Oyster Seed Hatcheries on the U.S. West Coast: An Overview

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Introduction

Oyster production in the United States has been diminishing for nearly 80 years. Natural disasters (including disease and predation), pollution, siltation, and land reclamation projects have all contributed to the decline. Present U.S. production is not even equal to what once came from the Chesapeake Bay alone.[1] Meanwhile, oyster imports have been increasing (Table 1).

Table 1.—United States oyster supplies, 1960-77, in millions of pounds.

Year	Oyster supplies U.S.[1]	Imports[1]	Total	West coast[2]
1960	60.0	6.6	66.6	11.0
1961	62.3	7.3	69.6	10.2
1962	56.0	7.4	63.4	10.8
1963	58.4	8.9	67.3	9.8
1964	60.5	8.2	68.7	10.0
1965	54.7	9.0	63.7	9.2
1966	51.2	12.0	63.2	7.8
1967	60.0	17.7	77.7	7.7
1968	61.9	15.6	77.5	7.8
1969	52.2	16.6	68.8	7.0
1970	53.6	15.5	69.1	8.0
1971	57.9	9.7	67.6	8.1
1972	52.5	22.3	74.8	7.3
1973	48.6	18.5	67.1	6.4
1974	44.9	16.0	60.9	5.1
1975	53.2	12.4	65.6	5.9
1976	54.4	18.0	72.4	N.A.[3]
1977	46.0	22.8	68.8	N.A.[3]

[1]For 1960-1973, U.S. Department of Commerce (1974); for 1974-77, U.S. Department of Commerce (1976).
[2]Published and unpublished data from Department of Fish and Game, California; Department of Fisheries, Washington; Department of Fish and Wildlife, Oregon.
[3]Not available.

[1]At the turn of the century, nearly 80 million pounds of oysters were harvested from the Chesapeake Bay (Matthiessen, 1971). In 1975 the total U.S. landings of oysters were reported as 53.2 million pounds (U.S. Department of Commerce, 1976).

Though U.S. oyster industry problems have been substantial, interest in identifying and solving the problems has accelerated. One measure of this research effort lies in a partial 22-year (1948-72) bibliography (Joyce, 1972) devoted almost entirely to oysters. It cites 4,117 references that appear at an accelerated rate.

A limited, but important, portion of the total research effort outlined by Joyce (1972), concerns hatchery propagation of "oyster seed," a loosely defined term referring to juvenile oysters of various ages which oyster growers place in suitable habitat. Oyster seed production, which includes the spawning of adults and a relatively short free-swimming larval period, has been an undependable link in the natural reproductive cycle of oysters.

Formal research was begun over 100 years ago to attempt to spawn oysters under controlled conditions and to improve on the chances of survival of the larvae and juvenile oysters (Brooks, 1879). A result of this has been the establishment of a small number of commercial oyster hatcheries. This paper discusses the role of commercial oyster hatcheries on the U.S. west coast.

Oyster Seed

Oyster seed may be placed by the grower into oyster beds in place of, or in addition to, those spawned and occurring naturally. Initially, oyster growers did not need to seed their beds. During the summer, resident adult oysters would spawn and the eggs would hatch in the warm waters surrounding the beds. Then, after a fairly short free-swimming larval period, the oysters would set on shells in the beds. Many growers facilitated the natural setting process by spreading cleaned shells of previously harvested adults in the beds.

Reliance on natural spawning has declined over the years due to some combination of the physical destruction of suitable available growing areas, such as pollution of the oyster waters, which kills the delicate oyster larvae, and the practice of growing transplanted oysters in water too cold to induce spawning but warm enough to raise oysters. The inhibiting effect of cold water on spawning is especially prevalent on the U.S. west coast where the Pacific oyster, *Crassostrea gigas,* is cultured (Steele, 1964). The west coast industry was built and, to a large degree, is still dependent upon growers being able to purchase Pacific oyster seed to restock growing beds.

Seed is purchased in either the "cultch" or "cultchless" form. Seed on cultch consists of cleaned adult oyster shell (cultch material) to which several young oysters (spat), have become permanently attached. Cultchless seed are single young oysters, available from some hatcheries, which have either been removed from the surface of initial attachment, such as plastic sheets, or were originally set individually on small pieces of shell or other calcium carbonate material.

