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Original article

Impact of fishing on fish assemblages in tropical lagoons: the example of the Ebrie lagoon, West Africa

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Abstract

Lagoon fish communities often consist of complex assemblages of numerous species, difficult to manage with conventional stock assessment models. Useful data are still lacking for evaluating the importance of man-made disturbance and reference situations are missing, especially in developing countries. As a consequence, by analysing data collected 20 years ago in two of the six sectors of the Ebrie lagoon (Ivory Coast), this study aims to evaluate the impact of fishing effort on fish assemblages. These two sectors (V and VI), located far from the inlet, have similar physical, chemical, biological and fish fauna characteristics. The major difference lies in the fishing intensity: sector VI has a low fishing intensity (fishing for personal consumption using only individual gear), whereas sector V is heavily fished (professional fishing with both individual and collective gear, particularly beach seines which result in a considerably higher fishing effort). Comparisons between the two sectors were based on two complementary scientific approaches: a 3-year commercial fisheries survey (1978-1980) and a 1-year experimental survey (1981). The impact of fishing on fish assemblages is analysed through the main characteristics of fish populations and communities. The results show that there were major changes including an increased catch yield (37.5-189 kg ha^{-1} y^{-1}), a lowering of fish diversity in catches, of fish biomass (100-20 kg ha^{-1}), of average catch length (22.6-14.6 cm) and of trophic level of catches (26-58.5% of herbivore/detritivore species in total catches). Such results are quite unusual because they occurred even in non-overfished ecosystems: the fish assemblage was deeply modified in sector V compared to the lightly fished adjacent sector VI, even though fishing effort in sector V was only high but at a reasonable level. These data must be completed by similar studies in tropical lagoons with variable levels of fishing intensity in order to understand fish assemblage re-organization when submitted to stresses of different intensity.

Résumé

Effets de la pêche sur l'organisation des peuplements de poissons dans les lagunes tropicales : l'exemple de la lagune Ebrié en Afrique de l'Ouest. Les peuplements de poissons lagunaires sont difficiles à gérer à l'aide de modèles halieutiques conventionnels car ils se présentent souvent sous la forme d'assemblages complexes composés de multiples espèces. Les observations actuellement disponibles sont encore insuffisantes pour évaluer l'importance des perturbations d'origine humaine et les situations de référence sont pratiquement inexistantes dans les pays en voie de développement. Dans cette optique, l'analyse de données collectées il y a 20 ans dans deux des six secteurs que compte la lagune Ebrié (Côte d'Ivoire), vise à évaluer l'effet de la pression de pêche sur l'organisation des peuplements de poissons. Ces deux secteurs (V et VI), très éloignés de l'ouverture sur la mer, ont des caractéristiques physiques, chimiques, biologiques identiques ainsi que des ichtyofaunes similaires. La seule différence notable réside dans l'intensité de l'exploitation par la pêche. Le secteur VI est faiblement exploité par une pêche d'autosubsistance fondée sur l'utilisation d'engins individuels alors que le secteur V est pleinement exploité par une pêche professionnelle reposant à la fois sur l'utilisation d'engins individuels et collectifs, en particulier les sennes de plage, ce qui se traduit par un effort de pêche beaucoup plus important. L'étude comparative des deux secteurs était basée sur deux approches scientifiques complémentaires: d'une part un suivi des pêches commerciales pendant trois ans (1978-1980) et d'autre part un échantillonnage annuel par pêches expérimentales à la senne tournante (1981). L'effet de la pêche est analysé à travers les caractéristiques propres des peuplements et celles des populations. Les résultats montrent que des changements majeurs sont intervenus incluant une augmentation des rendements (37,5 à 189 kg ha^{-1} an^{-1}), une baisse de la diversité spécifique dans les captures, de la biomasse de poisson (100 kg à 20 kg ha^{-1}), de la taille moyenne des captures (22,6 cm à 14,6 cm) et du niveau trophique des captures (26% à 58,5% d'espèces herbivores/détritivores dans les captures totales). De tels résultats enregistrés dans des écosystèmes non surexploités, sont assez surprenants: le peuplement de poisson a été

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considérablement modifié en secteur V si on le compare à celui du secteur VI adjacent mais peu exploité, et ce bien que l'effort de pêche conséquent en secteur V ne puisse être qualifié d'excessif. Ces résultats doivent être complétés par des études analogues dans des lagunes tropicales caractérisées par des niveaux d'exploitation différents, si l'on veut comprendre la réorganisation des peuplements de poisson soumis à des stress d'intensité variable.

Keywords: Fish populations; Fishing effects; Biomass; Diversity; Yield; Tropical lagoon; West Africa

1. Introduction

Until recently, the normal approach to marine fisheries management was based on global models (Schaefer, 1967), analytical models (Beverton and Holt, 1957) and stock-recruitment models (Ricker, 1954). In tropical inland aquatic ecosystems, more empirical relationships based on morphological parameters (morphoedaphic index, surface area of lakes, river length or basin area) or productivity index (phytoplankton primary productivity, total phosphorus) have been preferred (Henderson and Welcomme, 1974; Melack, 1976; Ryder, 1982; Hanson and Legget, 1982; Marshall, 1984; Laë, 1992; Crul, 1992; Payne et al., 1993).

