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EVOLUTION OF OYSTER AQUACULTURE : PROBLEMS AND PERSPECTIVES.

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ABSTRACT : The total marine molluscs produced by aquaculture had increased from 1984 to 1990 by 1 000 000 tons going from 1 993 985 tons to 2 964 688 tons. The oyster production remained constant with 870 000 tons. *Crassostrea gigas*, the Japanese oyster, represented more than 80 % of the oyster production but high mortalities appeared in different countries connected to end of Winter and Summer mortalities and development of new diseases. The cultivation of *Crassostrea virginica*, the American oyster, was limited (80 000 tons) by the spreading of two diseases (MSX and dermo) destruction of habitat and over-exploitation. Production of the flat oyster *Ostrea edulis* was still very limited by the presence of the *Bonamia* diseases in all the countries except on Mediterranean coast.

EVOLUTION DE LA CULTURE DES HUITRES : PROBLEMES ET PERSPECTIVES

RESUME : La production aquacole marine de mollusques a augmenté de 1984 à 1990 de 1 000 000 tonnes passant de 1 993 985 tonnes à 2 964 688 tonnes. La production d'huîtres est restée constante avec 870 000 tonnes. L'huître japonaise *Crassostrea gigas* représente plus de 80 % de la production d'huîtres mais de fortes mortalités apparaissent dans différents pays dues aux mortalités de fin d'hiver, aux mortalités estivales et au développement de nouveaux parasites. La culture de l'huître américaine *Crassostrea virginica* est limitée à 80 000 tonnes par l'extension de deux parasites (MSX et dermo), par la destruction de l'habitat et la surexploitation des gisements naturels. La production de l'huître plate *Ostrea edulis* est encore très limitée par la présence du parasite *Bonamia* dans tous les pays excepté sur la côte méditerranéenne.

Oyster culture is an old world practise which have been developed every where since the beginning of the first century. Pictures or old texts showed Chinese, Japanese, Roman or American indians techniques which were all using branches of wood... Since these time, the technics have changed with lot of improvement : control of the recruitment by following the abundance of oyster larvae in the water, development of the efficiency of new collectors and their deposit time to avoid fouling. Recently hatcheries and nurseries can supply spat for areas without reproduction. For the growing phase the techniques of culture in rack or bag on table have been developed for intertidal zone and raft or long-line systems have been performed for suspended culture. These types of cultivation belong without doubt to aquaculture. But in some other cases, like in Chesapeake Bay, it is not very clear if the oysters are produced with aquaculture techniques. If we retain the FAO definition "farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators etc... Farming also implies individual or corporate ownership of the stock being cultivated. For statistical purposes, aquatic organisms which are harvested by an individual or corporate body which has owned them throughout their rearing period contribute to aquaculture,..." In that case for example the Maryland fishery of oysters belongs to aquaculture as they used dredged shells to enhance the recruitment, they have a reseeding plan of the juvenils, the stock of oysters is a common resource but which can be exploited only by oystermen under licences (Héral et al., 1990 ; Rothshild et al., 1991).

STATISTICS OF THE AQUACULTURE PRODUCTION

Following the FAO statistics data (1984–1990) the general trends of aquaculture are :

- an increase of the total production from 10 117 940 tons to 15 322 675 tons which represent an increase of 66 % (fig. 1),
- the large production of fresh water fishes which increase from 3 802 111 tons to 7 344 957 tons with respectively 37 to 48 % of the total production,
- the little percentage of production from marine fish and crustaceans but with a clear tendency to an increase for marine fish from 627 590 tons (6 %) to 1 066 777 tons (7 %) and for crustaceans from 224 198 tons (2,2 %) to 705 703 tons (4,6 %) (fig. 2).

For the molluscs the total marine production is increasing with 1 000 000 tons more going from 1 993 985 tons to 2 964 688 tons. This increase is caused by development (fig. 3) of scallop culture (78 588 tons to 340 738 tons), of clams production (312 649 tons to 499 688 tons) and mussel culture (699 748 tons to 1 081 774 tons). During that period, the oyster production remains at the same level (863 940 tons to 876 629 tons).

OYSTER PRODUCTION

Except for the pearl oysters which are cultivated for their pearls, only 3 species are cultivated (fig. 4). The Japanese oyster *Crassostrea gigas* represents more than 80 % of the oyster production with a maximum of production from 678 619 tons to 761 924 tons and a maximum reached in 1987 with 839 816 tons. The American oyster *Crassostrea virginica* aquaculture is declining from 146 104 tons to 82 021 tons in 1990 and the flat oyster *Ostrea edulis* has now reached a constant low level of production (≃ 11 000 tons).

