

# Impact of acadja fisheries on the population dynamics of *Sarotherodon melanotheron* and *Hemichromis fasciatus* in a Lake Nokoué (Benin, West Africa)

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## ABSTRACT

**Key-words:**  
*acadjas,*  
*population*  
*dynamics,*  
*Sarotherodon*  
*melanotheron,*  
*Hemichromis*  
*fasciatus,*  
*Lake Nokoué,*  
*Benin*

In Lake Nokoué fishermen have developed the *acadjas* system which operates as an extensive aquaculture practice. Little is known about the population dynamics of fish fauna which colonizes those *acadjas*. Therefore, population parameters of two cichlids of Lake Nokoué, *Sarotherodon melanotheron* and *Hemichromis fasciatus*, sampled in areas within and without *acadjas* were investigated using length-frequency data collected between June 2003 and December 2004. For the two species, asymptotic length,  $L_{\infty}$  was higher within than without *acadjas* (26.8 cm and 24.1 cm respectively for *S. melanotheron*; 18.5 cm and 16.5 cm respectively for *H. fasciatus*).  $K$  and  $\Phi'$  values recorded outside *acadjas* were higher than inside *acadjas* for *H. fasciatus* whereas the same values were very slightly different without and within *acadjas* for *S. melanotheron*. *H. fasciatus* is a fish predator and branches or woody debris of *acadjas* are not favourable for its hunting activities. The total and natural mortality rates for the two species were higher outside than inside *acadjas* showing so the role of protection insured by *acadjas* systems. *Acadjas* have more impact on *H. fasciatus* than on *S. melanotheron*. A possibility of management is to reorganize the distribution of *acadjas* over Lake Nokoué in order to keep some areas in which no *acadjas* would be allowed for fish species that growth is better without *acadjas*.

## RÉSUMÉ

Impact des pêcheries en acadjas sur la dynamique des populations de *Sarotherodon melanotheron* et *Hemichromis fasciatus* du lac Nokoué au Bénin (Afrique de l'Ouest)

**Mots-clés :**  
*acadjas,*  
*dynamique*  
*des populations,*  
*Sarotherodon*  
*melanotheron,*

Au lac Nokoué, les pêcheurs ont développé des systèmes d'*acadjas* qui fonctionnent comme une sorte d'aquaculture extensive. Peu est connu sur la dynamique des populations des espèces de poissons qui colonisent ces *acadjas*. C'est ainsi que des investigations ont été menées sur les paramètres de population de deux espèces de poissons-cichlidés du lac Nokoué, *Sarotherodon melanotheron* et *Hemichromis fasciatus*. Les échantillons ont été collectés à l'intérieur et à l'extérieur des *acadjas* entre juin 2003 et décembre 2004, puis analysés en utilisant les distributions des fréquences des tailles à l'aide du logiciel FiSAT. Pour les deux

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Hemichromis  
fasciatus,  
Lac Nokoué,  
Bénin

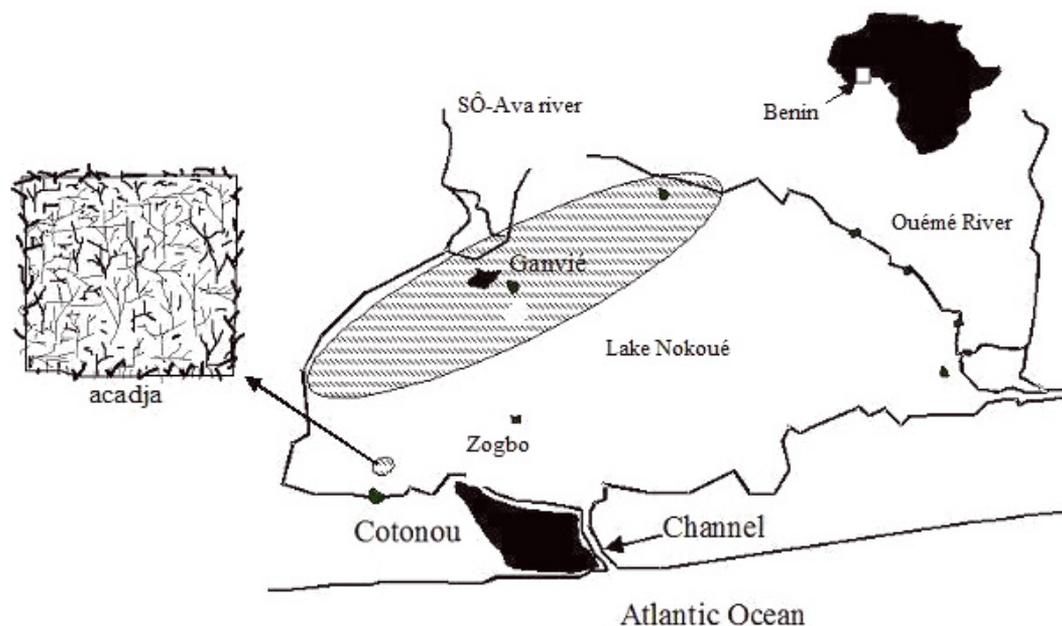
espèces de poissons, la taille asymptotique  $L_{\infty}$  était plus élevée à l'intérieur qu'à l'extérieur des acadjas (respectivement 26,8 cm et 24,1 cm pour *S. melanotheron*; puis respectivement 18,5 cm et 16,5 cm pour *H. fasciatus*). Les valeurs de K et  $\Phi'$  enregistrées à l'extérieur des acadjas étaient plus élevées que celles enregistrées à l'intérieur des acadjas pour *H. fasciatus*, alors que les mêmes valeurs étaient légèrement différentes à l'extérieur et à l'intérieur des acadjas pour *S. melanotheron*. *H. fasciatus* est un poisson prédateur et les branches et les morceaux de bois ne sont pas favorables à ses activités de chasse. Les taux des mortalités totale et naturelle pour les deux espèces étaient plus élevés à l'extérieur qu'à l'intérieur des acadjas montrant ainsi le rôle de protection assuré par les systèmes d'acadjas. Cette étude a révélé que les acadjas avaient beaucoup plus d'impact sur *H. fasciatus* que sur *S. melanotheron*. Comme possibilité d'aménagement, il faudrait réorganiser la distribution des acadjas à travers tout le lac Nokoué dans le but de préserver une superficie où l'installation des acadjas serait interdite et cela pour des espèces dont la croissance est meilleure en l'absence des acadjas.