Prior to 1971 the west coast oyster industry was heavily dependent on shipments of oyster seed on cultch from Japan. Oyster seed is collected in Japan on oyster shell which is punched and strung on wire. Each wire is about 6 feet long and contains 100 or more pieces of shell. Ten such wires, known individually as ren, equal a case, containing between 13,000 and 20,000 spat.

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The rens are used to collect spat by being suspended in waters rich in oyster larvae during the spawning season. Then, carrying their load of set oysters, the wires are removed from the water, graded for spat count, packed in wooden crates, and shipped by boat to the United States. During transit the crates of cultch are periodically sprayed with seawater.

Since about 1971, substantial and more or less consistent additions to the supply of oyster seed have become available. This seed is caught by methods similar to the Japanese, but in west coast waters. Before 1971, natural spawning was quite irregular for the three natural spawning areas on the west coast: Dabob and Willapa Bays in Washington, and Pendrell Sound in British Columbia.

In 1971, after more than 20 years of very undependable west coast seed production, 33,000 cases of seed were collected from a natural spawn in Dabob Bay. In the previous year, for comparison, the total volume of seed planted in the entire State of Washington was only 27,000 cases, of which 22,000 were imported from Japan (Westley, 1976). Since 1971, there have been 4 years when more than 30,000 cases of seed have been collected in Dabob Bay: 1972, 1973, 1974, and 1977. There was a complete set failure at Dabob Bay in 1975 and 1976.

Hatchery Technique Developments

The current emphasis on hatchery techniques to produce oyster seed is motivated by the lack of a constant west coast source of seed and a threefold increase in the cost of Japanese seed between 1960 and 1975. Developing commercial hatchery methods to replace total reliance on natural sets has been at least a 100-year endeavor. The first report of successful artificial spawning of oysters was in 1879 (Brooks, 1879). Brooks was able to develop free-swimming oyster larvae from eggs and sperm stripped from adult female and male oysters during the normal spawning season.

All the steps in the hatchery process were not completed by Brooks because he was unable to rear the larvae he had hatched. Larval rearing remained the central hatchery problem for decades due to inadequate information on oyster diets. Two years after Brooks' work and in spite of a deficiency in nutritional information, M. Bouchen-Brandeley in France was able to spawn oysters, raise the larvae in large outdoor ponds, and finally set the larvae on collectors (Kellogg, 1910). Apparently, natural nutrients in the large ponds were sufficient for the larvae.

Following Brandeley, and during the early part of the 20th century, most research was directed toward improving the techniques of spawning and larval rearing. Experimentation with setting materials and techniques, is more recent.

Some of the most important research into the spawning characteristics of oysters was done by Victor L. Loosanoff (1937). Loosanoff's work was built, at least in part, on clam research done earlier by David Belding (1910) and Irving Field (1924). Belding and Field are most responsible for identifying and experimenting with the variables such as water temperature, salinity, and chemicals which affect time of spawning and degree of success. Loosanoff (1945) was the first to report successful experiments to induce spawning of oysters out of season. Loosanoff does acknowledge, however, that others, most notably D. L. McKernan and Vance Tarter, were simultaneously achieving the same results at the State of Washington oyster laboratory at Gig Harbor.

Some of the most important research leading to successful commercial development of oyster hatcheries relates to larval rearing. Not until 60 years after Brooks' work was definitive research done on the diet of oyster larvae. In England, Bruce et al. (1940) published the first results on oyster larvae growth rates associated with various algal diets. Their work was based on earlier studies in England during the 1930's by H. A. Cole (1937) on the European oyster, *Ostrea edulis*. It was not until 1953 that a similar study on larval diets was completed by Davis (1953) in the United States for the Virginia oyster, *Crassostrea virginica*. As stated, most research into the techniques and materials needed to set oyster larvae occurred rather recently.

