Artificial capture of mangrove oyster spat *Crassostrea gasar* (Mollusca, Bivalvia) in Casamance estuary (Senegal)

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Abstract. The artificial catch system for the mangrove oyster spat, *Crassostrea gasar*, was studied in the estuary of River Casamance (southern Senegal), taking into account the strength of the current on the banks, the orientation of the collectors in reference to the current tide, light exposure and the type of surface on the collectors (smooth or rough). The best capture is obtained when the strength of the tidal current is between 0.6 cm s^{-1} and 1 cm s^{-1}. Depending on the current direction, the largest number of larvae is found on the collectors with a sagittal position (0.27 post-larvae per square cm). For individual collectors, the best bindings are observed on rough surfaces (0.19 cm^2 post larvae) and those not exposed to light (0.18 cm^2 post larva). The interaction between the various factors we studied allowed us to notice the significant differences between the capture of post-larvae of oysters depending on the shore (current velocity) and the orientation (right-side- horizontal collectors, right-side perpendicular collectors) on one hand, and the direction and the type of surface (horizontal position/smooth surface, oblique position/smooth surface) on the other hand. These results on the capture of post-larvae are useful, even very important for improving the binding of oyster spat necessary for mangrove oyster farming.
Key Words: spat, collectors, *Crassostrea gasar*, Casamance, Senegal.

Introduction. In Senegal, the deposits of marine mollusks are practically the only pieces of land assigned to women by tradition and custom (Diadhiou et al 2002; Kebe & Charbit 2007; Fall 2009). It is also impossible for them to have access to plots of land and fields in their villages (Diadhiou 1995).

Due to the demographic pressure and climatic hazards (drought, climate change) in recent years, the exploitation of marine mollusks in the estuarine systems of Sine-Saloum and Casamance, the two major areas where we obtain most of the output, is declining (Dème 2009; Kébé & Dème 2010).

Besides a traditional farm, individual and family associative groups develop an intensive cultivation around some villages of Saloum like Dionewar and Niodior (Diadhiou 1995; Grandcolas 1995; Dème et al 2000). This has made many women move further and further away from their home land in search of new deposits, which sometimes leads to conflict with people in those villages and an increase in the production costs. The rising sea levels, changes in marine and river currents, changing sea water salinity also have a negative impact on the production of mangrove oysters, *Crassostrea gasar.* These factors are, at the same time, among the causes in the rise of the mortality rate of the mangrove which constitutes a natural stand for the mollusk (Diouf et al 1998; Frechette et al 2003; Thiam et al 2011).

It is in this context that the mangrove oyster farming was initiated in 1988 in Lower Casamance (Figure 1) with support from the French Institute of Research for the Development (IRD) and The French agricultural research and international cooperation organization (CIRAD), within the framework of an oyster farming project. This activity, however, requires skills regarding the optimal catching conditions for the oyster spat. Gilles (1992) addressed the problem in Casamance studying its potential catchment areas.

The present article analyzes the optimal conditions of artificial collection of mangrove oyster spat in its natural environment. This type of study has been done on oyster species such as *Crassostrea virginica*, *Ostrea lurida* but not on the mangrove oyster, *C. gasar*. Indeed, the only studies on the capture of its spat concern the effect of temperature, salinity and surface type of the collectors (Gilles 1992; Thiam et al 2011).

