing against to the last sentence. Sometimes products will compete against similar products. For example, pork versus beef, chicken versus fish, shrimp versus scallops versus surimi based versions of both. Products will also compete directly against each other on the basis of species, quality, availability (including reliability) and price. Scallop will compete against scallop, oyster against oyster, etc. Coho against King against Atlantic salmon. A buyer is usually looking for a good deal, and if given a choice of suppliers, will buy from the supplier who can not only produce a product of consistent quality, but at a fair price with a reliable and consistent supply.

You should examine whether demand is growing for your product. If demand exceeds supply, you will not have to displace existing product in order to start your business and your marketing costs should not be as high. And, if you can turn out a good product, you may be able to sell it under a futures contract which will provide you with some cash in advance. If supply exceeds demand, then you will need to spend on marketing in order to sell your product. What you will need to do is to displace existing product by offering either a lower price or better quality, both of which are difficult to do.

In aquaculture, foreign interests are heavily invested and will present the major competition to Alaskan products. Alaska is postured quite well to be competitive in the U.S. market against most foreign competitors. However, low cost foreign producers (Chile is often mentioned as a future low cost producer) may well be able to consistently undersell Alaskan producers in the future. You should be aware of such market threats and have a strategy to meet them.

Other important marketing considerations include who will sell your product for you, how it will be stored, and how it will be transported to market. Fresh product will need to be handled expeditiously, particularly from Alaska. Brokers can move some product and traditionally do so for many Alaskan fishing interests.

5. Will you be trading in international markets?

Finally, if you are going to be involved in foreign markets, you will have to learn about export requirements and export financing. Many Alaskan banks are not very experienced in foreign export finance and you may have to deal with non-Alaskan banks in order to trade internationally.

There is a whole new language to learn when involved in foreign trade. Most of it has to do with the requirements of shipping, and meeting import/export restrictions. Phrases such as bills of lading, letter of credit, tariffs, will have to be learned. Since many Alaskans have been involved in fishing for wild stocks of salmon, they will already be familiar with the requirements. If you are not, the resources are available to assist you.

B OPERATING YOUR BUSINESS

6. Do you have a business plan?

The business planning process, and the actual writing of a business plan, gives you an opportunity to determine how all of the demands of operating a business will be handled. You should personally be involved in putting together your business plan. Although some of the elements may be beyond your current expertise, going through the process of writing a business plan will help you learn what will be required of you. Business assistance organizations such as the Alaska Small Business Development Center of Alaska, located in Fairbanks, Anchorage and Juneau, can assist you with the business plan preparation. There are also a number of publications available to guide you. This section contains a brief guide to what a business plan is and what it should contain.

Worksheet number 1 is an outline for a sample business plan. Take a look at it and examine the kinds of questions it asks. This outline can be used as your table of contents and will guide you in writing. This work book will go over the sections contained in the business plan briefly. They are the questions you need to answer before you will be able to start your business.

WORKSHEET NUMBER 1

Outline of Business Plan

*Cover Sheet

*Statement of Purpose

*Statement of Contents

I. The Business Policy Statement
   - A. Description of Business
   - B. Market
   - C. Competition
   - D. Location of Business
   - E. Management
   - F. Personnel
   - G. Application of Funds and Expected Effect

   Business Interests of Participants

II. Financial Data
   - A. Sources and Applications of Funds
   - B. Capital Equipment List
   - C. Balance Sheet
   - D. Income projections
   - E. Breakeven Analysis
   - F. Pro-Forma Cash Flow
   - G. Deviation Analysis
   - H. Historical Financial Reports
   - I. Summary

III. Financing Proposal

IV. Supporting Documents

   Sources of Information and Assistance

Your business plan covers a lot of material, and at the end, you should have a written document that you can give with pride to potential partners, investors, brokers or buyers, bankers, key employees and others. The final product should look good. It will represent you, your thought and planning for some time to come. It should also be a living document, revised when needed, and frequently consulted to make sure your original plan is still on track.

I. The Business Policy Statement

The first part of the business plan sets out the policies you will be following in operating your business. This section shows that you have fully considered all aspects of the business and have settled upon what you will be doing. It describes how you will be dealing with possible problems and how you will deal with success. If you plan to grow, that plan for growth will be reflected in the plan.

A. This first section should describe the business you are going into and why you believe you will be successful at it. For an aquaculture business, you should discuss the product you are going to raise, who you will market it to, whether you are just starting out or buying an existing business, the form of business organization you will be operating under (sole proprietorship, partnership, corporation), and when and how you will operate (date open, hours of work, seasonality if applicable). In particular, since aquaculture business requires a period of growth before a product will reach market, growth and harvesting requirements should also be mentioned.

B. Your market is crucial, and should be discussed next. If you can specifically identify your market, do so. For example, will you be selling through a broker, or will you be marketing directly to restaurants, smokeries, grocery stores, meat markets, or institutions such as hospitals, prisons and schools. You should also discuss major market considerations such as: will demand for your product be growing or declining?, is competition increasing?, can you reduce your costs of production and increase productivity in the near future? is your present capacity and planned future capacity sufficient for you to hang on to existing markets? Market planning should be ongoing and will, if properly conducted, enhance your competitiveness.

C. As a part of market planning, you should also know your competition. If you have local competition, note it. In providing aquaculture products, your competition is essentially worldwide, although you do have some advantage in the U.S. marketplace through not having to deal with import restrictions and tariffs. Since aquaculture is growing worldwide, you should also be aware of and monitor future competition. If supply exceeds demand, as has happened in many U.S. farming and ranching industries, the most price competitive suppliers will prevail.

D. In discussing location of the business, you should note that Southeast Alaska is competitively postured to support aquaculture businesses. Transportation by both air and water is good. There is good tideland available and the waters are clean, although political availability of that tideland may be poor. As for specific location, you should identify your site, its good characteristics, its access, and the improvements that need to be made in order to support the business. Transportation and access are also important consideration to note.

E. Every small business, aquaculture business included, needs good management. A considerable number of small businesses fail because of managerial incompetence. Your discussion should include a description of who will manage the business, what their <u>relevant</u> work experience is, what duties and responsibilities each manager will have, what salaries and benefits will be paid, and what the other resources available to the business (attorneys, accountants, laboratories, consultants) will be. When looking at relevant work experience, certainly experience in the fishing industry, small business management, fisheries biology and seafood marketing will count.

F. Personnel is another important consideration. You should discuss the number of people needed, their skills, whether they are available, part timers needed (if any), whether overtime will be necessary, wages, training for inexperienced personnel, and seasonal requirements. For aquaculture businesses in Alaska, it is also important to discuss any logistical problems in getting your employees to work and whether they will have to be housed at the site.

G. Regardless of where your funds are coming from, whether personal funds or borrowed, you should discuss how those funds will be applied (what will be purchased) and the effect you expect from those funds. For example, if you purchase an automatic feeder, how many employees will it replace, and at what cost. If you are purchasing a boat, why is it required and what use will it receive. If you are installing capital facilities, you should discuss the expense of installation and how it will help you produce a profit. Each item purchased (or to be purchased) should be listed and priced. You should be aware that quality is important in Alaska because of the lack of availability of certain types of trained repair personnel and the distances required in order to travel to a site and make repairs. Invest in quality when you can. If you are attempting to borrow funds to buy some of the items, list the total available collateral you will be able to provide. Borrowers will be interested.

Finally, you should summarize the information you have developed in this section. Mention the interest that each participant in the business will have and how they will relate to the business, whether as board member, manager, employee or passive investor.

II. Financial Data

In the financial section, think of your presentation as showing how you will manage the business. Cash is the key to your business. You need cash to start, operate and manage the business. You will need to know how you plan to use your cash, how that cash is actually being used, and when you will need more of it. The first step in establishing your finance plan is to establish your bookkeeping system. This can be done either in house by you or your staff, or by trained professionals, or a combination of both.

There are five control documents to be used in preparing and monitoring your financial plan. They will be discussed in more depth, but they are the balance sheet, income or profit and loss statements, a breakeven analysis, a pro-forma cash flow (projected cash flow that can essentially serve as your budget) and a deviation analysis.

A. The first section under financial data should detail where you expect the funds to start your business will come from, and how they will be applied. Some of this work has been done in the last business policy section. It should be repeated here in a slightly different context if you are planning to try and borrow funds.

B. A list of capital equipment you expect to purchase will need to be included as an application of the funds you anticipate borrowing.

C. A blank balance sheet is shown in worksheet 2. The balance sheet shows your company's assets, liabilities and net worth at any particular time. Balance sheets are all similar except to the detail that one decides to go into. The sample given is adequate for most needs and can be expanded if necessary. The balance sheet can be either audited or unaudited. If audited, your accountant will so specify. Audited balance sheets may be necessary for some purposes. This means that an accountant has examined the books, the controls established and has been satisfied that the records are accurate.

Balance sheets can also be analyzed to show the general health of your business. As an example, working capital is calculated by subtracting current liabilities from current assets. Low or negative working capital indicates trouble.

D. A breakeven analysis is a calculation that tells you the number of sales needed in order to breakeven, that is, enough sales to cover your expenses. It is a good suggestion to underestimate sales and overestimate expenses when calculating a breakeven. The basic breakeven formula is:

Breakeven Sales in Dollars = Fixed Costs + Variable Costs

This formula requires you to calculate your fixed costs, which are those costs you incur whether you make any sales or not, and your variable costs, which are those costs incurred to produce your product for sale. Once you have calculated your breakeven, you know the level of production you must meet and sell in order to make a profit -- assuming you can hold your variable expenses to their estimates.

E. The next important document is your pro forma income statement. Pro forma is accounting language for projections. You are projecting what you expect your income and expenses to be according to the best information you have available. You are going to have to forecast the future. Worksheet 3 is a sample pro forma income statement with appropriate expense items. You need to fill in the blanks with your anticipated sales, expenses, and taxes to arrive at a projected net income after taxes. Preparing the income statement can also help you budget your expenses.

