AQUACULTURE POTENTIAL
IN
COOS BAY, OREGON

by
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and
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1977

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Introduction...

Aquaculture, the farming of aquatic species, has great potential in Coos Bay, Oregon, as well as in many other parts of the world. Mariculture, a form of aquaculture which involves the farming of the seas and estuaries, may alleviate much of the pressure now placed on agriculturally based food production. With the advent of intensive aquaculture in Coos Bay, increases in capital investments and employment will occur. This will enhance the already important role of Coos Bay in the economy of southwest Oregon.

This report deals with a number of the important aspects of aquaculture. It is intended to furnish the reader a background into the nature of marine aquaculture in general as well as provide detailed information on the conditions which exist in Coos Bay that relate to the practice of mariculture.

The report is divided into several parts. After reviewing the factors basic to aquaculture, there are three sections on those species that may be suitable for culture in Coos Bay. In each of these sections, charts are presented containing information on characteristics of the particular fishes, invertebrates, or algaes being considered as well as on culture methods and related factors, and feasibility in Coos Bay, Oregon. The legal aspects of aquaculture in Oregon are reviewed in the following section. This includes current reference material on Oregon laws relevant to the practice of aquaculture. The next section thereafter pertains to water quality and includes useful information based on analysis of water conditions at different locations in Coos Bay. The final part deals with the need for and possibility of developing a shellfish depuration center for shellfish grown in areas of the bay which presently do not meet health standards. The report itself ends with a brief comment on the future for aquaculture in Coos Bay and a bibliography on materials useful to persons interested in studying aquaculture.

While the report pertains to Coos Bay, its usefulness is by no means limited just to this region. Anyone interested in aquaculture can use much of the species information in deciding on the feasibility of mariculture in different localities.

The information found within came from many sources, the most valuable of which were agencies and individuals working in the various areas of specialization. We are especially grateful to the following who shared their knowledge and ideas with us: Wilbur Breeze, Oregon State University, Newport, Oregon; Glen Carter, Dept. of Environmental Quality, Portland, Oregon; Elmer Case, Dept. of Fish & Wildlife, Newport, Oregon; Sharrel Davison, State Sanitation, Portland, Oregon; Bob Demory, Dept. of Fish & Wildlife, Newport, Oregon; Derrell Demory, Dept. of Fish & Wildlife, Newport, Oregon; Tom Gaumer, Dept. of Fish & Wildlife, Newport, Oregon; Wally Hublou, Dept. of Fish & Wildlife, Portland, Oregon; Bob Hudson, All Coast Marketing Association, Coos Bay, Oregon; Ernie Jefferies, Dept. of Fish & Wildlife, Portland, Oregon; Ed Lippert, Portland State University, Portland, Oregon; Al McGee, Dept. of Fish & Wildlife, Charleston, Oregon; Marvin McGlothlin, Dept. of Environmental Quality, Portland, Oregon; Michael Neushul, University of California at Santa Barbara, Santa Barbara, California; Laimons Osis, Dept. of Fish & Wildlife, Newport, Oregon; Rob Rogers, Eureka Fish Packing, Coos Bay, Oregon; David Sant, Weyerhaeuser, Coos Bay, Oregon; Jim Vail, Anadromous Fish Corporation, North Bend, Oregon; and Illustrations by Joanne Salley.

Thanks is given to D. Jon Grossman, Chief, Editorial Branch, Food and Agriculture Organization of the United Nations, Via delle Terme di Caracalla, 00100-Rome, Italy; Fishing News Books Ltd., 1 Long Garden Walk, Farnham, Surrey, England; and Mr. Santo A. Furfari, Shellfish Sanitation Branch, Food and Drug Administration, Washington, D.C., for authorization to reproduce "Shellfish Purification: A review of current technology," and is "Reproduced from the Proceedings of the FAO Technical Conference on Aquaculture, held in Kyoto, Japan, 25 May - 2 June 1976. The Proceedings are to be published by Fishing News Books Ltd., 1 Long Garden Walk, Farnham, Surrey, England, during 1978."

My thanks also is extended to my father, Dr. Harold Jambor, and my sister, Margaret Jambor-Merschdorf, for their valuable support, guidance, and editing assistance.

Finally, thanks is shared with Doris Boylan for typing this report and Joanne Salley for the illustrations.

Nick Jambor
Jerry Rilette

July 1977

Factors Basic to Aquaculture...

Of those species being cultured world wide a number of them are suitable for Coos Bay. These are identified and examined in this report. Other species are also discussed because there seems to be a curiosity about these particular organisms.

There are eleven factors of importance to the aquaculturist when considering different species.[1] Briefly described, these factors are as follows.

Environmental conditions - ranges for factors such as salinity, temperature, pH, and dissolved oxygen are given. These are preferred ranges and do not describe the maximum ranges. Also included are substrate requirements.

Behavior - includes feeding types, habitat, molting cycles and other characterist■cs peculiar to a given species.

Disease and Predation - pertains to diseases which are known to occur and to organisms that prey on a species.

Genetics - known genetic crosses have been noted.

Bioererget-cs - includes the best ages for harvesting, time before maturity and food conversion ratios. Food conversion ratios are the expected or actual weight gain of an organism fed a known amount of food. For example 5:1 means 5 parts of protein were fed to an animal to get 1 part of protein weight gain in that animal.

Culture methods - refers to types of culture techniques for a species.

Site Selection and Site Rights - refers to water quality, the available open spaces and bottom composition in a bay. Certain areas for different types of culture are suggested. Agencies involved in rite acquisition are listed in Table 1.

Processing - refers to methods of processing currently employed.

Potential uses - pertains to the product and by-products of plants and animals that have a usefulness.

Economics - entails suggestions to individuals involved with economic decision making.

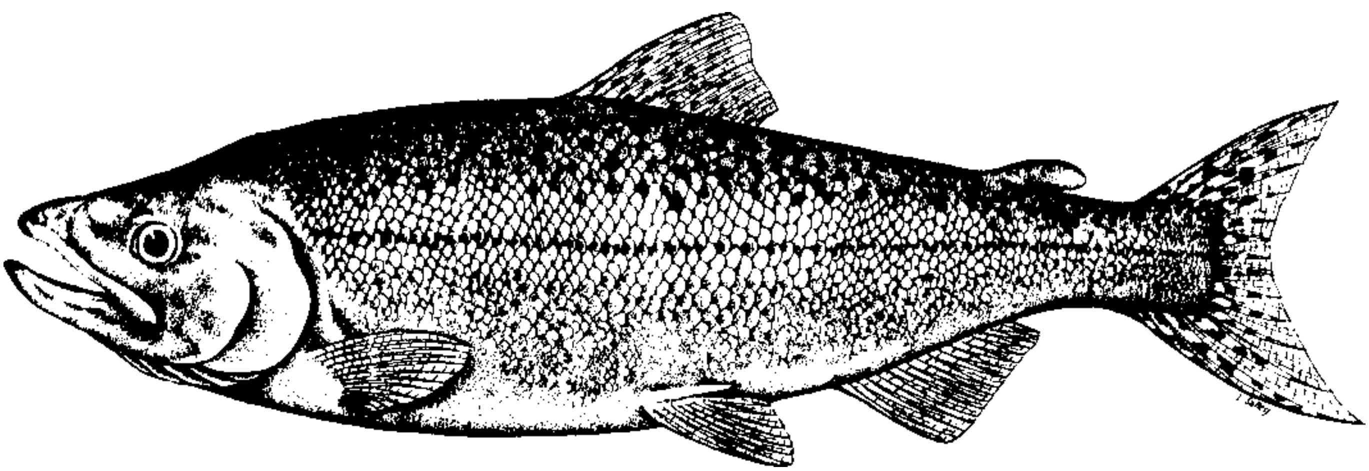
Environmental effects - pertains to the environmental effects from intensive mariculture practices.

These are the main factors which an aquaculturist should consider in determining what can be grown and why.

On the basis of the information obtained from authorities in the field and others, recommendations for future mariculture practices are offered.

FOOTNOTES

1. H.R. MacCrimmon, J.E. Stewart, and J.R. Brett. 1974. Aquaculture in Canada--The practice and the promise. Bulletin of the Fisheries Research Board of Canada. #188



Fishes...

True aquaculture practices of fishes have been practiced in the Asian countries for centuries. As early as 475 B.C., spawning of captive carp in China was described and advocated as a profitable business by Fan Li in the first known treatise on aquaculture.[1] Japan has been instrumental in the culturing of various species of fishes in recent years. These fishes, raised for their food value and certain esthetic qualities, include fish such as pompano, Trachinotus carolinus; black porgy, Mylio macrocephalus; red porgy, Chrysophrys major; carp, Cyprinus; and tilapia, Tilapia spp. The Japanese, have also been instrumental in devising methods in which a fast swimming, pelagic fish, the yellowtail, Seriola quinqueradiata; is captured and raised to marketable size. Successful spawning of the yellowtail has not been realized, though techniques are being worked on. The possibility of raising any of these fishes within Coos Bay is unlikely. Problems include lack of usable areas, adverse salinity and water temperatures, and small market demand for many of the lesser known species.

While fishes comprise one of the important commercial fisheries in the area, a marine aquaculture (mariculture) program in Coos Bay of the commercially important fish has yet to be realized.

Sea ranching, an entity of aquaculture, found its genesis in the Coos Bay area with the advent of the Anadromous Fish Corporation in 1976. Further interest has been shown by the recent acquisition of a permit to release salmon into Coos Bay by Weyerhaeuser. Sea ranching involves a shore based hatchery, a release and recapture site, and methods for processing. A checklist of permits required for private hatcheries in Oregon is presented in Table 1. This also indicates the agency responsible for issuing the different permits required.

TABLE

Checklist of permits required for private hatcheries in Oregon

TIpe of Permit	ReE.ponsible
Water rights	Office of the State Engineer Salem, Oregon 97310
Private hatchery permit	Department of Fish & Wildlife 17330 S.E. Evelyn Clackamas, Oregon 97015
Importation of fish or fish eggs	Oregon Department of Fish & Wildlife P.O. Box 3503 Portland, Oregon 97208
Pollutant diE;charge	Department of Environmental Quality 2595 State Street Salem, Oregon 97310
1:uilding permit; Land use approval	(appropriate local agencies)
Works in navigable waters	District Engineer U.S. Army Engineer District, Portland P.O. Box Box 2946 Portland, Oregon 97208
Division of State Lands Fill and Removal Law	and Director Division of State Lands 1445 State Street Salem, Oregon 97310
Wildlife hatchery license	Department of Fish & Wildlife P.O. Box 3503 Portland, Oregon 97208
Clearance to sell fish an[a]l fishery products	Department of Agriculture Salem, Oregon 97310

All anadromous fishes, such as the salmonids, striped bass, Morone saxatilis; American shad, Alosa sapidissima; and sturgeon, Acipenser spa.; return from the sea to breed in fresh water. The sea rancher allows the stock to graze on the ocean and recaptures them upon their return, thus circumventing raising costs. Though returns may be as low as 2 or 3% of released fish, sea ranching is felt to be economically feasible.[2] At this time, two species of Pacific salmon, the chinook, Oncorynchus tschawytscha; and the coho, O. kisutch; have been released and it is expected that the chum salmon, O. keta; will be released in the future.

For each of the fishes which are presently regarded as possible for commercial raising, a chart containing information on characteristics, culture methods and related factors, and feasibility in Coos Bay is presented at the end of this section.

The salmon are the most likely fish to be raised commercially at this time. Other fishes that could be considered are the red snapper, flat fishes, and other bottom fishes. The problem with these fishes however, is that there is a strong trawl boat industry in Coos Bay. This industry makes economic feasibility of spawning, raising, harvesting and processing of fishes easily caught off-shore dim.

The future of fish culture is then directly related to off-shore commercial fisheries. The viability of sea ranching is good for it circumvents certain costly operations of the aquaculturist and the commercial fisherman. Thus sea ranching is a definite alternative and should be considered by anyone interested in the culturing of fishes.

For further information contact the following in the Coos Bay area:

Anadromous Fish Corporation
P.O. Box 825
North Bend, Oregon 97459
756-3923

State of Oregon
Department of Fish & Wildlife
P.O. Box 5430
Charleston, Oregon 97420

Weyerhaeuser
3050 Tremont
North Bend, Oregon 97449
756-5121

FOOTNOTES

1. J.E. Bardach, J.H. Ryther, and W.O. McLarney. 1972. Aquaculture: The Farming and Husbandry of Freshwater and Marine Organisms. Wiley Interscience, New York, London, Sydney, Toronto.

2. Weyerhaeuser. 1976. Personal communications.

CHINOOK SALMON *Oncorynchus tshawytscha*

Environmental Conditions	The Chinook salmon, also known as the king salmon, is indigenous to Coos Bay. The juvenile stages are spent in fresh and estuarine water, and demand a continuous high quality water supply, while the adult stage is spent in the open ocean.
Behavior	Spends 1-2 years in fresh water and then enters the ocean for an average of 3-4 years, before returning to fresh water to spawn. The young feed on small bottom fishes and insects, while the adults feed on euphausids and such fishes as herring, sand lance and rockfishes.
Disease and Predation	The striped bass and certain trout may eat the juvenile stages, while certain marine mammals prey on the adults. Fungal, bacterial and viral diseases including Vibrio and infectious pancreatic necrosis (IPN) may be present. Ernie Jeffries,of the Oregon Department of Fish and Wildlife, noted that disease transfer from stocking areas is a problem.
Genetics	The adult female deposits 3,000-11,000 eggs and both female and male die after spawning. Hybrids are possible and have been achieved. Bob Demory, of the Oregon Department of Fish and Wildlife, feels that the destruction of race integrity is a questionable practice.
Bioenergetics	Adult fish return 4-6 years after hatching and attain an average size of 15 pounds.
Culture Methods	Presently there are two separate culture methods possible. In pond culture the fish are never released into the sea and are normally raised to pan size. In the other method the fish are released into the ocean as soon as possible and are recaptured upon their return. This is termed sea ranching.

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Site Selection	For pond culture an adequate water supply must be obtained. This would entail being relatively close to the mouth of the bay. Site location for a release and recapture site, as in sea ranching, should also be near the mouth of the bay. Areas along the North Spit have shown to be adequate and further release and recapture sites might also be located along the North Spit.
Site Rights	See Table I for permits required for hatcheries. For policies relating to licensing and operating of private salmon release and recapture facilities, see: Oregon Revised Statutes 508.700-745; and Oregon Department of Fish and Wildlife, Policy Relating to Licensing and Operation of Private Salmon Release and Recapture Facilities Draft, June 29, 1976.
Processing/ Potential Uses	Present uses include the use of roe, canning, freezing and smoking of meat. Potential uses are in the areas of animal fodder and fertilizer.
Economics	According to Rob Rogers, Bandon Fisheries, Coos Bay, July, 1976, the Chinook salmon brings the highest price per pound of any of the salmon. David Sant, a Weyerhaeuser public relations person, stated that according to one of their marketing studies, the current market for salmon is excellent. Returns of 1-2% of released fish in sea ranching are expected according to Sant. John Donaldson, Oregon Department of Fish and Wildlife, stated in Mariculture Laws, August 1975, that salmon ranching entails a high initial investment.
Environmental Considerations	Introduction of fishes should be carefully examined to prevent transmission of diseases, inferior gene pools and possibilities of replacing other important animals. Water quality problems, such as thermal and waste pollution, can affect the livelihood of the fish. A possible overload of the natural carrying capacity of Coos Bay should be analyzed.
Recommendations	At this time two new release and recapture sites have been licensed and further development in this area should be carefully examined for the following reasons. 1. Disease problems 2. High initial capital investment 3. Concern over potential flooding of the market (Bob Hudson--All Coast Marketing Association) 4. Returns have yet to be realized in the Coos Bay area from existing sea ranching operations

SILVER SALMON *Oncorhynchus kisutch*

Environmental Conditions	The silver salmon, also known as the Coho salmon, is native to the Coos Bay area. The juvenile stages are spent in fresh and estuarine waters, and demand a continuous high quality water supply, while the adult stage is spent in the open ocean. An important consideration in the placement of a hatchery is then the water supply.
Behavior	Silver salmon are anadromous fish which spend 1-2 years in fresh water and 1-2 years in the ocean before returning to fresh water to spawn. Like other salmon, they will return to the stream that they originated from. Juveniles feed on small terrestrial insects, young adults feed mainly on a variety of fish and crustacea, including: crab larvae, euphausids, and barnacle larvae, and adults will feed on euphausids, squid and fishes.
Disease and Predation	Fungal, bacterial, and viral diseases are known. Predators include the striped bass and large trout which feed on the juvenile stages. Marine mammals may feed on the adults. Disease transfer from stocking areas has occurred.
Genetics	Hybrids are possible, though destruction of race integrity is a questionable practice.
Bioenergetics	Rapid growth during the last few months before entering fresh water is realized. Females deposit between 2,000-3,000 eggs.
Culture Methods	Presently there are two separate culture methods. In pond culture, the fish are never released into the sea and are normally raised to pan size. In the other method, the fish are released into the ocean as soon as possible and are recaptured upon their return. This is termed sea ranching.

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Site Selection	For pond culture an adequate fresh and marine water supply must be obtained. This would entail being relatively close to the mouth of the bay. Site location for a release and recapture site, as in sea ranching, should also be near the mouth of the bay. Areas along the North Spit have shown to be adequate and further release and recapture sites, we feel, could also be located along the North Spit.
Site Rights	See Table I for permits required for hatcheries. For policies relating to licensing and operating private salmon release and recapture facilities, see: Oregon Revised Statutes 508.700-745; and Oregon Department of Fish and Wildlife, Policy Relating to Licensing and Operation of Private Salmon Release and Recapture Facilities Draft, June 29, 1976.
Processing/ Potential Uses	Present uses include the use of roe, canning, freezing and smoking of meat. Potential uses are in the areas of animal fodder and fertilizer.
Economics	David Sant, Weyerhaeuser public relations person, stated that Weyerhaeuser's studies indicate that the salmon market is expandable, though concern over potential flooding of the market was expressed by Bob Hudson of the All Coast Marketing Association in July of 1976. John Donnaldson of the Fish Commission of Oregon, stated in a paper given at the Mariculture Law Symposium in August of 1975, that the initial investment in salmon farming is high.
Environmental Considerations	Introduction of fishes should be carefully examined to prevent transmission of diseases, inferior gene pools and possibilities of replacing other important animals. Water quality problems, such as thermal and waste pollution, can affect the livelihood of the fish. A possible overload of the natural carrying capacity of Coos Bay should be analyzed.
Recommendations	At this time two new release and recapture sites have been licensed and further development in this area should be carefully examined for the following reasons. 1. Disease problems 2. High initial investment 3. Returns have yet to be realized in the Coos Bay area

CHUM SALMON Onocorynchus keta

Environmental Conditions	The Chum salmon, also known as the dog salmon, has its greatest abundance from Puget Sound to Southeastern Alaska. Environmental conditions south of Puget Sound then are not ideal for the Chum salmon.
Behavior	Spawning takes place in late summer, normally close to the mouth of rivers. Chum salmon fry migrate into estuarine waters almost immediately after emergence. Chum salmon are adapted to coastal streams which have minimal summer stream flows and high summer temperatures. These streams are not suitable for the reproduction of other salmonids, because of the extended fresh water juvenile stages of those species. Juveniles feed primarily on insects, while adults feed on euphausids, squids, amphipods and crab larvae.
Disease and Predation	These animals spend little time in the estuary and thus lower the possibility of encountering diseases, though they are subjected to the same diseases which affect both the Chinook and Coho salmon.
Genetics	Hybrids are possible.
Bioenergetics	Females deposit between 2,000-4,000 eggs. The Chum salmon return in 3-5 years after entering the ocean and average 10 pounds. Spawning occurs as late as April.
Culture Methods	Sea ranching and pond culture.

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Site Selection	A release and recapture site would best be situated along the bay side of the North Spit.
Site Rights	See Table I for permits required for hatcheries. For policies relating to licensing and operating of private salmon release and recapture facilities see: Oregon Revised Statutes 508.700-745; and Oregon Department of Fish and Wildlife, Policy Relating to Licensing and Operation of Private Salmon Release and Recapture Facilities Draft, June 29, 1976.
Processing/ Potential Uses	Present uses include the use of roe, canning, freezing and smoking of meat. Potential uses are in the areas of food, fodder and fertilizer. Canned Chum is considered inferior to other salmon due to lack of red color and low fat content.
Economics	As of this time, no real market for Chum salmon has been developed. As with any type of aquaculture, the initial investments are high. Some growers feel that they will be success-ful with a 1-2% return, according to David Sant, Weyerhaeuser's public relations person, Coos Bay.
Environmental Consideration	Introduction of fishes should be carefully examined to prevent transmission of diseases, inferior gene pools, and possibilities of replacing other important animals. Water quality problems, such as thermal and waste pollution, can affect the livelihood of the fish. A possible overload of the natural carrying capacity of the Coos Bay estuary should be analyzed.
Recommendations	At this time, two new release and recapture sites have been licensed and further development in this area should be examined for the following reasons: 1) disease problems; 2) capital investments are high; 3) concern over potential flooding of the market, as expressed by Bob Hudson of the All Coast Marketing Association; 4) no returns have yet been realized for Coos Bay; and 5) natural stocks for Chum eggs are low and eggs are difficult to obtain at this time.

STRIPED BASS *Morone saxatilis*

Environmental Conditions	The Striped Bass was introduced to the West Coast in 1879 and 1882. They spawn in estuarine conditions and have an extensive salt water range.
Behavior	Spawning occurs in the spring. Striped bass feed on shiner perch, spring salmon, shrimp and other Striped Bass.
Disease and Predation	Heavy predation during the fry stage is experienced.
Genetics	
Gioenergetics	Growth rates are fast though somewhat changeable. At 8 years some fish may weigh 35-40 pounds. Females reach maturity by the seventh year and as early as the fifth. Males are somewhat faster to mature, taking 3-5 years. The female will deposit up to 2,000,000 eggs.
Culture Methods	Cage or pond culture as used for the yellowtail in Japan and sea ranching could be considered.

Site Selection	Probable site location would be on the North Spit, with deep ponds that have a good exchange of water. Oxygen content should be 5 ppm or better.
Site Rights	Division of State lands. Table I Army Corps of Engineers
Processing/ Potential Uses	Fresh market, smoked and canned. Potential--food, fertilizer, fodder, and fish meal.
Economics	Development of the market needed. Investments would be high, very similar to salmon ranching. First returns would be after second spawning.
Environmental Considerations	A possible overload of the natural carrying capacity of this area should be closely analyzed.
Recommendations	Artificial spawning techniques are in the preliminary stages at this time, and careful consideration as to where stock would be found must be made. A natural population now exists which is not heavily fished. This may indicate a general disinterest in this fish.

AMERICAN SHAD *Alosa sapidissima*

Environmental Conditions	Spawn in shallows just above the mouth of branch streams. Temperatures must reach 11.6°C before spawning will commence and drops in temperature during spawning will halt the act. Spawning occurs in the evening.
Behavior	Anadromous fish, shad lay planktonic eggs, developing into benthic fry which return to the sea after one summer. The American shad was introduced to the West Coast in 1871. The Shad feeds on small fish and crustaceans which are caught in their gill rakers.
Disease and Predation	Predators include about any larger carnivorous fish. Predators take large numbers. Little is known about diseases.
Genetics	
Bioenergetics	Enter estuary in late summer and spawn in late spring. Mature after 4-5 years (at this time the fish is usually 18-19 inches long). Female will lay up to 150,000 eggs. Shad normally return to fresh water after 4-8 years at sea.
Culture Methods	Artificially spawned. These animals would be sea ranched in a method very similar to that of the salmon.