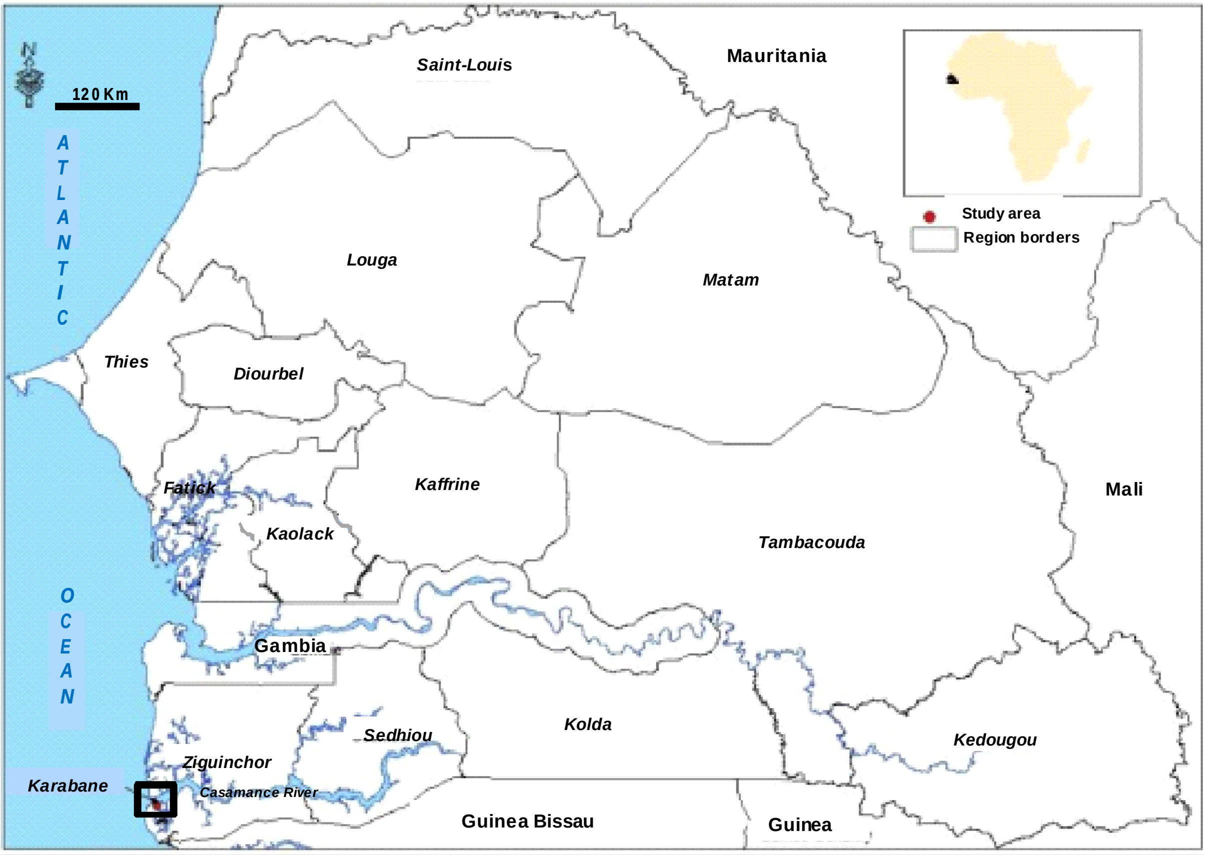

Figure 1. Map showing the study areas located in Casamance of Senegal.

Material and Method. Nine collectors made of EVERITE plates measuring 156 cm^2 each, with a rough surface on one side and a smooth one on the other, are attached to each of the five rebar skeleton in the shade of the mangroves, an area naturally occupied by oysters, between -10 and +50 cm regarding the surface of the water, the natural height of the oyster fixing raciness on stilts of the mangroves in the estuary of Casamance (Figures 2 and 3). Three of the five porches are installed on the right bank; the other two are placed on the left one. The bases are regularly reinforced for stability. Every third day, all the collectors (27 of them on the right bank and 18 on the left) are pulled out of the water for observation of the oyster spat.

To analyze the capture of the oyster spat, we take into account the angle formed by the collector and the soil, the type of surface on the collector (smooth or rough), their orientation (position is sagittal, oblique, horizontal, perpendicular or not exposed to light). The analysis of 18 collector's surfaces are made under a binocular microscope in the laboratory. After this operation, the collectors are cleaned with a wire brush and then dried for 24 hours before re-use. The current velocity is measured at the beginning of the study at slack tide on both banks of the affluent, at the study sites of the oyster larvae capture. This speed is calculated by measuring the distance covered by a polystyrene float over a known distance for a certain period (the result is the number of meters covered per second). Given the low amplitude in the sector, these values are representative of the average data of the current.