Such relationships have now become inadequate because they only define maximum yields without paying attention to the biological properties of the ecosystem. In addition, in recent years, attention has increasingly focused on the conservation of biodiversity and the maintenance of a "healthy environment". As a consequence, one way to understand the impact of overfishing is to study the responses of assemblages through a sequence of changes in species composition that may be termed the "fishing down process" (Regier and Loftus, 1972; Rapport et al., 1985). A plateau of total catches (Fig. 1) can occur when fishing effort increases above a certain intensity and results from a re-organization of fish communities and populations. At the beginning of exploitation, the larger individuals are eliminated followed by the larger species. Then, as fishing effort targets smaller sized species and increases in magnitude, most taxa become rare and exploitation produces only a few species for which average catch lengths are small. In such a state, even if the total yield is constant, fish biomass and catch per unit effort are low (Welcomme, 1985).

Over the last decade, there has been growing concern about overfishing and most of the studies in this particular field of research have been conducted in the cold or temperate marine environment and mainly in the demersal part of the ecosystem (ICES, 2000). Though public interest is increasingly focusing on the protection, conservation and surveillance of estuaries and lagoons, little scientific interest has been given to these shallow coastal environments, especially in the tropics. However, these ecosystems are perfectly suited for answering new scientific questions in fishing biology because they are often fully or over-exploited, generally by multispecific and multigear fisheries. As stated by Welcomme (1995, 1999), systematic monitoring is still not carried out in most inland fisheries and even if a great amount of experience has been acquired from various aquatic ecosystems, these approaches have not been systematically explored. Related to the previous points and revisiting data collected in two western sectors of the Ebrie lagoon (Ivory Coast) 20 years ago (beginning of the 1980s), the present study is a comparison of two similar parts of a lagoon subjected to significantly different fishing efforts in terms of

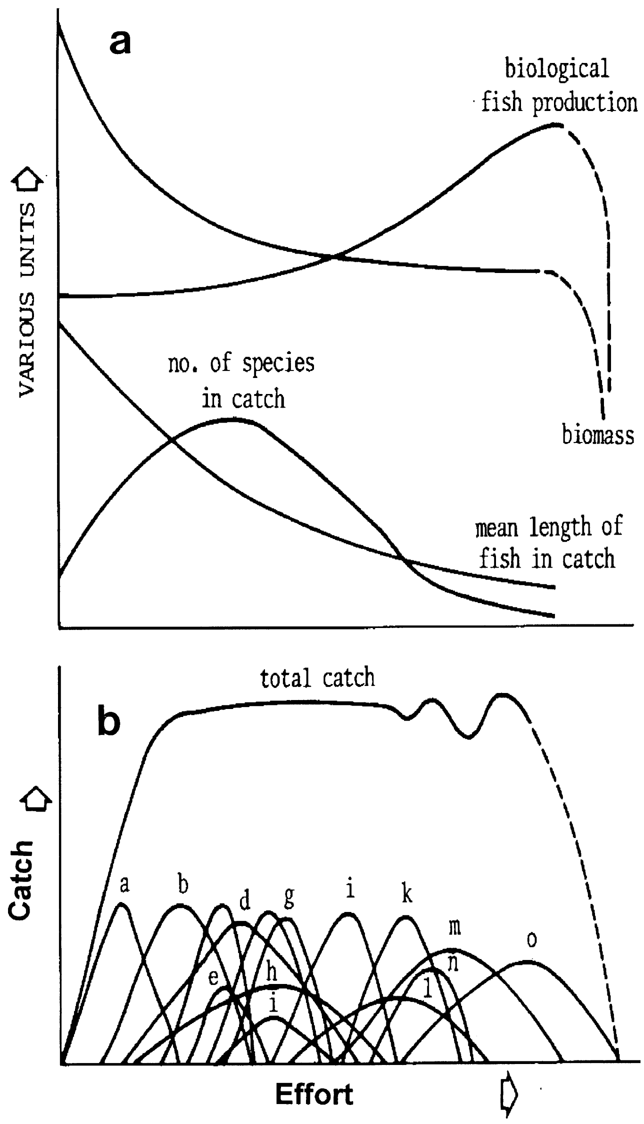

Fig. 1. Theoretical changes in a fish community when subjected to increasing fishing pressure: (a) of certain population and fishery parameters; (b) of total catch showing schematic evolution of individual species 'a' through 'o' (Welcomme, 1985).