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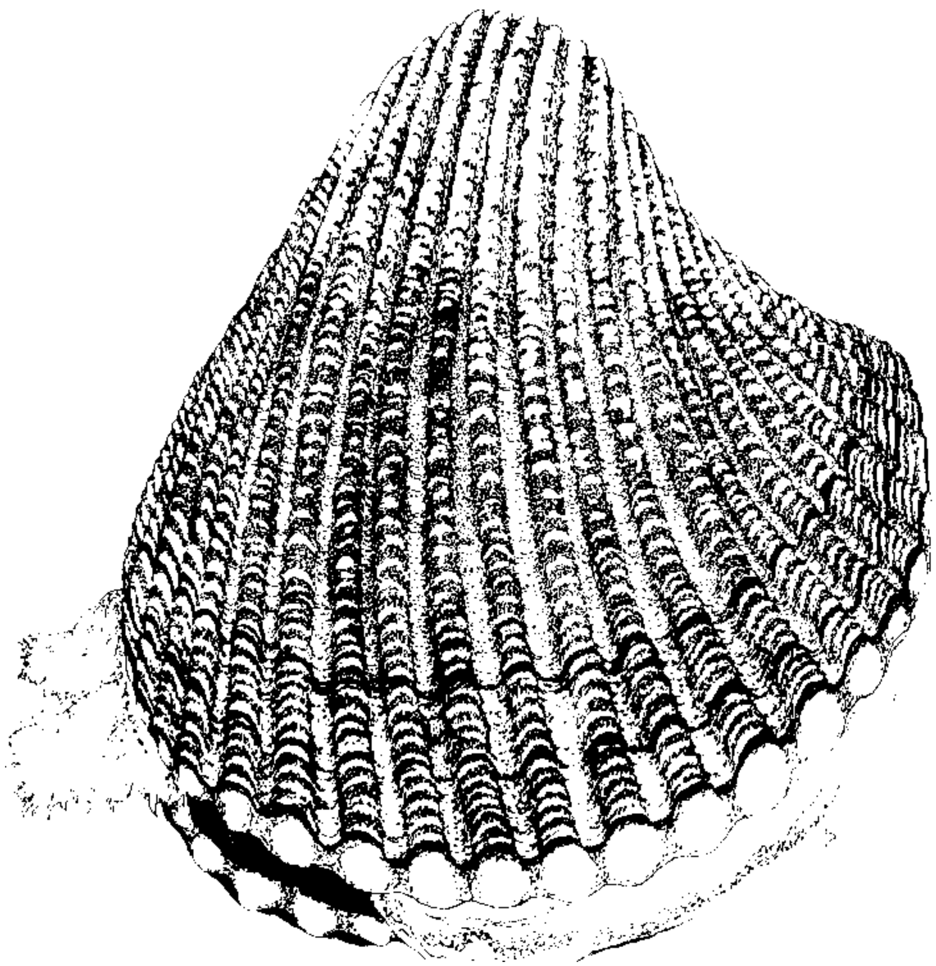
Site Selection	On the North Spit, with release/recapture sites similar to salmon.
Site Rights	Division of State Lands. Army Corps of Engineers.
[redacted]	This fish would be processed for fillets and roe. Valued for flesh and roe. Uses include fodder and fertilizer.
[redacted]	At present there is no strong market for Shad. Employment would be in hatchery maintenance, harvesting, processing, and marketing. Shad has a present market value less than one cent per pound. Authorities feel that a market for shad may be developing on the East Coast (Mr. Wally Hublou, Oregon Department of Fish and Wildlife).
Environmental Consideration	Effects of adding numerous fish to natural carrying capacity should be considered.
Recommendations	1) Market development necessary. 2) A large initial investment must be expected. 3) Probably not feasible at this time, especially as some other species may be a better investment.



Invertebrates ...

The invertebrates comprise the most important group of animals to be considered. These animals normally feed off the base of the food chain and thus utilize that food source which man has not yet tapped directly with success. Some of the cultured invertebrates have been bred and raised, and some, like the oyster and clam, already have an established market. The invertebrates also form a group that lends itself well to both monoculture and polyculture. Of all the invertebrates, the oyster has the distinction of being the only one which can legally be raised within Coos Bay for commercial purposes.[1]

An appropriate word to describe the water within a bay is the word soup. The water is comprised of thousands of small microscopic organisms that the biologist loosely refers to as plankton. The plankton can be broken down into two major groups, the phytoplankton and the zooplankton. Phyto, meaning plant, and plankton, meaning free floating, relate to these microscopic organisms that use energy from the sun to grow aid reproduce, much like land plants. Zooplankton are the animals that are free floating within the water column. Animal larvae are the major contributor to the zooplankton. The plankton forms the base of the food chain and were it possible, we would harvest the plankton. Since the difficulties in economically harvesting microscopic organisms are monumental, man has opted to harvesting the next best thing, the animals which feed on the plankton. Filter feeders do just that. Animals which belong to this group of filter feeders include the oysters, clams, mussels and scallops.

In the culturing of any species the hatchery becomes an integral part of a successful operation. It enables a steady and constant supply of juveniles to be available to the aquaculturist. Without this supply, any aquaculture venture stands little chance of success.

There has been success with hatcheries for algae, fish and invertebrates. Presently there are a number of private hatcheries operating in the states of Washington and California. Since Oregon does not have a private invertebrate hatchery, seed stock is not readily available, making a local hatchery a viable option.

Most species cultured in various parts of the world have no ready market in the Coos Bay area. Animals such as the sea urchin (Strongylocentrotus franciscanus), and the mussel (Mytilus edulis), demand a high market value in Japan and other parts of the world, but have little or no market appeal in the Coos Bay area, according to Derrell Demory of the Oregon Department of Fish and Wildlife. There exist a number of species which have established a good market in this area and along the West coast, notably the oyster, crab, clam and shrimp.

Aquaculture can be of two forms, monoculture or polyculture. Monoculture is the raising of a single species, such as with an oyster farm. Polyculture involves the raising of a number of different species within the same confines. The invertebrates lend themselves well to polyculture. In Yaquina Bay, Oregon, oysters are raised concurrently with salmon in ponds at Oregon Aqua Foods.

The opportunities for polyculture are unlimited if compatible species are selected. Combinations such as oysters, fish and a detrital feeder are possible. Pond productivity can also be enhanced by the careful addition of fertilizers to create an artificial plankton bloom that would create more available food for the filter feeders. Also systems involving the use of processed sewage to increase amounts of nutrients in the water have been used.[2]

Another possible system of polyculture involves the raising of marine algae to create new habitat for many animals. The types of animals that could be introduced into this system can be dependent upon, or independent of, the fauna of a bay. If one were to work with a closed system, i.e., filtered seawater and ponds closed to a bay, the introduction of species would be dependent upon the aquaculturist. If an open system is used then those animals naturally living within a bay that can make use of this new habitat would flourish. Either an open or closed system properly managed will create a situation of increased productivity.

The invertebrates show the greatest potential for present development. Hindering the further development of oyster culture within Coos Bay is the closing of about half the bay to commercial shellfish production due to sanitary regulations. The planning and operation of a central depuration or purification plant in Coos Bay is suggested in a later section of this report. Through this, the potential of Coos Bay to shellfish culture could be realized.

Following are charts for those invertebrates which can be considered for aquaculture in Coos Bay. These give information on characteristics, culture methods and related factors, and recommendations to aquaculturists considering raising them.

FOOTNOTES

1. Northwest Mariculture Laws. 1974. Papers and presentations from a Symposium held at the Law Center. University of Oregon, pg. 17.
2. E. Lewis, Chin Kramer and Mayo Inc. Design of an Aquaculture Facility for Woods Hole Oceanographic Institute. Seattle, Washington.

OYSTERS

Environmental Conditions

	Temperature °C	Salinity	Common Name
Crassostrea gigas	15-30	23-28 ppt	Pacific
Crassostrea virginica	17.5-32	to 32 ppt	Eastern oyster
Ostrea edulis	15-20	above 25	European flat oyster

Optimum growth occurs if dissolved oxygen content of the water is at least 6 ppm. High levels of siltation will cause mortalities to occur.

Behavior	The oyster is a sessile filter feeder. It can alternate between being male or female throughout its life. 0. edulis is sensitive to temperature variations and is not tolerant of turbidity in the water. All oysters feed on phytoplankton and zooplankton.
Disease and Predation	The oyster drill, starfish and some mammals are predators. Filter feeders may eat some of the larvae if dispersal currents are not present. These animals have the ability to concentrate toxins and if these toxins are deadly mass mortalities will occur.
Genetics	Genetic crossovers have occurred. Introduction of Crassostrea regularis has been suggested by Wally Hublou of the Department of Fish and Wildlife.
Bioenergetics	Growth is dependent upon availability of food, temperature, sex and culture method. Animals normally reach harvestable sizes in 20-36 months. They can be artificially spawned. C. gigas reaches harvestable size in 18-24 months, C. virginica in 4-5 years reaches an average size of 7.5 cm and 0. edulis can obtain 8 cm in 4 years.
Culture Methods	Include bottom, long line, raft, stick, tray, rack, and hanging cultures.

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Site Selection	Presently the only approved shellfish growing areas are those areas south of an imaginary line 1 running west from the Sitka Dock. If a depuration site was created, the entire bay would be suitable for the culture of different shellfish. See section on Depuration and map of approved growing areas, Figure 1.
Site Rights	Site rights are controlled by the Division of State Lands in tidal areas. In navigable waters the Corps of Engineers must be contacted. Growing areas are leased from the state for $2.00 per acre per year.
Processing/ Potential Uses	Processing would require a shucking house with cold storage facilities. Mainly used for a food source. Byproducts may be used for animal supplement, fertilizer and fodder. Shell can be resold to the hatchery for use as cultch.
Economics	A good market exists with demand at times higher than supply. Areas of employment would be in stocking, maintenance, harvesting, depuration, shucking, packaging, marketing, and distribution. First returns would be in 20-36 months.
Environmental Considerations	Stick culture may increase local siltation. The effect of introduction of large numbers of animals must be considered.
Recommendations	Oyster farming should definitely be considered as a viable aquaculture practice. Our recommendations are: 1) That an oyster co-op be formed. With monies from this co-op, a common hatchery, depuration site, and shucking and processing house could be developed. 2) The entire bay be used (with depuration site). 3) Use of the most efficient culture method be utilized.

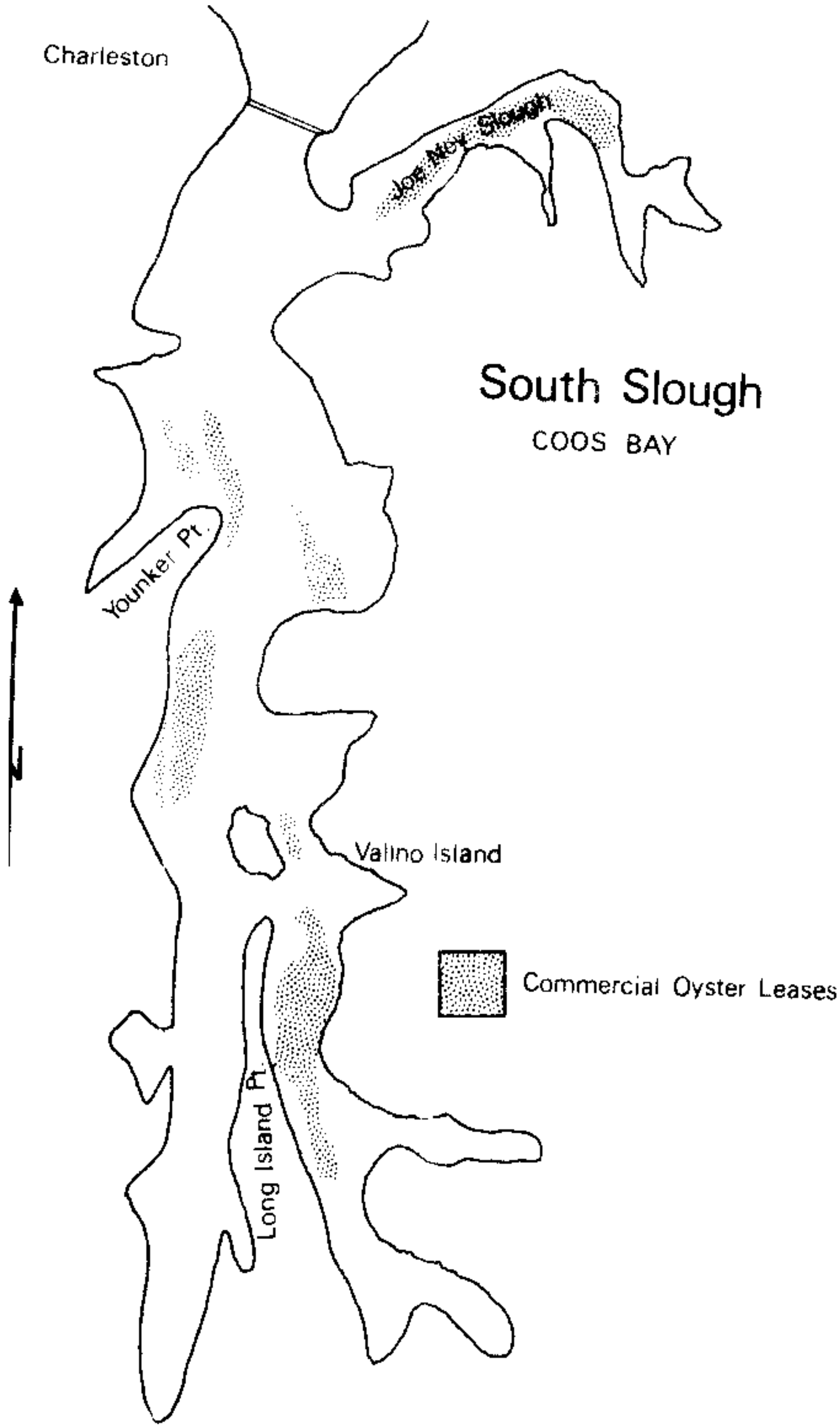
Charleston
Joe Ney Slough
South Slough
COOS BAY
Younker Pt.
Valino Island
Commercial Oyster Leases
Long Island Pt.

Figure I

MUSSELS *Mytilus edulis*

Environmental Conditions	Salinity optimum is 22.7-35 ppt. Temperature: 5-20°C. Dissolved oxygen of at least 3 ppm. All environmental conditions must be suitable or the mussel will try to migrate.
Behavior	Predominantly sessile. Growth is mainly during the summer. These animals are filter feeders and have the ability to concentrate pollutants.
Disease and Predation	Mussels are preyed upon by starfish, trematodes, parasitic copepods and some gastropods. Most predation can be avoided with off bottom culture.
Genetics	Natural spat is collected in those parts of the world where mussel culture is extensively practiced, such as France.
Bioenergetics	Can grow to harvestable size in 18-24 months. Growth is seasonal and mainly occurs in the summer months. Mussels submerged will grow more rapidly than those occasionally exposed.
Culture Methods	Bay culture would include bag, rack, raft, long line and possible stick culture. Bottom culture should be avoided for it would allow for easy predation.

Site Selection	Areas within Coos Bay below the Sitka docks meeting the salinity requirements of at least 22.7 ppt can be made suitable.
Site Rights	Division of State Lands. Army Corps of Engineers.
Processing/ Potential Uses	Fresh, steamed and pickled. Since mussels do not close their shell tightly when removed from water, dessication becomes a problem, making shipping in a fresh state difficult. Uses include food, fertilizer, animal supplements and laboratory purposes.
Economics	At the present time there is no strong local market for the mussel.
Environmental Considerations	Disease problems are compounded with high population densities, and care must be taken with waste disposal.
Recommendations	1. At present there exists a large natural population that is not heavily harvested, which indicates a lack of interest in the mussel as a commercial food source. 2. There are no laws concerning the culture of mussels and this would make it difficult to prove ownership. 3. With market development, we feel that mussel culture can be feasible.

SHRIMP CULTURE   sub-order <u>nutantia</u>

Environmental Conditions	Prefer a coarse, light sand for the bottom of the pond. They can withstand large temperature variations (2-30°C), but prefer around 25°C. Salinity should be near 35%0. Oxidation-reduction values for the bottom should be near +30mv. Oxygen saturation is favorable. Stratification of water layers should be avoided. Ponds are stocked favorably at about 20 juveniles/sq. m. of water.
Behavior	Shrimp are nocturnal feeders and hide themselves under the bottom and during the day. At night they will surface to feed. When water quality is poor, shrimp are known to jump around in the water. They molt about every 10 days. Larvae feed on diatoms and also a formula feed is used. Post larval juveniles feed heavily on benthonic organisms. Adult shrimp are fed clams, mussels, fish, various species of crabs and euphausids. Order of preference for feeds is clams, oysters, nereids, squid, mantis shrimp, gobies, mackerels, in descending order.
Disease and Predation	Fish are major predators. Fish enter in larval stages and may feed on both shrimp and feed. Proper dosages of rotenone have been successful in eradicating unwanted fish. Diseases: Microsporidia is a parasite of the white shrimp. Black gill is caused by an imperfect fungi that is related to saprolegnia. Several diseases due to pathogenic bacteria have been reported (Vibrio).
Genetics	Live mature shrimp are captured and bred in captivity. Hybrids would be likely.
Bioenergetics	Breeding is accomplished in the summer months. Food conversion ratios vary from 19.7:1-5.7:1, dependent upon type of food fed and stage of shrimp studied and survival rates. In actual laboratory tests, values ranged from 4.58:1-10.49:1. This later data is dependent upon body weight of the Crimp, in other words, the larger shrimp ate more. Growth rates of 3.5%/day have been noted.
Culture Methods	Pond culture located on deserted salt beds or on sandy beaches along inner bays have been used. Straight sea water is utilized. Ponds average 3ha. Tank culture: Use 1-1.5 meters of water, with 2-3 daily flushing of 30% at each flushing.

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Site Selection	Sandy beaches with access to tidal flows of ocean water, or near the mouth of the bay where salinity is high.
Site Rights	Division of State Lands. Army Corps of Engineers.
Processing/ Potential Uses	In Japan, the market is for fresh shrimp. Were large quantities available, cooking and then freezing could be an alternative. Food and fodder.
Economics	Japan and the United States demand 30, of the total world production of frozen shrimp at the present time. The price of shrimp varies depending on the market and the quality of the shrimp. They may sell for up to $18/kg. To produce one kilogram of shrimp on a farm of 40 tons annual production, costs $9.4/kg, with 42% in feed, 18% in wages and 17% in marketing.
Environmental Considerations	Flushing of ponds will be a necessity to avoid environmental conditions harmful to the shrimp. Potential problems in discharging organic wastes into the bay would need to be considered.
Recommendations	1. Pond culture with heated water would be preferable. By covering the pond, heat would be conserved and the fresh water from rain would be prevented from entering the ponds and causing water stratification. 2. A large, fresh pan shrimp would be a worthwhile addition to our diverse seafood selection.

ABALONE *Haliotis rufescens*

Environmental Conditions	The abalone requires 35 ppt salinity. Its best growth rate is between 20-25°C. Major flooding with increased siltation may cause heavy mortalities.
Behavior	The abalone is a grazer, holding onto the substrate by its muscular foot and feeds subtidally on kelp. Damage to the foot will cause the animal to bleed to death.
Disease and Predation	Strongylocentrotus franciscanus occupies similar habitat and may outcompete Haliotis rufescens. Main predators include the sea otter, crabs and boring clams.
Genetics	
Bioenergetics	The spawning reflex appears to be triggered by a sustained water temperature of 20°C. The free swimming larval stage lasts 1-2 weeks. In normal conditions around Coos Bay, it takes 4-14 years for the abalone to reach its harvestable size of 20 cm. Of 5,000 planted in Whale Cove and monitored annually the ratio of tagged to untagged suggested a 5% survival of the original planting. Growth of these animals parallels that found in California, growing to 20 cm in 4 years.
Culture Methods	Pond or tank using water of 35 ppt in salinity. Can be spawned when water temperature ranges from 15-20°C. By heating and then allowing to cool in a 6 hour period several times the abalone can be successfully spawned. Potassium chloride may also be used to induce spawning.

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Site Selection	Deepwater ponds or cages in the water column, or a method to insure that hiding places and shade are present.
Site Rights	Division of State Lands. Army Corps of Engineers.
Processing/ Potential Uses	The removal and cleaning of the "foot," with mechanical tenderizing. Used for food, animal food supplement, and jewelry.
Economics	The market could be for a fresh or frozen product. There is already an existing nation-wide market. People could be employed in maintenance (diver operations), harvesting, processing, and marketing. Investments would be in seed cost, pond construction, water transportation, diving, and equipment, but it would take 10-14 years for returns..
Environmental Consideration	Abalone would be well suited for poly-culture operations.
Recommendations	Problems in the area of seed stock supply exist. The cost of heating water in order to reduce growth time in pond culture is expensive at this time.

AMERICAN LOBSTER *Homarus americanus*

Environmental Conditions	A constant temperature of 15.9°C is best for tank growth. Salinity: open ocean. This animal is normally found in deep waters off of the East Coast.
Behavior	Two seasonal molting times. Animals may live 50-100 years. Will act as scavengers eating dead fish and shellfish.
Disease and Predation	Lobsters are very cannibalistic towards each other in larval stages. Bacterial disease which enters during the molting process is a problem.
Genetics	Selective breeding for rapid growth is possible.
bioenergetics	It takes 5-7 years to grow to harvestable size. In heated ponds, this time can be reduced to 2-3 years. Growth dependent on food supply, water temperature, and sex.
Culture Methods	Pond culture.

Site Selection	Probable best site would be along North Spit with water pumped in from the ocean.
Site Rights	Division of State Lands. Army Corps of Engineers.
Processing/ Potential Uses	Most of the market would be for live animals, which would only require a packaging and shipping operation. Food and related products.
Economics	The market for the declining supply of American lobster is excellent. This sort of aquaculture practice would employ people in the breeding, harvesting, maintenance, and marketing. Profits probably would not be realized for 2-3 years at the very minimum and probably would be 7-9 years.
Environmental Considerations	Before the introduction of the lobster is to occur, the problem with the disease Gaffkemia would have to be eliminated.
Recommendations	This aquaculture practice may have problems in the following areas: importation of eggs, maintaining a colony, low temperature of the Pacific waters which may cause some molting problems.

DUNGENESS CRAB *Cancer magister*

Environmental Conditions	The Dungeness is indigenous to the area and found from mid-California to the Aleutians. This crab prefers sandy bottoms.
Behavior	These animals increase in size by a process called molting. This process occurs several times prior to sexual maturity and usually once a year thereafter. The Dungeness is a detrital bottom feeder and very cannibalistic.
Disease and Predation	Great losses occur in larval stages from heavy predation, cannibalism and pollution.
Genetics	Difficulty in molting while in captivity has been a constant problem to breeders.
bloenergetics	Usually breed in May and June. They have a larval stage lasting up to 12 weeks. The Dungeness reaches sexual maturity at the end of its third year.
Culture Methods	At the present time no successful commercial crab farm has been operated, though culture work on the Dungeness has been carried on at the Oregon State University Marine Science Center in Newport, Oregon, and at the University of California's laboratory at Bodega Bay, California.

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Site Selection	Areas along the North Spit below the Sitka docks in which ponds or cages could be erected might be feasible.
Site Rights	Division of State Lands. Army Corps of Engineers.
Processing/ Potential Uses	Cooking and cleaning and removal of meat, followed by canning and/or freezing. A strong fresh market also exists. Food, fodder and fertilizer.
Economics	There exists an excellent market for fresh and frozen crab meat, and the meat demands a high price per pound.
Environmental Considerations	
Recommendations	1. Authorities feel that the existing stocks, because of proper management, will always be able to provide enough crab meat through the existing fisheries. 2. At the present time, no successful commercial crab farm has been operated.

RAZOR CLAMS *Siliqua patula*

Environmental Conditions	Found on exposed open ocean beaches and beaches close to the ocean where salinities are high. It is indigenous to the area. Found normally below the 0 tide level.
Behavior	Normally found from the surface to 45 cm below the surface. They are capable of digging 30-60 cm vertically/minute. They are filter feeders and feed on plankton.
Disease and Predation	Problems with predators are few for the adult razor is capable of rapid motility. Larvae and young are preyed upon by fish, mammals and other invertebrates.
Genetics	Genetic crosses may be done in the future, but as of this time no work has been done with genetic hybrids of razor clams.
Bioenergetics	Razor clams have been shown to grow 45-110 mm in 2 years, 90-120 mm in 3 years and 110-125 mm in 4 years. They spawn in June and July, though sperm and egg can be present March through July.
Culture Methods	Bottom culture is presently employed. Hatchery methods for the clams are similar to that of the oyster.

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Site Selection	Razor clams can be grown in areas with a clean sandy bottom and constant high salinities. An area like the North Spit near the mouth of the bay should be suitable. Possible spill islands near the mouth of the bay might be utilized.
Site Rights	Division of State Lands. Army Corps of Engineers.
Processing/ Potential Uses	Razor clams can be processed rapidly and with a good percentage of meat retained as compared to other clams. According to Darrell Demory of the Department of Fish and Wildlife in Newport, there is a 50% meat yield from the Razor clam. Potential uses include food, fodder and fertilizer. There exists a large market demand by crab fishermen for use as bait.
Economics	There is a large demand for the Razor clam in the Northwest. Prices paid for the razor clam are the highest paid for any of the clams.
Environmental Considerations	Possible problems from increased densities, disease transfer and disposal of wastes must be considered.
Recommendations	D rrell Demory feels that this is one of the most feasible clams for farming.

COCKLES *Clinocardium nutallii*

Environmental Conditions	They are found commonly in Coos Bay in sand or sand/mud substrates, up to 8-10 cm below the surface.
Behavior	These clams may reposition themselves up to 10 cm below the surface. They are filter feeders, feeding on plankton.
Disease and Predation	Predators include the starfish, octopus, crabs, boring molluscs and shore birds. Extremes in salinity or temperatures along with excessive siltation can cause mortalities to occur.
Genetics	Hybrids have been possible with other species of clams.
Bioenergetics	Cockles reach an average size of 7-8 cm in 6 years.
Culture Methods	Bag suspension and bottom culture may be used. Fencing may be used to prevent predators from entering the culturing area.

