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

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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. Syn-odas 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 semi-structured 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 =ABUNDANT (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
<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
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<th>Year</th>
<th>Location</th>
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<tbody>
<tr>
<td>1964</td>
<td>East of Tripoli</td>
<td>41</td>
<td>1990</td>
<td>East of Tripoli</td>
<td>40</td>
</tr>
<tr>
<td>1965</td>
<td>East of Tripoli</td>
<td>40</td>
<td>1991</td>
<td>El Biban Lake</td>
<td>36</td>
</tr>
<tr>
<td>1978</td>
<td>East of Tripoli</td>
<td>30</td>
<td>1991</td>
<td>Kélibia, near the harbour</td>
<td>36</td>
</tr>
<tr>
<td>1980</td>
<td>East of Tripoli</td>
<td>30</td>
<td>1991</td>
<td>Kélibia, one mile out off the coast</td>
<td>36</td>
</tr>
<tr>
<td>1983</td>
<td>West of Tripoli</td>
<td>30</td>
<td>1991</td>
<td>Kélibia, 3 miles out off the coast</td>
<td>36</td>
</tr>
<tr>
<td>1984</td>
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<td>30</td>
<td>1991</td>
<td>Kélibia, 4 miles off the coast</td>
<td>36</td>
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<tr>
<td>1990</td>
<td>West of Tripoli</td>
<td>30</td>
<td>1991</td>
<td>Kélibia, 5 miles off the coast</td>
<td>36</td>
</tr>
<tr>
<td>1993</td>
<td>West of Tripoli</td>
<td>30</td>
<td>1991</td>
<td>Kélibia, near the harbour</td>
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<tr>
<td>1995</td>
<td>West of Tripoli</td>
<td>30</td>
<td>1991</td>
<td>Kélibia, near the harbour</td>
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<td>1997</td>
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<td>30</td>
<td>1991</td>
<td>Kélibia, near the harbour</td>
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<td>2000</td>
<td>West of Tripoli</td>
<td>30</td>
<td>1991</td>
<td>Kélibia, near the harbour</td>
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<td>2003</td>
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<td>30</td>
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<td>Kélibia, near the harbour</td>
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<td>2005</td>
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<td>1991</td>
<td>Kélibia, near the harbour</td>
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<td>2007</td>
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<td>30</td>
<td>1991</td>
<td>Kélibia, near the harbour</td>
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<td>2009</td>
<td>West of Tripoli</td>
<td>30</td>
<td>1991</td>
<td>Kélibia, near the harbour</td>
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<td>2010</td>
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<td>1991</td>
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<td>2012</td>
<td>West of Tripoli</td>
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<td>1991</td>
<td>Kélibia, near the harbour</td>
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<td>2014</td>
<td>West of Tripoli</td>
<td>30</td>
<td>1991</td>
<td>Kélibia, near the harbour</td>
<td>36</td>
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<tr>
<td>2016</td>
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<td>30</td>
<td>1991</td>
<td>Kélibia, near the harbour</td>
<td>36</td>
</tr>
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<td>2018</td>
<td>West of Tripoli</td>
<td>30</td>
<td>1991</td>
<td>Kélibia, near the harbour</td>
<td>36</td>
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<td>2020</td>
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<td>30</td>
<td>1991</td>
<td>Kélibia, near the harbour</td>
<td>36</td>
</tr>
</tbody>
</table>

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 fishermen who remembered the time and the site of first captures well, were reported.
In 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 “COMMON” 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 “OCCASIONAL” in 2013. 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...
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.

<table>
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<th>LIBYA</th>
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<td>breakpoint year</td>
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<tr>
<td><strong>H. far</strong></td>
<td>1979, 1994, 2007</td>
<td>91.327</td>
<td>2004</td>
<td>88.071</td>
</tr>
</tbody>
</table>

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 “ABUNDANT” 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.

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

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