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When does this fish spawn? Fishermen's local knowledge of migration and reproduction of Brazilian coastal fishes

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Abstract Fishermen's local knowledge of fishing resources may be an important source of information to improve artisanal tropical fisheries management, such as those found in Brazil, where most data on fish biology is lacking. We aim to study the local ecological knowledge that Brazilian coastal fishers have about reproductive aspects (season, places and migration) of 13 coastal fish species of commercial importance. We selected fishermen with more than 30 years of fishing practice and we interviewed a total of 67 fishermen: 29 from the southeastern coast, from the communities of Puruba, Almada, Picinguaba and Bertioga, and 38 from the northeastern coast, from the communities of Valença, Arembepe and Porto Sauípe. In the interviews, we used standardized questionnaires and showed photos of fish species. Our results indicate some general patterns in fishes' reproduction according to fishermen knowledge: fish species spawn in open ocean, near reefs or in coastal rivers (estuaries); some fishes reproduce during the summer and others in winter, while some have more defined spawning months. The main fish migratory patterns mentioned by interviewees were: long migrations along the coast, usually in the South to North direction, short migrations among reefs, fishes that do not migrate, migrations between the shore and open ocean and migrations between the sea and coastal rivers. Fishermen's knowledge differed among fish species: most fishermen did not know spawning places or seasons of large pelagic fishes, which raised concerns of their possible depletion. We compared such ethnoichthyological information with available scientific data, indicating promising insights about reproduction and migration of Brazilian coastal fishes. Data gathered from local fishermen may provide inexpensive and prompt information, potentially applicable to fisheries management. Our approach might be useful to several other small-scale fisheries, especially the tropical ones, where there is a high diversity of target species and a low biological and ecological knowledge about these species.

Keywords Fishery management · Marine fishes · Ethnoichthyology · Fish reproduction · Fish migration

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Introduction

Human communities that depend upon natural resources show often a detailed knowledge of the biology and ecology of plants and animals (Gadgil et al. 1993; Berkes 1999; Diamond 2005). Ethnobiology is the scientific discipline dedicated to the study of such local ecological knowledge (Berlin 1992; Berkes 1999). Albeit one of the first surveys analyzing local ecological knowledge of Caribbean fishers about marine fishes was published about 40 years ago (Morril 1967), it was only recently that the potential contribution of this kind of survey to advance fisheries science has been widely recognized (Huntington 2000; Johannes et al. 2000; Haggan et al. 2003; Drew 2005; Mathooko 2005). Indeed, studies recording and analyzing fishers' LEK have been useful to better understand local fishing practices and customary or common management rules (Johannes 1978, 2002; Berkes 1999), to gather new biological information about fish ecological aspects, such as migration, feeding habits and reproduction (Johannes 1981, 1988; Johannes et al. 2000; Valbo-Jorgensen and Poulsen 2001; Silvano and Begossi 2002, 2005), to improve impact assessments (Johannes 1993) and to aid in marine conservation (Roberts et al. 2003; Drew 2005), among other applications. Furthermore, fishers' LEK may compliment conventional biological surveys, by improving research design (Poizat and Baran 1997), by providing more refined and locally based data (Aswani and Hamilton 2004; Huntington et al. 2004), and by revealing past abundance trends in the population of exploited fishes, from before conventional fish landing data started to be recorded (Pauly 1995; Sáenz-Arroyo et al. 2005). Fishermen's knowledge of fishing resources is especially important to support fisheries management in developing tropical countries, due to the lack of research and biological data on exploited fishing resources in a local or regional scale (Johannes 1998; Johannes et al. 2000; Drew 2005; Mathooko 2005). Unfortunately, fishermen's LEK has been often overlooked or dismissed by biologists (Johannes 1993; Huntington 2000). Such resistance to consider fishermen's LEK and points of view might be harmful to fisheries management, especially in the context of complex, poorly known tropical fisheries (Johannes et al. 2000; Mathooko 2005). On the other hand, the researcher should not to take fishermen's LEK without checking (Huntington 2000). Ethnobiological surveys bring the methodological and conceptual tools to ''translate'' fishermen's knowledge, providing useful, and often new, information and guidelines to the related disciplines of fish biology and fisheries, and aiding to devise a multidisciplinary approach to marine conservation (Drew 2005).

Notwithstanding its high relevance to fisheries management, reproductive patterns of tropical marine fishes are still poorly known, mainly due to the difficulties involved in studying marine fish reproduction (Sadovy 1996). Fishermen usually exploit fish schools (Parrish 1999) and fish spawning aggregations (Coleman et al. 1996), and fishermen's knowledge about spawning patterns and migratory behavior of marine fishes has advanced biological research (Johannes 1981; Johannes et al. 2000). Nevertheless, fishermen's knowledge usually deals with local processes (Degnbol 2005), which may reduce its efficacy to reveal general biological patterns of fishes, especially for those with a wide geographical distribution. However, such general patterns can be addressed by a comparative approach, which integrates results of standardized surveys conducted in two or more fishing communities, located along the distributional range of a fish species or a fish community (Valbo-Jorgensen and Poulsen 2001; Silvano and Begossi 2005).

Brazilian artisanal coastal fishermen are low-income people and usually they show a weak political organization (Diegues 1999), often being neglected in official management measures (Begossi and Brown 2003). Although these fishermen have developed a detailed knowledge of the classification and the ecology of marine and estuarine fishes (Cordell 1974; Marques 1991; Begossi and Figueiredo 1995; Paz and Begossi 1996; Silvano and Begossi 2005), most of the published surveys do not address in detail potential applications of local knowledge in fisheries management. Coastal fisheries management in Brazil is restricted to few and relatively inflexible broad rules, due in part to a lack of data on the biology and ecology of target fishes. Indeed, most of the available data about reproduction of Brazilian marine fishes are in scattered reports, dissertations and surveys (some with data collected as much as 40 years ago), usually published in local or regional journals with narrow circulation (Almeida 1965; Sadowski and Dias 1986).