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Site Selection	Current populations may be found on spoil islands near the Sitka docks, in the South Slough and other areas. Sand or sand/mud substrates are preferred.
Site Rights	Division of State Lands. Army Corps of Engineers.
Processing/ Potential Uses	Relatively hard to clean and process as compared to other clams. Meat is used mainly for chowder. Potential uses include food, fodder and fertilizer.
Economics	No large local market exists.
Environmental Considerations	Problems from increased population densities, disease introduction and waste pollution should be considered.
Recommendations	At the present time laws prevent the culturist from clam farming.

QUAHOG <u>Mercenaria mercenaria</u>

Environmental Conditions	The quahog is tolerant of variations in temperature, but not salinity. They require at least 22 ppt for successful hatching and development of larval stages. Not found locally.
Behavior	This clam is typical of any clam. It lives in the bottom substrate and reaches to the surface with its "neck" or siphon. It is a filter feeder, feeding on plankton.
Disease and Predation	Starfish, crabs, shore birds and boring molluscs are predators.
Genetics	Crosses of Mercenaria mercenaria with Mercenaria campechiensis have occurred.
lioenergetics	This animal grows to marketable size in 2 years in warm waters, and 5-8 years in colder waters. Marketable size is approximately 2-3 inches.
Culture Methods	Bottom culture is employed.

Site Selection	This particular species likes to grow on a firm bottom, made up primarily of sand. Areas of high siltation should be avoided. Parts of the North Spit, below the Sitka dock may be adequate.
Site Rights	Divison of State Lands. Army Corps of Engineers.
Processing/ Potential Uses	Fresh or canned are the two primary methods of processing. Potential use as a food source.
Economics	Development of the market would be needed before the Quahog becomes economically feasible.
Environmental Considerations	Possible problems from increasing population densities must be considered.
Recommendations	At the present time, laws prevent the culturist from clam farming.

BUTTER CLAM *Saxidomus giganteus*

Environmental Conditions	The butter clam, also known as the Washington or hardshell clam, is indigenous to Coos Bay. It is found in substrates consisting of gravel/mud or sand/mud. Butter clams grow best on crushed 2-4 cm gravel.
Behavior	They usually locate 15-30 cm below the surface and are only capable of retracting the neck. The butter clam is a filter feeder, feeding on plankton.
Disease and Predation	Predators include the starfish, octopus, crabs, boring molluscs, and shore birds. Extremes in salinity or temperatures along with excessive siltation can cause mortalities to occur.
Genetics	Hybrids have been possible with other species of clams.
Bioenergetics	Average growth rate is 2.5 cm per year. By planting in March, survival rates of 28% and higher may be realized over planting in December.
Culture Methods	Bottom culture similar to that used for the gaper is practiced. It is possible to mark juveniles with the vital stain, sodium alizarin monosulfate. The stain is incorporated into new shell growth leaving a red mark, for easy identification.

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Site Selection	A proper substrate must be developed in this region before intensive culture methods can be practiced.
Site Rights	Division of State Lands. Army Corps of Engineers.
Processing/ Potential Uses	These clams are normally processed so that they can be fried, minced or steamed. Food, fodder and fertilizer.
Economics	Market development needed before this would be feasible.
Environmental Considerations	Possible problems from high population densities should be considered.
Recommendations	At the present time laws prevent the culturist from farming clams.

GAPER CLAM *Tresus nuttalli*

Environmental Conditions	The gaper or empire clam is found locally in the bay in sand or mud, usually 25-60 cm below the surface.
Behavior	The gaper is capable of limited mobility. It is a filter feeder and thus feeds on plankton.
Disease and Predation	Predators include the starfish, octopus, crabs, boring molluscs, rays, and shore birds. Extremes in salinity or temperatures along with excessive siltation can cause mortalities to occur. The parasitic protozoan, Haplosporidia, causes white lumps throughout the tissue and may cause the tissue to become flaccid. Haplosporidia is found all along the Oregon coast.
Genetics	Hybrids have been possible with other species of clams.
Bioenergetics	Gapers reach an average size of 13-20 cm in seven years. They reproduce between January and July. The larvae spend several weeks in a free swimming stage, at which time they will settle to the bottom.
Culture Methods	Bag suspension and bottom culture have been used. When using bottom culture, the seed is set out at slack tides, high or low, so that seed will not be swept out of the bay by the tide before settling. Fencing has been used to prevent predators from entering culturing areas.

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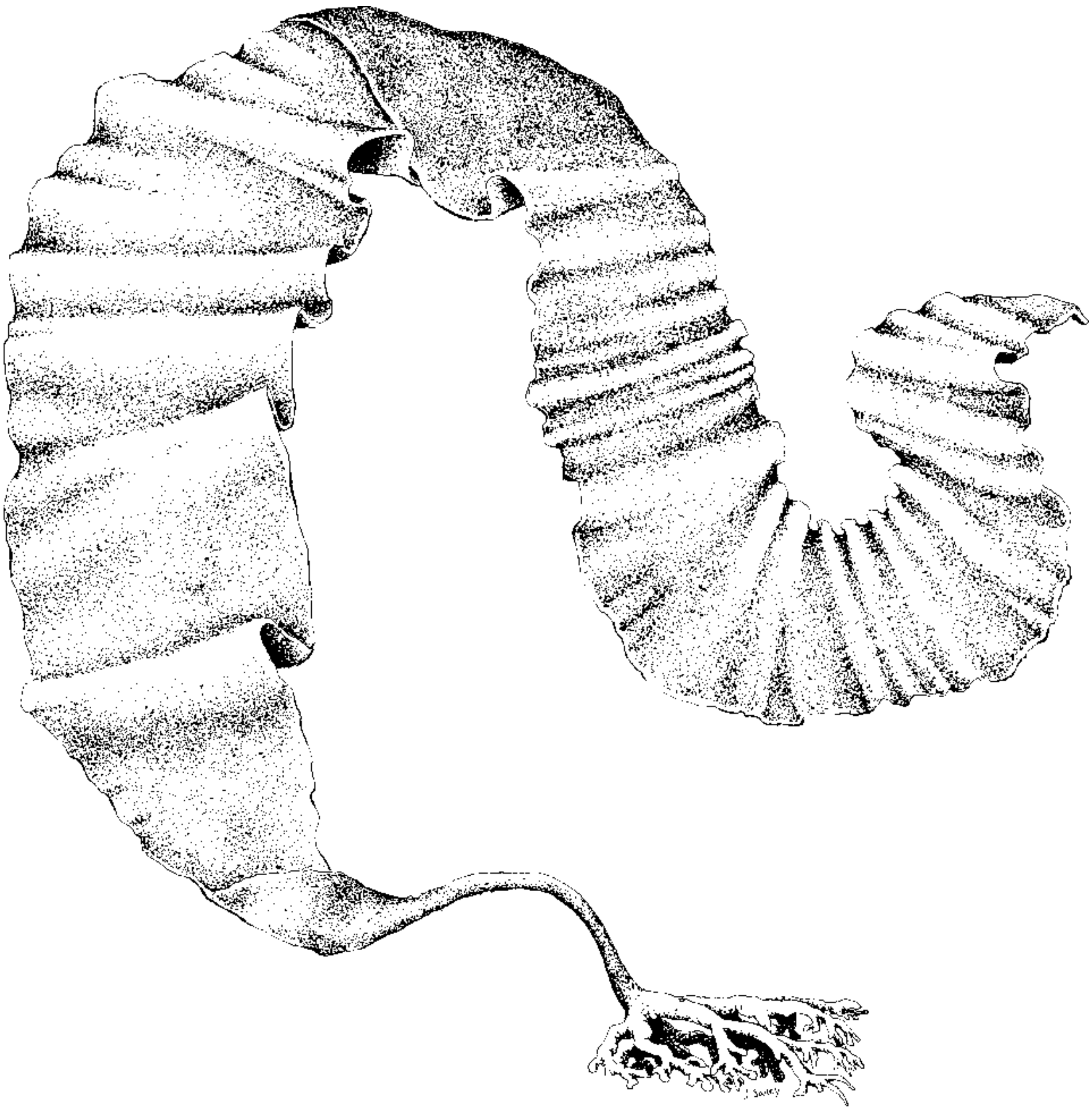
Site Selection	Within the estuary with sandy or sand/mud substrate. These animals could be grown commercially below Valino Island in South Slough and the lower half of Coos Bay, below the Sitka docks, for commercial use.
Site Rights	Division of State Lands. Army Corps of Engineers.
Processing/ Potential Uses	The gaper is very difficult to process for it takes an experienced shucker 2 minutes to clean and remove the meat. Most of the meat is used in the making of chowder. Food, fodder and fertilizer.
Economics	Presently a fresh, local market exists, but development of the market is needed. Meat yield of 13-20% can be expected, which makes this clam less desirable than others.
Environmental Consideration	Possible problems from increased densities should be considered.
Recommendations	1. At the present time, laws prevent the culturist from clam farming. 2. Recently diver operated harvesters have been used with good success. Some authorities, such as Wilbur Breeze, Oregon State University, feel that the harvesting of these animals will decrease natural populations, which may make the culturing of clams a feasible operation.



Algae ...

"Algae form all or part of the primary productivity base for most types of aquaculture, and especially mariculture. Phytoplankton and macrophytes utilize organic wastes, produce oxygen and contribute to the food chain in many fish culture operations so that the culture of algae or the management of algal populations may be considered as an integral part of many forms of fish and shellfish culture. Algae are also utilized directly, however, in providing a valuable source of human food, crop manure, and raw material for the chemical and pharmaceutical industries."[1]

The brown algae and red algae, phylum Phaeophyta and Rhodophyta respectively, form the two main groups of economically important algae. The red algae are utilized mainly for food, and act as the major source of agar-agar and carrageenan, while browns serve their usefulness through the properties of the algin associated with them and as a food source, animal fodder and fertilizer.

Of the red algae found throughout the world, about thirty genera are of commercial importance. Several of them are found in the Coos Eay area from Cape Arago to the North Spit. General reasons for not finding important reds within the bay in large amounts relate mainly to environmental conditions. Factors that can inhibit or prevent growth include salinity, small suitable sub-tidal areas, temperature, light intensity, and a general lack of hard, clean substrate for attachment. All of the above factors can be altered to provide optimum growth areas for the algae.

To alter the environmental conditions on a permanent basis requires capital and an area within a bay to carry out a plan. Assuming capital to be available, one is faced with the proposition of acquiring property within a bay. At this writing there are no laws that specifically lend themselves to the legalities of a party wanting to utilize public properties for a private alga farm. Tidelands are both privately and publicly owned, while land below the low low tide line belongs to the state.[2] Also, public access, recreation and navigation take priority over private interests.3

The law is not the only concern. Once persons competent to design and operate algae farms have been found, one still needs to have adequate processing plants available. The nearest bulk algae processor is the Kelco Company, located in San Diego, California. Local processing plants should be built and operated to avoid problems associated with the transporting of large quantities of algae.

The culturing of the browns, especially the _Laminaria,_ has been taking place for years in various parts of the world, and intensive culture of _Macrocystis_ in North America is presently occurring in Southern California.[4] In the past decade the culturing of algae has been researched and the reasons for this are numerous. The brown algae is useful as a food source for human and animal consumption _(Nereocystis),_ as fertilizers, and after processing, as valuable material in the medical, chemical, textile and food industries. The potential for expanding its usefulness is good. Along with this growth new jobs would be created.

There is also a demand for agar-agar, algin and carrageenan, all of which are derived from either the red or brown algae. The continuing demand for these derivatives looks good.[5] Since these derivatives are one of the most important aspects of the algae, a brief explanation what each of these derivatives is, what they do and from which algae they may be extracted is presented here.

CARRAGEENAN

Carrageenan is a polysaccharide extracted from *Chondrus* and *Gigartina* and in recent years from *Eucheuma* and *Iridaea,* all of which are red algae. The applications of carrageenan are dependent upon its properties to act as a gelling agent. It is mainly used then as a thickener, stabilizer, and gelling agent. The removal of the carrageenan from the algae involves a process of freezing and thawing the algae many times, which causes the algae to release the carrageenan.

Those red algae which are found locally in the bay and contain carrageenan include *Iridaea* and *Gigartina.* Harvesting methods for the carrageenophytes include collection of storm cast weed, raking of bottom substrate with long handled rakes, and picking by hand in operations involving culture on nets.

AGAR-AGAR

Agar-agar is a class of vegetable gums derived from at least twenty-eight genera of seaweeds. Agar's properties lends itself well to use as a culture medium and making casts of objects in dentistry, plastic surgery, criminology and sculpture. The food industry uses agar as an emulsifier, stabilizer, gelling agent and thickener. Agar prevents tackiness and retards the aging process in breads. Confectioners find it useful in candies, ice creams and sherberts. In the medical profession agar serves a major market as a laxative (Serutan), and as a culture medium.

It has been estimated that U.S. agar consumption in 1966, was 1,050,000 pounds with about 40% going to laboratory, pharmaceutical and dental uses, while 30% went to the bakery and confectionary industries. The remaining 30% was distributed among the meat packers and various miscellaneous users.[6]

ALGIN

Algin is also a vegetable gum and is one of the principle constituents of most brown algae. Its properties of gelling and thickening allow for its use as a thickener, emulsifier and suspending agent. Algin is used in many areas such as the drug, textile, paper and food industries.

The naturally occurring brown algae, _Macrocystis,_ is one of the most important alga in terms of algin production. Though it contains substantially less algin than a number of other brown seaweeds, it is the most accessible and easily managed.

Harvesting of the giant kelp _Macrocystis_ presently involves large ships with cutter blades used to cut the top 3-4 feet off the plant. In this manner a number of harvests per year are realized. On the west coast the main bulk of _Macrocystis_ processing takes place in San Diego, California, by the Kelco Company. The Kelco Company is also involved, along with the Department of Fish and Game of California, in the maintenance and propagation of the giant kelp beds. Much work in this area has been accomplished.7

CONCLUSION

The seaweed of major economic importance that grows in the Coos Bay area is the brown alga _Macrocystis._ This particular algae grows in the open ocean and harvesting techniques using large ships with cutter blades have been employed elsewhere. The development of an algae farm within the bay at this time seems less than favorable. Laws, lack of proper conditions, harsh weather, no real local market and the general state of the art of algae culture in Coos Bay tends to make one wary of the culturing of marine algae. The opportunities, were it possible to get around these problems, are immense and exciting. Perhaps someday we will see a commercial enterprise set up in which the kelp Macrocystis is harvested and cared for like any high yield land crop.

In the following charts, information on the characteristics, culture methods and related factors, and recommendations on the commercial raising respectively of red and brown algae in Coos Bay is presented. Table II is a detailed outline of activities related to the manipulation et natural energy and materials in an algae aquaculture enterprise.

FOOTNOTES

1. Neish. 1975. Culture of Algae and Seaweeds. FAO Technical Conference on Aquaculture. Kyoto, Japan.

2. Ownership of Oregon Estuaries. 1975. State of Oregon - Division of State Lands.

3. Oregon Attorneys Opinion : 6861. Issued Sept. 17, 1971.

4. I. Ashkenazy. 1975. Manna from the Sea. Oceans: Nov. 3.

5. I.C. Neish. 1975. Culture of Algae and Seaweeds. FAO Technical Conference on Aquaculture. Kyoto, Japan.

6. V.J. Chapman. 1970. Seaweeds and Their Uses. Methuen and Co., Ltd., London, 173 pp.

7. I. Ashkenazy. 1975. Manna from the Sea, Oceans: Nov. 3.

RED ALGAE	Rhodophyta
Environmental Conditions	Found worldwide, intertidally,and subtidally. Type of species present is dependent upon bottom conditions, light intensity and environmental conditions.
Behavior	Attached to substrate. Growth of thallus is nearly apical. Complete absence of flagellated cells during any life stage. Feeds by photosynthesis.
Disease and Predation	Fungal, bacterial, and viral diseases have been discovered. Successful growth and establishment can be greatly affected by grazing of sea urchins, limpets, boring and grazing molluscs.
Genetics	
bioenergetics	See Table II.
Culture Methods	Present culture methods fitlude the use of artificial substrates such as rings, rafts, and ropes. Some practices have increasd yield by dynamiting the bottom (to increase available substrate), weeding unwanted plants, and importing mother plants into the area.

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Site Selection	Open ocean and areas in the bay with stable high salinity.
Site Rights	As of this time, no laws have been written concerning the establishment of marine plant aquaculture.
Processing/ Potential Uses	For the edible species, the entire plant is usually consumed. Agar processing utilizes 6-7% of the total weight. Used for food, fodder, fertilizer, Agar, Carrageenan, trace elements. One species, Digenia simplex, is made into an antihelminthic.
Economics	The econimic feasibility of cultivating red algae has not been strongly establishes on the West Coast. The Lummi Indians of Washington State have sold Iridea to processors in Maine. This type of aquaculture would require manpower and capital investment in the initial set-ups, maintenance, harvesting, processing and marketing.
Environmental Considerations	1. Intensive algae aquaculture will increase habitat space of pelagic fishes and benthic organisms. 2. There may be a decrease in bottom production due to an decrease in light penetration.
Recommendations	1. Laws affecting the harvesting of algae should be reconsidered. 2. Prospective marine algae farmers should look at Oregon Revised Statute 274.885.

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Table II

The manipulation of natural energy and materials through activities involving the use of capital and labour in an algal aquaculture enterprise

Activities involving the use of capital and labour	ORGANIC ENERGY AND MATERIALS		INORGANIC ENERGY AND MATERIALS		
				Solar radiation	
	Seed stock	diseases and pests	Water, dissolved nutrients and gases	Photic energy	Thermal energy
1. Invest in capital equipment which transports and modifies natural energy and materials	Enclosures, ponds, buildings, substrate, rafts and other suspension materials	Filters and sterlizers	Water distribution system and equipment for fertilizer provision	Electric lights, reflectors and shades (to control weed growth)	Heaters, coolers. thermal effluent
2. Purchase and apply consumable materials; purchase energy, materials and labour for maintenance and operation of equipment	Materials, energy and labour to maintain enclosures, substrate and suspension materials	Filtration materials, pest control agents, water treatment materials, energy and labour for pest contaminant control	Energy to pump water; materials and labour to maintain distribution system	Light bulbs, maintenance materials and energy to operate and maintain lights or shades	Materials and energy to operate and maintain heat exchangers, valves heating plants or refrigeration units
3. Conduct applied biological research to develop crop control and management techniques	Genetics, clone selection; population biology, ecology, phytosociology	Pathology, microbiology, mycology, biochemistry, herbivore control	Nutritional physiology	Physiology of photosynthesis and respiration	Physiology
4. Monitor crop and culture conditions; control *use* of energy and materials to achieve optimal benefit:cost ratio	Control population structure by monitoring and regulating harvest rates, density, distribution pattern, etc.	Monitor and control levels of pests and contaminants	Regulate water flow and fertilizer rates to get optimal cost: benefit	Control light intensity, quality and duration if possible	Monitor and control water temperature
	CULTURED ALGAE BIOSYNTHESIZE THE DESIRED END PRODUCTS				
5. Harvest, process and market the yield; maximize efficiency or profitability by regulating aquaculture farm production to suit market structure to as great an extent as possible	Regulate harvest rate to maintain optimal population structure and density	Integrate harvest regime with pest **control levels** to suit market demands	Integrate harvest techniques and water management	Manipulate access to light to "finish" the product before harvesting	Manipulate temperature as an aid to "finishing" or storing end product

BROWN ALGAE Phaeophyta

Environmental Conditions	Principally temperate, rarely reproduce above 12-16°C. Salinity, light intensity, wave action, and type of available substrate will affect what species are present.
Behavior	Mature only under cold water conditions. Found attached to substrate in subtidal and tidal areas. Photosynthesis used for energy production. Mineral requirements include Ca, Mg and Fe.
Disease and Predation	Fungal, bacterial, and viral diseases have been discovered. Successful growth and establishment can be greatly affected by grazing of sea urchins and abalone. Limpets, boring and grazing molluscs can also be a potential problem.
Genetics	Hybrids have been produced.
Bioenergetics	See Table II.
Culture Methods	Present culture methods include the use of artificial substrates such as rings, rafts, and ropes. Some practices have increased yield by dynamiting the bottom, weeding unwanted plants, and importing mother plants. Laminaria and Macrocystis have lent themselves well to mechanized harvesting methods. Nereocystis may also lend itself well to mechanical harvesting.

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	Site Selection	Open ocean and areas in the bay with constant high salinity.
	Site Rights	As of this time, no laws have been written concerning the establishment of marine plant aquaculture.
01	Processing/ Potential Uses	Processing brown algae for food would involve harvesting, washing, cutting, drying and packaging. If the algae was to be used for algin production, it would be harvested and processed (repeated freezing and thawing). Potential uses include food, fodder, fertilizer, emulsifiers, stabilizers, gelling agents, trace elements and use in the dental field. The textile industries use algin as a thickener of pastes and a paper sizer.
	Economics	Brown algae of high quality is in demand by the Kelco Company of San Diego, California. Investments for culture and harvesting equipment may be quite high. Necessary equipment might include ropes, weights, anchors, settling ponds, tanks, boats, SCUBA equipment, and harvesting and drying areas.
	Environmental Considerations	1. Intensive algae aquaculture will increase habitat of pelagic fishes and benthic organisms. 2. There may be a decrease in bottom production due to a decrease in light penetration.
	Recommendations	1. Commercial harvesting of Marcocystis along with culture methods should be considered. 2. Laws affecting the harvesting of algae should be reconsidered. 3. The future of algae of high quality looks good. 4. Prospective marine algae farmers should look at Oregon Revised Statutes 274.885.

Legal Aspects...

Laws that pertain to in-bay aquaculture practices are essentially limited to oyster culture. The reason for this is mainly a historical one. When most, if not all of the present regulations were being developed, aquaculture other than of oysters and fish was an unheard of concept.[1] In-bay culture of fish, i.e., the raising from egg to harvesting size within a confined area, has yet to be realized in Oregon. Thus with fish culture, one must consult those agencies involved in water-use planning within the bay (see Appendix C) in order to obtain information on policies and regulations.

OYSTER CULTURE

In the culturing of oysters, regulations governing oysters are found in the Oregon Revised Statutes (ORS) 509.425-509.510 (see Appendix A) and in the Oregon Attorney Opinions (OAO)625-10-275 through 625-10-295 (see Appendix B). These are briefly commented upon here.

LAND ACQUISITION

In order that the potential oyster farmer will know of oyster lands, all oyster lands have been classified (ORS509.425). This is a general classification encompassing all likely oyster lands with a brief description of their suitability for oyster culture.

Upon locating unused oyster lands the individual may apply for new oyster plats (ORS 509.431). A notice of intent must be published once a week for two consecutive weeks in a newspaper of general circulation in the counties where oyster plats are requested, as well as notifying the Fish Commission. Thirty days after the publication the Fish Commission may grant or deny use of the area referred to in the application.

TAXES

Upon obtaining oyster plats, fees that must be paid are a $2/year/acre and 5 on each gallon of oysters produced (ORS 509.441).

WITHDRAWAL OF LANDS

Other laws pertain to the established oyster farmer. ORS 509.439, states that unproductive oyster lands (resulting from controllable factors) may be reclaimed for re-distribution. Uncontrollable factors include the unavailability of seed stock, infestation by pests or disease and health restrictions. Controllable factors include paying of taxes, and the improper use of lands, for which those lands can be reclaimed by the state for redistribution.

PUBLIC ACCESS

ORS 509.455, states that oyster plats when properly marked are deemed and protected as private property, but such plats may not restrict the rights of the public to the use of the water of this state in a normal and customary manner. OAO-6861, issued September 17, 1971, may clarify this statute. "The gist of this opinion was that though the State of Oregon has and can sell or lease submersed or submersible lands, the rights of the public to hunt and fish by constitutional guarantee were never relinquished. Thus the public may hunt or fish upon the oyster persons land, but the public is restrained from harvesting or unduly disturbing the grower's oysters which are considered to be domesticated animals."[2]

Thus the oyster person utilizing public property should be aware of his rights and those of the public.

A number of problems that the culturist of other invertebrates will encounter involve ownership rights. Who owns the clams on a private clam bed after there has been a natural spawn adjacent to your beds? The ability to prove ownership of your clams is paramount in preventing the general public from claiming rights to those clams. This will be the case for the raising of any indigenous species that still spawn naturally in the area that the aquaculturist utilizes.

The reason the public can not go and take oysters from the oyster farmers beds is that there no longer exists a naturally spawning population of oysters in Coos Bay.[3] All seed stock is presently purchased from out of state sources and one may show legal ownership through this transaction (OAR10-295).

Until the laws are changed, one can foresee little future for the great potential that invertebrate aquaculture presents. Perhaps when the demand for food grown in an economically feasible manner becomes essential, the laws will be changed. In the meantime, it is hoped that our legislators will be foresighted enough to look ahead and change these laws gradually so that we may plan and prepare for our future.