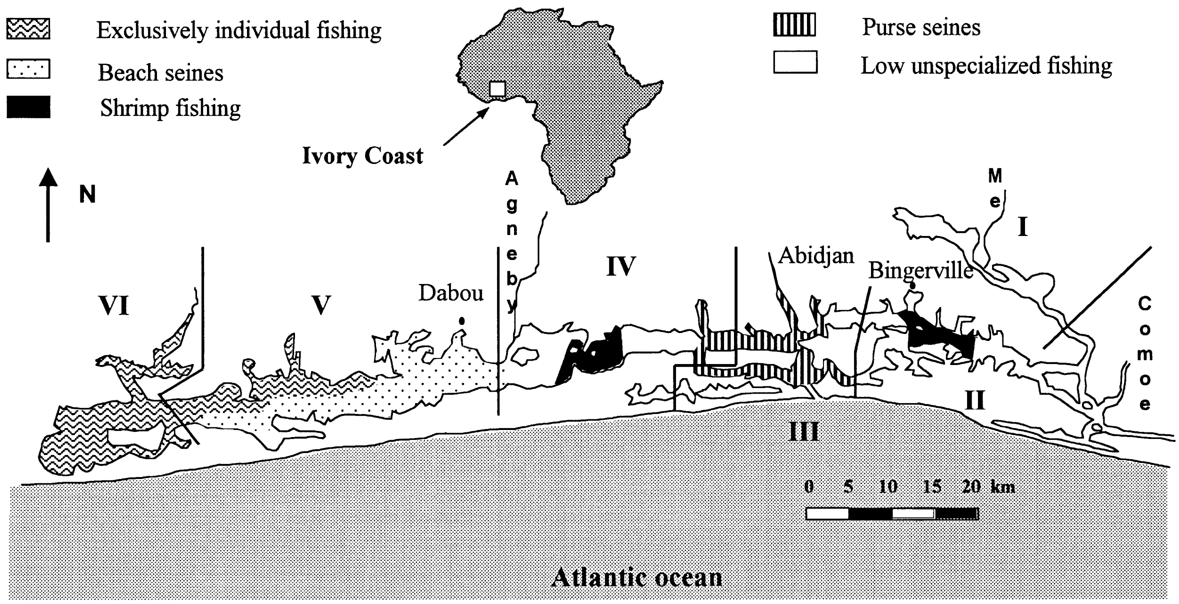

Fig. 2. Map of the Ebrie lagoon and representation of fishing activities at the time of the study (19781980). Labels I to VI represent the six sectors defined by Durand and Skubich (1982) and derived from the hydroclimate, primary and secondary production, and the fisheries.

their fish biomass, fish assemblages, yield, length and trophic level composition.

2. Materials and methods

The Ebrie lagoon, the largest lagoon in West Africa, with an area of 566 km^2, has been permanently connected to the sea since the opening of a man-made channel, the Canal de Vridy, in 1950. Freshwater input comes from a tropical transition regime river, the Comoe, and two small coastal forest rivers, the Me and the Agneby (Fig. 2).

Studies on the hydroclimate, primary and secondary production, and the fisheries of Ebrie lagoon, resulted in the definition of six sectors (Durand and Skubich, 1982). The constant communication with the ocean produces typical estuarine characteristics, at least in the sectors located near the Vridy canal (III, II and IV). These parts of the lagoon, under the direct influence of both the ocean and the flow of the Comoe River, are temporally variable (daily and seasonal variations) and heterogeneous. Salinity, for instance, varies from 0 (during the rainy season) to 35‰ (dry season). Conversely, Sectors V and VI that are oligohaline, stable, and homogeneous (Durand and Guiral, 1994), were the focal axis of our studies. Located in the western part of the lagoon, they represent nearly 50% of the total area (Table 1). Sectors V and VI were very similar with respect to morphological, hydrological, physical, chemical, geochemical and isotopic criteria (Durand and Skubich, 1982; Guiral and Ferhi, 1989, 1992). In addition, these sectors show similar assemblages of phytobenthos, phytoplankton, zooplankton, benthic communities and large crustaceans (Albaret, 1994; Le Loeuff and Zabi, 1994; Dufour, 1994; Pagano and Saint Jean, 1994; Lhomme, 1994). Fish communities are also similar with respect to species richness (22 in sector V and 23 in sector VI) and species composition (Jaccard community coefficient: 0.88). Consequently, they have been grouped together in the same ichthyological zone (Albaret, 1994). Sectors V and VI could not be distinguished on the basis of physical, chemical or biological characteristics. The major difference between these sectors lies in the fishing intensity.