The main goal of this paper is to analyze local ecological knowledge on reproduction and migration of 13 marine and estuarine fishes, through interviews with experienced fishermen in seven artisanal fishing communities along the southeastern and northeastern Brazilian coasts. We also compare fishermen's knowledge with available biological data from the ichthyological literature, to propose insights that could improve our current biological and ecological knowledge and contribute to fisheries management. The results of this study may also be applicable to similar sites where these fishes also occur, especially when broad patterns in migration and reproduction of the studied coastal fishes are observed.

Materials and methods

Study sites

We studied seven artisanal fishing communities, four in the North of São Paulo State, southeastern Brazilian coast, and three in the North of Bahia State, northeastern Brazilian coast (Fig. 1, Table 1). These study sites and fishing communities were selected because of the lack of detailed ethnoichthyological surveys in these areas, compared to other coastal areas in southeastern and northeastern Brazil (Marques 1991; Begossi and Figueiredo 1995). We also selected the studied regions according to logistic and opportunistic advantages: these sites have been the focus of other research projects and the fishing communities of Arembepe and Valença were already addressed in previous surveys (Kottak 1967; Cordell 1974).

On the northeastern coast of Bahia, the artisanal fishermen exploit lobster, shrimp and fishes

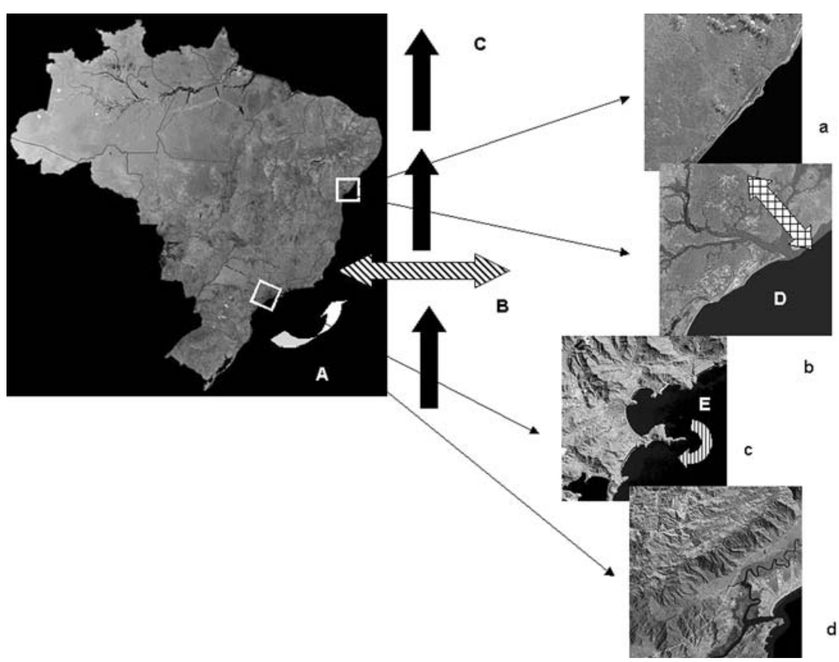

Fig. 1 Map of Brazilian coast showing the studied sites (**a**) Arembepe, (**b**) Valença, (**c**) Ubatuba region, where are located the fishing communities of Almada, Puruba and Picinguaba and (**d**) Bertioga. Main migratory patterns mentioned by fishermen (Table 4) are illustrated: (A) migration along the coast (not long distances), (B) migration between the shore and open ocean, (C) long migration from South to North direction, (D) migration between the sea and coastal rivers and (E) short migration around nearby reefs. Source of maps: E.E. De Miranda & A.C. Coutinho. Brasil Visto do Espaço. Campinas: Embrapa Monitoramento por Satélite, 2004

Table 1 Fish species addressed in this survey, with the most mentioned common names and total number of interviewed fishermen, for each fish species and fishing community

Fishes	Fishing communities, Bahia coast			Fishing communities, São Paulo coast				Total of interviewees		
	Arembepe	Valença	Porto Saupe	Almada	Picinguaba	Puruba	Bertioga	BA	SP	All
Caranx spp.[a]	Guaricema	Xumberga	Guaricema	Olhudo	Olhudo	Carapau	Xaréu	38	29	67
Centropomus parallelus	Robalo	Robalo	Robalo	Robalo	Robalo	Robalo peva	Robalo	38	29	67
Cynoscion jamaicensis	Pescada	Pescada						23		23
Epinephelus marginatus	Garoupa	Garoupa [d]		Garoupa	Garoupa	Garoupa	Garoupa	23	29	52
Euthynnus alleteratus				Bonito	Bonito	Serrinha[e]	Bonito		29	29
Lutjanus synagris	Ariocó	Cioba	Ariocó					38		38
Micropogonias furnieri				Corvina	Corvina	Corvina	Corvina		29	29
Mugil platanus	Tainha	Tainha		Tainha	Tainha	Tainha	Tainha	23	29	52
Mycteroperca acutirostris	Badejo	Badejo	Badejo	Badejo	Badejo	Badejo mira	Miracelo	38	29	67
Pomatomus saltatrix	Enchova	Enchova		Enchova	Enchova	Enchova	Enchova	23	29	52
Scomberomorus brasiliensis	Cavala[b]	Cavala	Cavala					38		38
Seriola lalandi	Enchova[c]	Olhete	Enchova					38		38
Trichiurus lepturus				Espada	Espada	Espada	Espada		29	29
Number of interviewees	13	10	15	10	7	4	8	38	29	67

