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SEA OTTERS AND ALASKA'S DEVELOPING SEA FARMING INDUSTRY

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INTRODUCTION

Mariculture is defined as the farming of aquatic plants, fish and shellfish in salt water. Currently, mariculture is experiencing an upsurge of interest in Alaska. Global markets for mariculture products are strong and a flagging Alaskan economy favors the development of new industries in the state.

Interest in mariculture has prompted federal, state and local governments to streamline the permit process for mariculture applicants, define geographic regions appropriate for mariculture, and provide incentive for investment in mariculture. Of equal importance has been research into the impact mariculture may have on existing resource users and the environment. Rader et al. (1988) has compiled a review of these potential impacts along with a list of guidelines which might minimize them. Much of the effort regarding environmental questions has focused on avoiding or minimizing problems which have developed with mariculture in countries with established sea farming industries, notably, Japan, Norway, Australia, New Zealand, France, and Spain, to name a few. This approach, although sufficient for predicting and preventing many problems, does not account for one particularly unique feature of western North America, the presence of sea otters (Enhydra lutris), a reknowned predator of various species of shellfish (Calkins 1978; Estes et al. 1981; Garshelis et al. 1986). With the exception of British Columbia, Washington, Alaska, and California, no area currently involved in mariculture has populations of sea otters. Of those areas with sea otters, the population in Alaska is clearly the largest (Calkins and Schneider 1985; Rotterman and Simon-Jackson 1988).

Potential interactions between sea otters and sea farms could include depredation by sea otters of farmed animals, entanglement of sea otters in gear, damage to gear, displacement of sea otters from critical habitat, and lowered productivity of natural prey species within localized areas due to competition or habitat degredation from intensive mariculture practices. All of these may lead to otter harassment and increased human-caused mortality.

Areas in Alaska under development for mariculture and within current sea otter ranges include the Kodiak archipelago, Kachemak Bay in Lower Cook Inlet, and parts of Prince William Sound. In addition, expanding sea otter populations in several areas may come into contact with mariculture developments established in current otter-free areas.

Shellfish and sea vegetable mariculture are currently the only legal forms of mariculture in Alaska. Salmon farming, which is likely to have the greatest economic impact of all types of mariculture operations, has been vigorously opposed by traditional salmon-fishing interests. For this reason, and the importance of shellfish in the sea otter diet, this report will focus primarily on shellfish farming. Species presently being cultured around the state include the Pacific or Japanese oyster (Crassostrea gigas) and the Blue mussel (Mytilus edulis) (Rader et al. 1988). In addition, scallop mariculture is under development.

The objectives of this paper are to give an overview of the current status of the industry in Alaska, identify potential problems between mariculture and sea otters and recommend measures to prevent or reduce these problems. It is inevitable that sea otters and sea farms will co-exist in Alaska. It is our hope that their co-existence can occur without significant detriment to either.

METHODS

The principal sources of data on mariculture permits and permit activity are the Army Corps of Engineers (COE) and the Department of Natural Resources' Division of Land and Water Management (DNR). Data identifying dates of mariculture applications were taken from the reference number of each application. If an individual had more than one permit from an agency or permits from both sources of permit information, only the earliest date was used. In addition, the DNR provided information concerning the proposed state regulatory changes for sea farming. Most other information concerning the status of the industry in Alaska has come from conversations with individuals involved in mariculture and recent reports dealing with sea farming in Alaska (Larrson 1986, Hemming 1987; Peyton et al. 1987; Pierce 1987; ReLonde 1987; Rader et al. 1988).

We make reference to 3 separate regions of Alaska corresponding to the State of Alaska's fisheries management zones. Region 1 refers to waters of Southeast Alaska (SE) including the entire panhandle north-west to Cape Suckling. Region 2 includes waters of Southcentral Alaska (SC) encompassing Bristol Bay north-east of the Alaska Peninsula, Cook Inlet and Kachemak Bay, Prince William Sound, and waters east to Cape Suckling. Bristol Bay is not currently involved in any mariculture activity. Region 4 covers all of Southwest Alaska (SW) including Kodiak Island, the Alaska Peninsula, and the Aleutian chain although Kodiak is the only area currently involved in mariculture in this region. Region 3, the Arctic-Yukon-Kuskokwim (AKY) region, is not included as plans for sea farming operations currently do not exist for that area and will not likely develop because of seasonal ice formation.

RESULTS

History of Mariculture in Alaska

Aquatic farming is not new to Alaska. Initial attempts at sea farming concentrated on beach culture of the Pacific oyster. From the early-mid 1900's SE Alaska oyster growers planted oyster seed with minimal success except in the areas of George and Carrol inlets near Ketchikan. The industry which continued sporadically throughout this period, did not see any real success until new culture techniques were developed in the late 1970's. The work of 2 oyster farmers, Robin Larsson of Wrangell and Warren Pellet of Sitka, initiated the industries move from the extensive production methods of beach and bed culture to the more efficient intensive surface tray and net methods used today (Rader et. al. 1988) This brought about a renewed interest in culturing oysters and resulted in the development of a significant fledgling industry centered among the remote islands near Wrangell in SE Alaska.

Work with species other than oysters has just begun within the last five years. Farming of blue mussels has occurred in Kachemak Bay near Homer since the early 1980's using off-bottom culture methods adapted for Alaska (Hemming 1986). In addition, a project concentrating on the feasibility of collecting and raising weathervane scallop spat in waters around Kodiak Island was initiated in April, 1987 (Peyton et al. 1987). A similar project researching laboratory propagation of the giant kelp (Macrocystis pyrifera) has been underway for three years. The eventual goal of that project is ocean culturing of M. pyrifera near Sitka (Rader et al. 1988).

Economics of Mariculture

Economically, Alaska's greatest potential market share in mariculture lies in the farming of salmon with shellfish and sea vegetable farming of potential importance to the economic diversification of coastal communities (Pierce 1987). Mariculture as an industry is still in its infancy in the state and its economic benefits to Alaskans remains to be seen; however, a growing demand on the U.S. and world markets for seafood (Fig. 1) combined with a general leveling off of worldwide commercial fisheries landings has produced a strong and growing market for aquaculture products (Pierce 1987). By the year 2010 mariculture is expected to account for 24.3% of the total world production of fish and shellfish, up from 12.2% in 1983 (Fig. 2).

Idealistic proponets of mariculture in Alaska see the industry as a series of small "mom and pop" farms scattered throughout coastal regions of the state. For mariculture to be a significant diversification of the states coastal economy, larger scale operations will need to develop (Rader et al. 1988; Pierce pers. comm.). Certain mariculture activities, for example salmon and scallop farming, may not even be feasable on a small scale.

At present the only commercially successful mariculture operations capable of supporting a resident family are oyster farms in SE Alaska. Based on an economic model created by ReLonde (1987), a profitable oyster farm in Alaska must plant at least 250,000 spat each year. Such a facility would produce a positive cash flow in the third year and the facility would be paid off in 10 years.

Oysters produced for the gourmet market sell for about 50 cents each or $3.00/lb. Currently oyster growers in Alaska are enjoying a growing market for their product, due to an increased domestic appetite (the U.S. consumes almost 60% of the world's total production of oysters annually; Glude and Chew 1982) and decreased production in some areas outside Alaska due to water quality problems (Pierce 1987).

Small mussel farmers can expect to work on a slimmer profit margin and it will be important to keep overhead costs to a minimum (Hemming 1986). The current wholesale price of mussels is about $1.45/lb. Based on the economics furnished by the only commercial mussel grower in the state, a family living at the site would need to raise approximately 30,000 lbs of mussels per year to support itself after initial costs where met (Hemming 1986; Pierce 1987). Existing commercial production is satisfying local demand thus marketing prospects will need to expand within or outside Alaska if growers expect to survive on mussel production exclusively (Hemming, pers. comm.). Large scale mussel operations, producing 10,000-100,000 lbs per day of harvesting, exist in Europe and New Zealand (Hemming pers. comm.) and a few operations in the U.S. are capable of producing over 100 MT annually (Lutz 1985); conceivably the potential exists for similar sized facilities in Alaska.

Historically the price of scallops has remained relatively high thus they are a very attractive mariculture prospect (Pierce 1987). The current market price is over $4.00/lb. Because of the larger investment needed to produce scallops, it is likely that large scale operations will be necessary (Pierce pers. comm.; Osborn pers. comm.).

Legal Status

Development of mariculture projects for oyster, mussel, scallop and sea vegetables have much less opposition from the traditional finfish industry than the more controversial salmon farming, which explains the separation of these forms of mariculture by state law makers (Gov. Sheffield memo, Mar.,1985). Current legislation continues to reflect this separation. Senate Bill No. 514 (SB 514) passed in May, 1988 extends an earlier moratorium on finfish farming until July, 1990 while granting authority for the establishment of sea farming regulations and defining permitting and tideland leasing policies for the farming of marine shellfish and kelp. This legislation reflects the policy of the state to: 1) encourage the establishment and responsible growth of an aquatic farming industry in the state; and (2) that allocation of aquatic farming sites be made with full consideration of established and ongoing activities in an area (Policy statement on SB 514). This bill gives the Alaska Department of Fish and Game (ADF&G) authority to regulate and issue permits specifically for aquatic farms and hatcheries including collection and culture permits. In addition the Department of Natural Resources now has a policy for issuing tideland permits and leases for aquatic farming. As part of this new policy, the legislation stipulates the identification of aquatic farming districts and subdistricts within which mariculture sites may be selected (Sec. 38.05.855 of SB 514). No tideland leases for mariculture may be issued before these areas are identified (Janet Buralson pers. comm.). In November 1988 the DNR, Division of Land and Water Management, finished its nomination process for identifying areas with a high potential for mariculture development as well as areas with major opposition to such development (Janet Buralson, pers. comm.; Janetta Pirtchard, pers. comm.).

Permit Process

In anticipation of legislative action, the various state and federal agencies involved in mariculture have developed ways of handling permit applications more efficiently. A consolidated shellfish permit has been developed by the state to cover the most frequently needed permits required of aquatic farmers and the entire application process is now coordinated by the State Division of Governmental Coordination (DGC).

The permit process works as follows: once the mariculture zones are established, any part or all of a zone may be opened for at least a 60 day application period during a given year. During this application period the DGC receives requests for aquatic farming permit applications either by direct request from an individual or by referral from another agency. The DGC then sends out a Consolidated Shellfish Farm Application (CSFA) and a Coastal Project Questionnaire to the applicant. The questionnaire helps the applicant identify the various state and federal permits needed other than the CSFA. The applicant then returns the completed CSFA and other appropriate applications along with the questionnaire and any other pertinent information to the DGC which in turn distributes the information to the various agencies and completes an Alaska Coastal Management Plan consistency review for the project. Once all the agencies have the necessary information they review the project and each has its own public notice period at which time recommendations for acceptance or denial of the permit can be heard along with the addition of required stipulations on the various permits. Only after the review process may the permits be issued. Coordination of this effort has greatly reduced the time in which it takes to obtain the necessary permits. The whole process, which once could have taken as long as 8 years to complete (Larsson, 1986), should be completed within 90 days (J. Pirtchard, pers. comm.).

Regulations

At this time draft regulations drawn up for aquatic farming by the State are available from the DNR, Division of Land and Water. Currently the regulations do not require the mariculture applicant to identify anti-predator plans for a proposed operation nor is there specific policy for siting farms within areas inhabited by sea otters.

