Contribution of local fishermen to improving knowledge of the marine ecosystem and resources in the Republic of Guinea, West Africa

Jean Le Fur, Athanase Guilavogui, and Antoine Teitelbaum

Abstract: We assessed the quality of fishermen's local ecological knowledge, or LEK, as a potential source of information about coastal ecosystem functioning in the Republic of Guinea. Interviews were conducted by means of partial immersion or repeated surveys at six landing sites. In each site and for each topic, discussions were conducted with 3 to 15 individual fishermen and 1 to 10 groups of fishermen. Knowledge was obtained about habitats, substrate preferences, the location of nurseries, reproductive cycles, fish diet, and the trophic network of the Sciaenid community, the major resource for fisheries in this area. We systematically compared the reliability of the information collected with that of scientific information collected in parallel surveys or published data. The contribution of LEK should be considered on a case-by-case basis. Indeed, LEK could be used as (*i*) a supplementary source of scientific studies (seabed description), (*ii*) a basis for new scientific investigation (species reproductive cycle), (*iii*) the only possibility to obtain information (nursery location), (*iv*) a surrogate to scientific surveys providing an identical level of validity (fish diets) or a satisfactory proxy (trophic network) in a context of limited resources and data in which wide-ranging knowledge relating to the entire coast must be obtained.

Résumé : Nous caractérisons l'étendue et la qualité du savoir écologique des pêcheurs (SEP) comme source potentielle de connaissances sur l'écosystème de la zone côtière de la république de Guinée. Le SEP a été obtenu par immersion partielle ou enquêtes répétées dans six centres de débarquement. Dans chaque site et pour chaque sujet, les enquêtes ont été réalisées sur un ensemble de 3 à 15 pêcheurs individuellement et de 1 à 10 groupes de pêcheurs interrogés simultanément. Les SEP obtenus concernent les habitats, les préférences édaphiques, la localisation des nourriceries, les cycles reproductifs, le régime alimentaire et le réseau trophique de la communauté à sciaenidés, la principale ressource démersale dans cette région. Les SEP obtenus ont été systématiquement associées, lorsque c'était possible, à une information scientifique équivalente collectée en parallèle ou issue de la littérature. Le SEP peut être utilisé selon les cas comme (*i*) source complémentaire aux études scientifiques (description des habitats), (*ii*) inspiration pour de nouvelles recherches (cycles reproductifs des espèces), (*iii*) seule source possible de connaissance (localisation des nourriceries), (*iv*) substitut aux études scientifiques dans un contexte de validité similaire (régimes alimentaires) ou comme un proxy acceptable (réseaux trophiques) dans un contexte limité en moyens et en données disponibles pour lequel une variété de connaissances doivent être acquises sur l'ensemble de la zone côtière.

Introduction

Fisheries management and research nowadays focus strongly on an ecosystem approach to fisheries (EAF; Browman and Stergiou 2004; Garcia and Cochrane 2005; Pitcher et al. 2009), promoted alongside similar approaches (Garcia et al. 2003), such as ecologically sustainable development (Fletcher 2006) and ecosystem-based fishery management (Christie et al. 2007; Marasco et al. 2007). In addition to fishery, governance, or social-related issues, these new approaches require a "resource ecology" perspective with consideration of the physical, nutritional, and competitive natural environment in which marine resources develop (Garcia and Cochrane 2005; Rice 2008; Zhang et al. 2009).

An EAF is now considered necessary for all fishery systems, including those of developing countries (Sherman and Duda 1999; Sinclair et al. 2002), for which the adoption of this approach is a major issue (Mathew 2003; Heck et al. 2007). This is the case in the Republic of Guinea, whose coastal area has highly productive demersal fishery resources and is subject to major threats (Domain et al. 2000; Sidibe 2003; Ukwe et al. 2006). Guinea is currently in the process of defining the conservation issues it faces with the establishment of wetland sites of international importance under the

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Ramsar Convention (Ramsar Convention Bureau 1997 in Seto and Fragkias 2007) and the identification of marine protected areas (International Union for Conservation of Nature 2007, 2008).

However, to ensure efficient EAF implementation (Mathew 2003; Rice 2008), this country needs to accumulate large amounts of ecological and social information. For example, an EAF may involve the identification of marine protected areas (Browman and Stergiou 2004; Garcia and Cochrane 2005; Greenstreet et al. 2009) as potential conservation zones (Sissenwine and Murawski 2004). As far as the specific focus of knowledge about the ecosystem is concerned, this would require an inventory of current ecological communities, vulnerable species, critical habitats and their relationships, resource life traits, and trophic relationships for the entire shoreline and possibly the entire ecosystem. In this situation, fishermen's local ecological knowledge (LEK; Olsson and Folke 2001; Davis et al. 2004) may be a valuable source of information, addressing the problem of the diverse nature and quality of the ecological knowledge required.

Since the pioneering work of Johannes (1981, 1984), the intrinsic value of local operators' knowledge of the ecosystem within which they work has been increasingly recognized (Davis and Wagner 2003; García-Allut et al. 2007) and used. Study protocols have been refined, with comparative approaches between countries (Folke 2004; Silvano and Begossi 2005) or precise quantification of the knowledge acquired (Moreno et al. 2007, Silvano and Begossi 2010). The traditional knowledge of fishermen is now used for many purposes, including the deciphering of ecological interactions (Folke 2004) and studies of trends (Neis et al. 1999) and changes (Johannes et al. 2000; Gullström et al. 2006). This knowledge is also used to deal with questions concerning particular taxonomic groups (Davis et al. 2004; Silvano and Begossi 2005; Grant and Berkes 2007) or specific issues, such as fish aggregation (Moreno et al. 2007), habitats (Bergmann et al. 2007), trophic relationships (Pikitch et al. 2004), or the identification of sampling areas (Davis et al. 2004). Finally, various cultures and traditions concerning fishing activity have been shown to be based on a structured corpus of knowledge (Hickey 2007; Houde 2007). In addition to simply providing a reservoir of facts (Baelde 2007), this knowledge may be determinant when trying to resolve questions relating to conservation measures or sound management design (Hickey 2007; Berkes 2008).

The use of LEK has been described as an asset for the implementation of an EAF (Garcia and Cochrane 2005; Gray and Hatchard 2008; Paterson and Petersen 2010). However, the practical use of LEK, although increasing (Prigent et al. 2008; Silvano and Valbo-Jørgensen 2008; Gerhardinger et al. 2009), is not common within this context, and its reliable use is sometimes called into question (e.g., Davis and Wagner 2003; Haggan and Neis 2007). Indeed, many studies have focused on the relationships and associations between local knowledge and "modern scientific knowledge" (Johannes and Neis 2007). Most recognize the complementary nature of LEK (García-Allut et al. 2007; Williams and Bax 2007) to various degrees: separate from (Wilson et al. 2006; Symes 2008), complementary to (Silvano et al. 2005; Baelde 2007; Hall et al. 2009), or enhancing (D'Incao and Reis 2002; Aswani and Lauer 2006; Berkes et al. 2007) scientific knowledge. The reliable use of local ecological knowledge as a basis of management decisions also remains a matter of debate, and various approaches for increasing its validity have been proposed (Davis and Wagner 2003; Maurstad et al. 2007).

We evaluated the potential and reliability of this source of knowledge as a means of improving ecological knowledge acquisition in the development of an EAF. This study was carried out along the coast of Guinea, which boasts a large community of fishermen (Chavance 2000) with potentially valuable knowledge for the identification of sensitive areas, such as areas of marine resource renewal. Wide-ranging ecological knowledge was obtained from fishermen and compared with knowledge from equivalent scientific sources. We focused on general perception of the environment (seasons, habitats, and biotopes), particular knowledge about reproduction (location of nurseries, reproductive cycle), and feeding (diets of fish, trophic network). We present the approach developed and the knowledge provided together with the equivalent scientific information obtained either from surveys carried out in the field during the study or from published data. We then consider the quality of LEK and scientific results for improving knowledge about the coastal ecosystem.

