



Mediterranean Marine Science

Vol 16, No 3 (2015)



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doi: 10.12681/mms.1179

To cite this article:

BOUGHEDIR, W., RIFI, M., SHAKMAN, E., MAYNOU, F., GHANEM, R., BEN SOUISSI, J., & AZZURRO, E. (2015). Tracking the invasion of Hemiramphus far and Saurida undosquamis along the southern Mediterranean coasts: A Local Ecological Knowledge study. *Mediterranean Marine Science*, *16*(3), 628–635. https://doi.org/10.12681/mms.1179

Tracking the invasion of *Hemiramphus far* and *Saurida lessepsianus* along the southern Mediterranean coasts: A Local Ecological Knowledge study

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Handling Editor: Murat Bilecenoglu

Received: 12 December 2014; Accepted: 8 June 2015; Published on line: 13 October 2015

Abstract

Local Ecological Knowledge of 92 professional fishers from Tunisia and Libya was used to investigate the occurrence and establishment of the exotic *Hemiramphus far* and *Saurida lessepsianus* along the southern Mediterranean coasts. According to fisherman's knowledge, *H. far* and *S. lessepsianus* appeared in Libya in 1980 and 1989, respectively. In Tunisia these species were observed later on, in 2004 and 2007. Currently both *H. far* and *S. lessepsianus* are well distributed and established, along the entire surveyed area, from Tobruk (eastern Libya) to Tabarka (western Tunisia). A statistical analysis of the qualitative trends in abundance perceived by the respondents shows that both species have significantly increased in abundance in Tunisia. In Libya an increase in the abundance of *H. far* was also apparent during the first decade of the 21st century, but the current abundance of *S. lessepsianus* was found to be stable at the level of occasional captures. Given the lack of regular environmental monitoring programmes in the area, these findings provide information that could not have been obtained otherwise. Besides improving our understanding on the status and chronology of these invasions, this approach highlights the value of fisherman's knowledge to reconstruct ecological processes in the course of rapid historical modifications.

Keywords: Lessepsian migration, biological invasions, Hemiramphidae, Synodontidae, fish, fishermen.

Introduction

Exotic species represent a matter of growing concern for the Mediterranean Sea (Galil 2007; Zenetos et al., 2010) deeply altering the structure of native communities (Fanelli et al., 2015), but data on their distribution and abundance are often difficult to gather (Azzurro 2010; Azzurro et al., 2013). Indeed, due to the massive efforts needed to actively survey marine habitats, the real distribution of these species may be under-estimated, especially in poorly monitored areas of the Mediterranean Sea (e.g. Elbarassi et al., 2014). Nevertheless, the so-called 'Local Ecological Knowledge' (LEK) (Johannes, 1998) is emerging as a new and alternative information source to overcome these limits. LEK can be defined as the information that a group of people have about local ecosystems and it aims to extract data and information from individuals' memory. This information is increasingly employed to understand ecosystem processes (e.g. Le Fur et al., 2011), animal abundances (e.g. Anadón et al., 2009) and to investigate the ecological traits and historical trends of a diverse array of marine organisms (e.g. Rosa et al., 2014; Silvano & Begossi, 2012). Recently LEK has been applied to the reconstruction of geographical and historical trends of some Mediterranean fishes (Azzurro et al., 2011; Maynou et al., 2011) and its use is considered to be particularly

helpful in data-poor coastal ecosystems (Beaudreau & Levin, 2014), like the southern Mediterranean. Here we used LEK to investigate the distribution of two invasive fish species along the Mediterranean coasts of Libya and Tunisia: The black-barred halfbeak *Hemiramphus far* (Forsskål, 1775) (Hemiramphidae) and the lizardfish *Saurida lessepsianus* Russell, Golani & Tikochinski, 2015 (Synodontidae). Both species are absent from fishery statistics in both countries, being reported under general names together with other fishes. This information gap, together with the lack of regular environmental monitoring programmes in the area, makes it challenging to track the occurrence and possible range expansion of these exotic species with traditional methods.

