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A methodology for the stocks assessments of cultivated oysters along the French Atlantic coasts.

Cédric BACHER (1), Jean-Pierre BAUD (2), Alain BODOY (1), Jean-Marc DESLOUS-PAOLI (1), Jean-Paul DRENO (3), Maurice HERAL (1), Danielle MAURER (3), Jean PROU (1).

ABSTRACT : Assessments of the reared stocks of the pacific oyster (*Crassostrea gigas*) has recently been conducted on the French centers of mollusc cultivation. The methodology included both estimates of density obtained by subsampling in the field, and aerial photographs which covered the intertidal cultivated area. Estimations of local biomasses were obtained by a random subsampling within different strata, according to the modes of cultivation and the geographical areas. Aerial photographs all over the bay permitted to measure the areas effectively used for the molluscs culture. They were analysed either extensively for smaller bays such as Arcachon and Bourgneuf, or by a systematic sampling for larger areas (Bay of Marennes-Oleron). The stocks were computed as the product of biomass and cultivated surfaces. The results indicated that, 82 000 tons of oysters were present in august 1985 in Marennes-Oleron, 38 000 tons in Arcachon (June 1985) and 38 680 tons in the bay of Bourgneuf (september 1985).

(1) IFREMER, B.P. 133, 17390 LA TREMBLADE
(2) IFREMER, Polder des Champs, 85230 BOUIN
(3) IFREMER, Quai du Commandant Silhouette, 33120 ARCACHON

Introduction :

The oyster culture is an old activity, which has been present in France for one century. With a commercialized production averaging 100 000 tons for the last years (Héral, 1986a), this country is the fourth world largest producer, after the United States, the Japan and the Republic of Korea (Glude, 1979 ; FAO, 1982). Its production is almost entirely based at the present time, on the pacific oyster, *Crassostrea gigas*. The main rearing areas are located in a mediterranean lagoon (Thau) where are produced approximately 10 000 tons yearly and along the French Atlantic coasts. Three bays contribute to 70 % of the whole production, namely the bays of Arcachon, Marennes-Oléron and Bourgneuf. The oyster culture is also encountered in other, small centers scattered on the Brittany coasts and in Normandy.

This activity had to face several problems in the past. The indigenous flat oyster was the first to be cultivated. Mass mortalities were observed in the twenties, and an oyster industry based on spat collection, had developed on the portuguese oyster, *Crassostrea angulata*. The production was rapidly increasing and reached a amount of 100 000 tons by the early sixties. But the occurence of a branchial illness, followed by mass mortalities, led to the disparition of the species. At the same time, the flat oyster, still cultivated in Brittany, was infested by parasites (*Marteilia refringens* and *Bonamia ostreae* (Grizel, 1983)) and its culture regressed. Some spats of the japanese oyster (*Crassostrea gigas*)were then imported and a new production started, wich reached the same level of 100 000 tons by 1980.

Despite the extension of the cultivated areas, the stocks of the species are locally increasing and the same situation which caused the disparition of the portuguese oyster could be encountered in the future, as it is demonstrated by the study of Héral (1986b). This author has reconstituted from statistical, and commercial sources, the level of the stocks of oysters from the beginning of the century. The decline of the portuguese oyster appeared to be linked with an overtaking of the carrying capacity of the ecosystem. Research efforts have then been made to define this carrying capacity for the concerned bays and to evaluate the cultivated stocks in each rearing area. The knowledge of these two informations is a requirement for the definition and the implementation of a management programme.

While a considerable attention has been given to fish stocks assessments, very few works were devoted to the estimation of the cultivated stocks of

molluscs. This paper presents the methodology chosen for the stock assessment of the intertidally cultivated oysters and the sampling strategies now in use on the Atlantic Franch coast. The particuliarities of the culture in the mediterranean lagoons, which consists in tables under what the oyster lines are hanged, led to a different sampling strategy, requiring the use of divers, which has been published elsewhere (Hamon and Tournier, 1986).