## 1 INTRODUCTION

In Africa, aquatic ecosystems biodiversity is threatened by increasing subsistence and commercial fishing activities (Daget, 1988; Lévêque and Paugy, 1999). The degradation of the aquatic environment due to siltation, erosion, deforestation, and also possibly to water supply shortage, associated with limited rainfall, are also a matter for concern. The majority of fish production from Benin's inland waters comes from the coastal lagoons: Lake Nokoué and Porto-Novo lagoon. Due to the intensive exploitation of the resources, the effects of over-fishing have been highlighted (Lalèyè et al., 1993, 2003; Niyonkuru et al., 2003) and there are fears that biodiversity might decline if the fishing pressure continues to increase. In addition fishermen in Lake Nokoué and Porto-Novo lagoons have developed the acadjas system which operates as an extensive aquaculture practice (Welcomme, 2002). Acadjas are brush-park enclosures of various forms (circle, square, rectangle polygon) and areas (from 600 m<sup>2</sup> to several hectares). These areas are filled with horizontal soft wood branches or woody debris. A bamboo framework often surrounds the core structure of the brush park to define its limits. They contribute to overall production of the water body in which they are found by increasing reproduction (Lalèyè et al., 1995a, 1995b), fry survival, shelter for adult and, when properly managed, overall recruitment to the fishery in general. They provide an important amount of food because of the abundance of epiphytic organisms, boring insects and mollusks on the submerged surfaces of the wood and the roots systems, and because of the bottom mud enriched by decay of the woody material (Welcomme, 2002). Acadjas recently covered 35% of the Lake Nokoué and contributed for 40% of the island water catches in Benin (Lalèyè et al., 2007). Seventy-seven percent of the catch of Lake Nokoué and Porto-Novo Lagoon come from acadjas systems. All over the lake, cichlid fishes (*S. melanotheron*, *Hemichromis fasciatus* Peters, 1858 and *Tilapia guineensis* Bleeker 1862) contribute about 31% of the total production (Direction des Pêches, 2005). Inside acadjas, current studies showed that cichlids contribute about 95% (i.e. 87%, 6% and 2.5% respectively for *S. melanotheron*, *H. fasciatus* and *T. guineensis*) of acadjas production (Niyonkuru, 2007).

Furthermore, in Lake Nokoué, in the areas where important concentrations of acadjas are noticed, Gnonhossou (2006) reported that food items of *S. melanotheron* were dominated by organic detritus (75%) followed by plant food (20%) whereas *H. fasciatus* is about 76.1% ichthyophagous.

The impact of acadjas on fish population parameters is still poorly known. This paper is an attempt to investigate growth, mortality rates and recruitment patterns inside and outside acadjas for the two more abundant cichlids species which also have different sizes and feeding habits: *S. melanotheron* and *H. fasciatus*.



**Figure 1**

Map of Lake Nokoué, showing the two areas investigated in this study (the dashed zone is the one with densities of acadjas).

Figure 1

Carte du lac Nokoué montrant les deux zones d'étude (la zone hachurée indique la présence d'acadjas).

## MATERIALS AND METHODS

### > STUDY AREA AND SAMPLING SITES

Lake Nokoué (6°25'N, 2°36'E, Figure 1) is the largest (approximately 150 km<sup>2</sup> at low tide) and the most productive brackish water body in Benin (Lalèyè and Moreau, 2004). It is linked eastwards with the Porto-Novo lagoon (30 km<sup>2</sup>) via the Totchè channel (about 5 km long). At the north of the lake lies the Ouémé Delta, this covers an area of 1000 to 9000 km<sup>2</sup> according to the season, and is flooded every year by the Ouémé River (Lang and Paradis, 1977). In its southern part, Lake Nokoué receives sea water throughout the Cotonou channel (about 4.5 km long). For the purpose of this study, two areas were considered, one called Zogbo and the other one called Ganvié (Figure 1), already sampled by Lalèyè *et al.* (1995, 2003). The Zogbo area is located in the south of the lake and is partly influenced by Atlantic Ocean waters (salinity slightly higher than in Ganvié area is recorded). Only very scarce acadjas are operated in this part of the lake. The Ganvié area is located near the floating village of Ganvié (25 000 inhabitants) where the water is characterised by a high level of organic pollution (Lalèyè *et al.*, 2003; Niyonkuru *et al.*, 2003) and an extremely high density of acadjas. In Lake Nokoué, monthly water temperatures vary between 25.2 and 33.1 °C (monthly average: 27.9 °C) at the surface and between 25.3 and 30.2 °C (monthly average: 27.6 °C) at 1 m depth. Depth and transparency vary respectively from 0.9 to 1.80 m (average: 1.25 m) and 0.23 to 0.84 m (average: 0.51). Salinity varies greatly during the year from 0.0 to 31.4 g·L<sup>-1</sup> at the surface (average: 13.3 g·L<sup>-1</sup>) and from 0.0 to 31.5 g·L<sup>-1</sup> at 1 m depth. All over the year, salinity is slightly higher at Zogbo station than elsewhere in the lake because of its proximity to the sea. The lowest salinity values are noted near Ganvié because its proximity of the Sô River. During the flood season, from September to November, the salinity decreases to less than 1 g·L<sup>-1</sup>, due to the inflow of fresh water from the Ouémé River. Surface dissolved oxygen levels vary from 0.54 to 7.7 mg·L<sup>-1</sup> (average: 3.62 mg·L<sup>-1</sup>) and 0.1 to 6.23 mg·L<sup>-1</sup> (average: 3.1 mg·L<sup>-1</sup>) at 1 m depth. Low dissolved oxygen is observed near Ganvié because of human

settlements (Lalèyè *et al.*, 2003). The pH varies from 6.5 to 8.4 in surface water and from 7.0 to 8 at 1 m depth. The conductivity varies from 0.1 to 43.9  $\mu\text{S}\cdot\text{cm}^{-1}$ .