The black-barred halfbeak *Hemiramphus far* is originally found in tropical and subtropical waters of the Indo-West Pacific, Red Sea and East Africa to Samoa, north to the Ryukyu Islands, south to northern Australia and New Caledonia (Collette, 1999). Halfbeaks are commercially exploited in many parts of the world (Fishstat, 2013) such as along the Arabian Sea Coast of Pakistan where the species is considered of great economic importance (Yousuf & Khurshid, 2008). *H. far* was one of the first Lessepsian fishes to have entered the Mediterranean Sea. It was recorded first from Palestine under the name of *H. marginatus* (Steinitz, 1927) and afterwards it spread along the

coasts of Syria, Turkey, Greece, Croatia, Egypt, Libya (Golani et al., 2013). The presence of H. far has also been documented from the coasts of Tunisia and Algeria, but only in the form of isolated records: in September 2003 a single specimen was captured by purse seine off El Haouaria, Cape Bon, at a depth of about 40 m (Ben Souissi et al., 2005) and in December 2003 another single specimen was captured by Rafraf (North-East Tunisia) with a trammel net (Charfi-Cheikhrouha, 2004). More recently, isolated captures of *H. far* have been reported from Collo Bay in Algeria (Kara et al., 2012) and Italy (Falautano et al., 2014). To our best knowledge there is no published information about the possible establishment of *H. far* to the west of Libya (Bariche, 2012; Golani et al., 2013). No available data existed on the occurrence of this species in Libya until 2006 (Shakman & Kinzelbach, 2006).

The lizardfish S. lessepsianus is a demersal fish, which inhabits soft bottom substrates. It is widely distributed in the Indo-Pacific from the Red Sea and East Africa to Australia and Japan (Fischer & Bianchi, 1984). So far, in the Red Sea-Mediterranean, this species has been commonly reported (and misidentified) as Saurida undosquamis (Richardson 1848) or S. macrolepis Tanaka 1917. Only very recently Russell et al. (2015) described S. lessepsianus as a new species. In the Mediterranean Sea, S. lessepsianus was first recorded in Israel (Ben-Tuvia, 1953). Almost immediately afterwards, this species established abundant populations along the eastern Mediterranean, attaining commercial importance (e.g. Ben-Yami & Glaser, 1974; Can & Demirci, 2004). It spread through the entire eastern Mediterranean (Golani et al., 2013) up to the Adriatic Sea (Dulčić et al., 2003), causing serious impacts on biodiversity. It has been listed among the 100 worst invasive species in the Mediterranean (Streftaris & Zenetos, 2006). The occurrence of this Lessepsian lizardfish in Libya has been reported only recently (Shakman & Kinzelbach, 2007) and in Tunisia, only the record of a single specimen was reported: in October 2004, by a benthic trawl, off Mahdia, in northern Gulf of Gabès, at a depth of 70 m on sandy muddy substrate (Ben Souissi *et al.*, 2005). To our best knowledge no other information is currently available on the establishment of *S. lessepsianus* along the north-African coasts.

Methods

Sampling area and interviews

Data were based on 92 interviews: 24 of which were collected in Libya and 68 in Tunisia. In Libya, interviews were carried out from February to December 2013, in Tobruk (eastern Libya) and Tripoli (western Libya). In Tunisia, fishermen were interviewed during the period October 2010 - December 2013, over seven main locations: Zarzis, Gabès, Mahdia, Kélibia, Gulf of Tunis, Bizerte and Tabarka (Fig. 1). The study was directed to every local professional fisherman with 10 or more years of experience in fishing. Fishermen were approached during their activities in harbours, according to the general guidelines given by Azzurro et al. (2011). Each interview was realized after informing fishermen on the objectives of this report. Due to the level of schooling of fishermen, terms were consented orally. In order to test the ability of questioned people to correctly identify the species, color photos of both H. far and S. lessepsianus were showed to them as well as



Fig. 1: Locations of the southern Mediterranean coasts where the interviews were performed. In Libya: 1) Tobrouk, 2) Tripoli. In Tunisia: 3) Zarzis, 4) Gabes, 5) Mahdia, 6) Kélibia, 7) Tunis (Goulette, Salambo, Sidi Bou Said, Sidi rais, Byrsa), 8) Bizerte, 9) Tabarka.

pictures of morphologically similar native fish (i.e. Synodus saurus and Aulopus filamentosus which resembles S. lessepsianus and Belone belone which resemble to H. far). Only those people who unambiguously identified H. far and/or S. lessepsianus were interviewed. Interviews were carried out in Arabic language on the basis of a semistructured conversation (Appendix 1) between the researcher and a participant. The interview tackled questions related to the time and location of species occurrences and qualitative indices of species abundance along a temporal series. Specific questions included the 'time of first capture', 'fishing techniques used' and 'best day-catches'. Respondents were asked to provide a qualitative ranking of abundance through time on an annual basis according to the 6 different grades reported by Azzurro et al. (2011) and slightly modified: 0 =ABSENT; 1 =RARE (once in a year); 2=OCCASIONAL (sometimes in a fishing period); 3=COMMON (regularly in a fishing period); 4 =ABUN-DANT (regularly in a fishing period and abundant); 5=DOMINANT (always in a fishing period and with great abundances). The duration of interviews ranged between 15 and 45 minutes.