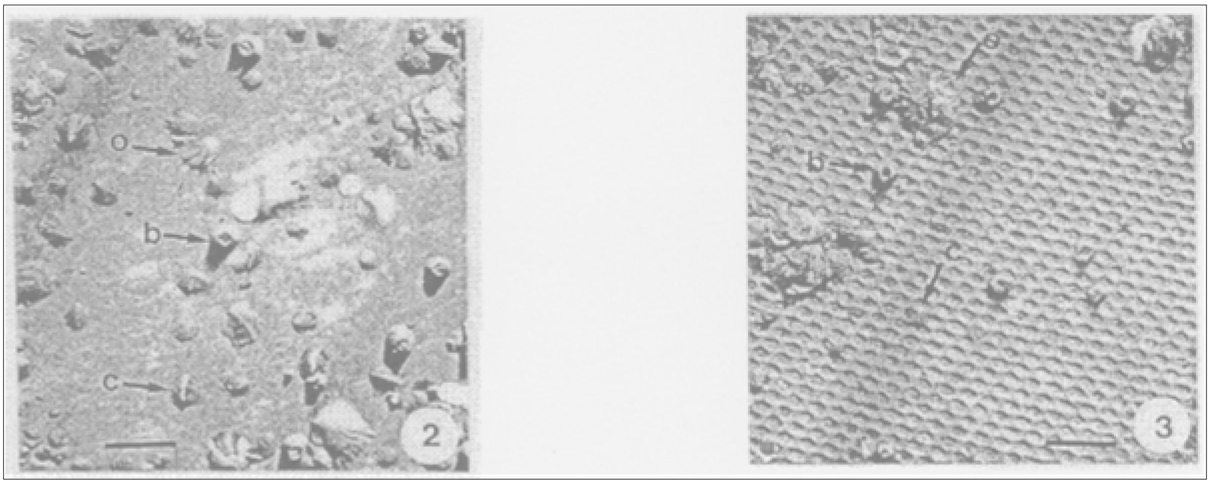

Figure 2. Collectors made of EVERITE plates: (c) oyster spats, (b) barnacles, and (o) *Ostrea edulis*. (2 = smooth side, 3 = rough side).

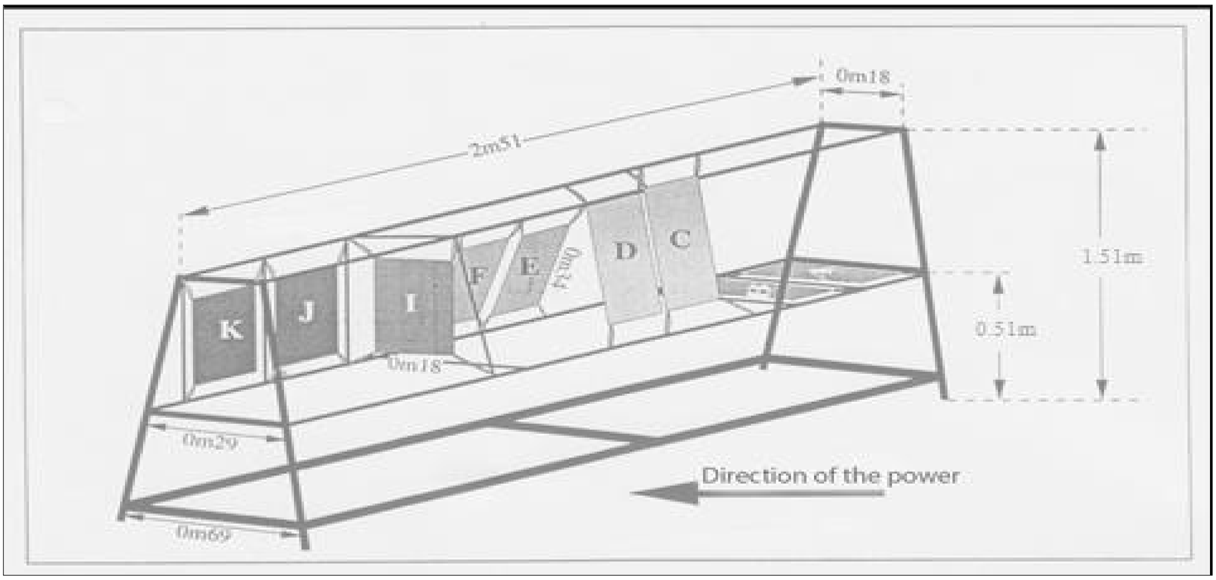

Figure 3. A frame holding collectors made of EVERITE plates. A and B are horizontal plates; C, D, E and F are oblique plates; I, J and K are sagittal, ⟵ : direction of the power.