Objectives :

Two main objectives were researched through the stock assessments of the cultivated oysters. At the present time, an attempt is made to built a model of the ecological functionnement for the coastal ecosystem in the bay of Marennes-Oléron. The quantity of available food and the way it is produced, the turnower of the water masses and the energetic budgets of the populations are parts of this scientific effort, as well as the estimation of the biomass of cultivated oysters. Another pratical aim of the study was to define some management rules for the production, since a previously cited work indicated a risk of epidemic illness, and the slowering of the growth rate.

The achievement of the objectives led to the determination of the biomass, at a time of the year when it reaches its maximum level in a bay. The seasonality of the growth rate, the period of selling, and the way of cultivating the oysters, which includes some exchanges between different bays, modify the biomass of oysters along the year. The period when this biomass is at its highest, generally occurs during Summer for the bay of Marennes-Oleron and was therefore chosen for the sampling.

The two main variables considered were the cultivated surfaces and the local densities. But another variable, related to the technique had to be added.

The analysis of the quantity of oysters cultivated in an area depends on the different techniques used for the rearing. The older technique consists in the sowing method, the oysted being spread out on the ground. The parcels are protected by plastic fences, in order to avoid the dispersal of oysters by storms. In another techniques, the different types of spat collectors, which are 1 metre long, are installed on metallic tables 0.5 m above the sediment. The on-growing period usually last between one or two years, sometimes three years. This off-bottom technique is locally named as "half-rearing". After that time, the oysters are removed from the collectors and put in trays, or bags made of a plastic wire netting, for the end of their growth, until they are removed from

where the spat is collected are generally separated from the culture areas. Since the biomass on the collectors, before they are moved to the culture areas can be considered as negligible in regard of the cultivated oysters, these spat collecting areas were not investigated. The relative proportion of these three different technique (ground cultivation, off-bottom techniques for half-rearing or rearing in trays or bags) will differ between the culture areas, both for historical and ecological reasons.

For the off-bottom culture, the surface occupied is only a part of the cultivated surface, since the rows of tables are separated by a free space, and the percentage of actually occupied surface had to be considered as a third variable in addition to the two others.

Presampling :

A stratification of the areas available for cultivation was made according to their geographic position and their biological productivity (Bacher, 1984). The five selected strata (fig. 1) were then divided into two substrata corresponding to the ground culture and the off-bottom culture. Since the variance within each substratum was not known, a presampling strategy for the first year was then defined, by allocating a number of samples in each stratum and substratum, proportional to the surface calculated with the land register established by the administration . Such a stratified presampling strategy does not correspond to the optimal allocation, but Cochran (1977) indicates that the variance obtained by this stratified sampling strategy, was less then that given by a simple ramdom sampling.

The percentage of the surface of the land register really occupied for rearing is obtained by considering a sampling unit which corresponded to a square of 10 000 m^2 = 1 hectare (ha) = 2,469 acres.

