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Updated checklist of bony fishes along the Libyan coast (southern Mediterranean Sea)

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Abstract

Here, we provide an updated review of both native and nonindigenous ichthyofauna occurring in the waters of Libya, one of the largest and less-studied marine areas of the Mediterranean basin. With respect to the most recent information, the list of Libyan bony fishes was updated with 104 species for a total of 304 listed taxa. Out of these species, 271 are native, 6 are endemic to the Mediterranean, 22 are nonindigenous and of Lessepsian origin, and 5 are a range of expanding taxa from Gibraltar. Information on the distribution and abundance of Lessepsian fishes along the Libyan coast was gained through both field surveys and interviews with local small-scale fishermen, which contributed to filling large information gaps in this area. This combined approach allowed us to gather a more complete representation of nonindigenous species along the Libyan coast and indicated three assessment areas, corresponding to the eastern, central and western sectors of the country, which should be considered in future monitoring programs.

Keywords: Osteichthyes; Nonindigenous fishes; Mediterranean Sea; Local Ecological Knowledge.

Introduction

Among all Mediterranean countries, Libya provides one of the largest, more interesting and less-studied marine areas of the basin (Coll *et al.*, 2010; 2013). The approximately 2000 km of coastline is characterized by low levels of anthropogenic pressure (Badalamenti *et al.*, 2011), relatively little contamination (Galgani *et al.*, 2014) and an increasing number of new species that are conquering these waters as well as other sectors of the eastern Mediterranean Sea (Bariche, 2012; Golani *et al.*, 2017; Elbaraasi *et al.*, 2013).

The current information on Libyan fish biodiversity is particularly limited (Bilecenoglu *et al.*, 2002), representing a significant gap in knowledge for Mediterranean sciences. The relevance of this ‘Libyan gap’ (Elbarassi *et al.*, 2014) is recognized as a serious constraint for the assessment of the biodiversity of this basin (Coll *et al.*, 2010), which encompasses approximately 7% of the total marine fish species in the world (Abdul Malak *et al.*, 2011).

So far, Libyan fishes have been the subject of a number of studies since the pioneer investigation of Vinci-

guerra in 1881. Gorgy *et al.* (1972) listed a total of 62 taxa; a few years later, Sogreah (1977) presented a list of 131 species, and Contransime (1977) reported 185 bony fishes, whereas the more complete checklist of bony fishes is so far the one reported by Al-Hassan & Elsilini (1999), who reported 201 species. Recently, Shakman & Kinzelbach (2007) provided a useful list of 16 exotic fishes of Lessepsian origin occurring in Libyan waters, and Belhassan *et al.* (2017) reported new data on the species composition and relative abundance of ten exotic fishes in eastern Libya.

Here, our aim is to provide an updated checklist of the marine bony fishes of Libya, which will be based on both the revision of the available literature and new field surveys. For the new immigrants that have recently been recorded in these waters, their establishment and geographical origin will be examined and discussed.

Methods

Data and samples were collected within the framework of a 5-year research project carried out by the Zool-

ogy Department of the Faculty of Science, University of Benghazi. A total of 12 surveys were carried out on-board local fishing vessels from December 2009 to December 2013, and fishery landings and local fish markets were periodically monitored during the same period. The study area included the major fishing ports of Libya (Fig. 1) and the cities of Tobruk, Derna, Benghazi, Raslanof, Sirte, Musrata and Tripoli. In these areas, commercial fishing is mainly represented by bottom trawlers, operating either over coastal or deep-water habitats. Small-scale fisheries mostly operate with artisanal gears such as trammel nets, various types of gillnet, mid-water and bottom longlines, and encircling nets.

Some fishermen actively contributed to this research, and in some cases, they provided voucher specimens and/or photographic documentation of species perceived as rare or new in the fishing area. Taxonomical identification was mostly performed according to Fisher *et al.* (1987), Nelson (2006), and, in some cases, specific literature. Specimens were preserved and finally deposited in the zoological collection of the Aquaculture and Fishery Laboratory - Zoology Department - Faculty of Science, University of Benghazi. Information collected by field surveys was compared to information extracted from a comprehensive bibliographic search performed on both scientific and gray literature. Scientific names were checked according to Eschmeyer *et al.* (2016) and listed in alphabetic order within each family. The year of the first Mediterranean record of Lessepsian species was based on Azzurro *et al.* (2014) and Golani *et al.* (2017). An expert evaluation of nonindigenous species (NIS) abundances was performed by the authors from data collected by both field surveys and interviews with local fishermen. These interviews were performed by showing pictures of NIS and asking fishermen to express the perceived abundance of species in six ranks of abundance, according to the approach given by Azzurro *et al.* (2011) and Boughedir *et al.* (2015): 0 = *absent or not recorded*; 1 = *single record* (caught only once); 2 = *rare* (caught once a year); 3 = *occasional* (caught sometimes in the fishing period); 4 = *frequent* (caught once a month or less in the fishing period); and 5 = *common* (caught regularly in the fishing period). When doubts arose on the correct identification of the species, the data collected from the interview were discarded. For each survey location, the 'Lessepsian score' was expressed as the sum of the ranks of each species recorded in the area.