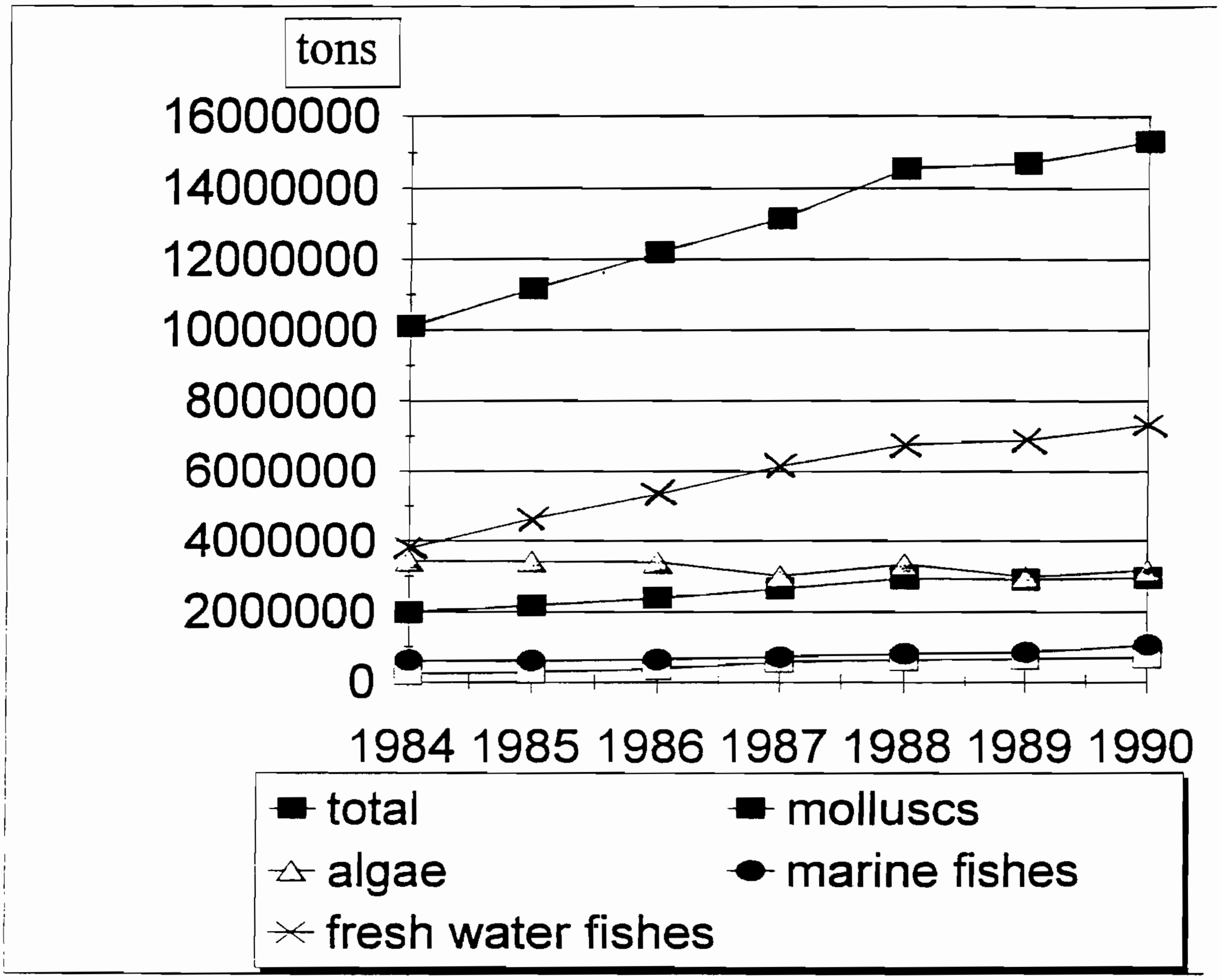


Figure 1 : Evolution of the world production of aquaculture for the different groups (data source FAO).

