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1. Introduction

There is considerable interest in growing Crassostrea gigas in New England in lieu of the native oyster C. virginica. Seed oysters from hatcheries have been introduced for experimentation in Maine and Massachusetts. A symposium entitled Exotic Species in Mariculture (Mann ed., 1979) was held at Woods Hole in September 1978, to discuss the desirability of introducing C. gigas to the New England coast.

Crassostrea gigas, the Pacific oyster, is a vigorous, fast-growing oyster species that seems to adapt easily to most temperate zone coasts. High yields are an attraction to oyster growers. The species also seems to exhibit resistance to most diseases encountered so far. It is now established on the major coasts of the Northern Hemisphere except the Atlantic Coast of North America. The latest deliberate introduction of C. gigas was to Western Europe. It is now established from the Netherlands to Spain and also in Yugoslavia. It is also grown in England and Germany from hatchery seed oysters because their waters are too cold for reproduction to occur naturally.
2. Purpose of Introduction

Before an introduction is made, the question should be asked:
What is the purpose of introduction of this species?

This question leads immediately to a consideration of the climate
of the proposed geographic region and the status of native species
living there. Whole coastlines must be considered, not just a
locality, a state, or a body of water. If the introduction is
successful, man will distribute the new species by transplantation if
it does not spread naturally by reproduction. Successful introduction
of an exotic species is irreversible once it is established. The
species will find niches where it can persist.

The adaptations of the two genera of oysters in their native
habitats must be considered prior to introductions. Tropical species
should not be introduced to temperate zones and vice versa.
Crassostrea species are adapted to continental-type coasts with cold
winters and hot summers. They require high temperatures (usually
>20°C) for breeding and are often cultured intertidally or in shallow
waters. Ostrea species are adapted to oceanic-type climates with cool
summer and warm winter temperatures. They will not withstand
intertidal exposure. They breed at relatively cool temperatures
(generally <20°C). Crassostrea species release eggs into open waters
in very large numbers and depend upon dispersion during a long larval
life for successful reproduction. Ostrea oysters hold their eggs and
larvae in the gill chamber (incubate) for varying periods depending on
the size of the eggs. These variations in size and number of eggs,
and early release or incubation, are adaptations to water temperatures that control development and to rates of dispersal of larvae. Transfer of a species adapted to a continental climate to an oceanic climate results generally in failure of reproduction because temperatures are too low in summer. The reverse transfer subjects Ostrea species to high summer and low winter temperatures that are inhibitory to growth and survival if not direct causes of mortalities. Excessive reproduction is more difficult to control and correct in culture in open waters than no reproduction. The latter can often be alleviated by manipulation of broodstocks and choice of breeding areas or by hatchery production of seed oysters. A careful balance between areas for breeding and those for growth is most desirable to avoid fouling of shells and competition between young oysters and growing market stocks.

3. Introduction of C. gigas to North America

A brief history of the importation of C. gigas to the Pacific Coast of North America is instructive. After many years of imports of spat from Japan, the Pacific oyster was established from British Columbia to California. Only a few relatively low-flushing bodies of water were warm enough to produce seed regularly. With the interruption of importation of seed from Japan in the early 1970's by high costs and by diversion of seed oysters to France, the industry became nearly self-sufficient in seed stocks. The introduction of C. gigas was highly successful as a replacement for the small (2 inches at 4 years age), slow-growing native oyster Ostrea lurida, the Olympia
oyster. Infectious diseases of C. gigas have been relatively
unimportant on the Pacific Coast. Due to careless handling in the
early years of importations, a great variety of exotic invertebrates
and plants were introduced to the Pacific Coast (Hanna, 1966; Quayle,
1964; Bourne, 1979).

4. Importation of C. gigas to Europe

The introduction of C. gigas to Western Europe was a less
desirable importation for several important reasons. Foremost was the
established culture of two highly desirable species, both native,
along the coasts of Europe. Ostrea edulis is adapted to cold waters
from Northern Spain to Norway. Crassostrea angulata is native to
Spain and Portugal, but it was grown in Northern Europe from seed
stocks provided annually by France, and the Iberian Peninsula. These
two species provided a wide choice of geographic races of oysters
adapted to climes from Norway to Spain and to Yugoslavia.

The usual fluctuations that occur in oyster production occurred
over the years in Western Europe caused by climatic variations and
diseases. The flat oyster, O. edulis, was grown for the luxury trade
whereas the Portugese oyster, C. angulata, was sold more cheaply in
large quantities. It is not clear why the first Pacific oysters from
Japan were introduced to France in 1966, for there were no reported
biological problems that could justify this extraordinarily risky
measure. There was great demand for oysters in Europe and limited
supplies. Presumably economic and political demands for expansion of
the industry were the basis for the introductions.
5. Occurrence of New Diseases along Atlantic Coast of Europe

In February or March 1966, 900 kg of _Crassostrea gigas_ spat on shells were imported from Japan to the Marennes-Oleron region of France. In November 1966, Trochon found specimens of _C. angulata_ with diseased gills in the same waters. France was the primary producer of Portuguese oyster seed; oysters were transplanted regularly to Great Britain, Brittany, Spain and the Mediterranean Sea. By the fall of 1967, the disease was widespread in France and an embargo was placed on further imports from Japan until February 1969. England placed an embargo on relaying French oysters when notified of the disease problem by the French in the spring of 1968. Pacific oysters shipped from Japan and Korea directly to the laboratory at Trinite-sur-Mer were found to have perforations and lacerations of gills similar to those found in _C. angulata_. Notched gills of uncertain cause were found also in _Ostrea edulis_ and _Mytilus edulis_. Soon "maladie of the gills" was found in all the countries where shipments of French flat oysters were routinely transplanted—England, Spain, and Portugal. In 1968, specimens of oysters and pictures of the disease in Great Britain were received in the United States for study. It was a new disease of oysters not previously observed.