The geographical origin of the Libyan bony fishes was based on Froese & Pauly (2016) and, in some cases, on species-specific literature. A cluster representation of survey locations according to the ranked abundance of Lessepsian species was performed with the software Past 3 (Hammer *et al.*, 2001) and was based on Euclidean distances.

Results and Discussion

The high diversity of the Mediterranean Sea is well reflected by the richness of marine species that live in Libyan waters and by the wide range of marine habitats

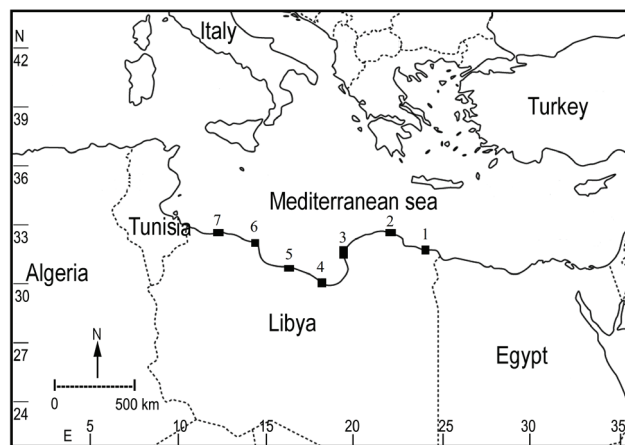


Fig. 1: Map showing the study area and locations where both fishery surveys and fishermen interviews were performed along the Libyan coast (1, Tobruk; 2, Derna; 3, Benghazi; 4, Raslanof; 5, Sirte; 6, Musrata; 7, Tripoli).

that characterize this country (Ben-Abdallah *et al.*, 2011). Our revision reports a total of 304 bony fishes belonging to 22 orders and 97 families (Table 1). With respect to the most recent appraisal given by Al-Hassan & Elsilini (1999), we added 104 new species, which is more than one-third of those previously stated. This represents a significant update to the inventory of bony fishes of Libya that contributes to the information generated by historical studies (Fig. 2), filling an important gap in knowledge (Elbarassi *et al.*, 2014) of marine biodiversity in Libya. According to the geographical origin, our update includes 271 native species; 6 endemic species; 22 Lessepsians; and 5 of Atlantic Ocean origin (Fig. 3). The Zilli's tilapia *Tilapia zilli*, mentioned by Al-Hassan & Elsilini (1999), was not considered in the present checklist because it was already removed from the exotic species list of the Mediterranean (Golani *et al.*, 2017) for its freshwater habits.

Our findings also provided a significant update on exotic fish occurring in Libyan waters. We know that sev-

(continued on page 102)

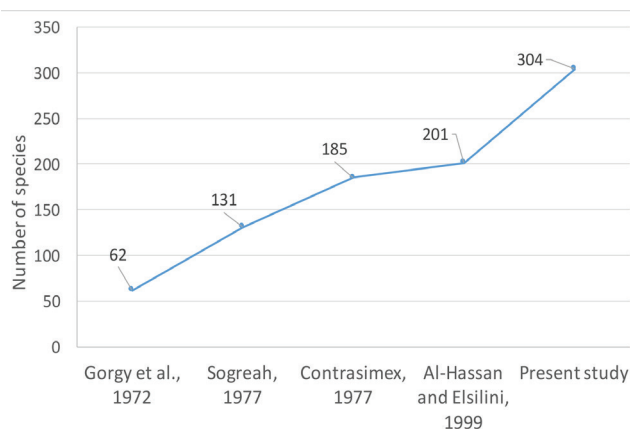


Fig. 2: Number of species included in the previous checklists of Libyan fishes and in the present study.

Table 1. The checklist of bony fishes of the Libyan coast on the Mediterranean (N = Native; E = Endemic of the Mediterranean Sea; A = Atlantic Ocean origin; L = Lessepsian species).

