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Introduction into France of the Japanese oyster (*Crassostrea gigas*)

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The Japanese oyster *(Crassostrea gigas)* has been introduced in France on a large scale to replace cultivation of the Portuguese oyster *(Crassostrea angulata)*, affected by a viral disease. The importation took place from 1971 to 1975, with broodstock coming from British Columbia (Canada) and spat from Japan. Good growth rate and success of the natural setting on the French Atlantic coast attested to the success of this implantation, with a production which reached 80 000 t by 1976. The precautionary measures associated with this transfer limited the implantation of an introduced fauna, 15 years after, to: *Balanus amphitrite, Aiptasia pulchella* and, on the Mediterranean coast, *Undaria pinnatifida* and *Laminaria japonica*. The authors also discuss the possible role of *Crassostrea gigas* in spreading the viral disease.

L'huître japonaise *(Crassostrea gigas)* a été introduite massivement en France dans le but de subvenir au remplacement de l'élevage de l'huître portugaise *(Crassostrea angulata)* décimée par une maladie virale. Ces importations effectuées de 1971 à 1975 concernent des géniteurs provenant de Colombie Britannique (Canada) et du naissain en provenance du Japon. De bonnes performances de croissance et le succès du captage sur la côte atlantique française traduisent la réussite de l'implantation de cette espèce dont la production a atteint, dès 1976, 80 000 tonnes. Les précautions associées à cette importation ont permis de limiter l'implantation d'une faune associée dont les principales espèces, 15 ans après, sont: *Balanus amphitrite, Aiptasia pulchella* et, sur la côte méditerranéenne, *Undaria pinnatifida* et *Laminaria japonica*. Enfin est discuté le rôle possible de *Crassostrea gigas* dans la propagation de la maladie à virus.

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Introduction

During 1967, Portuguese oysters (*Crassostrea angulata*), cultivated mainly in the Bays of Arcachon and Marennes-Oléron but also in different rivers of the Brittany coast, were affected by a disease characterized by lesions of the labial gills (Comps, 1969, 1970a). From 1970 to 1972 the oysters of this species developed a second syndrome, the main signs of which were invasion of connective tissues by blood cells, some showing an abnormal size with inclusions, and an increase in the number of brown cells (Comps, 1970a; Deltreil, 1973). These symptoms occurred simultaneously with a major mortality of the oysters (*C. angulata*), which nearly disappeared from the French coast between 1970 and 1973. Further studies allowed Comps *et al.* (1976) and Comps (1983) to demonstrate the infectious nature of this epizootic caused by an iridovirus. No studies have been reported on the economic effects of the disease on oyster culture, but the annual loss in total weight of adult oysters reached 60 000 t and the loss in production was estimated at 556 million francs. Faced with this crisis, which affected nearly 5000 oystermen, it was necessary quickly to find a solution with a substitute species, principally to maintain employment. After extensive observations and discussions, the massive introduction to France of the cupped oyster, *Crassostrea gigas*, was officially decided upon and carried out, beginning in 1970.

Historical

The unofficial nature of some of the first importations does not allow us to trace exactly the early history of the introduction of *C. gigas*. However, the first spat

from Japan were probably planted in the Bay of Marennes-Oléron in 1966 (Le Borgne *et al.*, 1973) and Trochon, pers. comm.). These transfers were made by an oysterman fascinated by the fast growth rate and the quality of *C. gigas* at a time when the production of *C. angulata* was declining, the stocks were exhibiting higher levels of mortality, and large decreases in growth rates were occurring (Héral *et al.*, 1986). The first test gave good results, so the oystermen decided to introduce other samples of Japanese spat from Sendai Prefecture.

Faced with the increase in introductions, and because of a concomitant increase in mortality of *C. angulata* with the introduction of *C. gigas*, the "Institut Scientifique et Technique des Pêches Maritimes" proposed that the importation be stopped. This measure was disapproved of by some of the oystermen. The action brought about a visit to Japan by French experts in 1969 with the aim of surveying the different oyster producing areas to determine the quality of the Japanese oyster and the spat, to examine the fouling organisms, and to study the pathology of this species, especially the lesions of the labial gills which had been observed. After comparing the malformations of the labial gills of the two species concerned, the mission concluded that the lesions discovered on *C. gigas* gills were due to mechanical causes. The mass mortalities in *C. angulata* cultivation during 1970 and 1971, at a time when the imported *C. gigas* appeared healthy (Comps, 1972), led to the official decision to introduce this exotic species to the French coast.

Importation operations

Two operations were carried out: one to create sanctuaries, the other to supply the oystermen with spat.

"Operation Resur"

The operation called "Resur" was accomplished after a visit by experts to British Columbia (Canada); they confirmed the technical feasibility of transferring large quantities of adult oysters for reproduction and investigated the sanitary quality of the Canadian oyster beds. The Canadian oysters (*C. gigas*) were directly planted from 1971 to 1975 in different French bays, where the cultivation occurred. Histological observations during all these operations showed that they were free of disease. The quantities of oysters planted in the different bays and years are given in Table 1.