F. A cash flow statement is probably the most crucial document of the five control documents mentioned. Worksheet 4 is a sample cash flow statement. The cash flow projects when cash is available and when expenses must be met. The projection is done monthly and uses only actual cash transactions. A cash flow allows you to plan for seasonal expenditures that

WORKSHEET NUMBER 2

Pro-Forma Balance Sheets				
For Fiscal Years Ended 1988, 1989, and 1990				
	----------Fiscal Years----------			
	1988	1989	1990	
ASSETS	$	$	$	
Current Assets				
Cash				
Accounts Receivable				
Inventory				
Supplies				
Prepaid Expenses				
Total Current Assets				
Fixed Assets				
Leasehold Improvement				
Fixtures/Furniture				
Buildings				
Equipment				
Vehicles				
Total Deprec. Assets				
Less: Accum. Dep.				
Total Fixed Assets				
TOTAL ASSETS				
LIABILITIES				
Current Liabilities				
Accounts Payable				
Current Part of Long-Term Liabilities				
Total C.L.				
Long-Term Liabilities				
Notes Payable				
Bank Loan Payable				
Equity Loan Payable				
Total L.T.L				
TOTAL LIABILITIES				
NET WORTH/OWNER'S EQUITY				
Owner's Equity				
Retained Earnings				
Total Equity				
TOTAL LIABILITIES AND NET WORTH				

WORKSHEET NUMBER 3

	Pro-Forma Income Statement			
For Fiscal Years Ended		, 1988, 1989, and 1990		
	----------Fiscal	Years----------		Industry
	1988	1989	1990	Percents
Net Sales Income	$	$	$	%
Cost of Goods Sold (exp)				
Cost of Brood Stock				
Feed				
Direct Labor				
Other				
Total C.G.S.				
Gross Profit Margin				
Operating Expenses				
Accounting and Legal				
Depreciation				
Insurance				
Interest				
Maintenance				
Rent/Lease				
Supplies				
Telephone				
Travel				
Utilities				
Administration				
Shipping Containers				
Other				
Other				
Other				
Total Operating Expenses				
Net Income Before Taxes				
Income Taxes				
Net Income After Taxes				

WORKSHEET NUMBER 4

Pro-Forma Cash Flow
January 1988 to December 1988

	January 1988	February 1988	March 1988	April 1988	May 1988	June 1988	July 1988	August 1988	September 1988	October 1988	November 1988	December 1988
Cash Receipts												
Income from sales												
Wholesale												
Retail												
Total Cash Receipts												
Cash Disbursements												
Costs of Production												
Variable Labor												
Accounting and Legal												
Insurance												
Transportation												
Fixed Cash Disbursements												
Loan No 1												
Mortgage/Lease												
Total Cash Disbursements												
Net Cash Flow												
Cumulative Cash Flow												
Fixed Cash Disbursements												
Utilities												
Salaries												
Payroll Taxes & Benefits												
Office Supplies												
Maintenance												
Licenses/Permits												
Packing Materials												
Telephone												
Miscellaneous												
TOTAL FIXED CASH DIS.												

might be higher than usually incurred. A good cash flow can also help you keep any borrowings under a line of credit as low as possible so you don't accrue additional interest expense. Once the cash flow is prepared, you also have a good budget to go by.

G. Worksheet 5 gives you two sample deviation analysis forms. One for a monthly deviation analysis and one for a year to date analysis. The deviation analysis allows you to use your budget (cash flow) to compare your projections with actual expenses. Any deviation discovered can alert you to either problems or opportunities. If your projections are high and actual expenditures low in one month, you might be able to isolate the successes and implement them permanently. If expenses are high and projections low, you will be alerted to the problem early and be able to correct it.

H. Finally, any historical financial reports you have (such as last year's financial statements) will be included. If not, then you may need the personal financial statements of the principals involved in the firm if you are seeking a loan.

III. The Financing Proposal

If you are looking for financing and using your business plan as a tool to help find it, then this section will need to be included in the business plan. By now, you have fine tuned your capital needs and will know what your operating expenses are. In the aquaculture business, you are going to have expenses long before you will have sales to offset them with. You will now know the growth cycles for the seafood you have chosen to grow. The question now is, how will you finance the growth?

There are two types of financing for your business, equity and debt. Equity consists of cash or capital contributed to the business. If the owners put in cash and it does not have to be paid back, the cash becomes equity. The same is true if a vehicle, a computer or other equipment is contributed. Every business needs equity in some amount. Businesses with a small amount of equity are considered thinly capitalized, which can create problems for the business, particularly if there are not other resources available to the business. In partnerships, the equity in the business is represented by the partners' capital and drawing accounts. In corporations, stock (common and preferred) represent the corporation's equity.

Debt consists of funds loaned to the business that must be repaid out of earnings. There are many different types of debt that you must become familiar with. Long term debt is generally used to finance large capital

WORKSHEET NUMBER 5

	BUDGET DEVIATION ANALYSIS			
	Pro-Forma Income Statement			
	Month of			
	A	B	C	D
	Actual	Budget	Deviation	% Deviation
	For Month	For Month	B-A	C/B x 100
			$	%
Net Sales Income	$	$		
Cost of Goods Sold (exp)				
Cost of Brood Stock				
Feed				
Direct Labor				
Other				
Total C.G.S.				
Gross Profit Margin				
Operating Expenses				
Accounting and Legal				
Depreciation				
Insurance				
Interest				
Maintenance				
Rent/Lease				
Supplies				
Telephone				
Travel				
Utilities				
Administration				
Shipping Containers				
Other				
Other				
Other				
Total Operating Expenses				
Net Income Before Taxes				
Income Taxes				
Net Income After Taxes				

WORKSHEET NUMBER 5

	BUDGET DEVIATION ANALYSIS			
	Pro-Forma Income Statement			
	Year to Date			
	A	B	C	D
	Year	Budget	Deviation	% Deviation
	To Date	To Date	B-A	C/B x 100
Net Sales Income	$	$	$	%
Cost of Goods Sold (exp)				
Cost of Brood Stock				
Feed				
Direct Labor				
Other				
Total C.G.S.				
Gross Profit Margin				
Operating Expenses				
Accounting and Legal				
Depreciation				
Insurance				
Interest				
Maintenance				
Rent/Lease				
Supplies				
Telephone				
Travel				
Utilities				
Administration				
Shipping Containers				
Other				
Other				
Other				
Total Operating Expenses				
Net Income Before Taxes				
Income Taxes				
Net Income After Taxes				
CALCULATIONS:	A. ADD current month actual to last month's year to date ana			
	B. ADD current month budget to last month's year to date ana			

improvements such as a building, facilities, and expensive equipment. Mid-term debt can be used to finance vehicles, computers and moderately priced or short lived equipment. Short term debt is generally used to finance operating expenses or inventory. Debt can be either secured or unsecured. The various types of secured debt includes bonds, mortgages, deeds of trust, security interests, and pledges. Debt can come from any number of sources. Some business owners have financed some of their operations with credit cards, personal loans from friends and relatives, bank loans, guaranteed loans from SBA and EDA, stretching out accounts payable (trade credit), and factoring, among others. Some of these sources may not be available to you, but you should be aware of them should an opportunity arise.

Your financing plan should balance debt and equity sufficient to allow you to get a good start. Once the business is operating and you are making sales, and hopefully profits, you will be able to replace debt with equity. Or you may be able to replace bank debt with loans from the owners of the business.

You should also outline your dividend policy, if you are organizing as a corporation, and wage and salary structure, if you are organizing as either a partnership or a sole proprietorship. Investors will want to know if you have such policies established. In reality, dividends and high wages are not generally available in a new business where all earnings are generally put back into the business.

IV. Supporting Documents

Supporting documents include any number of items you may have such as construction plans (in abbreviated form) for the facility you plan to construct, resumes of principals in the firm, sales quotations for capital equipment you plan to buy, letters of intent from potential buyers, character and reference letters, business documentation such as leases, partnership agreements, incorporation documents, and any other important, relevant information.

C. SUMMARY

If you have completed the organizational and planning steps outlined

7. What resources can you turn to for help?

There are other resources you can call on to assist you with your business. The State of Alaska is interested in aquaculture as an issue, and once the policy debates are settled by the legislature, will probably provide assistance to potential aquaculture businesses, either through contract with technical assistance providers, or with information and other resources. The Marine Advisory Program and Cooperative Extension Service are valuable resources. Following are technical assistance resources available to you in Southeast Alaska and some books and publications that will help you with both the business plan and with becoming current about aquaculture issues and technology. There is an Alaska Aquaculture Association that can acquaint you with the issues and technology.

Good luck in your pursuit of entrepreneurship in aquaculture.

Technical Assistance Providers in Southeast Alaska

The Alaska Economic Development Center

School of Business and Public Administration
University of Alaska Southeast
1108 F Street
Juneau, Alaska 99801
(907) 789-4402

Patrick M. Anderson, Director
Annabell Revels, Secretary

The Alaska Economic Development Center (AEDC) was started in 1985 by the School of Business and Public Administration, University of Alaska Southeast, with funding from the U.S. Department of Commerce, Economic Development Administration, and the State of Alaska Division of Business Development. AEDC was started in order to use University resources to assist communities and organizations with their economic development activities, including organizational assistance, economic development research, development planning, workshops and seminars, feasibility studies for community projects, and informational resources. Priority is given to those projects and activities that either create or retain jobs and support community economic development and diversification.

The Alaska Business Development Center

2217 N. Jordan Ave.
Juneau, Alaska 99801
(907) 789-3660

Ron Walt, Director

The Alaska Business Development Center (ABDC) offers a program of business technical assistance for small businesses located in Juneau. Funded by the City/Borough of Juneau and the State of Alaska Division of Business Development, the ADBC is staffed by Ron Walt. A fee of $10.00 per hour is charged for services, although other arrangements can be made. Some of the services offered by the ABDC include business plan preparation, loan packaging, market research and plans, bookkeeping system design, business certification assistance, help in securing bonding, and bidding/ estimating. The ABDC also conducts a number of workshops on various business topics throughout the year.

The Minority Business Development Center of Alaska

1011 E. Tudor Rd., Suite 210
Anchorage, Alaska 99503
(907) 562-2322

Mr. Francis Gallela, Director
Ann Campbell, Consultant
Alicia Quinones, Consultant

The Minority Business Development Center of Alaska (MBDC) is a statewide technical assistance program operated by the Community Enterprise Development Corporation of Alaska. Funded by the U.S. Department of Commerce, Minority Business Development Administration, the MBDC is a source of assistance for minorities who are operating businesses in Alaska or who are thinking about going into business. The MBDC provides a variety of services for minorities that covers most aspects of business. They can prepare cash flow projections, pro forma operating statements, balance sheets, loan packages, business plans, and investment packages. The MBDC can help you set up new financial or administrative systems, audit your operating systems, and recommend changes to increase efficiency, and provide assistance in bidding for and winning contracts from both the public and private sectors. The MBDC charges a modest hourly fee of $10.00 per hour for businesses with less than $500,000 in annual revenue and $17.50 per hour for larger businesses.

Tlingit & Haida Central Council OEDP Committee

320 West Willoughby, Suite 300
Juneau, Alaska 99801
(907) 586-1432

Eric Loomis, Economic Development Planner

The Tlingit and Haida Central Council, the regional Alaska Native tribal entity for Southeast Alaska, has an Economic Development Administration Redevelopment Area grant to assist tribal members with their economic development needs. T & H has recently formed a regional Overall Economic Development Program Committee to work with village tribal entities to prepare both local OEDP plans and a regional plan.

U. S. Economic Development Administration in Alaska

U. S. Department of Commerce
Economic Development Administration
701 "C" Street, Box 10
Anchorage, Alaska 99513
(907) 271-5857

Bernev Richerts, Jr.

The United States Department of Commerce, Economic Development Administration, operates a number of economic development programs in the State of Alaska through its state office located in Anchorage. Among the many programs offered are the EDA Research and Evaluation Program, Economic Development District planning support, Technical Assistance for economic development projects, Business Development Assistance Loans, a Public Works Impact Project program, and the Sudden and Severe Dislocation Program. EDA has a long history of involvement in Southeast Alaska economic development activity and is actively looking for good projects to support. EDA officials regularly travel to Southeast. The EDA representative in Alaska is Bernhard (Berney) Richerts, Jr.

