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Assessments of natural mortality of cultivated oysters (*Crassostrea gigas*) in the bay of Marennes-Oleron (France).

by

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ABSTRACT : The natural mortality of oysters could by considered, in a man controlled ecosystem, as the result of the action of biological factors, and human factors other then the harvest of the population. Such mortalities need to be estimated in order to be used in population dynamics, as a tool for management purposes. In Marennes-Oleron bay, different ways of estimating the natural mortality are available. Several oyster farms were monitored for assessing growth, mortality and production in rearing conditions. Furthermore, an experimental framework which includes 15 stations gave an appraisal of the same factors under controlled conditions. Finally, another estimate will be soon available by comparing the number of recruited oysters, and the number of oyster available for commercialisation, which were effectively reared within the bay. The seasonal mortality was described and its implications in terms of population dynamics were discussed.

Introduction :

In population dynamics, the mortality is usually refered as the fishing mortality and the natural mortality, which includes all the other causes of lethality then the fishing action. These concepts have been widely applied to the fisheries. They have reached a certain level of complexity as testified by the number of papers related to this subject. But only a few works were devoted to the population dynamics of cultivated molluscs (Askew, 1978). Yet, the biological aspect has received a large attention (Sindermann, 1979).

Mass mortalities were often recorded in the past, in several countries. Among them, Japan, France, The United States and the United Kingdom had their production drastically reduced and the losses have sometimes exceeded 95 % of existing population in a single growing season. As a cause of these mass mortalities, were invoked several factors such as diseases, environmental conditions, eutrophication (Mori, 1965), starvation, predators and toxins (Mackin, 1961a). In some cases, the cause of these mortalities had remained unknown. These spectacular events should not overlook the continuing, background mortalities, which are not less important in diminishing regularly the population size.

Mass mortalities are easy to notice and then to evaluate, because of their obvious economic action. But the basic, natural mortalities are generally less evident while they actually contribute to a large amount in economic losses. They are difficult to reveal as they are sometimes obtructed by mass mortalities, or they are restricted to geographic areas or time periods. The people would consider them as normal and inevitable. Since they do not remain constant all over the year, the basic requirements of several models in population dynamics are not fulfilled. This is partially due to some environmental factors which can act seasonally on the mortalities, such as temperature, salinity (Andrews, 1982), food availability (Maurer and Borel, 1986) or the seasonal action of predators (Woelke, 1961). The man action, during the rearing of the oyster may also contribute to the seasonality of these mortalities. The spat removing from the collectors, which traditionally occurs during spring, and the moving of oysters from part to part of the rearing areas are known to cause time dependant mortalities, or to exagerate them (Perdue *et al.*, 1981). The techniques of cultivation may also act on the natural mortality rates (Manzi *et al.*, 1977 ; Walne and Davies, 1977), as well as the population densities (Sheldon, 1968). A same influence of stocks on mortalities was demonstrated by Dickie et al (1984) on the mussel *Mytilus edulis*. Ricker (1975) defines the natural mortality as being the result of all the other factors then fishing (or collecting). While the man impact could hardly be considered as a natural cause of mortality, it seemed easier to group together all the factors other then the final catch for selling, since they interact during the life time of the oysters. The purpose of this paper is to present some ways of estimating these so called natural mortalities, which are presently in use in Marennes-Oleron bay, and to analyse their possible use in the population dynamics of the cultivated oysters.

The method permiting to assess the mortality rates from the age composition was originally developped for the fishes (Saila and Lough, 1981). It was recently extended to the length-frequency data by Breen and Fournier (1984), who give extended details on its use. Gruffydd (1974) estimated the natural mortality of an unfished population of the scallop *Pecten maximus* from its age composition. Its application on oysters population faces several problems. The length of the Japanese oyster is a higly variable parametre, because it depends on the space available for the individuals. When this space is reduced, the shell growth will be rather in length then in width. Furthermore, the recently formed shell is very fragile and is easily broken by the movements of the individuals in the trays or on the ground. In cultivated areas where the oysters reproduce, and where the spat is collected, the recruitment is variable from one year to another. This induces variations in the relative age-composition, which make the assessment of mortality rates imprecise. Another source of variation in the age composition is that the growth rate of the individuals are highly variable. An overlapping of a length-frequency distributions then occurs, and an oyster of 100 mm, or 70 g, may be two or four-years old. All these reasons made the methods based on age composition or length-frequency distributions unusefull for the assessment of natural mortality of cultivated oysters. Neither can be employed the longevity date, as it was proposed by Hoenig (1983), for natural stocks. As this author had mentionned, exploited or cultivated stocks are characterized by an age truncature, and the individuals can not approach their maximum longevity. The use of the gonad body weight to predict natural mortality (Gunderson, 1980) could be of some interest for the molluscs species, but needs further investigations. The statistics of oysters production, as they are actually computed, are not adequate for population dynamics purposes (Heral et al., 1986), because of the bias introduced by the use of taxes statistics and because of the customary exchanges of oyster between different rearing areas.