When more than one name to a fish species was frequently cited in a given fishing community, alternative names are mentioned in footnotes. BA = Bahia, northeastern Brazilian coast, SP = São Paulo coast, southeastern Brazilian coast

[a]Two fish species from the same genus were used in the survey: *Caranx latus* in São Paulo fishing communities and *Caranx crysos* in Bahia fishing communities. We grouped the two for analysis, as they belong to same genus and are similar in appearance

[b]Also called "Sororoca"

[c]Also called "Olho de Boi"

[d]Also called "Badejo"

[e]Also called "Bonito serrinha"

in reefs, open sea and estuaries, usually with small boats and using several types of fishing gear, some of which are typical, such as the 'calão', a kind of seine net used to catch shrimp and small fishes (Cordell 1974). There are also large-scale fisheries equipped with large boats and a crew of several fishermen (up to 15), which go fishing over large distances for several days at sea. In Bahia, such fishing is usually done with hook and line, targeting pelagic fishes (mainly Scombridae and Carangidae) and reef fishes (mainly Lutjanidae and Serranidae), which are also exploited by artisanal small-scale fishermen (Ivo and Hanson 1982). Artisanal fishermen often work as a crew on large fishing vessels.

On the southeastern Brazilian coast, artisanal fishermen are the caiçaras, inhabitants of areas with Atlantic Forest remnants, who rely mostly on coastal fisheries as a source of food and cash and who descend from indigenous Brazilians and Portuguese colonizers (Begossi 1998; Diegues 1999). Fish is the main protein source for caiçara fishermen, who use mainly gillnet and hook and line to catch fishes (mainly Pomatomidae, Serranidae, Mugilidae, Sciaenidae, Centropomidae and Carangidae), shrimps and squids (Begossi 1996). Caiçara fishing communities have been facing difficulties and conflicts, such as an increase in tourism and competition with large-scale commercial fishing vessels. Brazilian governmental environmental agencies, besides being ineffective in dealing with these problems, have been constraining the caiçaras' subsistence and small-scale fishing activities (Begossi 1995; Begossi et al. 2001).

Data collecting and analysis

In each studied fishing community, we interviewed selected fishermen according to the following criteria: those who fish as their main economic activity (active or retired), and who have at least 30 years of fishing practice in the studied region. We thus analyzed a restricted sample of more experienced fishermen, whom we found based on data from previous surveys and interviews. We used such an approach because previous ethnoichthyological surveys show that older fishermen are usually more knowledgeable about fish reproduction and migration (Silvano and Begossi 2002). Indeed, local knowledge may be unevenly distributed among fishermen and selecting appropriate informants is an important step in gathering useful information (Johannes et al. 2000).

We interviewed fishermen using standardized questionnaires with the questions: Where and when does this fish spawn? Does this fish migrate ('run')? When, and to where (migratory routes)? We showed fish species to fishermen as color photographs, in the same order for each interviewee. Details of this interviewing methodology are in other surveys (Silvano and Begossi 2002, 2005). We selected 13 coastal fish species for this survey (Table 1), in order to include representatives of the most important fish groups often caught by these artisanal fishermen in several aquatic habitats: reef fishes from the Lutjanidae (*Lutjanus synagris*) and Serranidae (*Epinephelus marginatus*, *Mycteroperca acutirostris*), estuarine fishes from the Mugilidae (*Mugil platanus*) and Centropomidae (*Centropomus parallelus*), demersal fishes from Sciaenidae (*Cynoscion jamaicensis, Micropogonias furnieri*) and pelagic fishes from the Carangidae (*Caranx crysos*, *C. latus, Seriola lalandi*), Pomatomidae (*Pomatomus saltatrix*), Trichiuridae (*Trichiurus lepturus*) and Scombridae (*Euthynnus alleteratus, Scomberomorus brasiliensis*). We made the surveys during July 2003 (Arembepe and Valença, Bahia), August 2004 (all São Paulo fishing communities) and January 2005 (Porto Sauípe, Bahia). The number of interviewed fishermen varied for each fish species, as some fish species were addressed in some fishing communities but not in others (Table 1), due to differences in abundance and commercial importance of fishes among studied fishing communities. We also reduced the number of fish species in some communities in order to optimize our sampling effort and time spent during interviews. However, we included some fish species in all surveys (Table 1). We interviewed fishermen about *Caranx latus* in the Southeast and about *C. crysos* in the Northeast. This was due to possible differences in abundance and commercial importance of these fishes between the two regions, and because we intended to compare our results with previous surveys

Table 2 Spatial and temporal patterns of spawning of coastal fishes, numbers are % of interviewees who mentioned each data