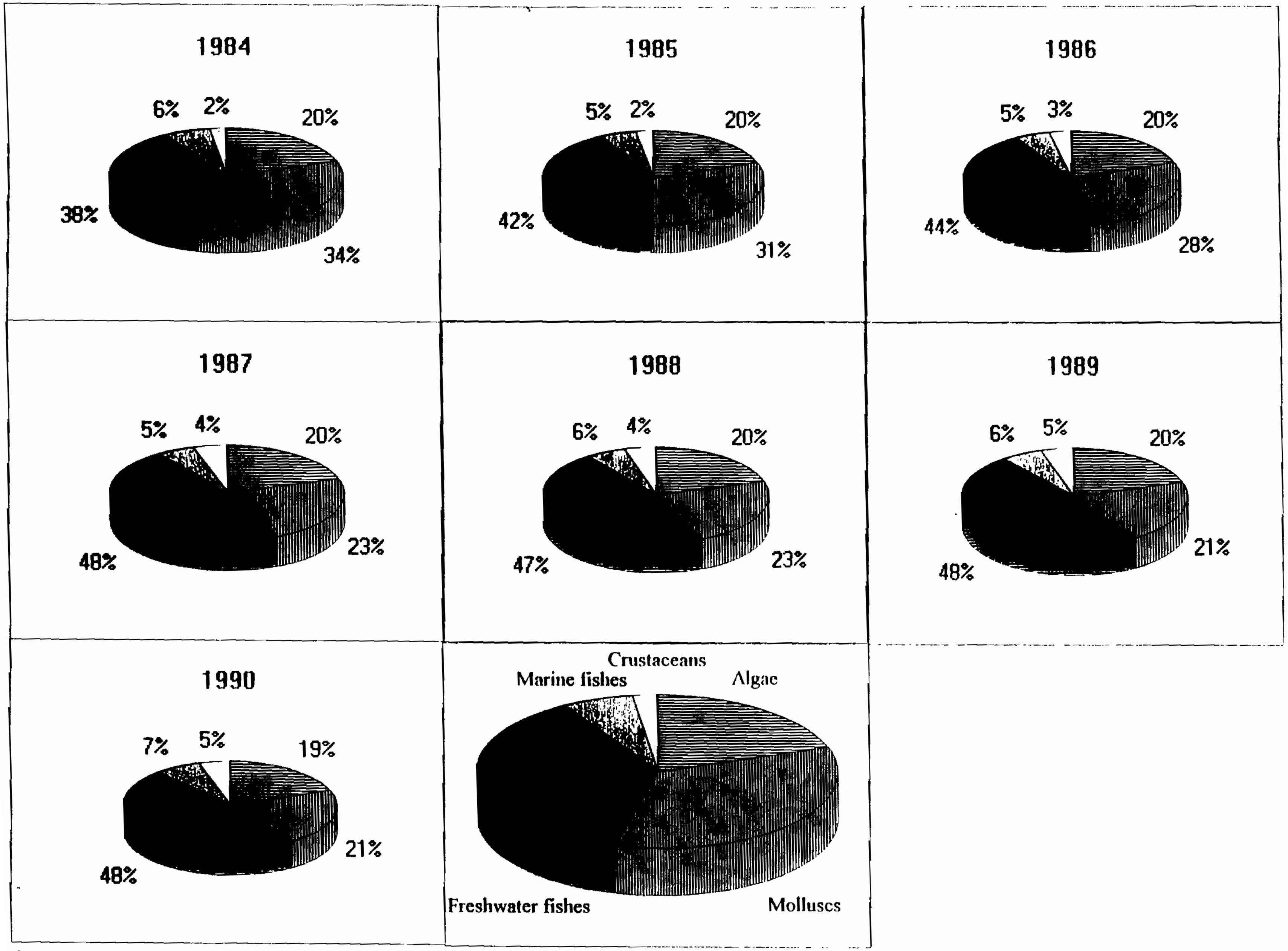


Figure 2 : Evolution of the percentage of the differents groups of animals and plants which are cultivated (data source FAO).