Three methods are presently in use for the estimation of the natural mortality in our laboratory. Their respective choice will depend on the technique. For the ground culture, a quadrat of 0.5 m^2 is utilized. Its position being chozen by random, all the live and dead oysters are counted, and the sample is repeated three times. Are considered as dead oysters, those with the two valves opened ("boxes" and the left valves. The count of the left valves does not totally suppress the critics made about this method by Mackin (1961b). The shells are not always carefull removed after the harvest, and these remaining valves will produce an overestimate of the mortality. Another source of misleading comes from the fact that some shells are full of mud and remain closed. Since they give a sound very similar to that of live oysters, it is difficult for untrained people to differenciate them. These quadrats counts are mainly used in case of mass mortalities, i.e. higher then 20 % (Sindermann, 1979 ; Woelke, 1961) on oyster beds.

For the off-bottom culture in trays or bags, the direct assessments of mortality are somewhat more precise, since all the oysters are alive when they are installed for cultivation. In most cases, the time corresponding to the control can be known from the professional people, or deduced from the management rules, which include in some areas, precise times for the installation and the removal of the culture, every years. Such assessments are used either for mass mortalities, or as a routine operation, including the monitoring of the production of selected oyster farms. The background, natural mortality may be estimated from this way, during long periods.

Furthermore, experiments are regularly conducted for the monitoring of growth and mortality under controlled conditions. They consists in trays which are divided in fifty boxes, each of them housing an oyster. A net maintains all the individuals immobilized, in order to avoid any movement and impact against the walls, which would cause a poor growth. Such test trays were installed in four different areas of the Marennes-Oleron bay, and at three different intertidal levels. They provided data on the natural mortality, on a monthly basis, thus permitting to gain a better knowdledge of its seasonality. The data are presented in the tables 1 to 4.

Table 1 : Results of a monitoring of the mortality in four different areas of Marennes-Oleron bay, for trays of fifty, individually separated oyster kept at the mean low water of spring (MLWS). The results correspond to the number of dead oysters between may 1985 and April 1986.

Time / Area name	M	J	J	A	S	O	N	D	J	F	M	A	Total	%
Doux	1	1	4	0	0	0	0	2	1	0	0	0	9	18
Lamouroux	1	0	4	1	0	0	0	0	0	0	0	0	6	12
Merignac	1	0	5	1	0	0	1	0	0	0	0	1	9	18
Ronce	9*	3	0	1	2	1	1	0	0	0	0	1	18	36
Total	12	4	13	3	2	1	2	2	1	0	0	2	42	21,0

* four predators (star fish) were found into the tray

The results concerning the first count at Ronce in Table I is mainly due to the action of predators, which usually are not able to enter the trays. The predation due to the starfishes on the oysters is usually low, since they preferably feed on the natural, unprotected beds of mussels. If this count is excluded, the average mortality falls to 16.5 % for the corresponding tidal level (MLWS). The annual mortalities at different levels are then comprise between 15 and 16.5 %, for oysters which were 18 months-old at the beginning of the experiment. These oysters were not handled and brought back to the oyster farm for sorting, several times during the year, and then would have suffered higher annual mortality rates, if they were kept in such rearing conditions.

Table 2 : Numbers of dead oysters in trays of 50 separated oysters, kept at the Average Low Tide Level (ALTL). The fifty area was split into three different shoals. Same period as in Table 1.

