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RESEARCH ARTICLE OPEN ACCESS

DIET OF THE MANGROVE OYSTER CRASSOSTREA GASAR (ADANSON, 1757) AND PLANKTON DIVERSITY IN LAKE NOKOUÉ

David Akélé[1*], Armel Gougbédji [1], Hyppolite Agadjihouédé [1,2] and Philippe Lalèyè [1]

[1]Laboratory of Hydrobiology and Aquaculture, Faculty of Agronomic Sciences, University of Abomey-Calavi, 01 BP 526, Cotonou, Benin
[2]National University of Agriculture, School of Aquaculture, Research Laboratory in Aquaculture and Aquatic Biology and Ecology (LaRABEA), BP 43 Kétou, Benin

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Corresponding author: David Akélé

ABSTRACT

The diet of the mangrove oyster *Crassostrea gasar* was studied in Nokoué Lake to provide data for oyster culture in south Benin. Specimens of *C. gasar* were collected monthly from July to September during the flood season. The stomach contents were analyzed as well as planktonic abundance. Planktonic organisms were collected using plankton net of 30 µm mesh size and observed under the microscope. In total, 102 stomachs were examined. The results showed that the diet of *C. gasar* is composed mainly of phytoplankton (96.04%) and zooplankton (1.80%). Among the phytoplankton organisms, the chlorophyte *Stigeoclonium aestivale* (44.86%) is the preferential food while *Oscillatoria sp* (Cyanophyte, 13.84%), *Gyrosigma hyppocampus* (diatom, 10.97%) and *Lyngbya martensiana* (Cyanophyte, 8.89%) are secondary foods. The other phytoplankton organisms are additional food items. Oyster diet composition showed significant variations between months and between class sizes. Moreover, data on planktonic composition of Lake Nokoué revealed that the diatom *Aulacosira ambiga* is the most predominant phytoplankton species. However, it was very little represented in the stomach; this indicates a selectivity in the diet of *C. gasar*.

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INTRODUCTION

Worldwide, mollusks in general and bivalves (oysters, mussels, etc.) in particular, play an important role in the economy of several countries (Baron, 1992; Ortega and Sutherland, 1992). In Benin, oysters, commonly called "Adakpin" in Fon and "Atcha" in Yoruba, are aquatic resources exploited by continental fishing. In the south of the country, the mangrove oyster *Crassostrea gasar* is harvested in Nokoué Lake (Sènouvo, 2003), in Lake Ahémé and in the coastal lagoon (Pliya, 1980; FAO, 2008). These oysters are exploited by 5550 women in the regions of Avlo, Avlekete, Djegbadji and Ouakpe-Daho (Kinkpe et al, 2005). The extent of this exploitation reveals that oysters are an important source of income and protein. It is therefore imperative to introduce them in farming to meet the needs of the populations and the survival of the species. However, the control of the breeding requires scientific knowledge on the species in particular on its feeding in natural environment. This justifies the current study which aims to determine the composition of the diet of *Crassostrea gasar* in Lake Nokoué.

MATERIAL AND METHODS

Study area: Lake Nokoué is located in southeastern Benin in the regionof Abomey-Calavi. With an area of approximately 150 km^2, it is the most important brackishecosystem in Benin (Villanueva, 2004). With a depth varying between 0.4 m and 3.4 m, Lake Nokoué opens directlyinto the Atlantic Oceanviathe Cotonou Channel over a length of 4.5 km and a width of about 300 m (Gnohossou, 2006). It is connected to the east to the Porto-Novo lagoon by the Totchéchannel and to the west to the Sô River. The spatio-temporal variations in the physico-chemicalparameters of Lake Nokoué are caused by the inflow of sea water during the low-water period and freshwater from the Sô River and the Ouémé River (Figure 1).

Sampling and data analysis: The sampling station on Lake Nokoué is the Ganvié site (Fig. 1), chosen according to its accessibility in flood season and the presence of oysters. Specimens of *C. gasar* were collected monthly in July, August, and September 2012 between 6:00 and 7:00 am.