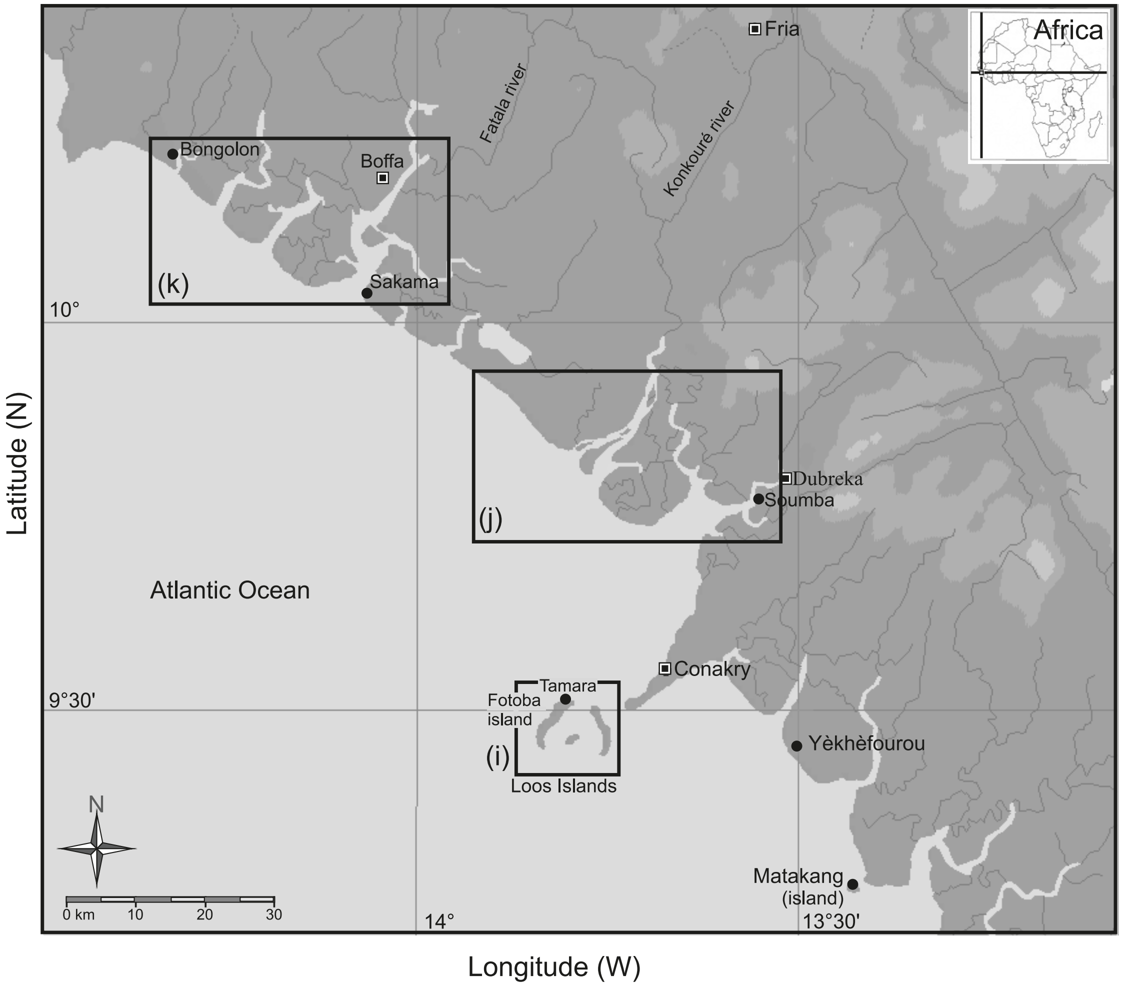
Materials and methods

Study site and the population of fishermen surveyed

The coastal ecosystem of Guinea is a large delta complex composed of a collection of plains divided by the estuaries of a large number of water courses. It is a highly productive zone enriched in coastal silt from the rivers. According to Saenger and Hegerl (1983), conditions in this area have favoured the development of one of the largest mangrove forests in Africa, which, within a complex trade-off between positive and negative factors (Baran 2000), play a major role as nursery areas for most of the fish species harvested. Within this ecosystem, a major demersal assemblage of fish species, known as the "Sciaenid community" (Longhurst 1966), named after the predominant family present, develops (Domain 1989 in Domain et al. 2000). This very diverse community (18 families, 38 species) is closely associated with the muddy bottoms and desalinated waters of estuaries (Sidibe 2003). It moves back and forth between the estuaries and the open sea, with complex dynamics (Baran 1995). The Sciaenid community is the main source of fish for industrial (Lesnoff et al. 2000) and artisanal (Chavance 2000) demersal fisheries in Guinea. However, many gaps remain in our bioecological knowledge of this community and its potential sustainability, given the high level of fishing to which it is subjected (Baran 2000). The main features requiring clarification concern trophic relationships between the fish communities and the estuarine environment and the conditions in which reproduction occurs and juvenile stages develop (Baran 1995).

The fishing industry in Guinea can be subdivided into an industrial fleet of 200 boats, mostly run by foreign companies, and a small-scale fishery of 2500 wooden canoes of various types, 41% of which are motorized (Sidibe 2003). These boats are distributed between 120 identified landing sites (Chavance 2000) of various sizes, mostly embedded within the numerous mangrove estuaries along the coast. A

Fig. 1. Location of the study sites for the two survey phases. Black dots indicate the landing sites at which the surveys were conducted. Inset (*i*) corresponds to Fig. 3; insets (*j*) and (*k*) correspond to Fig. 4.



chronic situation of conflict has been described in which illegal industrial vessels repeatedly penetrate into the areas reserved for small-scale fisheries (Guilavogui et al. 2004). The coastal demersal stocks were almost entirely unexploited before 1985. Following the establishment of the republic and the liberalization of fishing, there has been a large and rapid increase in fishing pressure over the last 25 years (Gascuel et al. 2008). Fish stocks are now threatened, with demersal marine resource abundance and the mean length of species now only a third their values in 1985 (Sidibe et al. 2004).

The study took place in the central coastal areas of Guinea (Fig. 1) and was divided into two phases. The first phase was carried out in 1999 in the Loos Islands, a small archipelago off the Conakry Peninsula. These fish-rich islands are a traditional fishing zone. The study focused on the harbour of Tamara on the island of Fotoba. This island had a population of 39 fishermen, comprising native fishermen of the Soso ethnic group and migrant fishermen who arrived from Sierra Leone in the 19th Century. These fishermen use drift nets, trammels, floating nets, or fishing lines.

The second phase of the study took place in 2001–2003 in the principal estuaries in the central coastal area of Guinea. These estuaries are bordered by mangroves and are representative of the coast in this region. Five harbours used for the unloading of catches by local fishermen were studied by means of repeated surveys in this phase of the study: Bongolon, Sakama, Soumba, Matakang, and Yèkhèfourou. These harbours were selected for study on the basis of the large number of fishing boats unloading there and the long tradition of fishing at these sites. Fishing boat captains and former fishermen were selected for the survey; less than 10% of those interviewed were literate.

Survey design and interview strategy

Integration into the fishermen's environment

Johannes (1981) established the fundamental principles for obtaining high-quality local knowledge. The principal requirement is a "socio-ecological" approach, established such that fishermen are placed at their ease. These principles (adapting working hours to those of the fisherman interviewed, avoiding brief interviews or visits) led to a survey protocol based on two different communication approaches.

The first phase of the study (Loos Archipelago) was carried out by a French biologist (A. Teitelbaum) who stayed in the fishing village for 6 weeks and in the lives of the fisherman on land and at sea. Within this phase, the most suitable form to interview fishermen was a mixture of "meetings

Table 1. Number of interviews with fishermen conducted for each of the subjects studied.

	Survey sites						
	Phase I	Phase II					
	Loos	Matakang	Yèkhèfourou	Soumba	Sakama	Bongolon	Total phase II
Description of seasons	—; —	3; 1	4; 2	—; 5	—; 2	—; 3	7; 13
Nature of the seabed	15; 10	—; —	—; —	7; 5	10; 2	6; 3	23; 10
Prefered biotopes	15; 10	3; 1	4; 2	7; 5	10; 2	6; 3	30; 13
Nursery areas location	—; —	—;—	—; —	7; 5	10; 2	6; 3	23; 10
Reproduction cycle	—; —	—; 1	—; 2	7; 5	10; 2	6; 3	23; 13
Fish diets	15; 10	3; 1	4; 2	7; 5	10; 2	6; 3	30; 13
Trophic networks	—; —	3; 1	4; 2	7; 5	10; 2	6; 3	30; 13

Note: Within each cell, the first value corresponds to the number of fishermen interviewed individually; the second value is the number of groups of fishermen interviewed during the survey at the given site. The number of active fishermen within each group varied (some arriving, some leaving, some talking, some being silent) and was not reported. Each group contained from 4 to about 20 fishermen.

under a tree" lasting about 1 hour with either one or several fishermen, full-day meetings sharing the life of a fisherman or fishing crew on the boat (10 different fishing crews), and several weeks of interaction with the fishermen with whom the scientist was staying (trips out to sea, accommodation, meals). We also approached fishermen not permanently based on the island (mostly dive fishing), most of whom came from the Conakry Peninsula.