Alaska Division of Business Development

Department of Commerce and Economic Development
P.O. Box D
Juneau, Alaska 99811
(907) 465-2017

Larry Merculieff, Director
Jim Wiedeman, Development Specialist
Tom Lawson, Alaska Economic Development Strategy

The Division of Business Development is the small business advocate for the State of Alaska and is located in the Alaska Department of Commerce and Economic Development. DBD is involved in programs that attract business and industry to the State and assists residents in starting new businesses and expanding existing businesses. For example, they are currently providing funding for the Alaska Business Development Center, Inc., the Small Business Assistance Center for Alaska, and the Alaska Economic Development Center, among others. A number of local governments have used the DBD for assistance in preparing and submitting grant applications. DBD has also organized a number of regional seminars and workshops on various aspects of business management and community economic development. And, under a grant from EDA, the Division of Business Development is also working on the statewide economic development strategy. The strategy, entitled "Trade Alaska," will provide a map for economic development in Alaska.

Alaska Small Business Development Center

School of Business and Public Administration
University of Alaska Southeast
1108 F. Street
Juneau, Alaska 99801
(907) 789-4402

Paul Kennedy, Director

Funded by the State Division of Business Development and the U.S. Department of Commerce, Small Business Administration, the Small Business Development Center of Alaska (SBDC) is a new business technical assistance program. The lead agency for the SBDC is the Anchorage Community College. In Southeast Alaska, a sub-center is established at the University of Alaska Southeast, with the colleges at Ketchikan and Sitka serving as outreach sites. The SBDC provides a number of services ranging from one on one technical assistance to courses, seminars and workshops on business topics. They also provide referrals to other Technical Assistance programs, loan sources, and will maintain a library of books, periodicals and other research resources for small businesses. And, recognizing the importance of exporting for Alaska small businesses, the SBDC plans to provide information and other resources for businesses involved in international trade.

Other Resources

Business Planning Guide. Published by the Alaska Department of Commerce and Economic Development through Upstart Publishing Company, Inc., Dover, New Hampshire, in 1983.

Aquaculture in Alaska. Prepared by the House Research Agency, Alaska State Legislature, February 1987. House Research Agency Report 87-B.

Salmon Farming in Alaska - Economic Feasibility and Socioeconomic Impacts. By Robert R. Logan and John Weddleton, University of Alaska Fairbanks. April 1987.

Alaska Marine Resource Quarterly, Cooperative Extension Service, University of Alaska Fairbanks, USDA and Sea Grant Program. A quarterly publication. 2221 E. Northern Lights Blvd., #220, Anchorage, AK 99508.

LOCAL FINANCING FOR AN AQUACULTURE VENTURE

Bill Hall
Alaska Commercial Fishing and Agriculture Bank
Anchorage, Alaska

I am Business Development Officer for the Alaska Commercial Fishing and Agriculture Bank (CFAB). This paper has information on what CFAB can do for the aquaculture businessperson, and also general information on local financing for aquaculture.

I address the subject of aquaculture not as a biological activity, but as an economic or business activity. This is because my primary subject is local financing, and an understanding of finance requires some discussion of economic concepts and assumptions.

COMMERCIAL CREDIT

My first assumption is that to CFAB, the term finance means commercial credit. And commercial credit means the extension of credit for profit. We all understand that commercial banks are in the credit business for profit, but there has been some confusion about CFAB's intended purpose in this regard. Let me make it clear that CFAB is also in the credit business for profit. What does this statement mean? It means that because CFAB's equity capital from the state of Alaska has a repurchase requirement, CFAB must earn a profit with which that equity capital can be repurchased. It means that because CFAB obtains additional loan capital from a commercial source, the farm credit system, and thereby the bond market, CFAB must earn a profit with which to pay for the interest that we pay on the money that we lend to our members.

Our profit motive is not an arbitrary policy decision of management. It is a condition of our existence. It is a requirement for sustained viability. If CFAB fails to earn profits, it will someday cease to exist as a source of credit.

ECONOMIC VIABILITY

My second assumption is that economic viability is a prerequisite for obtaining commercial credit. Most of your time at this conference will be spent learning about and discussing aquaculture in terms of its biological viability. My advice to you is that for purposes of obtaining financing, you must consider aquaculture in terms of economic viability. Fortunately for all of us, I am not an economist, and I will not attempt to answer questions relating to the economic viability of aquaculture in Alaska. Rather, I will simply state that if economic viability can be established, then there will be no shortage of private sector capital.

Another way of making this last statement is to say that one test of economic viability is the availability of private sector capital. If I were to stop here, I would have the makings of a true "catch-22" proposition. On the one hand, financing for aquaculture will not be available until economic viability can be established, and on the other hand, the test of economic viability is the availability of private sector capital. Fortunately, this apparent dilemma does have a solution.

RISK AND THE LOAN APPLICATION PROCESS

For the purpose of obtaining commercial credit, the solution to the foregoing dilemma is the loan application process. This process begins with you, the prospective borrower, and it ends with the credit decision of the commercial lender. Like it or not, the commercial lender will make a judgment as to the economic viability of your aquaculture venture, at least in terms of its ability to repay the proposed debt. It is, therefore, in your best interest to understand the criteria by which commercial lenders evaluate proposed business ventures.

It is fitting that the title chosen for this presentation refers to aquaculture as a venture, because aquaculture as it is being discussed at this conference, does fit the dictionary definition of venture as a speculative business enterprise. The dictionary also describes venture as an undertaking involving chance, risk, or danger.

The subject of risk has different meanings for different people. The fish culturist thinks of risk in terms of survival rates, while the lender thinks of risk in terms of profit and loss. In an aquaculture venture, financial loss is the probable result of poor fish survival; and since I represent the lender, I will discuss risk from a financial point of view.

It will come as no surprise to you that lenders are concerned about the risks to which they expose their capital. This is because no lending program can be sustained without a successful repayment program. And the success of any repayment program is a direct consequence of the risks associated with any business venture.

The quantification, evaluation, and analysis of risk is of great importance to the commercial lender, and a great amount of effort is expended on loan applications in an attempt to develop reliable risk data. The past history of commercial lending has served to demonstrate that this activity should be a vital part of the lending proc-

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ess. However, no amount of data can eliminate the final requirement for determination between acceptable and unacceptable risk. This is the judgment call that constitutes the essence of the credit decision.

The ability of any person or persons to exercise sound judgment in regard to risk is a function not only of objective analysis of available data, but also the subjective evaluation of the assumptions, components, and circumstances of each business proposal. Given these judgmental requirements, the lending institution and the people who conduct the business must follow certain general guidelines in the conduct of the lending activities.

The key word in this regard is "general" because experience has produced some principles that have proven critical to the successful evaluation and management of risk. In CFAB's brief seven-year existence, these principles have been given new significance as they have been applied, or in some unfortunate cases not applied, in the Alaska seafood and timber industries.

CREDIT CONSIDERATIONS

With this introductory discussion in mind, I will discuss these general principles by expressing them in terms of the factors or elements which a lender must look for in evaluating the payback potential of a loan request. The best way that I know to do this is to discuss the type of data and the guidelines that enter into a credit decision.

As lenders, we know from experience that the payback potential of a loan request is good if the following factors exist:

1. The business applying for the loan has a long and successful history of profitable operation.
2. The owner has a substantial investment in the business and, because of the money that he has invested, is vitally concerned about the conduct of the business.
3. The existing debt of the business is not excessive in relation to assets and cash flow.
4. The proposed debt of the business, or increase in debt, can reasonably be expected to be paid back from existing cash flow based on past experience.
5. The applicants possess the financial resources to survive cash flow failures due to production, management, or market problems.
6. The business has a viable financial plan for the future.
7. The business has the management abilities to carry out the plan.

All credit requests will, to some degree, be evaluated in terms of the foregoing. In addition to this, risk factors relative to production and marketing activities of each business venture must be evaluated.

PRODUCTION RISK

Production risk factors specific to a mariculture business are also faced by both the fishing and farming industries. Mariculture, like farming, runs the risk of crop failure, or, in the case of fishing, run failure. But mariculture operators, unlike farmers, have very limited experience with the successful culture of aquatic organisms. Mariculture is, in essence, an untested technology.

Please do not misunderstand my meaning here. I understand that there are successful mariculture businesses in the world. However, the production aspects of mariculture must be considered untested in Alaska, because the success of a mariculture project is dependent upon local environmental conditions and the specific biological requirements of animals and plants within that local environment.

It is important to emphasize here that the productivity risk associated with mariculture is not only a function of the performance and abilities of the owners and operators, but, more important, it is a function of the technology itself. In other words, the question of human ability is secondary to the question of biological viability.

The question of human ability in regard to credit is more germane to the subject of management than it is to production. And this includes not only those activities associated with product development and production, but also those associated with personnel management, financial planning, financial management, and marketing. When all of these activities are considered together, they describe aquaculture as a business activity.

Unfortunately, developing businesses, such as aquaculture, are not always created by people with outstanding business management skills. They, therefore, have a history of being undercapitalized in terms of financial resources and understaffed in terms of human resources. Such ventures are usually created by entrepreneurs who are committed to the development of new products or services. Their very existence is dependent on the creative abilities and drive of visionaries. The question of management capability, or lack thereof, and its risk is therefore a subject of great importance to the prospective lender.

MARKET RISK

The market risk for any new venture is great. The market risk for a perishable product is even greater. No amount of planning and analysis can guarantee market success. The success of an aquaculture venture is inextricably tied to the ability of the product produced to compete in the marketplace. Marketing is, therefore, a major risk factor in any new business venture.

CONCLUSION

Given the foregoing analysis, it is apparent that the critical challenge facing CFAB, or any lender, is one of balancing the survival requirement of profit with the reality of risk. Or, to put it another way, the lender must make a determination between acceptable and unacceptable risk.

Unacceptable risk is the risk for which the lender cannot create defenses against loss. It is a fact of life that lenders cannot charge their customers, that is, their performing customers, a rate of interest sufficiently high enough to compensate for losses due to nonpayment. Given this reality, the commercial lender has the obligation to exercise prudent and conservative judgment in the conduct of his activities, because neither the lender nor the performing borrowers, who make the lender viable, can afford to pay for the failure of the unsuccessful borrowers. Please remember, the lender is in business to make a profit; without profit, he cannot exist.

For the potential aquaculture entrepreneur, the challenge is to convince the lender, or potential investors, that biological viability exists and that it can be transformed into economic profits. If an applicant does have this capability, financing, such as that provided by CFAB, is a realistic possibility.

QUESTIONS AND ANSWERS

Q. Why is it that if you have, for example, an oyster farm, CFAB won't lend money on it?

A. If you can convince CFAB that you have the financial resources to manage it in a profitable way and develop the profits, then CFAB would certainly be interested in looking at it.

Q. I've called CFAB at least three or four times, and everybody else in the state, trying to find money. I already have a successful aquaculture business, and another one dealing with oysters, and everybody I've talked to has said flat no, they don't have any programs for mariculture and they don't know anybody who does. It doesn't seem like there is any, as far as I can see. I have a business plan and proven capabilities in the field, and I can't even get in the front door.