	Common name	Origin	Reference*
ANGUILLIFORMES			
Anguillidae			
<i>Anguilla anguilla</i> (Linnaeus, 1758)	European eel	N	HE
Muraenidae			
<i>Gymnothorax unicolor</i> (Delaroche, 1809)	Brown moray	N	HE
<i>Muraena helena</i> Linnaeus, 1758	Mediterranean moray	N	HE
Ophichthidae			
<i>Dalophis imberbis</i> (Delaroche, 1809)	Armless snake eel	N	PS
<i>Echelus myrus</i> (Linnaeus, 1758)	Painted eel	N	HE
<i>Ophisurus serpens</i> (Linnaeus, 1758)	Serpent eel	N	PS
Congridae			
<i>Ariosoma balearicum</i> (Delaroche, 1809)	Bandtooth conger	N	HE
<i>Conger conger</i> (Linnaeus, 1758)	European conger	N	HE
<i>Gnathophis mystax</i> (Delaroche, 1809)	Thinlip conger	N	PS
CLUPEIFORMES			
Clupeidae			
<i>Alosa alosa</i> (Linnaeus, 1758)	Allis shad	N	PS
<i>Alosa fallax</i> (Lacepède, 1803)	Twaite shad	N	PS
<i>Herklotsichthys punctatus</i> (Rüppell, 1837)	Spotback herring	L	PS
<i>Sardina pilchardus</i> (Walbaum, 1792)	European pilchard	N	HE
<i>Sardinella aurita</i> Valentines, 1847	Round sardinella	N	HE
<i>Sardinella maderensis</i> Lowe, 1838	Madeiran sardinella	N	HE
<i>Sprattus sprattus</i> (Linnaeus, 1758)	European sprat	N	PS
<i>Etrumeus golanii</i> (DiBattista, Randall & Bowen, 2012)	Round herring	L	SH
Engraulidae			
<i>Engraulis encrasicolus</i> (Linnaeus, 1758)	European anchovy	N	HE
OSMERIFORMES			
Argentinidae			
<i>Argentina sphyraena</i> (Linnaeus, 1758)	Argentine	N	HE
<i>Glossanodon leioglossus</i> (Valenciennes, 1848)	Smalltoothed argentine	N	PS
STOMIIFORMES			
Gonostomatidae			
<i>Cyclothone braueri</i> Jespersen & Tåning, 1926	Garrick	N	PS
<i>Cyclothone pygmaea</i> Jespersen & Tåning, 1926		E	PS
<i>Gonostoma denudatum</i> Rafinesque, 1810		N	PS
Sternoptychidae			
<i>Argyropelecus hemigymnus</i> Cocco, 1829	Half-naked hatchetfish	N	PS
<i>Maurolicus muelleri</i> (Gmelin, 1789)	Silvery lightfish	N	HE
Phosichthyidae			
<i>Ichthyococcus ovatus</i> (Cocco, 1838)	Lightfish	N	PS
<i>Vinciguerria attenuata</i> (Cocco, 1838)	Slender lightfish	N	PS
<i>Vinciguerria poweriae</i> (Cocco, 1838)	Power's deep-water bristle-mouth fish	N	PS

(continued)

Table 1 (Continued)

	Common name	Origin	Reference*
Stomiidae			
<i>Chauliodus sloani</i> Bloch & Schneider, 1801	Sloane's viperfish	N	PS
<i>Stomias boa boa</i> (Risso, 1810)	Boa dragonfish	N	PS
AULOPIFORMES			
Aulopidae			
<i>Aulopus filamentosus</i> (Bloch, 1792)	Royal flagfin	N	HE
Chlorophthalmidae			
<i>Chlorophthalmus agassizi</i> Bonaparte, 1840	Shortnose greeneye	N	HE
Synodontidae			
<i>Saurida lessepsianus</i> Russell, Golani & Tikochinski, 2015		L	HE
<i>Synodus saurus</i> (Linnaeus, 1758)	Atlantic lizardfish	N	HE
Paralepididae			
<i>Arctozenus risso</i> (Bonaparte, 1840)	Spotted barracudina	N	PS
<i>Lestidiops jayakari</i> (Boulenger, 1889)	Pacific barracudina	N	PS
<i>Paralepis coregonoides</i> (Risso, 1820)	Sharpchin barracudina	N	PS
Evermannellidae			
<i>Evermannella balbo</i> (Risso, 1820)	Balbo sabretooth	N	PS
MYCTOPHIFORMES			
Myctophidae			
<i>Benthoosema glaciale</i> (Reinhardt, 1837)	Glacier lantern fish	N	PS
<i>Ceratoscopelus maderensis</i> (Lowe, 1839)	Madeira lantern fish	N	PS
<i>Diaphus holti</i> Tåning, 1918	Small lantern fish	N	PS
<i>Diaphus rafinesquii</i> (Cocco, 1838)	White-spotted lantern fish	N	PS
<i>Electrona risso</i> (Cocco, 1829)	Electric lantern fish	N	PS
<i>Gonichthys cocco</i> (Cocco, 1829)	Cocco's lanternfish	N	PS
<i>Hygophum benoiti</i> (Cocco, 1838)	Benoit's lanternfish	N	PS
<i>Hygophum hygomii</i> (Lütken, 1892)	Bermuda lantern fish	N	PS
<i>Lampanyctus crocodilus</i> (Risso 1810)		N	PS
<i>Lampanyctus pusillus</i> (Johnson 1890)		N	PS
<i>Lobianchia dofleini</i> (Zugmayer, 1911)	Dofleini's lantern fish	N	PS
<i>Myctophum punctatum</i> Rafinesque, 1810	Spotted lanternfish	N	PS
<i>Notoscopelus bolini</i> Nafpaktitis, 1975		N	PS
<i>Symbolophorus veranyi</i> (Moreau, 1888)	Large-scale lantern fish	N	PS
LAMPRIFORMES			
Lophotidae			
<i>Lophotus lacepede</i> (Giorna, 1809)	Crested oarfish	N	PS
Trachipteridae			
<i>Trachipterus trachipterus</i> (Gmelin, 1789)	Mediterranean dealfish	N	PS
<i>Zu cristatus</i> (Bonelli, 1819)	Scalloped ribbonfish	N	PS
GADIFORMES			
Macrouridae			