March 1989 marked the end of a two-year experimental period for mariculture in Kachemak Bay State Park where the DNR, Division of Parks issued special use permits for mussel farming in Halibut Cove Lagoon. The Division of Parks intends to propose regulations paralleling those developed by the Division of Land and Water (draft policy statement on mariculture, Division of Parks, Sept. 21, 1988).

Permit Activity

Interest in mariculture has risen substantially over the last five years as measured by numbers of applications for mariculture permits. Applications to state and federal agencies have risen from essentially zero before 1980 to a high of 35 new applicants in 1987 (Fig. 3). From COE and DNR records we found a total of 91 applications for mariculture permits since 1981 with 63 permits actually issued by the COE and/or the DNR and 12 applications still pending. The remaining 16 applications have been closed or withdrawn. Of the 75 open permits, 9 specify salmon and will not be considered further.

The timing of increased interest in mariculture differed among the 3 regions (Fig. 4). The SE region showed the first increase in permit activity followed by the SC region and lastly the SW region. All regions show a dramatic decline in the number of applications for permits in 1988 as the DNR formulated new regulations for the industry. The SE region holds a slight lead in actual number of open permits (Fig. 5). More importantly, although there are no data that indicate the actual level of participation, our estimates show the SE region with a three-fold lead in numbers of permit holders actively participating in mariculture (Fig. 5). There is a marked difference in the ratio of active vs. open permits among the regions. According to Robin Larsson, past president of the Alaska Shellfish Growers Association, there are 21 permitted oyster farms in the SE at various stages of operation with 8-12 producing oysters. Of those only a few are producing at commercial levels. In the SC region there are very few active mariculture operations. The Division of Parks has issued all 16 permits for mussel farming in the Halibut Cove Lagoon experimental area, with each allowed two grow-out rafts. To date, only 8 rafts are in the water and not all of these are in use. The only commercial producer of blue mussels in the state is in Halibut Cove. Division of Land and Water records indicate only 3 other operations in the water for the rest of the SC region (J. Pirtchard pers. comm.). In Kodiak a pilot scallop project has had spat collectors in the water over the last 2 summers with the first years collection of spat in a grow-out facility in Kempff Bay. Only one other permit holder is developing a mariculture site at Kodiak Island.

Oysters are the most commonly specified species on permits followed by mussels and multi-species permits (Fig. 6). The records show only 1 permit exclusively for scallop; however, scallop are included in 6 other of the "shellfish" or multi-species permits. These are permits for farms specifying a variety of shellfish to be produced and break down as follows: three permits for oyster/mussel/scallop farms, two permits for oyster/mussel farms, two permits for oyster/scallop farms, two permits stating only "shellfish" and one permit for an oyster/scallop/clam farm.

There appears to be regional preferences for farming particular species of shellfish (Fig. 7). The SE region raises oysters almost exclusively and holds 24 of the 28 oyster farming permits. Similarly the SC region holds all the exclusive mussel farming permits for the state. It also contains the only permit for the raising of sea urchins in Alaska. Kodiak seems to prefer a multi-species approach to mariculture with 5 of its 6 open permits classified as shellfish operations. In fact, half of the multi-species permits for Alaska are at Kodiak. Despite the apparent multi-species approach of Kodiak Island shellfish farmers, our interviews suggest that scallops are the real target and all but one permit there includes this species.

Life Histories and Culture Techniques

Oysters

Alaska has only one native species of oyster. The Native or Olympia oyster (<u>Ostrea</u> <u>lurida</u>) is found from Baja California to SE Alaska as far north as Sitka (Johnson and Snook 1927; Rice 1973). This oyster was the original mainstay of the commercial oyster industry on the West coast of North America (Conte and Dupuy 1981). Today, however, a larger non-native species, the Pacific or Japanese oyster (Crassostrea gigas), is the most commonly raised oyster on the Pacific coast with the largest production coming from the state of Washington (Burrel 1985; Pauley et al. 1988). Under natural conditions C. gigas may reach sizes of 8 to 12 inches in length and live as long as 40 years (Abbot 1974). Harvestable size is about 3 inches long (Else et al. 1987; Pauley et at. 1988).

Pacific oyster spat (juvenile oyster used as seed) are imported yearly for grow-out on Alaskan farms (Else et al. 1987). This oyster is, in fact, the only species allowed into Alaska with strict regulations prohibiting importation of oysters from all but a few certified sources (hatcheries) on the Pacific Coast of North America (Pierce 1987). C. gigas requires substantially warmer water temperatures than O. lurida to induce spawning (Burrel 1985; Pauley 1988), consequently, C. gigas rarely spawns naturally in Alaska, hence the need for yearly stocking. Though Pacific oysters prefer warmer water, they can withstand below freezing temperatures whereas O. lurida cannot (Burrel 1985). They grow well enough in Alaska with floating culture methods to compete with farms further south. Floating culture techniques decrease the time needed to produce marketable size oysters in any area by 1 to 2 years compared to bottom culture in the same area (Quayle 1971). Thus farms in Alaska can still produce marketable size oysters in 2-4 growing seasons (Larsson 1986), compared with 2-4 growing seasons for bottom-cultured oysters in California and southern Washington and 4-6 growing seasons for bottom-cultured oysters in northern Washington, British Columbia, and Alaska (Pauley et al. 1988). It is unclear how lack of spawning influences oyster quality. Pierce (1987) contends that lack of spawning allows harvest of a product in Alaska at times when oysters further south are not marketable due to their bitter, mushy quality during the summer spawning period; however, Burrel (1985) states that oyster quality is diminished when prevented from spawning by insufficiently warm water temperatures.

In Alaska floating culture methods have replaced the old beach culture methods of the past. These types of facilities take advantage of warmer surface water temperatures and facilitate continuous feeding by the growing oysters. Two methods have been developed in Alaska. The most common technique is raft culture. Rafts, also called oyster trays or "floating beaches" (Larsson 1986), are basically a floating framework, usually of logs, supporting some type of netting or mesh, sometimes made of plastic or coated wire (Fig. 8). These rafts suspend the oysters within 1 or 2 feet of the surface and may be covered for protection from predators. Eleven of 17 oyster farm permits for which we have construction information use raft culture methods. The second method uses stacking oyster trays or "lantern nets" which may be hung from long lines or raft frames. This technique employs individual plastic mesh trays hung one below the other from the supporting structure (Fig. 9).

The oyster spat or seed are purchased and transported to the site where the "cultch" (shell fragments or other material onto which the spat have settled) are "planted" by distributing them within the trays. The oysters must be regularly cleaned of fouling organisms and sorted. Similarly, the trays themselves require regular cleaning or the fouling material may reduce water flow through the facility to the detriment of the growing oysters.

Floating culture methods have 5 advantages over beach culture methods; (1) growth to marketable size is considerably reduced; (2) the quality of the oysters is markedly improved; (3) mortality caused by siltation and bottom predators does not occur; (4) a larger proportion of the water column is utilized with the three dimensional design of such construction vs. the two dimensional character of bottom culture; and (5) it allows the use of what would otherwise be unsuitable farm sites (Quayle 1971; Hickman 1980; Burrel 1985; Pauley et al. 1988). The primary disadvantage of this method is the increased handling, labor, and cost.

Mussels

Blue mussels, unlike Pacific oyster, are indigenous to Alaskan waters; therefore, suitable conditions for growth and reproduction can be found throughout southeastern, southcentral and southwestern portions of the state. Blue mussels have a worldwide distribution including the Arctic Ocean to South Carolina on the east coast of North America and the Bering Sea to California on the west coast (Rice 1973; Abbott 1974). Under natural conditions blue mussels grow intertidally and subtidally forming dense clumps firmly attached to the substrate by a fibrous byssus. After spawning the resulting larva settle on any surface to which they can attach themselves, residing as filter feeders (Johnson and Snook 1927), and can grow to a length of 3 inches (Abott 1974). Growth rates; however, are quite variable depending upon water salinity and temperature, population density and severity of the external environment (e.g. surf and abrasion). In high density populations exposed to harsh physical conditions along the British coast, mussels of 20-30 mm in length can be 15-20 yrs old (Seed 1976). Similarly in the Baltic Sea, where low salinities exclude most competitors, blue mussels attain a maximum size of only 40 mm (Kautsky 1982). Under optimal growing conditions they may reach 50 mm in 18 mos (Seed 1976; Bayne and Worral 1980). The growth rate of cultured mussels may be 2 to 25 times that of mussels in natural bottom populations (Wallace 1980; Lutz 1985). Using floating mariculture techniques in Alaska, mussels started from thumb nail size spat (about 11 mm) reached harvestable size of 50 mm in 12-18 months (Hemming 1987).

Mussel growers have the advantage over oyster farmers in that readily available seed stock are collected in the wild.

Mussel spat may be collected using spat collectors (lines hung in the water during mussel settlement periods to which mussel larvae attach themselves) or the small seed mussels may be scraped from intertidal rocks etc. in the area. Once collected the mussels are generally grown out on heavy lines suspended in the water. The mussels are placed evenly along a highly frayed line called "christmas tree rope" and held there by an outer tubular netting until they attach themselves. The netting can be removed after mussel attachment or is commonly left on in which case the mussels grow through it and it eventually rots off. The grow-out lines themselves may be suspended from floating rafts (Fig. 10) or hung from buoyed longlines (Fig. 11). A typical 10' by 20' raft may produce 5,000 lbs of mussels each year (Hemming 1986). The longline system will endure wave action more readily than rigid raft culture and is favored for relatively exposed sites. From the permits for which I have information, 15 of 18 mussel farmers propose raft construction and the other three use a longline system.

Scallops

The targeted Weathervane scallop, the worlds largest species of scallop, is capable of living 16 years or more and reaching 12 inches in diameter (Kaill 1986; Rice 1973). It is a locally common and generally deep water species found from Alaska to Oregon (Rice 1973). P. caurinus has historically been harvested commercially in Alaska from the waters off Yakutat and Kodiak. Relatively large populations also are known to exist in Kachemak Bay and Prince William Sound (Kaill 1986). These mollusks, like mussels and oysters, have a planktonic free-floating larvae or fry stage which attaches itself to any available substrate. Unlike mussels and oysters, the young scallops break the attachment after several months and fall to the bottom where they spend the rest of their life as mobile adults. On the bottom they are able to propel themselves about with jets of water created by clapping the two valves together (Johnson and Snook 1927).

Another species with potential for mariculture in Alaska is the native purple hinged rock scallop (Crassadoma gigantea) (Rader et al. 1988). The rock scallop has a free-swimming juvenile stage but differs from the weathervane scallop by attaching themselves to rocks or old shells as adults. They sometimes attain a diameter of 10 inches (Rice 1973).

Scallop mariculture has only recently begun in Alaska and at this time feasability studies for spat collection and culture are underway near Kodiak island. After 2 years of collection efforts, few of the targeted weathervane scallop spat have been collected. Most spat collected have been of the Pink scallop (Chalamys hericia), a smaller species. Not all of this years collection of spat have grown to identifiable size (Bill Osborn pers. comm.).