Time and place of spawning[b]	Fish species[a]												
	Cspp	*Cpar*	*Cjam*	*Emar*	*Eall*	*Lsyn*	*Mfur*	*Mpla*	*Macu*	*Psal*	*Sbra*	*Slal*	*Tlep*
Don' t know where	48	21	65	40	55	39	24	15	39	52	42	66	41
Reefs	10	3		31		18		2	37	6	3	3	
Reef's crevices		1		8	14	5			10				
Rivers (estuary)		43*						38		2			3
Rivers' mouth		4					3	6		2			
Submerged logs in the river		7						8	1				
Open sea, offshore	15	1			28	*	38**	10**	1	8*	3	3	41*
Mud bottoms	3					8	3				3		
Patos' Lagoon (South Brazil)[c]	1				3			19		2			
Brazilian southern coast	3				3			23		15			
Inshore, coastal waters	1	3		2	3		14						7
Offshore rocky outcrops ("parcéis")				4	3		7		3	4			
Coastal sandy beaches		3					14	2		2			3
Islands	3			2	7		3**			4			10
Do not know when	6	28	65	54	41	39	10	13	54	54	34	63	31
Summer	9**	1	9	12*	34**	3**	21	6	7	2**	2**	5*	14*
Winter	4	6*	4	4		13	10**	8**	6*	8	8	5	10
Spring							**	**	*		**		*
Autumn									*				
Year round	3	3*	4	4	7		14	4	7			3	24
Total number of interviewees	67	67	23	52	29	38	29	52	67	52	38	38	29

Information gathered from scientific literature are marked ** for the same species in the study regions and * for other related species or the same species in other regions from Brazil or elsewhere

[a]Codes for fish species (Table 1): Cspp (*Caranx* spp.), Cpar (*C. parallelus*), Cjam,(*C. jamaicensis*), Emar (*E. marginatus*), Eall (*E. alleteratus*), Lsyn (*L. synagris*), Mfur (*M. furnieri*), Mpla (*M. platanus*), Macu (*M. acutirostris*), Psal (*P. saltatrix*), Sbra (*S. brasiliensis*), Slal (*S. lalandi*), Tlep (*T. lepturus*).

[b]Literature sources to reproduction and migration of studied fishes: Almeida (1965), Ivo and Hanson (1982), Sadowski and Dias (1986), Fonteles-Filho and Ferreira (1987), Vazzoler (1991), Vieira and Scalabrin (1991), Ibagy and Sinque (1995), Haimovici and Krug (1992, 1996), Juanes et al. (1996), Muelbert and Sinque (1996), Martins and Haimovici (1997), Gillanders et al. (1999), Aliaume et al. (2000), Romagosa et al. (2000), Andrade et al. (2003), Barreiros et al. (2004), Teixeira et al. (2004)

[c]This spawning ground was only mentioned by southeastern fishermen

made in the Southeast. We aggregated the answers about these two fish species for analysis, considering their overall similarity and taxonomic relatedness (same genus) (Table 1). Furthermore, answers given by northeastern and southeastern fishermen about these two fish species did not differ regarding their main characteristics, such as whether they migrate or not ($\chi^2 = 1.56$, d.f. = 1, $P = 0.26$), main patterns ($\chi^2 = 7.87$, d.f. = 3, $P = 0.05$) and seasons ($\chi^2 = 5.11$, d.f. = 3, $P = 0.16$) of migration, or main sites ($\chi^2 = 5.85$, d.f. = 2, $P = 0.05$) and seasons ($\chi^2 = 5.65$, d.f. = 3, $P = 0.13$) of spawning.

Whenever sample sizes (number of fishermen's citations) allowed, we compared fishermen's answers about some general migratory and reproductive characteristics of fish species through chi-square tests, using the number of interviewees' citations (Fowler and Cohen 1990). Although sometimes the same fisherman mentioned more than one feature for the same fish species (e.g. spawning both in winter and summer), we considered samples as independent, as we believe that one answer would not be influencing the other, even when both answers were given by the same person. Three fish species (*C. jamaicensis, S. lalandi* and *S. brasiliensis*) were excluded from the chi-square analyses comparing migratory patterns and spawning sites, due to the low number of citations (Table 2). We also used chi-square tests to compare frequency of doubts (number of fishermen who answered 'I do not know ') relative to the total number of interviewed fishermen for each fish species. Such comparison may indicate differences in fishermen's knowledge of distinct fish species (Silvano and Begossi 2002).

We show data as a percentage of all interviewed fishermen for each fish species, in order to standardize distinct sample sizes among fish species (Table 1). The sum of percentages shown in rows of Tables 2–5 may sometimes be more than 100%, as some interviewees mentioned more than one aspect for the same fish species (Table 2). Among all data obtained, we show the data mentioned by 10 fishermen or more (the most cited). To properly quantify, tabulate and compare the answer of each interviewed fisherman, we selected information of broader scope, referring to general spatial or temporal features, counting how many fishermen mentioned that information. For example, if an interviewee said "this fish spawns in the open ocean, during the hot season, mainly during January", we marked one fisherman referring to "open ocean" (habitat), "hot season" (spawning period), and "January" (spawning month). Therefore, the sum of

Table 3 Spawning calendar of coastal fishes according to fishermen, numbers are % of interviewees who mentioned each data

Fishes	Autumn			Winter			Spring			Summer			All seasons
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Total number of interviewees
Caranx spp.	4**	1	3	3	1	6	7	4	1	7	9	7**	67
C. parallelus	10	4	3*	10*	7*	15*	7*	12*	10	16	13	10	67
C. jamaicensis					4	9	13	9		4			23
E. marginatus	4			10	10	4	6	10	12	12*	8	4	52
E. alleteratus	3	3		3	3	7	3	10	17**	21**	14	10	29
L. synagris	3	3	5	5	5	8	5	16	8	2**	3**	3	38
M. furnieri		3	14	21**	21**	28**	28**	10**	28**	28	21	10	29
M. platanus	2	2	15	44	42	29**	12**	10	4	4	4	2	52
M. acutirostris	4*	*	1*	3*	3*	7*	12*	13	12	9	6	4	67
P. saltatrix	*	4	6	6	4	12	13	15	13*	6*	4**	4**	52
S. brasiliensis	13	5	3	3	3	3	8	11	8**	11**	11	16	38
S. lalandi	3						3	11	3	11	5	11	38
T. lepturus				10	7	10	14*	21*	14*	14*	3*	3*	29