Most accounts attribute the first development of "cultchless" oyster setting techniques to W. W. Budge in 1967, who was working for Pacific Mariculture[2] (Dupuy et al., 1977), a commercial oyster hatchery in California. However, one important development in setting techniques, occurring nearly a half century earlier is often overlooked. Most of those who have studied the history of oyster seed hatcheries attribute to W. F. Wells, working in 1920, the first successful spawning, rearing, and setting of oysters in confined jars and tanks in a laboratory. These three steps are essential to a complete hatchery. Previous successful larval rearing took place only in large outside ponds.

One important aspect of Wells' work appears to be overlooked. Wells (1920) set oysters on boards covered with a lime and sand mixture. As the set juvenile oysters grew, they crowded each other and began to turn up on edge and break loose from their attachments. Following separation from the boards the spat were raised in trays in seawater. The young spat were subsequently placed in growing beds upon attaining sufficient size, as single unattached oysters. Apparently Wells developed one of the earliest "cultchless" hatchery techniques, as well as providing the earliest example of the total hatchery concept.

Research effort and success over the past century are reflected in the practices of current commercial oyster seed hatcheries. The major steps for the several variations in hatchery practices are summarized in Figure 1. These steps applied in unison with knowledge about water quality and disease control have subsequently reduced the risks in propagating juvenile oysters or larvae.

[2]Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

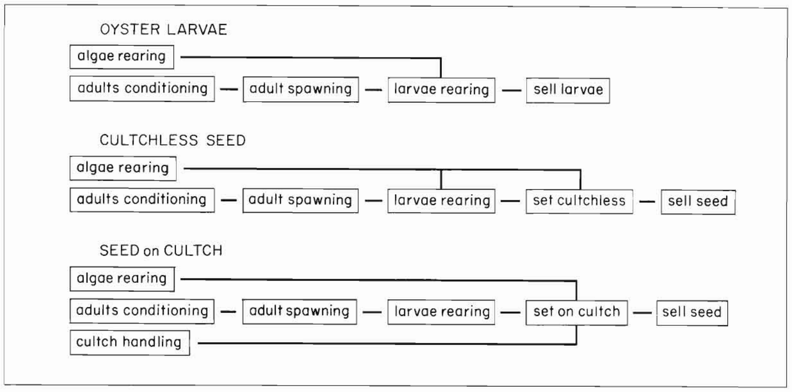

Figure 1.—Primary oyster hatchery operations for hatcheries producing larvae, cultchless seed, and seed on cultch.

Oyster Hatcheries: Problems and Potentials

The future of west coast oyster seed hatcheries depends on the interactions of several variables which, together, determine the market for oyster seed. The market for seed involves such elements as changing consumer demand for oyster products to water temperatures in the natural seed-propagating areas of Dabob Bay. This discussion identifies and considers the effects of changes in the major variables. The probable immediate future of west coast oyster hatcheries is briefly discussed.

The method used to identify market complexities faced by oyster hatcheries is based on the decision-making process of the oyster growing rather than the hatchery operator. The oyster grower makes two decisions which affect the oyster seed market: 1) Which mode of culture to use, and 2) where to get the desired type and quantity of seed. The process followed here captures only the major issues in the grower's decision-making process. As in other businesses, each member of the industry faces different circumstances, which makes each decision-making process unique.

Since the different oyster culture techniques involve the use of different forms and sizes of seed, the total size of any particular segment of the industry determines the demand for each form of seed. The following analysis of the different cultural techniques which employ both seed on cultch and cultchless seed indicates the forces affecting the demand for oyster seed.

Seed on Cultch

The choice of cultural technique for west coast oyster growers is and has been relatively easy. Here, bottom culture is traditional, beginning with seed on cultch spread evenly on or near intertidal lands from barges during high tide. During low tide, the previously spread seed is more evenly distributed by hand. Hand-transfer of seed, though declining, is used to thin overly-dense growing beds and to transfer oysters from seeding beds to fattening beds.

It takes from 2.5 to 4 years after planting before oysters are harvested when raised on the bottom. Most, however, are harvested after 3 years. Three harvesting methods are currently in use on the west coast. The first involves filling large baskets by hand during low tide and then at high tide locating the baskets by an attached marking buoy and loading the then submerged baskets by crane onto the oyster barge. The second method uses two dragline dredges mounted on each side of the oyster barge. Finally, and only recently introduced to the west coast industry, rather large hydraulic suction dredges are used to harvest and to transfer seed from bed to bed. Nearly the entire west coast production of oysters in 1975, 5,832,417 pounds, was produced with such techniques (Case 1976, Moos, 1975, and Oliphant[3]).