## > FISH SAMPLING AND DATA ANALYSIS

From June 2003 to December 2004 fish samples were obtained from the two areas with the assistance of fishermen who used gill nets, cast nets, scoop nets, long lines and the so-called “*Médokpokonou*”, a locally-designed small-mesh trap net. All these gears were used throughout the year to catch indiscriminately all fish species and helped to have diversified samples in terms of fish length. The sample sizes were:

- 2500 and 2829 specimens of *S. melanotheron* inside and outside acadjas respectively (from 2 to 17 cm, TL);
- 1207 and 2000 specimens of *H. fasciatus* inside and outside acadjas respectively (from 1.5 to 23.5 cm, TL).

The resulting length frequency data were analysed using the FiSAT software package (Gayaniilo and Pauly, 2002) which incorporated a routine called ELEFAN I for estimating the growth parameters based on the von Bertalanffy growth formula (VBGF) expressed in the form (Pauly, 1979):

$$L_t = L_\infty [1 - e^{-K(t-t_0)}]$$

where  $L_t$  is the predicted length at age  $t$ ;  $L_\infty$  (cm) is the asymptotic length or maximum;  $K$  (per year) is a growth constant (Pauly, 1980);  $t_0$  is the age the fish would have been at length zero. As a preliminary estimate of  $L_\infty$ , the maximum observed length in the length frequency distribution was selected and multiplied by 1.05 as suggested by Moreau (1987). Using as a starting step this computed value of  $L_\infty$ ;  $K$  values were scanned using non-parametric scoring of the von Bertalanffy growth function (VBGF) fit using ELEFAN I. Several other seeded values of  $L_\infty$  were investigated in order to identify the one which maximizes the scoring of the VBGF.

The longevity ( $t_{\max}$  in years) was calculated from Pauly's equation (1984) viz.  $t_{\max} = 3/K$ . The growth performances of the two species both outside and inside acadjas were compared using the Phi-Prime index ( $\Phi'$ ) of Munro and Pauly (1983):  $\Phi' = \log_{10}K + 2\log_{10}L_\infty$ .  $\Phi'$  expresses what different growth patterns have in common. It can serve to establish the potential growth of fish strain under different environmental stress condition.  $\Phi'$ -values obtained in this study were compared with other previous estimates available in FishBase 2009 (Frøese and Pauly, 2009) or in the literature. The parameters  $L_\infty$  and  $K$  obtained were used as input to length – converted catch curve analyses in order to obtain estimates of the total mortality ( $Z$ ), following Pauly (1983). The natural mortality ( $M$ ) was estimated using the empirical formula of Pauly (1980); viz.:

$$\log_{10}M = 0.0066 \log_{10}K - 0.279 \log_{10}L_\infty + 0.6543 \log_{10}K + 0.4634 \log_{10}T$$

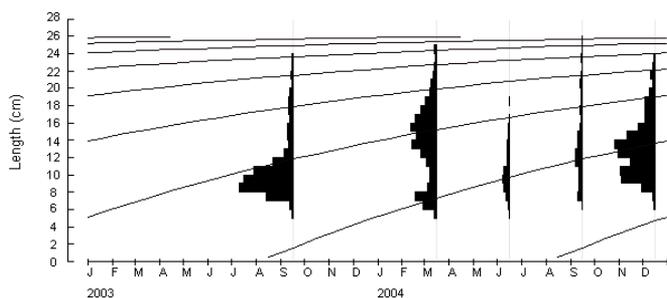
where  $T$  is the mean annual environmental temperature ( $^{\circ}\text{C}$ ); in this case, 28  $^{\circ}\text{C}$ .

The fishing mortality rates,  $F$ , were calculated as  $Z - M$  and the exploitation rate,  $E$ , was computed as  $F/Z$  (Gulland, 1969).

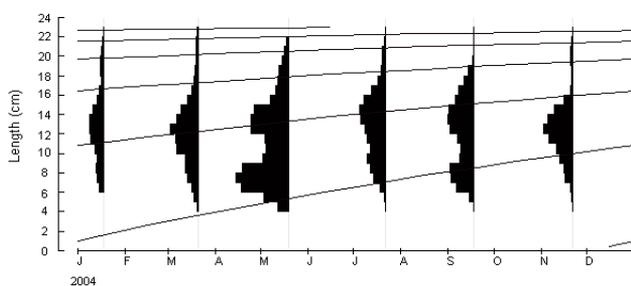
## RESULTS

The length frequency distributions and the estimated growth curves for the two species inside and outside the acadjas are shown on Figure 2. Longevity was about 5.5 and 5.8 years for *S. melanotheron* and 1.4 and 3.8 years for *H. fasciatus* respectively outside and inside acadjas.

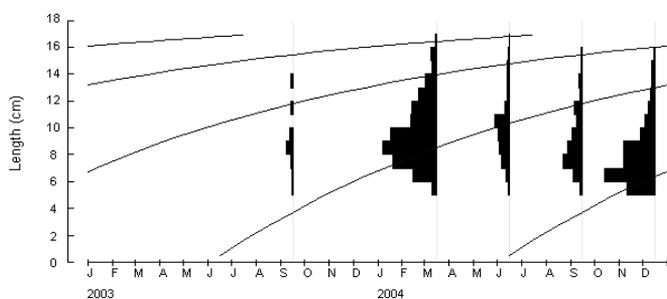
Outside and inside acadjas, the von Bertalanffy growth models for *S. melanotheron* were:  $L_t = 24.1[1 - e^{-0.55(t+0.02)}]$  and  $L_t = 26.8[1 - e^{-0.52(t+0.02)}]$  respectively.