Following are the appendices referred to above which may be useful to persons interested in considering developing an aquaculture enterprise.

FOOTNO1ES

1. Northwest Mariculture Laws. 1975. Papers and presentations from a Symposium held at the Law Center. University of Oregon, Eugene. Pg.

2. ________. Pg. 16.

3. Al McGie. 1976. Oregon Department of Fish and Wildlife. Personal communications.

Water Quality...

One of the most important considerations when looking into the prospective future of aquaculture the quality and quantity of available water. Phis is often referred to as the "limiting factor," that , with no water, or water of bad quality, no culture program is possible. Water quality conditions for ideal growth may vary considerably from species to species, but whatever the species, the higher the quality of water, the more likely the success of the operation.

In recognition of the importance of water quality in the development of an aquaculture industry in Oregon, and for other reasons, the State Legislature passed the following statute.

O.R.S. 509.505 Placing in water matter injurious to shellfish.
It is unlawful for any person, municipal corporation, political subdivision or governmental agency to deposit or allow to escape into, or cause or permit to be deposited or escape into any public waters of this state, any substance of any kind which will or shall in any manner injuriously affect the life, growth or flavor of shellfish in or under such waters (Formerly 509.460).

Important parameters of water quality for aquaculture are temperature, salinity, dissolved oxygen, pH, total dissolved solids, hardness, turbidity, and coliform organisms.

TEMPERATURE The water temperature of Coos Bay varies greatly. Existing water quality standards indicate that no discharges will be permitted which raises the temperature of water above 64°F. Increased temperatures will have an adverse effect on many of the native fish and aquatic life. "The adverse effect of increased temperatures on salmon is of particular significance in the Pacific Northwest since relatively small increases in temperature retard hatching and egg development, cause stress in juvenile fish, promote disease and disturb adult fish migration. Temperatures in the range of 48-58°F. would be more desirable during salmon spawning periods. (Coos-Curry Environmental Protection Program, Volume 1, Water Resource Management Plan, April 1974).

SALINITY The salinity of the water of Coos Bay is related to the amount of runoff, climatic conditions, and tidal influx of saltwater. Winter rains and high runoffs will greatly lower the salinity of most parts of Coos Bay. Organisms which presently live in this region are able to withstand this fluctuation. However, great variance in salinity will cause mortality.

DISSOLVED OXYGEN(DO) This is the amount of oxygen in the water. It is commonly expressed in mg/liter which is also referred to ppm. The water quality standards of estuarine waters state that it must be at least 6 mg/liter.

DO is utilized by bacteria during the breakdown or reduction of organic matter, and because of this it is a good indicator of the presence of organic waste material.

pH pH is the measure of hydrogen-ion activity. In the absence of external influence, the variations of pH in good quality waters are generally small. The pH in shellfish growing areas must be between 7.0 and 8.5. In other areas of the bay the pH must be within the range of 6.5 to 8.5.

TOTAL DISSOLVED SOLIDS(TDS) Total dissolved solid concentrations such as heavy metals can greatly affect fish and other aquatic organisms. At this time there are no major problems with heavy metals, insecticides, and pesticides in Coos Bay[2] (Glen Carter, DEQ, July 1976).

HARDNESS Hardness of the water is caused by the presence of minerals, particularly magnesium and calcium, and sometimes iron, manganese, strontium, and aluminum. Often the presence of these metals will have detrimental effects on many organisms. Anadromous Fish Corporation has had problems with excessive iron in the water at their planned hatchery located at Jordan Cove.3

TURBIDITY Turbidity is the measure of the scattering of light as it passes through water. It is caused by suspended material, silt, and sometimes algae. High turbidity is detrimental to shellfish, fish, and other aquatic life. In estuarine waters no discharge causing more than a 5 Jackson Turbidity Unit increase is allowed. Turbidity readings fluctuate throughout the year. Heavy siltation areas should be avoided for shellfish culture.

COLIFORM ORGANISMS The coliform group of organisms is not in itself harmful to man. However, the presence of coliform organisms is a reliable indication of the potential existence of pathogenic bacteria. Two basic analyses are generally conducted, both of which express the results in terms of the number of organisms per 100 ml of sample. The total coliform analysis includes organisms which are found in various types of vegetation in soil, and within the intestines of man and all warm-blooded animals. The fecal coliform test measures only these organisms which inhabit the intestines of man and animals. High fecal coliform counts may also be caused by animal waste such as the untreated runoff from feedlots. The tests are significant in evaluating both the potential of a stream for spreading waterborne diseases and the effectiveness of waste treatment methods.[4] Oregon state water quality standards state that fecal coliform counts may not exceed 70/100 ml in shellfish growing areas and 240/100 ml in other estuarine areas.

The Department of Environmental Quality has been monitoring the water quality of Coos Bay from 1957, and of South Slough from 1967. Mr. Glen Carter, July 1976, of the Department of Environmental Quality, stated that he thought that the water quality of Coos Bay would probably not change (except for the decrease in the amount of chlorides) or improve very much in the future because of slow flushing action in the bay and the presence of inland farming, which causes high coliform counts during periods of high runoff.

The following graphs are of the water temperature and salinity viewed over an eleven month range. All information was compiled from the Department of Environmental Quality printouts from the past nineteen years. The high and low ranges of both parameters are plotted. Note that assigned numbers of water quality checkpoints do not correlate with those of the Department of Environmental Quality. Figure II shows those assigned numbers to actual site location in Coos Bay.

FOOTNOTES

1. Coos-Curry Environmental Protection Program. 1974. Vol. 1, Water Resource Management Plan.

2. Glen Carter. 1976. Personal Communications. Department of Environmental Quality. Portland, Oregon.

3. J. Vail. 1976. Personal Communications. Anadromous Fish Corporation. North Bend, Oregon.

4. Coos-Curry Environmental Protection Program. 1974. Vol. 1, Water Resource Management Plan.

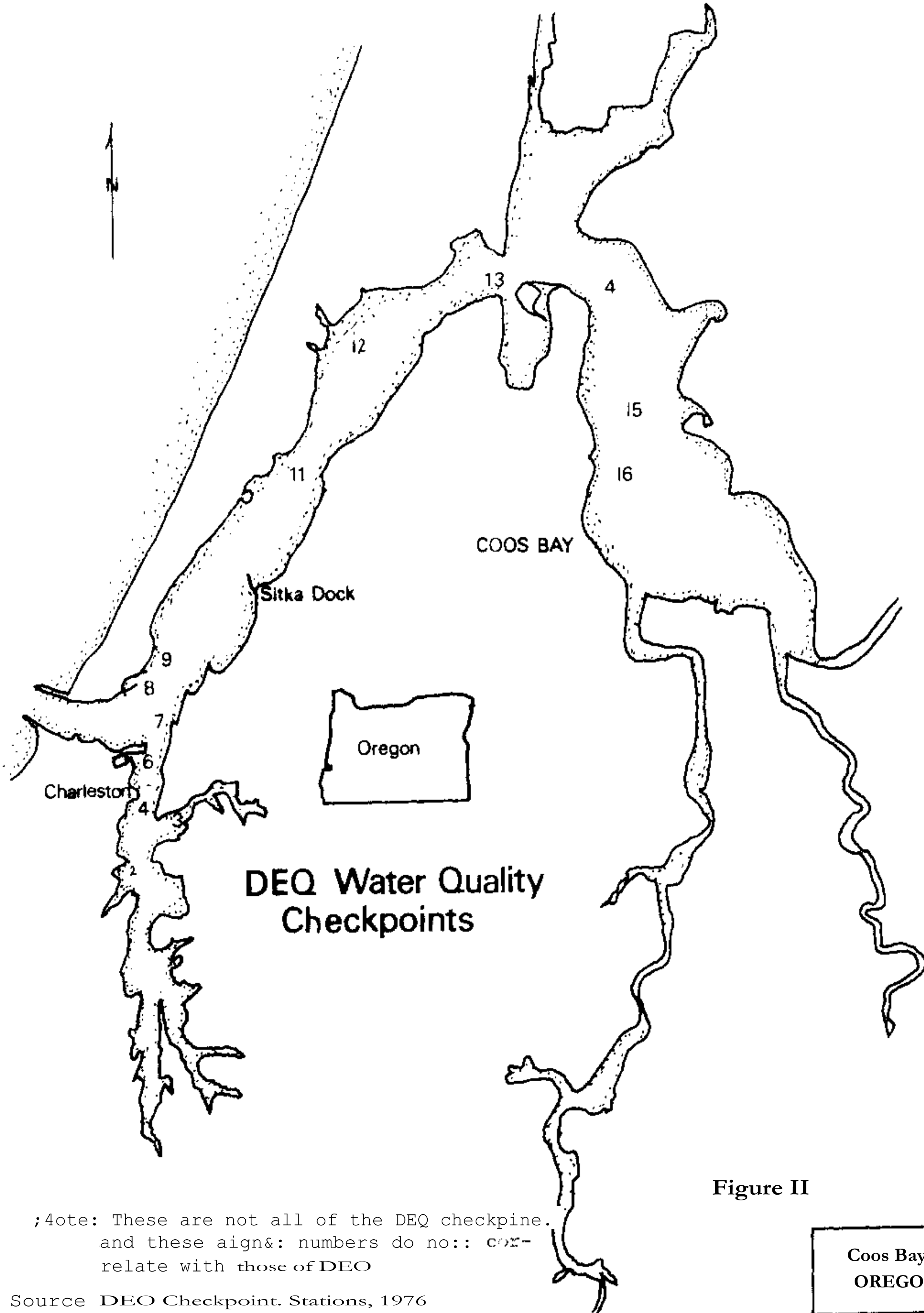


Figure II

;4ote: These are not all of the DEQ checkpine. and these aign&: numbers do no:: cor- relate with those of DEO

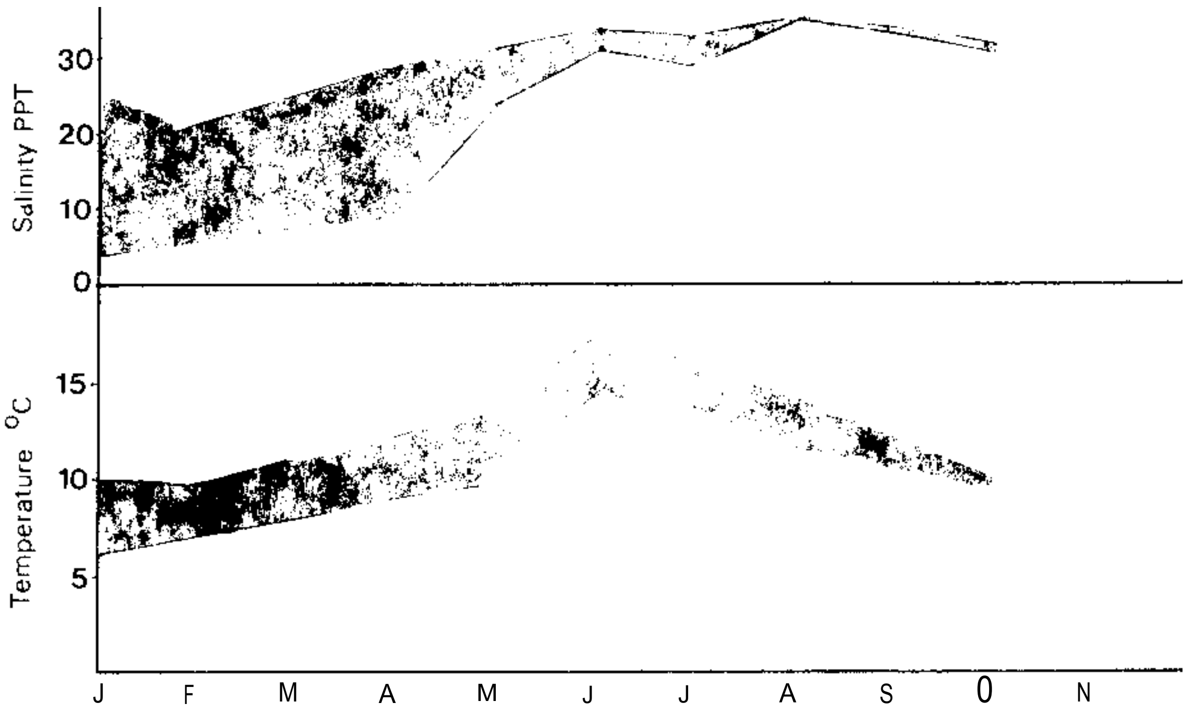
Source DEO Checkpoint. Stations, 1976

Coos Bay
OREGON

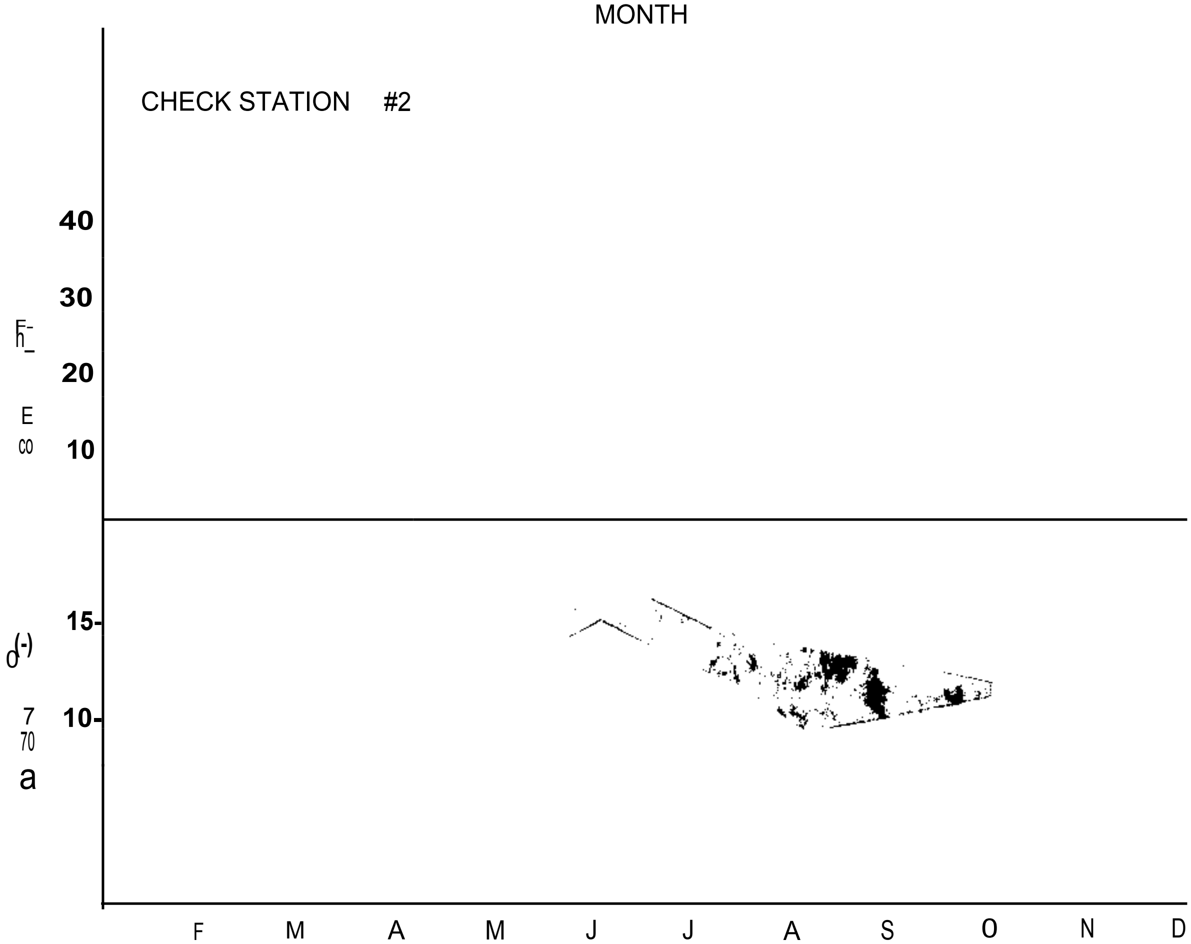
DEQ WATER QUALITY CHECK POINTS

CHECK STATION #1

Shaded area shows high and low extremes over a 19 yr. period.



CHECK STATION #2



DEQ WATER QUALITY CHECK POINTS

CHECK STATION #3

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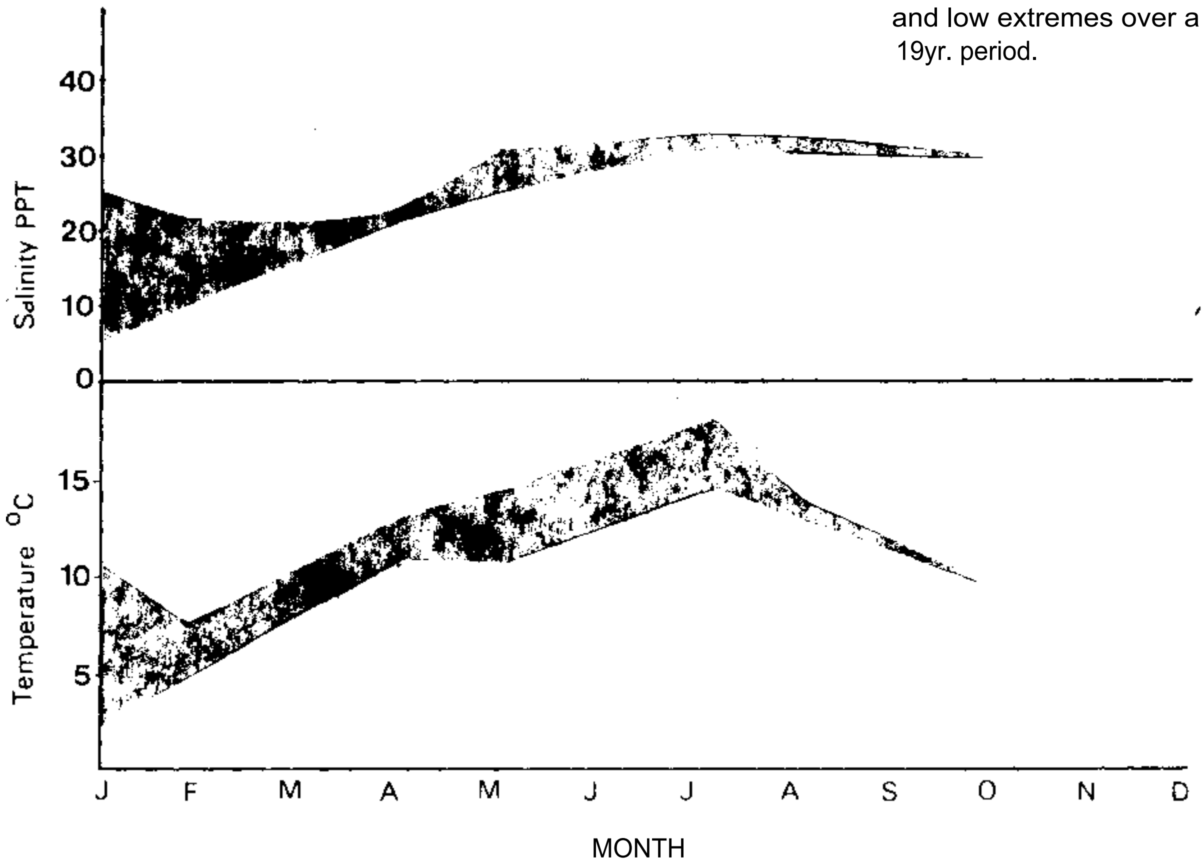
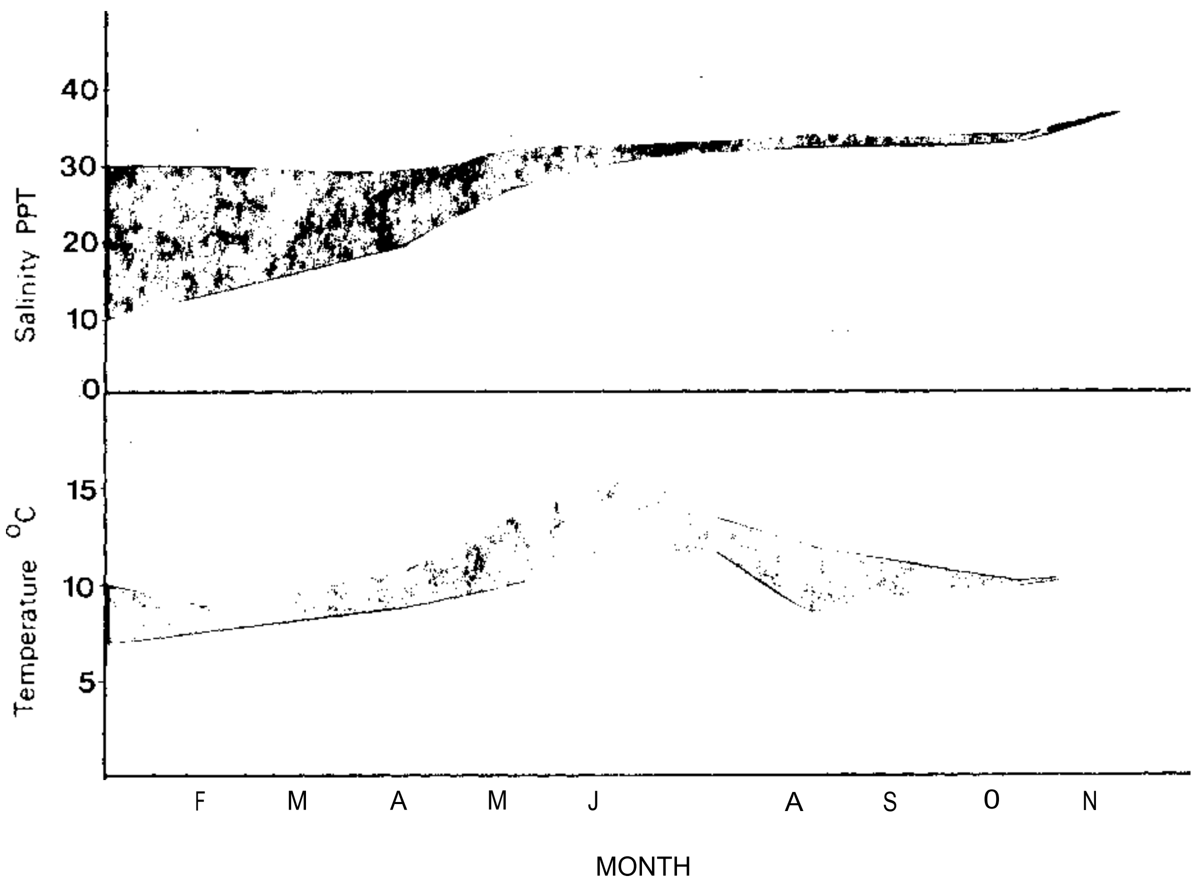
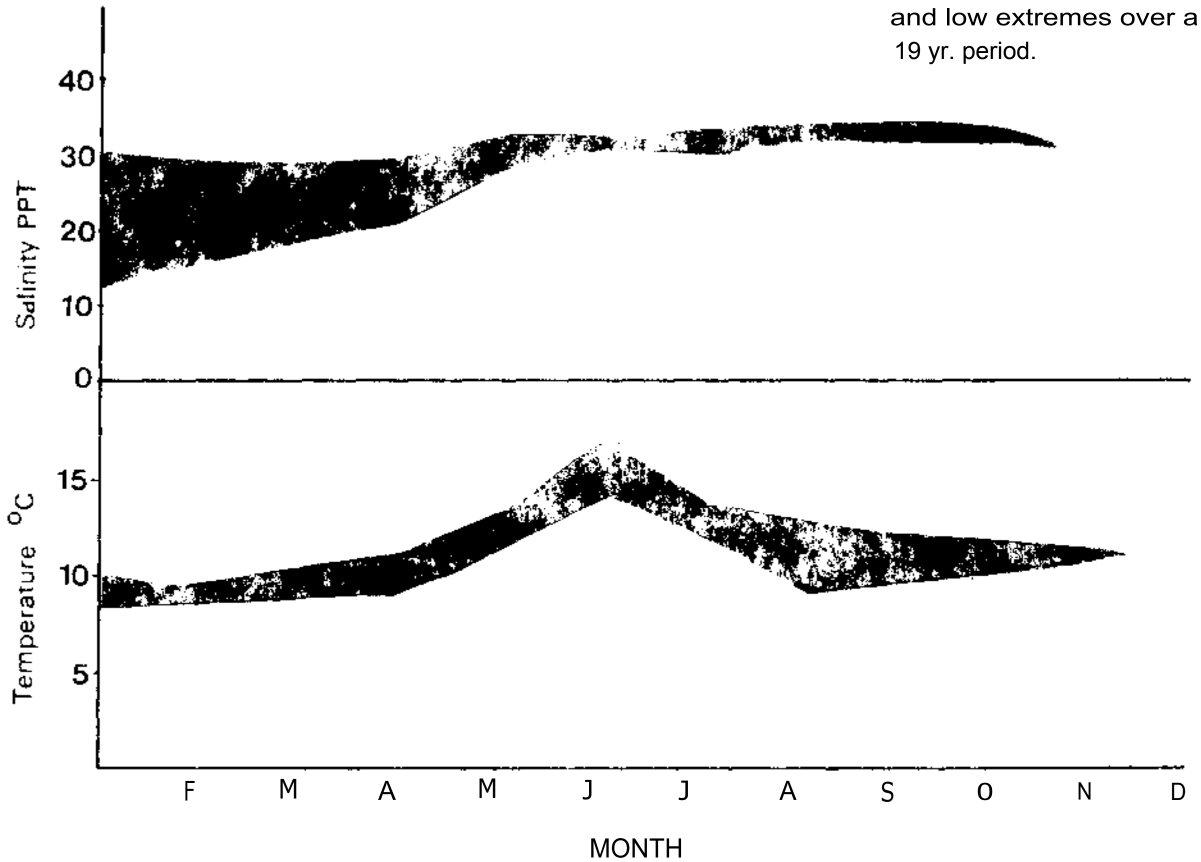