A major originality of this study is that two types of data resulting from two complementary approaches are available in the Ebrie lagoon for the same period (beginning of 1980s): an artisanal fisheries dataset and a fish communities dataset. An artisanal fisheries dataset is used because such fisheries in West African lagoons are very dynamic. As a consequence, fishermen use a series of fishing gear to capture a diversity of target species in various biotopes. Fishing strategies reflect seasonal variations in the fish communities. Adjustment of gear use is very rapid, and catches, as well as the nature of the fishery, provide an accurate idea of the phase of the fish community available for exploitation. Together, these data

Table 1
Environmental comparison between occidental sectors (V and VI) of the Ebrie lagoon, West Africa

	Surface area (Km^2)	Freshwater inputs (m^3 y^{-1})	Mean salinity (February-August)	Recurring rate of lagoon water (y^{-1})	Sedimentary biotopes	Benthic communities
Sector V	170	178×10^6	3.4–2.3	0.4	Same in both sectors[a]	Same in both sectors[a]
Sector VI	135	185×10^6	3–0.8	0.4		

[a] After Le Loeuff and Zabi (1994).

provide an interesting means of assessing the fishery because they cover the full range of biotopes and fishing activities, and they express the diversity, and the spatial and temporal variability of the fish communities available for exploitation. On the other hand, these data could be insufficient if part of the fish communities were disregarded by fishermen or not accessible to gear. From this point of view, the community, synecological approach is meant to broaden the scope of the effects of fishing, to include non-commercial species and to explore the usefulness of selected tools in evaluating the impacts of fishing (Bianchi et al., 2000).

Available information used for this study is based on the following factors:

2.1. Information on the resource and the fishing pressure from fishery studies

Data were obtained by sampling the artisanal fishery (there is no industrial fishery in Ebrie lagoon) in sectors V and VI from January 1978 to December 1980, following the methodology in Laë, 1992; Laë and Hié Daré, 1989; Ecoutin et al., 1994. Five sampling stations in sector V and four in sector VI were sampled over a 7-day period each month. Capture and fishing effort data were collected independently at every sampling site. Fishing effort was computed from a daily survey of the activities of 20 fishing families in the same village. Estimates of catch and biological data were collected from returning fishing canoes sampled at the landing places with an average of 200 surveys per month. Fishing effort data and fish landing data collected by the survey network were extrapolated to the two different sectors and to individual populations of fishermen using descriptors of the fishery, such as the number of fishermen by professional class, or the number of fishing units that were estimated during a preliminary census of the whole lagoon (Laë, 1992; Laë and Hié Daré, 1989; Ecoutin et al., 1994).

2.1.1. Data processing

As artisanal fishery studies are quite imprecise because of the large number of fishermen, and the scattering and variability of fishing activities, it was decided, in order to reduce risk of errors, to process 3 years of data (1978-1980). As a consequence, results for fishing effort, catch composition per gear, yield per hectare and length composition are annual means in sectors V and VI, calculated from January 1978 to December 1980.

2.2. Ecological data on fish communities

Observations and surveys of fish communities have been conducted periodically in Ebrie lagoon using a 300 m long, 18 m high (always reaching the lagoon bottom), 14 mm mesh size purse seine at 65 stations distributed over the whole lagoon system (Albaret and Legendre, 1985), of which 11 were located in sectors V and VI and were used in the present study complementing the artisanal fishery data collected during the same time period. Ecological survey samplings were performed during the dry (February 1981) and the rainy (August 1981) seasons. Detailed information was collected on species composition, structure of fish communities and life history traits of the main species.

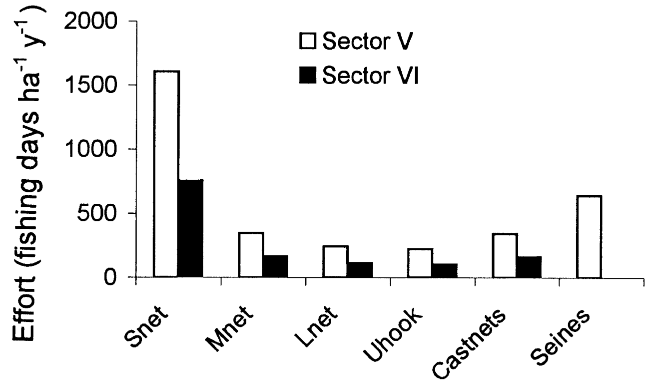

Fig. 3. Type and intensity of fishing effort (fishing days ha^{-1} y^{-1}) in sectors V and VI of Ebrie lagoon, West Africa. Snet: small mesh gillnet, Mnet: medium mesh gillnet, Lnet: large mesh gillnet, Uhook: unbaited multihook lines.

(1) Species composition of fish communities: fish collected in the seine samples were sorted to the species level, counted and weighed.
(2) Fish biology study: in each sample, 50 fish of each species were measured (fork length) in order to establish the size structure of populations. A qualitative identification of the stomach contents was made in order to determine the main trophic characteristics and level of each species in the community food web.

Purse seine fishing was conducted without active fish school search (blind fishing) and one seine haul was regarded as a reproducible fishing effort unit and the catch per unit effort (CPUE) as a pertinent fish biomass index.