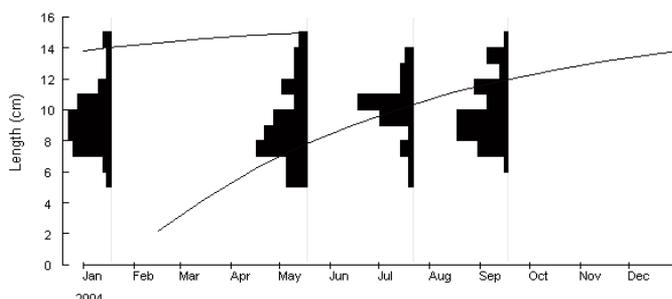
(a)



(b)



(c)



(d)

**Figure 2**

Length frequency distribution and estimated growth curves for the two species: (a) *S. melanotheron* (inside acadjas), (b) *S. melanotheron* (outside acadjas), (c) *H. fasciatus* (inside acadjas) and (d) *H. fasciatus* (outside acadjas).

Figure 2

Les distributions des fréquences des tailles avec les courbes de croissance pour les deux espèces : (a) *S. melanotheron* (à l'intérieur des acadjas), (b) *S. melanotheron* (à l'extérieur des acadjas), (c) *H. fasciatus* (à l'intérieur des acadjas) et (d) *H. fasciatus* (à l'extérieur des acadjas).

**Table 1**

Estimates of growth and mortality parameters and derived parameters for *S. melanotheron* and *H. fasciatus* inside and outside acadjas.

Tableau 1

Paramètres de croissance et de mortalité et autres paramètres dérivés pour *S. melanotheron* et *H. fasciatus* à l'intérieur et à l'extérieur des acadjas.

Parameters	<i>S. melanotheron</i>		<i>H. fasciatus</i>	
	Inside acadjas	Outside acadjas	Inside acadjas	Outside acadjas
$L_{\infty}$ (TL, cm)	26.8	24.10	18.5	16.5
$K$ (yr <sup>-1</sup> )	0.52	0.55	0.78	2.10
$t_0$ (yr)	0.02	0.02	0.02	0.02
$t_{max}$ (an)	5.80	5.50	3.80	1.40
$\Phi'$	2.57	2.50	2.42	2.73
$M$ (yr <sup>-1</sup> )	1.20	1.28	1.75	3.46
$Z$ (yr <sup>-1</sup> )	1.53	1.66	2.68	4.62
$F$ (yr <sup>-1</sup> )	0.33	0.38	0.93	1.16
$E$	0.21	0.23	0.35	0.25

$L_{\infty}$ : asymptotic length,  $K$  (per year): growth constant,  $t_0$ : age at zero length,  $Z$ : total mortality,  $F$ : fishing mortality,  $M$ : natural mortality,  $E$ : exploitation rate,  $t_{max}$ : longevity,  $\Phi'$ : phi-prime index.

$L_{\infty}$ : taille asymptotique ou longueur maximale théorique atteinte par le poisson, TL: longueur totale, SL: longueur standard,  $K$  (an<sup>-1</sup>): coefficient de croissance,  $t_0$  (an<sup>-1</sup>): âge théorique correspondant à la taille nulle,  $Z$  (an<sup>-1</sup>): mortalité totale,  $F$ : mortalité par pêche,  $F$  (an<sup>-1</sup>): mortalité due à la pêche,  $M$  (an<sup>-1</sup>): mortalité naturelle,  $E$ : taux d'exploitation,  $t_{max}$  (an): longévité potentielle,  $\Phi'$ : indice de performance de croissance.

Similarly, for *H. fasciatus*, the two equations were:

$$L_t = 16.5[1 - e^{-2.1(t+0.02)}] \text{ and } L_t = 18.5[1 - e^{-0.78(t+0.02)}] \text{ respectively outside and inside acadjas.}$$