Since bottom culture, the predominant method, employs oyster seed on cultch, there is a sizable demand for such seed. A rough estimate of the quantity of seed on cultch demanded, based on west coast use during the past 10 years, runs about 50,000 cases per year. It is common for the total to be very much higher or lower during individual years. The estimate is an average, based primarily on statistics of total production and cases of seed planted, provided by the Washington State Department of Fisheries.[4]

The immediate future holds little promise that the total seed planted on cultch will significantly exceed 50,000 cases. In fact, since the 1950's, the total seed planted in the State of Washington has declined from an average of 53,000 cases to 39,000 cases per year during the first 6 years of the 1970's. However, since an increase in the amount of seed planted might be beneficial to oyster hatcheries, there is some merit in exploring ways such an increase could come about.

Several ways to increase total oyster production are based on techniques of production different from the traditional bottom culture. Many of the alternative culture methods do employ seed on cultch, however. A good synopsis of alternatives to bottom culture is presented by Bardach et al. (1972). In general, the use of stakes or suspending rens from rafts allows growers to generate greater production

[3]Oliphant, M. S., Associate Marine Biologist, Department of Fish and Game, California State Fisheries Laboratory, Long Beach, Calif., pers. commun., 1977.

[4]The seed planted in Oregon and California are estimates computed by dividing annual oyster production in each of those states by a conversion factor of 20 gallons of production per case of seed planted. The conversion factor is approximately the average return in the State of Washington between 1966 and 1975. If, for example, 1,000,000 pounds are harvested, and a gallon of oysters weighs approximately 8 pounds, then it can be estimated that 6,250 cases of seed were planted [(1,000,000 pounds)/(8 pounds/gallon)/(20 gallons/case)] to achieve that production.

by using the water column instead of the bottom alone.

So far, very little west coast oyster production is done with alternative techniques employing oyster seed on cultch. Two factors are mainly responsible for restricting movement into the alternative cultural techniques. The primary limiting factor is the belief of many growers that the cost of producing oysters by methods using stakes, racks, or rafts is greater than the increase in returns from increased production. The word "belief" is used because there are a few growers on the west coast successfully employing cultural techniques other than bottom culture.

The second limiting factor is both social and political. Intensive cultural methods involve placing structures such as stakes and racks on intertidal flats, or rafts or longlines in deep water. Stakes and racks employed in the intertidal areas are exposed during low tide, and can literally cover the bottom over large areas where oysters are cultivated in this form. The stakes and racks, in the eyes of many, are a form of visual pollution and may be vigorously opposed. Rafts and longlines used in deeper water, also have negative visual aspects and, depending on location, may be impediments to navigation. In view of these restraints, the movement into intensive cultural techniques, even if economically feasible, will develop slowly, if at all.

Cultchless Seed

Use of cultchless seed on the west coast is both limited and experimental. One Oregon grower rears cultchless seed in stacks of trays until it is large enough to be transferred to one of several layers in a wire cage where it remains with only periodic cleaning and thinning until harvest. This grower is only one of a handful on the west coast who has oyster ground which is not intertidal, and was successful in obtaining permits to place oyster-growing facilities in navigable waters. Expansion of this method of production is limited primarily by the same restraints as those experienced by nonbottom growers employing seed on cultch, discussed previously.

Cultchless seed is also being experimentally placed in intertidal oyster ground instead of the traditional seed on cultch. At present the practice looks uneconomic due to high mortality and, hence, low yield if small, less expensive seed is used, and too costly when larger, more expensive seed is used. The practice is not being ruled out, however, as only preliminary results are available.[5]

Finally, the relatively small size of cultchless seed (2-mm seed is sold) opens markets for cultchless seed which do not exist for the extremely bulky cultch type seed. Where 1 million spat would equal about 67 cases (167 bushels) of seed on cultch, the same amount of cultchless seed is equal to only about 1 liter (slightly more than 1 quart). Many millions of cultchless seed oysters can, and are, being sent throughout the world by hatcheries on the west coast. The market for cultchless oyster seed, while very small on the west coast, may prove significant worldwide. Also, if some of the experiments mentioned earlier are successful, a modest expansion of the present market for cultchless seed on the west coast could occur.