3. Results

3.1. Fishing effort

The major difference between sectors V and VI lies in the type and intensity of fishing exploitation supported by each (Fig. 3). In sector V (3400 fishing days ha^{-1} y^{-1}), fishing effort is much more intensive than that in sector VI (1291 fishing days ha^{-1} y^{-1}), and the types of fishing gear are different. In sector VI, the fishermen use a wide variety of individual fishing gear (operated by one fisherman and sometimes a child) to target a diverse fish assemblage. The gear includes gill nets of different meshes, unbaited multihook lines, bow nets, and cast nets. In sector V, fishermen use the same diversity of individual fishing gear, but they also extensively use large (around 1 km long), small mesh (13 mm), and collective beach seines. These beach seines cannot be used on an irregular bottom or on very soft sediment. They require the involvement of 14-16 fishermen for 7-9 h. All fish species can be caught, including very small ones or very young ecophases. Collective fishing requires full-time fish-

Table 2
Relative contribution (%) of the main species or genera caught by the different gears used in the Ebrie lagoon between 1978 and 1980 (Snet: small mesh gillnet, Lnet: large mesh gillnet, Uhook: unbaited multihook lines)

	Snet	Lnet	Uhook	Cast net	Beach seine
Ethmalosa fimbriata	52				38
Elops lacerta	23			4	18
Chrysichthys spp.	5	1	56	16	10
Tilapia spp.	1	1	6	43	6
Polydactylus quadrifilis	2	14	7	2	
Trachinotus teraia		65	11		2
Tylochromis jentinki				29	10
Others	17	19	20	6	16
CPUE (kg trip $^{-1}$)	4.1	1.5	1.4	4.7	200

ermen while individual fishing is often performed by occasional or seasonal fishermen. Different fishing intensities have characterized sectors V and VI for more than 10 years. As early as 1973, Gerlotto et al. (1976) recorded at least 59 beach seines in sector V compared to only one in sector VI. This means that about 1000 fishermen were at this time involved in collective fishing. Ten years later, the situation was similar with 42 beach seines counted in sector V (Ecoutin et al., 1994). In the same year, there were 2250 registered fishermen in sector V compared to 520 in sector VI.

3.2. Selectivity of the different fishing gears

Catches were mainly composed of *Ethmalosa fimbriata* for small mesh gillnets, *Trachinotus teraia* for large mesh gillnets, and *Chrysichthys* spp. for unbaited multihook lines (Table 2). On the contrary, cast nets and beach seines had multi-species fish catches. From this point of view, as fishing gears are selective both for fish composition and length structure, they can be considered as good indicators of fishing levels.

3.3. Yields per hectare

As shown in Fig. 4, 3 years average yields of the artisanal fishery in sector V (derived from total fish catches collected from January 1978 to December 1980), were much higher (188.9 kg ha^{-1} y^{-1}) than those in sector VI (37.5 kg ha^{-1} y^{-1}). Catch compositions were markedly different in both the sectors. In sector V, *Ethmalosa fimbriata* was the main species (averaging 41% of the total weight of landings from 1978-1980), while in sector VI, catches were more divided into several species (*Chrysichthys* spp. 25.8%, *Elops lacerta* 22.5%, *Liza* spp. 10.8%, *Polydactylus quadrifilis* 10.8%, *Ethmalosa fimbriata* 8.4%).

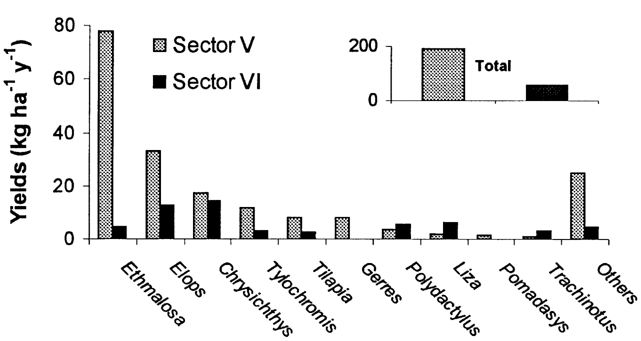

Fig. 4. Species yields (kg ha^{-1} y^{-1}) in sectors V and VI of the Ebrie lagoon. Annual mean of 3 years, derived from total fish catches collected from January 1978 to December 1980.

3.4. Biomass index and community structure

The very high average biomass index measured by purse seine sampling in sector VI, more than 100 kg ha^{-1} against less than 20 kg ha^{-1} in sector V (Albaret, 1994), was mainly due to populations of relatively large, territorial, species (bagrids and cichlids), where large individuals were numerous.

In sector V (high fishing pressure), one species, *Ethmalosa fimbriata*, accounted for almost 70% of total fish numbers, while in sector VI (very low and selective fishing pressure), no species really predominated the community, and the species abundance distribution was much more gradual (Fig. 5). Catfishes, *Chrysichthys nigrodigitatus* and *C. maurus*, were the most abundant species in sector VI (respectively, 29% and 14%).