Information gathered from scientific literature are marked ** for the same species in the study regions and * for other related species or the same species in other regions from Brazil or elsewhere. Literature sources of scientific data are in Table 2

Table 4 Spatial and temporal migratory patterns of coastal fishes, according to fishermen, numbers are % of interviewees who mentioned each data

Migratory routes and seasons	Fish species												
	Cspp	*Cpar*	*Cjam*	*Emar*	*Eall*	*Lsyn*	*Mfur*	*Mpla*	*Macu*	*Psal*	*Sbra*	*Slal*	*Tlep*
Running fish (migrates)	96*	70	61	60*	100	50*	66**	100**	45*	83**	95	74*	86
Do not migrate (sedentary)	4	22	13	31*		32	34		49	8	3	11	14
Around reefs		1		25*		13			19	2	3	8	
River (estuary)—sea	1	43	9				*	38**		2			
"Arribação"[a]	1		9	6		16			9			3	
Offshore-coast	9*	1		4	17	*	48*	12	1	6	3	*	14
North–South	4	3		2		3		10	1*		3	3	3
South–North	3	4		10	48	13	3	62**	6	44**	11	13	34
Deep waters–shallow waters	13		13	8		5*		2			18	11*	
Searching for food	16	6	4	2	10	5			7*	8	11	5	17
Everywhere along the coast	9		4		10	3	10*	2	1	2	18	11	10*
Do not know when	3	6	26	10		3			12	15	3	22	3
Summer	33	9	9	10	45		17	8	7	4	26	13	3*
Winter	4	16		8	3	22	10**	17**	6	15**	5	11	14
Autumn							**	**					
Spring										**			*
Year round	22	7	4	10	7	13	17	2	9		18	18	3
Along the tides	1	7	9	4				2			3		
During rains and storms		7		4		3		2				3	
Total number of interviewees	67	67	23	52	29	38	29	52	67	52	38	38	29

Information gathered from scientific literature are marked ** for the same species in the study regions and * for other related species or the same species in other regions from Brazil or elsewhere. Literature sources of scientific data and codes for fish species are in Table 2

[a]Typical seasonal migration, related to the water temperature and to the fish feeding behavior. Mentioned only by northeastern fishermen

Table 5 Migration calendar of coastal fishes, according to fishermen, numbers are % of interviewees who mentioned each data

Fishes	Autumn			Winter			Spring			Summer			All seasons
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Total number of interviewees
Caranx spp.	16	6	3	3	1		4	9	13	16	18	13	67
C. parallelus	4	4	3	12	9	7	9	6	10	12	9	7	67
C. jamaicensis										4			23
E. marginatus	2		4	2		2		10	10	4	4	2	52
E. alleteratus	17	10	10	3		7	7	10	14	31	31	21	29
L. synagris	*	3 *	5 *	13 *	11 *	8 *	5 *	3 *	3 *	*	*	*	38
M. furnieri	3 **	7 **	14 **	14 **	14 **	14 **	14	17	7	10	7	3	29
M. platanus		19	40 **	44 **	33 **	8	2		2		2	2	52
M. acutirostris	3	4	3	3	1	1	3	1	4	6	4	3	67
P. saltatrix	4	4	12	15 **	17 **	8 **	13 **	12 **	15 **	6	4	4	52
S. brasiliensis	11	3	3	3	3	3	3	3	8	8	8	11	38
S. lalandi	5	3	5	3					3	3	5	8	38
T. lepturus	7	3	3	3	3	10	10	21	24 *	17 *	7 *	7	29

Most mentioned months for each fish species are highlighted. Information gathered from scientific literature are marked ** for the same species in the study regions and * for other related species or the same species in other regions from Brazil or elsewhere. Literature sources of scientific data are in Table 2

all fishermen that mentioned such general features was used to calculate the percentages shown in Tables 2–5, according to procedures from other ethnoichthyological surveys (Silvano and Begossi 2002, 2005).

Results

We interviewed a total of 67 fishermen (Table 1) from 34- to 83-year-old (average = 63 years), who have been fishing in their respective regions for an average period of 45 years. Notwithstanding the potential differences in culture and knowledge among studied fishing communities, we grouped data for analysis, in order to verify broad patterns. Nevertheless, we also briefly addressed some of the more remarkable differences between the answers given by fishermen from São Paulo and Bahia States.

Comparison of percentages of fishermen's doubts (answers 'I do not know where and when', Table 2) showed that spawning sites ($\chi^2 = 547$, d.f. = 12, $P < 0.001$) and spawning seasons ($\chi^2 = 537$, d.f. = 12, $P < 0.001$) of some fish species are better known to fishermen. Comparing expected and observed values, fishermen showed fewer doubts about reproduction of estuarine *C. parallelus, M. platanus* and demersal *M. furnieri* (Table 2). By contrast, most of the interviewed fishermen did not know spawning places or season of large pelagic fishes, such as *E. alleteratus, P. saltatrix* and *S. lalandi*, as well as the demersal fish *C. jamaicensis* (Table 2).