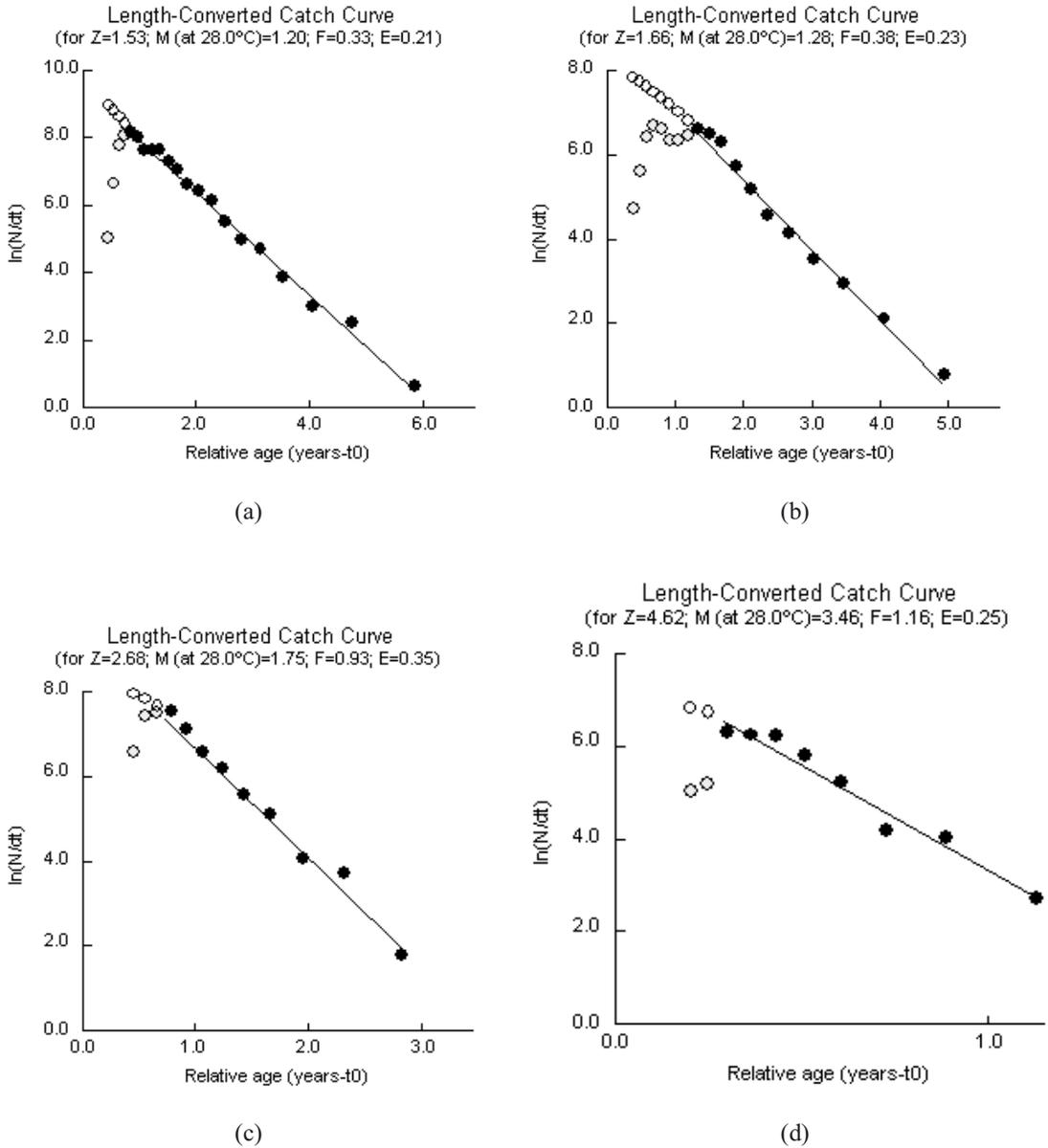
$L_{\infty}$  estimated for fish inside acadjas (26.7 and 18.5 cm respectively for *S. melanotheron* and *H. fasciatus*) were higher than  $L_{\infty}$ -values for fishes caught outside the acadjas (24.1 and 16.5 cm for the same species) (Table 1). The highest  $K$ -values were noticed outside acadjas for both species with a high difference for *H. fasciatus* (Table 1). Higher  $\Phi'$ -values are noted inside acadjas (2.57) for *S. melanotheron* and outside acadjas (2.75) for *H. fasciatus* (Table 1).

The length-converted catch-curve (Figure 3) analysis produced total mortality estimates of  $Z = 1.66 \text{ year}^{-1}$  and  $1.53 \text{ year}^{-1}$  respectively outside and inside acadjas for *S. melanotheron* and  $4.62 \text{ year}^{-1}$  and  $2.68 \text{ year}^{-1}$  for *H. fasciatus* outside and inside acadjas respectively. For both populations, the natural mortality,  $M$ , was higher outside the acadjas than inside. Again, this is particularly clear for *H. fasciatus* (Table 1).

A major recruitment peak was found for *S. melanotheron* from April to August outside acadjas (Figure 4b). Inside acadjas, recruitment seems to occur from March to September with a maximum in August (Figure 4a). The recruitment pattern as established for *H. fasciatus* seems to show two maxima of breeding activity: one in March to May (very clear outside acadjas) and another one in September–October, easily identified inside and outside acadjas (Figures 4c and 4d). The maximum appearing in September is in coincidence with the beginning of the flood season in Southern Benin (Figure 4).

The breeding season was investigated during the present study (Niyonkuru, 2007) by reference to the proportion of mature stages in both sexes. Figure 5 is a summary of the results concerning females. For *S. melanotheron*, several maxima of breeding activity could be identified with this method, in April, July and September (Figure 5a). Possibilities of a continuous breeding activity with variations of the level of this activity might be considered.

For *H. fasciatus*, the recruitment pattern observed outside acadjas (Figure 4d) is in close agreement with the trends of evolution of the maturity at the population level (Figure 5b). This agreement is not so clear inside acadjas even if a maximum of activity is identified in September and October by using the two methods.



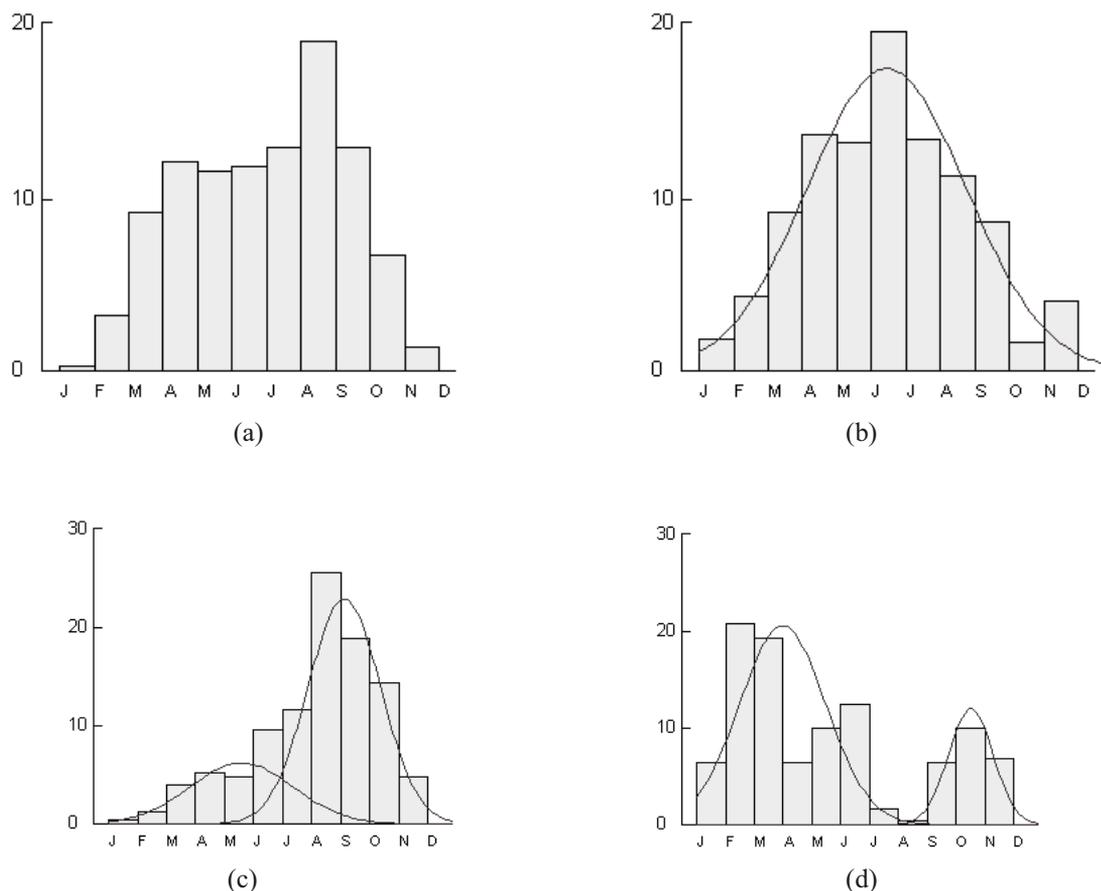
**Figure 3**  
Instantaneous total mortalities, for the two species: (a) *S. melanotheron* (inside acadjas), (b) *S. melanotheron* (outside acadjas), (c) *H. fasciatus* (inside acadjas) and (d) *H. fasciatus* (outside acadjas).