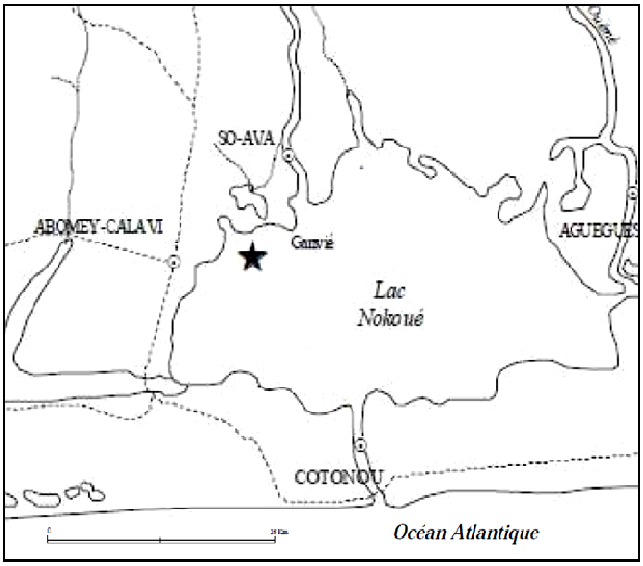

Figure 1. Sampling site for oyster *Crassostrea gasar* specimens on Lake Nokoué

A sample of 40 individuals grouping all sizes was collected per month and then fixed with 70°C alcohol. In the laboratory, the height was measured taken on each oyster specimen. Each stomach was dissected and its contents diluted in 10 ml of water. This volume was then observed by sub-samples of 1ml under a light microscope (x100). Phytoplanktonic and zooplanktonic organisms were identified according to Durand and Lévêque (2000), Ouattara (2000), Van Vuuren et al (2006) and Bellinger and Sigee (2010). The Hynes (1950) point method was used to determine the relative importance of different food items in the stomach. Indeed, scores were alloted to the stomachs according to their filling level: 20; 15; 10; 5; 2 and 0 respectively for full, 2/3 full, half full, 1/4 full, almost empty and empty stomachs. Then, the different planktonic species identified are classified in their taxonomic groups. Scores (0; 1; 2; 4; 8; 16) are attributed to each food item based on its volume, the oyster size, and the score assigned to the stomach. Table 1 inspired by the work of Hynes (1950) was used as a model in the application of the point alloted method to the present study.

The size classes were determined according to the distribution of Loire (2009); thus three size classes were retained: Small Size : 0 < Heigth ≤ 4 cm ; Mean size : 4 < Heigth < 7 cm and Large Size : Heigth ≥ 7 cm. To determine the contribution of each food item in the diet, Natarajan and Jhingran (1961) Index Preponderance of was used. Its formula is :

$$\mathrm{IP} = \frac{V_i O_i}{\sum V_i O_i} \times 100\ ;$$

Where O_i = Occurrence of the index i et V_i = Index volume i.

The following statistical treatments were carried out with the Statistica 6 program : Spearman's rank correlation coefficient was used to test the relationship between month and size class diets (Critical probability retained: P=0.05).

The χ2 test performed on the proportions of the PI of the main foods detected the significant differences (P < 0.05). In addition, in order to compare the composition of the stomach to that of the environment, plankton was sampled in Lake Nokoué with a conical plankton net of 30 µm mesh size. This plankton was fixed with 5% formol.

RESULTS

Diet composition : The global composition of the diet of *C. gasar* and its variation over the three months of sampling are presented in Table 2. From a total of 102 specimen's *C. gasar* stomachs examined, 83 were full and 19 were empty. The percentage of emptiness's was 18.6%. The diet of the 83 stomachs showed 27 food types with a predominance of phytoplankton at over 96% of the PI (Table 2). Among phytoplankton, Chlorophytes were the most abundant (46.92%). Cyanophytes, Diatoms and Rodophytes come respectively with 22.77%, 20.39% and 5.96%. In fact, the species *Stigeoclonium aestivale* (Chlorophyte) is classified as a preferred food. The secondary foods are *Oscillatoria sp* (Cyanophyte) *Gyrosigma hippocampus* (Diatom) and *Lyngbya martensiana* (Cyanophyte). The remaining foods (*Aulacosira ambiga*, *Navicula sp*, *Bostrychia sp*, other foods) are classified as additional foods.