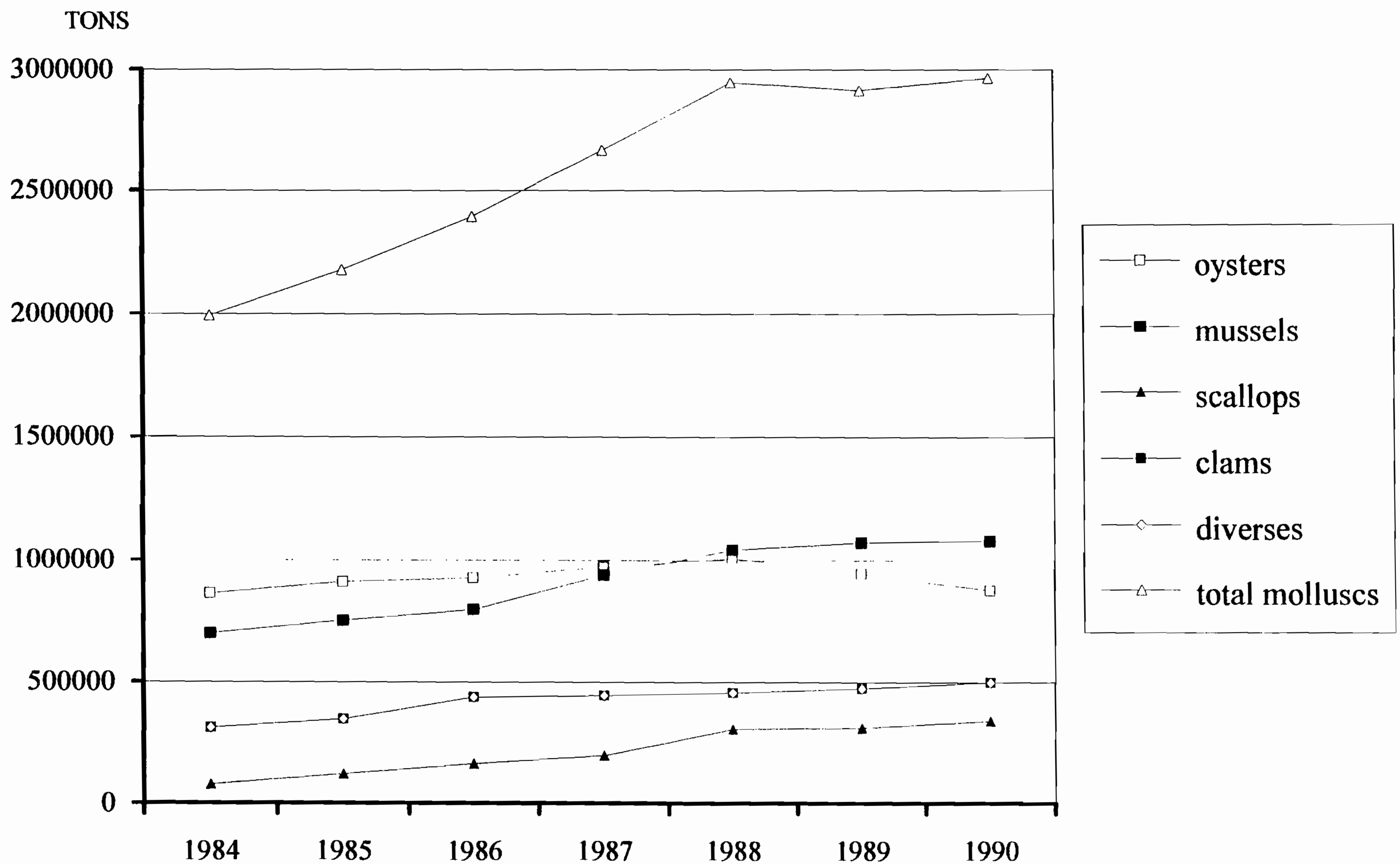


Figure 3 : Evolution of the world production of aquaculture for the different groups (data source FAO)