Phase II was carried out in estuaries by a Guinean researcher (A. Guilavogui); for each visited site, the same approach was repeated: following their arrival (by car or by canoe), the scientific team met with the village chief and informed him of the aim of their stay. The chief then designated himself or a guide to introduce the team to designated knowledgeable fishermen (old fishermen and captains). During their stay, the team members could also ask to meet other people (snowball sampling). Apart from this procedure, the terms and conditions of meetings (number of meetings and their length) with fishermen or groups of fishermen depended on fishing activities and the availability of the fishermen. Overall, this phase consisted of a series of six stays of 5–6 days at a time, each involving a partial immersion in village life. During phase II and for each of the areas of knowledge considered, we questioned 7 to 30 fishermen (Table 1) between the ages of 30 and 70 years in individual surveys, in which fishermen freely expressed their knowledge on the subjects considered. A second approach was used in which several fishermen were brought together to discuss specific subjects. The results presented for each subject are a final compilation of the various notes taken during the surveys.

Semidirected interviews

Detailed questionnaires prepared in advance proved unworkable because the series of questions clearly disturbed some of the fishermen interviewed. Many appeared determined, at all costs, to provide an answer to any question posed, and this approach may therefore entail a risk of discrepancy between the fisherman's true knowledge and the answers given. We optimized the quality of the accounts given by fishermen by taking notes, using questionnaires only to guide the interviews, and to identify the subjects to be considered.

Use of intermediaries

In both phases of the study, one or two individuals trusted by the fishermen and capable of translating between fishermen and researchers were employed as intermediaries. In phase I, an interpreter (A. Sökhö Camara) living in the village was used. A. Teitelbaum already had basic competence in the local language. In phase II of the study, an interviewer–interpreter (R. Manet Karemba) from the research centre, who had previously worked in a fishing crew in the area, served as an intermediary. The choice of intermediary seemed to be crucial, affecting the way in which questions were posed, the reconstitution of responses, and the likelihood of meeting people with relevant knowledge (Johannes et al. 2000; Davis and Wagner 2003). This contribution was qualitative and could not be quantified. The intermediary may, for example, account for cultural misinterpretation and provide real added value in terms of the worth of the data collected (Ames 2007).

Use of maps

Map drawing has been described as a good way to interact with fishermen (Bergmann et al. 2007; Wilson et al. 2006). During phase I, the fishermen could read scale maps of their fishing territories with no particular difficulty; during phase II, after some training, fishermen were able to interpret the views of their fishing zones from above (Aswani and Lauer 2006). They could thus locate the density of fish or the nature of the seabed.

Subject areas included in the study

A set of domains of information (environment, resources, and their relationships) linked to the Sciaenid community was investigated during the surveys. Information domains were selected on the basis of their value for both understanding the Guinean marine ecosystem functioning and evaluating rigor and confidence in the results obtained, since the purpose of the study was to confront LEK and equivalent scientific knowledge. We present within this section the subject areas included in this work, together with the way in which the corresponding scientific information was obtained, where possible.

Perception of time

For each season, we characterized the criteria defining the climatic situation, fishing practices, and the abundance and succession of marine organisms. This knowledge was extracted from group discussions in the second phase of the study and compared with the usual types of seasonal segmentation of the year.

Nature of the seabed

Most of this knowledge is gained from observation of the samples of seabed brought to the surface by their fishing gear. This became especially clear during the first phase of the study on the Loos Archipelago, where the seabed is more heterogeneous than that in the mangrove. The research team accompanied the fishermen in their boats 4 days per week, on average, during the study period. During these outings, the nature of the seabed was determined and cross-checked by bucket or anchor sampling (for silt) or diving when conditions were favorable. Each fishing crew helped to complete, on board, an outline map of the islands (same scale and size as Fig. 3) based on its own usual fishing zone (dependent on the fishing gear used and the target species). The resulting overall map is a synthesis of maps developed over the 6-week stay of phase I. Zones were identified with maps and by GPS. These results were compared with data extracted from the general map proposed by Domain and Bah (1993).

Biotopes

Preferences of the organisms for particular substrates were systematically addressed during the interviews at the various sites studied in phases I and II; fishermen were asked about the type of substrate on which each demersal species they targeted was found. We also cross-checked the information obtained with published results concerning the Guinean area.

Fish reproduction

The nursery zones of the principal species exploited were identified for the two principal estuaries of Fatala and Konkoure. The overall distribution was determined by putting together all the accounts recorded in the participatory processes (Table 1), with base maps used as a medium of communication for each survey site concerned (Bongolon and Sakama for the Fatala estuaries and Soumba for the Konkoure estuary). After discussion on land, canoe trips were organized to position, with a GPS device, the areas described by fishermen.

The reproduction cycle also was investigated in phase II on the basis of collective and individual interviews. Results for the bonga shad (*Ethmalosa fimbriata*) were compared with the reproductive cycle described by Baran (1995) for the Fatala estuary.

Fish diet

Fishermen routinely open the fish they catch, principally during the operations carried out during the treatment of the catch. This provides them with information about the stomach content and diet of the fish. Fishermen were systematically asked about the feeding habits of the fish they targeted. For this topic, questions were of the kind, “What do you find when you open the belly of the fish?”. We present results only for affirmations that we were able to confirm at more than one survey site.

In parallel, we compared fishermen’s knowledge of the diet of the fish they caught with the results of stomach content analyses carried out on site during the first phase of the study. The scientific analysis was carried out as follows: after each fishing trip, fish gut contents were analyzed immediately on landing, after their purchase, or with the agreement of the fish buyers. The fish were identified and classified to species level, measured, and weighed. The contents of their stomachs were analyzed with a binocular lens and an electronic balance. The repletion status of the fish was scored, together with the amounts of each type of food and the frequencies of occurrence. We retained the results obtained only for taxonomic groups for which at least 50 stomachs were analyzed. The results were then used for an overall synthesis of all the stomachs studied and converted into “presence–absence” format for comparison with the statements of the fishermen. Stomach contents were analyzed in October, at the end of the rainy season. The food regimes are therefore not entirely representative of the nutrition of these species generally throughout the year.

Reconstruction of the trophic network

For this subject, the initial questions were of the kind, “What do the fish eat?”, posed species by species, starting with major species of the Sciaenid community. More often than not, the discussion moved on to an informal description of the global network by fishermen or groups. Each question was debated by fishermen, and the discussion then led to a description of the global families (trophic levels) of fishes within the ecosystem. The trophic network question was addressed at all study sites during phase II surveys and systematically discussed during the group interviews. The notes taken on this topic were collated at the end of the surveys. The results are presented as an integrated overview, bringing together the various accounts. The resulting trophic network therefore reflects the major trophic relationships and does not contain rarely recorded taxonomic groups or details that varied with the fishermen interviewed and the location.

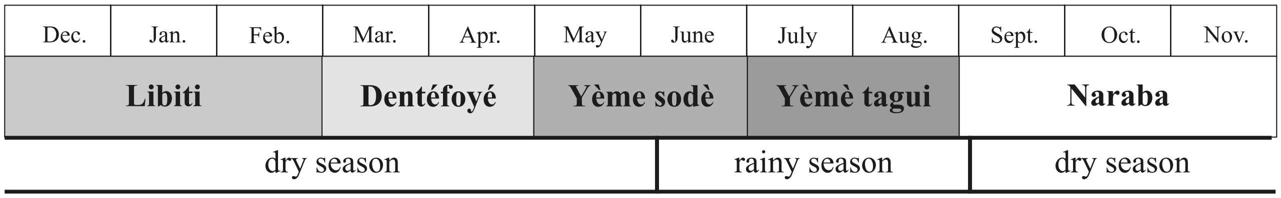
The descriptions of the trophic network were compared with the results of a trophic network model developed for the Guinean marine ecosystem by Guénette and Diallo (2004*a*, 2004*b*) using the Ecopath approach (Christensen and Pauly 1992). This method uses estimates of the proportion of each prey in the consumers’ diet based on a trophic mass balance analysis of the global ecosystem (Christensen and Walters 2004). In their model, Guénette and Diallo (2004*a*) have reconstructed diets from composite bibliographic sources. The Ecopath model also deals with a large number of taxa, but we considered only those species discussed by the fishermen.