(continued)

Table 1 (Continued)

	Common name	Origin	Reference*
<i>Coelorinchus caelorhincus</i> (Risso, 1810)	Hollowsnout grenadier	N	HE
<i>Hymenocephalus italicus</i> Giglioli, 1884	Glasshead grenadier	N	HE
<i>Nezumia aequalis</i> (Günther, 1878)	Common Atlantic grenadier	N	HE
<i>Trachyrincus scabrus</i> (Rafinesque, 1810)	Roughsnout grenadier	N	PS
Moridae			
<i>Gadella maraldi</i> (Risso, 1810)	Gadella	N	HE
Gadidae			
<i>Gadiculus argenteus</i> Guichenot, 1850	Silvery pout	N	HE
<i>Merlangius merlangus</i> (Linnaeus, 1758)	Whiting	N	HE
<i>Micromesistius poutassou</i> (Risso, 1827)	Blue whiting	N	PS
<i>Trisopterus luscus</i> (Linnaeus, 1758)	Pouting	N	PS
<i>Trisopterus minutus</i> (Linnaeus, 1758)	Poor cod	N	HE
Lotidae			
<i>Gaidropsarus biscayensis</i> (Collett, 1890)	Mediterranean bigeye rockling	N	HE
<i>Gaidropsarus mediterraneus</i> (Linnaeus, 1758)	Shore rockling	N	HE
<i>Molva macrophthalmalma</i> (Rafinesque, 1810)	Spanish lin	N	HE
Phycidae			
<i>Phycis blennoides</i> (Brünnich, 1768)	Greater forkbeard	N	HE
<i>Phycis phycis</i> (Linnaeus, 1766)	Forkbeard	N	HE
Merlucciidae			
<i>Merluccius merluccius</i> (Linnaeus, 1758)	European hake	N	HE
OPHIDIIFORMES			
Ophidiidae			
<i>Ophidion barbatum</i> Linnaeus, 1758	Snake blenny	N	HE
<i>Ophidion rochei</i> Müller, 1845		N	HE
Carapidae			
<i>Carapus acus</i> (Brünnich, 1768)	Pearl fish	N	HE
BATRACHOIDIFORMES			
Batrachoididae			
<i>Halobatrachus didactylus</i> (Bloch & Schneider, 1801)	Lusitanian toadfish	N	PS
LOPHIIFORMES			
Lophiidae			
<i>Lophius budegassa</i> Spinola, 1807	Blackbellied angler	N	HE
<i>Lophius piscatorius</i> Linnaeus, 1758	Angler	N	HE
GOBIESOCIFORMES			
Gobiesocidae			
<i>Diplecogaster bimaculata</i> (Bonnaterre, 1788)	Two-spotted clingfish	N	HE
<i>Gouania willdenowi</i> (Risso, 1810)	Blunt-snouted clingfish	N	PS
ATHERINIFORMES			
Atherinidae			
<i>Atherina boyeri</i> Risso, 1810	Big-scale sand smelt	N	HE

(continued)

Table 1 (Continued)