A. I'll guarantee you right now you can get in the front door at CFAB. I'm not going to tell you that the answer will always be yes. There have been some changes in the past two or three years at CFAB, and if you have a proposal and plan, we will take a look at it.

Q. It sounds like you don't finance any start-up operations. Is that true?

A. That's true. There has been some confusion about CFAB's role. Early on, CFAB did finance some start-up operations, and we're paying dearly now for not having exercised proper judgment. Therefore, the policy of CFAB is that in order to make sure that our program continues, we cannot assume that kind of risk now. Again, there are ways to protect against that kind of risk by other resources. One way that I've recently learned about is insurance against losses. Another is guaranteeing repayment of the loan from sources other than the actual start-up venture. But, in terms of making the loan for a new aquaculture venture, it is difficult to convince a lender that it's a prudent thing to do.

Q. Has the CFAB board discussed putting a percentage of your annual lending capital aside for potential mariculture or aquaculture projects?

A. No, they have not.

Q. Do you intend to ask the board about that?

A. We really do not operate that way. We look at every proposal and decide whether we would earn interest on such a loan. I suspect that our board of directors would not be interested in allocating a certain percentage of our resources to specific businesses. But I can't speak for them.

Again, I'd like to emphasize that there's confusion about CFAB itself. Some people see CFAB as a development bank or venture capital operation. The way CFAB is structured, it cannot operate that way, or it will cease to exist.

I have a few more comments I'd like to make to you in the time remaining to me. With the full knowledge that I may be alienating Miss Garza, our chair, I'd like to introduce an unscheduled speaker who I think may have something to offer to you. [Mr. Hall at this point removed his coat, tie, and dress shirt, and wearing a t-shirt with a large fish on it, spoke as follows.]

ALASKAN AQUACULTURE REFLECTIONS

Good afternoon, my name is Bill Hall. I've been a commercial salmon fisherman for the past 26 years. I've also been a founding director of the Prince William Sound Aquaculture Corporation, its first secretary-treasurer, and, for a short time, its business manager. (I'm sort of looking out of the corner of my eye to see if there is one of those hooks to drag me off the stage.)

Before I begin, I would like to invite you to consider for a moment those who have made past contributions to the development of aquaculture in Alaska who are not here today. My limited experience in this activity does not qualify me to list all the people who have made such contributions, but there are two people with whom I have had the privilege to work who are very special to me.

Wally Noerenburg was a biologist. He was a commissioner of the Alaska Department of Fish and Game and an intelligent force behind the development of private nonprofit aquaculture in Alaska. Wally is no longer with us, but his ability to see the good in people and to work with people for the common good should serve to guide all of us in our endeavors.

Armin Koernig is not able to be with us today. Armin is a fisherman, and he was also the driving force behind the development of private nonprofit aquaculture in Alaska. Armin's ability to forge his vision into a reality should serve to remind us all here today that cooperative effort can achieve undreamed-of successes. The reason Armin is not with us here today is that he is with his wife, who is receiving treatment for cancer at present.

I'd like to ask you to pause with me just for a moment of silence in memory of Wally, and in the hope that Mrs. Koernig will return to health in the near future. Thank you.

In 1975, I got a small grant from the Alaska Humanities Forum for the purpose of organizing and hosting the state's first aquaculture conference, which was held in Cordova. On the basis of that experience and subsequent experience with the development of private nonprofit aquaculture, I would like to offer for your consideration some reflections that may serve to enlarge your present perspective on aquaculture in Alaska and enhance the value of this conference to you.

The first aquaculture conference was held in Cordova by the Prince William Sound Aquaculture Corporation with a grant from the Alaska Humanities Forum. The grant was for $5,000, and we returned the unused portion to the Forum, which at that time was unheard of.

We required that the conference address not only the biological dimensions of aquaculture, but also the social and economic dimensions. Also, the first conference was part of the broader effort to accomplish the specific purpose of producing more pink salmon for the purse seine fishermen of Prince William Sound.

Those of us who were involved in that effort were faced with a double challenge. To begin with, we needed to educate ourselves and the fishermen of the Prince William Sound area about the opportunities for salmon aquaculture. We also faced the problem of designing and implementing a political strategy for the purpose of creating a new public policy which would serve to define a new relationship between the public and private sectors in regard to aquaculture development.

We did not realize at the time that we were engaged in the process of change that few of us understood. We did understand the change in the narrow sense, that it was motivated by the need of an organized group of fishermen for more pink salmon. That need provided the motivation and the justification necessary for the creation of a public nonprofit aquaculture program that has produced impressive successes. Unfortunately, the Sheffield administration was convinced that the world market did not need more pink salmon. The program consequently lost its momentum and its source of funding. Confusion has been the result of that decision and disagreements over policy and purpose have crippled the program since. The situation has not improved.

Last year, with the introduction of legislation that would authorize and facilitate the expansion of aquaculture with new species and new methods and for new purposes, economic diversification for profit, the disagreements have increased both in dimension and in the number of people involved. Many fishermen now see aquaculture as a threat, and when people are threatened by change, they tend to act in a negative manner.

The situation must be changed. It must be changed because we all stand to lose as a result of adversarial confrontation. On the other hand, the common good can only be advanced by cooperative effort that serves to define the means by which aquaculture can serve the needs of all Alaskans.

As a fisherman and an advocate of private nonprofit aquaculture in Alaska, I become very uncomfortable when I hear opposition to salmon farming expressed as biological arguments, which could be used against the private nonprofit salmon ocean ranching program.

Last year, in Prince William Sound, of the fish that were caught, it is estimated that over 70 percent of the pink salmon were produced by the hatcheries in the area. As a fisherman who has benefited from such aquaculture success, I am uncomfortable with the controversy that has the potential to erode support from existing programs and, at the same time, preclude consideration of future opportunities.

I'm also uncomfortable with the organized and calculated effort to create a system of private-for-profit aquaculture apart from and outside of the existing Alaska seafood industry. This effort can only serve to increase the potential for conflict and disagreement.

Aquaculture and commercial fishing have a common purpose, which is the production of food for profit. The marketplace of the future will require and reward only the producers who can provide a product mix that responds to the public needs. This will require an integrated and cooperative effort between the commercial fishing industry and the emerging aquaculture industry.

In conclusion, I would like to propose that the participants of this conference adopt as their theme the following statement of purpose: "The Fourth Alaska Aquaculture Conference is dedicated to the purpose of bringing Alaskans together in a cooperative and creative effort to define a means by which aquaculture, in all of its present and potential manifestations, can be utilized for the benefit of all."

INVESTMENT IN AQUACULTURE

Jim Fralick
Ministry of Agriculture and Fisheries
Victoria, British Columbia

The number of farms in British Columbia has increased considerably, for salmon, between 1984 and 1987. The interesting thing is that British Columbia has had aquaculture for years. The Pacific oyster was brought to British Columbia in 1912 from Japan. Oysters were brought from the East Coast around 1923, and the industry has been going in British Columbia ever since. Trout culture was in operation in the mid-1950s. Salmon aquaculture was actually started in the early 1970s with the first product being sold about 1974.

The federal government established a demonstration farm in the early 1970s, as well. We could have competed with the Norwegians right from the start, and the Norwegians would have been coming to us. For some reason, we didn't.

In 1984, we had 10 farms. The industry has increased somewhat during the years 1984 to 1987, but still not appreciably. In 1984 and 1985 the total gross sales was about $2 million. In 1986 it went to about $6 million, which was largely the result of salmon sales. And we anticipate that in 1989 or so it should be over $100 million to $150 million. We have a total gross sales from fisheries of about half a billion dollars.

BRITISH COLUMBIA INDUSTRY

Investment in British Columbia aquaculture is approximately $150 million to $200 million. Virtually all of this investment has been made in salmon aquaculture during the past three years. To put this in perspective a recent federal-provincial study identified the following funding requirements for a typical salmon farm operating in British Columbia:

1. 100 tons per year production
2. Capital costs of $200,000 (50 percent for cages and pens)
3. Annual operating cost of $450,000 (45 percent for feed)

The average proposed farm in British Columbia is at least twice this production output per annum.

There are two different yet extremely important components to the development of financing for aquaculture. The first is the creation of a climate for investment. The second is the actual mechanism for investment.

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CLIMATE FOR INVESTMENT

One must realize that the creation of a good climate for investment in aquaculture is normally beyond the control of the private investor. Thus, supportive activities are most likely undertaken by, and are the responsibility of, government and private sector elements who are proponents of aquaculture. It is essential to keep in mind that it is the investor who is the ultimate consumer in aquaculture financing. Aquaculture must be marketed to the financier just as other products are and the financier's preferences must be considered. They cannot, however, be catered to totally without regard for the rest of society and so it may be necessary to compromise.

What is it that the financier is looking for when seeking a new location to develop aquaculture business?

Physical Inputs

The basic elements must be available to meet the physical and biological needs for the culture of the species in question. This means optimum or at least acceptable water temperatures, salinities, currents, exposure to waves, and in some cases substrates. In addition, there must be access to stocks of the organism to be cultured and supplies of food to sustain growth. A locale must have these basic attributes before it can even be considered for aquaculture although deficiencies can be overcome through engineering. British Columbia and Alaska are highly desirable areas for the culture of many finfish and shellfish.

Infrastructure

Next, we should look at what is available in the way of infrastructure to support commercial aquaculture. It is essential that the aquaculturist have a reliable means of supplying the farm with feed for the stock and other goods, as well as efficient transportation to the marketplace. This latter aspect is of grave importance in aquaculture because one of the primary attributes of aquaculture is the high quality and freshness of the product. However, good transportation systems also often coincide with a stable labor market. Much of the training that is needed for aquaculture can only be obtained through hands-on experience on the farm which is built up over a number of years. This farm experience cannot be acquired by transient workers, and long-term employees are unlikely to be available in an area unless they have ready access to their families and homes. Such access is dependent upon good transportation whether by air, road, or boat.

Radio or telephone communications are required in aquaculture to a much greater extent than is realized before establishing a farm. Daily communications with the head office, suppliers, and the marketplace is common. An investor who cannot have ready communication with his investment when he perceives a potential problem is usually uneasy.

Disease diagnostic and health care of the farm stock, education, and extension services related to stock husbandry and farm management are necessary if the business is to be profitable. Most individual investors or firms cannot afford to provide the high level of technical expertise and equipment that is required in these fields. This is particularly true because the cultivation of many species is so new that standard levels of operation and performance have not been set. Even the most elementary research and development is lacking with the culture of most species, whether finfish or shellfish. The transfer of technology from other locations where success has been achieved often leads to a new set of problems which require specific answers. For example, mussel culture appears to be very successful in eastern Canada and across our border in the state of Washington, but the few farmers who have tried mussel culture in British Columbia find that mortalities during the summer make their farm's profitability tenuous. Similarly, due to concerns for human health, areas of the coast are closed because of paralytic shellfish poisoning. The problem is that these closures cover a far more extensive area than is necessary because there is insufficient capability for government to monitor all of the stocks and there is a desire to err on the side of safety. The result is that farmed shellfish stocks which have no trace of toxin are kept from the market shelf because there is no one to inspect and declare them safe.