Results

Ecological segmentation of the year

The ecological segmentation of the year by fishermen differed from standard classifications. The local fishermen knew the 12 months of the Gregorian calendar. They grouped these months together into distinct seasonal periods (Fig. 2). Each period was defined by criteria dependent on variations in the physical parameters of the marine and coastal environment. Their classification was based principally on wind and rainfall conditions. The interviews also indicated that these seasons took into account the characteristics of currents, atmospheric visibility, and sunshine intensity, as well as the

Fig. 2. Comparison of the scales of temporal observation of Guinean fishermen (middle) with the Gregorian calendar (top) and the progression of seasons in the tropical zone (bottom).



temperature, salinity, and turbidity of the water. The fishermen related their segmentation of the year to the behaviour of the fish, including the arrival and departure of fishing resources. Five principal periods were identified: two of 3 months and three of 2 months (Fig. 2).

"Libiti" (December, January, February) is a calm period characterized by inshore breezes. Sunshine intensity is weaker during this period, and many species migrate towards the seabed. Drift-net fishing is therefore effective. Large, seabed-dwelling shrimps (*Parapenaeopsis atlantica*, *Penaeus notialis*) are abundant, and groups of common dolphins (*Delphinus delphis*) are observed in the coastal areas, where they hunt fish.

"Denté foyé" (March, April) is characterized by the arrival, generally in the afternoon, of strong offshore winds. These winds are described by the fishermen as corresponding to the peak of the continental trade winds blowing from the east to the northeast (Pezennec 2000). The water is warm both at the surface and at the seabed, and most fish migrate further out to sea, obliging the fishermen to travel large distances to reach them. This is the start of the sardinella (*Sardinella maderensis*) season and also corresponds to the first appearance of jellyfish (Leptomedusae and Limnomedusae suborders; "yébognè" in Soso). Fishing trips are limited during this period and accidents are frequent.

"Yèmè sodè" (May, June) corresponds to the start of the rainy season. This period is characterized by tornados, known as "tornadè foyé", and signals the end of the "denté foyé" or coastal winds. The wind triggers the migration of pelagic fish to the coastal zone, favouring the formation of large shoals of fish. This is the major fishing period (also named the "miraculous" fishing season by fishermen). Some fishermen think that in addition to the effects of the wind, the thick clouds forming on the coast might attract the fish. This period is also characterized by the migration of marine sea turtles (various species from the Chelonioidea superfamily) to the coastal zone. Some fishermen think that the turtles come to reproduce, whereas others think that they come to feed on jellyfish, which are also abundant during this period.

"Yèmè tagui" (July, August), in the middle of the rainy season, is characterized by a large decrease in the salinity of coastal waters and a large increase in turbidity. Certain species, such as the bonga shad (*E. fimbriata*) move further out to sea.

"Yèmè donkhoè" or "naraba" (September, October, November) corresponds to the end of the rainy season. The sky is blue and the sun shines. There are no violent winds and fishing conditions are good, particularly for the bonga shad. The large species of commercial interest (*Pseudotolithus* spp., Ariidae) are also heavily fished during this period.

Nature of the seabed

In the Loos Islands, we found general agreement between the fishermen participating in the study concerning the nature of the substrate and the positions of the various zones. This made it possible to construct a map of the nature of the seabed in this area. Fishermen identify three types of seabed around the Loos Islands (Fig. 3*a*). First, sandy seabeds take the form of (*i*) pure sand with a phenomenon known as "the river" ("ribakoui" in Soso) and comparable to underwater sand dunes, consisting of a large strip of pure, nonsilty sandbank about 10 m below the water surface, (*ii*) sand banks, and (*iii*) sandy seabeds. The second type is a mixture of sand and silt, known as "poto-poto". This mixture is divided into three classes: pure silt, sandy silt, and silty sand. Moreover, vernacular expressions describing the degree of "stickiness" of the poto-poto provide a continuous qualitative reflection of the sand–silt mixture. Rocky seabeds constitute the third type.

This set of classifications is compared with that proposed by Domain and Bah (1993). These authors also used a classification for sand and one for silt, expressed in lutite content. The cross-referencing of these two classifications led to the definition of five classes for the area studied (Fig. 3*b*), to which the classes recognized by the fishermen on the basis of sand and silt content can be related.

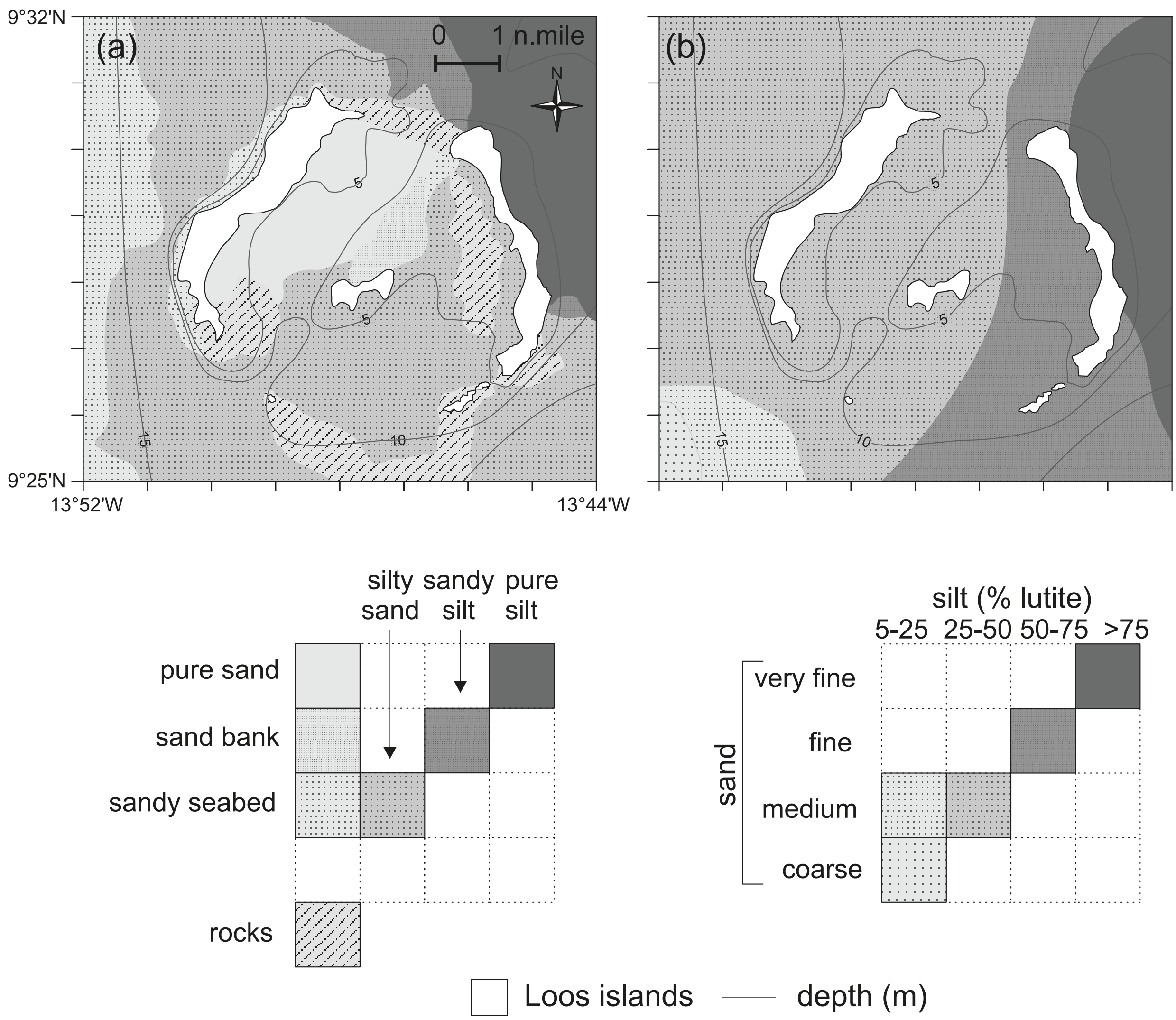
Good concordance was found between the seabed structures identified with the two approaches in the area studied. The main differences were the lower proportion of sandy silt identified by fishermen and the greater detail provided by fishermen overall. For example, rocks are also locally identified as grey or red rocks and generally divided into visible rocks and sunken rocks, which are themselves broken down into isolated rocks, rocky ridges, and highly rocky seabeds not shown on the map. In the estuarine area (second phase of the study), LEK also provided another vernacular classification of silt based on color and consistency: soft silt (bolbola), black silt (bora fore), red silt (bora gbéli), and whitish silt (bouibora or bora fikhè).