Figure 3  
Les mortalités totales instantanées des deux espèces : (a) *S. melanotheron* (à l'intérieur des acadjas), (b) *S. melanotheron* (à l'extérieur des acadjas), (c) *H. fasciatus* (à l'intérieur des acadjas) et (d) *H. fasciatus* (à l'extérieur des acadjas).

## DISCUSSION

The main observation from the present study is the difference between values obtained inside and outside acadjas which is particularly clear for *H. fasciatus* but not for *S. melanotheron*. This difference of adaptation of the two species to the acadjas fishing system needs clarification.

For a similar K-value of inside and outside acadjas, *S. melanotheron* has a larger  $L_{\infty}$  in acadjas. This might reflect higher food consumption inside acadjas. The duration of the operation



**Figure 4**

Recruitment pattern for the two species: (a) *S. melanotheron* (inside acadja), (b) *S. melanotheron* (outside acadja), (c) *H. fasciatus* (inside acadja) and (d) *H. fasciatus* (outside acadja).

Figure 4

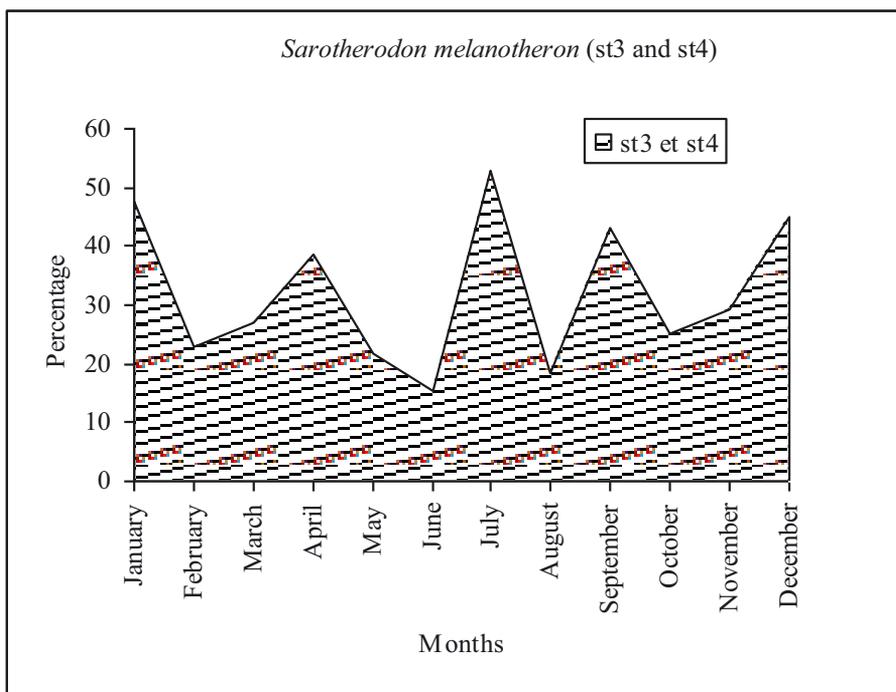
Les modèles de recrutement des deux espèces : (a) *S. melanotheron* (à l'intérieur des acadjas), (b) *S. melanotheron* (à l'extérieur des acadjas), (c) *H. fasciatus* (à l'intérieur des acadjas) et (d) *H. fasciatus* (à l'extérieur des acadjas).

of the acadjas system (between 1 and 2 years) is much lower than the longevity of the tilapiine fish whereas it is similar to the longevity of *H. fasciatus*.