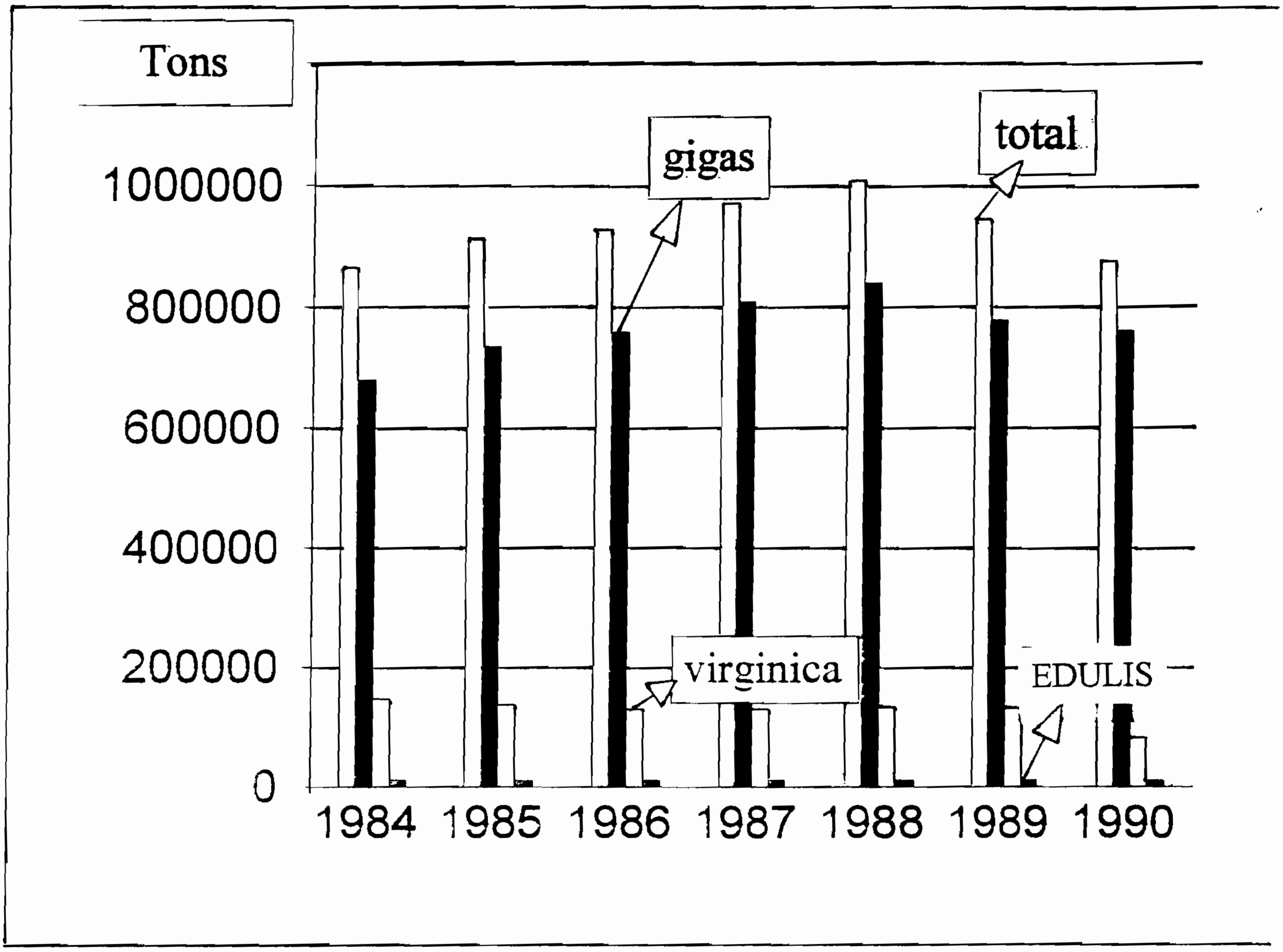


Figure 4 : Evolution of the world oyster production from the 3 main species : *Crassostrea gigas, Crassostrea virginica* and *Ostrea edulis*(data source FAO).

- *Crassostrea gigas*

Japan is the first country cultivating this oyster with a large development since 1950. Since 1984 production has been stable round 250 000 tons (fig. 5), despite some problems of mass mortalities which occured during summer on young oysters (Koganezawa, 1975). Tamate et al. (1965) and Mori (1979) explained it was caused by physiological disorder : the maturation of the oysters consumed all the carbohydrates reserves transformed in lipids in the gamets with no more glycogen available for metabolism.