Seabed preferences (knowledge about biotopes)

In this field, the oldest fishermen with extensive experience of fishing tended to be the most knowledgeable. Fishermen clearly distinguished between different environmental characteristics. For example, according to the fishermen, *Pseudotolithus senegalensis* (bobo in Soso) hunts shrimps close to the coast on "hard" silts, whereas *Tilapia* sp. are encountered on white soft silts (borafikhè), where it hunts crabs. The abundance of the bonga shad depends on water dynamics (tide cycle), etc.

We reconstituted the biotic preferences of the various species from the data collected in the surveys and selected only those groups for which comparison with published results was possible (Table 2).

Fig. 3. Seabed map for the Loos Islands and correspondence between local ecological knowledge (LEK) and published knowledge. (*a*) Map constructed from the knowledge of local fishermen and confirmed with control samples. (*b*) Map constructed based on the general seabed map of the Guinean exclusive economic zone by Domain and Bah (1993). The seabed classification grid is the original key from this last source. Map (*a*) is constructed with a grid corresponding as closely as possible to that of map (*b*). 1 nautical mile = 1.852 km.



Knowledge concerning fish reproduction

Location of nurseries

Local fishermen acquire their knowledge of fish reproduction by catching juveniles and observing the physical state of mature fish (e.g., “if the fish isn’t pregnant it’s flat, with a dry skin. Its belly gets bigger during the laying period”, as stated by MS, a retired fisherman from Sakama) and fish morphology during processing operations. Through these observations, the fishermen localize the nurseries and determine the periods of maturation and egg laying. Fishermen precisely located current nurseries for two estuaries within the study (Fig. 4). For the Konkoure estuary (Fig. 4*a*), differences were observed between the two principal estuary arms, with *Pseudotolithus elongatus* widely distributed in the Konkoure arm, whereas the Soumba arm was mostly occupied by *Polydactylus quadrifilis* and *Arius* sp.

Again, in the Fatala estuary area (Fig. 4*b*), the fishermen indicated different distributions of juveniles and reproductive activity for different species between the arms of the estuary. These differences in distribution were particularly marked for *Pseudotolithus elongatus*, *Liza* sp., *Ethmalosa fimbriata* and *Arius* sp., which appeared to colonize different spatial niches. By contrast, a limited area in the northwest of the zone was found to contain a nursery for many species. The fishermen were unable to provide a meaningful interpretation for this situation.

Reproductive cycle

Fishermen identified periods during which mature adults migrated towards the laying zones and periods of juvenile recruitment. Interviews were conducted about the reproductive cycles of 11 species. However, comparison with available scientific data was possible only for the bonga shad within the Fatala estuary. For this species (Fig. 5), the two oldest fishermen interviewed about this topic (KS, aged 70, and MS, of unknown but probably similar age) provided considerable detail about reproduction (e.g., temporary vertical separation of

Table 2. Comparison of knowledge relating to preferences between local fishermen (A, B) and published results (c, d, e, f).

		Nature of the seabed (source)					
Latin name	Local name	Sand	Silt	Hard silt	Rock	Shells	Broad tolerance
Arius sp.	Konkoe	e	e	B	B	B	—
Ilisha africana	Lati	e	B, e	—	B	B	—
Lutjanus sp.	Woli	—	—	—	B, c, e	B	—
Pomadasys jubelini	Kessi kessi	c	A, c	B	B	B	f
Pseudotolithus brachygnathus	Fouta	A, c	c	B	—	B	—
Pseudotolithus elongatus	Bobo	—	B, d, e	—	B	—	—

Note: A, phase I of this study; B, phase II of this study; c, Schneider 1990; d, Diouf 1996; e, Domain et al. 2000; f, Sidibe 2003.

males and females, links between the period of reproduction and the rice harvesting season). These fishermen reported that mature females started to swim up the estuaries at the end of March, the eggs being laid in April and May. After egg-laying, the fry hatch and continue to develop and grow in the mangrove until October. They then migrate towards the estuaries, where fishing takes place from November to March. In March, the individuals not caught by the fishermen swim up the estuaries to complete the cycle. The period of reproduction described by old fishermen differs markedly from that described by Baran (1995) for the same area. This author showed that reproducers of this species were most abundant in September and October, whereas juveniles were most abundant from January to June. Reports of interviews with fishermen in the Fatala study area about observed areas of reproduction confirmed the calendar presented by the older fishermen, but with additional accounts for reproduction in September and October.

Knowledge concerning trophic relationships

Fish diets

Results of the stomach content analysis have been compared with the accounts of the fishermen for the species for which sufficient number of dissections were carried out (Fig. 6). Both sources of information indicated a high proportion of shrimp in the diets of fish from this ecosystem, the essentially piscivorous diet of the highest trophic level target species, the relatively low importance of molluscs in the diet of the fish, the selective diet of *Pseudotolithus elongatus*, and the omnivorous diet of *Drepane africana*.

For 12 of the 70 cells (17%), the analytical results did not agree with the fishermen's declarations: the consumption of molluscs by *Polydactylus quadrifilis* and of benthos by *Pseudotolithus brachygnatus* and *Pseudotolithus typus* or the omnivorous diet of sea catfish (*Arius* sp.). Similarly, fishermen reported the consumption of benthic moss and worms, whereas these food items were not found by analysis of fish stomach contents. Fishermen did not identify a benthophagic diet for *Drepane africana*, whereas such a diet was observed in stomach analyses.

Finally, single accounts were excluded as a result of the protocol used (e.g., the extreme example of a fisherman reporting the presence of a bird in the stomach of a ray, possibly as a result of the ingestion of a dead chick that fell into the mangrove from a tree). Some of the single observations filled in known gaps in our knowledge but were nonetheless not included in this analysis.

Trophic network

In addition to food intake, the fishermen effectively identified the relationships between the feeding habits of the various biological groups and explicitly reconstituted trophic networks. The trophic network constructed from the fishermen's accounts could be compared (Fig. 7) with the equivalent scientific results obtained by Guénette and Diallo (2004*a*, 2004*b*).

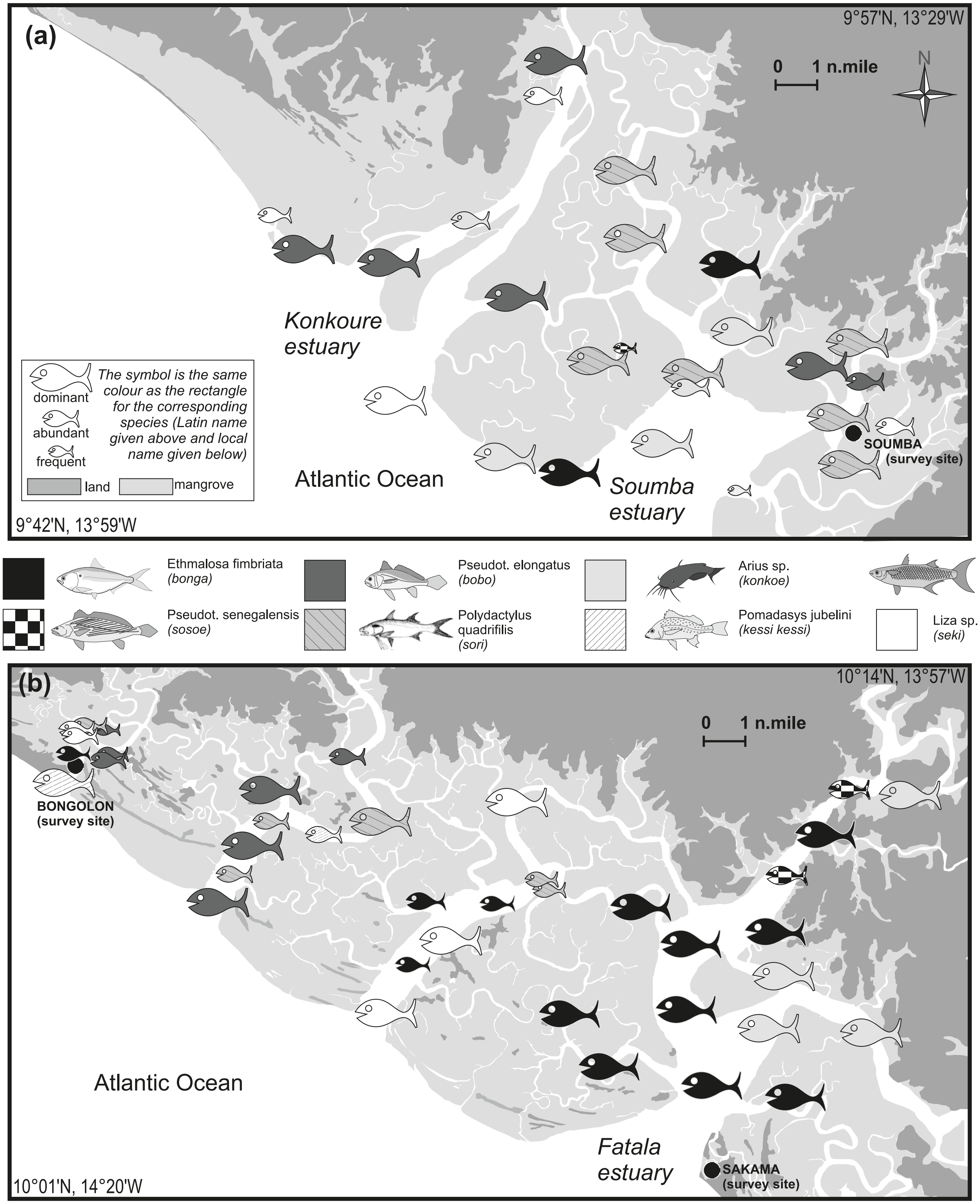
The fishermen identified five categories–levels, differing from standard trophic webs. For comparison purposes, we used the Ecopath scale as a reference similar to that of Lindeman (1942 in Gascuel 2005), with a trophic levels of 1 for primary producers and debris, 2 for secondary producers, 3 for their predators, and a maximum trophic level of 4 to cover top predators.