The spat collecton equipment is being developed as a collaboratory effort with ADF&G, the Kodiak Area Native Association (KANA), and the Japan Overseas Fishery Cooperation Foundation. It is designed after similar equipment used for scallop spat collection in Japan. The working unit of the collector is composed of a 20 meter line, called a ren, suspended in the water from a buoyed longline system (Fig. 12). Attached to each ren are many small mesh collection bags similar to onion-bags (Fig. 13). Each collection bag containes a monofilament line mesh filler as an attachment surface for larval scallop. The outer onion-bag has a mesh large enough to allow the larvae to enter and settle on the inner filler. During the initial stages of development, the spat grow too large to escape through the outer bag and are "captured" as they fall from the inner mesh. The collectors are placed in the water in areas with known scallop populations and left throughout the time of spat settlement. Much of the research to date has focused on the timing of settlement and growth rates by placing and periodically examining test rens.

The spat that have been collected are going through intermediate grow-out in "accordian net" or "pearl nets" that are similar to oyster "lantern nets". This suspended cage culture system will likely be used for most of the intermediate grow-out stages while later stages may utilize facilities similar to oyster culture rafts (Osborn pers. comm.). Individal scallops also may be suspended by a fine line through a hole in the shell for the final growth period. The scallops should reach a harvestable size of approximately 5 in in diameter within 2-3 yrs after the spat are transferd to the intermediate grow-out nets (Kaill 1986).

Site Suitability

Growth of all filter-feeding mollusks is largely a function of water temperature and salinity, turbidity, food availability, and physical disturbance. These factors are all influenced by such things as water depth, tides, flushing rates, current velocities, proximity to fresh water discharges, and proximity to competitors and predators. Each species has different tolerances for extremes of these conditions, thus growth rates will vary among sites for the various species involved in mariculture.

Oysters imported into Alaska grow best in the warmest water available. Floating culture facilities take advantage of the warmest surface layer for optimal oyster growth. Water temperature is not as critical for mussels and scallops, which are adapted to the cold water environment, but optimal growth will still be found at the warmer water temperatures. None of these shellfish species tolerate silt well which will cause pearl formation in their tissues.

Adequate tidal flushing and current flow to circulate food, oxygenated water and transport metabolic wastes from the shellfish are important site characteristics for all species. Shellfish have proven to be extremely efficient filter feeders capable of removing a majority of available food particles as they move through the raft; therefore, adequate circulation is extremely important to achieve optimal growth. Water quality must be extremely high and sites must not be located near sources of industrial, municipal, or sewage pollution. Areas chronically contaminated with paralytic shellfish toxins are best avoided.

Water depth must be sufficient to prevent grounding of facilities at any tidal level and physical disturbance should be minimal. Here mussels have the greatest tolerance and may grow well in relatively exposed areas on longline systems.

Types and numbers of predators should be determined. Areas of concentrated predator populations should be avoided as well as areas considered to be critical habitat for wildlife.

Additional non-biological siting considerations include compatibility of other primary or secondary uses of the site, for example, log transfer facilities, seafood processing plants, harbor developments, mining claim access points, and anchorages for commercial and recreational boats to name a few. Access to shore for living quarters, processing facilities and storage may be useful, and year-round access to the site by boats or planes will be necessary.

Predators

It seems likely that shellfish farmers will experince losses to some kinds of predators. In fact, predation still remains a major obstacle to successful shellfish culture in many parts of the world (Jory et al. 1984). Sea stars, carnivorous snails, particularly the introduced Japanese oyster drill (Ocenebra japonica), various crabs, some fish species, gulls, sea ducks and some mammals are all known predators on farmed shellfish (Chew 1979; Burrel 1985; Lutz 1985; Hemming 1986; Kaill 1986; Rader et al. 1988). Rader et al. (1988) is the only publication we know of that mentions marine mammals, and specificly sea otters, as potential predators of shellfish farms. Rader et al. (1988) also mentions mink (Mustela vison), land otters (Lutra canadensis), habor seal (Phoca vitulina), sea lions (Eumatopias jubata), bald eagles (Haliaeetus leucocephalus) and herons as potential predators though none are considered a specific problem for any particular species.

Many bottom predators will be avoided with floating culture methods; however, a number of bottom-dwelling predators have a free-floating larval stage similar to shellfish larvae (Jory et al. 1984). A major problem for scallop farmers may be starfish larvae which, like the scallop larvae, are free floating and in search of attachment substrates. The starfish larvae enter the collector along with the scallop and devour the scallop as they grow (Naidu and Scaplen 1979; Kaill 1986). Other fouling organisms may clog the collectors (Hortle and Cropp 1987).

The grow-out facility will provide habitat for a variety of fouling organisims, few with benefical value. (Kaill 1986; Hemming 1987). Contamination of shellfish may result from anti-fouling compounds used on culture trays and nets (Davies and Paul 1986; Davies et al. 1986). The only suitable control method may be routine cleaning of the facility to reduce the amount of unwanted organisms. Mussel grow-out lines can be inverted regularly to reduce problems with sedimentation, and floating structures may be beached occasionally to kill unwanted organisms.

The oyster drill can cause significant damage (Burrel 1985 and the best protection is careful control of imported spat to preclude them from becoming established at the site (Pauley 1988).

Sea Ducks, including scoters (Melanitta spp.), eiders (Somateria spp.), goldeneye (Bucephala spp.), and harlequin ducks (Histrionicus histrionicus) have been identified as problems to shellfish farms (Dunthorn 1971; God 1981; Lutz 1985; Hemming 1987; Jefferds 1987; Rader et al. 1988). Mussels, in particular, make up a major portion of the diet of these waterfowl (Petersen 1981; Koehl et al. 1984; Sanger and Jones 1984; Vermeer and Bourne 1984). Most waterfowl seem to prefer smaller mussels ranging from 1-30 mm (Dunthorn 1971; Petersen 1981; Godo 1981); however, the feeding activity of the ducks may dislodge the larger, less preferred mussels resulting in significant losses to the small farmer (Hemming, pers. comm.; Dunthorn 1971; Lutz 1985; Skidmore and Chew 1985). These same species may find young oysters desirable (Rader et al. 1988) and we suspect young scallop may also be a temptation. Wintering sea ducks number in the millions throughout ice-free regions in coastal Alaska (Forsell and Gould 1981, Degange and Sanger 1987, Conant et al. 1988).

Sea otters are the predators most likely to conflict with shellfish mariculture because of their preferred diet, their abundance in coastal waters, and their expanding range in Alaska (Rader et al. 1988). Although this fact is recognized in one report (Rader et al. 1988), it has not received much attention in most discussions of mariculture to date.

The sea otter is an extremely efficient predator of shellfish and other benthic invertebrates in the coastal zone of western North America, and where present, can have a major influence on nearshore benthic communities by reducing the size, density, and biomass of epibenthic and infaunal invertebrates (Estes and Palmisano 1974; Estes et al. 1978, 1982; Simenstad et al. 1978; Duggins 1980; Breen et al. 1982; Kvitek et al. 1989a). Known prey species of sea otters include sea urchins (Strongylocentrotus spp.), abalone (Haliotis spp.), numerous genera of clams (e.g.,Siliqua, Saxidomus, Protothaca, Tresus, Humilaria, Gari, Mya, Macoma, Spisula, Serripes, Clinocardium, mussels (Mytilus spp.), rock scallops (Hinnites giganteus), Dungeness crab (Cancer magister), rock crabs (Cancer spp.), kelp crabs (Pugettia spp.), spiny lobsters (Panulirus interruptus), sea stars (Pisaster spp.), octopuses (Octopus spp.), a variety of other invertebrates, waterfowl (VanWagenen et al. 1981; Riedman and Estes 1987) and, in some parts of Alaska, slow moving bottom-fish (Estes and Palmisano 1974; Estes and Van Blaricom 1985). Foraging by sea otters on oysters in the wild has not been reported although captive otters are capable of shucking and eating them when offered (Estes and Van Blaricom 1985).

The caloric requirements of sea otters are great relative to their size (Morrison et al. 1974; Costa 1978; Costa and Kooyman 1981, 1984). This is due to the lack of insulative blubber that protects most other species of marine mammals. Survival depends upon a dense pelage and adequate caloric intake. Captive individuals may consume 23-37% of their body weight in food organisms each day (Costa 1978).

The importance of various prey species in the diet of sea otters varies depending on habitat type, length of otter occupation, population density, season, and individual preferences (Ebert 1968; Vandevere 1969; Wild and Ames 1974; Calkins 1978; Estes et al. 1981; Garshelis et al. 1986). Sea urchins compose the major portion of the diet in newly repopulated islands in the Aleutian Islands. Epibenthic fish now make up an important component of their diet on at least one island near equilibribium density in the Aleutians (Estes et al. 1981). In southeastern Alaska sea urchins also seem to be an important food of sea otters as they first move into unpopulated areas (Rosenthal and Barlotti 1973; Thomas 1988). Dungeness crabs and large clams formed a significant portion of the diets of sea otters in newly re-populated areas of eastern Prince William Sound but small clams and mussels were more important in long-established parts of the Sound (Estes et al. 1981; Garshelis 1983; Garshelis et al. 1986). Sea otters in recently occupied habitat at Kodiak Island prefer large butter clams to other prey (Kvitek et al. 1989a; DeGange unpubl. data). In portions of the Kodiak Archipelago occupied by sea otters for many years, diets were more diverse than in more recently occupied areas but otters consumed smaller food items, most of which were clams (DeGange unpubl. data).

Although predation by sea otters on mussels is widespread (Hall and Schaller 1964; Calkins 1978; Estes et al. 1981; Faurot et al. 1986; Harrold and Hardin 1986), it is unclear how important mussels are to sea otters as a food source. VanBlaricom (1986) has documented reductions in the sizes of mussels in Prince William Sound corresponding to areas recently occupied by female sea otters and pups. There is some evidence that mussels may be particularly important to recently weaned otters because they are accessible and easy to eat (Garshelis 1983; Garshelis et al. 1984; Monnett pers. comm.).

Alaska is unique in that it is inhabited by 90% of the worlds population of sea otters. The remaining 10% are distributed among California, Washington, British Columbia and eastern USSR (Schneider 1981; Calkins and Schneider 1985; Rotterman and Simon-Jackson 1988). The present range of the sea otter in Alaska includes almost all their historical range in the Aleutian Islands and along coastal habitats in the southern Bering Sea and Gulf of Alaska. Notable, unfilled gaps in distribution occur at Kodiak Island, in Lower Cook Inlet, along the northeastern Gulf of Alaska, and in southeastern Alaska. Overlap with ongoing mariculture development occurs in the Kodiak Archipelago (Fig. 13), in Kachemak Bay in Lower Cook Inlet, and in portions of Prince William Sound (Fig. 14). The inside waters of SE Alaska contain the largest proportion of the states active shellfish farms, but the closest sea otters are on the outside coast (Fig. 15). The extent to which expanding populations of sea otters on the outside coast of SE Alaska will colonize the inside passages is unknown (Pitcher 1987) although there are no historical records of sea otter from this area.

Two undeveloped farm sites in the Kodiak Archipelago are within areas inhabited by substantial numbers of sea otters: Onion Bay on the south side of Raspberry Island, with seasonally up to 200 sea otters; and Raspberry Strait on the north side of Raspberry Island with regular counts of up to 500 animals. Tidal and submerged lands around Afognak Island are managed by the U.S. Fish and Wildlife Service. Under one management alternative, much of this land will be under intensive or moderate management which permits mariculture. The Fish and Wildlife Service projects that 7-14 shellfish mariculture operations may be established around Afognak Island, perhaps many of them in Raspberry Strait, a high density sea otter area. Exclosures to discourage predation by sea otters will be required by the special use permits for those operations (Alaska Maritime National Wildlife Refuge Final Comprehensive Conservation Plan).