Statistical analysis

The time series of semi-quantitative abundance data were subject to breakpoint structural analysis (Bai, 1994; Zeileis et al., 2003) to assess the year(s) of statistically significant change in abundance, over the period 1970-2013, for each species and the two countries separately. Briefly, the breakpoint analysis consists in randomly splitting the data series in two or more subsets ("data windows") and the mean level compared by way of a modified F-test (known as structural change sc test, Zeileis et al., 2003). The procedure was repeated iteratively until all significant breakpoints (if any) are identified (Bai, 1994). The number of significant breakpoints and their associated dates were assessed by the Bayesian Information Criterion (BIC) (Zeileis et al., 2003). The breakpoint analysis was performed with the R library strucchange, developed by A. Zeileis at the University of Economics, Vienna (Wirtschaftsuniversität Wien, Austria).

Results

Interviewed fishermen were all men of age ranging between 32 and 75 years. Overall, 43 respondents provided information on only *H. far*, 20 fishermen on only *S. lessepsianus* and 29 on both species. All the respondents demonstrated the ability to recognize both *H. far* and/or *S. lessepsianus* and to be well aware of some conspicuous taxonomical characters of the species (e.g. the vertical dots on the caudal fin of *S. lessepsianus*). In Libya, local names are used for both *H. far* and *S. lessepsianus* in Arabic (Abomeshfa and Shkhrmo, respectively), whilst in Tunisia these species are still not designated with local names due to their recent occurrence. In general, fishermen were highly collaborative and keen to share their knowledge with researchers. The distribution of fishing gears used by fishermen to capture both species in Libya and Tunisia is shown in Figure 2. A total of 58 fishermen remembered the exact location and approximate year where they first captured *H. far*, whilst 40 fishermen provided the same information for *S. lessepsianus* (Table 1).

According to the fishermen, H. far is captured along the eastern Libyan coasts (Tobruk) since the eighties' and it is being observed in western Libya (Tripoli) since 2007. In Tunisia, this species was firstly captured in 2004, from the area surrounding the fishing harbour of Gabès. The species is mainly captured by purse seine and it represents an occasional species of nets and trolling lines. In Tunisia and western Libya the best day-catches exceeded 50 kg with purse seine (mostly 'Lamparas', i.e. boats with powerful light to attract the fishes) but maximum values of less than one kg/day were reported for the other fishing techniques (Fig. 3). Captures of H. far were usually realized from the surface down to 40 m depth corresponding to soft bottoms and, in some occasions, above rocks, gravel and seagrass. According to interviewed fishermen, observations of S. lessepsianus in Libya were first reported in 1980 from the area of Tobruk and in 1990 from Tripoli. In Tunisia, S. lessepsianus was first reported in 2004 from the area of Mahdia. Fishermen reported to occasionally capture this species by nets, trawlers and longlines, mostly below 50 meters and over soft bottoms. Best-day catches did not generally exceed 1 kg/day over the entire sampling area (Fig. 3).

Average rank data for the last five years (2009-2013) are reported in Table 2. In most of the cases, both species were reported as "OCCASIONAL", but 33.3% of Libyan respondents reported *H. far* as "ABUNDANT" and 11.52% of Tunisian respondents as "COMMON" (regular in the fishing period). When questioned about



Fig. 2: Distribution of the fishing methods adopted by the interviewed fishermen in Libya and Tunisia: *H. far* respondents (tot: 67), *S. lessepsianus* respondents (tot: 69). Note that more than one fishing method could be adopted by a single respondent.