CHECK STATION #4

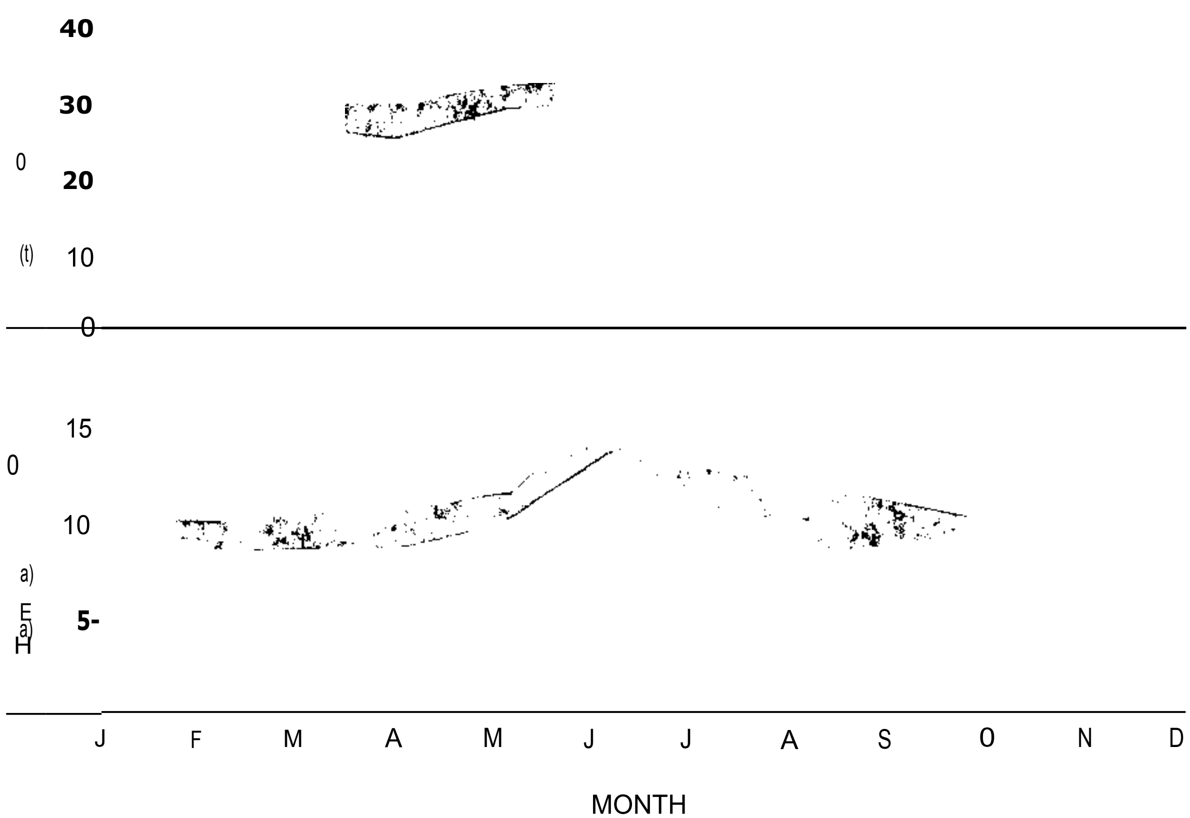


D E Q WATER QUALITY CHECK POINTS

CHECK STATION #5



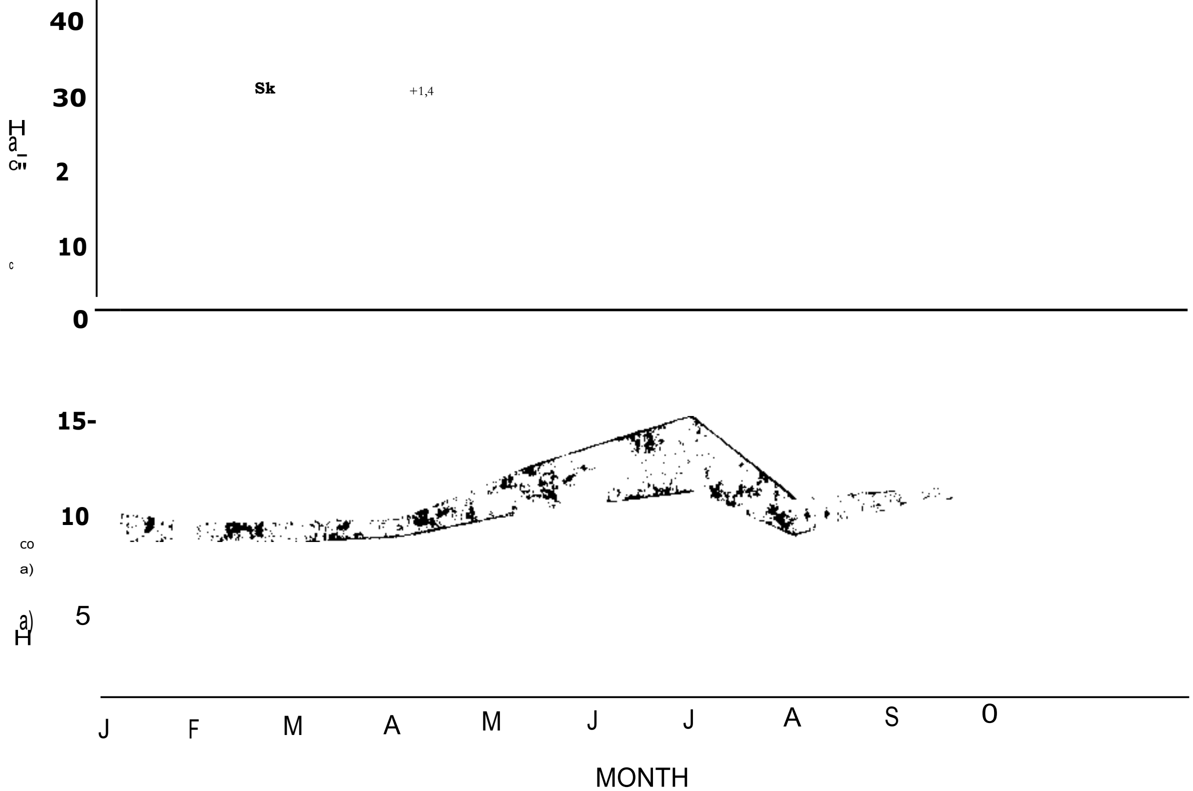
CHECK STATION #6



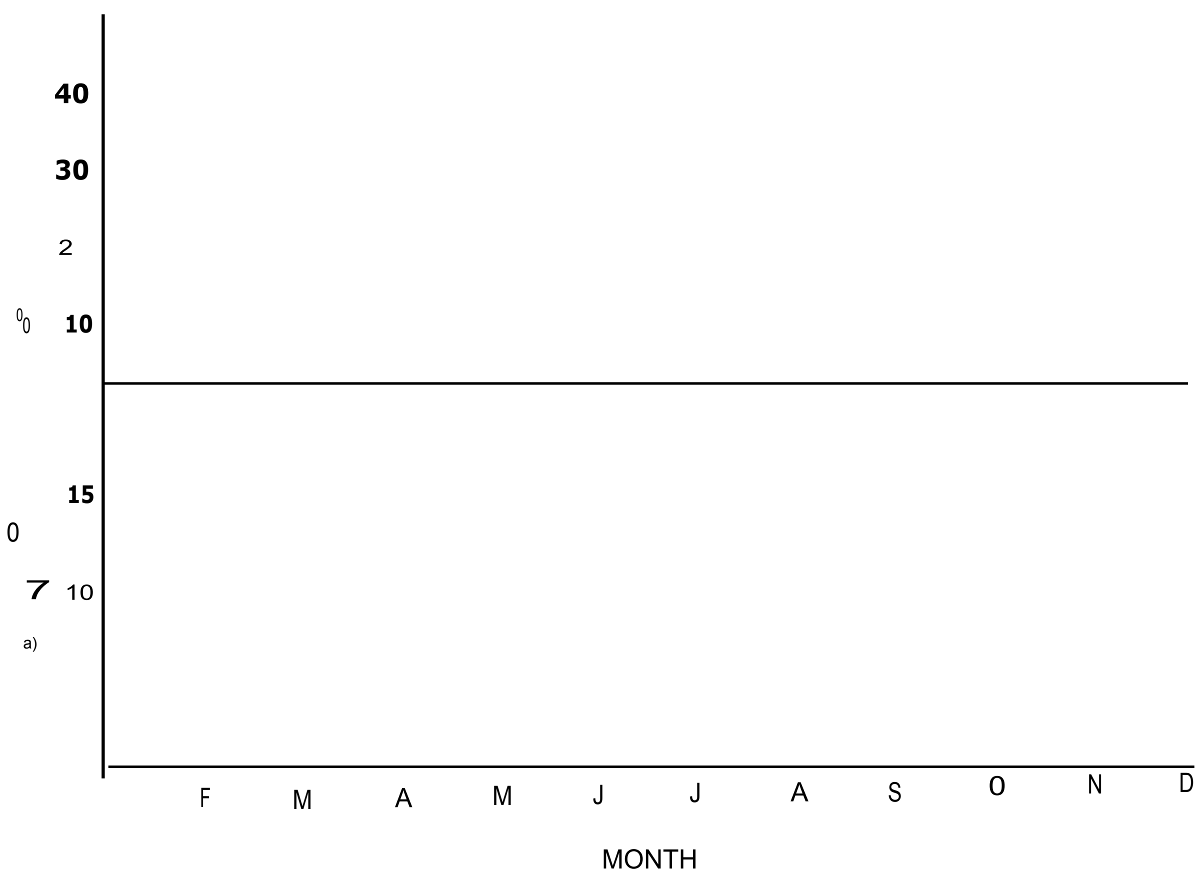
DEQ WATER QUALITY CHECK POINTS

CHECK STATION #7

Shaded area shows high and low extremes over a I9yr. period.



CHECK STATION #8



DEQ WATER QUALITY CHECK POINTS

CHECK STATION #9

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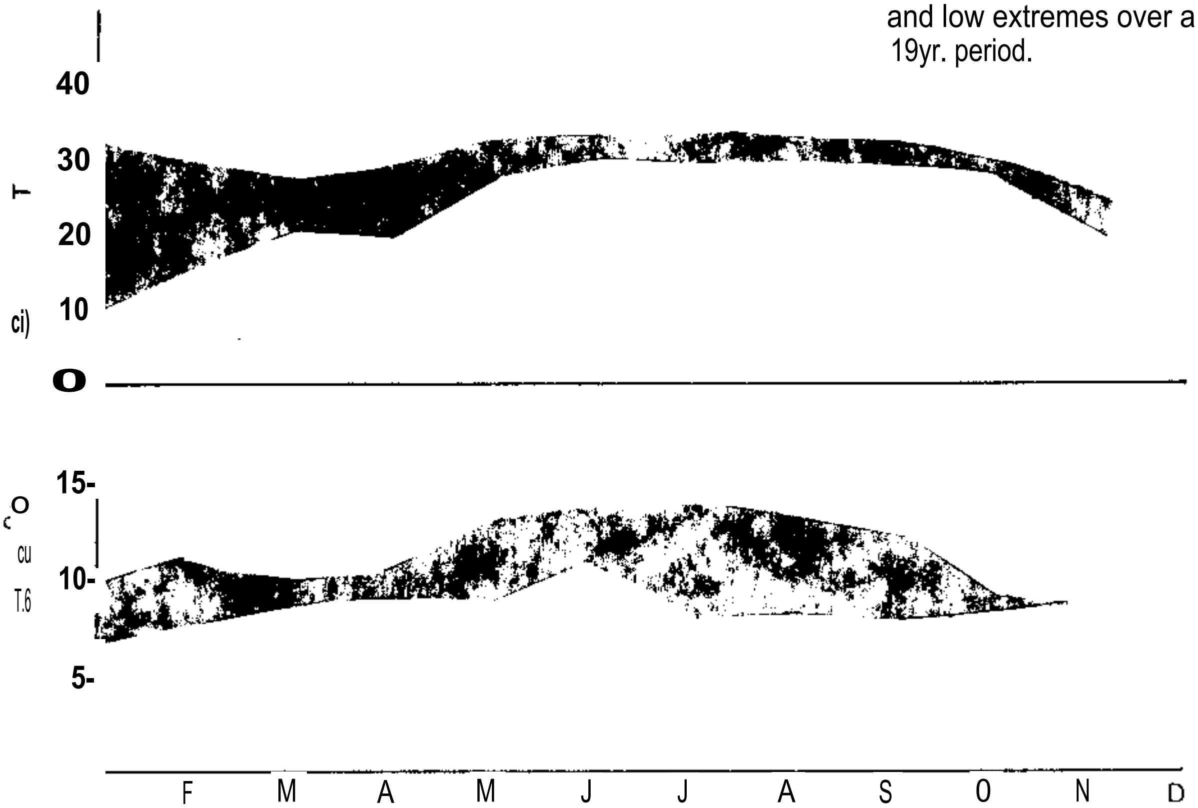

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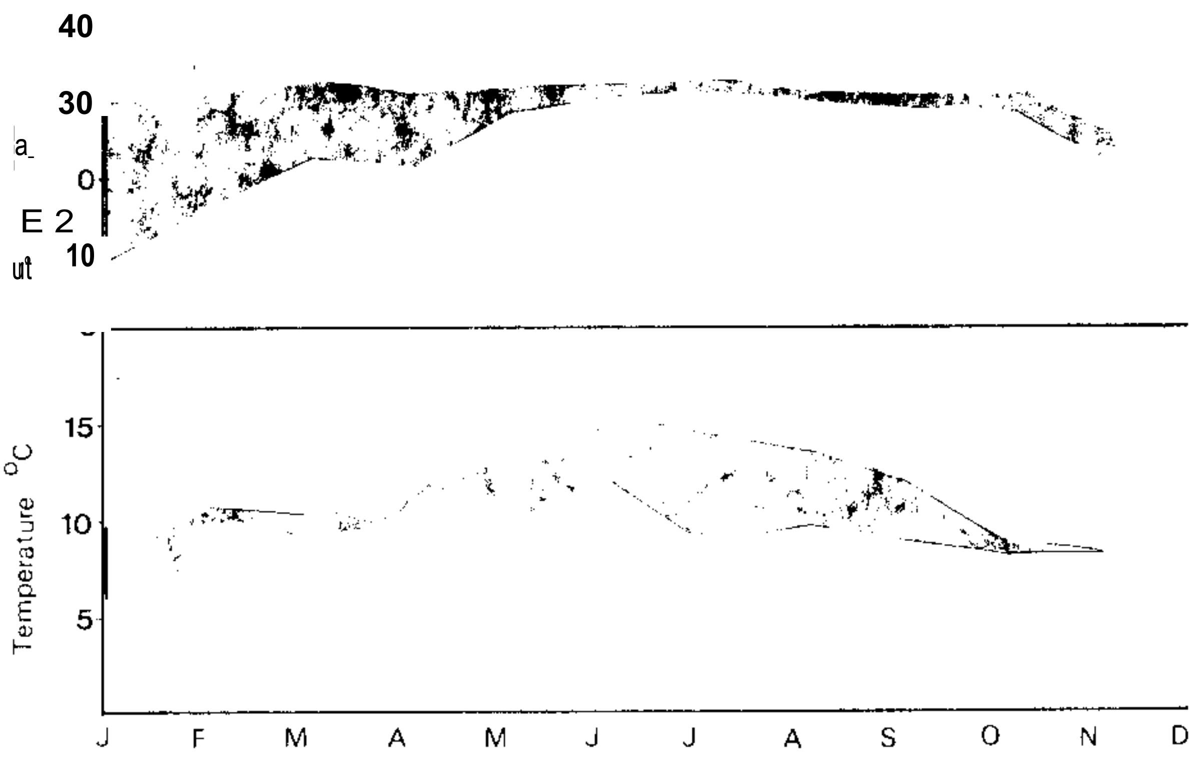
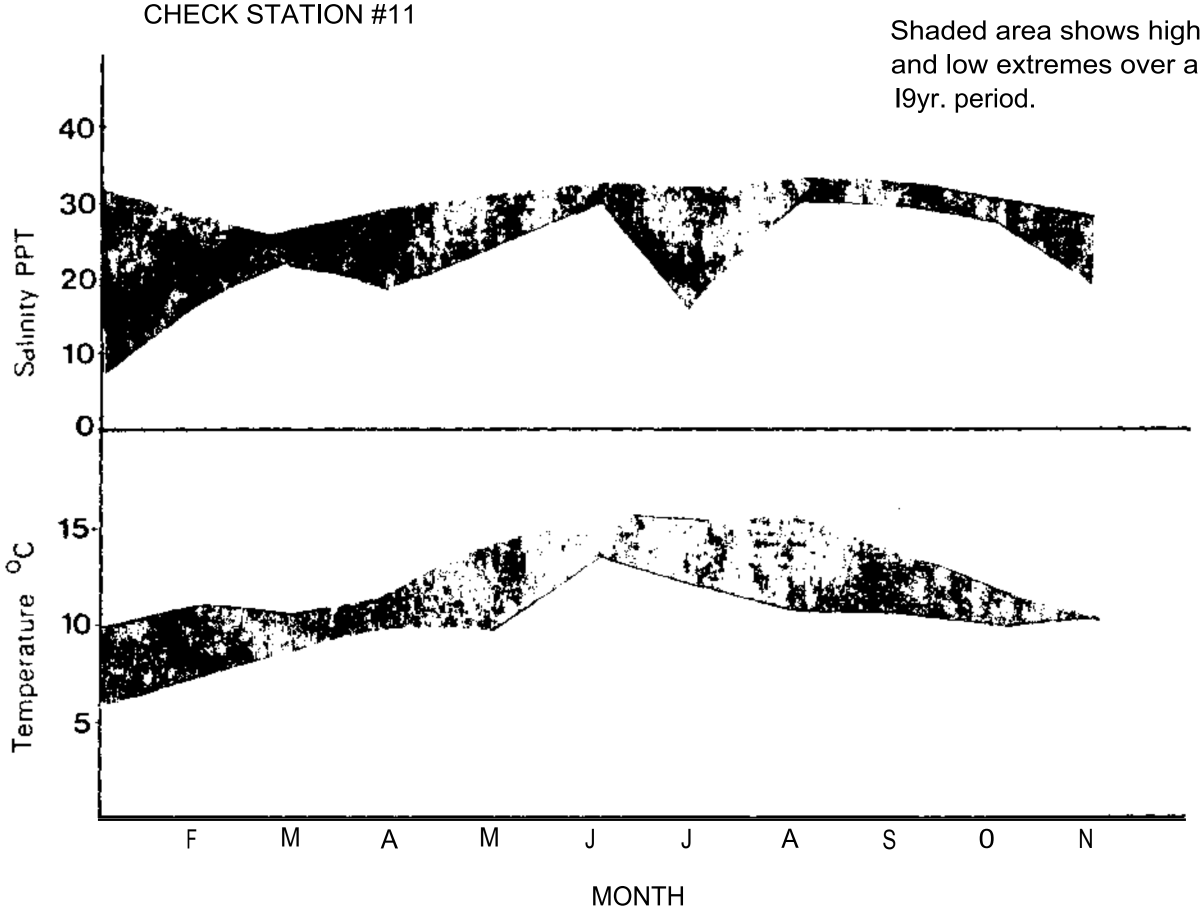


DEQ WATER QUALITY CHECK POINTS

CHECK STATION #11



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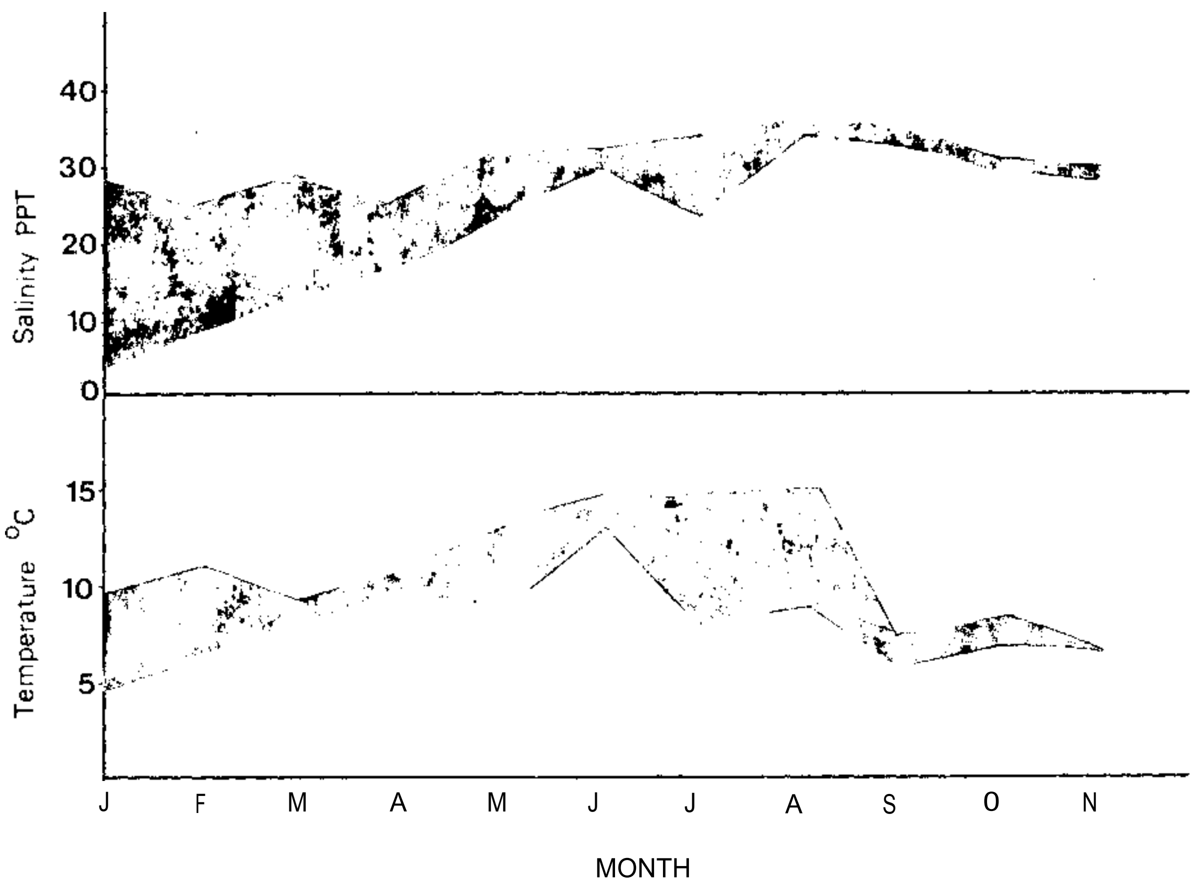