Two conclusions regarding the demand for oyster seed are apparent from the previous discussion. A significant demand exists for oyster seed and a significant increase in that demand is possible but not imminent. The likelihood of large increases in seed planted on the west coast each year is not great. As mentioned, significant change in local seed demanded is possible, but only if new production technologies, such as those which make use of the entire water column, are adopted.

There appear to be some good reasons why this development will be slow. First, most of the alternative technologies will be practical only if production costs can be reduced, a process that usually occurs rather slowly.

[5]Breese, W. P., Associate Professor of Fisheries, Oregon State University, Corvallis, Oreg., pers. commun., 1977.

However, the primary reason for expecting only modest growth is related to the sociopolitical issues. The use of the nation's estuaries is increasingly scrutinized. As various user groups compete, the process of altering the present uses becomes increasingly difficult.

Competing Seed Sources

The second major decision for a grower is where to buy seed. The question of a seed source (or sources) has become complicated, especially since 1971. At present, the west coast grower can choose among three potential seed sources: 1) Imported Japanese seed, 2) domestic and Canadian wild seed, and 3) hatchery seed.

Ideally, the grower would like to acquire seed solely on the basis of the greatest return per dollar spent. If the grower were able to make a decision, based simply on the cost per case of seed from each of the three sources, the task would be relatively simple. Such a calculation, however, is not easily accomplished. The fact that two cases of seed have the same spat count does not mean they will produce a similar amount of oysters, even when grown under the same conditions. Several factors contribute to variations in productivity.

One such consideration, for example, is the relative thickness of the underlying cultch material. Both wild seed and hatchery seed on the west coast are caught on local oyster shell, which are relatively thick and not easily broken. In contrast, Japanese seed is caught on a thinner shell, which can increase the amount of final production per case. The Japanese seed can be broken by hand, and sometimes even by crowding of the growing oysters on it. In either case, the breakable thin shell seems to lead to decreased mortality and, in turn, increased productivity.

Such differences in seed quality, regardless of the cause, complicates the grower's objective of maximum return per dollar spent on seed. Even if a decision can be made about which seed is preferred on the basis of quality, there is a further problem: availability of seed from each of the three sources may vary significantly.

In 1971 nearly 30,000 cases of seed were collected in Dabob Bay, Wash. The following year, orders for Japanese seed in the State of Washington dropped from 25,486 cases to 7,321 cases. The same pattern existed for the next 5 years. In 1976, after 2 years with no wild seed, growers in Washington ordered large quantities of seed from Japan. Then in 1977 large quantities of wild seed were again collected in Dabob Bay. A near failure in Japan to collect seed in 1977, coupled with the large set in Dabob Bay, meant that in 1978 little or no seed was imported. Wide variation in the supply of wild seed has provided a difficult marketing environment for the planning and development of west coast hatcheries.

The first oyster seed hatchery was built on the west coast in 1967 with the hopes of being able to compete with Japanese seed which was rapidly increasing in price (between 1960 and 1975 the price tripled). Some seed was sold, but the hatchery eventually failed due to biological problems. (Since then the hatchery has reopened, successfully.)

During the 1970's other hatcheries were opened, but the total seed sold or produced by all hatcheries and used by growers on the west coast has never been very large. Early in the 1970's the consistent natural sets in Dabob Bay meant that hatchery seed had to compete with the relatively inexpensive wild seed as well as the more expensive Japanese seed. The hatcheries were basically unable to compete.

Finally, in 1975 and 1976 when there was, for practical purposes, no wild seed collected on the west coast, the growers, especially in Washington, turned to the hatcheries and requested they produce the tens of thousands of cases of seed the growers needed. The outcome was not unpredictable. After 4 years of being unable to sell seed due to the large natural sets, the remaining hatcheries simply were not in a position to produce so much in such a short time. Thus, orders were sent to Japan in 1976 for seed to be delivered in 1977.