בווונפון איוט ובוווכוווטכוכט נוכ נווונכ מוט ו גווונס	LIBYA	LIBYA	LIBYA	LIBYA	LIBYA	\leq												TUNIS	SIA					
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1965 Tobruk gulf 32.077 24.038 1980 65 1965 Tobruk gulf 32.077 24.038 198	Tobruk gulf 32.077 24.038 1980 65 1965 Tobruk gulf 32.077 24.038 19	lf 32.077 24.038 1980 65 1965 Tobruk gulf 32.077 24.038 199	077 24.038 1980 65 1965 Tobruk gulf 32.077 24.038 198	.038 1980 65 1965 Tobruk gulf 32.077 24.038 198	980 65 1965 Tobruk gulf 32.077 24.038 195	65 1965 Tobruk gulf 32.077 24.038 196	965 Tobruk gulf 32.077 24.038 198	obruk gulf 32.077 24.038 198	32.077 24.038 198	24.038 198	361	88	52 15	980 G	abès, 2 miles from fishing port	34.028	10.373	2005	50	1990	Out off Salamboo	36.819	10.441	2006
1978 Tobruk gulf 32.077 24.038 1980 60 1975 Tobruk gulf 32.077 24.038 15	Tobruk gulf 32.077 24.038 1980 60 1975 Tobruk gulf 32.077 24.038 15	lf 32.077 24.038 1980 60 1975 Tobruk gulf 32.077 24.038 15	77 24.038 1980 60 1975 Tobruk gulf 32.077 24.038 19	.038 1980 60 1975 Tobruk gulf 32.077 24.038 19	980 60 1975 Tobruk gulf 32.077 24.038 19	60 1975 Tobruk gulf 32.077 24.038 19	975 Tobruk gulf 32.077 24.038 19	obruk gulf 32.077 24.038 19	32.077 24.038 19	24.038 19	5	680	34 15	997 G	annouch (Gabès)	33.957	10.177	2005	44	1994	Kélibia 2 miles out off the harbour	36.814	11.149	2008
1981 Tobruk gulf 32.077 24.038 1984 42 1986 Tobruk gulf 32.077 24.038 15	Tobruk gulf 32.077 24.038 1984 42 1986 Tobruk gulf 32.077 24.038 15	lf 32.077 24.038 1984 42 1986 Tobruk.gulf 32.077 24.038 15	077 24.038 1984 42 1986 Tobruk gulf 32.077 24.038 19	.038 1984 42 1986 Tobruk gulf 32.077 24.038 19	984 42 1986 Tobruk gulf 32.077 24.038 19	42 1986 Tobruk gulf 32.077 24.038 19	.986 Tobruk gulf 32.077 24.038 19	obruk gulf 32.077 24.038 19	32.077 24.038 19	24.038 19	5	680	57 15	975 B	izerte coasts	37.301	9.937	2006	48	1988	Kélibia	36.813	11.148	2011
1980 Tobruk gulf 32.077 24.038 1986 64 1964 East of Tripoli 32.915 13.455 19:	Tobruk gulf 32.077 24.038 1986 64 1964 East of Tripoli 32.915 13.455 19:	lf 32.077 24.038 1986 64 1964 East of Tripoli 32.915 13.455 19:	177 24.038 1986 64 1964 East of Tripoli 32.915 13.455 19	.038 1986 64 1964 East of Tripoli 32.915 13.455 19	986 64 1964 East of Tripoli 32.915 13.455 199	64 1964 East of Tripoli 32.915 13.455 199	964 East of Tripoli 32.915 13.455 199	ast of Tripoli 32.915 13.455 199	32.915 13.455 199	13.455 199	61	06	45 15	Z 786	aarat (Gabès)	33.863	10.196	2006	50	1990	Between Mahdia and Kerkennah	35.147	11.421	2008
1985 Tobruk gulf 32.077 24.038 1988 46 1982 East of Tripoli 32.915 13.455 199	Tobruk gulf 32.077 24.038 1988 46 1982 East of Tripoli 32.915 13.455 199	lf 32.077 24.038 1988 46 1982 East of Tripoli 32.915 13.455 199	077 24.038 1988 46 1982 East of Tripoli 32.915 13.455 199	.038 1988 46 1982 East of Tripoli 32.915 13.455 199	988 46 1982 East of Tripoli 32.915 13.455 199	46 1982 East of Tripoli 32.915 13.455 199	982 East of Tripoli 32.915 13.455 199	ast of Tripoli 32.915 13.455 199	32.915 13.455 199	13.455 1990	1991	0	55 15	Z 876	arzis, near coast	33.525	11.165	2006	42	1991	Mahdia	35.529	11.136	2008
1986 Tobruk gulf 32.077 24.038 1989 55 1978 Tobruk gulf 32.077 24.038 1990	Tobruk gulf 32.077 24.038 1989 55 1978 Tobruk gulf 32.077 24.038 1990	if 32.077 24.038 1989 55 1978 Tobruk gulf 32.077 24.038 1990	177 24.038 1989 55 1978 Tobruk gulf 32.077 24.038 1990	.038 1989 55 1978 Tobruk gulf 32.077 24.038 1990	989 55 1978 Tobruk gulf 32.077 24.038 1990	55 1978 Tobruk gulf 32.077 24.038 1990	978 Tobruk gulf 32.077 24.038 1990	obruk gulf 32.077 24.038 1990	32.077 24.038 1990	24.038 1990	1990		35 15	998 E	Biban Lake	33.235	11.317	2006	50	1993	Tabarka, out off	37.033	8.733	2011
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1980 West of Tripoli 32.858 12.872 2008 37 1992 East of Tripoli 32.915 13.455 1992	West of Tripoli 32.858 12.872 2008 37 1992 East of Tripoli 32.915 13.455 1992	ipoli 32.858 12.872 2008 37 1992 East of Tripoli 32.915 13.455 1992	558 12.872 2008 37 1992 East of Tripoli 32.915 13.455 1992		008 37 1992 East of Tripoli 32.915 13.455 1992	37 1992 East of Tripoli 32.915 13.455 1992	992 East of Tripoli 32.915 13.455 1992	ast of Tripoli 32.915 13.455 1992	32.915 13.455 1992	13.455 1992	1992		43 15	990 K	élibia	36.785	11.102	2008	50	1989	Sidi Bou Said	36.935	10.421	2010
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1984 West of Tripoli 32.858 12.872 2009 65 1980 East of Tripoli 32.915 13.455 1992	West of Tripoli 32.858 12.872 2009 65 1980 East of Tripoli 32.915 13.455 1992	ipoli 32.858 12.872 2009 65 1980 East of Tripoli 32.915 13.455 1992	58 12.872 2009 65 1980 East of Tripoli 32.915 13.455 1992		009 65 1980 East of Tripoli 32.915 13.455 1992	65 1980 East of Tripoli 32.915 13.455 1992	980 East of Tripoli 32.915 13.455 1992	ast of Tripoli 32.915 13.455 1992	32.915 13.455 1992	13.455 1992	1992		38 15	993 S	di Mechreg	37.197	9.059	2008	48	1997	Goulette	36.854	10.457	2013
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Table 1. First captures of H. far and S. lessepsianus, according to the fishermen's ecological knowledge. Year, locations and approximate coordinates are given. Only interviews (N=58) with