Monthly variation of the oyster diet : The foods items consumed by *C. gasar* by month and their preponderance index are listed in Table 2. A total of 16, 25 and 18 food items were respectively identified in July, August and September 2012. Regardless the month, *S. aestivale* is the preferential food of the oyster (Figure 2). Meanwhile, the secondary foods vary from months to months. Indeed, the secondary foods in July are *Oscillatoria sp*, *A. ambiga*, *L. martensiana* and *G. hippocampus*. In August, the secondary foods are *Oscillatoria sp*, *Bostrychiasp*, *G. hippocampus* and *L. martensiana*. In September, the secondaryfoods are *G. hippocampus* and *Oscillatoria sp*. Spearman's rank correlation (RS) test performed between months taken in pairs pointed out a significant difference between *C. gasar* diets in July-August (P < 0.05); July-September (P < 0.05) and August-September (P < 0.05) month pairs. Likewise, proportions of of *S. aestivale* showed significant variations between months (χ2 test; P < 0.0001).

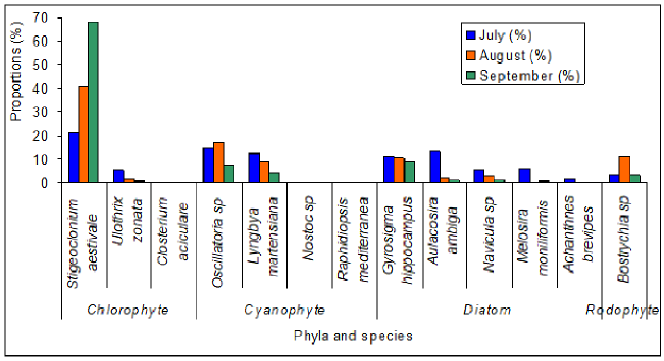

Figure 3. Monthly variation of phytoplankton species abundance in oyster diet

Variation of the diet according to the size of the individuals : The diet composition of the examined specimens according to size classes is detailed in Table 3. According to, the preferential food was *S. aestivale* regardless of the size of the specimens (Figure 3). Moreover, secondary foods vary according to size classes. In reality, small size individuals consume *Oscillatoria sp*; medium size individuals consume *Oscillatoria sp* as well as *G. hippocampus* and large size *G. hippocampus*.

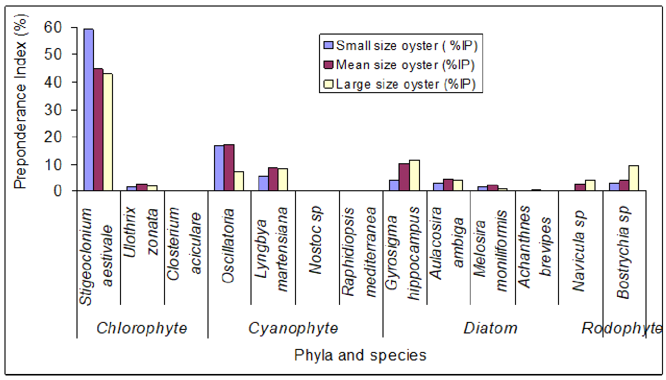

Figure 4. Variation of phytoplankton species in oyster diet according to size classes

Table 1. Method of points allotment to food species (Adapted from Hynes, 1950)

	Food items	Food species	Points alloted
Larger size	Chlorophyte	*Stigeoclonium aestivale* (60)	8
	Cyanophyte	*Oscillatoria sp.* (50)	8
	Copepod	*Thermocyclops neglectus* (8)	4
		Total	20
	Chlorophyte	*Stigeoclonium aestivale* (50)	8
Mean size	Chlorophyte	*Lyngbya martensiana* (30)	4
	Rotifer	*Brachionus angularis* (6)	2
	Zooplankton	*Zooplankton eggs* (3)	1
		Total	15
	Chlorophyte	*Stigeoclonium aestivale* (105)	8
Small size	Diatom	*Gyrosigma hippocampus*	2
		Total	10

Table 2: Diet composition of *Crassostrea gasar* in July, August and September (%IP = Preponderance index percentages; n = number of stomachs examined)