The fishermen did not consider debris and primary producers to be part of the trophic network. Hence, these elements were coded as level 0 (Fig. 7). In the fishermen's opinion, level I corresponds to organisms (crabs and shrimp) feeding exclusively on the primary substrate consisting of plant debris and silt. This level comprises principally detritus feeders and seems to be similar to reference trophic level 2. Fishermen's trophic level II comprises species feeding on both the organic substrate and individuals at the first level in the food chain. It therefore includes a mixture of detritus eaters and carnivores. This level seems to be intermediate between levels 2 and 3 of the Ecopath classification. Fishermen's trophic level III corresponds to rays and giant African threadfin (*Polydactylus quadrifilis*), which feed on the lower trophic levels. Level IV corresponds to sea catfish (Ariidae), a group of full omnivores. These fish are said to feed on both the elements of the primary substrate and individuals from levels I and II. Finally, level V corresponds to strictly piscivorous fish, such as sharks. These last animals do not feed, in principle, on organisms below level II.

Discussion

The use of two protocols to explore a wide range of topics resulted in the convergence of LEK toward limited but exploitable information about the Sciaenid community, of potential use for the development of an EAF. Conclusive results were obtained about the successive seasonal phases, habitat location, the seabed preferences of groups of species, and the location of nursery areas in the mangroves and estuaries. Fishermen also displayed usable knowledge about the diets of the various species and trophic relationships within

Fig. 4. Location of nursery areas in (*a*) the Konkoure estuary by the fishermen of Soumba (inset "*j*" of Fig. 1), (*b*) the Fatala estuary by fishermen from Bongolon and Sakama (inset "*k*" of Fig. 1). 1 nautical mile = 1.852 km.



the fish assemblage. Some potentially useful information, such as the timing of reproductive periods, could not be used without complementary research, because the information provided by the fishermen conflicted with the findings of scientific studies.

We focus here on three topics to assess the validity of the information obtained: the biases associated with the approach used, the factors increasing confidence in various types of knowledge, and a comparison of the reliability of LEK and scientific knowledge.

Fig. 5. Differences between scientific and local knowledge concerning the reproduction cycle of the bonga shad in the Fatala estuary. (*a*) Baran (1995) bimestrially estimated frequencies (adapted from the original). (*b*) Qualitative synthesis of the narratives of the oldest fishermen from Sakama. When fishermen described a migration or trend, their accounts were transposed into a progressive decrease or increase; bars indicate observed reproduction spots described by fishermen at the Bongolon and Sakama survey sites. In both panels, dark gray shading is for reproducers, and light gray shading is for juveniles.

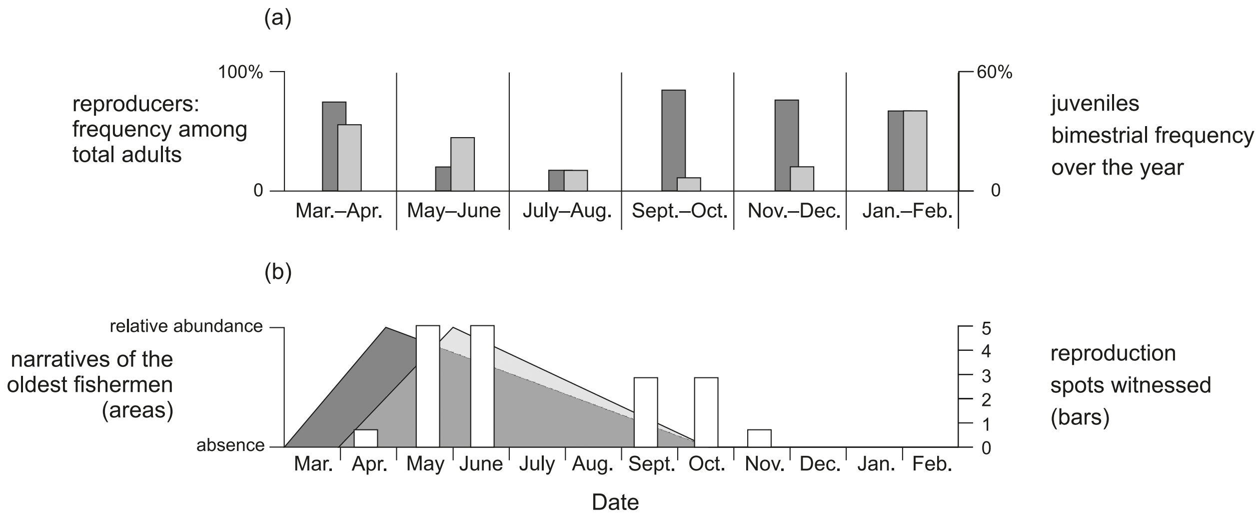
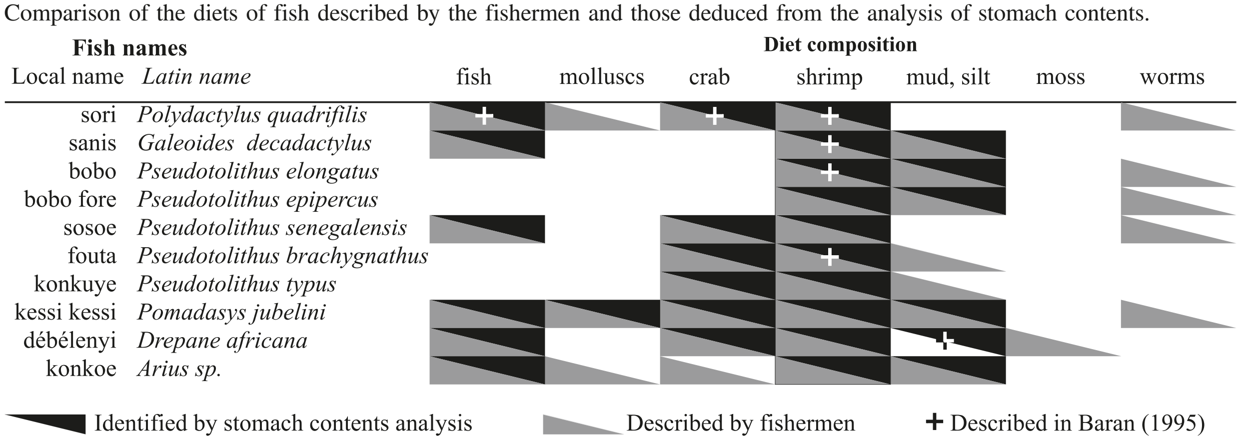
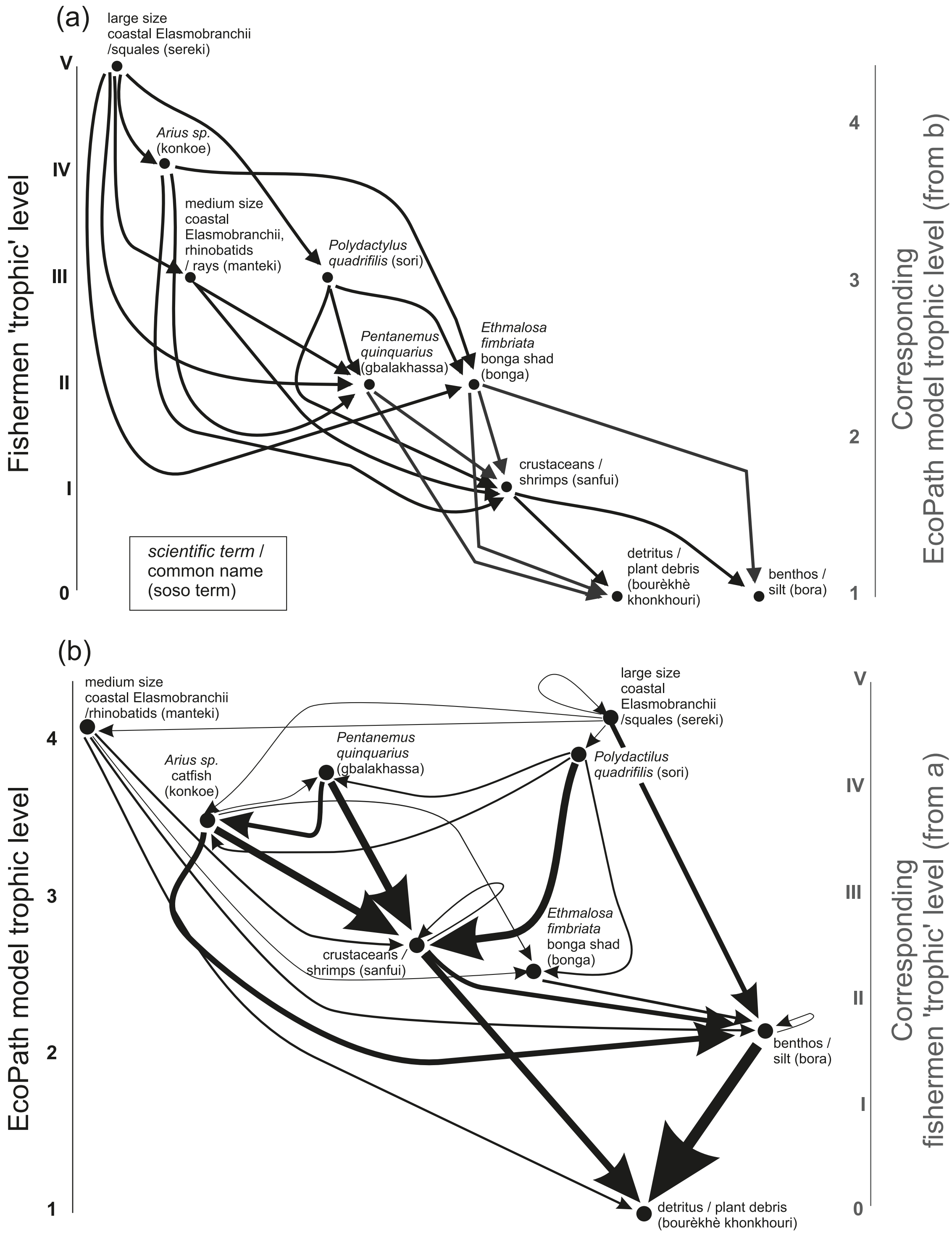