Fig. 3: Average best-day catches (and SD) for H. far and S. lessepsianus reported by Libyan and Tunisian fishermen.

Table 2. Percentage distribution of *H. far* and *S. lessepsianus* during the last five years (2009-2013). Data were computed on the basis of the respondents who recognized and captured the one and/or the other species.

	Democry dehum democ	LIBYA		Т	UNISIA
	Perceived abundance	H. far	S. lessepsianus	H. far	S. lessepsianus
0	ABSENT	10.0	0.00	12.44	11.22
1	RARE (once in a year)	0.00	42.5	36.40	32.14
2	OCCASIONAL (sometimes in the fishing period)	56.7	57.5	39.63	53.06
3	COMMON (regular in the fishing period)	0.00	0.00	11.52	2.55
4	ABUNDANT (regular and abundant in the fishing period)	33.3	0.00	0.00	0.00
5	DOMINANT (always with great abundances in the fishing period)	0.00	0.00	0.00	0.00

the fishing period, *H. far* respondents indicated Autumn: 11.1% of respondents; Autumn and Winter 38.9%; Winter 33.3%; Winter and Spring 16,7%. On the contrary, no specific season was indicated for *S. lessepsianus*.

The results of the breakpoint analysis are shown in Figure 4 and Table 3. A progressive increase in captures from the date of their first appearance onwards is apparent for both species in Tunisia but only for H. far in Libya. H. far in Libya made its first statistically significant appearance in 1980, and its abundance increased progressively in 1994 and 2007 to be perceived as "COM-MON" in 2013. S. lessepsianus passed from "ABSENT" to "RARE" in 1989 and its abundance increased in 1995 and 2002 to be perceived as "RARE" to "OCCASION-AL" in 2013. In Tunisia H. far passed from "ABSENT" to "RARE" in 2004, although its trend is rapidly increasing and was considered "ABUNDANT" by a few fishers in recent years. S. lessepsianus in Tunisia passed from "ABSENT" to "OCCASIONAL" quickly after 2007, and its perceived abundance is also growing rapidly, with some fishers classing it as "COMMON" in recent years.