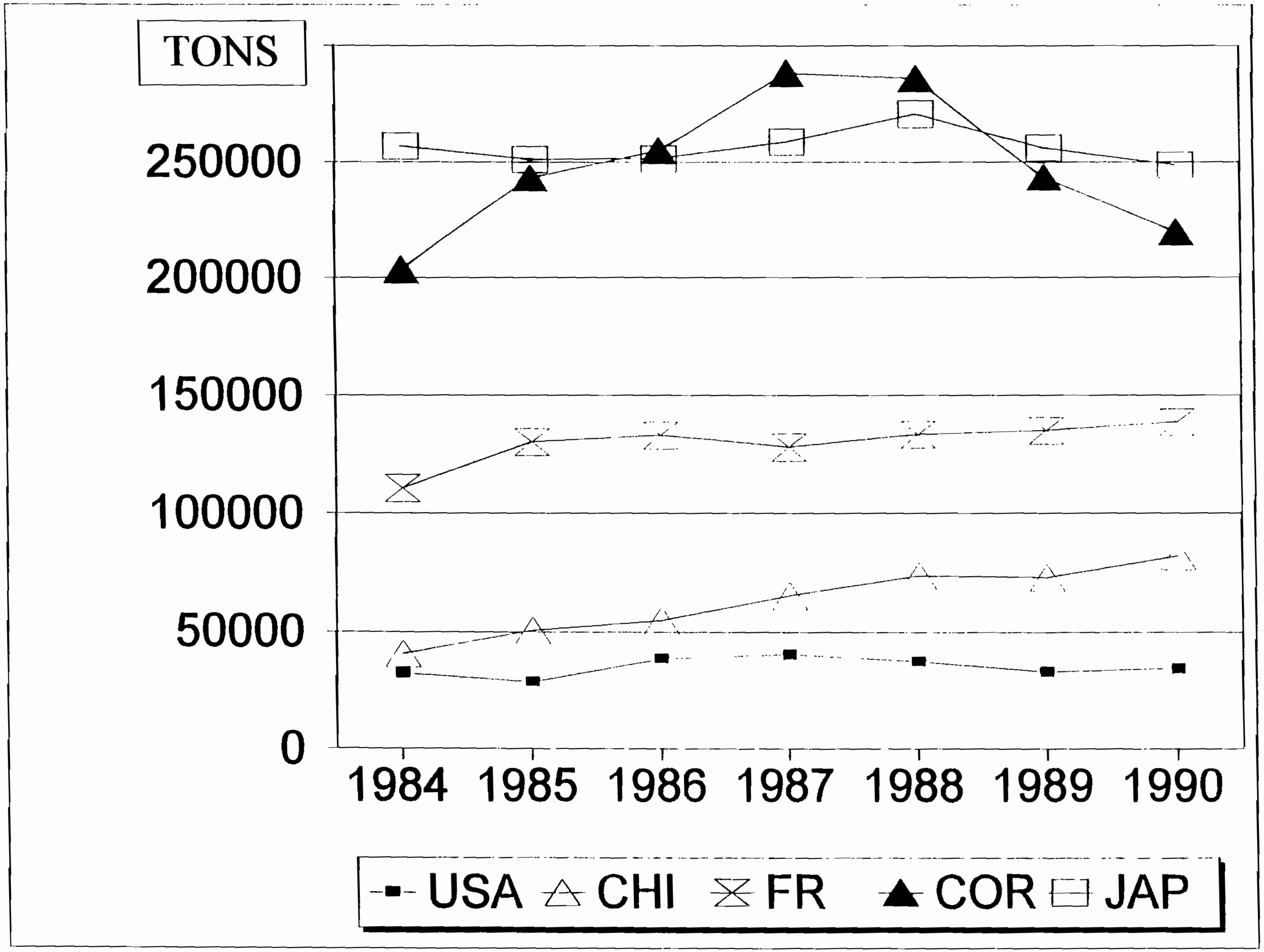
The settlement of natural spat is abundant, but the oyster farmers under control of their cooperatives have managed to control the number of collectors which are put each year in the water. Nevertherless this did not help to overpassing the carrying capacity of some bays by increasing the numbers of rafts causing decline of the growth rate (1→2 years) (Héral, 1993). In Hiroshima bay they decided to reduce the number of rafts to obtain good growth rate again.

In Korea, the production of *Crassostrea gigas* had reached 288 000 tons in 1987 and is decreasing afterwards. The production is still decreasing now due to several factors : the presence of a protozoaire *Marteiloides chungmuensis* which lives in the ova and which can eventually cause a sterilisation of the oysters. High mortality of spat and in springtime of young oysters could be associated to a lack of food connected to the overloading of cultivated oysters of the bays and too bad quality of the water caused by waste spill.

In France, the production of *Crassostrea gigas* is still increasing to achieve 140000 tons in 1990 (Héral and Deslous-Paoli, 1991). The main problem which limits the oyster production is of space and management of the coastal area, oyster cultivations are concentrated in closed bays with overstocking problem exceeding their carrying capacity (Héral et al., 1992). Recently 2 parasites have been described on this species : An herpes-like virus which infected Pacific oyster larvae and caused mortality in hatcheries (Nicolas and al., 1992). The virus has been found in survival spat coming from hatcheries associated with high mortalities (Renault, com. pers., 1993). On adult oyster, a *chlamydia* like has been found without being directly associated to mortalities (Renault et Cochennec, 1993). As in Japan, summer mortalities occured quite often in June and July on young oyster (Maurer et al., 1986). These mortalities are not associated with parasites but with a lack of energy reserve, even the cells of the digestive gland have been lysed to use their glycogen content for their metabolism. At the end of wintertime (March to May), sometimes high mortalities can occur (Deslous-Paoli and Héral, 1989 ; Bodoy et al., 1980). They are caused by a long period of starvation during wintertime with a decrease of the dry weight which can reach 30 %. At the beginning of the spring, water temperature increases, causing an increase of the metabolic demand and if the spring phytoplanktonic bloom is delayed due to climatic condition, the desequilibrium between the energy demand and the energy available increases at a period where the oysters have consumed all their reserves.

In China, the production has doubled from 40 688 tons in 1984 to 82 354 tons in 1990. Mass mortalities occured in China like in Korea with no clear evidence that they can be caused by parasites, by quality of the water or physiological reasons.