Hatcheries have continued to exist on the west coast despite the problems (five are in commercial operation), but only one small hatchery of the five is strictly independent of other income sources, and sells seed to west coast oyster growers. Two hatcheries primarily produce cultchless seed, and depend in large part on sales of seed in Europe. The other two commercial hatcheries are associated with organizations which also grow oysters.

Im et al. (1976) provided some insights into west coast oyster seed hatchery problems and their economic viability. The study indicated that hatcheries appear to be economically feasible, but there is some question about "whether more than one or two plants could survive . . . ." The original promise of hatcheries — to guarantee seed of a consistent quality when, where, and in the form needed—although potentially feasible, has not been sufficient to guarantee the survival of a large number of hatcheries.

Hidu (1969) pointed out three obstacles to the successful development of hatcheries: 1) The cost of alternative seed sources; 2) the lack of development in demand for cultchless seed; and 3) the failure to develop genetically superior strains of oysters. The situation has not changed appreciably.

Success in any of the three areas would encourage the development of a hatchery industry. If costs of hatchery seed can be reduced to compete with natural sets, then growers will be more likely to turn to hatcheries. If growers adopt techniques employing cultchless seed, hatcheries already exist to supply that seed. Finally, if genetically superior strains of fast-growing or disease-resistant oysters can be developed, only hatcheries could produce commercial quantities of the new pure strains.

Although the past success for oyster seed hatcheries has been limited, the future holds several encouraging prospects with respect to the obstacles outlined by Hidu (1969). One new idea to reduce the cost of hatchery seed is being tested commercially in Oregon with the sale to growers of setting size larvae by a local hatchery. Setting the larvae on cultch or as cultchless seed will be an activity of the grower, not of the hatchery as in the past.

At this time, very little is known about the overall economics of such an operation. One advantage of a hatchery which sells larvae is that many growers shuck their own oysters and, therefore, have cultch available, thus avoiding the costs of hauling shell to and from hatcheries or natural setting areas.

The traditional independent hatchery producing seed on cultch must acquire shell from growers, set the larvae, and then transport the shell with attached spat back to growers. Handling costs are likewise incurred by growers who take shell to Dabob Bay to catch wild seed. A significant portion of the cost of both is the transportation of the bulky cultch. The farther the grower and the hatchery are from each other and from Dabob Bay, the more likely it is that the larvae technique will be advantageous. It is no surprise, then, that the first oyster larva hatchery on the west coast was built in Oregon, which is a distance from the wild seed source in Dabob Bay, but close to producing areas where oyster shell is abundant. Time will tell if the savings in transportation costs of shell, and the existence of an assured seed source, will be sufficient to make the oyster larva technique competitive with wild seed collection in Dabob Bay.[6]

The second concern expressed by Hidu (1969), the full development of cultural techniques employing cultchless seed, is also receiving considerable attention on the west coast. The existence of an expanding market for half-shell and baking oysters holds considerable potential. In both cases the product sold is a single adult oyster in the shell, and the price is greater than that which the grower receives for equivalent amounts of shucked single oysters broken from clumps of oysters raised on cultch. Since it is usually true

[6]Analysis in this research is based on an assumption that large quantities of wild seed will be available from Dabob Bay on a regular basis. Three or four years of seed failure in Dabob Bay (not likely, but possible), and a continuation of the increase in the price of Japanese seed (very likely), would lead to an immediate and significant improvement in both the acceptability of hatchery seed to growers and economic stability of hatcheries.

that well-formed oysters of a consistent size and shape draw a better price in the half-shell market, the development of techniques employing cultchless seed is indicated.

As discussed, the potential for production of cultchless oysters in trays or cages is probably limited by sociopolitical considerations. Hence, there will be further impetus for developing alternative techniques for growing cultchless oysters.

At least two are presently being explored. The best known technique is the placement of large singles on intertidal lands. The second includes several ideas, collectively known as "out-bay" culture. Out-bay culture is a process of growing oysters in trays and cages in large tanks, raceways, or troughs. The holding areas are constructed near a source of seawater, and pond-raised algae is used as a food source for the growing oysters.