Markets

Certainly the accountant's adage that a deal isn't made until the check is in the bank is true. But, unless the product can be sold in the marketplace there will be no possibility of a check. Most financiers already know that a product is acceptable to the marketplace and have an idea of the price before making a decision to invest in aquaculture. The question is whether this can be done profitably. Today, seafood markets are strong but soon the market will become very competitive and the importance of lowering costs of production and transportation to market will be realized. The proximity to the marketplace through reliable, low cost transportation will become paramount. The proximity of British Columbia and Alaska to the Pacific Rim markets puts them in a strong position.

Political Supports

The investor, particularly the overseas investor, is usually very concerned about the attitude and role of government as it relates to the business of aquaculture. A supportive yet laissez faire role seems to be the most desirable. By supportive, I mean that government should have a vision of how aquaculture will fit into the social fabric of the community and be committed to helping aquaculture to develop within that vision even in the face of adversity. This also means establishing policies for development and providing stability by making only essential changes to those policies as required. A year ago British Columbia went through a major process in this regard. Salmon farming appeared to be expanding so rapidly that it would soon be out of control, and many private citizens as well as government personnel became concerned. The industry was composed of 30 farm sites during the summer of 1985 but by November of 1986 there were 700 applications to set up new farms. Although many people were encouraged by the prospects for the establishment of a new growth sector in our economy, there was also concern that development would not be rational and that there would be grave implications for the fishing sector of the British Columbia economy.

Therefore, the Premier announced the creation of a commission of inquiry. The inquiry was intense, providing 52 specific recommendations. The primary areas of evaluation were:

1. The impact on commercial fishery operations, markets, and localized production-related facilities.
2. Potential environmental impacts and effect on wild stocks.
3. Impact and involvement of local government and interest groups.
4. Government approval and monitoring procedures.

A special government steering committee composed of senior members from all the provincial agencies worked closely with industry to implement the recommendations quickly. Today, less than half a dozen of the recommendations have yet to be implemented fully. The moratorium on issuing new farm sites, which was imposed at the time of the inquiry, has now been lifted in stages depending upon the level of conflict and as studies and public meetings have been completed. Investor confidence appeared to wane during the moratorium and in the wake of the policy changes that followed. However, confidence has returned, largely as a result of immediate responses to the recommendations and government setting its course of action.

It is particularly interesting that although there were over 700 applications to initiate farms a year ago, a recent government survey indicated only 129 sites were in operation during the summer of 1987.

Constructive Regulations

Regulation of an industry is essential to ensure that standards of conduct and operation are established and obeyed. In this way stability can be achieved, conflicting resource users are considered, product quality is assured, and the interests of society are protected. The regulations must, however, achieve a useful purpose. Otherwise the ability to conduct the aquaculture business will be impaired and investors will go elsewhere or to other industries. Without rational regulations this industry cannot develop and with poor regulations it will likely falter.

MECHANISMS FOR INVESTMENTS

Once the climate for investment has been established and the investor feels comfortable, the investor must choose a mechanism to inject his money into the business. This is the point at which most people think the investment decision begins. It is, in fact, the point at which the investor begins to gain control over the investment. This control is exercised through the investment mechanism which the investor chooses to undertake. Aquaculture as a business is risky and the investor wants to minimize his exposure to that risk while simultaneously gaining from the profitability. That profitability may be several years away given the time it takes to grow most aquaculture organisms to marketable size.

I will now try to give you some indication of how the $150 million to $200 million of investment in British Columbia has been obtained.

Equity Financing

Equity financing may be obtained through private placements or publicly through the stock market.

Private funding is almost without exception the means used to initiate an aquaculture business in British Columbia. The owner puts up a sum of money in exchange for ownership of a portion of the business. As additional funds are required, more partners are taken into the business and the original owner's share of the business declines, even though the overall equity in the business has increased. This form of investment gives the owners extensive control over the activities of the business.

The stock market is another mechanism for obtaining funds. Seven aquaculture enterprises have chosen to list their companies on the Vancouver Stock Exchange. The total amount of capital secured by the companies through this means has been approximately 40 million dollars. The problem with this method is that ownership is spread across a large number of people or organizations and it becomes necessary to market both the aquaculture products and the business itself—often resulting in conflicting objectives within the organization. The cost of going public can be in the range of $300,000 which in itself means that the goals of the business must include the development of a very large business. It is preferable to make the big errors when the costs are low, as when a company is small and learning from its mistakes. Stockholders, on the other hand, want dividends and higher stock prices which of necessity result from greater production.

Firms that must depend on issue of stock to finance expansion can run into difficulty when stock prices fall as they did recently. For example, the stock prices of the seven companies listed on the Vancouver Stock Exchange dropped an average of 33 percent between October 8 and October 30, 1987. Although this does not affect the investment already in the companies, it does limit their ability to use the stock market to care for the animals that were put into the sea during the summer.

Debt

Debt financing is another means to finance a business but it does require a great deal of confidence on the part of the lender. This is particularly true for new ventures which do not have a proven track record during their first few years of operation. In aquaculture neither the industry nor the individual business have such track records. The purchase of equipment would normally be undertaken through long-term debt while short-term operating capital would be obtained through commercial banks and similar institutions. However, because of the perception of risk, these lenders demand high interest rates and/or extensive security. Since most of the money will be tied up in equipment, which the lender views as having low resale opportunity, or in the farm stock, which is at risk to disease, predation, or escape, security is often requested in the form of a home or other property.

Trade Credit

In businesses where a large portion of the expenditures are made to a supplier such as the feed manufacturers in salmon farming, it is sometimes possible to obtain trade credit. In this way the farmer is able to defer the bulk of the feed bill until the fish have gone to market. Because the requirement for feed is enormous relative to other costs, trade credit is a potential means to reduce overall cash requirements. Several feed companies are looking at this option in British Columbia.

Some processing firms have offered product sales contracts to fish farmers. These contracts allow the farmer to obtain working capital in exchange for an agreement that he will sell his fish to the processing firm at a specified price. Although this offers the farmer funds, it reduces his ability to make choices, such as to whom he may sell and how he will conduct his business. Lenders often take an interest in the management of the farm once their funds are at risk.

Some equipment manufacturers have offered equipment in exchange for a direct or indirect equity position in the farm. Not only has this led to farmers buy ing equipment that they would not otherwise purchase, but it also means that some farmers have presumably lost control of the farm to the equipment manufacturer.

GOVERNMENT ASSISTANCE

Two years ago the government in British Columbia published a booklet on financial programs for aquaculture. Approximately ten programs were identified as available to aquaculture business. In reality, the number was much smaller—only two have been used to any extent. Even these two programs have provided only a fraction of the funding requirements of the industry. The first of these programs is established under the Agricultural Credit Act. It allows the applicant to obtain a loan of up to $300,000 for either capital purchases or operations. The interest rate is prime plus one and the bank is guaranteed payment on defaults up to 25 percent of its portfolio. However, this is still considered too risky by most banks and they either will not process the loan application or require additional security from the farmer before doing so.

The result is that after the program was established in 1983, until the summer of 1987 only 14 applications had been forwarded for funding; of those, only 5 were drawn. Currently, there are two loans outstanding for a total of $340,000. Clearly, the program isn't working.

The second program is the Aquaculture Incentive Program which is the only aquaculture-specific loan available in British Columbia. It was established in 1985 and allows loans of up to $100,000 to be made for capital purchases only. The farmer must match the amount of the loan in making the purchase but does not have to make any repayment until years three to five when the loan is retired. It is interest-free.

Fifty-six loans have been made under the program for a total of $3.8 million. This is a very small fraction of the funding needed by aquaculturists and there is no indication that the program will be extended beyond its five-year term.

SUMMARY

In closing, I would like to emphasize that aquaculture has a great potential for economic development in areas like British Columbia and Alaska but that it is a new and not well understood industry. This lack of understanding is not only in the production process but also in the realm of public perception. Alaska is taking a rational approach to establishing aquaculture by reviewing its implications and developing a strategy for incorporating aquaculture into the socioeconomic fabric of the state. It is important to realize that investors are looking for a supportive and stable political climate in which to develop aquaculture. If you are serious about aquaculture then you must consider the viewpoint of the investor and take steps to meet his needs, while considering other aspects of society. Currently, funding is the single most limiting factor to the growth of aquaculture in North America.

QUESTIONS AND ANSWERS

Q. How can the political questions involved in aquaculture be addressed, and how long will that take?

A. I don't want to purport to you that British Columbia has done everything perfectly. I think we've done things right, but not necessarily perfectly.

We looked to Norway to see what they had done. We could have developed in British Columbia (and Washington as well) as quickly as Norway did. In Norway, on the other hand, the government had a very strong hand in it. They limited the size of the farms because they wanted the socioeconomic aspect of it to be a certain way.

In British Columbia, and in the rest of North America, we want something more private-enterprise motivated. And in the long run, what we're going to find is that when we do get going, we're going to be as competitive, or more competitive, as those other countries.

It is important for Alaska to communicate within the state, with the sectors that are here, and to decide what they think aquaculture can do and how it can fit without causing too much problem and too much dislocation. That means a certain degree of compromise. You don't have to lay out a five-year plan. You have to develop a vision, and the government has to communicate that vision to the investors so that they know where you're going. You know there are going to be some problems, because unforeseen problems are always happening in aquaculture, but you have to plan to work together to resolve them. When you come out of the moratorium, you should have a direction and be prepared to move in that direction.

Q. How did British Columbia resolve the conflict between commercial fishermen and aquaculture? I know that the British Columbia fisherman have a strong lobby, and there must have been some conflict.

A. It is not completely resolved. On the other hand, we're not getting the complaints that we were. In one area where there is a lot of fishing going on, we declared a moratorium; then we had public meetings, and consulted the fishermen who were operating there to find out what areas were absolutely essential for tying up. If a fisherman sets his net in a small bay and then drifts into a fish farm, that is a real physical problem. We talked to them about setting things up so that there wouldn't be such problems.

Obviously, there was compromise. Some people aren't going to be totally happy with the solution, others are. But some of our problems were solved in that way.

Marketing was one of the earlier concerns that the fishermen had. We're finding that many of the processing firms who buy salmon from the fisherman are also buying from the aquaculturists. I think that's one of the important things to point out. Our fishing industry was picking up about 100,000 tons of the five species of salmon in the last couple of years, although the amount went down this past year. On the other hand, salmon aquaculture produced only 397 tons a year ago. Only about 3 percent of the 100,000 tons from commercial fishing actually goes into the fresh seafood market, whereas all of the aquaculture product is going into the fresh seafood market.

We're not always dealing with the same market for fishery and aquaculture seafood. For a while our assumption was that fishery and aquaculture seafood were going to very different segments of the market and didn't have any relationship or effect on one another. I'm not sure that's true anymore, at least not on the positive side. A couple of years ago when we had the strong fishery production, we didn't notice any real problems in the marketplace.

Last year, when the wild fishery production was down, salmon prices were extremely high, and the people were able to sell fish that we normally wouldn't want to sell into the market. But the consumer was very happy with it. There was nothing wrong with the product; it just wasn't a premium aquaculture product. So that leads us to believe that there is a marketing relationship with the two seafoods.