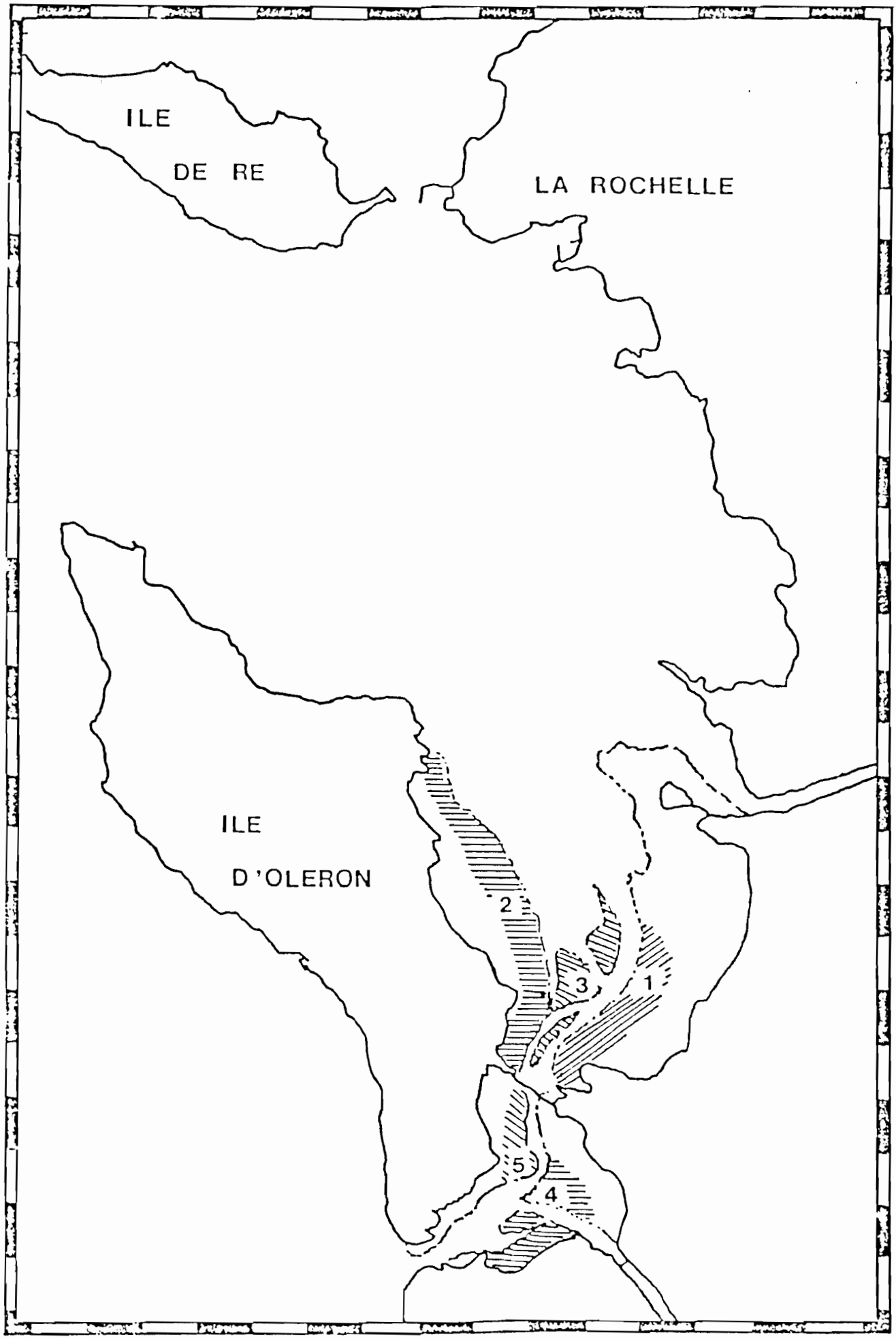
The estimation of the biomass and densities was made by means of another, 2 degrees sampling. The primary units were the squares previously described and the secondary units consisted in small areas of 0.5 m^2. The biomass was measured by weighing the oysters within a wooden frame of that area, for the ground technique. The trays and bags commonly in use for oyster culture in France were

also of 0.5 m^2. They constitute therefore the secondary sampling unit for the off-bottom technique. Three of them, randomly chosen in the field were weighed in each primary unit. The number of randomly chosen primary units was 54, which corresponds approximatly to 6 % of the cultivated surface. The percentage of the actually cultivated surface on the area granted for cultivation was obtained from an aerial photographic coverage of the whole area, made at the same time of the sampling.

The data collecting represented 80 days-persons and the results are shown in table 1.

Table 1 : Results of the presampling (1984). For the ground culture, the cultivated areas are in hectares (1 hectare = 10 000 m^2 = 2,469 acres). The percentage corresponds to the cultivated surface on the granted surface. For the off-bottom culture, the lengths are those of the rows of tables, 1 m wide ; the percentages correspond to the surface. All the biomass are given in metric tons.

Substrata	ground culture			off bottom culture		
Strata	Cultivated surface (ha)	%	Biomass (tons)	Length (km)	%	biomass (tons)
1	292	52.1	15 057	195	17	3 873
2	-	-	-	551	32	12 559
3	35	100	2 494	495	54	10 384
4	147	91.7	7 161	380	42	9 839
5	139	48.3	5 523	66	7	1 939
Total	613	59	30 235	1 867 = 506 ha	30	38 594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The precision of the stock figure was 25 %, both for the ground culture and for the off-bottom culture. This precision was not considered as satisfactory. An attempt has then been made to increase this precision by increasing the stratification, according to the tidal level for the same sampling. Another computation was then made by dividing a stratum into two parts (high tidal level, low tidal level) comprising the same number of primary unit. This attempt was unsuccessfull, since the precision for the stratum declined only from 51 % to 48 %.