Shannon diversity indices (I) and evenness values (E) confirm that species diversity was higher in sector VI than those in sector V (I = 2.28, E = 0.69 and I = 1.98, E = 0.59, respectively).

3.5. Length composition

The overall length frequency distributions of catches of all species combined shows that the average length was smaller (14.6 ± 4.7 cm) in sector V than that in sector VI (22.6 ± 6.4 cm). In addition, it clearly appears that the length distribution was unimodal in sector V, whereas two modes were clearly visible in sector VI (Fig. 6a). This difference is not only due to the presence of beach seines in sector V because the fish lengths in catches by individual gear in sector V were also unimodal, in contrast to the same gear in sector VI (Fig. 6b). In fact, the intensive fishing pressure in sector V has led to an undoubted decrease in medium- and large-sized fish. This can be interpreted as a rejuvenation of fish stocks as usually described in fisheries studies.

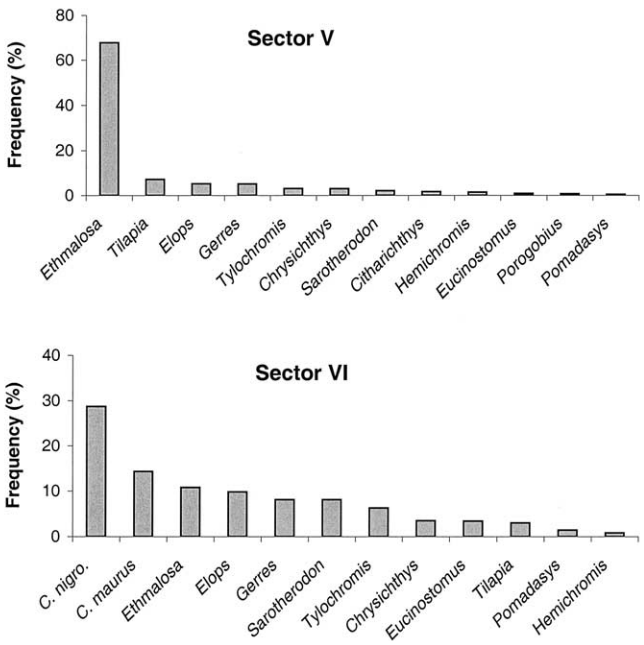

Fig. 5. Abundance distribution of species (numbers) in 1980 in sectors V and VI of the Ebrie lagoon, West Africa.

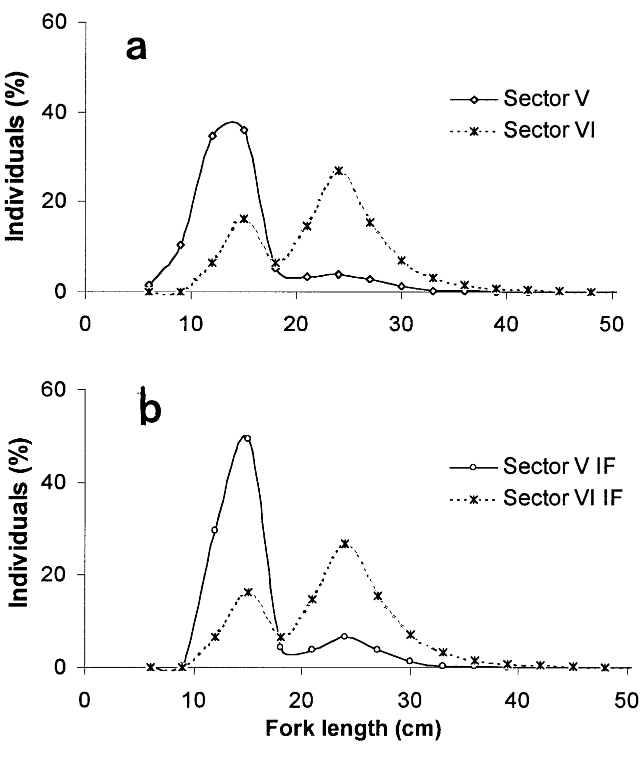

Fig. 6. (a) Length (cm) composition of total catches in sectors V and VI of Ebrie lagoon, West Africa; (b) Length of individual fishing in sectors V and VI.

For each of the main species the average and maximum observed lengths were generally smaller in the strongly exploited sector V than those in sector VI (Table 3).

3.6. Trophic levels

The food items of the Ebrie lagoon fishes have been divided into 16 categories and six major trophic groups have been defined: ichthyophagous, malacophagous, macrocrustacean predators, planktonophagous and microbenthophagous, detritivores (Albaret, 1994).

However, in order to compare the trophic structures in sectors V and VI, only three groups corresponding to the major trophic levels were used: piscivores, invertebrate consumers, herbivores and/or detritivores.