Q. What's the level of European investment in British Columbia aquaculture?

A. I don't know. We don't do any continuing surveys. I would say that it is relatively high, but I don't know how high.

Q. I was told that there is not as much conflict with the commercial fishermen as there is between the union and land-based operations.

A. I'm not aware of a problem with union workers. There has always been an problem, at least a perceived problem, between aquaculturists and fishermen, and between aquaculturists and the upland owners. There are some areas where people just don't want to see anything started, and it wouldn't matter what the operation would be, they just don't want to see it in the area. No matter what the aquaculturist does, he simply is not welcome. We have other areas where people actually want aquaculture, and want it badly. In fact, there are a couple of regional districts in British Columbia, one on the west coast of Vancouver Island, where consultants have been hired to put together a compendium of good sites.

In Washington state just about everything is developed. No matter where the aquaculturist goes, either there is some industrial development or there is some upland development that creates a problem.

In British Columbia and Alaska, there are some areas where development is minimal and the possibility exists that the people would be happy to see aquaculture come in.

PANEL DISCUSSION FOR MARICULTURE PERMITTING

Panel Members:
David Benton, Alaska Department of Fish and Game
Jeanne Hanson, U.S. Army Corps of Engineers
John Harmening, U.S. Forest Service
Dena Henkins, Alaska Department of Environmental Conservation
Diane Mayer, Moderator, Division of Governmental Coordination
Bob Palmer, Alaska Department of Natural Resources
Manny Soares, Alaska Department of Environmental Conservation

MS. MAYER: This discussion is limited to shellfish mariculture activities. Alaska legislation passed last year prohibited the permitting of finfish farms, although there is considerable interest in finfish farming.

Each of the permitting panelists represents an agency with authority for approving mariculture facilities on public lands in Alaska. As regulators, we see several aspects of acquiring approval for mariculture facilities. The first aspect, and perhaps the most complex, is siting of those facilities. Siting requires approval from five agencies, both state and federal. Our system brings the various agencies together so that the applicant has one single review for the siting of the facility.

The Division of Governmental Coordination (DGC) relies on the cooperation and expertise of the state's resource agencies: Alaska Department of Fish and Game (ADF&G), Department of Natural Resources (DNR), and Department of Environmental Conservation (DEC), to help the applicant identify what permits might be needed.

If a proposal is complex enough, the applicant should come in to talk about it with the key parties from the agencies. Once all the material has been submitted by the applicant, our division will set the schedule for the review by agencies. Then we receive comments from the agencies regarding their regulatory responsibilities. We also coordinate with the federal agencies.

Based on the comments received, we identify issues and then we provide a forum for the applicant and agencies to resolve problems. They may come out with a design change should that be necessary to meet stipulations. If the issues cannot be resolved, the system also provides a rapid elevation to the director.

There is a pamphlet available called *How to Apply for State Permits in Alaska's Coastal Zone*, which gives the schedule and time frames for applying for a permit.

MR. PALMER, DNR: Alaska obtained the tide and submerged lands at the time of statehood from the federal government, under the Submerged Lands Act. The state owns the tide and submerged lands from the line of mean high water (the average of all high tides) to the 3-mile boundary. All the sites suited for mariculture probably fall within that range.

We have available two methods of gaining the use of state tidelands. One is a land use permit and the other is a lease. Land use permits are temporary. Oyster growers use them because the growers are in an experimental phase-testing area, trying out new techniques, trying to get spat. There are no survey requirements or pricing requirements for the land use permit. There is just the filing fee and the $50 per acre use fee.

A lease requires a full-blown tidelands survey, which can run $2,000 to $4,000, depending on the location. That basically locks the permittee into that site, so if he wants to move out, he loses that money. I advise people to stay away from consideration of a lease when they are still experimenting. The tideland appraisal requires an appraiser to establish a value of the site. The appraisals are fair market values and are used to calculate annual lease fees. These are all up-front costs, which are risky. A land use permit does not have the land guarantee present in a lease, but it does allow a farmer to go into a mariculture project at a relatively low cost.

During the process of land use rights, one of the major concerns is user conflicts. Mariculture is just one use of tide and submerged lands. Presently we have large areas for log storage, log transfer, refuge harbors for

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fishing fleets, and recreation and tourism, as well as wilderness values that need to be protected. All these compete with mariculture for sites.

To evaluate an application, we put it through the agency review as well as a public review. We make adjacent landowners aware of it, and we put it in the newspapers. In 60 to 90 days we have all those comments and we can evaluate the cost vs. benefit of a specific project.

Documents are being produced now to help review conflicts. We will use the comprehensive coastal zone management plans, and we are presently developing three land plans that incorporate a lot of the tide and submerged lands. One is around Prince of Wales, one is Prince William Sound, and one is now being started for the Etolin Island area. These documents are useful in deciding land uses, both present and future, on state tide and submerged lands.

MR. HARMENING, Forest Service: The U.S. Forest Service feels that mariculture is a valid use of the national forest lands, where it is consistent with upland uses. We feel it is very important that we are contacted early in the permitting process and that coordination exists between all the agencies. A lot of problems occur when a person goes through only one permit process, for example tidelands, and then finds out that he has difficulty getting other necessary permits.

Permits are required for all commercial activities on national forest land. Several criteria must be satisfied before upland use can be permitted in a national forest. For commercial special uses: (1) There cannot be any private land available for that specific use. It must be demonstrated that the national forest land is the only land available for the particular commercial activity in that area. (2) The project must be in the public interest and consistent with regional land use plans.

The current U.S. Forest Service policy is that we will not issue any permanent special use permits. Mariculture is fairly new and it does tie up areas for a long time to the exclusion of other uses. A permanent use is defined as an exclusive right to that use for 10 to 30 years. We have been issuing special use permits for temporary uses that are renewable annually. Once a person can show that his project is viable, that he is making money, that he is a bona fide mariculturist, then we will consider issuing a more permanent permit. We realize that the lack of a permanent permit can be a problem for some of our applicants in obtaining loans.

The application process for a special use permit starts at the local district office. There are four forest service areas in Alaska: the Chugach forest, the Stikine forest area out of Petersburg, the Chatham area out of Sitka, and the Ketchikan area. Each of these forests has administrative units that are responsible for land management. At the district office we can tell you whether there are any conflicting uses in the area. We can discuss with you the permits that will be required from the other agencies. We can discuss what the land use management plan shows for that area. And if we have some problems, the applicant will find out early enough so another site can be chosen.

Few of the forest service areas are good for mariculture purposes and free of conflicts. As the industry grows, more and more conflicts will become apparent.

The original Tongass Land Use Management Plan was approved in 1979, and is currently being revised. The plan is revised every 10 years. Some of the new things that come along, such as mariculture, have to be addressed. I suggest to each one of you that you get involved in that process; respond to the announcements for public participation in the planning.

MS. MAYER: Having talked to the land managers regarding siting requirements, we now can go on to other regulators on siting issues.

MS. HANSON, Corps of Engineers: We have an application packet available. We have jurisdiction through Section 10 of the Rivers and Harbors Act of 1899 and Section 404 of the Clean Water Act. Under Section 10, any structures that are in or affecting navigable waters of the United States require a Department of the Army permit. Under Section 404, any work that involves the discharge of dredged or fill material into waters and/or wetlands of the United States requires a permit. Mariculture activity requires a permit under Section 10 and under 404, if any of the upland areas are to be filled.

At present we are working on a coordinated permit application so that once the permit process is started, the applicant won't have to go from one agency to the next trying to get the permit issued. We want to make it a more efficient process.

Presently the Department of the Army permit system involves a 30-day public notice period. Regulatory considerations include (but are not limited to) navigation, safety, esthetics, general environmental concerns, fish and wildlife values, water quality, and the welfare of the people.

There are certain requirements to complete an application. We need a site drawing, an overview, a cross section of your project, and a vicinity map. The vicinity maps have to be good enough so that somebody from Kalamazoo can read them.

Once we get a complete application we issue a public notice. During that time different agencies comment on the application; then we send the comments to the applicant. At that time the applicant can either rebut or work out any objection that may come in from other people who are interested in the area. At the end of this time, we go through the environmental section of the decision document. If we receive the proper certification from the state, we issue the permit.

MS. HENKINS, DEC: The Environmental Quality Division of DEC has two major involvements with shellfish mariculture. Perhaps the most important is that we have to certify the Corps of Engineers permit.

Section 401 of the Clean Water Act specifies that for any activity requiring a federal permit that involves discharge into U.S. waters, the state must certify that the water quality standards will be met. This is called a 401 certification or a Certificate of Reasonable Assurance. This certification decision is processed with the coastal zone consistency determination.

If the activity is found consistent, a 401 certification is issued within five days. If the activity is found inconsistent, a 401 certification is denied and the federal permit cannot be issued.

Our other major involvement with shellfish mariculture is the sewage disposal associated with a caretaker or residence cabin at the site. The department has to review plans for the sewage disposal system, which also includes gray water or wash water. It is important, particularly with shellfish culture, that the shellfish do not get close to sewage contaminated water. The standard that most commonly has to be met is a concentration of not more than 14 fecal coliform bacteria per 100 milliliters. If the system is the same as a single-family residence, the department rarely issues a waste disposal permit. We just review the plans. The department also does not issue waste disposal permits for shellfish rafts themselves.

MS. MAYER: Last year in the legislative session, Senate Bill 297 passed which became known as the finfish moratorium. Another aspect of that bill is that it expanded the shellfish farming program in the state.

MR. BENTON, ADF&G: There are changes that relate to both the siting and the stocking of shellfish farms. Senate Bill 297, in addition to placing a moratorium on finfish farming for a year, provided the Commissioner of Fish and Game with the authority to issue permits for spat collection for use by an established farm. This change has opened doors and cleared a path for expanded shellfish mariculture programs in Alaska.

Following the passage of the bill, ADF&G got together with the other state agencies and with the Department of Law to look at the best system for facilitating shellfish farming. The Coastal Zone Management Permit processing system that is already in place was used to devise a permit for ADF&G, which we called the Shellfish Farm Permit.

The permit gives the department a role in the biotechnical review of a shellfish farm. We look for four criteria in the plans submitted by the prospective grower. We want to know whether there will be adverse effects on fish and wildlife habitat and the natural stocks, particularly commercially important fish stocks. We look at the relationship of the proposed activity and other existing uses; we coordinate with DNR and the U.S. Forest Service when examining potential user conflicts. And we look at the potential for success of the proposal. We are not interested in whether somebody has the financial resources to initiate a project. We want to know whether the proposed activity, including the arrangement of the growing facility and the site, are going to be successful within a reasonable period. If two people apply for a choice site, we want to be able to determine who is more likely to be successful.

As these discussions indicate, there are several different kinds of permits. Obtaining a permit is a fairly confusing process. While drafting Senate Bill 297 we attempted to make the permitting process simpler for the shellfish farmer, to eliminate the running around to DEC, DNR, and ADF&G. We are now putting together the Shellfish Farmer's Application Packet. This packet will consist of one questionnaire to be completed for all permits needed from state agencies to site the project. That would include the DNR permits, DEC and water quality permits, and coastal consistency—everything needed to put the facility in the water and start it up.