Fig. 6. Comparison of the diets of fish described by the fishermen and those deduced from the analysis of stomach contents.



A key characteristic of the LEK approach is that knowledge was not obtained by direct data sampling but by using fishermen's reports, which, even if recorded in a standard way, may still be biased. One potential source of discrepancy was the differences in language used by the respondents. For example, "grand capitaine" is the name given to *Polydactylus quadrifilis* by fishermen of the Soso ethnic group, whereas this same name is used by fishermen from Sierra Leone within the same port to designate *Pseudotolithus brachygnatus*. Subtleties of this kind may not be always picked up during interviews or in subsequent analyses. Furthermore, the success of interviews may be enhanced by the quality and skills of the translators or other intermediaries (see Materials and methods), but the need for translation nonetheless represents an additional step (between experience and "knowledge") and is a possible source of imprecision in the knowledge retrieved. The selected set of fishermen interviewed may also be a source of bias in the quality of the knowledge provided (Davis and Wagner 2003; Silvano and Begossi 2005), given the diverse status, specialization, and experience (Johannes et al. 2000; Grant and Berkes 2007) of the fishermen. We tried to minimize the impact of this bias by working with a broad range of individuals in various locations and then compiling the results obtained. However, it is difficult to determine whether working with another set of fishermen would have generated similar results. An example was provided by the study of species diets; overall, fishermen did not report the partly benthophagic diet of *Drepane africana*, whereas stomach analyses confirmed this diet, also reported by Baran (1995) and Diouf (1996) in Senegal. Another set of fishermen might have mentioned this feeding behavior. The use of a sampling saturation strategy (Davis and Wagner 2003), in which increasing numbers of fishermen are interviewed until no new substantial information is obtained, might help to overcome problems relating to this type of inaccuracy. However, this would require a much greater effort (Davis and Wagner 2003). Moreover, in this study we explored a wide range of subjects within various interview situations, such as the diversity of the periods in which meetings occurred, seasons, authority relationships within the groups interviewed, and the fishermen's personalities and their feelings about the survey (Ames 2007). This context generates an undetermined level of variability. These sources of inaccuracy may be difficult to avoid, making it

Fig. 7. Comparison of the trophic network reconstituted on the basis of (*a*) local ecological knowledge and (*b*) an Ecopath modeling approach (Guénette and Diallo 2004*a*, 2004*b*) for the species described by the fishermen. The thickness of the arrows in network *b* is proportional to the contribution of the relationship to the diet of the predator. The *y* axis on the right is the reported scale of the alternative figure for sake of comparison; the horizontal scale is arbitrary.



harder to demonstrate quantified validity. Hence, in most cases, the domain of validity of the knowledge obtained was difficult to assess and the use of a qualitative "level of confidence" for each type of knowledge might give a more accurate evaluation of LEK

Based on the observations made within this study and in previous work, we identified two factors associated with a higher level of confidence in a given piece of information. First, knowledge directly related to fishing success appeared to be more reliable, because the acquisition of such knowl-

Table 3. Qualitative summary of the comparison between local ecological knowledge (LEK) and scientific knowledge for the topics studied.

	Ecology			Fish reproduction		Trophic relationships	
LEK compared with scientific knowledge	Ecological segmentation of the year	Seabed habitats	Edaphic preferences – biotopes	Nursery localization	Reproductive cycle	Fish diets	Trophic network
Overall agreement	–	+	+	–	–	+	+
Overall discrepancy	–	–	–	–	+	–	–
Only tractable by means of LEK	–	–	–	+	–	–	–
Provides complementary insight	+	–	–	–	–	–	–

Note: Four main situations can be identified that were (+) or were not (–) observed within the study.

edge is essential for successful fishing practice (Symes 2008). For example, the fishermen had extensive knowledge of each type of seabed, because this knowledge is an essential determinant of the type of fishing gear to be used and provides information about the type of resource present. Knowledge associated with repeated observations was also considered to increase the level of confidence (Williams and Bax 2007). Repeatability may be established through the existence of a large number of accounts of the same phenomenon, such as the identification of seasons, or may relate to recurrent practices. This is the case for the continuous comparison of catches with habitats that provides fishermen with knowledge of the preferences of the different groups of fish or the identification of diets through the repeated gutting of fish during the processing of catches. In this study, all the results presented correspond to knowledge amassed from repeated observations.

The systematic comparison of LEK with scientific knowledge gave an estimate of the reliability of LEK, particularly concerning the possible use of LEK as a knowledge source within an EAF. Several different situations were observed (Table 3).