Another proposed mariculture site on the east side of Near Island, adjacent to the town of Kodiak, is near a frontal group of more than 100 sea otters that recently arrived from the north side of the island. The only active mussel farm at Kodiak Island is in Anton Larsen Bay on the north side of Kodiak Island where a few sea otters are occasionally present. The only other developed mariculture site is in Kempff bay on the south end of Kodiak Island. Few if any sea otters visit this bay possibly due to its proximity to the village of Akhiok.

The Halibut Cove Lagoon experimental mariculture area has a number of mussel rafts in the water and although the area outside the bay has a resident population of otters, otters are rarely seen within the lagoon. Foraging by sea otters on mussels suspended from rafts has not been observed (Hemming pers. comm.).

Prince William Sound holds several sites all within otter habitat. Two oyster farms are located on Hawkins Island, near Cordova, on the east side of the Sound. This area is seasonally occupied by as many as 500 otters although the bays in which they are sited are infrequently visited by otters (Monnett pers. comm.). Sea otters, which have been observed at the sites, have not caused problems, in fact, they have been welcomed by one farmer who believes they are eating mussels that foul his rafts.

Movements and Range Expansion of Sea otters

Dynamics of sea otter movements and range re-colonization will likely confound attempts to isolate sea otters and mariculture sites from one another. Telemetry studies of sea otters at Kodiak Island, Prince William Sound and on the north side of the Alaska Peninsula suggest that movements of individuals of up to 30-50 km are not unusual (Garshelis and Garshelis 1984; Monnett and Rotterman 1988; Ralls et al. 1988; DeGange and Monnett unpubl. data). These studies also indicate that sea otters routinely move seasonally from exposed, open areas in the summer to protected areas in the winter.

The U.S. Fish and Wildlife Service has proposed managing sea otters zonally in Alaska. Under such a management plan, the Service would maintain, if warranted, a series of otter-free zones specifically designated as shellfish production zones. Establishemnt of sea otter-free zones will likely be easiest if areas already free of sea otters are chosen. Siting of new mariculture sites within these sea otter-free zones logically would reduce conflicts between the two. Currently, sea otters are re-occupying the remaining unfilled gaps in their historical range at a rapid rate; therefore the opportunity to establish sea otter-free zones without removal or harvest of large numbers of sea otters is diminishing.

Garshelis et al. (1984) suggests that re-occupation of unfilled historical range by sea otters occurs in a series of steps. The advancement of the otter "front" is initiated by groups made up primarily of young and non-territorial males. They feed on the largest and most calorically rich prey and as that prey is depleted, move on to unexploited feeding areas. Females tend to back-fill in behind the males and reproductive males establish territories in the new female areas. As the population of an area nears its carring capacity, food availability becomes more of a limiting factor. Sea otters respond to low food availability by increasing the amount of time they spend feeding (Estes et al. 1982; Garshelis et al. 1986) Low food availability may also be accompanied by increased mortality (Kenyon 1969), and perhaps lower reproductive rates and reduced pup growth. In isolated areas such as remote islands, male groups are relegated to more exposed habitat (Schneider 1978, Kenyon 1969). Seasonal mortality may occur, particularly during late winter storms (Kenyon 1969). Mariculture farms, established in regions that are at carrying capacity may attract sea otters.

Rader et al. (1988) reports that the Alaska Department of Fish and Game considers mariculture operations as an attractant to sea otters and does not support the destruction of sea otters under state regulations allowing the taking of animals in defense of life or property. The state recommends non-lethal methods to protect mariculture farms. Harassment or killing of sea otters for the protection of a mariculture facility would not be permissible under the Marine Mammal Protection Act of 1972 which gives complete protection to sea otters except for subsistence hunting by Alaskan natives. Perhaps native Alaskans would be legally allowed to kill sea otters that were creating problems around a mariculture facility, but only if the sea otters were used for subsistence purposes.

At present there are few data to evaluate sea otter-mariculture conflicts. Currently the primary form of shellfish mariculture along the Pacific coast of North America is the Pacific oyster with Washington state producing approximately 5 times the combined production of British Columbia, Oregon, and California (Chew 1983, 1984; Burrel 1985; Pauley et al. 1988). The primary oyster production areas of Washington and California are within protected bays and lagoons, most notably Puget Sound and Willipa Bay in Washington (Chew 1979, Pauley 1988), outside the current and historic sea otter range within these states (Jameson et al. 1986; Riedman 1987; Bowlby et al. 1988;). Mussel farming in the contiguous United States is in its infancy with much of the growing effort taking place in New England (Lutz 1985). On the west coast the effort has been largely in Tomales Bay north of San Francisco and in Puget Sound of Washington (Lutz 1985; Shaw et al. 1988), all areas out of the otter's current range.

The only region where interactions between sea otter and sea farming have been reported is British Columbia. Oyster farmers have not experienced problems with sea otters to date (Michael Gordon, pers. comm.); however, there are reports of otter harassment and shooting by oyster farmers. (Michael Gordon, pers. comm.). It is difficult to determine how widespread such instances are or the significance of these individual cases to the local population of sea otters. Salmon farms have experienced some problems with sea otters in British Columbia; however, most have been caused by lax or ill kept protective devices (Derik Monteith, pers. comm.).

Deterrence of Predators

Oyster farmers using raft culture may prevent predation by use of mesh or plywood covers (Else et al. 1987). Stacking trays using an empty tray on top could provide easy and effective predator prevention (Wisely et al. 1979; Jory et al. 1984; Else et al. 1987). Protection of mussel rafts and longlines may be more difficult. Jefferds (1987), and Rader et al. (1988) report that the best protection for mussels from scoter predation may be enclosure of the rafts with nets. However, while exclusion and isolation nets and pens may provide adaquate protection of the shellfish crop, they generally require considerable capital investment and constant attention and monitoring (Jory et al. 1984). The resulting increase in cost for nets and labor may be prohibitive for the small operator already operating on a slim profit margin (Hemming 1986; Hemming pers. comm.).

Other techniques which have been used to discourage predation on farmed shellfish by seaducks have been to anchor the mussel rafts in water much deeper than the normal feeding depths of the diving ducks (Hemming 1987; Hemming pers. comm.) or to provide a sacrificial crop at the surface to satisfy the ducks while maintaining the commercial crop in deeper water (Gunn et al. 1983). Surface alarms and under water sirens used to keep feeding ducks out of the area have been tried but with little success (Lutz 1985).

Methods of controlling sea otter predation are limited and as yet untested. Net exclosures and culture pens such as those used for protection from sea ducks may provide sufficient protection if the cost of installation and upkeep are not prohibitive. Acoustical methods for excluding sea otters from an area were unsuccessful (Davis et al. 1988).

Careful siting may be the most effective method of preventing depredation problems. Rader et al. (1988) recommends not siting farms within 1 mile of concentrations of sea ducks, sea otters or other marine mammals to avoid predation.

Discussion

Increased interest in mariculture in Alaska has been the result of a favorable economic climate and the recognized potential of the state to become a leader in mariculture production. Three additional items have probably been factors in the substantial increase in numbers of mariculture permit applications. First is simply a greater awarness of the permiting requirments by individul farmers and the increased attention given the permiting regulations by the state agencies involved. This is likely the case in SE where oyster farming has been going on at low levels for many years but without strict permiting requirments. Second has been the demonstration by a few individuals that sea farming is feasible and profitable in Alaska. Robin Larsson first brought oyster spat to his SE Alaska farm in 1978 resulting in the first commercial sale of oysters in 1983 and establishment of the Alaska Shellfish Grower's Association (Larsson 1986). James Hemming was the lone Army Corp of Engineer mariculture applicant for 1983. His efforts resulted in the first commercial harvest of blue mussels in 1986 and a subsequent increase in permit activity for the SC region from 1985 to 1987. Third, has been the addition of private and public support. For example, oyster farmers in southeastern Alaska became a part of an extensive multi-agency mariculture pilot project in the Etolin Island area near Wrangell. This support facilitated establishment of Etolin Island as the center for oyster farming in Alaska. The state also established Halibut Cove Lagoon in Kachemak Bay State Park as an experimental area for mariculture and this area has become the center of mussel farming for the state. Most recently, the cooperative development effort for scallops have established Kodiak Island as the primary region for research on scallop mariculture. Permit activity suggests that Kodiak will become the leading scallop mariculture area in the state.

The interest in aquatic farming is just now being reflected in the ability of State and Federal agencies to process and issue permits for this acitivity efficiently. The permitting process had been a cumbersome, time consuming, and intimidating process for the individual interested in mariculture. The new regulations and procedures, although still not simple, are designed to encourage inceased particpation in this new industry and promote its establishment in new areas. The coastal zone management plan for Prince William Sound is the first such plan to incorporate specific provisions for mariculture making it the most likely area for development under the new requlations (Janetta Pirchard pers. comm.).

So what does all this mean for otters and shellfish farmers? Are they compatible with each other? Based on the dietary preferences of sea otters for shellfish, their need for eating large quantities of food, their tendency towards optimal foraging (Kvitek et al. 1989a), their abundance and distribution, and their size and strength, we feel there is a strong potential for conflict between sea otters and this industry in Alaska. There are several factors that might influence the susceptibility of mariculture farms to depredation from sea otters including the location of the site, the species farmed, the size of the farm, and the status of the nearby population of sea otters, specifically its size, density, and composition, the length of time it has occupied the area, and its status with respect to carrying capacity and hence availability of food.

Available data suggest that existing oyster farms are in little danger from sea otters. Oyster farms are almost all located within the inside waters of southeastern Alkaska and there are no data that suggest sea otters ever occupied that area (Kvitek et al. 1989b). There is potential for problems for oyster farms sited within existing sea otter range such as has occurred in British Columbia, but even here problems have been minimal (Michael Gordon, pers. comm.). If problems should arise, they could be rectified by addition of covers to the grow-out facilities. Paralytic shellfish toxins, which are common in the inside waters of southeastern Alaska are likely to be a bigger problem to shellfish farmers in southeastern Alaska than sea otters (Kvitek et al. 1989b).

Scallop farmers also may experience problems from sea otters but several features of scallop farming may limit the severity of these obtacles. First, grow-out techniques are likely to be similar to oysters, thus covers could be added to effectively eliminate predation. Secondly, scallop operations will conceivably be operating on a larger scale than oyster or mussel farms and thus will be able to absorb costs associated with predator proofing the facility more readily. Third, because of the size of future scallop farms and the amount of labor required to produce scallops, grow-out facilities are likely to be limited in number and sited near towns or villages where native subsistence hunters and other disturbances already exclude sea otters to some extent.

Of all types of mariculture operations, small mussel farms are most likely to encounter problems with sea otters. Sea otters are known to feed on mussels (Estes et al. 1981; Garshelis 1983; Estes and VanBlaricom 1985; DeGange unpubl. data) and have been demonstrated to be able to reduce the size and biomass of wild mussels (Van Blaricom 1987). In addition, the small mussel farmer trying to establish himself within the narrow profit margin afforded by this type of farm, may not be able to afford protective exclosures. Finally, mussel farms are developing within areas of well established sea otter populations, often in fairly remote areas. Thus, a substantial number of these farms scattered along the coast may have significant secondary effects to sea otters through exclusion, competition and entanglement.