SAS software (Statistics Analysis System, SAS Institute Inc., NC, USA); PRODAS (Professional Data Analysis System) and NDMS (version 1.01) are used to process the data. The exposure of the collectors shows some obvious problems of redundancy with the orientation. It will therefore be excluded from the treatment of the data. A model ultimately subject to the "General linear model" SAS procedure is then retained with the time factor, encoded as three different ways for the periods (beginning of September; from 19 September to 1 October; from 19 to 25 October) described, as well as the set of explanatory variables corresponding to the capture sites themselves: bank, orientation related to the current, collectors, light, surface type of collectors.

Results. The model chosen involves therefore all simple effects (time, bank, orientation, surface type and light) as well as some interactions (Table 1).

Recruitment was moderate at the beginning of September. It was during the second period (19 September and 1 October 1993) that the highest uptake values were obtained (37 post-larvae set by collectors of 156 cm^2). Then follows a sharp fall in the number of spat, reaching near zero at the end of October (19 and 25 October) (Figure 4). Oyster spat capture was better on the right bank, the sagittal position, the rough surface collectors, collectors unexposed to light (Tables 2 to 7).

Considering all factors, the best seed collection is noted in the second period on the sagittal collector. At the same time it decreased on the oblique, perpendicular and horizontal ones. The results of the different analysis according to the different parameters of the study are shown on Figure 5.

Table 1

Linear model for the capture of the mangrove oyster spat at Karabane (in Casamance) according to environmental factors. *Ddl*: Degree of freedom; *p:* probability

Factors	*Ddl*	*F value*	*P*
Period	2	182.38	0.0001
River bank	1	38.27	0.0001
Orientation	3	36.10	0.0001
Surface	1	66.80	0.0001
Light	1	20.26	0.0001
Interactions	*Ddl*	*F value*	*P*
Period * River bank	2	15.54	0.0001
Period * Orientation	6	14.08	0.0001
Period * Surface	2	16.67	0.0001
Period * Light	2	10.41	0.0001
River bank * Orientation	3	4.86	0.0023
Orientation * Surface	3	7.49	0.0001
Orientation * Light	1	3.88	0.0492
Model	27	29.23	0.0001

Grouping experiment dates into three periods (beginning of September; from 19 September to 1 October; from 19 to 25 October) shows the intensity of the capture in relation to time (Figure 4).