Approximately 80% of the total number of species collected in the whole Ebrie lagoon were classified as predators (with the majority being unspecialized predators: ichthyophagous, malacophagous, large crustacean eaters), and only approximately 20% were phyto- or zoo-microphagous. But among the latter were some of the most abundant species in the lagoon, including *Ethmalosa fimbriata*, *Sarotherodon melanotheron*, *Tilapia guineensis*, *Liza grandisquamis*, *Liza falcipinnis* and *Mugil curema*. Most of the species showed a relatively low dietary specialization and a great trophic adaptability (Albaret, 1994). In sectors V and VI, the proportion of unspecialized predatory (75%) and microphagous species (25%) was about the same as in the rest of the lagoon.

The artisanal fishery catches showed that the cumulative weight of fishes belonging to the herbivore and detritivore group of species in sector V represented 58.5% of the total weight of catches and 25.6% in sector VI (Fig. 7). The piscivore group accounted for 23.1% of fish catches in sector V and 35% in sector VI.

In the fish community as seen through seine sampling, the difference between sectors V and VI was even more accentuated with the number of phytophagous fishes reaching 77% (Fig. 7).

4. Discussion

In the Ebrie lagoon, intensive fishing effort in sector V (3400 fishing days ha^{-1} y^{-1} vs. 1291 fishing days ha^{-1} y^{-1} in sector VI), could be responsible for a re-organization of the fish community. At low fishing effort, fish biomass was high (100 kg ha^{-1}), the fish yield was low (37.5 kg ha^{-1}), the average catch length was high (22.6 cm) and the ratio of piscivore fish (35%) was higher than herbivores/detritivores (26%). On the contrary, for high fishing effort, fish biomass is low (20 kg ha^{-1}), fish yield is high (189 kg ha^{-1}), average catch length is low (14.6 cm) and the ratio of piscivore fishes (23%) is lower than the herbivore/detritivore one (58.5%).

As fish biomass declined, CPUE decreased although fishing effort increased. High yields in sector V can be explained by the rejuvenation of fish stocks whose average length was much lower than that in sector VI. Another significant fact is the predominance of one species, *Ethmalosa fimbriata* (41% of total catch), in sector V whereas in sector VI, the two most abundant species, *C. nigrodigitatus* and *C. auratus*, only accounted for 25.8% of total catches. A lowering of fish

Table 3
Average length (L) and maximum observed length (MOL) expressed in millimeter, in low fishing pressure sector VI and high fishing pressure sector V of Ebrie lagoon, West Africa. Data were collected from 1978 to 1980. N is the number of measured fishes and S.D. is the standard deviation

Species	Sector V				Sector VI			
	N	*L* (mm)	S.D. (mm)	MOL (mm)	*N*	*L* (mm)	S.D. (mm)	MOL (mm)
Chrysichthys maurus	118	132	30.7	241	684	201	62.4	373
Chrysichthys nigrodigitatus	15	155	62.3	270	1375	250	81.0	543
Elops lacerta	203	174	42.0	303	470	192	43.2	346
Ethmalosa fimbriata	2643	94	23.9	168	515	124	13.6	171
Eucinostomus melanopterus	35	97	13.9	128	161	97	16.9	139
Gerres nigri	198	85	14.7	142	387	99	20.1	172
Hemichromis fasciatus	59	131	37.1	216	38	148	26.8	199
S. melanotheron	82	188	23.2	283	387	210	23.6	291
Tilapia guinensis	278	166	52.3	294	144	179	53.9	290
Tylochromis jentinki	122	138	49.6	280	300	133	60.6	289

diversity is a good indicator of a stressed ecosystem (Lévêque, 1995) and it is commonly agreed that the higher the fish diversity, the more stable the fish community. The lowering of fish diversity was also reflected at the trophic level by the increase in phytophagous and detritivore species in the strongly exploited fish community. In sector V, this process was mainly based on the presence of *Ethmalosa fimbriata*. This West African species lives and reproduces from nearly fresh water to hyperhaline waters and is an opportunistic feeder (Charles-Dominique and Albaret, 2003). It shows true migratory capacity. In Ebrie lagoon, most of the reproductive activity occurs at salinities higher than 10 mg l^{-1}, from December to April (dry season) near the inlet in sector III. Juveniles stay in the area for 4 months after reproduction until they reach 6 cm fork length. They then spread out in the lagoon attaining a size of 12 cm at 9-10 months. They then return to spawn near the inlet. However, both sectors V and VI represent the same habitat for *Ethmalosa fimbriata* in terms of water salinity and food resource quality and quantity. Minute differences in these two important distribution factors, between sectors V and VI, could only have a minor influence, if any, on *Ethmalosa*'s local distribution. As a consequence, the decrease in *Ethmalosa* abundance in sector VI may be mainly attributed to the intensive selection made in sector V both by collective and individual gear. This is supported by *Ethmalosa* catches in sectors V and VI of 1800 and 50 t, respectively.