Importation of spat for cultivation

From 1971 to 1977 spat were imported from Japan to reseed the oyster grounds. The imported spat were cultchless or were set on oyster shells or scallop shells. Each imported sample had certificates of origin and sanitation. Control of the samples was carried out when the truck arrived for customs clearance. Control measures included an index of quality for the spat, an estimate on a subsample basis of the quantities of spat, scrutiny for the presence of predators, and collection of tissues for histological analyses. Depending on the results of these examinations the whole sample could, if necessary, be destroyed. Otherwise, before being planted in French coastal areas, each shipment of spat on collectors was immersed in fresh water to destroy fouling organisms and predators, especially flatworms of the genus *Pseudostylochus*. Table 2 summarizes the quantities of spat which were introduced from 1971 to 1977 from Japan to the French coast.

The tests and inspections carried out on both the Canadian adult oysters and the Japanese spat not only provided data on the efficiency of the importations, but also indicated certain modifications which occurred in the biotopes.

Biological data

The massive introduction of *C. gigas* happened at a time when mass mortalities of *C. angulata* were taking place, so competition between the two species, mainly for food and space, did not occur. Since the stocks of cultivated oysters were very low after 1970, the growth rates in length and weight were excellent in all the bays; market size was reached 18 to 20 months after setting at a mean total weight of 70 g. This growth performance was not

Table 1. Quantities (in t) of adult oysters imported from British Columbia and planted in the main French cupped oyster bays.

Centres of oyster culture	1971	1972	1973	1974	1975	Total (t)
Bay of Bourgneuf		10	10			20
Area of La Rochelle		30.5	58			88.5
Bay of Marennes-Oléron	65	106	50	0	35	256
Estuary of the Gironde		30	30			60
Bay of Arcachon	52.5	60	25			137.5
Total (t)	117.5	236.5	173	0	35	562

Table 2. Quantities (in t) of spat collectors imported from Japan and estimation of the quantity of spat.

Regions	1971/1972	1972/1973	1973/1974	1974/1975	1975/1976	1976/1977	Total
Mediterranean	147	224	55	107	23.5	0	556.5
Arcachon	475	598	30	73	0	0	1 176
Marennes-Oléron	1 212	2 536	210	546	0	10	4 574
La Rochelle and Vendée	205	727	302	631	44	0	1 909
Bretagne North and South	413	741	132	573	0.5	0	1 859.5
Total	2 452	4 826	729	1 930	68	10	10 015
		Estimation of quantity of spat in millions					
	1 226	2 413	365	965	34	5	More than 5 billion

sustained; the same market size required 36 to 40 months immediately after 1976 for oysters cultivated in the Bay of Marennes-Oléron, with production varying from 10 000 t to 80 000 t (Héral *et al.*, 1986). These data were confirmed in another area by Deltreil (pers. comm.) who recorded the growth rate of experimental samples in the Bay of Arcachon. During this period (1972–1976), there was a decrease of 50% in the annual growth rate of oysters cultivated with a starting weight of 20–25 g (Table 3).

Rebuilding of the sanctuaries resulted in natural setting on the Southwest Atlantic coast from La Rochelle to Arcachon, particularly in the Bay of Marennes-Oléron, in the Gironde estuary, and in the Bay of Arcachon. Since *C. gigas* larvae need a higher temperature than *C. angulata* larvae (Héral *et al.*, 1986) the setting was irregular at first (Le Borgne *et al.*, 1973), depending on summer climatic conditions. However, with the large increase in the cultivated stocks which participated in spawning, an adequate supply of *C. gigas* spat was achieved by the French oyster centres beginning in 1975.

C. gigas has not been affected by major parasites since its introduction in France. Comps (1972) noted its resistance to gill disease of *C. angulata*. Cahour (1979) observed some young stages of *Marteilia* sp. in the stomach epithelium. Summer mortalities comparable to those described in the United States by Beattie *et al.* (1980) have been observed several times when the sea temperature was above 21°C, particularly in the Bay of Arcachon (Maurer *et al.*, 1986). His (1977) reported the parasitic copepod *Mytilicola orientalis* associated with *C. gigas*, but it did not invade indigenous species.

Table 3. Changes in the growth rate of *C. gigas* between 1972 and 1976 in the Bay of Arcachon, and mean weight after one year.