	Common name	Origin	Reference*
<i>Atherina hepsetus</i> Linnaeus, 1758	Mediterranean sand smelt	N	HE
<i>Atherinomorus forskalii</i> (Rüppell, 1838)	Red Sea hardyhead silverside	L	HE
CYPRONODONTIFORMES			
Cyprinodontidae			
<i>Aphanius fasciatus</i> (Valenciennes, 1821)	Mediterranean banded killifish	N	HE
BELONIFORMES			
Scomberesocidae			
<i>Scomberesox saurus</i> (Walbaum, 1792)	Atlantic saury	N	HE
Belonidae			
<i>Belone belone</i> (Linnaeus, 1761)	Garfish	N	HE
Hemiramphidae			
<i>Hemiramphus far</i> (Forsskål, 1775)	Black-barred halfbeak	L	PS
<i>Hyporhamphus picarti</i> (Valenciennes, 1847)	African halfbeak	N	HE
Exocoetidae			
<i>Cheilopogon heterurus</i> (Rafinesque, 1810)	Mediterranean flyingfish	N	HE
<i>Hirundichthys rondeletii</i> (Valenciennes, 1847)	Black wing flyingfish	N	PS
<i>Parexocoetus mento</i> (Valenciennes, 1847)	African sailfin flyingfish	L	HE
BERYCIFORMES			
Trachichthyidae			
<i>Hoplostethus mediterraneus</i> Cuvier, 1829	Mediterranean slimehead	N	HE
Holocentridae			
<i>Sargocentron rubrum</i> (Forsskål, 1775)	Redcoat	L	HE
ZEIFORMES			
Zeidae			
<i>Zeus faber</i> Linnaeus, 1758	John dory	N	HE
SYNGNATHIFORMES			
Fistulariidae			
<i>Fistularia commersonii</i> Rüppell, 1838	Bluespotted cornetfish (L)	L	PS
Centriscidae			
<i>Macroramphosus scolopax</i> (Linnaeus, 1758)	Longspine snipefish	N	HE
Syngnathidae			
<i>Hippocampus guttulatus</i> Cuvier, 1829	Long-snouted seahorse	N	HE
<i>Hippocampus hippocampus</i> (Linnaeus, 1758)	Short snouted seahorse	N	HE
<i>Nerophis ophidion</i> (Linnaeus, 1758)	Straightnose pipefish	N	PS
<i>Syngnathus abaster</i> Risso, 1827	Black-striped pipefish	N	HE
<i>Syngnathus acus</i> Linnaeus, 1758	Greater pipefish	N	HE
<i>Syngnathus phlegon</i> Risso, 1827		N	PS
<i>Syngnathus typhle</i> Linnaeus, 1758	Broadnosed pipefish	N	HE
SCORPAENIFORMES			
Sebastidae			
<i>Helicolenus dactylopterus</i> (Delaroche, 1809)	Blackbelly rosefish	N	HE

(continued)

Table 1 (Continued)

	Common name	Origin	Reference*
Scorpaenidae			
<i>Scorpaena elongata</i> Cadenat, 1943	Slender rockfish	N	HE
<i>Scorpaena loppei</i> Cadenat, 1943	Cadenat's rockfish	N	HE
<i>Scorpaena maderensis</i> Valenciennes, 1833	Madeira rockfish	N	PS
<i>Scorpaena notata</i> Rafinesque, 1810	Small red scorpionfish	N	HE
<i>Scorpaena porcus</i> Linnaeus, 1758	Black scorpionfish	N	HE
<i>Scorpaena scrofa</i> Linnaeus, 1758	Red scorpionfish	N	HE
Dactylopteridae			
<i>Dactylopterus volitans</i> (Linnaeus, 1758)	Flying gurnard	N	HE
Triglidae			
<i>Chelidonichthys cuculus</i> (Linnaeus, 1758)	Red gurnard	N	HE
<i>Chelidonichthys obscurus</i> (Walbaum, 1792)	Longfin gurnard	N	HE
<i>Eutrigla gurnardus</i> (Linnaeus, 1758)	Grey gurnard	N	HE
<i>Lepidotrigla cavillone</i> (Lacepède, 1801)	Large-scaled gurnard	N	HE
<i>Lepidotrigla dieuzeidei</i> Blanc & Hureau, 1973	Spiny gurnard	N	PS
<i>Trigla lyra</i> (Linnaeus, 1758)	Piper gurnard	N	HE
<i>Trigloporus lastoviza</i> (Bonnaterre, 1788)	Streaked gurnard	N	HE
Famiy Peristediidae			
<i>Peristedion cataphractum</i> (Linnaeus, 1758)	African armoured searobin	N	HE
PERCIFORMES			
Moronidae			
<i>Dicentrarchus labrax</i> (Linnaeus, 1758)	European seabass	N	HE
<i>Dicentrarchus punctatus</i> Bloch, 1792	Spotted seabass	N	HE
Polyprionidae			
<i>Polyprion americanus</i> (Bloch & Schneider, 1801)	Wreckfish	N	HE
Serranidae			
<i>Anthias anthias</i> (Linnaeus, 1758)	Swallowtail seaperch	N	HE
<i>Cephalopholis taeniops</i> (Valenciennes, 1828)		A	BE
<i>Epinephelus aeneus</i> (Geoffroy Saint-Hilaire, 1817)	White grouper	N	HE
<i>Epinephelus caninus</i> (Valenciennes, 1843)	Dogtooth grouper	N	HE
<i>Epinephelus costae</i> (Steindachner, 1878)	Goldblotch grouper	N	HE
<i>Epinephelus fasciatus</i> (Forsskål, 1775)	Blacktip grouper	N	HE
<i>Epinephelus marginatus</i> (Lowe, 1834)	Dusky grouper	N	HE
<i>Hyporthodus haifensis</i> (Ben-Tuvia, 1953)	Haifa grouper	N	HE
<i>Mycteroperca rubra</i> (Bloch, 1793)	Mottled grouper	N	PS
<i>Serranus cabrilla</i> (Linnaeus, 1758)	Comber	N	HE
<i>Serranus hepatus</i> (Linnaeus, 1758)	Brown comber	N	HE
<i>Serranus scriba</i> (Linnaeus, 1758)	Painted comber	N	HE
Callanthiidae			
<i>Callanthias ruber</i> (Rafinesque, 1810)	Parrot seaperch	N	HE
Apogonidae			
<i>Apogon imberbis</i> (Linnaeus, 1758)	Cardinal fish	N	HE