Out-bay culture offers the advantage of increasing control of the environment to the point where storms, silt, predators, and currents are not the problems they are when oysters are raised intertidally. Also, although out-bay culture operations will not be free of sociopolitical constraints, they should be relatively more free than operations which need to construct permanent or semipermanent structures in bays and estuaries. However, a real impediment does exist to the rapid development of out-bay operations. Construction and pumping costs can be very high. At present the technique is experimental and no definitive answer is available on the economic feasibility of out-bay culture methods.

As in so many other areas of the oyster industry, further research is needed in the area of out-bay culture. The real issue, however, is not whether the half-shell or baking oysters are produced intertidally, out-bay, or another way, but the fact that cultchless seed will be needed and hatcheries likely will be the seed source. Therefore, as the market for adult single oysters increases naturally or is induced through marketing promotions, the future of oyster seed hatcheries is enhanced.

Finally, the third area referred to by Hidu (1969), genetics, while now of relatively minor importance, could profoundly affect the oyster industry. For instance, few Pacific oysters are sold in the summer months on the west coast due to the fact that the marketability of oysters declines as the water temperature increases and they approach the onset of spawning.

Another Asian species, *Crassostrea rivularis,* might provide a partial solution. There is speculation, though no conclusive documentation, that it may make an ideal "summer oyster," since it apparently remains firm in west coast waters throughout the summer. A firm oyster available during the summer is potentially very important to the west coast oyster industry. The many coastal summer tourists of Washington, Oregon, and California could provide a large market for such oysters.

A third Asian oyster, and a subspecies of *Crassostrea gigas,* the Kumomoto, may also be produced by hatcheries. The Kumomoto is prized for its small size and as such, commands a price in the market from four to five times that of the Pacific oyster.

The Kumomoto, like *C. rivularis,* also has desirable qualities through the summer. Kumomoto seed used to be imported from Japan, but is no longer available. In the future, hatcheries will be the only source for seed.

An additional issue related to genetics, which can have a positive influence on hatcheries, is the potential development of an "improved" oyster. That is, at some point in the future there is reason to believe a more rapid growing, or a disease-resistant oyster, will be developed. Again, only hatcheries could provide pure strains of such an oyster in commercial quantities. Genetic issues may, in the long run, be of the most importance to the future of hatcheries. When pure strains of oysters are needed, whether they be *C. rivularis,* Kumomoto, or some as-yet undeveloped "improved" oyster, hatcheries likely will be the only source of supply.

Summary

Oyster hatcheries have been in existence on the west coast since 1967 and, despite early promise, have experienced only limited success. Problems include the existence of unpredictable natural sets of oysters in the State of Washington, and the lack of development in cultural techniques employing cultchless seed.

There is, however, reason for optimism. The hatcheries' ability to compete with natural sets is judged to be improving, and there is evidence of a growing demand for types of oyster seed which can not be met with natural seed. More growers are likely to be either switching to or starting up with at least some of their production being cultchless seed.

There is also reason to believe that hatcheries will continue to reduce costs; some by further advancement of techniques and equipment, and some by such radical moves as the sale of larva rather than seed to growers. Finally, and with a somewhat longer view in mind, both the development of genetically superior oyster strains and the adoption of out-bay culture techniques might, some day, make the oyster industry totally dependent on hatchery-produced oyster seed.

West coast oyster hatchery problems need not be viewed negatively. The west coast oyster industry is in a period of transition. What was once an industry of numerous small, family-type operations is now, with respect to production at least, heavily dominated by large family and corporate enterprises. The industry is modernizing and experimenting. Hatchery oyster seed production is just 11 years old on the west coast. As with many innovative movements, there are some failures and some successes. As this period of transition moves toward a close, it is believed hatcheries will find a more secure place in the oyster industry.

Literature Cited

Bardach, J. E., J. H. Ryther, and W. O. McLarney. 1972. Aquaculture. The farming and husbandry of freshwater and marine organisms. Wiley-Interscience, N.Y., 868 p.

Belding, D. L. 1910. Report upon the scallop fisheries of Massachusetts. Commonwealth of Massachusetts, State Printers, Boston, p. 1-51.