All three species of oysters showed the signs of gill disease but the heaviest mortality fell on _C. angulata_ in southwest France. Strangely, _C. angulata_ and _C. gigas_ are said to be the same species (Menzel, 1974) and are very similar in appearance. The disease subsided in England after importation was stopped. By 1970, severe
mortalities of the Portugese oyster virtually eliminated this species from France. With the help of large importations from Japan and British Columbia, *C. gigas* rapidly replaced *C. angulata*, therefore, French production figures do not reflect the tragedy that befell the Portugese oyster.

Large scale importations of seed oysters from Japan were made in the early 1970's (7,100 tons) along with 500 tons of adult brood oysters from British Columbia (Pendrell Sound). These large scale shipments by air of natural seed oysters ceased after 1975 but some hatchery spat from California are still being received (1979).

The gill disease causes gills to become notched, with separation of filaments and discoloration as tissues become abcessed and rot away. The disease is attributed to a virus.

A second new disease was found in *Ostrea edulis* in the northwest corner of Brittany in Aber Wrach and Aber Benoit in 1968. Aber disease caused sharp reductions in production of flat oysters in Brittany. It is a disease of the digestive tract. It is slow to develop in France and kills oysters primarily in the second summer. The pathogen was named *Marteilia refringens* and was reported by Perkins (1976) to be a haplosporidan related to *Minchinia costalis* and *Minchinia nelsoni* that are pathogens of the American oyster, *Crassostrea virginica*.

A third new pathogen was found in specimens of *O. edulis* imported to the Netherlands from France. It is very similar to *M. costalis*, a
pathogen of C. virginica, but it has specific differences. It was named Minchinia amoricana (Van Banning, 1977). It has occurred only rarely in the flat oyster.

It is impossible to prove the origin of these diseases, but they appeared immediately after the Pacific oyster was introduced from Japan. Gill disease and Aber disease were first found in waters where Pacific oysters were being grown concurrently. C. gigas is quite resistant to both diseases although they do occur in the species. It is probable that the usual low temperatures in summer along the Brittany coast prolong and inhibit the digestive tract disease of O. edulis. The greatest prevalences of disease and highest mortalities occurred in the hot summer of 1976 (+5°C). Warm summers permitted C. gigas to spread widely in British Columbia and occasional warm years will probably help distribute it in Europe as occurred in 1976 in the Netherlands.

Crassostrea gigas has completely replaced C. angulata as a culture oyster in France and it is used for production of oysters in England and Germany from British hatchery seed. About 70% of French oyster production is now (1979) derived from the Pacific oyster compared to 80% for C. angulata in the early 1960's.

6. The Role of Crassostrea gigas in New England

Is Crassostrea gigas needed in New England? If the new diseases of oysters in Europe came from Asia with C. gigas, why have they not appeared on the Pacific Coast of North America? Are these diseases a
threat to the American oyster? The slow development and low pathogenicity of Marteilia refringens compared to related American diseases suggest that warm temperatures favor the pathogen. I suspected previously that Minchinia nelsoni came from Asia because C. gigas appeared to be resistant to it in Delaware waters.

Presumably, C. gigas would be introduced to eastern North America through hatchery-reared seed oysters. This would greatly reduce the risks of importing exotic diseases compared to use of oysters from natural sets in open waters. However, economic and political decisions can take unexpected turns when disaster threatens an industry. Already it is rumored that France intends to import more C. gigas brood oysters from Pendrell Sound after failure of spatfall for a couple of years.

The problem with use of C. gigas in New England is that attempts to isolate or quarantine areas using the species are unlikely to succeed. Man will most certainly redistribute this exotic oyster when growth rates demonstrate its vigor.

New England is the primary region of the western Atlantic Coast where use of C. gigas is proposed. There is skepticism and opposition to its use among most oyster growers in the area because they fear its effect on native oysters and local environments. Then, too, it is not considered a desirable raw oyster for the half-shell trade which now commands high prices for C. virginica. Whereas C. gigas may tolerate slightly cooler waters for growth and reproduce at slightly lower
temperatures than C. virginica, the natural production of any oyster species in the area is likely to be intermittent and growers probably will rely increasingly on hatchery-produced seed oysters. Considering these dubious advantages and the problems of seed oysters, it would seem advantageous to select by genetic breeding a fast-growing southern race of C. virginica to fit hatchery production and possibly use off-bottom tray culture in the colder waters. Oysters as far south as Chesapeake Bay are winter hardy subtidally and grow much faster than natives in New England. Another alternative is extension to other New England areas the culture of Ostrea edulis, which is now utilized on a small scale in Maine. Seed oysters of Ostrea edulis could be hatchery produced. This species commands a high price in Europe, and it does not present a threat of competition for C. virginica in southern waters provided no new importations with diseased oysters are made from Europe. Brood stocks of flat oysters with 30 years adaptation in Maine waters are available for hatcheries from Maine.