(continued)

Table 1 (Continued)

	Common name	Origin	Reference*
Pomatomidae			
<i>Pomatomus saltatrix</i> (Linnaeus, 1766)	Bluefish	N	HE
Echeneidae			
<i>Echeneis naucrates</i> (Linnaeus, 1758)	Live sharksucker	N	HE
<i>Remora remora</i> (Linnaeus, 1758)	Shark sucker	N	HE
Carangidae			
<i>Alectis alexandrina</i> (Geoffroy Saint-Hilaire, 1817)	Alexandria pompano	N	PS
<i>Alepes djedaba</i> (Forsskål, 1775)	Shrimp scad	L	PS
<i>Campogramma glaycos</i> (Lacepède, 1801)	Vadigo	N	PS
<i>Caranx crysos</i> (Mitchill, 1815)	Blue runner	N	HE
<i>Caranx hippos</i> (Linnaeus, 1766)	Crevalle jack	N	HE
<i>Caranx rhonchus</i> Geoffroy Saint-Hilaire, 1817	False scad	N	HE
<i>Lichia amia</i> (Linnaeus, 1758)	Leerfish	N	HE
<i>Naucrates ductor</i> (Linnaeus, 1758)	Pilotfish	N	PS
<i>Pseudocaranx dentex</i> (Bloch & Schneider, 1801)	White trevally	N	HE
<i>Seriola dumerili</i> (Risso, 1810)	Greater amberjack	N	HE
<i>Seriola fasciata</i> (Bloch, 1793)	Lesser amberjack	A	SH
<i>Seriola rivoliana</i> (Valenciennes, 1833)	Longfin yellowtail	A	SH
<i>Trachurus trachurus</i> (Linnaeus, 1758)	Atlantic horse mackerel	N	HE
<i>Trachurus picturatus</i> (Bowdich, 1825)	Blue jack mackerel	N	HE
<i>Trachurus mediterraneus</i> (Steindachner, 1868)	Mediterranean horse mackerel	N	HE
<i>Trachinotus ovatus</i> (Linnaeus, 1758)	Pompano	N	HE
Coryphaenidae			
<i>Coryphaena hippurus</i> (Linnaeus, 1758)	Common dolphinfish	N	HE
Bramidae			
<i>Brama brama</i> (Bonnaterre, 1788)	Atlantic pomfret	N	PS
Lobotidae			
<i>Lobotes surinamensis</i> (Bloch, 1790)	Tripletai	N	PS
Haemulidae			
<i>Pomadasys incisus</i> (Bowdich, 1825)	Bastard grunt	N	HE
Sparidae			
<i>Boops boops</i> (Linnaeus, 1758)	Bogue	N	HE
<i>Crenidens crenidens</i> (Forsskål, 1775)	Karanteen seabream	L	HE
<i>Dentex dentex</i> (Linnaeus, 1758)	Common dentex	N	HE
<i>Dentex maroccanus</i> (Valenciennes, 1830)	Morocco dentex	N	HE
<i>Dentex macrophthalmus</i> (Bloch, 1791)	Large-eye dentex	N	HE
<i>Dentex gibbosus</i> (Rafinesque, 1810)	Pink dentex	N	HE
<i>Diplodus annularis</i> (Linnaeus, 1758)	Annular seabream	N	HE
<i>Diplodus cervinus</i> (Lowe, 1838)	Zebra seabream	N	HE
<i>Diplodus puntazzo</i> (Walbaum, 1792)	Sharpsnout seabream	N	HE
<i>Diplodus sargus</i> (Linnaeus, 1758)	White seabream	N	HE