Siting of mariculture operations may be the best and the most convenient way to prevent problems associated with sea otters. Given what we know of the movements of sea otters and the rapidity with which they can re-invade and re-populate vacant habitat (DeGange and Monnett unpubl. data; Garshelis et al. 1984; Pitcher 1987, 1988; Riedman 1987; Irons et al. 1988; Rotterman and Simon-Jackson 1988) placing of mariculture facilities outside of 1 mile from concentrations of marine mammals will not necessarily confer protection on the operation as has been suggested by Rader et al. (1988). With the exception of parts of the inside waters of southeastern Alaska, it is likely that any site chosen for mariculture will eventually come into contact with sea otters if current management practices continue. Therefore mariculture operations are likely to be placed along a gradient between those areas recently occupied by sea otters with high densities of both sea otters and prey or areas at carrying capacity characterized by low food availability. In the former areas, production of sea otters will be high but many animals may not bother shellfish farms because of abundant natural high energy foods. Exceptions may be young, recently weaned individuals or immature sea otters looking for an easily obtainable food source. At the other extreme, in areas at carrying capacity, mariculture operations could represent an attractant to many individuals of all ages, but particularly recently weaned or immature sea otters. It is doubtful that a small mussel farm could survive many visits from sea otters in an environment with low natural food supplies.

Despite what appears to be a gloomy prognosis, we believe permit guidelines could be established that would allow successful mariculture, even for mussels, in areas occupied by sea otters, but not without risk. First, we believe persons applying for mariculture permits within existing and future sea otter range should provide saticfactory non-lethal plans for predator control. The regulatory agencies involved should provide information to applicants regarding potential predators and acceptable methods of control as has been suggested by Rader et al. (1988). The agencies should reserve the right to revoke permits and leases if unacceptable methods of control are employed. We recommend that mariculture sites be clustered such as has occurred around Etolin Island and in Halibut Cove. Clustered operations are more easily defended than solitary ones and continued activity and noise at the site may discourage exploration by local sea otters. Clustering would also minimize the total amount of habitat utilized by this industry and thus reduce displacement impacts. Clustered operations should be located as close as practical to existing towns and villages, to take advantage of activity, disturbances, and native subsistence hunters which might already be keeping sea otters away. Frequently within existing sea otter range there are small bays and lagoons that are infrequently visited by sea otters. If a cluster of operations is established in such a lagoon it may be relatively easy to keep inquisitive sea otters out. Clustering small operations may also facilitate the development of shellfish cooperatives and associations which could share the costs of predator-proofing the facility. We strongly recommend against the siting of mariculture facilities in areas already at carrying capacity for sea otters where food is in short supply and where farms may attract sea otters. Although other areas within the range of sea otters will also reach carrying capacity in the future, it is likely that sea otters will learn to stay away from mariculture facilities if those facilities are established during the early stages of reoccupation when natural prey is still abundant.

Summary

Shellfish mariculture is a rapidly developing industry in the Pacific Northwest of North America. Oysters are the principal species cultured throughout this region although the industry is diversifing to include mussels and scallops. Only in

Alaska and British Columbia do existing and planned mariculture facilities overlap with sea otter distribution. Culture techniques for oyster and scallops in Alaska, particularly the use of trays and covers, should reduce the likelihood of depredation by sea otters. Blue mussel culture, however, may be highly succeptible to sea otters, especially those facilities located in remote areas and those sited within areas of low food availability for sea otters. Proper siting of new mariculture facilities could help reduce potential conflicts with sea otters. We recommend that in Alaska:

1) mariculture facilities established in existing or future sea otter range be clustered.

2) mariculture facilities be locatied in bays and lagoons infrequently used by sea otters.

3) mariculture facilities not be sited in areas of long established otter populations with low natural food availability.

4) applicants for mariculture permits be required to submit detailed plans specifying intended methods of dealing with avian and mammalian predators.

5) the Alaska Department of Fish and Game provide the new

applicant with information on sea otter and sea duck populations in their area of interest and in addition supply current facts concerning the legal status of sea otters, sea ducks and other potential shellfish predators along with currently acceptable methods of control.

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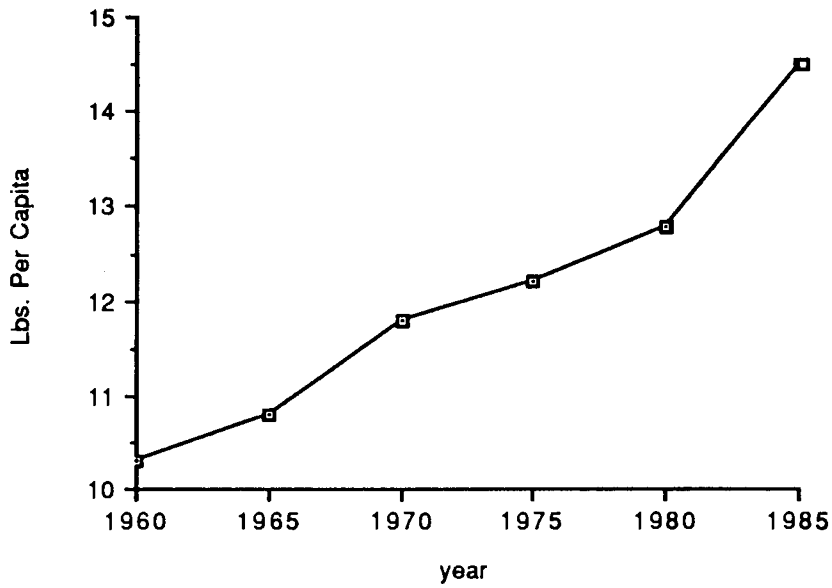

Fig. 1. Trend in per capita consumption rates of fish and shellfish in the U.S. (based on data from the National Marine Fisheries Service and summarized in Pierce 1987).

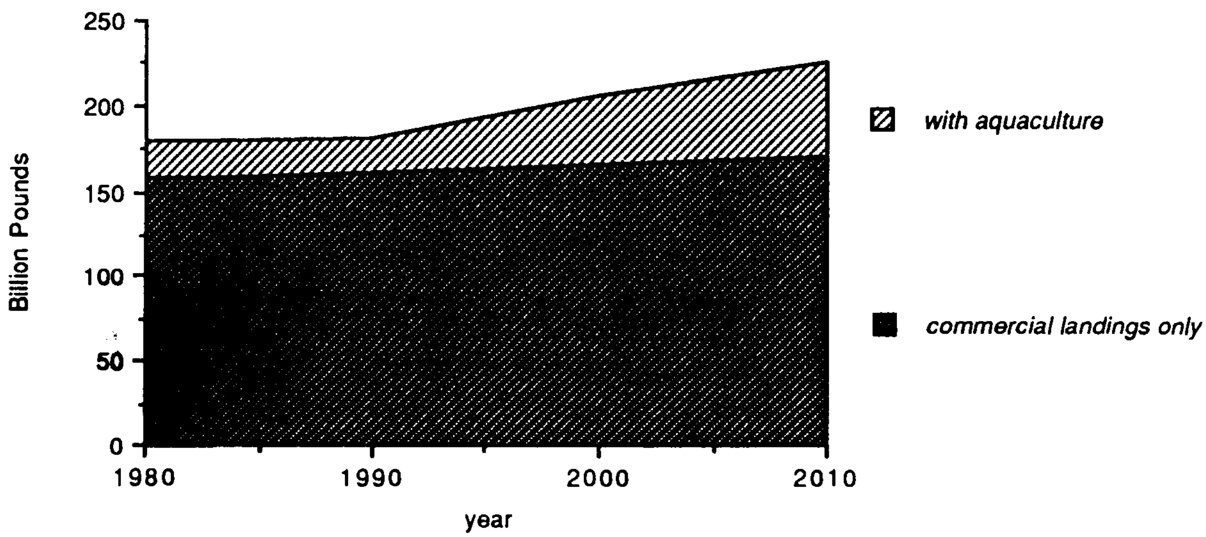

Fig. 2. Annual world harvest of fish and shellfish as projected by the International Aquaculture Foundation (reproduced from Pierce, 1987).

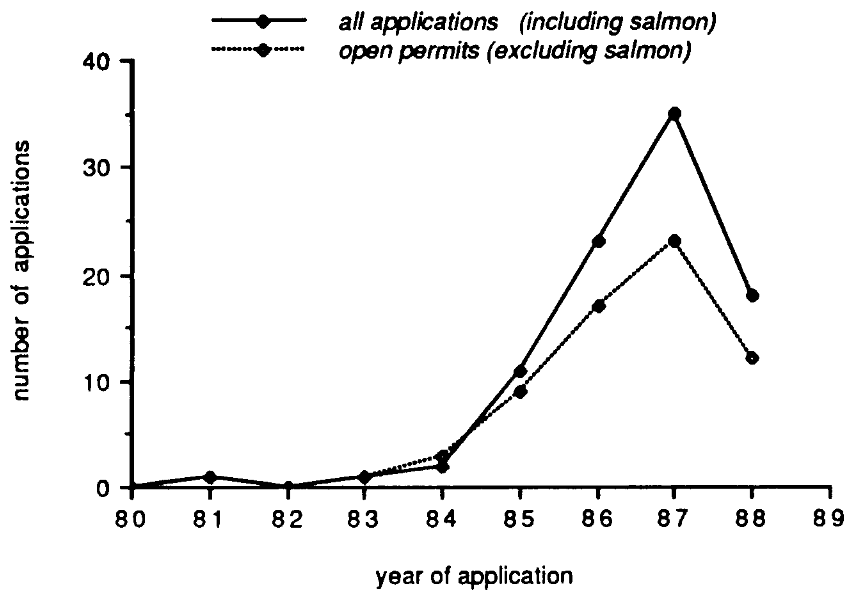

Fig. 3. Total number of mariculture permit applications (including salmon) and currently open shellfish permits (excluding salmon) in Alaska by year.

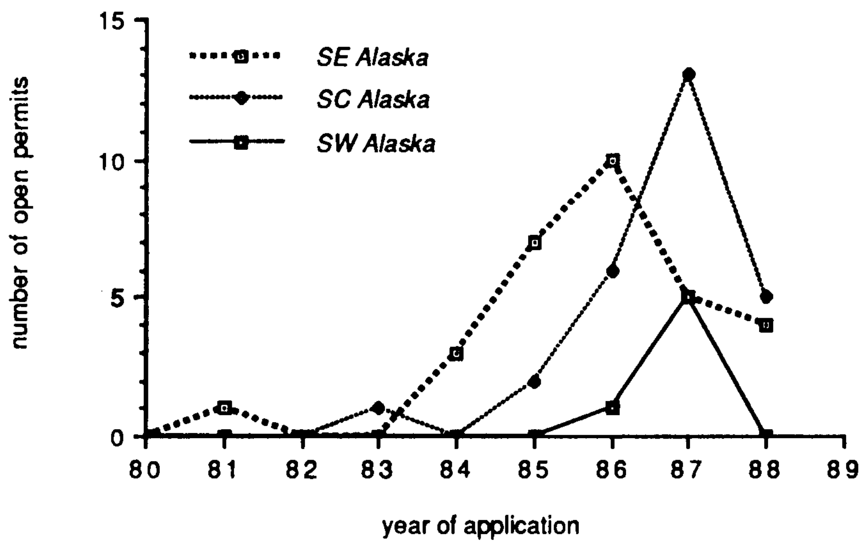

Fig. 4. Number of mariculture permit applications in each region of Alaska by year.