In America : the Japanese oyster production occured only on the west coast with the main production coming out from efficient hatcheries which practiced the remote setting for eyed larvae. The production remains constant round 30 000 tons. Summer mortalities are described in that country since several years without being associated to parasites but in relation with the gametogenic cycle (Perdue et al., 1981) with higher mortalities in females.



<u>Figure 5</u> : Evolution of the Japanese oyster (*Crassostrea gigas*) aquaculture production for the main countries (Japan, Korea, France, China, USA).

Several parasites have been described on that species on the west coast : the oyster velum virus disease (OVVD) has been described by Elston (1979) and by Elston and Wilkinson (1985). This lymphocystis virus can cause 50 % mortality on young larvae. Several bacterial diseases have been reported : some on larvae which destroy the hinge ligaments of juveniles oysters (Dungan and Elston, 1988) some other bacterial diseases were recorded on adults which were associated to summer mortalities, sometimes called "focal necrosis" (Elston et al., 1987). An agent described by Leibovitz et al. (1978) much alike *Dermocystidium* presented a mycotic etiology causing velum lesion with 95 % of mortalities in hatcheries and wild stock. Protozoa called "microcell" and named Mikrocytos by Farley et al. (1988) can cause high mortality on *Crassostrea gigas* adults more than 50 % (Hervio, com. pers.). This parasite is very similar to *Bonamia ostreae* parasite of the flat oyster.

Some other countries produce *Crassostrea gigas* like Canada on the west coast (3 420 tons →3 856 tons). They have the same problem as on the US coast. In New Zealand there is a beginning of an aquaculture production with 2 100 tons.