Foods items		**Food species**	**Global (n=102) %IP**	**July (n=22) %IP**	**August (n=40) % IP**	**September (n=40) % IP**
Phytoplankton	Chlorophyte	*Stigeoclonium aestivale*	44.86	21.28	40.83	68.14
		Ulothrix zonata	2.05	5.10	1.69	0.75
		Closterium aciculare	0.00	-	0.02	0.00
	Cyanophyte	*Oscillatoria sp*	13.84	14.94	17.05	7.58
		Lyngbya martensiana	8.89	12.77	8.92	4.11
		Nostoc sp	0.03	-	0.21	0.00
		Raphidiopsis mediterranea	0.01	-	0.07	0.00
	Diatoms	*Gyrosigma hippocampus*	10.97	11.09	10.59	8.74
		Aulacosira ambiga	4.34	13.33	2.11	0.90
		Navicula sp	3.13	5.38	2.96	1.01
		Melosira moniliformis	1.65	5.75	0.28	0.65
		Achanthnes brevipes	0.29	1.51	0.02	0.04
	Rodophyte	*Bostrychia* sp	5.96	3.58	10.98	3.19
Zooplankton	Rotifers	*Anureopsis navicula*	0.31	1.68	0.11	-
		Asplanchna girodi	0.54	0.90	0.70	0.11
		Brachionus angularis	0.13	1.12	-	-
		Brachionus calyciflorus	0.07	-	0.07	0.07
	Copepods	*Calanoide*	0.09	0.45	0.16	0.02
		Copepod	0.00	-	-	0.02
		Thermocyclops neglectus	0.04	-	0.02	0.19
	Zooplankton eggs	*Zooplankton eggs*	0.62	0.56	0.70	0.45
Other foods	Plants	*Undetermined*	2.14	0.56	2.15	4.05
	Animal	*Caterpillar larva*	0.01	-	0.07	-
		A thousand paws	0.00	-	0.21	-
		Insect legs	0.00	-	0.07	-

Table 3: Diet composition of *C. gasar* according to size classes

Food items		**Food species**	**Small Size %IP**	**Mean size %IP**	**Large size %IP**
Phytoplankton	Chlorophyte	*Stigeoclonium aestivale*	59.15	44.77	43.02
		Ulothrix zonata	1.41	2.60	1.79
		Closterium aciculare	-	-	0.02
	Cyanophyte	*Oscillatoria sp*	16.90	17.17	7.36
		Lyngbya martensiana	5.63	8.75	8.51
		Nostoc sp	-	0.04	0.02
		Raphidiopsis mediterranea	-	0.02	-
	Diatoms	*Gyrosigma hippocampus*	4.23	10.27	11.77
		Aulacosira ambiga	2.82	4.29	4.19
		Melosira moniliformis	1.41	2.02	0.98
		Achanthnes brevipes	-	0.43	0.14
		Navicula sp	-	2.74	4.05
	Rodophyte	*Bostrychia* sp	2.82	3.79	9.66
Zooplankton	Rotifer	*Anureopsis navicula*	-	0.60	0.06
		Asplanchna girodi	-	0.65	0.54
		Brachionus angularis	-	0.22	0.02
		Brachionus calyciflorus	-	0.02	0.06
	Copepod	*Thermocyclops neglectus*	5.63	0.00	0.06
		Calanoide	-	0.34	0.06
		Copepods	-	-	0.02
	Zooplankton eggs	*Zooplankton eggs*	-	0.76	0.61
Other items	Plants	Indetermined		0.52	6.91
	Animal	Caterpillar larva	-	0.00	0.06
		A thousand paws	-	0.01	0.09
		Insect legs	-	0.01	0.02

The Spearman rank coefficient calculated from the percentages of the preponderance index shows that there is a significant difference between the diets of small and medium oysters ($P < 0.05$); small and large oysters ($P < 0.05$) as well as medium and large oysters ($P < 0.05$). This indicated an ontogenic variation in oyster diet. Chi-square test results for Small and mean size oysters ($\chi2=3.5$; $P < 0.7$); Small and large size oysters ($\chi2=4.40$; $P < 0.1$) and mean and large size oysters ($\chi2=0.1$; $P < 0.00$) pairs indicated a significant difference between the proportions of *S. aestivale*. Indeed, despite the fact that, Chlorophyte species *S. aestivale* remains the preferential food for all size classes, differences are observed in the secondary and additional foods of the three size classes.