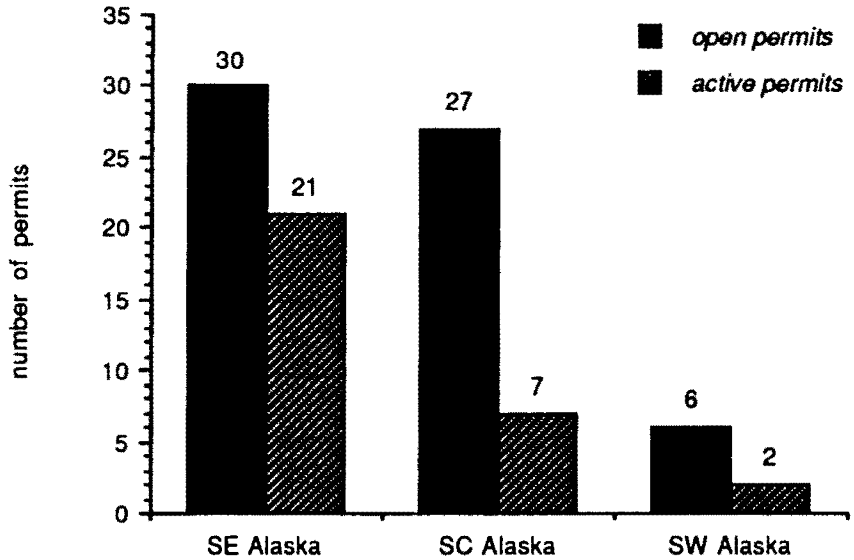

Fig. 5. Number of open vs. active* mariculture permits in each region.

* best estimates from interviews.

From 80 – 88

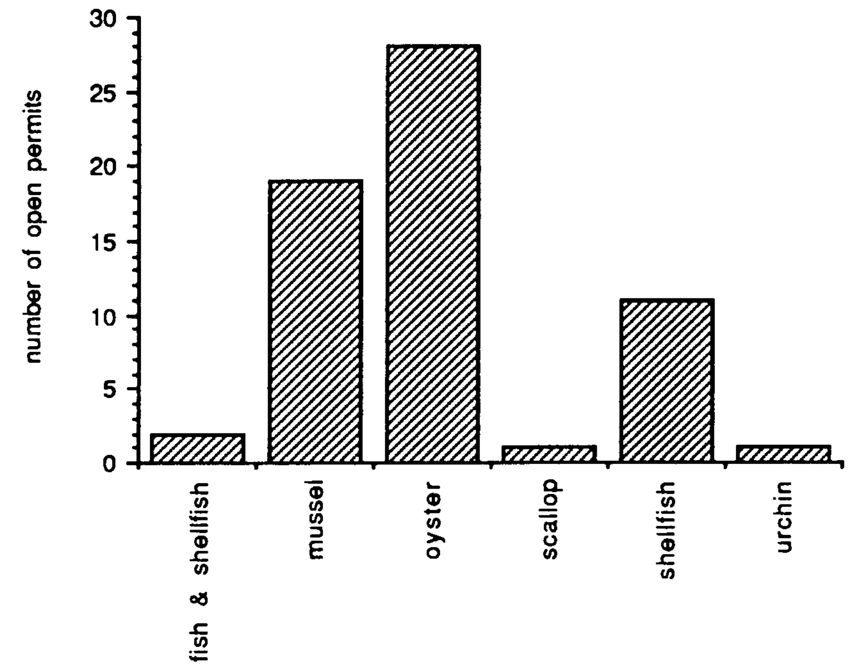

Fig. 6. Total number of open mariculture permits in Alaska for each species category through 1988.

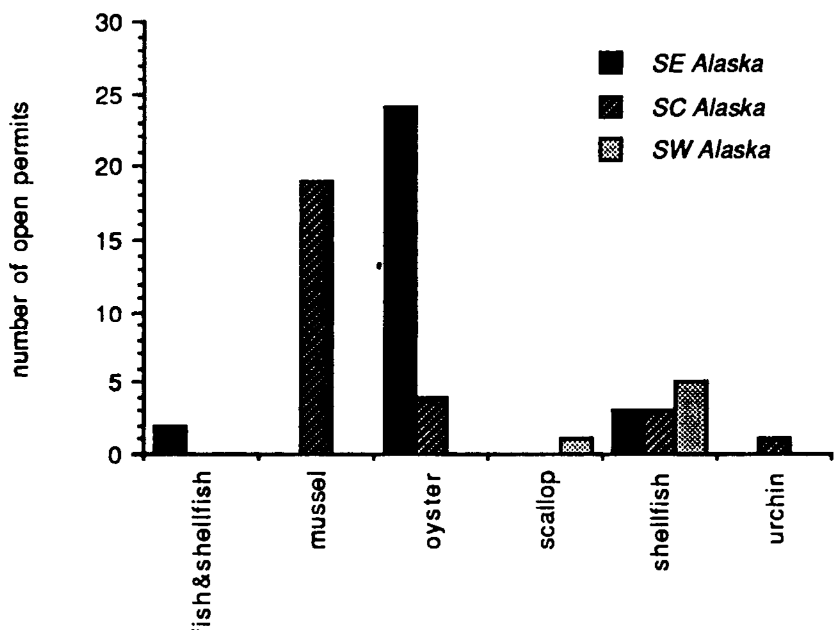

Fig. 7. Number of open permits for each species category in each region through 1988.

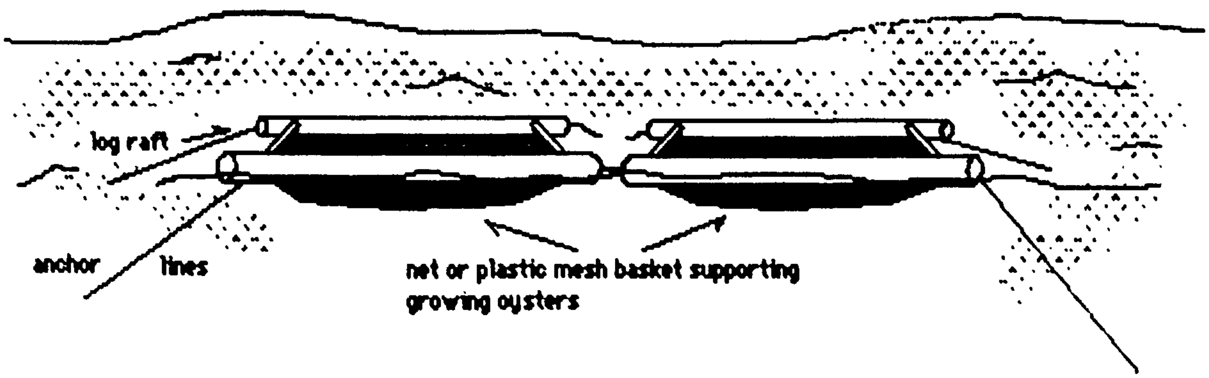

Fig. 8. Diagram of typical oyster tray or "floating beach" used in SE Alaska (drawn from description in Larrson 1986).

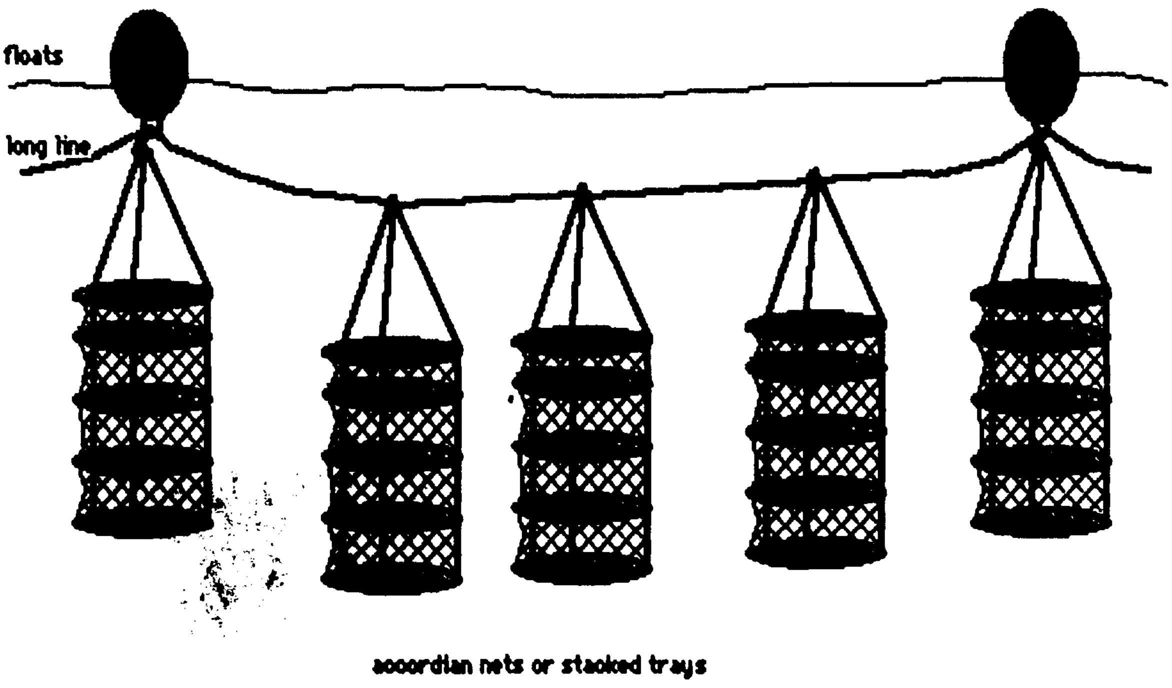

Fig. 9. Diagram of one type of stacked tray system for oyster and scallop culture (redrawn from Aquabionics COE permit application).