D E Q WATER QUALITY CHECK POINTS

CHECK STATION #13

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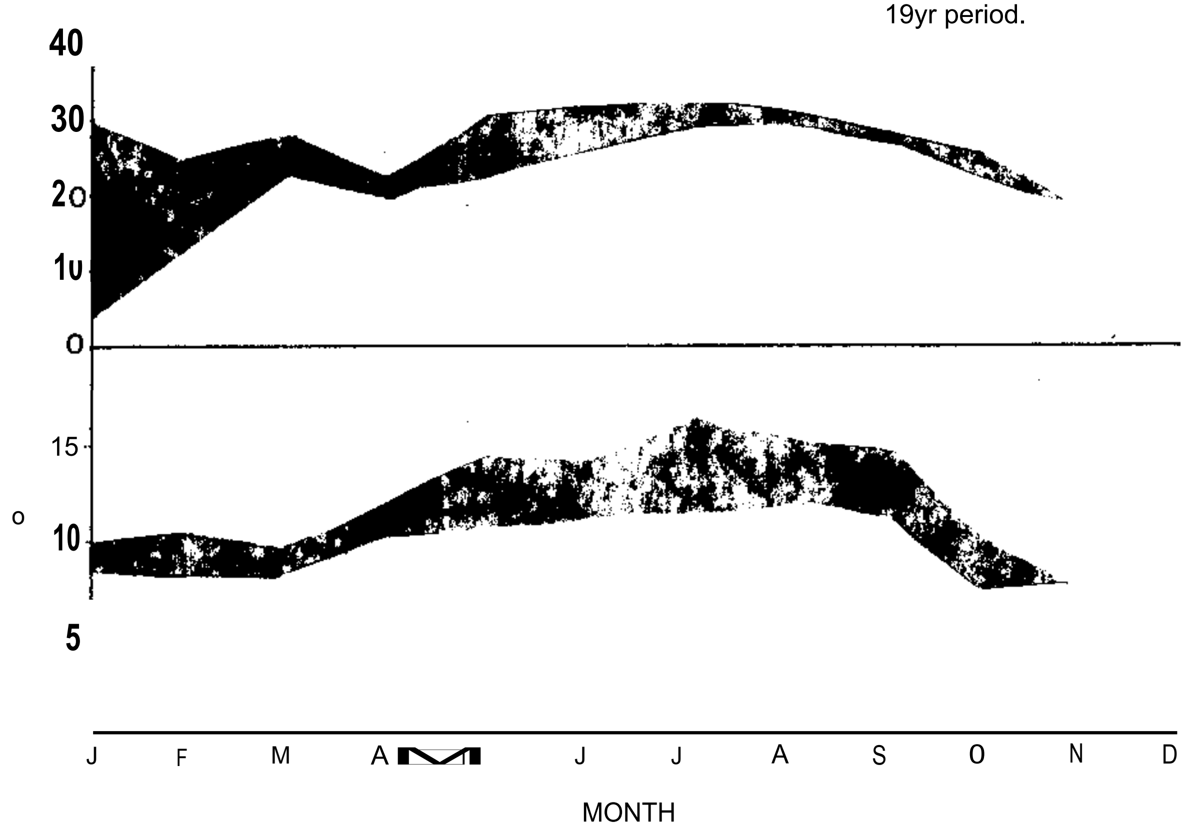

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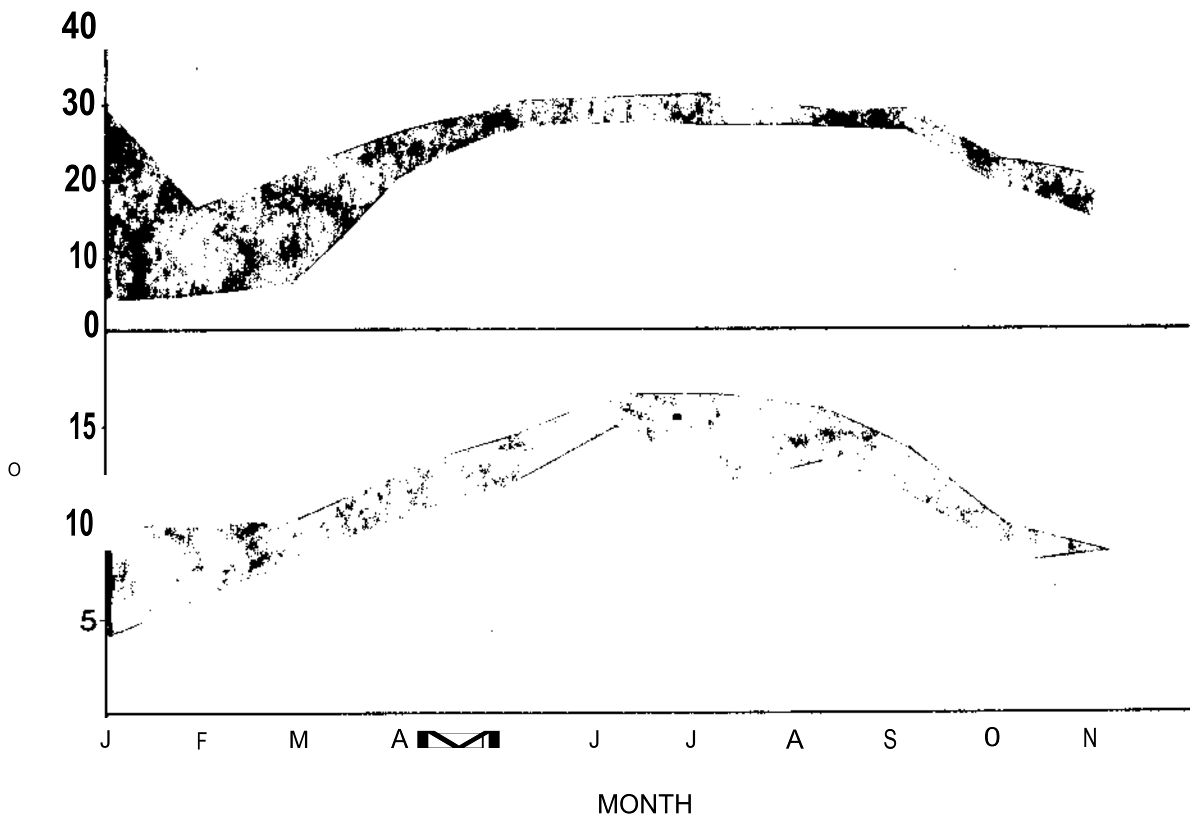

DEQ WATER QUALITY CHECK POINTS

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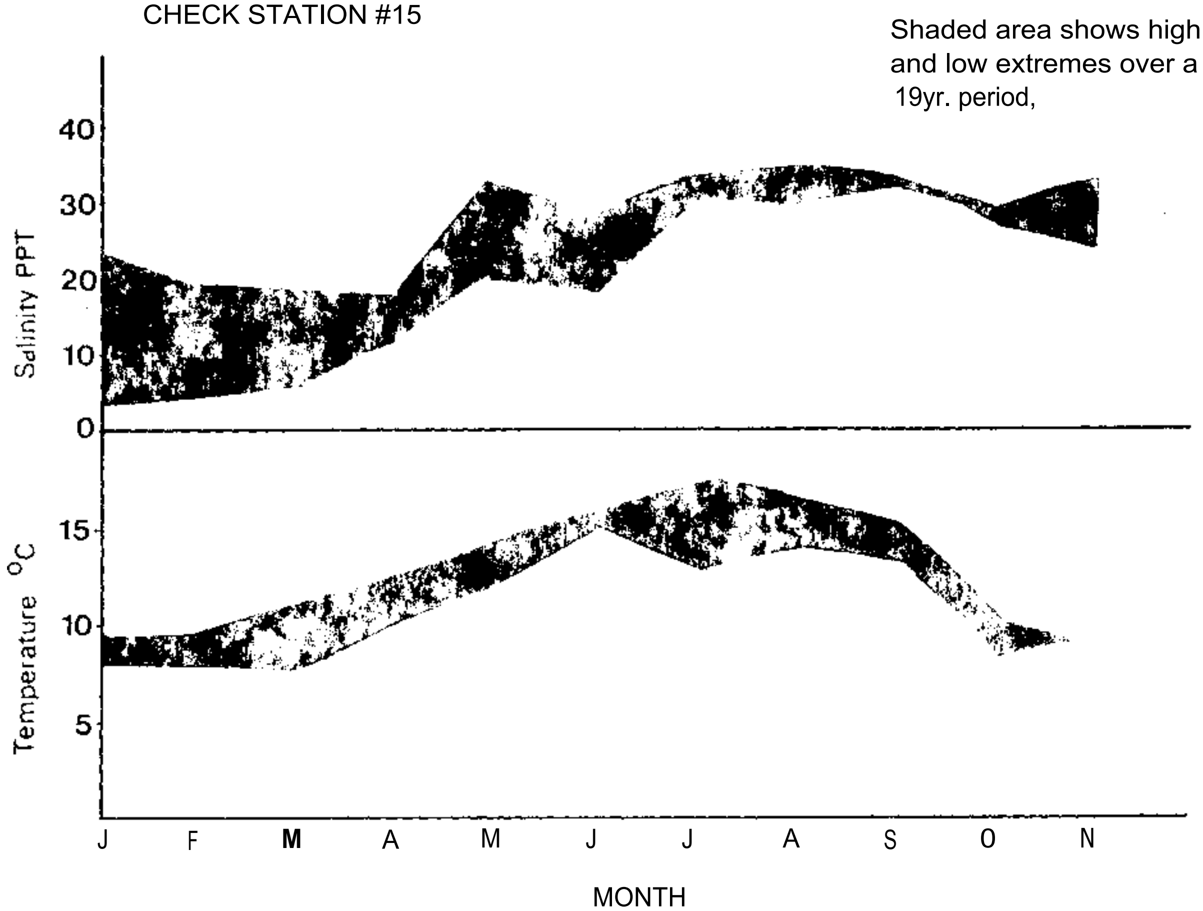

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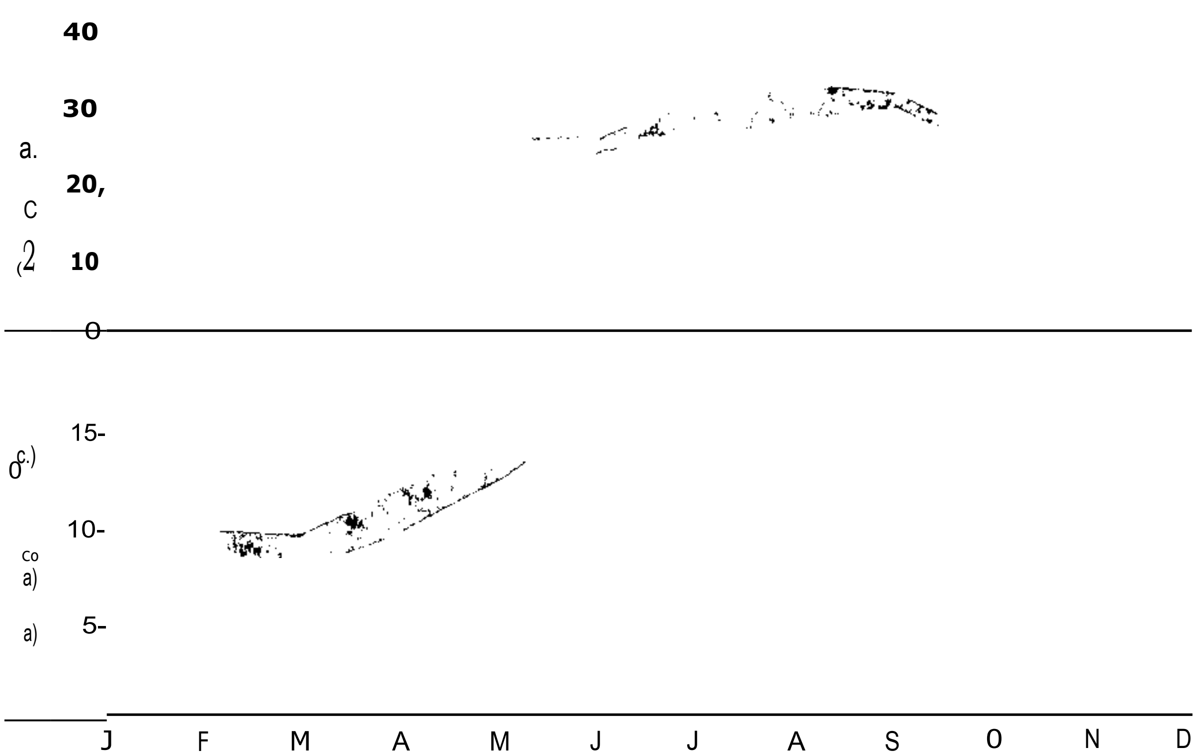

Shellfish Depuration ...

Shellfish depuration, or the purification of shellfish grown in polluted waters, offers man an alternative to the growing concern over available, clean shellfish culturing areas. In speaking with authorities on the water quality in Coos Bay, in July 1976, Sharrel Davison, Senior Sanitarian for the State Health Division, Portland, expressed the opinion that Coos Bay was "probably the dirtiest bay in Oregon." He ncted that the State Health Division gives final approval for commercial shellfish sales and felt that depuration is viable. Glen Carter, of the Department of Environmental Quality in Portland, Oregon, noted that the main reason for high bacterial counts is dairy and wild animal stocks. He feels that water quality probably would not get better with the new waste disposal system. He also noted that few insecticides, pesticides and heavy metals find their way Tito the bay. Therefore, one must deal with high bacterial counts which prevent oysters and other shellfish from being grown in a larger portion of the bay. The advent of a depuration site would allow for a quality product to be produced an/where in the bay where proper growth conditions are available.

A shellfish depuration site appears to be feasible for the Coos Say area. It would allow for commercial oyster culture to be extended above the state approved shellfish growing areas. Presently the approved areas are located in all waters south of an imaginary line gunning west from the Sitka docks to the North Spit. These are shown on Figure III. This open area comprises about half of all useable tidelands. Were a depuration site available, a twofold increase of oyster production could occur. Economic growth, increase in protein production and new areas of employment are the incentives

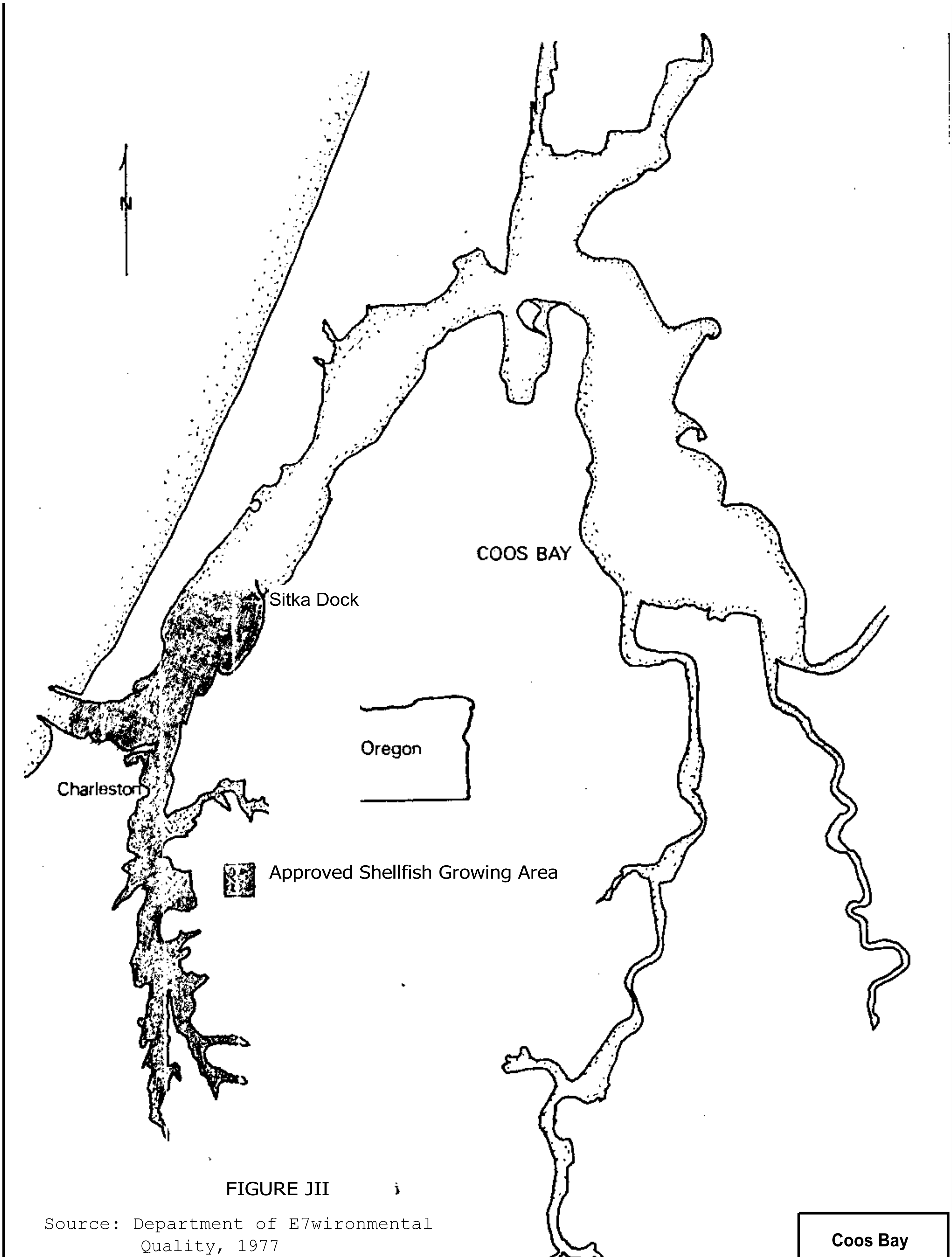

FIGURE JII

Source: Department of E7wironmental Quality, 1977 to pursue this project.

The availability of useable substrate for different types of shellfish culture is present in the bay, but most of this area is closed to shellfish culture for commercial purposes due to high coliform counts, an indicator of pollution. A depuration site would open most of the bay to shellfish culture, since shellfish grown in these closed areas could be brought to a central location for purging of undesirable elements. A shellfish co-operative could be formed among the farmers in this area and other parts of the coast to finance, operate and maintain such a plant. There would be an increase in available shellfish growing areas which would cause a like increase in production. Since all shellfish would be going to a common site, it would be advantageous to process and market them from the same locality. This would create a strong co-operative with the ability to develop a market as large as needed. If future large scale shellfish farming is to occur, a depuration center is needed and now is the time to lay the groundwork for a centralized site which will be a step towards planning for the future.

Following is an unabridged report on shellfish depuration taken from a report given at the Conference on Aquaculture in Kyoto, Japan, 1976. It was presented by Santo A. Furfari, of the Shellfish Sanitation Branch, Food and Drug Administration, Washington, D.C. It has been reproduced from the Proceedings of the FAO Technical Conference on Aquaculture, held in Kyoto, Japan, 26 May - 2 June 1972. The Proceedings are to be published by Fishing News Books Ltd., 1 Long Garden Walk, Farnham, Surrey, England, during 1978.

FAO TECHNICAL CONFERENCE ON AQUACULTURE

CONFERENCE TECHNIQUE DE LA FAO SUR L'AQUICULTURE

CONFERENCIA TECNICA DE LA FAO SOBRE ACUICULTURA

Kyoto, Japan 26 May - 2 June 1976

SHELLFISH PURIFICATION: A REVIEW OF CURRENT TECHNOLOGY

by

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ORGANISATION)ES NATIONS UNIES POUR L'ALIMENTATION ET L'AGRICULTURE, ROME, ITALIE
ORGANIVACION)ES LAS NACJONES UNIDAS PARA LA AGRICULTURA Y LA ALIMENTACION,
RJMA, :ITALIA

1. INTRODUCTION

Controlled purification of molluscan shellfish has been a recognized process throughout the world for many years. The research literature on the efficacy of this natural biological process begins at about the turn of the century (Dodgeson, 1928). Basic and applied research has been done in the United Kingdom, Spain, France, Italy, Sweden, Portugal, Japan, Canada and the United States (Furfari, 1966).

In England, France and Spain the process is an integral and mandatory part of the shellfish industry and it has been routinely used for many years. By contrast, in the United States, purification of shellfish is little known to the general public, and except for a few localities, the shellfish industry is not cognizant of the value of the process. The process has been sporadically used in Portugal, Japan, and Canada, but it has never been an integral or major part of the shellfish industry.

The purposes of this paper are to: describe the depuration process, discuss current commercial practices and public health ramifications of depuration, and review engineering parameters of the process.

2. PUBLIC HEALTH JUSTIFICATION

In discussing the justification for the process, complexities arise because of the various philosophies of the countries using the process. For example, in the United States, harvesting areas are deemed polluted by virtue of low-water quality, and are closed to shellfishing for direct market harvesting if the median total coliform concentration generally exceeds 70/100 ml. In most other countries, however, harvest areas are classified according to the bacteriological quality of shellfish meats. In Europe, shellfish may be harvested for purification regardless of water quality. This is not the case in the United States where levels of bacteria in water and shellfish prevent harvesting despite the possible use of a purification plant.

The need for purification arises from a need to protect public health, which is based on a continued desire on the part of the public to eat raw or inadequately cooked molluscan shellfish - shellfish are notorious for concentrating pathogenic micro-organisms from sewage-polluted sea water.

Each year, populations increase along the coasts with resulting increases in sewage pollution reaching the waterways. Efforts are underway in many countries to treat and disinfect sewage, but the population growth rate may be exceeding attempts to do so. Furthermore, the adequacy of sewage treatment is often questionable because of equipment and operational failures, frequent overflows as a result of rainfall, and by-passing of raw sewage. There are several reasons for by-passing: maintenance of equipment, flooding because of high stages of receiving waters, and slugs of untreatable industrial wastes, to list a few.

Shellfish control authorities cannot be assured that all harvesting areas within the influence of municipal sewage will never become polluted.

There always remains an element of risk. To assess the probability of contanination is difficult. Establishing a surveillance programme over such harvest areas is difficult because a sampling programme is costly and time-consuming. Thus, purification of shellfish in plants is an alternative :o no harvesting and it is thought of in the context of an added safety factor.

Another :'reason for using purification is to reduce the unknown hazard of viri-al pathogens, especially infectious hepatitis. Viral pathogens are extremely difficult and costly to monitor, both in the environment and shellfish. Laboratory methodology for detection of infectious hepatitis is non-existent. There are no standards for viruses in shellfish, yet there are many reports of infectious hepatitis transmission by the American oyster (Crassostrea virginica) and hard clam (Merccnaria mercenaria) (Liu, Seraichekas and Murphy, 1967). More recently, concern was raised about approved area oysters, Crassostrea virginica, which transmitted hepatitis to more than 200 people in two cities in the United States (Portnoy, 1975). The cities are 800 mi apart and the oysters were harvested from an area remote from them. Because of the repeated outbreaks of hepatitis which have been documented over the past 20 years, the need to purify all molluscan shellfish which are or may be subjected to direct or indirect sewage pollution will confront health officLals more and more.

3. SYNOPSIS OF COMMERCIAL PLANTS

Table I gives some basic information on existing or recently operated purification plants. These plants provide a wide variety of water treatments, tank designs, hydraulics, and operations. (The list is not comprehensive for European countries as the necessary information is not currently available to the author.)

The plant. in British Columbia, Canada, is not active nor is the larger plant in Maine which operated for about five years. Recent, but short-lived, pilot-commercial plants have been built and tried in Rhode Island (1964) , Florida (1966) , New York (1968) , Delaware (1970) , and California (1974). These ventures were not fruitful for a variety of reasons including poor business practices, lack of proof of efficacy, and/or inadequate planning.

3.1 Development in the U.S.A.

Commercial plants for American oysters, hard clams, and soft clams (Mya arenaria) have been sporadically tried in the United States but only the soft clam is currently being purified on a commercial scale on the northeastern seaboard. Why this situation exists is not really known since many oyster beds and hard clam areas throughout the United States are not being harvested because of moderate pollution. One explanation is that, because of the massive sewage treatment plant construction programme in the U.S.A., the shellfish industry is somewhat reluctant to invest in new shellfish purification plants which may not be needed in just a few years.

TABLE I

Synopsis of purification plants

Country	State province, etc.	Species	Capacity (approximate) for shellstock (1223)	Water treatment)	
U. S. A.	Maine	Soft clam (Mya. arenaria)	4. 3	UV	Plant closed in 1975 for refurbishing flow-through seawater system
	Maine	Soft clam LM arenaria)	1. 5	UV	Three such small plants are active in the city Scarbcro. Some use saltwater wells
	Massachusetts	Soft clam arenaria)	12. 1	UV	This plant was built about 1930 and converted from chlorination about 1960. Uses recirculation.
	New Jersey	Soft clam (M. arenaria)	10. 0	UV, FILT	This plant was a converted lobster pool. Uses recirculating system.
	New York	Hard clam (Mercenaria merceneria)	2. 0	UV, FILT, SED	Operated 1968-69 for pilot and feasibility studies.
Canada	British Columbia	Pacific oyster (Crassostrea gig *as)*	3. 6	UV	This plant operated from 1969 to 1972 for experimental and commercial purposes.
U. K.	England	European oyster (Ostrea edulis)	Varies	UV	Approximately 20 commercial plants; mostly small local operations
	Wales	Mussel (Mytilus edulis)		CL	Plant constructed in 1928. Uses a static or batch seawater system
Spain 2/	Gerona	Mussel (Mytilus edulis) Portuguese oyster (Crassostrea angulata) European oyster (Ostrea edulis) China (Venus gallina) Clams	3/	OZ	Several tanks with area of 1 020 m^2
	Tortosa			OZ, FILT	22 tanks each 30 m^2
	Cadiza			Solar	Recirculation *system*
	Huelva			Solar	Recirculation system
France-4i	Sete	Mussel (Mytilus edulis) Portuguese oyster **(Crassartrea angulata)** European oyster (Ostrea edulis)		OZ	
	Plougasnou			OZ	
	Le Crotoy			OZ, FILT, SED	

1/ UV - ultraviolet light; CL - chlorination: OZ - °zonation; FILT - filtration; SED - sedimentation.