The other role ADF&G is going to play is that we will have standards for transport permits. One of the roadblocks to any mariculture activity is acquiring, transporting, and holding brood stock. Previous to the bill passing there were no provisions for a prospective grower to get scallop spat or mussel seed from the wild. Bill 297 opened up that door. We reviewed the situation with the Department of Law and have revised our fish transport permit in order to accommodate shellfish farming. The original intent of the fish transport permit was for the protection of wild stocks from disease and genetic problems. We modified the regulations in order to make the permit applicable to the shellfish farmer with the goals to protect wild stocks and to make sure that there are no diseases or genetic problems.

MS. MAYER: Now I would like to change the setting. Let's assume it's a couple of years down the road and you're already sited and you are harvesting. There are requirements that need to be satisfied when harvesting and processing seafood.

MR. SOARES, DEC: The Department of Environmental Conservation and its Division of Environmental Health have the authority to regulate anyone harvesting or processing shellfish. Before any shellfish can be sold from a certain site, it is necessary for the state to initiate a shellfish site certification program. Within this program we have to meet the requirements that the Food and Drug Administration has set out under the National Shellfish Sanitation Program. Each state has to meet the Food and Drug Administration requirements in order to ship its shellfish interstate. Processors of shellfish are also under this program, and must meet the criteria. DEC tests samples and tests water quality in a given area. This testing must conform to the criteria established by the National Shellfish Sanitation Program.

Normally our section of the department is not contacted by the grower until one or two years down the line. This may present serious problems to the grower if he should run into a problem with water quality.

In many cases we receive copies of the Corps of Engineers' public notice concerning the application for a shellfish site. Mike Ostasz is our coordinator and he normally contacts the Corps to discuss the proposal. He wants to know what the grower intends to do on site, what shellfish species are to be grown, and the method of harvesting, processing, and shipping.

It can help tremendously if the prospective grower would contact us prior to making final site selection decisions. We can give the grower information on what to look for, e.g., types of pollution. The farmer then can pre-survey the area to assess it for acceptability.

Our certification of that site normally would not be done until the farmer is ready to harvest. Certification is time consuming and very costly and therefore we want to be sure everybody has obtained their DNR and other permits required for the site. It's possible to spend $2,000 on site certification.

For any new surveys our department requires transportation of personnel and samples from the site to the nearest commercial airport. For a remote site, we would fly the individual to the nearest commercial airport and the grower would transport that individual to his site and back to that airport.

This does put a burden on the growers, but we have been bearing the total cost up to this time. We have 55 new applications on file, and we are trying to determine their status. If you are one of the 55 that we have information about, you will be hearing from us through the mail explaining the nature of the certification process. If you have spat or are nearing the stage where you will have spat, and you will be harvesting within the next year, we request that you contact us as soon as possible because we want a six-month lead time to schedule surveys. Only a limited number of these surveys will be accomplished in this fiscal year. Right now we are requesting an additional position for spat surveys. But we will have to wait for the next fiscal year before we can do more than routine maintenance inspections. Each year we have to go back to the established farms for recertification.

QUESTIONS AND ANSWERS

Q. My question is for the DEC, Manny Soares. You're probably aware of the problems of **water testing** for bacteria. In Southeast Alaska we have quite a few private certified labs. What is to prevent us from using these private labs rather than sending the samples all the way up to Palmer within 24 hours?

MR. SOARES: The shellfish sanitation program does not prohibit that. We have set up a custom-designed delivery service with the postal service that guarantees delivery to Palmer. This is not to Anchorage and then Palmer, but it is directly to Palmer. Another practical thing to consider is the number of samples that we are running and the costs involved. We're pulling 15 water samples per day from one site as part of the certification process. The department will not cover the cost of sending these water samples to a private lab as opposed to sending them to our lab where we already have the personnel to run the samples. If a grower wanted to send them to a private lab, he would have to bear that cost, which is about $35 a sample.

Q. This question is for the DEC. For **testing shellfish**, with each shipment we have to send a pint of shucked meat to the office. Can we certify the site as with razor clam beaches? It's expensive on a weekly shipment basis to send off $25 worth of oysters each time. Would it be possible to certify a site for a month at a time?

MR. SOARES: We have certified the razor clam beaches for years. However, we have years of PSP (paralytic shellfish poisoning) and bacterial history on them. Many of the areas in Southeast have only recently been certified. We have no history on them and until we have established the required data base, we can't say that you won't have to submit the product.

Q. Would a tidelands lease guarantee exclusive ownership or **harvest rights** to animals introduced on the site?

MR. PALMER: We only permit species that are grown on rafts. We haven't started on bottom culture yet. Hunters and gatherers traditionally and legally have harvested from beach areas and we don't require permits for that. If someone came in with an application for bottom culture, I'm sure we would proceed with it, probably with a permanent lease. A permit does not give exclusive land rights; only a lease does. A permit allows a specific structure to be put on tide and submerged lands for a certain period of time. A lease would give land rights.

Q. Is the high pressure liquid chromatography (**HPLC**) method ready for testing for PSP, as a substitute for the mouse bioassay?

MR. SOARES: It's still in testing and has not received final approval.

Q. If the mariculture bill does pass, how much more will it cost the state to fund **regulations on shellfish**?

MS. MAYER: The Division of Governmental Coordination would have to add a person in the Anchorage and Juneau offices. We do not view the regulations of shellfish farming as a real spendy item. The regulatory system is in place and we would only have to absorb the additional number of growers. So two people certainly would cover it from our standpoint.

MR. PALMER: We based our DNR estimates on British Columbia's experience. Right now in Southeast we have three adjudicators (state land managers) and we have a case load of about 350. If we doubled that, we would have to double our capacity, add three more positions, and add travel expenses.

MR. BENTON: When the moratorium was being considered last year, ADF&G wanted about $40,000 to pick up our end of the bargain. If the numbers really increase we will need three additional people.

MS. HENKINS: DEC has not estimated additional cost for shellfish alone, but we would need more people.

MR. SOARES: My section of DEC would need one additional position in Southeast Alaska.

Q. What is the total time required to obtain the necessary permits? I am a little discouraged by what I have been hearing. What is being done to accelerate the permitting process?

MS. MAYER: The time required for pre-application is generally up to you. Once you get the applications filled out and get a complete packet to the bureaucrats, they will then be responsible for getting the papers through.

The state system schedules 34 days of review by the resource agencies. Depending on the comments received and the degree of controversy, the regional staff review of your proposal can go on out to day 50, and that is another 16 days. It may take that long to get a response from the interagency review that would result in a consistency finding by the Division of Governmental Coordination. State permits should follow that finding within five days. That would mean that within 55 days you should have your results.

The clock can be stopped if we find, in reviewing your application, that we need more information regarding the site. Sometimes a simple thing such as clarity of drawings causes delay. If we need something from you, either more or better descriptive material, that time would be up to you.

There is an exception to this—when an application for a lease is received. A lease normally is not issued unless you are actively productive in the area. An actual disposal of state land is not subject to the additional five-day limit and could take longer.

Thus, the consistency review requires 34 to 50 days. The consistency review decision and certification statement is then turned over to the Corps of Engineers.

MS. HANSON: As soon as we receive an aquaculture application at the Corps of Engineers, we put out the public notice (30 day period). Our public notice time runs concurrently with the state's review. Total processing time is 60 to 90 days from the time we receive the complete application.

At the end of the public notice period, we evaluate the comments received. If it looks like we will receive state certification, we send out a notice to you. If you agree with all the conditions and stipulations that may have been added to your Department of the Army permit, you sign off on it and return it to our office for validation. At this time there is a charge of $100 for a commercial venture. And once the state certification has been received from DGC and DEC, you will receive your validated Department of the Army permit.

If we don't receive state certification, the permit would be denied. If there is no reason given why the permit would be denied based solely on our requirements, it would be called a denial without prejudice.

So the total elapsed time is 60 to 90 days. Most of the permits have been getting out within 60 days lately.

MR. HARMENING: When the permit applications are received at the U.S. Forest Service, they are dealt with in the order received and each one of these permits requires an environmental analysis to determine the impact of the project. The way this procedure can be speeded up is for the applicants to participate in the environmental assessment by helping acquire the data or by helping finance the detailing of someone to the area.

A lot of the special use permit applications come in for other uses. I can't emphasize strongly enough that if you are anticipating going after a mariculture site permit to contact us early in the game.

MR. BENTON: Simplifying the state process is something that we did pay quite a bit of attention to this summer. We tried to put together a consolidated application packet that would make it a lot simpler for somebody who wants to start a shellfish farm. We hope to have the application packet finished when the ADF&G regulations are ready to go.

Q. What about the critical habitat areas like Kachemak Bay? I want to put a breakwater in to protect my rafts from two-legged predators, but according to the critical habitat regulations, I can't deny public access to my area. What's to stop a boat from dumping its bilges and poisoning everything I have? What can we do as mariculturists in these critical habitat areas to change legislation and protect ourselves?

MR. BENTON: These areas are of great concern to us. The problem is that the breakwater might affect circulation. I suggest that you talk to someone in the department to work out an alternative.

Q. In the lease program there is a clause that says "if an appraisal is required. . ." Who makes the determination if an appraisal is required?

MR. PALMER: Right now a formal appraisal is the only way we have of establishing a value. If you look in Alaska Statute 38.050.70 you will find that it says "shall be appraised by an approved appraiser." This involves a master appraisal institute (MAI) appraiser. In Southeast there are probably two qualified people to do this kind of work.

Q. Requiring an MAI appraiser eliminates the small businessman because of the cost.

MR. PALMER: I agree with you. However, legislative action would be required to change this requirement.

Q. In critical habitat areas, barriers to ingress and egress are prohibited. If I build a raft, I have automatically set up a barrier to ingress and egress. Has this been addressed?

MR. PALMER: The egress question is handled by the Southcentral Region. This access question is a problem for oyster rafts even in Southeast. There are stipulations put on permits that say that oyster growers cannot limit access around their facilities. It is true that pleasure boats could approach a farm site legally, come very close to the rafts, and possibly pollute the oysters. Legislative change or a policy change would be necessary to remedy the situation.

Q. There is an exclusive use provision built into lease agreements. How can exclusive use help us protect our sites?

MR. PALMER: Exclusive use applies to the land itself—tidelands and submerged lands. Navigable waters are involved. Navigable waters are those that are deep enough for a boat to travel. You may want to include barriers in your development plan to protect your investment within the boundaries of the lease. The construction of barriers (usually anchored booms) has to go through the review process.

MS. MAYER: I would like to make a few comments at this time. First, if someone has a permit he does not really have a land right, but a right to put a structure there. But with a lease, he has a right to the land. There is a different land status involved with a permit and a lease.

Second, if somebody establishes a farm site, can he tie up an entire bay? This is an issue involving lodges, float homes, or other commercial ventures. In the coastal program there is a standard regarding access. If somebody gets a permit for a commercial use, there still must be some access because these are public lands. With the growing interest in mariculture, we need to have some dialog about mariculture requirements. Perhaps there should be some restrictions against other users of that plot of ground for either safety or environmental health reasons, including waste discharging. We don't want to make it impossible for mariculturists to safely carry out their activity.