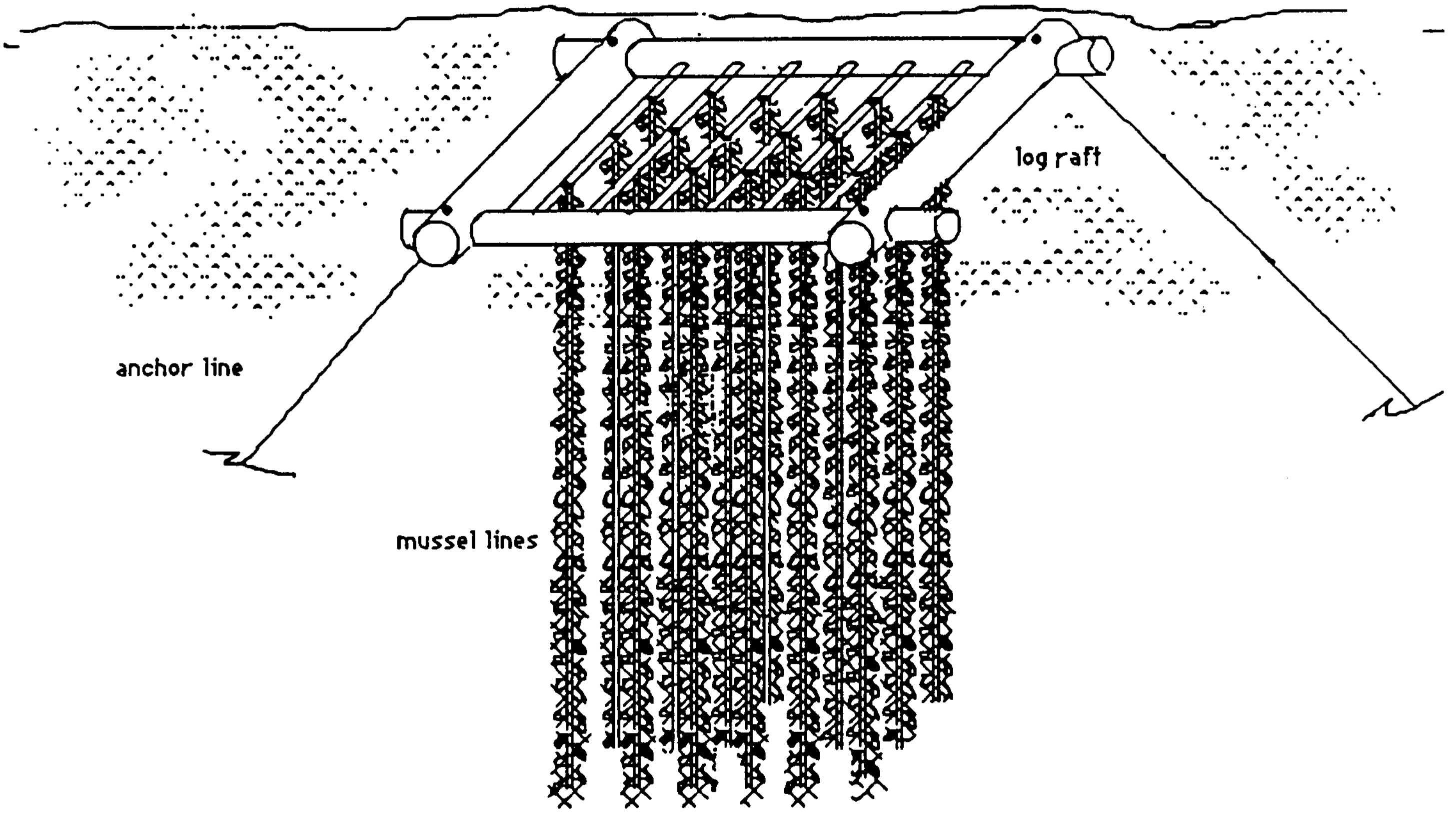

Fig. 10. Diagram of typical mussel raft used in Halibut Cove Lagoon.

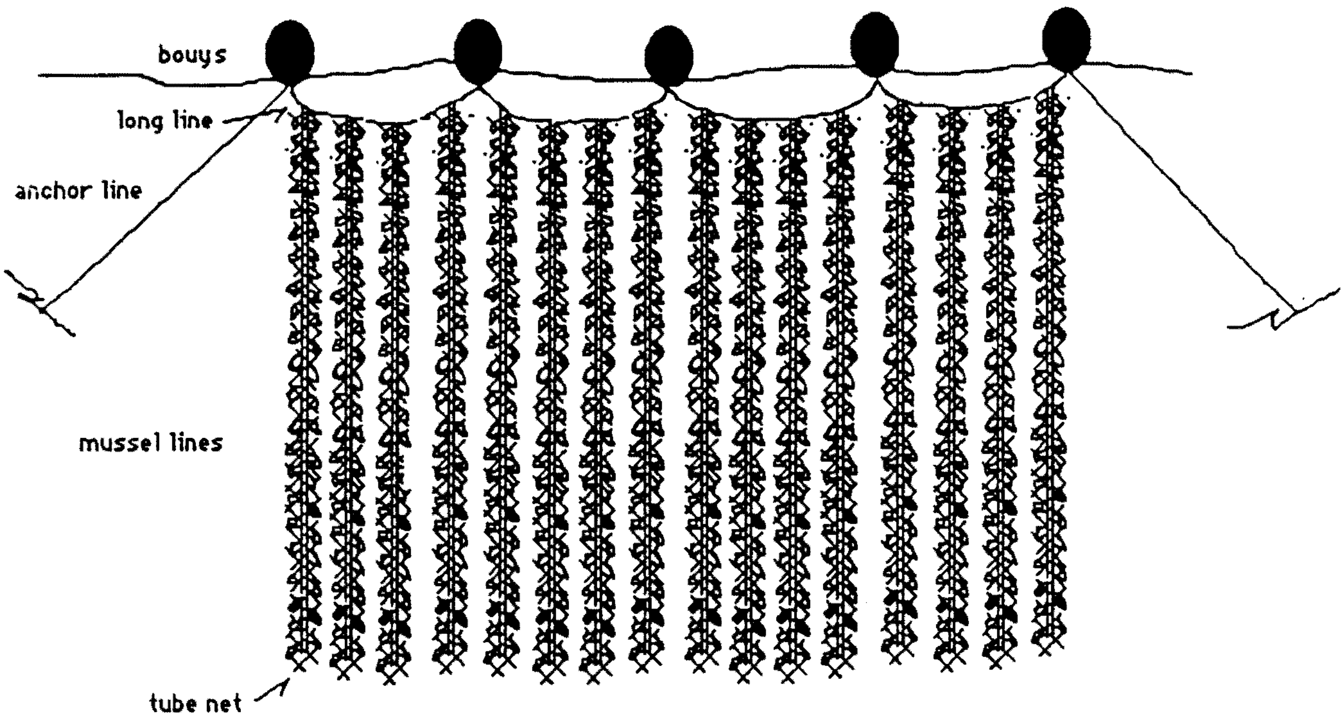

Fig. 11. Typical long line system for blue mussel culture.

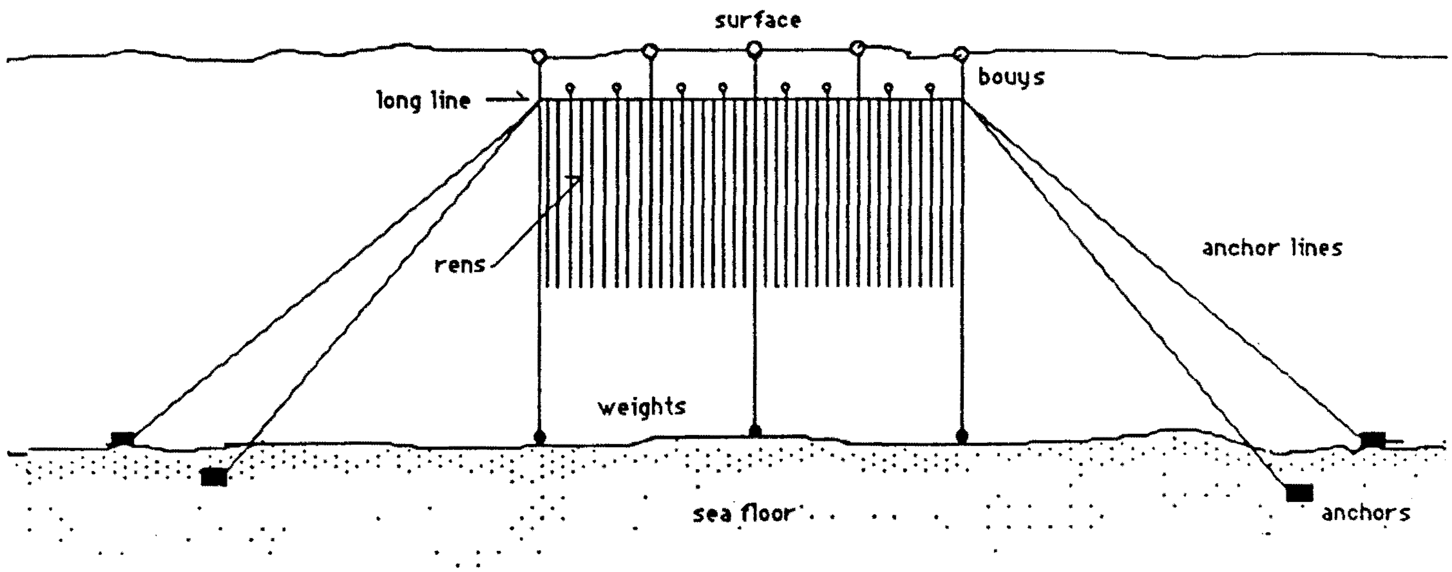

Fig. 12. Diagram of scallop spat collection gear used in Kodiak (redrawn from Peyton et al. 1987).

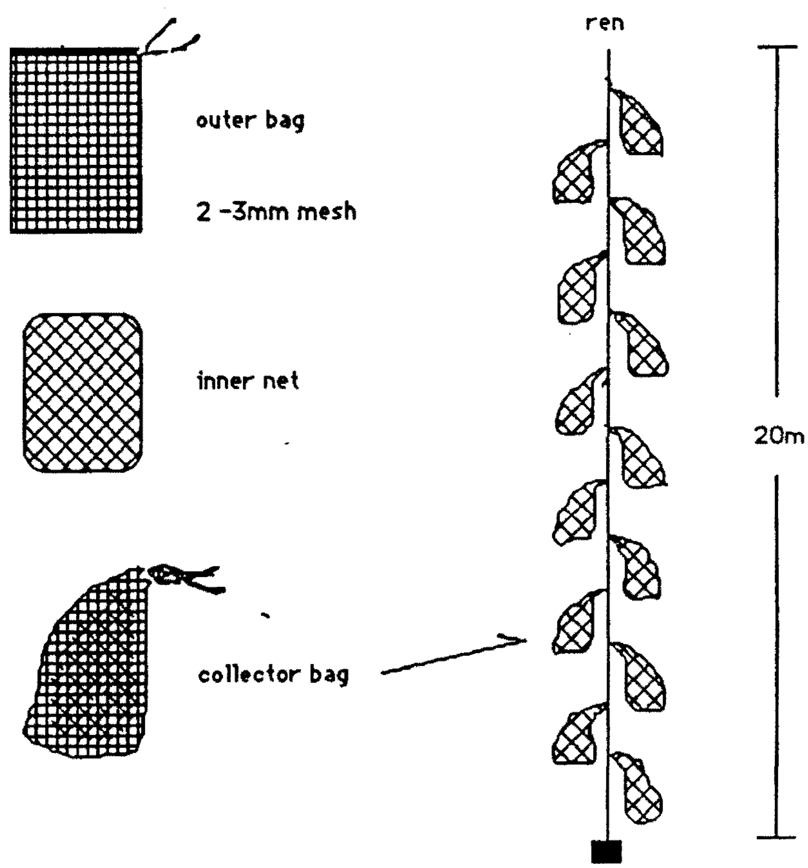

Fig. 13. Single unit of scallop spat collection gear (a ren; redrawn from Peyton et al. 1987).