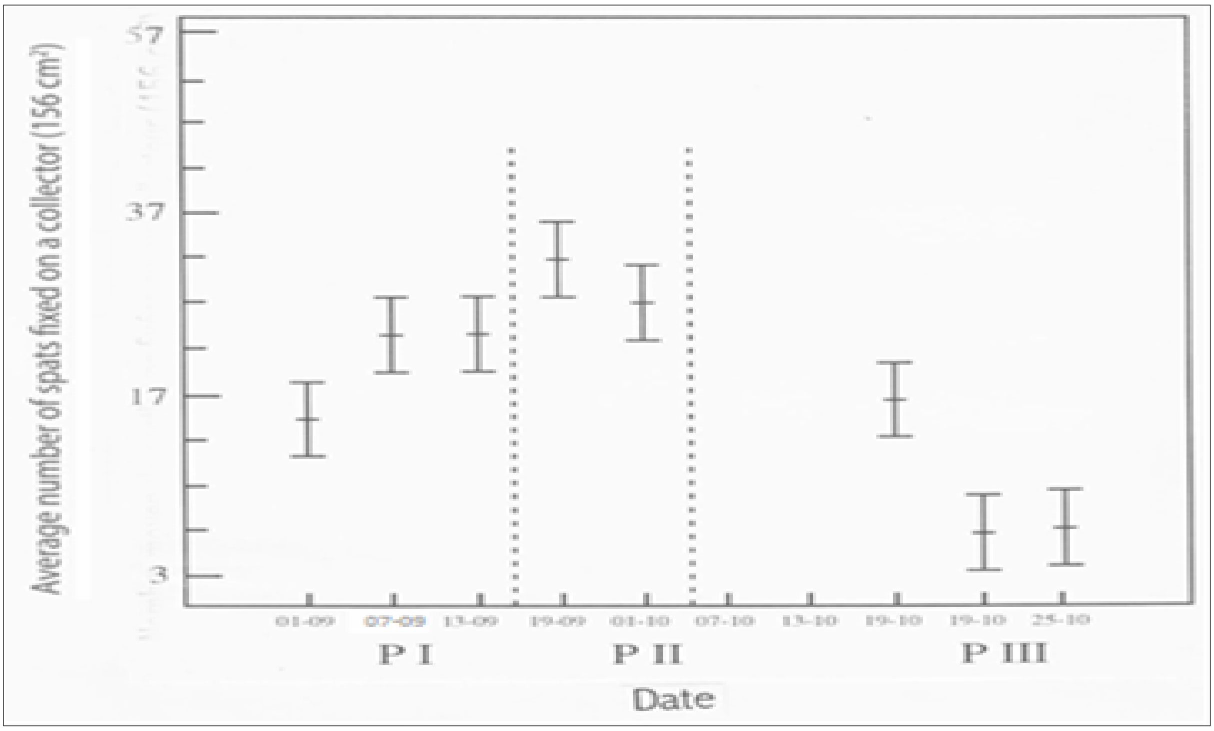

Figure 4. Relative importance the spat capture according to the period (beginning of September; from 19 September to 1 October; from 19 to 25 October).

Table 2

Post larva capture according to the river bank

River bank	*Number of tested collectors*	*Average number of post larva attached to one collector (156 cm^2)*	*Standard deviation*
Left	360	19.64	25.93
Right	540	30.02	38.35

Table 3

Post larva capture according to the river bank

River bank	*Number of tested collectors*	*Average number of post larva attached to one collector (156 cm^2)*	*Standard deviation*
Horizontal	200	17.22	21.88
Perpendicular	300	22.94	30.00
Oblique	400	26.84	32.86
Sagittal	100	43.44	55.20

Table 4

Post larva capture according to the type of collector surface

Surface	*Number of tested collectors*	*Average number of post larva attached to one collector (156 cm^2)*	*Standard deviation*
Smoothh	450	20.66	28.30
Rough	450	30.00	38.84

Table 5

Post larva capture according to light exposure

Exposition	*Number of tested collectors*	*Average number of post larva attached to one collector (156 cm^2)*	*Standard deviation*
Light	600	24.43	34.99
Darkness	300	28.17	32.90

Table 6

Level of significance interactions noted in the model. R: right side bank; H: horizontal position; O: oblique position; P: perpendicular position; S: smooth side. *p*: probability

Interactions	*Modalities*	*t value*	*P*
River bank * Orientation	R-H	-3.28	0.0011
	R-O	-2.44	0.0149
	R-P	-3.49	0.0005
Orientation * Surface	H-S	-3.79	0.0002
	O-S	-4.37	0.0001
	P-S	-2.31	0.0210
Orientation * Light	H-S	-1.97	0.0492

Table 7

Comparison tests for the capture on the two surfaces of the collectors according to the period (capture on a surface measuring 156 cm^2). *p*: probability; *ns*: not significant

Period	*Variances*			
	t value	*Df*	*P*	*Significance level*
1	-3.2063	448	0.00046	***
2	-4.0497	178	0.00000	***
3	-0.8674	268	0.36652	Ns

Considering all factors, the best seed collection is noted in the second period on the sagittal collector. At the same time it decreases on the oblique, perpendicular and horizontal ones. The results of the different analysis according to the different parameters of the study are shown in Figure 5.