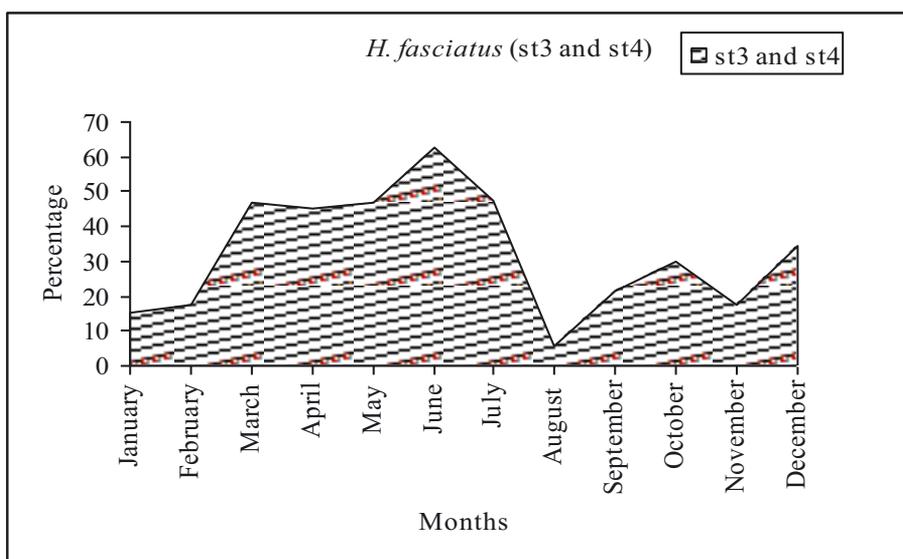
Cichlids are known for their limited movements meaning that a *H. fasciatus* can spend all its life inside an acadja (even if it moves frequently due to its predatory behavior) which is not possible for most tilapiine fishes. Branches in acadjas prevent the hunting behavior of predators, including *H. fasciatus* to be efficient therefore the growth performance as a whole (the phi-prime index,  $\Phi'$ ) is lower in acadjas than outside. Mortality natural in *H. fasciatus* higher outside acadjas could be due to movements and predation of larger fish.

Generally, if acadjas are left unexploited for a long period, for instance one year, fishes are protected from fishing, ecological conditions are favorable for their reproduction and time is sufficient for their growth. The estimated total mortality rates and natural mortality rates for the two species were higher outside than inside acadjas showing so the role of protection insured by acadjas systems.

Outside acadjas, fishes are subjected to daily intense fishing which can affect their growth. According to Welcomme (1999), the strong tendency for fish length to decrease as fishing pressure increases means that length-linked changes occur in a number of parameters.



(a)



(b)

**Figure 5**

Proportion in percentage by different stages of maturity (seasonal variations of the relative abundance of matures stages; stage 3: ripe ovocytes and stage 4: ready to spawn fish): (a) *S. melanotheron*, (b) *H. fasciatus*.

Figure 5

Les proportions en pourcentages par différents stades de maturité (variations saisonnières de l'abondance relative des stades matures; stades 3 et 4 : les ovocytes respectivement à maturation suffisamment avancée et ovocytes prêts à être pondus : (a) *S. melanotheron*, (b) *H. fasciatus*.

In addition, the higher  $L_{\infty}$  inside than outside acadjas might suggest that the movement of fishes inside the acadjas is very limited.

According to Welcomme (2002), the ecological performance of the park depends largely on whether or not fish breed within its confines and, if they breed, on the time they are allowed to do so. For *H. fasciatus*,  $K$  and  $\Phi$ -values are higher outside than inside of the acadjas because. *H. fasciatus* is a fish predator and branches or woody debris of acadjas are not favourable for its hunting activities. Thus, acadjas offers better conditions of reproduction and growth for detritivorous or herbivorous fishes than for predator fishes. Acadjas systems are known for their ecological performance in increasing production and are considered as a form of aquaculture, it is therefore important to underline that they can affect positively or negatively the life-history traits of fish species and consequently the yield and sustainability of fishing. Biodiversity and life history of several fish species like predators could be modified.

The population parameters values noticed in the present study should be compared to the ones available for the two species in other West African lagoons (Table II) which are characterized by a high level of eutrophication and an intensive fishing effort.

For *S. melanotheron*, the  $L_{\infty}$ -value recorded inside the acadjas was 26.7 cm; TL is among the highest values estimated for *S. melanotheron* in West Africa in Ebrié lagoon and Gambie River with  $L_{\infty}$ -values of 34 cm and 37 cm respectively (Villanueva, 2004), in Lake Ayamé ( $L_{\infty} = 31$  cm, Tah *et al.*, 2009) and in Lagos lagoon ( $L_{\infty} = 34$  cm, Fröese and Pauly, 2009) (Table II). The  $L_{\infty}$ -value recorded outside acadjas ( $L_{\infty} = 24.1$  cm, TL) is close to some others obtained in West Africa (Sakumo lagoon in Ghana with  $L_{\infty} = 25$  cm; Pauly, 1976; and in Togo lagoon,  $L_{\infty} = 23$  cm; Laë, 1992). The smallest  $L_{\infty}$ -value was recorded in the Muni lagoon in Ghana ( $L_{\infty} = 12.5$  cm, SL about 15.5 cm, TL, cm, Koranteng *et al.*, 2000). The  $K$ -values obtained in the present study for *S. melanotheron* is close to those noticed in the Sine Saloum delta and in Ebrié lagoon (Villanueva, 2004) and lower than several other values in the Sakumo lagoon (Ghana) ( $K = 0.74 \text{ year}^{-1}$ ), Muni lagoon (Ghana) ( $K = 0.70 \text{ year}^{-1}$ ), and Togo lagoon ( $K = 1.78 \text{ year}^{-1}$ ).

$\Phi'$ -values for *S. melanotheron* are also similar to data available in FishBase 2009 concerning Ebrié Lagoon and ponds (ranged from 2.54 to 3.03). In Lagos lagoon,  $\Phi'$ -value of *S. melanotheron* ( $\Phi' = 2.24$ ) is lower than those obtained in the present study. The lowest value was recorded in the Muni Lagoon, about 2.03 (Koranteng *et al.*, 2000).

The natural mortality rates and exploitation levels for *S. melanotheron* estimated in the present study and those available in other West African lagoons are presented in Table II. The natural mortality rates both inside and outside acadjas are among the highest values recorded in sub-region. The highest  $M$ -value was recorded in the Muni lagoon ( $M = 1.84 \text{ year}^{-1}$ , Koranteng *et al.*, 2000). However, the exploitation levels are among the lowest of the sub-region. Indeed, in Sine-Saloum lagoon, Gambie River and Ebrié lagoon, Villanueva (2004) recorded  $E$ -values of 0.51, 0.48 and 1.8 respectively. The highest  $E$ -value was recorded in Muni lagoon by (Koranteng *et al.*, 2000). So, we can say that, in Lake Nokoué, the total mortality rate of *S. melanotheron* is dominated by natural mortality.  $E$ -values obtained outside and inside acadjas did not indicate over-fishing.