The number of fishermen's citations for the three most mentioned fish spawning sites differed among fish species ($\chi^2 = 223$, d.f. = 18, $P < 0.01$). Thus, fishermen's answers distinguish fishes that spawn mainly in reefs (*E. marginatus*, *M. acutirostris* and *L. synagris*), in coastal rivers or estuaries (*M. platanus* and *C. parallelus*) and in open sea (*Caranx* spp., *E. alleteratus*, *M. furnieri* and *T. lepturus*) (Table 2). Interviewees mentioned both seasons (Table 2) and specific months (Table 3) of fish spawning. When they mentioned a season, we asked them to specify months, but they were not always able to do so. The calendar of fish reproduction based on fishermen's knowledge indicates that most of the pelagic and reef fishes spawn during the summer and spring months (Table 3). The estuarine *M. platanus* differed from all other fishes, spawning mainly during the winter months, *C. parallelus* spawns during both winter and summer, and *E. marginatus* spawns in late spring and early summer, but also during the winter. This fish showed a distinct pattern from other reef fishes (*L. synagris* and *M. acutirostris*), which spawn mainly during the spring (Table 3). For eight of the 13 studied fish species, at least one of the spawning months most mentioned by fishermen coincided with spawning months for the same (or related) fish species gathered from biological literature (Table 3).

Contrarily to what we observed for fish reproduction, few fishermen had doubts about fish migration (Table 4). Despite all fish species being regarded as migratory by at least some of the interviewed fishermen (Table 4), answers regarding whether a fish migrates ('running' fish) or not (sedentary) differed among the studied fishes ($\chi^2 = 104$, d.f. = 12, $P < 0.01$). Thus, the majority of fishermen considered nine fish species as being mostly migratory (Table 4), while four fishes, *L. synagris* ($\chi^2 = 1.61$, d.f. = 1, $P = 0.28$), *M. furnieri* ($\chi^2 = 2.2$, d.f. = 1, $P = 0.14$) and *M. acutirostris* ($\chi^2 = 0.06$, d.f. = 1, $P = 0.8$) were equally quoted as sedentary or migratory. Although the reef fish *E. marginatus* was considered mainly migratory ($\chi^2 = 4.17$, d.f. = 1, $P < 0.05$), several fishermen (31%) also mentioned it as being sedentary (Table 4).

The interviewees mentioned four main patterns of fish migrations (Fig. 1), which differed for the studied fish species ($\chi^2 = 301.8$, d.f. = 27, $P < 0.01$), thus making it possible to distinguish fishes that make long migrations along the coast, in the South to North direction (*M. platanus*, *P. saltatrix, Caranx* spp., *T. lepturus* and *E. alleteratus*), fishes migrating between the shore and open ocean (or between deep and shallow waters) (*M. furnieri*), fishes migrating between the sea and coastal rivers, according to prevailing tides and climatic conditions (*C. parallelus*), and reef fishes making short movements around nearby reefs (*E. marginatus, L. synagris* and *M. acutirostris*) (Table 4, Fig. 1). Some fish species showed two migration patterns according to the fishermen, such as *M. platanus* and *Caranx* spp. Besides both of these fishes migrating from the South to the North, the former also migrates between estuaries and the sea, and the latter also migrates between the shore and open-ocean (Table 4).

The calendar for fish migration according to interviewees (Table 5) generally agrees with the spawning calendar (Table 3). Fishermen's citations differed among fish species regarding migratory seasons (Table 4) ($\chi^2 = 65$, d.f. = 24, $P < 0.01$): pelagic fishes, such as *Caranx* spp., *E. alleteratus* and *S. brasiliensis* migrate during the summer, while *M. platanus, P. saltatrix* and *C. parallelus* migrate during the winter and the other fishes migrate year round (Tables 4 and 5). Fishermen's answers suggest that some migration patterns, such as long South to North migrations of *M. platanus* and *P. saltatrix*, as well as the offshore and inshore migrations of *M. furnieri* (Table 4) may be related to reproduction, as they coincide with the mentioned spawning sites (Table 2) and months (Table 3) for these fishes. Conversely, offshore and inshore migrations of some pelagic fishes, such as *Caranx* spp. and *T. lepturus*, may be related to feeding (Table 4). As observed for fish reproduction, fishermen's data about migration of *E. marginatus*, *Caranx* spp.*, M. furnieri, M. platanus* and *P. saltatrix* agree with proposed migratory patterns in scientific literature (Table 4). Literature data about migratory periods, which were only available for five of the studied fishes, usually agree with fishermen's data (Tables 4 and 5).

Discussion

Notwithstanding the extension of Brazilian coast, which harbors several fishing communities (Diegues 1999), we believe that our results may apply to southeastern and northeastern Brazil, as long as our sample includes several fishing communities, which exploit various habitats (reefs, coastal waters, beaches and estuaries). However, perhaps our results would have more limited application to other Brazilian coastal regions with peculiar environmental conditions and fishing communities, such as large estuarine lagoons in the far South and the Amazon River mouth in the far North. Although we showed the same fish species' photographs to all interviewed fishermen, it might be that some fishermen referred to fishes other than those shown to them. For example, northeastern fishermen might be talking about *Mycteroperca bonaci* and *Mugil liza*, which are more common there (Teixeira et al. 2004), instead of the congeners *M. acutirostris* and *M. platanus* (the species shown in photographs), which occur mainly in the southeast. Some differences between answers of northeastern and southeastern fishermen could, thus, be due to this distinct perception. For example, most of the answers regarding *M. platanus* reproduction came from the latter fishermen, who mentioned that this fish spawns in the Brazilian South, more precisely in Patos Lagoon (Table 2). Conversely, northeastern fishermen might be dealing with another similar Mugil species, which spawns elsewhere. Only northeastern fishermen mentioned the 'arribação' made by *L. synagris* and *M. acutirostris*. This sort of seasonal migration, related to the water temperature and to feeding, has been reported for *M. bonaci* (Teixeira et al. 2004) and *L. purpureus* (Ivo and Hanson 1982; Fonteles-Filho and Ferreira 1987) on the northeastern Brazilian coast, but it may not occur in the southeast.