Sampling strategy in 1985 in Marennes-Oléron :

The preliminary study made during the year 1984 allowed to select some ways for the improvment of the precision. The strata were redefined by means of the aerial photographs, in order to eliminate most of the non cultivated areas. The random selection of these primary sampling units was made by eliminating the remaining units which were still not cultivated and would have given a nul biomass. The final number of primary units of 1 ha (100 x 100 m) was increased from 54 in 1984 to 113 in 1985. This sampling effort then corresponded to 16 % of the ground culture, and 8.5 % of the off-bottom culture. All these primary sampling units were allocated to the different strata and substrata in an optimal way by using the function given by Cochran (in Frontier, 1983). The optimal number of units depends both on the sampling cost for each unit and on the variance for the primary level and the secondary level. These variances were previously obtained from the results of the presampling. Always in order to increase on the precision, the primary units for the off-bottom technique were split into the so called "half rearing" on collectors and the rearing in trays or bags. The number of primary units are shown in table 2.

The estimation of the cultivated areas was performed by using a new aerial photographs coverage. A grid, with a mesh of 3 mm was applied on the pictures. Each point corresponding to a cultivated surface was counted and this measurement was repeated 3 times. This systematic sampling on the photographs proved to give better results then a simple ramdom sampling of points (precision = 8.5 %), while the final determination for the cultivated surface by the grid method was 3 %. These results for 1985 are given in the table 3. The surface occupied by the ground culture appeared to have been overestimated by the presampling. This was due to the use of theoretically cultivated surfaces. The scale used for that coverage (1/10 000) did not allow to distinguish between the collectors and the trays.

Table 2 : Number of primary sampling units (10 000 m^2) optimally allocated in each stratum and substratum.

Strata	Ground culture	off-bottom culture			Total per stratum
		"half rearing" collectors	"rearing" trays/bags	Total	
1	19	3	5	8	27
2	-	14	18	32	32
3	10	10	6	10	20
4	7	7	6	13	20
5	18	15	11	26	44
Total	54	49	40	89	143

Therefore another photographs were taken at a larger scale (1|1500) on 94 randomly selected points in the off-bottom culture. Two different measurements were performed on these pictures : the first one (percentage of the occupied surface on the available surface) was practically constant over the different strata (33.8 %) with a precision of 1 %, and corresponded to the rules established for the off-bottom culture by the Direction of Maritim Affairs. These rules indicates that each rows of table, 1 metre wide should be installed every 3 metres, giving a percentage of occupied surface of 33 %. On the same pictures, were also measured the percentage of trays and collectors, by measuring their respective lengths (table 4). The stratum n° 3 appeared to be almost entirely free of collectors. The low precision is due to the tangle of the different cultures. Indeed the percentage of collector observed in one single picture may vary from 0 to 100 %.

Table 3 : Cultivated areas in each stratum for the year 1985 in Marennes-Oleron bay (unit = 10 000 m^2).

Strata	ground culture	off-bottom culture
1	94	27
2		334
3	94	176
4	90	132
5	60	26
Total	338	695

Table 4 : Percentage of collectors for the off-bottom culture, within the different strata.

Strata	Collectors (%)	Standard deviation
1	68	5
2	68	9
3	4	1
4	43	6
5	35	5

The estimation of the biomasses was obtained with a two degrees sampling strategy already described. The primary units were identical to these utilised for the assessment of the cultivated surfaces and the number of secondary units per primary units (3 times 0.5 m^2, 3 trays or bags, or three collectors) remains unchanged. 120 days-persons were used for these field measurements. The results are given in the table 5. The biomass was highly variable for the collector, which may correspond to different ages of oysters. The standard deviations allow to compute a precision of 23.6 % for these collectors, 8.3 % for the trays and 9.9 % for the ground culture.

Table 5 : Results of the field measurements :
Average biomasses and the corresponding standard deviation for each stratum. For the off-bottom culture, the results are given in $Kg.m^{-1}$ of tables. The actual biomass in $Kg.m^{-2}$ for a stratum is the third of these values.