(continued)

Table 1 (Continued)

	Common name	Origin	Reference*
<i>Diplodus vulgaris</i> (Geoffroy Saint-Hilaire, 1817)	Common two-banded seabream	N	HE
<i>Lithognathus mormyrus</i> (Linnaeus, 1758)	Sand steenbras	N	HE
<i>Oblada melanura</i> (Linnaeus, 1758)	Saddled seabream	N	HE
<i>Pagellus acarne</i> (Risso, 1827)	Axillary seabream	N	HE
<i>Pagellus bellottii</i> (Steindachner, 1882)	Red Pandora	N	HE
<i>Pagellus bogaraveo</i> (Brünnich, 1768)	Blackspot seabream	N	HE
<i>Pagellus erythrinus</i> (Linnaeus, 1758)	Common Pandora	N	PS
<i>Pagrus auriga</i> (Valenciennes, 1843)	Redbanded seabream	N	HE
<i>Pagrus caeruleostictus</i> (Valenciennes, 1830)	Bluespotted seabream	N	HE
<i>Pagrus pagrus</i> (Linnaeus, 1758)	Red porgy	N	HE
<i>Sarpa salpa</i> (Linnaeus, 1758)	Salema	N	HE
<i>Sparus aurata</i> (Linnaeus, 1758)	Gilthead seabream	N	HE
<i>Spondylisoma cantharus</i> (Linnaeus, 1758)	Black seabream	N	HE
Centracanthidae			
<i>Centracanthus cirrus</i> Rafinesque, 1810	Curled picarel	N	HE
<i>Spicara flexuosa</i> (Rafinesque 1810)		N	HE
<i>Spicara maena</i> (Linnaeus, 1758)	Blotched picarel	N	HE
<i>Spicara smaris</i> (Linnaeus, 1758)	Picarel	N	HE
Sciaenidae			
<i>Argyrosomus regius</i> (Asso, 1801)	Meagre	N	PS
<i>Sciaena umbra</i> Linnaeus, 1758	Brown meager	N	HE
<i>Umbrina cirrosa</i> (Linnaeus, 1758)	Shi drum	N	HE
<i>Umbrina canariensis</i> (Valenciennes, 1843)	Canary drum	N	HE
Mullidae			
<i>Mullus barbatus</i> Linnaeus, 1758	Red mullet	N	HE
<i>Mullus surmulletus</i> Linnaeus, 1758	Surmullet	N	HE
<i>Upeneus moluccensis</i> (Bleeker, 1855)	Goldband goatfish	L	PS
<i>Upeneus pori</i> Ben-Tuvia & Golani, 1989	Por's goatfish	L	PS
Pempheridae			
<i>Pempheris rhomboidea</i> Kossmann & Räuber, 1877			
	Vanikoro sweeper	L	PS
Kyphosidae			
<i>Kyphosus sectatrix</i> (Linnaeus, 1758)	Bermuda sea chub	A	EL
Cepolidae			
<i>Cepola macrophthalma</i> (Linnaeus, 1758)	Red bandfish	N	HE
Mugilidae			
<i>Chelon labrosus</i> (Risso, 1827)	Thicklip grey mullet	N	HE
<i>Liza aurata</i> (Risso, 1810)	Golden grey mullet	N	HE
<i>Liza carinata</i> (Valenciennes, 1836)	Keeled mullet	L	PS
<i>Liza ramada</i> (Risso, 1827)	Thinlip grey mullet	N	HE
<i>Liza saliens</i> (Risso, 1810)	Leaping mullet	N	HE
<i>Mugil cephalus</i> Linnaeus, 1758	Flathead grey mullet	N	PS

(continued)

Table 1 (Continued)