Although dealing with supposedly more knowledgeable and experienced fishermen, we observed an overall lack of knowledge about fish reproductive patterns, especially for some large pelagic fishes with high market value. Conversely, Pacific (Johannes 1981; Johannes et al. 2000) and Caribbean (Coleman et al. 1996) fishermen are very knowledgeable about fish spawning patterns. According to Diamond (2005), older people in traditional or illiterate societies are the equivalents of our libraries, accumulating and transmitting environmental knowledge. In this sense, one possible explanation for our results would be that studied Brazilian fishermen might be gradually loosing their local ecological knowledge, to the extent that they are in closer contact with urban centers and media-derived information, and fishing is being replaced by other economic activities, such as tourism (Begossi et al. 2001). If this is the case, then measures could be taken in order to avoid complete disruption of coastal artisanal fishing, a relevant economic activity, especially for poor people. Albeit in risk of vanishing due to modernization and acculturation pressures (Johannes 1978), traditional knowledge and associated management systems held by South Pacific fishing communities for centuries have been recovering more recently (Johannes 2002), showing that disruption of fishers' culture is not irreversible. However, knowledge loss may not be the main issue in the studied fishing communities, to the extent that fishermen did know reproduction habits of estuarine fishes. Moreover, interviewed fishermen did show good knowledge of fish migration (Tables 4 and 5) as expected, considering the importance of such knowledge to find and exploit marine fish schools (Parrish 1999). Another (and more plausible) explanation to the observed lack of fishermen's knowledge on reproduction of some fishes might be that such events are relatively rare and difficult to observe, contrarily to other biological aspects, such as fish habitat and diet (Silvano and Begossi 2002). In such cases, reproduction of large pelagic fishes may be rare to fishermen due to two main factors, not mutually exclusive. First, spawning occurs on short and limited spatial and temporal scales. Second, these fish species themselves are now scarce and fishermen have less contact with them. Indeed, some interviewed fishermen claimed that they were not able to mention reproductive patterns because they rarely (or never) catch these fishes with eggs. This situation deserves to be further investigated through biological research, as it raises concerns of over-fishing and depletion of these large pelagic fishes. A common pattern of over-fishing in artisanal fisheries is increased catches of less valued, medium-sized or small herbivorous and detritivorous fishes, associated with a decline in catches of large, high value, piscivorous fishes (de Boer et al. 2001). Our results, thus, raise some relevant questions: 'Does the observed lack of fishermen's knowledge of reproduction of large reef and pelagic fishes indicate decreases in the abundance of these fishes?' Are large pelagic fishes being replaced in fisheries by the well-known estuarine and demersal fishes?'

Fishermen's local ecological knowledge indicates general patterns in reproduction and migration of studied Brazilian coastal fishes. These patterns usually agree with available scientific data: for example, researchers already documented the South to North spawning migration of *P. saltatrix* and *M. platanus*, which migrate against prevailing oceanic currents that will carry eggs and larvae back to estuaries in the South (Sadowski and Dias 1986; Vieira and Scalabrin 1991; Haimovici and Krug 1996; Juanes et al. 1996). Indeed, seven of the interviewed fishermen

(10%), all from southeastern Brazil, mentioned that the former fish species migrates soon after ('follows') the latter. Thus, it would be worth checking this and the ecological factors influencing such an alleged association between these two fishes: are *P. saltatrix* preying on *M. platanus*? Are migratory movements of these two fish species triggered by similar environmental cues, such as differences in water temperature (Sadowski and Dias 1986; Vieira and Scalabrin 1991)? Understanding this would aid in managing and protecting spawning runs of two important target fishes. Furthermore, some of these migratory patterns were also recorded in previous ethnoecological surveys in other fishing communities: marine fishermen from Búzios Island (southeastern Brazil) and in Moreton Bay (eastern Australia) also mentioned a South to North migration of *P. saltatrix*, and its association with migration of mugilids (Silvano and Begossi 2005). We could not find data on migration or reproduction of some fishes and our data may, thus, be the only information currently available. Most of the literature referred to in this survey (Tables 2–5) addresses other related fish species, or the same fish species in other regions of Brazil and elsewhere. Thus, even observed correspondence between fishermen and literature data does not necessarily mean redundant information (Silvano and Begossi 2005).

Fishermen's knowledge recorded here sometimes disagrees with the scientific literature. Such discrepancy may provide new insights to be investigated by biological research, improving the existing knowledge base (Marques 1991; Aswani and Hamilton 2004). According to fishermen, overall migratory patterns of *M. platanus* match literature data. However, according to fishermen, this species spawns in rivers or estuaries and, according to scientists, in the ocean (pelagic coastal waters) (Table 2). Such discrepancy might arise from fishermen confounding spawning and nursery sites of this fish, to which estuaries provide an important growing and nursery site (Vieira and Scalabrin 1991; Romagosa et al. 2000). However, considering the lack of scientific knowledge on reproductive behavior of this fish in our study regions, fishermen's answers reported here might be worth checking, even if they sound unreliable to ichthyologists at first glance. Some fishes may show considerably inter-population variability regarding spawning sites, such as *M. furnieri*, which spawns in the sea (pelagic coastal waters) in Brazil (Vazzoler 1991; Ibagy and Sinque 1995) and in estuaries in Uruguay (Vizziano et al. 2002). Indeed, in our survey, fishermen's answers also indicated several spawning sites for this fish (Table 2). Sadowski and Dias (1986) made a broad mark-recapture survey of *Mugil cephalus* (possibly *M. platanus*) from 1954 to 1962 on the Brazilian south and southeastern coasts, identifying a South to North spawning run, but not finding spawning sites. Authors then use pieces of evidence from other places (such as Mexico) to argue that this fish could be spawning in open-ocean, near the coast. However, this fish also makes short lateral movements between estuaries and the sea during its spawning runs along the Brazilian southeastern coast (Sadowski and Dias 1986). Although eggs and larvae have not yet been observed in coastal rivers and estuaries, our data raise the hypothesis that perhaps some populations of *M. platanus* could be spawning near or inside estuaries. In Northern Australia, aboriginal fishermen claim that the *barramundi* (*Lates calcarifer*, Centropomidae) spawns in rivers, contrarily to the opinion of ichthyologists, who affirm that this fish spawns in the coastal sea. However, biological research in that region confirms that aborigines are right: the barramundi population shows a distinct spawning pattern there, differing from populations already studied in other Australian regions (Johannes 1988).