Area name		M	J	J	A	S	O	N	D	J	F	M	A	Total	%
Doux		0	1	0	1	0	0	0	0	0	0	0	0	2	4
Lamouroux		2	1	2	1	0	0	0	0	0	0	0	0	6	12
Merignac		1	4	0	0	1	0	1	1	-	-	-	-	(8)*	(16)*
Ronce		7	0	0	3	0	0	1	1	0	0	0	0	12	24
Central area	Dagnas	3	1	3	5	0	2	0	0	0	0	0	0	14	28
	Naules	0	2	0	0	1	1	0	0	0	0	0	1	5	10
	Bourgeois	4	0	1	1	0	0	0	0	0	0	0	0	6	12
Total		17	9	6	11	2	3	2	2	0	0	0	1	53	15.14

* In Merignac, the tray disappeared in January.

Table 3 : Numbers of dead oysters in trays of 50 separated oysters, kept at the Mean Low Water of Neaps (MLWN). Same period as in table 1.

Time / area names	M	J	J	A	S	O	N	D	J	F	M	A	Total	%
Doux	4	1	4	1	0	0	0	0	0	-	-	-	(10)	(20)
Lamouroux	2	1	0	0	1	0	0	-	-	-	-	-	(4)*	(8)
Merignac	0	2	1	0	1	0	0	0	0	0	1	0	5	10
Ronce	4	1	2	2	1	0	0	0	0	0	0	1	11	22
Total	10	5	7	3	3	0	0	0	0	0	1	1	30	15,0

* in Lamouroux, the tray disappeared before Christmas.

The seasonal mortality is described in the table 4, which summarizes the monthly results of all the experimental trays.

These data show that the seasonal mortality was at its highest in May, at the beginning of the experiment. After a small decrease, another high mortalities were observed at the end of August. They decreased slowly, until they become nul in February, and they rised again in March and April. The correlation coefficient with the water temperature (0.422) did not significantly differed from 0, thus indicating no tremendous effect of the temperature on these mortalities. Most of the individuals died in May, just after the beginning for this early mortality. The first one may be the stress consecutive to the start of the experiment, the oysters being kept out of the water for 24 hours. Furthermore, unpublished results on their biochemical composition indicated that their physiological condition was poor at the end of April 1985. The available food, represented by the chlorophyll values, raised only after that time.

Table 4 : Seasonal mortality of the oysters in Marennes-Oleron bay, from May 1985 to April 1986. The trays were installed at different tidal levels and different areas of the bay.

Time	M	J	J	A	S	O	N	D	J	F	M	A	Total
Dead oysters	39	18	26	17	7	4	4	4	1	0	1	4	125
%	5.2	2.4	3.5	2.3	0.9	0.5	0.5	0.5	0.1	0	0.1	0.5	16.7

These experimental results confirmed the field observations made on the seasonal mortalities. A general scheme can be given for the bay of Marennes-Oleron. Such a scheme should include both the action of the time of the year and the age of the individuals.