Date of the beginning of the study	Mean increase in the total weight after one year	Growth rate in % measured from starting weight a year before
1972	46	223
1973	44	203
1974	38	172
1975	33	151
1976	28	113

Fauna and flora introduced in different French coastal areas and associated mainly with the spat collectors have been described by several authors. During a study in the Bourgneuf Bay, Gruet *et al.* (1976) identified several animal species which survived after their introduction with Japanese collectors. The main species were the annelid *Hydroides enzoensi*, the cnidarian *Aiptasia pulchella*, the mollusc *Anomia chinensis*, and the cirripedes *Balanus amphitrite* and *Balanus albicostatus*. Perez *et al.* (1984) indicated that some algae in the Thau lagoon on the Mediterranean coast were probably associated with the introduction of *C. gigas* especially *Laminaria japonica* and *Undaria pinnatifida*. However, the history of the introduction of *Sargassum muticum* on the North European coasts indicated that the appearance of this algae was not associated with the introduction of *C. gigas*. Indeed, Farnham *et al.* (1973) reported this alga for the first time in Europe in the Isle of Wight near the large harbours of Southampton and Portsmouth. Later, Gruet (1976) and Kopp (1976) reported that *Sargassum muticum* had crossed the channel to Normandy. However, the rapid spread on the French coast could have been promoted by the transport of oysters from one bay to another. Thus, since 1982, this alga has spread to the Southwest Atlantic coast (Gruet, 1976; Belcher et Pomellec, 1988).

Technical and economic data

The *C. gigas* introduction was accompanied by the development of new techniques, particularly setting on new collectors and culture in racks or bags on tables. This last development opened up new areas for oyster

Table 4. Changes in the French production in t of the cupped oyster for the period 1960–1975. ----- transition years between *C. angulata* and *C. gigas*. (Source of data: Secrétariat général de la Marine Marchande).

Year	1960	1970	1971	1972	1973	1975
Cupped oysters (t)	65 900	40 300	18 800	53 900	61 100	85 000

production and increased the surface which could be used for oyster culture. Furthermore, the successful *C. gigas* introduction avoided a severe economic crisis in the oyster industry. Indeed, after a rapid decrease in annual production in 1971, the normal production of *C. angulata*, which had been about 65 000 t in 1960, was exceeded with *C. gigas* after 1975 (85 000 t) (Table 4). At present, *C. gigas* also substitutes for the flat oyster *Ostrea edulis*, because of disease problems in that species (Grizel, 1983). French production of *C. gigas* has now reached 150 000 t, with a value at first sale of nearly 1.3 billion francs, for market size oyster.

Discussion

Because the introduction in France of *C. gigas* was achieved in two stages, one unofficial the other official, it leaves open the question about the origin of the viruses which affected *C. angulata*. Three events occurred at approximately the same time, making it difficult to determine their exact order and to know their role and relative importance in the origin of the epizootic. These three events were: (a) the importation of *C. angulata* from Portugal, where gill disease had been described by Ferreira and Dias (1973); (b) the unofficial introduction of *C. gigas* from Japan; and (c) the progressive decline in the physiological condition of the French cultivated population of *C. angulata* (Héral *et al.*, 1986). These observations lead to four hypotheses: (1) the origin of the disease could have been in Portugal and the transfers from Portugal to France could have spread the virus; (2) the iridoviruses were pathogenic exotic agents introduced with *C. gigas*, a safe carrier host; (3) the viruses were present in the *C. angulata* populations or in French waters, but the disease expressed itself only after a decline in condition of the stock; (4) some combination of the above three hypotheses.

Recent studies (Bougrier *et al.*, 1986) of hybridization between *C. gigas* and *C. angulata* confirmed the presence of the iridovirus in the F1 *C. angulata* population cultivated in Morlaix Bay and in La Trinité River, where the culture of *C. angulata* and *C. gigas* had been very limited. This suggests that the hypothesis of a vertical transmission of the disease could be retained for the spawning adults of *C. angulata* coming from Portugal and favours the hypothesis of the origin of the virus in Portugal.

Even if the role of *C. gigas* in the origin of the epizootic in *C. angulata* is left uncertain, it is necessary to record that the importation of this species as a substitute which demonstrated resistance to the viral diseases of the Portuguese oyster and to the two protozoan diseases of the flat oyster (Grizel, 1985) permitted the maintenance and expansion of oyster culture on the French Atlantic coast.

Regarding the circumstances of this introduction, it is important to mention that zoosanitary precautions were taken by the use of numerous histological and cytological controls. Furthermore, the technique of immersing the spat and the collectors in fresh water reduced substantially the introduction of an associated flora and fauna. Indeed 15 years after the mass introduction, only a few species survive in very restricted areas. These are the barnacles, *Balanus amphitrite* and *Balanus albicostatus*, the actinoid *Aiptasia pulchella*, the mollusc *Anomia chinensis*, and the algae *Undaria pinnatifida* and *Laminaria japonica*. The invertebrate biomasses near the oyster grounds are very low and mostly less than those described by Thorp *et al.* (1987) in the English harbours.

Notwithstanding that the introduction of *C. gigas* in France continues to be a commercial success, it is important to underline that this kind of introduction can present considerable dangers, particularly from the zoosanitary point of view. It is essential when the situation is not dramatically urgent to take maximum precautions during the importation and especially to follow the ICES recommendations concerning the introduction of non-indigenous species.

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