According to Vazzoler (1991), there are two distinct populations of *M. furnieri* on the Brazilian coast: one in the south and the other in the southeast (encompassing our study region, Fig. 1). However, a recent study challenges this assumption: genetic similarities indicate that there could be just one population of *M. furnieri* in Brazil (Levy et al. 1998). Our results support the 'two populations' hypothesis, as most of the interviewed fishermen said that this fish species does not migrate over long distances or in the South to North direction (Table 4). There would, thus, be few contacts between individuals from southern and southeastern Brazil. Therefore, considering fishermen's assertions, we may raise the hypothesis that the observed gene flow between southern and southeastern populations of this fish could be related to passive transport of eggs and larvae along the Brazilian coast, instead of migration and interbreeding of adults. Combined evidence from our ethnoichthyological survey and literature thus suggest that more detailed migratory surveys would be desirable to solve this important question.

Another discrepancy between local and scientific knowledge refers to spawning of reef fishes from the Serranidae family (*E. marginatus* and *M. acutirostris*). According to interviewed fishermen, these fishes spawn near reefs and usually do not migrate, while according to the literature these fishes, especially *Epinephelus* spp., usually form large spawning aggregations and migrate over long distances to spawn away from their home reefs in the Caribbean (Coleman et al. 1996; Sadovy 1996). Interviewed fishermen in our survey did not mention such spawning aggregations, not even on the northeastern coast, which is similar to the Caribbean (tropical reefs, warm water). Furthermore, such spawning aggregations have not yet been documented in Brazilian coastal waters, albeit some researchers believe that they might occur (Andrade et al. 2003). Our results suggest that serranid spawning aggregations may not occur in Brazil, or, if they occur, they are probably rare, sporadic and usually not exploited by fishermen.

The efficacy of marine reserves (and zoning systems) to fishery management depends, among other things, on whether reserves afford protection of important habitats to critical and vulnerable life-stages of exploited fishes, such as spawning sites (Roberts et al. 2003). Our results may thus be useful to set marine protected areas and to devise ecologically sensitive zoning plans on the Brazilian coast, as we identify major spawning and migratory patterns of some Brazilian coastal fishes, according to fishermen's knowledge. For example, highly migratory fishes, such as *M. platanus* and *P. saltatrix*, might be managed in a distinct fashion than less migratory or sedentary reef and demersal fishes, such as *E. marginatus* and *M. furnieri*. Following the reasoning of Roberts et al. (2003), the former would be best protected by several smaller marine reserves along their entire migratory route, while the second may be best managed through single, larger, and strategically placed marine reserves. Moreover, our results also show that maintenance of exploited marine fish stocks may rely upon conservation measures from other connected habitats and ecosystems, such as coastal rivers and estuaries. Most of the interviewed fishermen mentioned the dependence of *C. paralellus* on estuaries and rivers for reproduction. Indeed, a biological survey also shows the importance of estuaries as nursery grounds for *Centropomus undecimalis* in Puerto Rico (Aliaume et al. 2000). Our results also aid in devising more flexible management rules: instead of closing all fishing activities during certain periods, managers might close fishing of some fish species (or fish groups) during their respective spawning seasons.

Conclusion

Data gathered from fishermen in this survey, which agree with data acquired from other fishermen elsewhere, and with literature data, might indicate real biological patterns. We do not claim that our ethnoichthyological data should replace biological surveys, but our results could help to elaborate such future surveys, to the extent that we can devise testable hypotheses about fish migration and spawning, based on fishermen's knowledge. Such an approach would save time and money, providing rapid results, readily applicable to fisheries management, thus following the 'data-less' approach proposed by Johannes (1998). Besides informing scientists and managers when devising management measures, our data would help to achieve the necessary involvement of the stakeholders (in our case, the fishermen), in the design and implementation of these measures, such as marine reserves (Roberts et al. 2003). Applying fishers' knowledge in management may not be an easy task, due to differences between fishers' and researchers' knowledge base and perceptions (Degnbol 2005). The agreements observed here between fishermen's and scientists' knowledge about fish migration and reproduction may be a starting point to devise a 'common ground' knowledge, which would be understandable to both researchers and users, thus being applicable in future co-management of fishing resources (Degnbol 2005). Our study shows that local fishermen's knowledge has the potential to improve understanding of reproduction and migration of Brazilian coastal fishes, as already observed in the tropical Pacific (Johannes 1981; Johannes et al. 2000) and in the Mekong River (Valbo-Jorgensen and Poulsen 2001). Furthermore, the ethnobiological approach and methods here reported could also be useful to the study and management of several other poorly known tropical fisheries, thus helping to improve dialogue and mutual understanding between fishers and researchers, which would ultimately benefit the development of sound marine conservation strategies (Drew 2005).

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