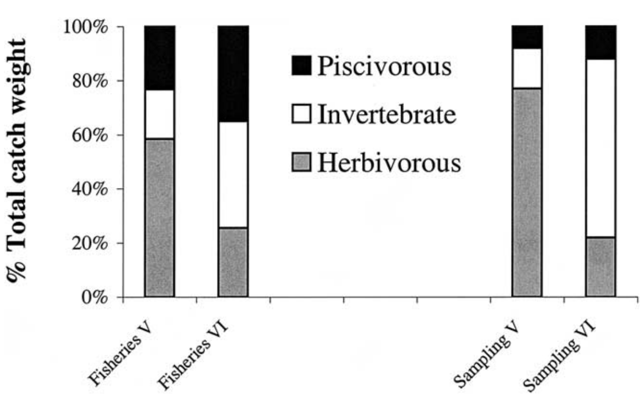

Fig. 7. Comparison of the trophic structure in sectors V and VI: (a) from the artisanal fisheries catches (weights); (b) from the ecological survey samples (numbers).

Consequently, the response of the Ebrie lagoon fish community to high fishing pressure is to evolve towards a smaller number of species, especially planktophage or detritivore ones at a low trophic level (*Ethmalosa fimbriata* in sector V) and a few predators at the top (*C. maurus*, *C. nigrodigitatus* and *Elops lacerta*). The major adjustment is obtained by shortening trophic chains and this particular point tends to emphasize the shifts in the P/B relationships of the fish assemblage.

Generally, the effects of fishing on fish communities include a decrease in their abundance, changes in age structure and size composition, and in species composition. These effects have been well documented in other coastal areas of the world including the Gulf of Thailand (Simpson, 1982), South Africa (Tomlin and Kyle, 1998) and Australia (Blaber et al., 2000). In West Africa, higher fishing effort in coastal lagoons results in higher yields per hectare but contributes to changes in the trophic structure (Laë, 1997): community structure may change if fishing directly removes or reduces populations representing specific trophic levels of the community (predators or prey). Overfishing of higher trophic level fish stocks (i.e. piscivores) generally results in refocusing of fishing effort on planktivores and a concomitant decline in the average trophic level of the landings (Pauly et al., 1998). This process seems to be the general rule at the level of world fisheries (Pauly et al., 1998). Concurrently, overfishing of higher levels can lead to a heavy dominance of populations, such as triggerfish on West African coasts (Gulland and Garcia, 1984) and octopus in Senegal and Mauritania (Faure, 2000), and surprisingly, these changes in relative abundance of species do not result in a lowering of total catches (Murawski et al., 1991). Dynamics observed at the ecosystem level are mainly the result of trophic interactions between species. Numerous examples of changes in specific composition of catches are now available, which can be attributed to fishing by trophic interactions between species (Hall, 1999).

In the Ebrie lagoon, the consequence of high fishing effort in sector V is a decline in species diversity, an initial increase in productivity of benthic/demersal and pelagic food webs, and the dominance of short-lived, especially pelagic, species.

In addition, in response to highly disturbed (stressed) situations, some species show remarkable ecophysiological adaptations and/or develop adaptations which affect growth and reproduction phenomena, such as early sexual maturity, dwarfism and growth variations (Albaret and Charles-Dominique, 1982; Stearns and Crandall, 1984; Stewart, 1988; Legendre and Ecoutin, 1989; Laë, 1994; Duponchelle and Panfili, 1998). In stressful situations, these species have demonstrated that their capacity to adapt is very high, which allows them to grow at the expense of species that are less plastic (Kaufman and Ochumba, 1993; Laë, 1994; Stiassny and Meyer, 1999). The effects have been reported not only at the population level, but also at the community level, which is profoundly modified (Sanyanga et al., 1995).

5. Conclusion

Our understanding of the effect of fishing activities on lagoon fish communities is still in an exploratory phase. As natural environmental variations act jointly with anthropogenic ones, it is difficult to dissociate the different sources of stress and identify general patterns. This is the reason why data collected in a “healthy environment” submitted to very low fishing pressure are very useful in order to understand the natural equilibrium and organization of fish communities in comparison with more intensively fished or overfished areas. As historical data are seldom available and fishing effort is hardly increasing from year to year in developing countries, an analysis of historical reference situations is necessary for assessing the impact of human activities. The theory of the “fishing down process” has often been evoked, but still needs to be supported by field data. From this point of view, scientific works carried out in the Ebrie lagoon 20 years ago, show that even in non-overfished ecosystems (fishing effort in sector V was high but at a reasonable level), there were major changes compared to the lightly fished adjacent sector VI. The main changes included lowering of fish diversity in catches, fish biomass, average catch length, trophic level of catches. These are new findings that need to be supplemented by data from similar tropical lagoons at different levels of exploitation. Analysis of historical data relating to low and intermediate fishing intensities compared to present fully exploited or overfished ecosystems of similar nature, would lead to a better understanding of fish assemblage re-organization when submitted to stress of different intensity.

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