2/ See San Feliu (1973).

3/ In 1960, 1 100 tons of shellfish; in 1970, 1 735 tons

4/ Personal communication J. LePauloue. Trailigaz, Paris (1975).

However, another reason relates to the fact that soft clams usually are fried or steamed but oysters and hard clams are eaten raw in large amounts. Thus, there is some distrust of the process, a paradox in view of the years of the European experiences. The distrust in the process relates mainly to viral depuration, especially of hepatitis. There are a considerable number of works on viral depuration (section 4.3) but none on hepatitis. The United States has spent several million dollars researching viral depuration and the limitations have been shown. Debate on this aspect still exists.

The soft clam plant in Massachusetts, which was built about 1930, is still operating. The basic tanks and layout have been used throughout the period of operation. Modifications in its operations have changed to keep up with the latest research on biology and engineering. Originally. water was treated with chlorine and recirculated using an aeration/ lift principle. The water is still being recirculated but by means of pumps and is still aerated to maintain oxygen levels. The water treatment, however, is being done now by ultraviolet (UV) light. The construction of the UV units follows the design of Kelly (1961). Monitoring of the process is no longer by the fermentation tube test for coliform, but by the elevated temperature plate test (Cabelli and Heffernan, 1970). Section 5 on monitoring and control'; discusses this further.

Despite the long tradition of soft clam depuration in Massachusetts, workers in Maine wished to improve the process. Goggins *et al.* (1964) demonstrated a flow-through system for smaller tanks and provided more detailed studies on the biological aspects of soft clam purification. The results of the pilot-scale research provided a basis for establishing methods of standardizing the purification process for other species.

Commercial soft clam plants of various sizes were subsequently constructed in Maine, but only three small plants are operating today. The Maine experiences showed that the use of salt water was not detrimental to the process, that flow-through systems were economically feasible and that small wooden tanks and plastic-coated wire baskets were quite desirable, and thus, the process economically feasible. The soft clam washer was another significant development. It provided for minimal breakage, excellent cleaning of mud, and culling.

The large soft clam plant in New Jersey offers a unique situation. The plant is a converted lobster pool. However, the plant contained many features needed for a soft clam purification plant. A year-round source of sea water was available and large underground concrete seawater storage tanks were appropriate for a recirculating process. The numerous (54) wooden tanks and their tiered arrangement offered flexible operation. Furthermore, a seawater cooling system used to maintain the lobsters has proven exceedingly useful for maintaining shelf-life of the soft clams after the purification. The drawbacks to this functional conversion a:fe: (i) poor product flow; (ii) poor tank hydraulics; (iii) lack of ability to maintain good separation of treated and untreated clams; (iv) small storage space; and (v) inability to install the commercially-bought UV units in a safe place. The drawbacks have been tolerated and have caused only minimal operational problems. However, the UV units which are in a corrosive and humid atmosphere have revealed electrical and safety problems. The plant also filters the raw water through fibreglass of the type used for insulation. Another innovation is the use of plastic mesh bags (in lieu of wire baskets). The bags, although less durable than plastic-coated wire baskets, are substantially cheaper (a few cents versus U.S. $20). Although the soft clam shells are quite fragile, breakage is minimal because of careful handling.

3.2 Recent Pilot Work - U.S.A. and Canada

Two important commercial-pilot plants were operated in North America in recent years. One was the work on hard clams in New York (1968-69) and the other was the work on the Pacific oyster (*Crassostrea gigas*) in British Columbia (1969-72).

The New York study took a broad approach by testing and considering such aspects as saltwater wells, filtration, settling, aeration, commercial UV units, heat exchange, costs, bacteriological efficacy, and viral depuration. The overall conclusion of the study was that the purification of hard clams was feasible both economically and bacteriologically. This study also considered practical aspects of tank construction, piping, and saltwater well operations and testing. Turbidity problems associated with surface water were handled initially with sand filtration and settling. However, saltwater well testing showed that water of uniform temperature and salinity was available throughout the year. The study recommended the use of a flow-through system using saltwater wells (New York, 1969).

Devlin (1973) provided a summary of the Canadian experiences purifying *C. gigas* from 1969 to 1972. The economic and biologic feasibilities of the process were demonstrated. Careful monitoring of the waters (flow rate, temperature, turbidity, dissolved oxygen) and bacteriological testing of shellfish resulted in cogent operating criteria. UV light was used to maintain levels of bacteria in the sea water and it was shown that the membrane filter was appropriate to monitor the effectiveness of the treatment. Operational problems and expenses were carefully documented to provide the shellfish industry with a good source book of information for that part of the country.

3.3 European Practices

There is no doubt that Europe is a prime source of information on practical aspects of purification. Several species of molluscs (many eaten raw) are purified and the sea water is being treated with UV, ozone and chlorination (Table I). The European plant have done considerable research with subsequent modifications to improve the process.

Wood (1961) has presented a standardized approach to purification of oysters for the United Kingdom and the many plants follow the methods outlined. He presented criteria for various sizes of plants to accomplish successful purification. The report demonstrates bacterial reduction rates under varying environmental parameters (temperature, salinity, dissolved oxygen, etc.). It is interesting to note that the U.K. still uses UV light for water treatment despite the fact that nearly all plants in Spain and France use ozone.

Details of some of the features of European plants are given in a later section.

4. BIOLOGICAL CONSIDERATIONS

4.1 Overall View

Shellfish must purify themselves; man merely provides the environment conducive to this process. Years of experience and research on biology of molluscan shellfish have provided a large body of knowledge which assists in optimizing this process. The more important environmental factors have been quantified for most commercial species of molluscs.

It is not possible in a report of this size to describe in depth all of the biological considerations but it is appropriate to point out the major aspects. ThE reasons are that the engineering design and operations of a plant are predicated on maintaining the proper biological state of the molluscs. Table CI presents the major physicological systems, the concomitant effectE, and the environmental parameters governing the functions.

These biological systems are stressed in the purification process since molluscs are not in their natural habitat. The stresses are particularly revealed in purification plants such as those in Massachusetts and New JErsey in which recirculated seawater systems are employed. In recircrlation systems, seawater temperature may rise, dissolved oxygen usually drops, metabolic wastes build up, and pH drops. Turbidity was a significant factor in design of the referenced hard clam pilot plant in New York. Because of this factor, exploration for saltwater wells was begun. The lack of food in well water is a major problem and the food factor has not been entirely answered. However, soft and hard cLams in the United States have been successfully purified in water provided from wells which have little available food.

The literature is replete with quantitative research on the effects of there environmental factors on the physiology of molluscs. Their practical relation to purification has been discussed by Cabelli (1970), Furfar:i (1966), Goggins *et al.* (1964), Heffernan and Cabelli (1970 and 1971), Presnell, Cummins and Miescier (1969), and Wood (1961). An excellent overall view of biology of shellfish with emphasis on oysters has been published by Galtsoff (1964).

Table II

Biological aspects of shellfish purification

Major biological system	Function	Purification process considerations
1. Excretory	(a) faeces production	Sea water should contain food to enhance purging of gut
	(b) pseudofaeces production	Turbidity factor
	(c) diapedesis	A factor in eliminating pathogens from the blood stream
2. Nervous	(a) detection of adverse environment	Proper temperature, salinity, dissolved oxygen, pH, to maintain overall activity
	(b) hibernation	Occurs with adverse environment
3. Respiratory (gills)	water transport	Dissolved oxygen levels. Low turbidity to prevent gill clogging
4. Musculoskeletal (adductor muscle and ligament)	shell opening and closing	Proper stacking of shellfish in baskets
5. Reproductive	spawning	Immediately after spawning, shellfish may not be active enough to purify. Spawning is induced by rapid temperature rises

Despite all that is known about the biology of molluscan shellfish, no reliable biological or physiological phenomena quantitatively demonstrate successful purification of pathogenic micro-organisms. It is merely presumed that a large population of molluscs in a tank are active and purifying if shells open and close, faeces and pseudofaeces are produced, or dissolved oxygen drops, and, in general, things appear normal. The only way to assure or demonstrate that purification has taken place is by the use of bacterial indicator systems.

4.2 Bacterial Reduction

Since the turn of the century, much research has been done on bacterial purification for oysters, clams, and mussels. The majority of the work has involved coliform bacteria, i.e., total coliform group, faecal coliform, or Escherichia coli. Only limited data are available for Salmonella, Shigella, and marine flora.

Ir order to show how bacteriological criteria for purification of molluscs in the United States were developed, it is appropriate to review some of the research along these lines.

The coliform data reveal species differences in rates of purification. For example, the American oyster, Crassostrea virginica, may reduce quite high Levels of coliform to indeterminately low levels in 24 hours, while the soft clam, Mya arenaria, is quite slow in reducing levels. Typical values for this oyster are given by Huntley and Hammerstrom (1971). Zero-hour values (time at which the purification process begins) in the realm of 1 700 faecal coliform/100 g typically reduced to 18/100 g in 48 hours. Zero-hour values in the range of 49 000/100 g reduced to 18/100 g in 72 hours. Different experimental set-ups, of course, produced different reduction rates. Presnell, Cummins and Iliescier (1969) showed 99.9 percent reductions of E. coli in 24 hours starting with values in the realm of 10^{7} E. coli/100 g. Wood (1961) showed for the European oyster, Ostrea edulis, rather consistent 99 percent reductions of E. coli to indeterminate values in 48 hours.

Heffernan and Cabelli (1970) showed for the hard clam, Mercenaria mercenaria, 99.99 ; percent reductions in E. coli in 48 hours, and non-detectable levels of E. coli after 24 hours when zero-hour values were less than 10^{4}/100 4.

Data by Goggin3 et al. (1964) on the soft clam, Mya arenaria, generally revealed 90 percent reduction in 24 hours. The data did not demonstrate a rapid decline in bacteria in the first 24 hours as indicated for oysters and hard clams. The Cabelli and Heffernan (1970) data for soft clams did show more rapid reductions, however.

Heffernan and Cabelli (1971) recommend target (or purified) levels of 25 faecal coliform/100 g at 48 hours of purification. This imposes a ceiling level at zero-hour for soft and hard clams of about 2 000 organisms/100 g. The inter-relationships of zero-hour bacterial level, time for purification, and target or finished product level are interesting from the point of view of what public health officials will allow. In Europe, there are no specified zero-hour values, yet for one locality in the United States, there are such values. Furthermore, the allowed zero-hour value is automatically set by an allowable water quality despite species differences in ability to accumulate sewage bacteria. Section 5 on monitoring and controls provides the standards used in the United States.

4.3 Viral Depuration

Inability to monitor viral depuration has possibly held back the use of the process for some species in many localities in the United States. Several good works on viral depuration are available in the research literature. Not only are they valuable with regard to viral depuration *per se*, but they are important from the aspect of the attainment of the perfect or ultimate purification process. This relates to the complete purging of all microbial contaminants and the optimization of environmental parameters needed to control the process.

To partially compensate for the inability to study hepatitis virus, research has been conducted on oysters *(Crassostrea virginica, Ostrea edulis)*, hard clams *(Mercenaria mercenaria)*, and mussels *(Mytilus edulis)*, using polio, coxsackie, and ECHO viruses. Generally speaking, viral accumulation and depletion rates follow that of coliform for the species studied, i.e., sometimes virus was present at 24 or 48 hours or longer depending on initial levels and other experimental factors.

Hamblet *et al.* (1969) showed that oysters *(Crassostrea virginica)* purified themselves of poliovirus in 48 hours, from greater than 103 Plaque Forming Units (PFU)/ml to non-detectable (<0.2/ml) despite turbidities as high as 80 mg/l. Mitchell *et al.* (1966) also showed rapid elimination of poliovirus from oysters at rates paralleling that of *E. coli.*

Liu, Seraichekas and Murphy (1967) demonstrated that the hard clam *(Mercenaria mercenaria)* could be purified of poliovirus at varying removal rates depending on temperature, salinity, and initial pollution levels. Some interesting questions brought up by these studies include: What initial levels of viral pollution are to be depleted? Do artificially polluted shellfish really simulate natural conditions? What pitfalls are there in experimental systems that cannot be foreseen for commercial size plants? Liu, Seraichekas and Murphy (1967) also raised the possibility that the poliovirus-shellfish interaction is not the same as that for hepatitis virus.

The crux of the matter, as they pointed out, is the initial level of virus in the molluscs. The fact that virus can be removed is not at issue any longer. The initial level of virus and its effect seem to be analogous to the initial level of bacteria. The initial level of virus relates to epidemiology of the pollution source and the subsequent die-off and dilution in the sea water.

5. MONITORING AND CONTROLS

As with any food process, there is a need to know that the process itself is working and that the product is safe for human consumption. Monitoring and control over the water by sampling are, therefore, required. The shellfish must also be sampled in an orderly manner.

In the United States, recommendations call for bacteriological sampling of water in the harvest area, the untreated process water, the treated water, and tank water at the plant. As data accumulate to establish a norm, the continued sampling will reveal problems as they arise. Attempts can be made to relate a p or finished product with evidence of poor water quality during the time a particular lot of shellfish was purified. Other water samples are taken for analyses of turbidity, salinity, and dissolved oxygen to determine if these factors were responsible for the poor product.

Shellfish sampling is required to determine if purification has taken place as evidenced by reduced bacterial levels, and if guidelines for the finished product are met. Although there is no official federal standard in the United States, the general guideline for the soft clam, Mya arenaria, is a median value of 50 faecal coliform/100 g of meat by a most probable numbEr (MPN) tube liquid broth technique or by an elevated temperature Elate test on modified MacConkey's media. In England, the allowed level of bacteria for Ostrea edulis is five E. coli colonies/ml of meat using a MacConkey's media, which is approximately ten times the guideline level in the United States.

Sampling frequency is not standardized in the United States, but it is left to the discretion of the health departments of the individual states. In Massachusetts, an elevated temperature plate test using a modified MacConkey's media is used since results are available in 18-24 hours (Heffernan and Cabelli, 1970). If a zero-hour value for Mya arenaria exceeds 1 600 colonies/100 g, the harvest area is immediately closed. If a zero-hour value falls between 1 000-1 600 colonies/100 g, another sample is taken after 24 hours of purification; if the 24-hour value is less than 500 colonies/100 g, the shellfish are released at 48 hours. If the 24-hour value is greater than 500 colonies/100 g, another sample is taken at 48 hours, and the shellfish are purified for an additional 24 hours. Shellfish are sampled at the plant at zero-hour. Only a few routine 24- or 48-hour samples are taken. Thus, it can be seen that emphasis is on good control over the harvest areas from which the shellfish are taken.

In Maine, several small plants are monitored by taking weekly zero-, 24-, 48-hour samples on certain lots. There are no limits on zero-hour values of faecal coliform by the MPN liquid broth method. However, the harvest area is carefully controlled by water sampling. The water in the harvest area rarely exceeds 700 total coliform/100 ml - about equivalent to 140 faecal coliform/100 ml.

In New Jersey, shellfish sampling emphasis is on the finished product; but again, the harvesting areas are carefully monitored by water sampling to assure that the median total coliform does not exceed 700/100 ml. When a plant starts anew, five sub-samples of shellfish are taken at 0, 24, and 40 hours for each lot. After several months of this heavy sampling, the sub-samples are reduced to two, three, and five at 0, 24, and 48 hours, respectively.

Raw and untreated water samples are taken in all plants on either a weekly or daily basis depending on circumstances. Temperature and salinity are measured daily. Dissolved oxygen is monitored in Massachusetts and New Jersey because the water is recirculated.

6. REVIEW OF CURRENT DESIGNS AND OPERATIONS

The purpose of this section is to present some fundamentals of current designs and to describe how existing plants deviate from these fundamentals with subsequent problems.

6.1 Plant Site

The site of a shellfish purification plant is of fundamental importance as it governs the design and layout of the structure, and thus governs internal operations, such as product flow. The most important factor in the site is a suitable supply of sea water for the shellfish. The site should be located where fluctuations in salinity are minimal; if this is riot possible, saltwater wells should be considered. Another important consideration is sewage pollution and whether extraordinary disinfection is required. The factors of temperature, turbidity, and dissolved oxygen are discussed later. The sea water should not contain industrial pollutants which may contaminate the shellfish.

Another factor in site selection is the suitability of a seawater intake and a discharge outfall. Poor planning will lead to operating problems associated with reliable pumping over all tides.

The plant in Massachusetts must operate on the tide simply because of poor plant siting. It is located on a river with a large tidal range of about 3 m. Cn low tide the salinity of the river is too low for effective purification; also on low tide, the coliform level is much higher than desired. Thus, the plant can only pump water on high tide when the saltwater wedge reaches the seawater intake. As the time of high tide advances one hcur each day, the plant's operations also advance one hour. This feature affects shellfish delivery, monitoring, timing, ability to handle large numbers of shellfish (wash and cull) and pumping. This has resulted in nany logistic problems when the pumps have failed at a critical time.

Saltwater wells are not always appropriate despite their utilization in Maine and New York. An oyster purification plant in Delaware encountered problems with hydrogen sulphide gas in the water with the accompanying sulphide odor tainting the shellfish. The plant had to change to the more polluted surface water supply. The saltwater wells in Maine are about 2 m deep, but the one in New York was about 40 m deep.

6.2 Plant Stricture

The physical structure of plants in the United States is varied. ſlost are wooden structures with shingled roofs. Generally, concrete floor slabs with drainage channels or traps are used. Some plants have been made by converting shucking houses or lobster pools. There is no standardized design for purification plants. There are, however, regulations governing sanitation of structures containing shellfish with regard to adequate wash water, cleanability of walls, floors, and equipment, animal and pest control, and adequate toilet facilities with sewage disposal.

An all-indoor plant is not mandatory, but in cold weather climates, the need is greater. Electrical equipment needs to be protected against wet weather and the subsequent corrosion and hazards. So far, all plants in the United States have had all components under a roof. However, in some plants in Europe, components, such as depuration or water treatment tanks are outdoors and other parts are indoors. There is no absolute rule about this.

6.3 Plant Laycut

The current idealized plant layoAt is given in Fig. 1. The major point is separation of the purified From the unpurified shellfish; however, efficiency and ease of product flow are important considerations.

This type of layout was basically attained at the large soft clam plant in Maine since it was constructed as a purification plant. However, none of the existing plants or the former pilot plants in the United States were constructed using the concepts of this layout. All of these plants were converted structures; e.g., lobster pools, wet storage areas, garages, shucking houses.

6.4 Shellfish Handling

The larger plants in the United ::;tates use tote carts to handle large Lots. However, the pilot operations in Maine used overhead trolleys with chainfall and pallets and the oyster plant in Delaware used conveyor belts.

The shellfish are ordinarily pla ed into appropriate baskets which do not inhibit proper water flow in the purification tanks. *Crassostrea virginica* and *Mercenaria mercenaria* are not placed in layers or in baskets over 8 cm deep. *Mya arenaria,* from experience, is allowed in baskets about 20 cm deep. Baskets currently used are made of wood with galvanized wire mesh, plastic-coated expanded metal or plastic-coated wire mesh. Dimensions are approximately 45 x 90 cm, but this has varied with individual circumstances and availability.

The large soft clam depuration plant in New Jersey uses plastic mesh bags. These have proven economically feasible and have not caused any insurmountable problems with the depuration process or with breakage.

6.5 Seawater Systems

Plastic pipe is recommended for eawater systems in the United States. This eliminates the corrosion problem caused by sea water, and also minimizes any problems with materials which could be toxic to both shellfish

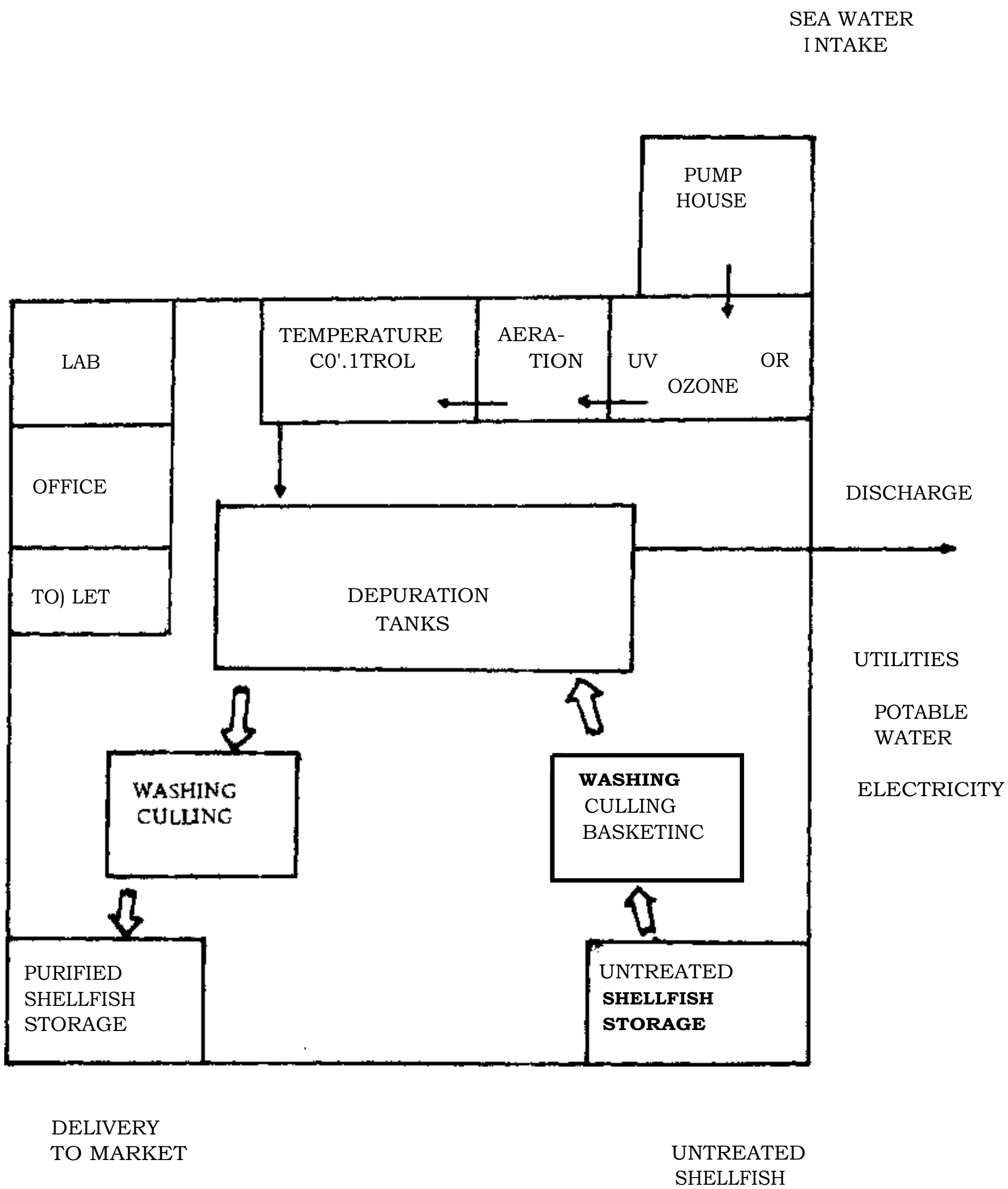

Fig. 1 Schematic of a shellfish p.trification plant

and humans. Experience has shown that seawater systems for purification plants should be engineered in advance to prevent operational problems. The practice of haphazardly putting together seawater systems has invariably resulted in malfunctions. Problems encountered include: poor pump priming, growth of marine life in piping systems that cannot be cleaned; and poor valving such that flow balancing among tanks and treatment units is impossible.

6.6 Water Treatment and Environmental Levels

The most important aspect of purification is assurance that shellfish receive process water comparable with their biological systems and that the shellfish do not become contaminated in that water. Each of the parameters of water quality is subject to species and geographic differences for a particular species. Although it is the responsibility of the official control agency or purification plant operator to experiment and find the best levels for these parameters, general ranges may be promulgated to be used nationwide in the absence of experimentation. These are given in Table III (Furfari, 1966).

Table III

Water-quality parameters for process sea water

Parameter	Minimum	Maximum
Temperature	10^{0}C	20^{0}C
Dissolved oxygen	5.0 mg/1	Saturation
Turbidity	-	20 JTU1/
Salinity	Within 20 percent of the value at the harvest area	

1/ JTU = Jackson Turbidity Units as defined by the Candle Turbidimeter.

All of the plants in the United States have experienced variable water quality causing them to use some form of treatment.

The plants in Maine require heat exchangers in the winter to raise water temperatures for soft clam purification. The plant in New Jersey must cool the water in summer and heat it in winter. The recent New Jersey requirement is for a minimum temperature of 4°C for soft clams.

The recirculating seawater systems in the United States and United Kingdom take into account the need for aeration. The general principle is a cascading or splashing. However, the Massachusetts soft clam plant utilizes both a timed air bubbling system and a splashing system by distributing the water over the surface of the tank.