	Ground culture		off-bottom culture			
Strata			Collectors		Trays/bags	
	$Kg.m^{-2}$		$kg.m^{-1}$		$Kg.m^{-1}$	
1	8.7	0.55	19.26	2.69	22.34	1.05
2	-	-	12.97	2.62	23.59	1.62
3	11.95	1.23	-	-	23.22	1.37
4	11.38	1.16	26.09	6.25	19.03	1.45
5	6.3	0.49	20.17	4.65	23.48	1.18
Mean	9.89	0.49	20.75	2.45	22.35	0.93

The results of the computation of the stock from the biomasses and the cultivated surfaces are given in table 6. The precision of this product (biomass x surface) is the square root of the sum of the squares of the different precisions. For the off-bottom culture, the cultivated area was the product of

the lengths of tables by the percentage of occupied surface. The precision was low for the estimation for the collectors.

This is probably due to a progressive increase of the time during which the oysters are cultivated in collectors. These oysters are sometimes three years-old and the weight of the collectors is therefore subject to large variations.

Table 6 : Results of the stock computation for the different techniques used in Marennes-Oleron bay.

Technique	estimated stock (metric tons)	Precision (%)
ground culture	33 480	10.1
off-bottom culture: collectors	26 175	26.5
off-bottom culture: trays and bag	23 067	15.6
off-bottom culture: total	49 242	15.87
estimation for the bay	82 722	10.3

The number of collectors put on 1 meter of table may also fluctuate in a large part. As a consequency for the next years, it seems important to obtain a better estimation of their densities, as well as an ageing of the oysters on the collectors. These two parameters will be obtained by no mean but field measurements, thus increasing the cost of the sampling. Another result which is not satisfactory is the percentage of collectors and trays, with a precision of 13 %. An increased effort of sampling could be made on the aerial photographs at

large scale, specially for the strata where the two off-bottom cultures are tangled.

Sampling strategies in other Atlantic bays :

The same sampling techniques were used at the same time for two other bays which are important centers of oyster culture. The particularities of these bays led to little variations with the general scheme exposed above.

In the bay of Arcachon, only four geographic strata were defined which corresponded to geographic entities. The ground culture largely predominates, with more than 65 % of the cultivated surfaces (Maurer and Borel, 1984). The number of primary units allocated to this culture was therefore higher than for Marennes-Oleron. In Arcachon, the primary units corresponded to granted parcels. These are easily recognizable on the field, and the biomass sampling became easier. The size of these primary units was then variable. The size of the secondary units was identical (0.5 m^2), but their optimal number was computed as being equal to 2 for the off-bottom culture.

The final result gave a biomass of 37 996 tons of oysters for June 1985 with a precision of 5.1 %.

The bay of Bourgneuf, located South of the Loire estuary, is protected by the island of Noirmoutier. The oyster culture is more recent then in the two other bays. The main particularities here is that most of the cultivation is made by the off-bottom technique (Saint-Felix et al., 1983). The sampling strategy in use at the present time does not significantly differ from that elaborated from Marennes-Oleron, excepted that the smaller surfaces permitted to realize an exhaustive measurement of the table lengths on the aerial pictures a the 1/10 000 scale for the whole of the bay. The percentage of collectors was determined on aerial pictures (1/2000) in andomly selected points, which covered 20 % of the cultivated areas. The estimation of the biomass was conducted with a 2 degree sampling, the primary units being of 1 ha and the 3 secondary units of 0.5 m^2. The final results for the bay of Bourgneuf gave a stock assessment of 38 620 tons with a precision of 5 %.

The stocks estimated in these three centers of oyster culture seem to be very high, particularly in Marennes-Oleron. lt is difficult to compare the results in 1984 (69 000 t) with those obtain in 1985 (83 000 t) because differents sampling technics have been used. However it seems, a tendancy of an increase of the biomass which is probably the consequency of an highly successfull recruitment in 1982. lf this trend would persist in the near future, the carrying capacity of the bay could be reached, with drastic reduction of the growth rates.

Such stocks assessments in the main centers of oyster culture will be achieved yearly and a monitoring of the available food will be implemented in these bays, in order to define the management rules allowing to preserve the French oyster production at their optimal levels.

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