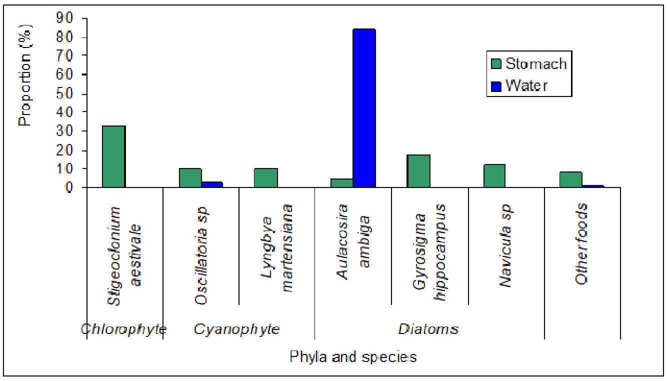

Figure 5. Variations of proportions of phytoplankton in the oyster stomach and in Lake Nokoué in July.

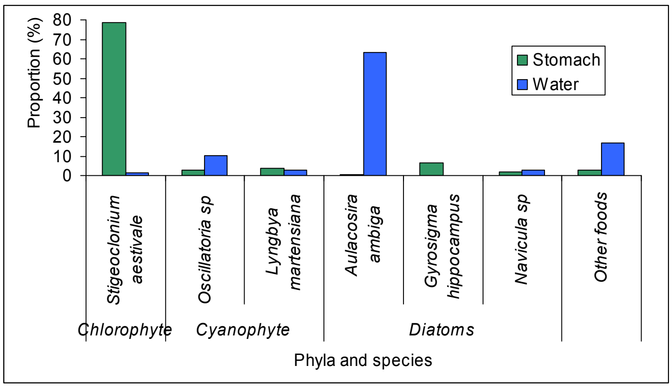

Figure 6. Variations of proportions of phytoplankton in the oyster stomach and in Lake Nokoué in September.

Table 4: Phytoplankton abundance in the stomach and in the environment

Food items	Food species	July (% Abundance)		September (% Abundance)	
		Stomach	Water	Stomach	Water
Chlorophyte	*Stigeoclonium aestivale*	32.52	0.00	78.78	1.19
Cyanophyte	*Oscillatoria sp*	10.34	3.20	2.96	10.13
	Lyngbya martensiana	10.34	-	3.59	2.90
Diatoms	*Aulacosira ambiga*	4.94	83.63	0.31	63.20
	Gyrosigma hippocampus	17.45	0.14	6.71	0.11
	Navicula sp	12.17	-	2.03	2.90
	Other foods	7.81	0.97	2.68	16.84

Prey selectivity in Lake Nokoué : Variations of the abundance of food species in the oyster stomach and in the water are shown in table 4. Figures 5 and 6 indicated that in July and September, the quantity of *S. aestivale* in the stomach are higher than that reported in the lake Nokoué. In addition, *Aulacosira sp*, very abundant in the lake is very little represented in the oyster stomachs. The $\chi2$ test reveals a significant difference between the quantities of *S. aestivale* from the middle and stomach in July and September. This remark stays the same for *A. ambiga* in July and September.

DISCUSSION

The general profile of the diet of *C. gasar* indicates that this species is a phytophagous feeding essentially on phytoplankton. These results are consistent with those of Thangavelu (1988) and Marazova*et al* cited by Zabi and Le Lœuff (1992), who found that oysters are phytophagous. The low emptiness coefficient (18.6%) would reflect a less advanced state of digestion. Therefore, sampling would have been done at the right time. *C. gasar* has a marked preference for Chlorophytes (46.92%), cyanophytes (22.77%) and diatoms (20.39%). These results are different from those obtained by Thangavelu (1988) for the species *Crassostrea madrasensis* in Pulicat Lake (South India). Indeed, the diet of this species is essentially composed of 52.8% diatoms, 45.7% detritus and 1.5% animal detritus. This difference can firstly be explained by the different living environments and secondly by the sampling time which is 2 years for *C. madrasensis*. The comparison made between the two studies is well justified in so far as the two species belong to the same genus *Crassostrea*. Moreover, we note a selectivity on the part of the oyster for certain types of food which are abundant in the stomach where as they are not preponderant in the environment. This selectivity was shown by the preferential ingestion of *S. aestivale* (53.60% in the stomach against 0.29% in the water), *Oscillatoria sp* (6.98% against 4.86% in the water) and *Gyrosigma sp* (12.56% against 0.14% in the water). Similarly, the abundance of *Aulacosira sp* in the environment as well as its rarity in the stomach confirm this selective trait of the bivalve's diet. A preferential choice of food is also observed in *Crassostrea madrasensis* in Pulicat Lake (Thangavelu, 1988).

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