For *H. fasciatus*, population parameters recorded in the present study and those available in sub-region are presented in Table II. The highest  $L_{\infty}$ -values were noticed in Lake Ayamé in Côte d'Ivoire,  $L_{\infty} = 27$  cm, Tah *et al.*, 2009) and Ebrié lagoon in Côte d'Ivoire,  $L_{\infty} = 25$  cm; Villanueva, 2004).  $L_{\infty}$ -value obtained in the present study inside acadjas was higher than that recorded by Moreau *et al.* (1995) in Taia River, Sierra Leone ( $L_{\infty} = 17$  cm). The lowest  $L_{\infty}$ -value was estimated in Lake Ahémé in Benin ( $L_{\infty} = 13.9$  cm; Niyonkuru, 2007). The  $K$ -value obtained in the present study outside acadjas is the highest of the sub-region (Table II). The lowest  $K$ -value was recorded in Lake Ahémé (Benin) by Niyonkuru (2007).

Regarding  $\Phi'$ -values of *H. fasciatus*, the lowest values were noticed by Niyonkuru (2007) in Lake Ahémé in Benin ( $\Phi' = 2.02$ ). Inside acadjas  $\Phi'$ -value obtained is among the lowest in the sub-region whereas the high and same  $\Phi'$ -value ( $\Phi' = 2.73$ ) was recorded in Ebrié Lagoon and outside acadjas in Lake Nokoué (Table II).

**Table II**  
**Estimates population parameters noticed in the present study and others available for the two species in West African lagoon.**

Tableau II

Paramètres de croissance enregistrés dans la présente étude et ceux disponibles pour les deux espèces dans les lagunes de l'Afrique de l'Ouest.

Species	Lagoons/estuaries	$L_{\infty}$ (cm)	$K$ ( $yr^{-1}$ )	$\Phi'$	M	$E = F/Z$	References
<b><i>S. melanothoron</i></b>	Lake Nokoué (inside acadjas)	26.8	0.52	2.57	1.20	0.21	Present study
	Lake Nokoué (outside acadjas)	24.10	0.55	2.50	1.28	0.23	Present study
	Lake Nokoué	27	0.8	2.73	1.5	0.32	Niyonkuru et al. (2007)
	Lake Ahémé	22.5	0.55	2.42	1.26	0.40	Niyonkuru (2007)
	Lake Ayamé	31	0.39	2.57	0.96	0.53	Tah et al. (2009)
	Sine-Saloum (Senegal)	22	0.60	2.46	1.08	0.51	Villanueva (2004)
	Ebrié (Ivory Coast)	34	0.42	2.69	0.97	0.18	Villanueva (2004)
	The Gambie River	37	0.39	2.73	0.89	0.48	Villanueva (2004)
	Sakumo (Ghana)	25.5	0.74	2.68	N.A.	N.A.	Pauly (1976)
	Togo	25	1.78	3.05	N.A.	N.A.	Laë (1992)
	Muni (Ghana)	12.5 (SL) or 15.5 TL	0.70	2.03	1.84	0.66	Koranteng et al. (2000)
	Lagos lagoon	33	0.16	2.24	N.A.	N.A.	Fagade (1974)
<b><i>H. fasciatus</i></b>	Lake Nokoué (inside acadjas)	18.5	0.78	2.42	1.75	0.35	Present study
	Lake Nokoué (outside acadjas)	16.5	2.10	2.73	3.46	0.25	Present study
	Lake Nokoué	17	1.0	2.45	2.1	0.18	Niyonkuru et al. (2007)
	Lake Ahémé	13.9	0.69	2.02	1.74	0.1	Niyonkuru (2007)
	Lake Ayamé	27	0.57	2.62	1.27	0.30	Tah et al. (2009)
	Lake Ebrié (Ivory Coast)	25	0.85	2.73	1.66	0.55	Villanueva (2004)
Taia River (Sierra Leone)	17	1.20	2.54	2.2	0.1	Moreau et al. (1995)	

N.A.: non available.

N.A. : non disponible.

The natural mortality rates and exploitation levels for *H. fasciatus* estimated in the present study and those available in other West African lagoons are presented in Table II. The natural mortality rate recorded outside acadjas is the highest in sub-region. The lowest M-value was recorded in Lake Ayamé ( $M = 1.27 \text{ year}^{-1}$ , Tah *et al.*, 2009). The lowest exploitation level ( $E = 0.1$ ) were recorded both in Lake Ahémé (Niyonkuru, 2007) and in Taia River (Moreau *et al.*, 1995). The E-value of 0.55 recorded by Villanueva (2004) in Lake Ebrié was higher than other E-values in sub-region. E-values obtained in the present study did not show over-fishing ( $E < 0.5$ ). But the highest M-values could indicate that in Lake Nokoué, the total mortality rate of *H. fasciatus* as *S. melanotheron* is dominated by natural mortality with higher values outside acadjas.

The major goal of our study was to show the impacts of acadjas fisheries on the life history characteristics of two species which have different feeding habits: *S. melanotheron* and *H. fasciatus*. It has been shown that the presence of acadjas could affect negatively some population parameters for some fish species such as predators like *H. fasciatus* in which the growth performance index is lower inside than outside acadjas. So, it appears that, even if acadjas are known as an efficient method to harvest fish production, the present study showed that they could have a negative impact on life history of some species. The major problem of Lake Nokoué is the continuous increase of the surface area occupied by the acadjas. Actually, more than 35% of the total area of the lake is covered by acadjas. Fishermen who have no access to acadjas complain frequently about their development and this leads to very serious conflictual situations. In order to avoid this conflictual situation and to protect other fish species which could be negatively affected by the acadjas systems, it is needed to organize at the lake level the allocation of spaces possibly devoted to the development of acadjas practices. Limitation of the extension of acadjas has to be implemented at the community level of each town or village located in the close vicinity of the lake outside acadjas; existing regulations on mesh size should also be reinforced.

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