Third, when a specific problem is coming to a head, the consistency review process can be used. This would get all the agencies in on it. If you feel that an unreasonable conclusion is being reached in your case or that more policy should be developed to set a standard in the new industry, you might want to take the conclusions from the regional review level and elevate the findings to the director. You can use that elevation process to raise the issue that established policy does not apply to new industry. In getting the approvals for your business, you should feel that you have every protection available so that you can have a viable and productive business.

Q. Is there a simplified application or permitting process for subsistence mariculture? Not diving, but setting up an oyster raft for subsistence.

MS. MAYER: If you are going to use public land and if you are going to place structures in the water, you're going to have to go through the permitting process. It's not the commercial nature of it; it's the structure.

Q. So if we just wanted to put a couple buoys out with a few lines, we'd have to go through this whole permitting process?

MS. MAYER: There are some smaller-than-a-breadbox regulations. There are ways that you can speed it up. There have been some permits granted for small operations which indicate that nobody cares about them. The applicant still has to present a design for the permit.

MS. HANSON: The Corps of Engineers has certain procedures that address projects that are smaller than a breadbox. There are nationwide permits that have been already approved. You should contact us; maybe yours would be pre-approved. These are only for individuals, for example, a subsistence raft.

Q. Would you clarify what is necessary for growing seaweed?

MR. PALMER: As far as land use goes, a seaweed grower is occupying certain areas of tide and submerged lands and would come under the same category as a raft. You would occupy public land and exclude others from using it, so you would need a formal permit and to reimburse the public for displacement. You would go through the same procedure as for an oyster raft.

Q. Are performance requirements included in your permits?

MR. PALMER: As far as the land use permits are concerned, we are starting to ask people what they have done in the last couple of years when they come in for a renewal. In our renewal letters, we're asking what has been done. We have 25 or 26 permitted sites for oysters in Southeast, and I don't believe half of them are producing or even have structures in place. So we're going to require the permittees to start putting their operation in or we will open up the land to somebody else.

MR. HARMENING: The U.S. Forest Service does not have any performance standards, per se, in the permits right now. However, so far we have been involved mostly with minimal facilities. These permits are only on a temporary or annual basis.

After three or four years, a farmer would have to show us that he needs additional facilities on the shore and that he has a valid business proposal included in a special use permit. Most stipulations in our permits relate to performance on land facilities.

MS. HANSON: A Department of the Army permit is normally issued for three years. But you can come in before the end of that time and request a time extension. You may or may not have to go through the review process, depending upon the laws in effect at that time.

Q. It appears that the Corps of Engineers is the only agency that has a performance requirement.

MR. BENTON: Regarding shellfish farming permits, ADF&G will ask for an annual report from the farmer. This has a couple of purposes. We would like to build up a body of data regarding the environmental conditions that lead to a successful farm. So we may ask the farmer to help us out by providing this information.

We also want to look at production. We want to know, for example, what kind of spat is being used at various locations.

MR. HARMENING: I have a few general comments concerning the administration of forest service lands. One matter is that if an area becomes very popular and has several mariculture proposals, the area would probably go out on prospectus and there would be a call for bids. In the future larger operations will require more shore facilities.

The other matter is the franchise. A franchise involves the exclusive use of land; it ties up a specific piece of land. Generally the public may be able to navigate around the commercial project using the franchise to adjacent areas. But we all know that if the project is in a small bay, quite often the physical presence of a commercial operation is a deterrent to people using the area.

Also, any type of onshore facility keeps people out to an even greater extent. Before we consider an onshore facility, a strong need must be demonstrated to us, and we require an environmental analysis or environmental impact statement if the area is greater than a specific size. We carefully scrutinize the purpose of the applicants because of the large number of permits that come through our office. It's best to inform everyone of this review process. If you are serious about doing mariculture, we want to help you.

Q. Many people who are interested in mariculture want to live close to their areas of production. Would the U.S. Forest Service permit them to use **timber** on that land for building a raft, a dock, or some kind of shoreside facilities?

MR. HARMENING: Depending on your location, there's a possibility that you could purchase the timber at the site. We can have small district ranger sales for that type of use. When you get your permit, you should discuss it with us. There would be some restrictions as to where you can harvest the trees, how far back they are, and how you pull them out. Each area has its own set of restrictions on the sales.

Q. I can see that a great deal of thought has gone into this program. It is very educational and very encouraging to be involved in mariculture. My question is if somebody has a special use permit for a short period of time and then somebody else comes in and asks for a lease in that same area, what **protection** does the first guy have?

MR. PALMER: Legally there is not much protection. It would fall upon an adjudicator in the DNR to decide whether the permit holder has put forth a good faith effort. We can negotiate a lease up to 10 years in duration. We are pushing for a policy that will allow us to negotiate the lease directly with those who have proven up a site and have started production. However, right now a protection gap does exist.

Q. My concern is that these small operations should support the people who are living in the area. My folks started a farm on Kruzof Island and they applied for a lease after 10 or 15 years of hard work. At that time the logging industry came through and made it hard for my folks to obtain the lease, and they were squeezed out. I would like the farmers to be aware of this kind of thing before they get too much invested. It would be nice if they could be guaranteed some rights.

Q. Representatives of DNR and ADF&G have pointed out several **statutory ambiguities**. They are trying to develop regulations, but obviously there are some things that still need to be addressed legislatively. What I'm wondering is if ADF&G and DNR are actively proposing solutions to these ambiguities, or whether they are passively waiting for these things to be cleared up by the legislature or by constituents pressuring legislators.

MR. BENTON: Since the legislature went home last spring, we have put together a working group with representatives from DEC, DNR, ADF&G, Commerce, Governmental Coordination, and Labor. We have implemented the shellfish regulations, and we are putting together a series of informational items for the commissioners and for the public and legislature that will address the mariculture issues. We're also looking at how other parts of the world are dealing with those issues. There has been a lot of debate, especially about finfish. We will be looking at all the options and out of that will come recommendations to address ambiguities.

MR. PALMER: The DNR is preparing proposals for the legislature. I would encourage those who are having problems to bring them to the attention of our office and the legislators. Quite often constituents carry a lot of weight with the legislators.

MS. MAYER: The question of making changes is a good one. If the departments have a question, the place to go is the Department of Law. If there is no answer, it is time to get legislation moving. Identifying where those holes are comes with experience. When you see them, you should report to the appropriate agency.

Q. It seems to me that the departments collect all the information from the applicants and know where the statutory problems are. So the onus would be on them to propose statutory changes to the legislature. An individual constituent communicating with one legislator is not nearly as effective as a department with a lot of data and more general legislative solutions in mind.

Q. A given area in Southeast Alaska has a limited number of sites that might be appropriate for mariculture. Five applicants might be good, fifteen would be crowded, and fifty would be disastrous for protecting public uses and values. This overcrowding occurred in our fisheries, and limited entry is the outcome. Is the **cumulative impact** problem being debated by this group, and if so, what solutions are they looking at?

MS. MAYER: Cumulative impact is a most difficult problem to project. The issue is certainly one that has been articulated in the legislative debate. There are several options. One is to keep issuing permits until we run into the situation. Fisheries went to limited entry. The oil companies call for nominations; once they have seen the nominations they decide where would be an appropriate place for an oil lease to occur. Other models will be created, because this is an issue we all are concerned about.

Q. If we assume that there are limited sites and there is a lot of interest in applying for sites, it is likely that initial applicants will be people who are in the information mainstream. It's possible that sites could be tied up quickly before people in Alaska's coastal communities or villages take a stab at a mariculture venture. Have you thought about giving **preference rights** to the occupants of coastal villages—protecting areas adjacent to communities so they can develop mariculture sites?

MR. PALMER: The only preference right we have for land use is the adjacent upland owners. We can negotiate directly with them for certain purposes. Some communities have rights to the tidelands in and around their communities. Sitka, Petersburg, and Wrangell all have such rights, but these are cities. Farmers would not want shellfish sites to be near communities because of pollution problems. Other than that, we can't even keep foreign applicants from coming in legally. There is no preference in existence now especially for Alaskans or people living in the community.

Q. A lot of people are concerned about floating structures and the problems of dealing with them. How does the Corps of Engineers deal with permits for **submerged structures**?

MS. HANSON: The Corps of Engineers' concern with a submerged structure would be the same as with a structure that is floating. We want to protect navigability under Section 10 of the Rivers and Harbors Act. We would look to the Coast Guard if the submerged structure were in coastal waters. The laws are there to protect navigation, safety, and public access.

HOW TO CHOOSE A LAND SURVEYOR

Rick G. Braun
Petersburg, Alaska

This report is a response to a request for information about services offered by registered land surveyors, how a land surveyor could assist a person in aquaculture site preparation, and how to choose a land surveyor.

Land surveyors are experienced in gathering and presenting geographic information and are trained to measure various parameters of geography. During aquaculture site selection and preparation, a land surveyor can assist the aquaculturist in the following ways:

1. Researching existing geographic information. There is a great deal of valuable information available at federal, state, and local agencies that the surveyor can assist in finding.
2. Preparing Corps of Engineers, Department of the Army permit applications. All structures built or operations conducted within the intertidal zone, in navigable waters or on wetlands require a Corps permit. Land surveyors can gather and present all the information required by the Corps. This information may include topographic and hydrographic surveying and mapping to determine upland and bottom contours.
3. Alaska Department of Natural Resources (DNR), Division of Lands will require a tidelands lease survey for permanent aquaculture operations. The state of Alaska owns all tidelands below the mean high water line. DNR requires the applicant to secure the services of a registered Alaska land surveyor to perform this survey. The surveyor will monument the corners of the lease parcel and prepare a plat according to DNR's survey instructions.
4. The aquaculturist will be required to submit other permit applications to the Department of Environmental Conservation and Department of Fish and Game. The land surveyor usually can offer assistance and advice in preparing these applications.

It is best to choose a surveyor who operates near the aquaculture site under consideration. A local surveyor will more likely be knowledgeable about the area and may have surveyed near the site. The surveyor should be experienced in performing Alaska tidelands surveys or Alaska state land surveys. Consult the yellow pages, talk to city or borough officials and local bankers and realtors to find names of reputable surveyors in the area.

Before engaging a surveyor to perform the tidelands lease survey, the applicant should wait for DNR's "decision to lease." After the "decision to lease" has been made, DNR will request the name and address of your surveyor. Survey instructions will be sent directly to the surveyor. All survey work must be performed by the surveyor and the survey should not commence until the instructions have been received.

It is advisable to ask the surveyor for a proposal before the work begins. The proposal should outline the work to be done and an estimate of costs, expenses, and date of completion. Costs and expenses can sometimes be reduced if the applicant can provide transportation, housing, or assistance during the survey. These arrangements should be settled before the survey begins.

If the applicant feels the survey costs are unreasonable and negotiations with the surveyor are not satisfactory, the applicant should request the surveyor to return the survey instructions to DNR and then select another surveyor. DNR must be informed when a new surveyor is selected.

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