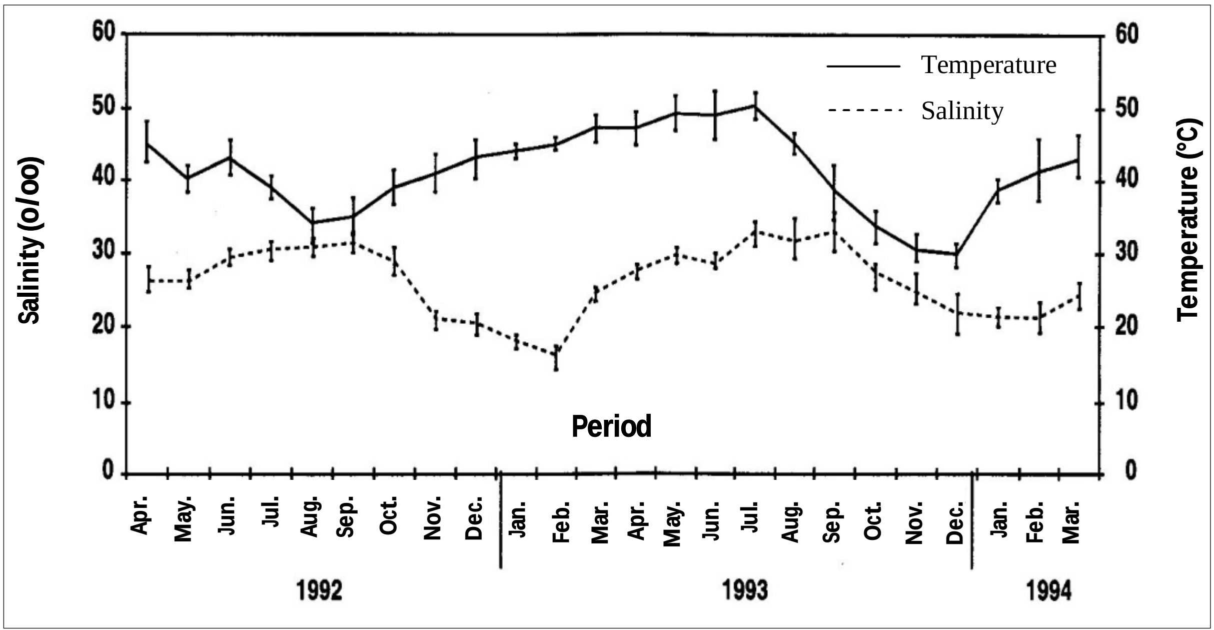

Figure 5. Evolution of environmental factors: salinity and sea water surface temperature.

Discussion

Influence of environmental factors. The influence of current velocity on the capture of planktonic larvae is a known phenomenon (Ndoye et al 2014). An experiment conducted in Guinea, at the mangrove area (low velocity zone) and upstream thereof (higher current zone) has a catchment 1.5 to 2 times more important (Marozova et al 1991). In the Gambia, Cham (1988) observed the same phenomenon in the area where the current is less strong, near the mangroves. This action of the current on the concentration of marine bivalve larvae is also underlined (Waldbusser et al 2015) in the study of the ecology of Morbihan oysters, *Ostrea edulis* and *Gryphea angulata*.

The role of salinity in determining the uptake of the mangrove oyster spat has been reported by many authors including Marozova et al (1991) in Guinea and Gilles (1992) in Casamance (Senegal). In shallow waters, salinity varies with the bathymetry (Richaud et al 2016) as it was the case of the Casamance estuary (Pages et al 1988). On the two banks, the depth not being the same, a variation of salinity is possible. This could explain the difference in the uptake.

Influence of the orientation of the collectors. A horizontal surface is likely to be filled in quickly, covered by particles in the water. The best collection of oyster spat is obtained on the collector with clean surfaces (Silveira et al 2011). The greater capacity of post larval settlement on the sagittal collector (collector in vertical position, relatively to the flow direction) can be interpreted regarding this particularity. On this collector, the sediment settles less easily than on the other collectors which have a more horizontal position. The vertical position is the orientation where the best capture of this oyster spat was observed in Guinea (Marozova et al 1991). It is also the position where the fixation of the barnacles is noted (Diadhiou 1995). Barnacles are the main group of competing species of oysters in Casamance.

The result obtained in this study is in agreement with the observations made by the authors who analyzed this phenomenon in Guinea Conakry (Marozova et al 1991), in Nigeria (Ansa & Bashir 2007) and in Brazilia (Gardunho et al 2012).

The larger capture on the smooth surface of the collectors (horizontal, oblique and perpendicular) could be explained by the greater quantity of dirt in the grooves of the rough surface in a given orientation. The horizontal, oblique and perpendicular positions capture a greater amount of suspended solids (due to gravity), which constitutes an obstacle to the good fixation of the spat on the surfaces of collectors (Silveira et al 2011).

Conclusions. This article on alternative spat collection of the oyster *C. gasar* points to two major lessons useful to the oyster profession. The first is the importance of the salinity and the current on the capture of oyster larvae. The second allows us to identify the role of the orientation of the collectors on the capture process. However, we notice a high scale capture parallel to collectors. So the barnacles constitute a competing group of species for the oyster (competition for food and space) therefore research should be developed for more scientific knowledge on the eco biology of this group, so that artificial capture of the mangrove oyster can be optimized.

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