In a flow-through seawater system, the general criterion for all species of shellfish is a flow rate of 105 1/min/cm of shellfish (Furfari, 1966). This generally assures that the dissolved oxygen level will not be below 5 mg/l.

There are no plants in the United States requiring salinity adjustments; however, because shellfish are expected to be active almost immediately upon the start of the purification process, the salinity of the process water is expected to be close to that of the harvest area. According to experimental data (Goggins, et al., 1964; Heffernan and Cabelli, 1970; Furfari, 1966) salinity of the process water should not vary by more than 20 percent of the salinity of the harvest site. Furthermore, minimum salinity values of 22 ppt for *Mercenaria mercenaria* (Heffernan and Cabelli, 1970) and 20 ppt for *Mya arenaria* (Cabelli and Heffernan, 1970) have been recommended. Purification rates for *Crassostrea virginica* were significantly reduced with salinities below 7 ppt (Presnell, Cummins and Miescier, 1969). The purification rates were better, however, when salinity was over 16 ppt.

6.7 Water Treatment for Microbials

In order to maintain sanitary conditions and to assure that the water used in purification is not contaminated, treatment of microbiological contamination is necessary. Pollution creates the need for depuration, and because it is more economical to locate the purification plant near the polluted harvest area, the source of process water is usually contaminated with pathogenic organisms derived from sewage. To avoid recontamination it is necessary to destroy the pathogens. This aspect of the process is very important.

Historically, the methods have involved chlorination, ozone, and UV light. Chlorination has been criticized because of the effects of the chlorine residue on the sensitive shellfish tissue. Chlorination followed by dechlorination with sodium thiosulphate had been used in the past in Europe but has been discontinued in recent years in France. Within the past 15 years, ozone and UV light have generally supplanted chlorination.

In France and Spain, several shellfish purification plants use ozone to sterlize the sea water. Ozone is well known as a powerful oxidizing agent capable of rapidly killing bacteria and viruses. One advantage of ozone over chlorination is that less time is needed for purification of the shellfish; in water, ozone rapidly dissipates to dissolved oxygen, while chlorine residue remains and affects the sensitive tissue of shellfish. It has been reported that shellfish purified in water treated with ozone have a longer shelf life (Institute of Marine Fisheries, 1974). Ozone was used for purification of sea water as early as 1929 (Violle, 1929). Detailed ozone requirements have been worked out by experiments at Sete, France (Institute of Marine Fisheries). For example, if water contains 2 000-5 000 E. coli/l, 1.50-2.10 g/m^3 of ozone is required to assure sterilization of sea water; 1 (2 000 E. coli/1 requires 1.15-1.50 g/m^3; 250-1 000 E. coli/1 requires 0.75-1.15 g/m^3. Ozone is also very effective in reducing the number of viruses, and much information on this property has been published in recent years (Rice and Browning, 1975).

UV light :.s used in the United Kingdom and United States in commercial plants. Its use as a disinfecting method for drinking water has long been known and numerous references are available on its effect on specific micro-organisms. However, experiments on its specific use in shellfish pur:ficatLon plants are relatively few. Significant studies include its use for Ostrea edulis in England (Wood, 1961), and for Crassostrea v3.rginica (Kelly, 1961) and Mya areraria (Goggins et al., 1964) in the United States. The effective penetration of UV light is limited by depth of water and turbidity which must be considered in design of seawater systems. Applications to sea water of commercially available units designed for clear drinking water may not be appropriate. The aspect of flow rate versus turbidity and their effect on survival of poliovirus in sea water under UV light has been studied (Hill, Hamblet and Akin, 1967). The authors recommended constant vigilance of turbidity of sea water for UV treatment units. By reducing the flow rate (increasing time of exposure) with rising turbidity or vice versa, effective disinfection of viruses can be achieved. Because of the many variables involved with design of UV systems, actual design criteria are not given in this paper. However, Table IV delineates the variables, their effects on design, and how they are inter-related.

Wocd (1961), Kelly (1961) and Goqgins et al. (1964) provide detailed design figures which are useful for commercial applications.

6.E Purification Tank Design

There are no standardized purification tank designs in the United States, but adherence to basic concepts will assure sound hydraulics and sanitation. These are:

(i) uniform hydraulic flow throughout the tank;

(ii) proper stacking of shellfish baskets or containers to minimize hydraulic short-circuiting;

(iii) cleanability and maintenance;

(iv) the prevention of disturbance of shellfish by vibrations, turbulence, etc.;

(v) the pxevent:on of contamination of shellstock.

Table IV

Design parameters for ultraviolet treatment units

Size of plant	The number of treatment units is a function of the number of shellfish, and the number of tanks.
Flow rate	The flow rate allowed through a particular unit depends on water quality and dimensions of the unit. The number of shellfish affects the flow rate.
Water quality	High levels of bacteria in sea water require more treatment units, more electrical power for more UV lamps, more residence time, and consequently larger UV units. Turbidity has the same effect.
Seawater system	Flow-through systems will generally require more UV lamps than recirculating systems.

These matters relate to size, depth, shape, materials of construction, and inflow-outflow piping arrangements.

In the United States, several materials have been used successfully; concrete lining with epoxy paint; marine plywood, coated with fiberglass; and prefabricated fibreglass tanks. These generally provide strong tanks with smooth non-porous surfaces for ease of cleaning.

Active soft clam plants in the northeast part of the United States have tanks with a variety of dimensions. For example, one plant has 54 small converted wooden lobster tanks, 1.2 x 2.43 x 0.4 m deep which are stacked in tiers of three above floor level. Another plant has four large concrete tanks, 1.52 x 5.1 x 1.54 m deep in which the tanks are abutted with a common wall 20.4 cm thick and are located partially below floor level.

The recommended physical features for new tanks in the U.S.A. would provide a maximum depth of about 0.9 m; a minimum space between baskets about 8 cm; a bottom slope of about 2 percent for quick drainage; a tank capacity of 4 000 1 of water/cm of soft clams and 6 400 1/cm of hard clams and oysters.

In the United Kingdom (Wood, 1961), a certain degree of standardization exists. Two tanks holding 10 000 oysters (*Ostrea edulis*) are 6.1 x 1.53 m and 0.51 m deep holding 540 oysters/m^2. Materials may be concrete or wood. For smaller plants, prefabricated tanks of abestos-cement are recommended in sizes up to 1.12 x 0.97 m to hold 660 oysters.

Such snail tanks can be combined and, depending on production rate, the system can be easily expanded.

7. CONTEMPORARY RESEARCH

7.1 New and Ongoing Work

Research on shellfish purification in the United States and elsewhere is at a low eob. The federal government is sponsoring two projects: one relating to virus in the soft clam *(Mya arenaria)*, the other to development commercial parameters for the American oyster *(Crassostrea virginica)*.

The virus work is basically a monitoring of an existing commercial soft cLam purification plant in Massachusetts. Samples of zero-hour and final product at 48 hours are run for enteric viruses. The work is ongoing and a final report will not be available until late 1976.

The oyster work is comprehensive and involves basic laboratory as well as commercial-scale work on purification rates with a wide variation in environmental parameters. This work is being done on oysters from Chesapeake Bay in Virginia. Although some of the work appears to be a repetPlion of that reported in the literature, there is a possibility of geographical differences. Some of the questions being answered concern the suitable ranges of the environmental parameters of these oysters. Temperature, turbidity, salinity, plankton density and condition index of the oyster have been studied. The influence of certain oyster diseases such as MSX and Dermocystidium have also been explored and in-depth studies of biodeposition have been carried out. Shellfish pumping rates have been correlated with rates of bacterial indicator depletion. Maximum permissible levels of bacteria are being determined and several large tank designs are being engineered to optimize flow rates and tank cleaning operations. Effects of waste products on the purification rate are also being studied. This project began in 1973 and will finish in 1976.

In the United Kingdom, some work is underway to purify hard clams in a new system of tiered trays but pubLished reports are not available as yet. (Personal communication, Peter Ayres, 1975, MAFF, Fisheries Laboratory, Essex).

As can be seen from the references, there was a peak of activity in the sixties, but the seventies brought a lull in research especially in the United States. The Canadians have done work on purification of oysters and clams in British Columbia and soft clams in Quebec and Nova Scotia. (The reports on these are not generally available and all of the work has not yet been published.)

7..2 Research Needs

The preceding section reveals the paucity of ongoing research on the purification process. Several questions must still be answered to provide assurances that the process is reliable or that it can be improved or made more rapid.

One basic need is a continuation of virus model studies in the laboratory to demonstrate how viruses may enter and leave the shellfish.

A complete interdisciplinary study of the process needs to be carried out to relate studies reported by bacteriologists and virologists to basic biology, engineering, or chemistry.

Effects of recirculating systems on artificial sea water should be studied in depth. Data are needed on the deterioration rate of sea water and efficient removal of metabolic waste products. The work of Allen et al. (1950) should be continued with modern technology and treatment methods.

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Table H

The manipulation of natural energy and materials through activities involving the use of capital and labour in an algal aquaculture enterprise

Activities involving the use of capital and labour	ORGANIC ENERGY AND MATERIALS		INORGANIC ENERGY AND MATERIALS		
				Solar radiation	
	Seed stock	Contaminants diseases and pests	Water, dissolved nutrients and gases	Photic energy	Thermal energy
1. Invest in capital equipment which transports and modifies natural energy and materials	Enclosures, ponds, buildings, substrate, rafts and other suspension materials	Filters and sterlizers	Water distribution system and equipment for fertilizer provision	Electric lights, reflectors and shades (to control weed growth)	Heaters, coolers, thermal effluent
2. Purchase and apply consumable materials; purchase energy, materials and labour for maintenance and operation of equipment	Materials, energy and labour to maintain enclosures, substrate and suspension materials	Filtration materials, pest control agents, water treatment materials, energy and labour for pest contaminant control	Energy to pump water, materials and labour to maintain distribution system	Light bulbs, maintenance materials and energy to operate and maintain lights or shades	Materials and energy to operate and maintain heat exchangers, valves heating plants or refrigeration units
3. Conduct applied biological research to develop crop control and management techniques	Genetics, clone selection; population biology, ecology, phytosociology	Pathology, microbiology, mycology, biochemistry, herbivore control	Nutritional physiology	Physiology of photosynthesis and respiration	Physiology
4. Monitor crop and culture conditions; control use of energy and materials to achieve optimal benefit cost ratio	Control population structure by monitoring and regulating harvest rates, density, distribution pattern, etc.	Monitor and control levels of pests and contaminants	Regulate water flow and fertilizer rates to get optimal cost: benefit	Control light intJisity, quality and duration if possible	Monitor and control water temperature
	CULTURED ALGAE BIOSYNTHESIZE THE DESIRED END PRODUCTS				
5. Harvest, process and market the yield; maximize efficiency **or** profitability by regulating aquaculture farm production to suit market structure to as great an extent as possible	Regulate harvest rate to maintain optimal population structure and density	Integrate harvest regime **with pest** control **levels** to suit market dem ands	Integrate harvest techniques and water management	Manipulate access to light to "finish" the product before harvesting	Manipulate temperature as an aid to "finishing" or storing end product

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The oceans have been credited by many with the ability of supplying vast amounts of protein for future generations. Technology focusing on harvesting and actual farming techniques have shown little advances in comparison to land based agriculture. With the desire to shift more of our protein demands towards the oceans, further development of mariculture techniques and practices must follow suit of agriculture, in order that the ever greater demands for food may be supplied. Mariculture does not promise to supply all necessary protein that the world demands, but may alleviate some of the pressure now placed on agriculturally based food production. Sound management in bosh agriculture and aquaculture can lead to a stable energy supply to which we might adapt.

The state of the art of mariculture, in its infancy, offers both deterrents and opportunities. In such a new field laws must be revised such that opportunities for sea farming may present themselves. Funding at present is through an individual or a group effort and hopefully federal funding may soon become available. Market development will be an essential step in making any farming operation a success.

The development of aquaculture appears favorable for Coos Bay. New areas of employment, capital investments and new industries will prove beneficial. Water quality standards will improve when investments relating to water quality are realized. The present importance of the bay corresponds in Coos Bay to shipping and in Charleston, to a fishing related community. Diversification into mariculture practices will lend a higher degree of economic and social stability to Coos Bay.

The time is ripe for further research and development of aquaculture in Coos Bay, Oregon.

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APPENDIX A

(Oysters)

509.425 Jurisdiction of commission over natural oyster beds. (1) The commission has jurisdiction over all the natural oyster beds in the waters of this state, and shall prescribe such rules for the protection of oysters therein and for the taking of oysters and oyster spat shells therefrom as in the judgment of the commission is for the best interests of the resource.

(2) It is unlawful for any person to take oysters from such natural beds unless he complies strictly with all of the rules made by the commission covering such taking.
[Amended by 1965 c.570 s.128; 1969 c.675 s.1]

509.427 Conversion of oyster plantations to plats;-requirements of plat. (1) All plats, rights, claims and plantations, and leases lawfully held for such plats, rights, claims and plantations which exist upon the passage of this 1969 Act shall be converted to plats, shall be filed with the commission by July 1, 1970, and shall:

(a) Include a legal description of the area applied for, specifying its acreage.

(b) Be accompanied by a map sufficient to permit the area applied for to be readily identified.

(c) Be accompanied by an application fee of $25 per plat.

(2) All lands held at the time of the passage of this 1969 Act for artificial oyster production under any of the laws of this state shall be given first consideration by the commission in order to allow uninterrupted usage during the transition to the provisions of chapter 675, Oregon Laws 1969.
[1969 c.675 S.10]

Note: Legislative Counsel made no substitution in 509.427 for "the passage of this 1969 Act" or "the time of the passage of this 1969 Act."

509.429 Oyster lands classified. The commission shall investigate and classify those state lands that are suitable for oyster cultivation.
[1969 c.675 s.11a]

509.420 [Repealed by 1969 c.570 s.152]

509.431 Applications for new oyster plats; requirements. Appli cants for new oyster plats, in addition to compliance with subsection (1) of ORS 509.427, shall:

(1) Cause notice of the application to be published once a week for two consecutive weeks in a newspaper of general circulation in each county where any area applied for, or any part thereof, is located. The notice must state the name of the applicant, the type of operation he proposes to conduct, and must describe the area to be planted with oysters.

(2) Not later than the 30th Clay after publication of the notice referred to in subsection (1) of this section, and upon finding that the notice complied with the requirements of that subsection, the commission may grant to the applicant the area applied for if the area is known to be available and if the commission has classified the area as suitable for oyster cultivation.

(3) IE the application referred to in this section is denied, the commission shall provide the applicant with a written statement explaining the reason for the denial.
[1969 c.675 s.11]

509.433 Availability of copies of ORS 509.427 and 509.431. The commission shall cause copies of the provisions of ORS 509.427 and 509.43: to be made available at the courthouse of each county in which an applicant's approved plat, or part thereof, is located.
[1969 c.675 s.12]

509.435 [Repealed by 1965 c.570 s.152]

509.436 Reports by oyster cultivators. Any person cultivating oysters shall file an annual report with the commission before March 1 of each year showing the number of gallons of each species of oysters harvested by him during the preceding calendar year. The report shall be made on forms provided by the commission.
[1965 c.570 s.59d; 1969 c.675 s.2]

509.439 Withdrawal of unproductive lands from oyster cultivation. (1) If, for a period of three years after the filing of a plat under chapter 675, Oregon Laws 1969, more than one-half the lands claimed under chapter 675, Oregon Laws 1969, are unproductive the commission may withdraw from a claimant and consider abandoned that portion of the unproductive lands that are in excess of one-half the lands claimed by such claimant. However, the reason for such unproductiveness shall not include restrictions by governmental health authorities, the unavailability of seed or infestation by pest or disease.

(2) The commission may withdraw from a claimant and consider abandoned those lands:

(a) On which the claimant fails to pay the fees or use taxes referred to in ORS 509.441, unless the commission is satisfied that there was reasonable cause for such failure.

(b) Which are not marked in the manner provided by ORS 509.455.

(c) Which are used or held for purposes other than oyster cultivation in the manner provided in chapter 675, Oregon Laws 1969.
[1969 c.675 s.13]

509.440 [Repealed by 1965 c.570 s.152]

509.441 Cultivation fees and use taxes. (1) Persons using state lands Ln the manner provided in chapter 675, Oregon Laws 1969 for cultivating oysters shall pay annual cultivation fees and use taxes quarterly to the commission. Fees and taxes become delinquent 30 days after the end of the quarter.

(a) Use taxes shall be in the amount of five cents per gallon of oysters if sold by the gallon, or five cents per bushel of oysters if sold in the shell by the bushel.

(b) The annual cultivation fee shall be in the amount of $2 for each acre claimed pursuant to chapter 675, Oregon Laws 1969.

(2) Annual cultivation fees and use taxes shall be assessed in lieu of property taxes, lease fees or rental charges for the use of lands upon which oysters are grown and harvested.
[1969 c.675 s.8]

509.445 [Repealed by 1965 c.570 s.152]

509.450 [Repealed by 1965 c.570 s.152]

509.451 Disposition of cultivation fees and use taxes. All moneys received by the commission under ORS 509.441 shall be paid over to the State Treasurer to be held in a suspense account established under ORS 293.445. After the payment of refunds and payment of costs of administration of the commission in carrying out ORS 509.425 to 509.455, that portion of the balance of the moneys in this suspense account as of the end of each fiscal year:

(1) That were received under paragraph (a) of subsection (1) of ORS 509.441 shall be deposited in the General Fund for general governmental purposes.

(2) That were received under paragraph (b) of subsection (1) of ORS 509.441 shall be deposited in the Common School Fund and credited to the Distributable Income Account under ORS 273.105.
[1969 c.675 s.9]

509.455 Oyster plats as private property; restriction of public use of waters prohibited. Any plats of oyster lands held by citizens of this state, if distinctly marked out by **means** which do not obstruct navigation, and not exceeding the extent allowed by regulations, shall be deemed and protected as private property. Such plats, however, shall not restrict the rights of the public to the use of the waters of this state in a normal and customary manner.
[Amended by 1969 c.675 s.3]

509.460 [Amended by 1963 c.113 s.1; 1965 c.570 s.124; renumbered 509.505]

509.465 [Repealed by 1969 c.675 s.21]

509.470. Private oyster beds acquired under prior law not affected. Nothing in ORS 509.425 to 509.455, 509.505 and 511.625 interferes with any rights in, or ownership of, any private plantations of oysters or oyster beds acquired or held under law existing on February 17, 1921.

509.475 [Amended by 1965 c.570 s.125; renumbered 509.510]

509.480 [Repealed by 1969 c.675 s.21]

509.485 [Repealed by 1969 c.(75 s.21]

509.490 [Repealed by 1969 c.(,75 s.21]

509.495 Transfer by reference to filed oyster plat. Sales, leases, assignments, conveyances, relinquishments and other transfers of oyster plantations and claims, or parts thereof, may be made by reference to the plat filed as provided in ORS 509.425 to 509.455. The heirs, successors, assignees and lessees of oyster plats are entitled to continued possession of such plats by compliance with ORS 509.425 to 509.455.
[Amended by 1969 c.675 s.4]

509.500 Prior claims, plats, transfers or debts unaffected. Nothing in ORS 509.480 to 509.495 invalidates any claim or plat filed prior to June 14, 1939, or invalidates in any manner any transfers, debts or conveyances made prior to June 14, 1939, of oyster claims or lands made by reference to any filed claims or plats.

(Shellfish)

509.505 Placing in water matter injurious to shellfish. It is unlawful for any person, municipal corporation, political subdivision or governmental agency to deposit or allow to escape into, or cause or permit to be deposited or escape into any public waters of this state, any substance of ary kind which will or shall in any manner injuriously affect the life, growth or flavor of shellfish in or under such waters.
(Formerly 509.460]

509.510 Taking shellfish from marked beds without permission; disturbing beds. It is unlawful, without the permission of the legal occupants, to take up shellfish from natural or artificially planted beds, which beds have been lawfully and plainly marked. It is unlawful wilfully to disturb the shellfish in such beds, the surfaces of such beds, or the markers.
[Formerly 509.475]

APPENDIX B

Oysters

Oysters Defined

625-10-275 The term oyster as used in these regulations includes oysters, oyster seed, oyster cultch, and oyster shell.

Statutory Authority:
Hist: Filed 3-4-66 as FC 140

Oyster Importation Prohibited Except by Permit

625-10-280 It is unlawful for any person to import oysters into this state for the purpose of planting or to plant the same in the waters of this state without first having obtained a permit to do so from the State Fisheries Director.

Statutory Authority:
Hist: Filed 3-4-66 as FC 140

Oyster Import Applications and Permit

625-10-285 (1) Any person before importing into this state any oysters for the purpose of planting shall first apply in writing to the State Fisheries Director for a permit to import the oysters. Such application shall be in the form of a letter and shall include the following information: maximum quantity to be imported, name of exporter, the approximate time the shipment will be made, and the name of the person or agency that will inspect the seed including a notarized certification from such person or agency at the time the oysters are inspected, declaring them to the best of his knowledge free from disease, infestation pests, and other substances which might endanger shellfish in the waters of this state.

(2) The State Fisheries Director shall issue a permit to import oysters for planting in the waters of this state when it has been established to his satisfaction that a qualified person or agency will inspect the oysters and certify them as being free of disease, infestation pests, and other substances which might endanger shellfish in the waters of this state.

Statutory Authority:
Hist: Filed 3-4-66 as FC 140

Prohibited Activities in Restricted Shellfish Area

625-10-290 (1) Netarts Bay and all waters, tidelands, and oyster handling facilities operated in conjunction with said water and tidelands of Netarts Bay are defined as a restricted shellfish area.

(2) All waters, tidelands, and oyster handling facilities operated outside the restricted shellfish area of Netarts Bay are hereby designated as unrestricted shellfish areas.

(3) It shall be unlawful for any person to move or transfer from a restricted shellfish area any oysters, any marine organisms adversely affecting oysters, or any other matter, tools, boats, scows, or other material whatsoever without first obtaining written permission from the State Fisheries Director.

Statutory Authority:
Hist: Filed 3-4-66 as FC 140

Oyster Seasons and Gear

625-10-295 (1) It is unlawful to take oysters for either personal use or commercial purposes from natural oyster beds located on unoccupied state lands.

(2) Upon permission of the legal occupants, oysters may be taken at any time for personal use or commercial purposes by means of dredges, tongs, rakes, or by hand from natural or artificial oyster beds which are:

(a) Privately owned.

(b) Held in accordance with the commercial fishing laws as an "oyster plantation."

(c) Held under lease from the Fish Commission of Oregon for purposes of oyster propagation or cultivation.

Statutory Authority:
Hist: Filed 3-4-66 as FC 143

APPENDIX C

Federal departments or agencies involved directly or indirectly with planning or resource analysis of Coos Bay area include:

Department of the Army--Corps of Engineers
Department of Agriculture--Soil Conservation Service
Department of the Interior--
- Bureau of Sport Fisheries and Wildlife
- Bureau of Outdoor Recreation
- Bureau of Land Management
- Geological Survey
- National Park Service

Department of Commerce--National Marine Fisheries Service
Department of Health, Education and Welfare--Public Health Service
Environmental Protection Agency--Water Quality Office
Department of Housing and Urban Development
Department of Transportation--Coast Guard

The Corps of Engineers permit system involving Sections 10 and 13 of the River and Harbor Act of 1899 is a secondary controlling factor for works and activities in the waters of Coos Bay. These activities are co-ordinated with numerous state and federal agencies.

The Coast Guard is responsible for aids to navigation, law enforcement regarding boat safety, water pollution investigation, and search and rescue.

About 25 Oregon State agencies are involved directly or indirectly with estuarine area use and planning. Some of these are:

Water Resources Board
Fish Commission
Department of Environmental Quality
Game Commission
Department of Commerce and Economic Development
Department of Highways
Department of Geology and Mineral Industries
Parks and Recreation Department
State Marine Board
Soil and Water Conservation District
Division of State Lands

TABLE I

Checklist of permits required for private hatcheries in Oregon

Type of Permit	Responsible Agency
Water rights	Office of the State Engineer Salem, Oregon 97310
Private hatchery permit	Department of Fish & Wildlife 17330 S.E. Evelyn Clackamas, Oregon 97015
Importation of fish or fish eggs	Oregon Department of Fish & Wildlife P.O. Box 3503 Portland, Oregon 97208
Pollutant discharge	Department of Environmental Quality 2595 State Street Salem, Oregon 97310
Building permit; Land use approval	(appropriate local agencies)
Works in navigable waters	District Engineer U.S. Army Engineer District, Portland P.O. Box Box 2946 Portland, Oregon 97208
Division of State Lands Fill and Removal Law	and Director Division of State Lands 1445 State Street Salem, Oregon 97310
Wildlife hatchery license	Department of Fish & Wildlife P.O. Box 3503 Portland, Oregon 97208
Clearance to sell fish and fishery products	Department of Agriculture Salem, Oregon 97310