Discussion

According to fishermen's ecological knowledge, both H. far and S. lessepsianus started to occur in Tunisian captures since 2004. This finding perfectly agrees with the chronology of first reports of these species made by professional scientists (Charfi-Cheikhrouha, 2004; Ben Souissi et al., 2005). In eastern Libya, both H. far and S. lessepsianus have been observed since the 1980's. As for S. lessepsianus, this finding matches the first Libyan record in 1982 (Zupanovic & El-Buni, 1982). In the case of *H. far* it was apparent that fishermen were well aware of this species before professional scientists were, in 2006 (Shakman & Kinzelbach, 2007). This latter observation highlights an important source of uncertainty in ecological observation that is related to major lags in detection of exotic species (sensu Crooks, 2011). Indeed, in many other occasions, Mediterranean fishermen were informed about the occurrence of exotic new taxa well before professional scientists. This has been the case of Metapenaeus monoceros, which was officially recorded in Tunisia in 1993 (Missaoui & Zaouali, 1995) but fishermen knew



Fig. 4: Changes in the perceived abundance of *H. far* and *S. lessepsianus* in Libya and Tunisia during the period 1970-2013. Y-axis represents a semi-quantitative index of abundance: 0 "ABSENT", 1 "RARE", 2 "OCCASIONAL", 3 "COMMON", 4 "ABUN-DANT" 5 "DOMINANT" (note that no fisherman classed any of the two species as dominant). Black line: mean of the annual observations across all fishers; dots: observations; horizontal dotted line: statistically significant mean line for the breakpoint periods; vertical dotted lines: years of breakpoint.

Table 3. Results of the breakpoint analysis for the selected models. All structural change tests based on the F-statistic were significant at p < 0.0001.

	LIBYA	4	TUNIS	SIA
	breakpoint years	F-stat	breakpoint year	F-stat
H. far	1979, 1994, 2007	91.327	2004	88.071
S. lessepsianus	1989, 1995, 2002	491.990	2007	571.930

this species years before (Jamila Ben Soussi pers. obs.). In one other case, a single specimen of *Fistularia commersonii* was captured by fishermen 25 years before its official detection in 2000 (Bariche *et al.*, 2014). The present collective picture provided by fishermen's LEK showed that both *H. far* and *S. lessepsianus* are widely distributed and established along the entire Tunisian coasts with increasing trend of perceived abundances after 2004. Likewise, the data from Libyan interviews showed an apparent increase in the abundances of *H. far* in the last decade. On the contrary, any recent increase has been reported for *S. lessepsianus*, whose captures are still occasional. Interestingly, several fishermen operating with nets and purse seine, reported observations of very large numbers (hundreds up to thousands) of *H. far* during night. Fishermen repeatedly reported that *H. far* has the ability to jump over the nets and purse seines thus avoiding capture. These behavioural observations agree with a typical trait of *H. far*, which is prone to leap and skitter at the surface avoiding the fishing gear (Bariche, 2012).

Certainly, no quantitative data can be estimated from this survey, being that the best-day captures give just a rough idea of the fished quantities. Moreover the perceived changes in species abundance can be clearly influenced by fishing methods and equipment. Beside the above-mentioned limitations, information reported by fishermen can be evaluated for both reliability (sincerity) and accuracy, that is the degree to which the provided information is near to reality (Silvano & Begossi, 2012). In the present study, interviews can be considered as highly reliable since the extracted information was really based on their daily fishing practices and because of the spontaneous curiosity of many of the respondents. We also may consider that the fisherman's knowledge is accurate, because the historical appearance of a 'new' fish species in captures is a special event that is easily remembered by the fishermen (Azzurro et al., 2011). Remarkably, the analysis of historical trends of abundance revealed coherent species responses for the different study locations and, as expected, invasion chronology followed the East-West gradient, from Tobruk in the eastern Libya to Tabarka in the western Tunisia. Surveying Local Ecological Knowledge about changes in exotic fish presence and abundance provided historical information that otherwise cannot be obtained. As a matter of fact, many southern Mediterranean countries lack the scientific efforts needed to properly track biodiversity changes. Under the urgency of tracking the advance of fish invasions in the Mediterranean Sea, we might broaden our confidence on Local Ecological Knowledge as monitoring tools for exotic species and consider fishermen as experts in these kinds of studies (Rosa et al., 2014). This would overcome the lack of data collection on large spatial and temporal scales, and provide a complementary way to track and to properly manage these rapid and ongoing changes in the marine environment.

Acknowledgements

The present work was developed within the framework of the project "Tropical signals" (CIESM, Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée) founded by Fondation Albert II of Monaco. We warmly acknowledge Paula Moschella for scientific coordination and Noelle Lucey for linguistic editing.

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