Brooks, W. K. 1879. Abstract of observations upon artificial fertilization of oyster eggs: An

embryology of American oyster. Am. J. Sci. 17:425-527.
Bruce, J. R., M. Knight, and M. W. Parke. 1940. The rearing of oyster larvae on an algal diet. J. Maricult., Mar. Biol. Assoc. U.K. 24:337-374.
Case, E. 1976. Commercial food fish landings in pounds round weight by State of Oregon administrative district for calendar year 1975. Oreg. Dep. Fish Wildl., Salem, 1 p.
Cole, H. A. 1937. Experiments in the breeding of oysters (*Ostrea edulis*) in tanks, with special reference to the food of the larva and spat. Fish. Invest., Minist. Agric., Fish. Food (G.B.), Ser. II, 15(4), 25 p.
Davis, H. C. 1953. On food and feeding of larvae of the American oyster, *C. virginica*. Biol. Bull. (Woods Hole) 104:334-350.
Dupuy, J. L., N. T. Windsor, and C. E. Sutton. 1977. Manual for design and operation of an oyster seed hatchery. Va. Inst. Mar. Sci., Spec. Rep. 142, 104 p.
Field, I. A. 1924. Biology and economic value of the sea mussel *Mytilus edulis*. Bull. U.S. Bur. Fish. 38:127-259.
Hidu, H. 1969. The feasibility of oyster hatcheries in the Delaware-Chesapeake Bay region. *In* K. Sprice, Jr. and D. L. Maurer (editors), Proceedings of the conference on the artificial propagation of commercially valuable shellfish: oysters, p. 111-129. Univ. Del., Newark.
Im, K. H., R. S. Johnston, and R. D. Langmo. 1976. The economics of hatchery production of Pacific oyster seed: a research progress report. Proc. Natl. Shellfish. Assoc. 66:81-94.
Joyce, E. A., Jr. 1972. A partial bibliography of oysters, with annotations. State of Florida, Dep. Nat. Resour., Spec. Sci. Rep. 34, 846 p.
Kellogg, J. L. 1910. Shell-fish industries. H. Holt and Co., N.Y., 361 p.
Loosanoff, V. L. 1937. Observation on propagation of oysters in the James and Corrotoman rivers and seaside of Virginia. Va. Comm. Fish., Newport News, 46 p.
———. 1945. Precocious gonad development in oysters induced in midwinter by high temperature. Science (Wash., D.C.) 102: 124-125.
Matthiessen, G. C. 1971. A review of oyster culture and the oyster industry in North America. Woods Hole Oceanogr. Inst., Woods Hole, Mass., 52 p.
Moos, D. W. 1975. 1975 fisheries statistical report. Dep. Fish., Olympia, Wash., 115 p.
Steele, R. N. 1964. Immigrant oyster (*Crassostrea gigas*) now known as the Pacific oyster. Warren Quick Print, Olympia, Wash., 179 p.
U.S. Department of Commerce. 1974. Basic economic indicators: oysters, 1947-1973. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Curr. Fish. Stat. 6273, 57 p.
———. 1976. Fisheries of the United States, 1975. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Curr. Fish. Stat. 6900, 100 p.
Wells, W. F. 1920. Growing oysters artificially. Conservationist 3:151.
Westley, R. E. 1976. Oyster growing and culture in Washington State. Wash. Dep. Fish., Point Whitney Shellfish Lab., 12 p.

Selected References

Baughmann, J. L. 1948. An annotated bibliography of oysters, with pertinent material on mussels and other shellfish and an appendix on pollution. Texas A&M Research Foundation, College Station, 794 p.
Breese, W. P., and R. E. Malouf. 1975. Hatchery manual for the Pacific oyster. Oreg. State Univ. Sea Grant Publ. ORE54-4-75-002, 21 p.
———, and W. Q. Wick. 1973. Oyster farming. Oreg. State Univ. Sea Grant Rep. 13, 8 p.
Im, K. H., and R. D. Langmo. 1977. Hatchery produced Pacific oyster seed. Oreg. State Univ. Sea Grant Publ. ORESU-T-77-010, 80 p.
Loosanoff, V. L., and H. C. Davis. 1963. Rearing of bivalve molluscs. Adv. Mar. Biol. 1:1-136.