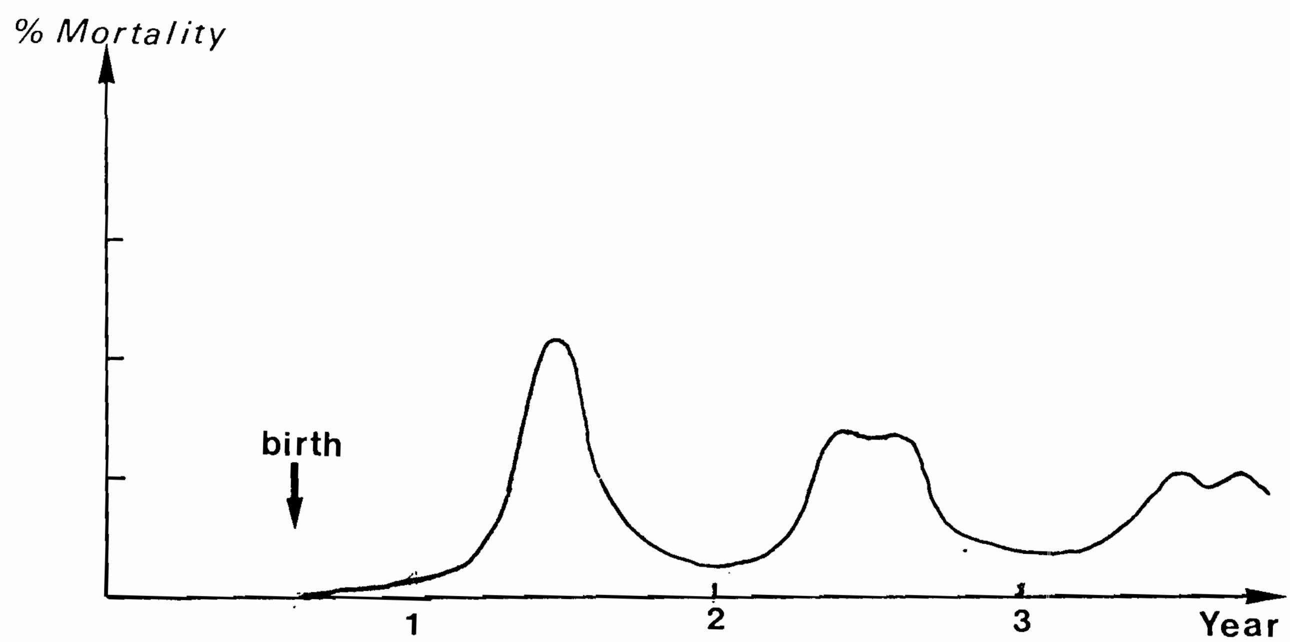

Figure 1 : Schematic evolution of the mortality rate for a population of Crassostrea gigas in Marennes-Oleron.

For the 0-group of oysters, the spat removing from the collectors is mainly performed in March and April, at a time when the oysters are starved. The percentage of mortality resulting from this operation depends on the skill of the farmer, but it can be evaluated to an average 25-30 %. The summer mortalities affecting mainly the 1 year-old oyster do not occur every year in Marennes-Oleron bay. They are generally noticed before spawning (Perdue et al., 1981), during the glycogenolysis phase of the carbohydrate cycle. They are less important and less regularly observed then in the neighbouring bay of Arcachon (Maurer et al., 1986), which however exhibit higher temperatures.

For the 2 years old and older oysters, two peaks are generally observed along the year in the mortality rates, their intensity being variable from year to year. At the end of the hydrological winter (April), the oysters were not fed from four to six months. When the water temperature rose, just before the planktonic bloom, the oysters had to face increased physiological needs, and then, some mortalities occurred. Another critical period, for these older oysters, is found after the spawning, which represents a stress. These two periods were found in our experiment, even if they were attenuated by the low density (100 individual.m^{-2}) of the experiment.

During the first three or four-years, the oysters remain unfished, because of their small size. Therefore in terms of population dynamics, the fishing mortality is nul : $F = 0$, and the instantaneous rate of total mortality, Z, equals the instantaneous rate of natural mortality, M (all the notations are those given in Ricker, 1975). For the part of the population which is not exploited, the actual rate of total mortality, A, in only composed of the part related whith the natural mortality, V. Then from Ricker :

$$A = I - S = 1 - e^{-M} = n$$

n : conditionnal rate of natural mortality and

S : actual rate of survival

The assessment of n will best be performed on a large period covering the unexploited stages, rather then during only one year. However, the considered oysters were intermediate between one year old oysters, suffering of higher rates or mortality, and older oysters, with lower mortality rate. The values obtained can be considered as an estimation of the annual rate of natural mortality (n). Their mean value (0.1705) was used to compute an assessment of the instantaneous rate of natural mortality : $M = 0.187$.

This estimation was kept for individuals which were not suffering from high densities, and frequent handling. The actual value of M for cultivated oysters will be probably higher. Even in that case, all these mortalities may be referred as the background mortality, and the action of mass mortalities has been excluded. At the present time, the japanese oyster, *Crassostrea gigas* did not suffered from mass mortalities in the bay of Marennes-Oleron. A pathologic survey is now installed, and no epidemic diseases were found, as it was the case for the branchial illness which eradicated the portuguese oyster, *Crassostrea angulata* by the early seventies. However, the stock of cultivated oysters increased rapidly after the import of the japanese oyster, and the carrying capacity of the ecosystem is probably reached, as it is demonstrated by Heral et al. (1986). The risk of epidemic illness then could reapears in the bay. Furthermore the high level of the stock will increase the density dependant mortalities. All these factors make the survey of the mortalities a necessity.

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