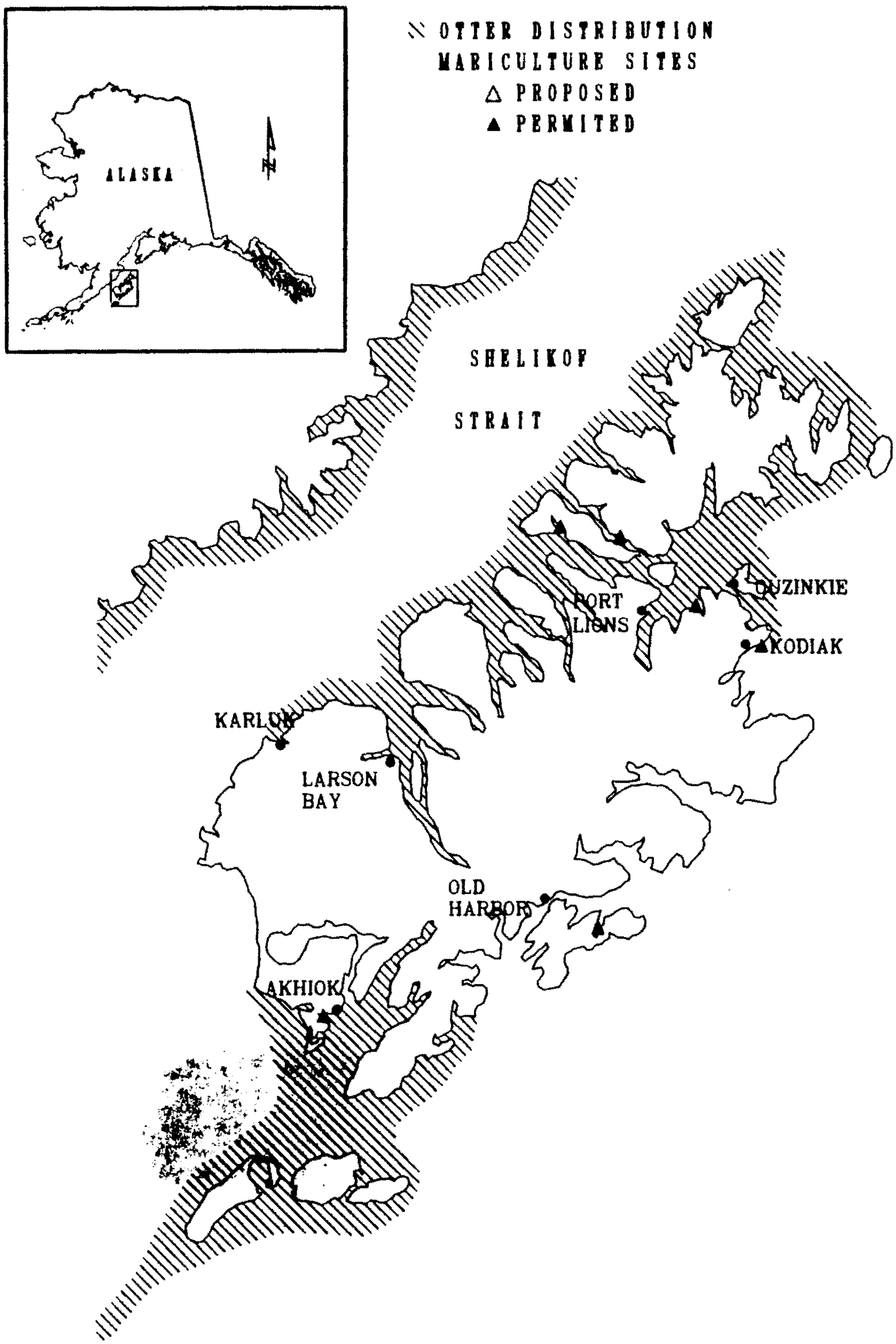

FIG 13. OTTER DISTRIBUTION AND MARICULTURE SITES ON KODIAK ISLAND, ALASKA (EXCLUDING SALMON FARMING SITES).

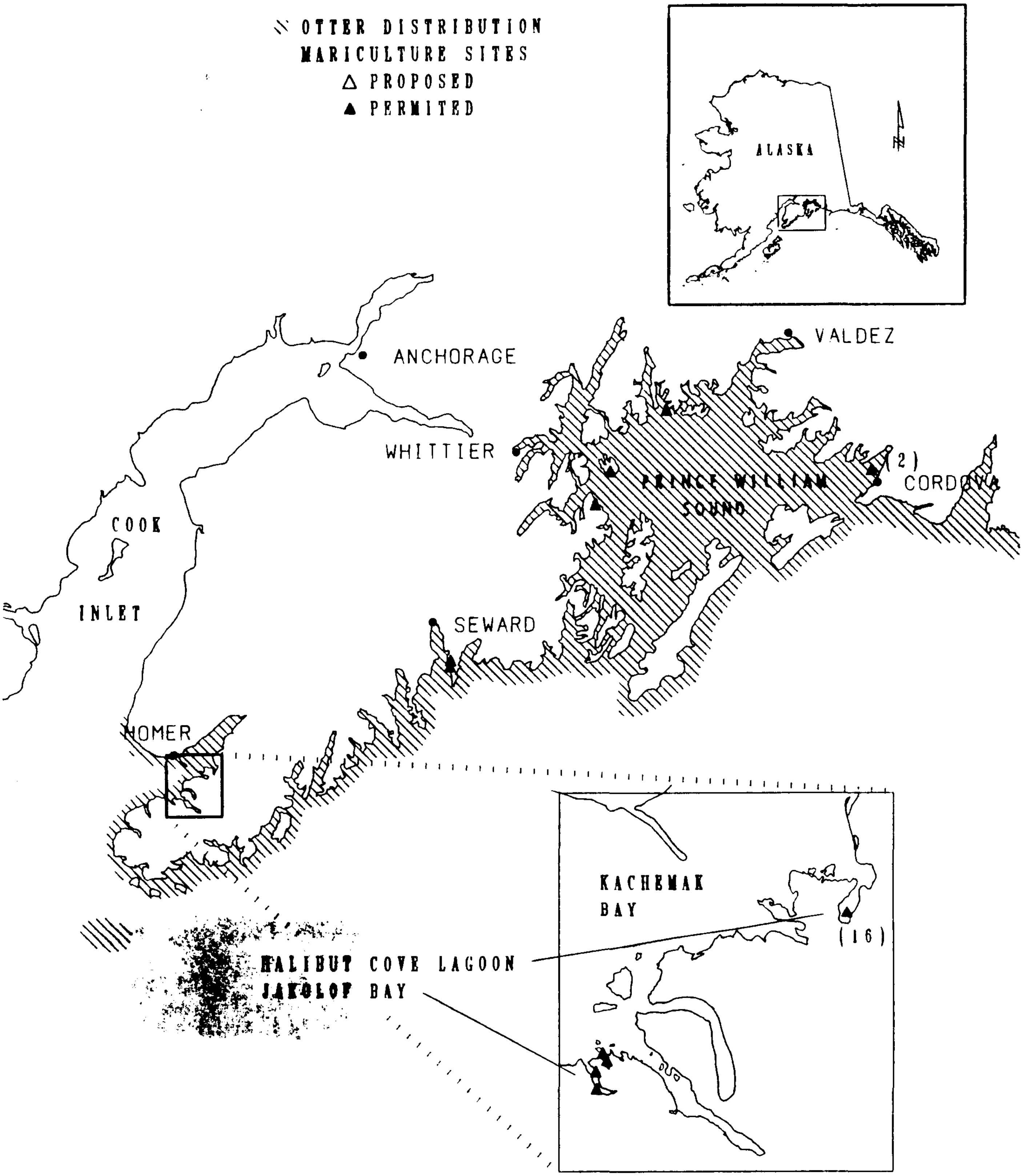

FIG 14. OTTER DISTRIBUTION AND MARICULTURE SITES IN SC ALASKA (EXCLUDING SALMON FARMING SITES). NUMBER IN PARENTHESES IS NUMBER OF MARICULTURE SITES IN THAT AREA.

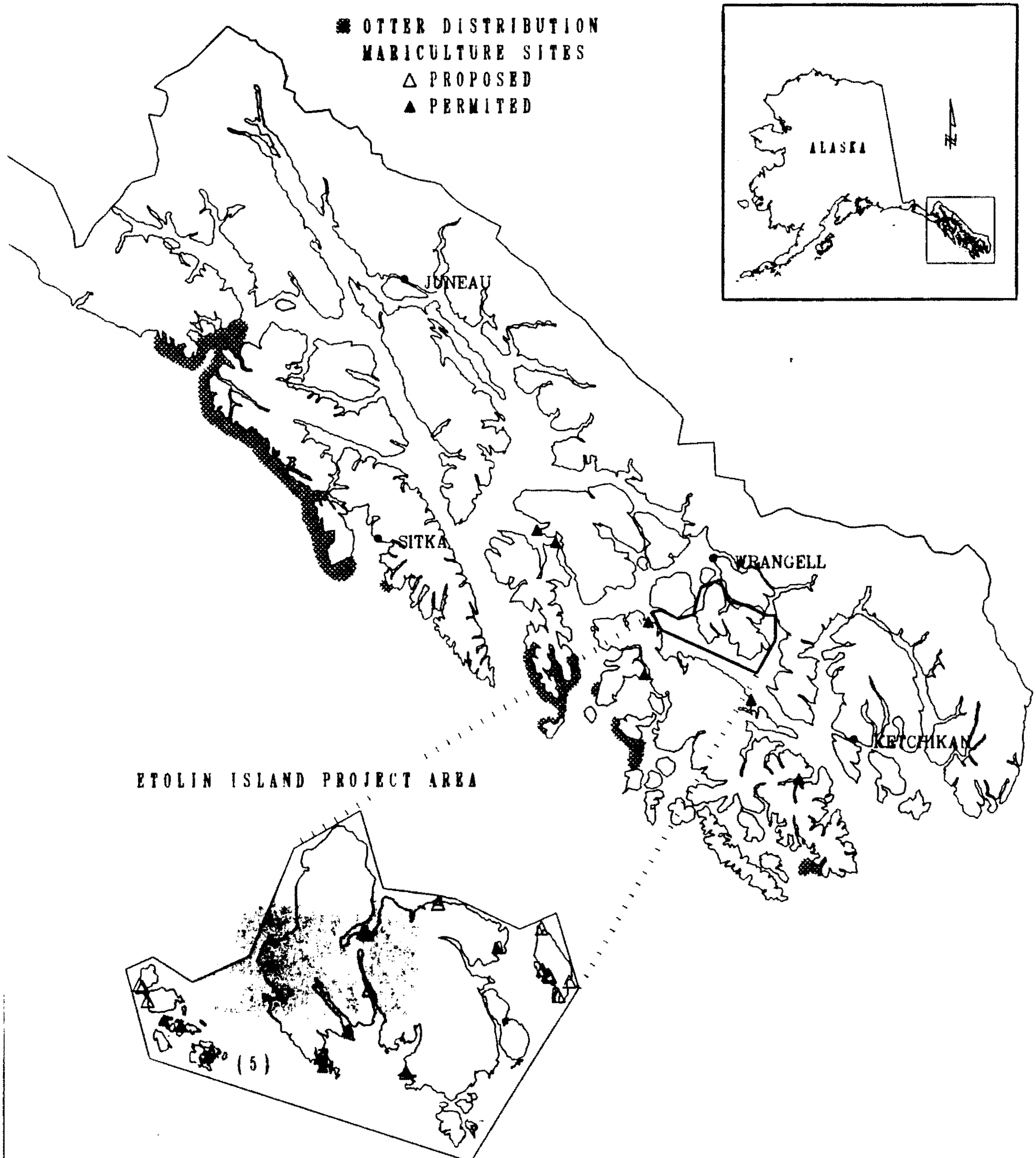

FIG 15. OTTER DISTRIBUTION AND MARICULTURE SITES IN SE ALASKA (EXCLUDING SALMON FARMING SITES). NUMBER IN PARENTHESES IS NUMBER OF MARICULTURE SITES IN THAT AREA.