An overall comparison was possible for most of the issues studied, but with differences in the degree of agreement obtained. Knowledge about fish diets appeared to be a straightforward case, with the possibility of an almost quantitative comparison (more than 80% concordance was observed between the two sources). It should be stressed that diet is highly variable and dependent on food availability and that much larger sample sizes would have been required to describe the diet of a particular species accurately. Nevertheless, discrepancies were found between the two data sources. On the one hand, the benthic diet of *Drepane africana* was confirmed by three scientific sources but not reported by fishermen. On the other hand, mollusks and crabs were not found in the diet of *Arius* sp., whereas fishermen were well aware of the opportunistic omnivorous nature of the Ariidae family (analyses showed the presence of miscellaneous wood and plastic objects in the stomachs of these voracious sea catfish).

Overall comparison was partly successful for species biotopes. In this case, differences can be observed in the knowledge recorded between different published studies, between published studies and the traditional knowledge of fishermen, and between phases I and II. When differences are identified between the sources of knowledge, we have no appropriate criteria for determining which sources are the most reliable or a threshold separating reliable and unreliable sources, because the observed habitat differences may be due to the great ecophysiological, reproductive, and dietary plasticity of these taxonomic groups (Baran 1995).

The information for seabed habitats was found to be concordant after reclassification of the seabed types identified by fishermen and in scientific approaches. This brings us back to the general agreement (Aswani and Lauer 2006; Ames 2007; Williams and Bax 2007) that LEK constitutes a rewarding source of knowledge for issues relating to seabed mapping. In the present case, LEK provided greater local detail than scientific survey of Domain and Bah (1993), which was constrained by low-resolution sampling; the scientific classification was established for the broad scale of the Guinean continental shelf, and the area studied is only part of this larger region. Other differences may be linked to differences in the intensity of sampling of the two approaches; only three samples were obtained in this area during the oceanographic transects leading to the construction of the scientific map. In this case, in accordance with the work of Huntington et al. (2004), these two results may be considered to provide complementary knowledge at two different scales.

Conversely, the comparison of the trophic networks obtained revealed that the Ecopath approach provided more details than LEK for trophic networks, because of inclusion of the relative strengths of the trophic relationships identified. Within the comparison, several other methodological features also differ between the two sources. The relationships described by the fishermen concerned the food actually ingested, whereas the Ecopath trophic level is an indirect indicator based on estimates of biomass transfer between levels (Christensen and Walters 2004; Gascuel 2005). As for seabed description, the LEK observation scale also differed from that used in scientific studies; Guénette and Diallo (2004*a*, 2004*b*) studied the entire EEZ, whereas fishermen described different local networks, sometimes even between estuaries. Differences in results were also found between the fishermen's perceptions and the modeling results. For example, the fishermen did not mention the importance of the benthos–debris relationship or the contribution of benthos. Self-predation relationships were also not recognized (or at least expressed) by fishermen. In the Ecopath model, the trophic relationships of the bonga shad were reduced exclusively to benthos consumption. By contrast, the fishermen considered this species to be a potential predator, particularly of shrimps. *Pentanemus quinquarius* was also identified as a high-level predator within the Ecopath model, whereas the fishermen considered it to be chiefly preyed upon. The fishermen also considered distinct "trophic levels" for the two types of Elasmobranchii: top level V for sharks and level III for smaller Rhinobatids. In all these cases, only partial agreement was obtained. However, the two sources appeared to give similar levels of knowledge with a certain number of major traits in common, including the diverse diet of Elasmobranchii, the predominance of shrimp as the principal food source in this food web, and the diversity of relationships between groups, most of which were identical for both approaches. The indicated differences did not reflect discrepancies in knowledge. Instead, they mostly reflected local conditions or the complementary nature of scientific and fishermen's knowledge.

In other cases, such as for the reproductive cycle of the bonga shad, discrepancies were found among the various sources of knowledge. There is a wide variability of the reproduction parameters described for this species (Charles-Dominique 1982), and differences have been observed between parts of a given estuary (Baran 1995). We therefore could not determine which piece of knowledge was valid. On the one hand, according to the approach of Maurstad et al. (2007), the descriptions of the reproductive cycle provided by fishermen for this particular species appear to be reliable, detailed narratives. These descriptions are also strongly supported by the extensive experience of the oldest fishermen concerning fish reproduction (Silvano et al. 2006). On the other hand the results presented by Baran (1995) were obtained by thorough analysis of bimestrial net sampling over a 1-year period. Such situations, with conflicting results, have been previously described (Johannes et al. 2000; Maurstad et al. 2007; Silvano and Begossi 2010). Johannes and Neis (2007) in particular reported a similar situation of wide discrepancies concerning the reproduction of barramundi (*Lates calcarifer*), for which further studies confirmed both sources of knowledge. However, in our case, no complementary study was available, and it was not possible to identify the threshold between accurate and incorrect knowledge.

In yet other situations, it was difficult to acquire knowledge or information through scientific studies. Indeed, the continuous activity and ubiquitous distribution of small-scale fishermen along the coastline results in a collective observation force (Williams and Bax 2007), well in excess of the likely provisions of an equivalent scientific protocol, in terms of both frequency and scope (Bergmann et al. 2007; García-Allut et al. 2007; Rochet et al. 2008). Repeatability greatly strengthens the contribution of LEK to EAF. This was the case for nursery localization; the identification of nurseries by scientific methods would require expensive detailed monitoring of multiple areas over a long period of time (Poizat and Baran 1997). However, fishermen were able, collectively, to develop maps of nursery locations including specific details for each estuary, and this knowledge may be crucial in the establishment of protected areas, for example, particularly for determining their location and size, to maximize conservation, biodiversity, and fishery benefits (Kupschus 2003; Browman and Stergiou 2004). Hence, this unique possibility to downscale argues for collaboration between scientists and fishermen in the design of future surveys.

The diverse set of standpoints (Table 3) reflects the diversity of contexts and issues linked to the use of LEK: substitutable, conflicting with its scientific equivalent, or with no scientific equivalent. Hence, there seems to be no set of common rules for the use of LEK, but different situations indicate that LEK should be used on a case-by-case basis, in each specific field of knowledge. This diversity of situations has been described before (Silvano and Valbo-Jørgensen 2008) and leads to different likelihood estimates of LEK. Based on the results of this study, for example, LEK could complement scientific studies (seabed description), be used as a source of new scientific investigation (bonga reproductive cycle), be considered as the only source of information (nursery location), could substitute for scientific surveys provided that the level of validity is identical (fish diets), or constitute a satisfactory proxy (trophic web).

Beyond addressing specific questions, LEK, as a single source of information, seems to address all the different dimensions (ecology, fish reproduction, trophic relationships) of ecosystem functioning simultaneously. The ecological segmentation of the year described by fishermen illustrates this well, with fishermen classifying the seasons more on the basis of ecological and local conditions than according to universal (spring–summer–autumn–winter) or regional (dry season – wet season) "climatic" classifications. Indeed, fishermen identified a set of criteria directly related to the seasonal clocks of the resources exploited (movements, abundances, arrivals, departures, replacements of taxonomic groups, weather). This indicates that they make use of a coherent synthesis of all the elements in a single scheme. This holistic approach has been reported before, in more general (Berkes et al. 2007; Symes 2008) or specific situations, such as the description of water characteristics (Barthélémy 2005) or traditional ecosystem resource knowledge and management (Poepoe et al. 2007). Going beyond case-by-case use, the fishermen's knowledge could therefore be considered as providing a complete functional description of the local ecosystem exploited. The differences in classification, insight, and viewpoints with respect to scientific studies (Moller et al. 2004; Berkes et al. 2007; this study) could indeed result in a complementary fishermen's "theory", paradigm (Ames 2007), or cosmology (Houde 2007) of marine resources and environment. This globally different insight could then constitute a complementary grid for ecosystem analysis, and understanding that it would be worthwhile to characterize further.

In developing countries lacking data and resources, such as the republic of Guinea, several authors have highlighted the practical relevance of LEK for obtaining knowledge (Johannes 1998; Silvano and Begossi 2010), particularly in the context of operational EAF, in which the cost of obtaining knowledge is an important argument (Cury et al. 2005; Garcia and Cochrane 2005). LEK could help to provide answers to questions relating to the identification of sensitive areas in terms of ecosystem productivity (Aswani and Hamilton 2004; Aswani and Lauer 2006), for which diverse knowledge along the entire coast must be obtained. The use of LEK may therefore be worth considering, not so much to guide management actions, although this use is possible (Silvano and Begossi 2010), but as a source of critical knowledge in areas in which it costs too much to carry out scientific studies (Maurstad et al. 2007). It would be possible to implement this approach by intensifying the two-way links between researchers and other actors, involving both mutual information acquisition and bidirectional structures (links) for communicating existing knowledge (Le Fur et al. 2002).

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