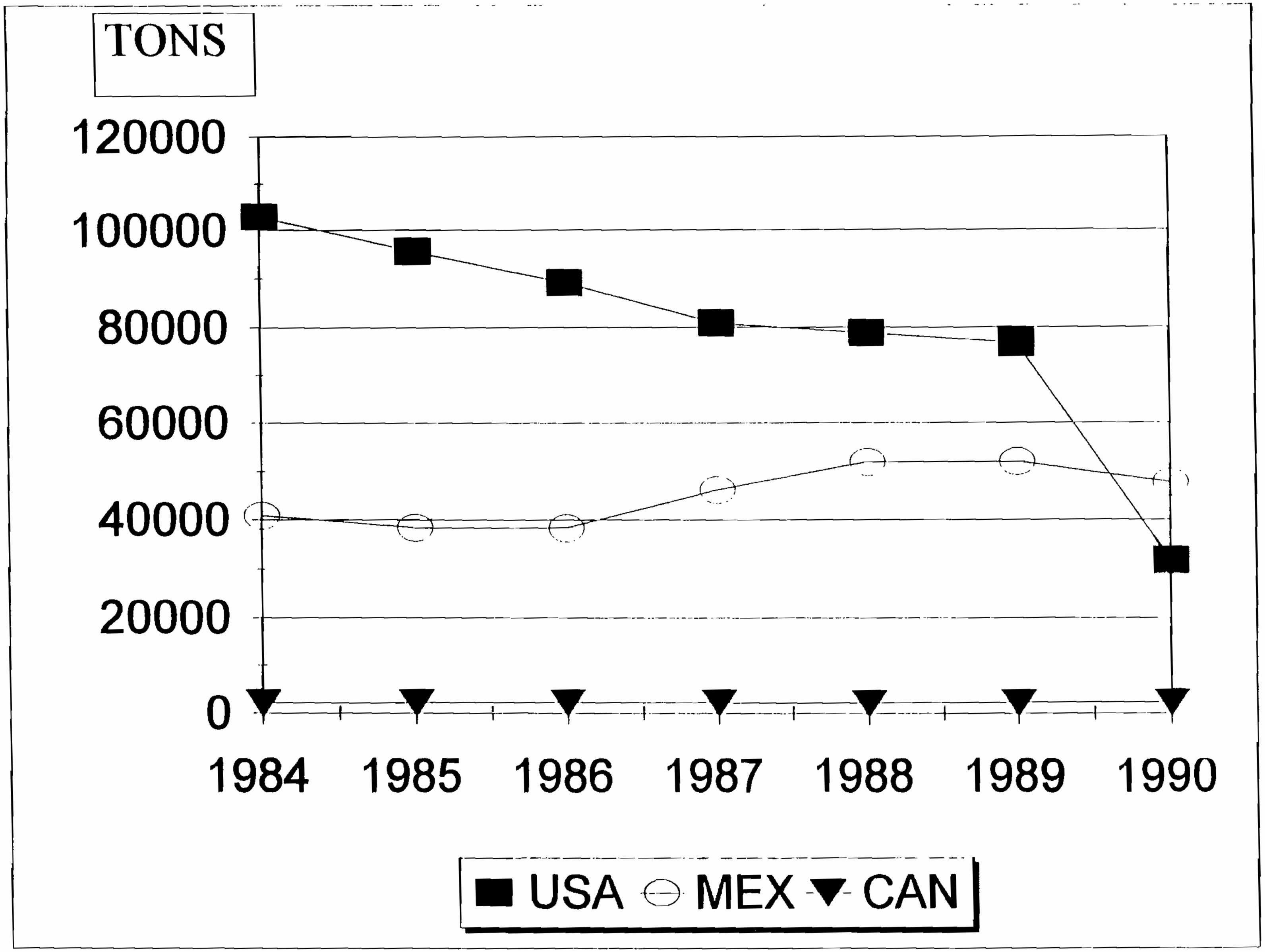
- *Crassostrea virginica*

The total production is declining from 146 100 tons to 82 000 tons in 1990. The landings in 1991 and 1992 will still decline mainly due to the failure of the US production which decreased from 102 000 tons to 32 000 tons (fig. 6). The Canadian production remains constant with 2 300 tons while Mexicans succeded to increase their production from 40 000 tons to 50 000 tons. The decline of the US production is mainly caused by the lack of production of Chesapeake bay which has been explained by Héral et al. (1990), Rotchshild et al. (1993) and Goulletquer et al. (1993). The conjunction of environmental factors (high sedimentation, anoxic conditions), bad management strategies (destruction of habitat, oyster reef, time of spreading the dredge shells, reseeding plan, absence of sanctuaries, and large over-exploitation of the stock) and diseases induced nearly the disappearing of this oyster production which has been the first in the world from the beginning of the century until the fifties.

The two main parasites which contributed to the destruction of the *C. virginica* production are *Minchinia nelsoni* (MSX) initially observed in Delaware Bay (Haskin et al., 1966). It spread in Chesapeake bay and in North Carolina. This parasite is salinity dependant under 10 ‰, oysters are not contaminated. The second parasite is *Perkinsus marinus* called "dermo" coming from the Gulf of Mexico (Ray, 1966), it spread later further to the North (Chesapeake Bay). This parasite is not salinity dependant and presents a high potential of infestation for the oysters in the vicinity by dispersion or parasites free in the water (Andrews, 1984). A gastropod as an intermediary host could also transmit the infection (White et al., 1988). Despite some research to select resistant strain of *C. virginica* against MSX (Ford and Haskin, 1987) and despite the selection of fast growth strain oyster, this doesn't allow to escape high mortalities.

- *Ostrea edulis*

The total production is only 11 000 tons and is very reduced in the different countries (France, Spain, Holland, Italian, Irland, USA...). Serious mortalities occured caused by two protozoa, by the *Marteilia refringens* disease (Grizel et al., 1974) mainly in coastal and estuarine zones. The second parasite *Bonamia ostreae* was discovered in France (Comps et al., 1980) but coming from west coast hatcheries of the USA, where it was called microcells (Katkansky et al., 1969) and later described as a *Bonamia* (Elston et al., 1986 ; Farley et al.,



<u>Figure 6</u> : Evolution of the American oyster (*Crassostrea virginica*) aquaculture production for the main countries (USA, Mexico, Canada).

1988). This parasite later spread in all European countries except on the Mediterranean sea, which explains the relative high Italian production. Programs are developed to obtain resistant strain to *Bonamia* by genetic selection (Martin et al., 1992). A small production could be maintained after an eradication plan and decrease of the densities of the culture.

CONCLUSION AND PERSPECTIVES

World oyster production is based nearly on one species *Crassostrea gigas* which presents in South East Asia, on the West coast of America as well in Europe different diseases. There is an urgent need to enhance :

- First the management of oyster bays to maintain good growth rate with high physiological conditions and low densities to avoid fast spread of diseases. Mono cultivation is also a problem, it would be better to associate different mollusc cultures as oysters, mussels, scallops...
- Secondly the genetic collaboration between the different countries to produce resistant strain to diseases by the means of quantitative genetic or at long term by gene transfer.
- Thirdly to the different strains of cupped oyster to maintain the species diversity to create hybridation diploïdes or triploïdes and to test their resistance to disease.
- Fourthly to increase the knowledge of the pathogens (cycle, infection...) to propose zootechnical plans and increase the information between the different countries ; avoid exchange of spat mainly between the different hatcheries with the remote eyed larvae technics.

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