	Common name	Origin	Reference*
<i>Oedalechilus labeo</i> (Cuvier, 1829)	Boxlip mullet	N	PS
Pomacentridae			
<i>Chromis chromis</i> (Linnaeus, 1758)	Damselfish	N	HE
Labridae			
<i>Coris julis</i> (Linnaeus, 1758)	Mediterranean rainbow wrasse	N	HE
<i>Ctenolabrus rupestris</i> (Linnaeus, 1758)	Goldsinny-wrasse	N	PS
<i>Labrus bergylta</i> Ascanius, 1767	Ballan wrasse	N	HE
<i>Labrus merula</i> Linnaeus, 1758	Brown wrasse	N	HE
<i>Labrus mixtus</i> Linnaeus, 1758	Cuckoo wrasse	N	HE
<i>Labrus viridis</i> Linnaeus, 1758		N	HE
<i>Symphodus cinereus</i> (Bonnaterre, 1788)	Grey wrasse	N	HE
<i>Symphodus doderleini</i> (Jordan, 1890)		E	PS
<i>Symphodus mediterraneus</i> (Linnaeus, 1758)	Axillary wrasse	N	HE
<i>Symphodus ocellatus</i> (Linnaeus, 1758)		N	HE
<i>Symphodus roissali</i> (Risso, 1810)	Five-spotted wrasse	N	HE
<i>Symphodus rostratus</i> (Bloch, 1791)		N	HE
<i>Symphodus tinca</i> (Linnaeus, 1758)	East Atlantic peacock wrasse	N	HE
<i>Thalassoma pavo</i> (Linnaeus, 1758)	Ornate wrasse	N	HE
<i>Xyrichtys novacula</i> (Linnaeus, 1758)	Pearly razorfish	N	HE
Scaridae			
<i>Sparisoma cretense</i> (Linnaeus, 1758)	Parrotfish	N	HE
Trachinidae			
<i>Echiichthys vipera</i> (Cuvier, 1829)	Lesser weever	N	HE
<i>Trachinus araneus</i> Cuvier, 1829	Spotted weever	N	HE
<i>Trachinus draco</i> Linnaeus, 1758	Greater weever	N	HE
<i>Trachinus radiatus</i> Cuvier, 1829	Starry weever	N	HE
Uranoscopidae			
<i>Uranoscopus scaber</i> Linnaeus, 1758	Stargazer	N	HE
Clinidae			
<i>Clinitrachus argentatus</i> (Risso, 1810)	Cline	N	HE
Blenniidae			
<i>Blennius ocellaris</i> Linnaeus, 1758	Butterfly blenny	N	HE
<i>Lipophrys trigloides</i> (Valenciennes, 1836)		N	HE
<i>Parablennius incognitus</i> (Bath, 1968)		N	HE
<i>Parablennius sanguinolentus</i> (Pallas, 1814)	Rusty blenny	N	PS
<i>Salaria basilisca</i> (Valenciennes, 1836)		E	HE
<i>Salaria pavo</i> (Risso, 1810)	Peacock blenny	N	HE
Callionymidae			
<i>Callionymus lyra</i> Linnaeus, 1758	Dragonet	N	HE
<i>Callionymus maculatus</i> (Rafinesque, 1810)		N	HE
<i>Synchiropus phaeton</i> (Günther, 1861)	Phaeton dragonet	N	PS

(continued)

Table 1 (Continued)

	Common name	Origin	Reference*
Gobiidae			
<i>Deltentosteus quadrimaculatus</i> (Valenciennes, 1837)	Four spotted goby	N	PS
<i>Gobius bucchichi</i> Steindachner, 1870	Bucchich's goby	N	HE
<i>Gobius cobitis</i> Pallas, 1814	Giant goby	N	HE
<i>Gobius cruentatus</i> Gmelin, 1789	Red-mouthed goby	N	HE
<i>Gobius niger</i> (Linnaeus, 1758)	Black goby	N	HE
<i>Gobius paganellus</i> Linnaeus, 175	Rock goby	N	PS
<i>Pomatoschistus marmoratus</i> (Risso, 1810)	Marbled goby	N	HE
<i>Pomatoschistus minutus</i> (Pallas, 1770)	Sand goby	N	PS
<i>Pomatoschistus tortonesei</i> (Miller, 1969)	Tortonese's goby	E	HE
Siganidae			
<i>Siganus luridus</i> (Rüppell, 1829)	Dusky spinefoot	L	HE
<i>Siganus rivulatus</i> (Forsskål & Niebuhr, 1775)	Marbled spinefoot	L	HE
Luvaridae			
<i>Luvarus imperialis</i> Rafinesque, 1810	Luvar	N	PS
Sphyraenidae			
<i>Sphyraena sphyraena</i> (Linnaeus, 1758)	European barracuda	N	HE
<i>Sphyraena viridensis</i> Cuvier, 1829	Yellowmouth barracuda	N	HE
<i>Sphyraena chrysotaenia</i> Klunzinger, 1884	Obtuse barracuda	L	PS
<i>Sphyraena flavicauda</i> Rüppell, 1838	Red barracuda	L	PS
Gempylidae			
<i>Ruvettus pretiosus</i> Cocco, 1833	Oilfish	N	PS
Trichiuridae			
<i>Lepidopus caudatus</i> (Euphrasen, 1788)	Silver scabbardfish	N	HE
<i>Trichiurus lepturus</i> Linnaeus, 1758	Largehead hairtail	N	PS
Scombridae			
<i>Acanthocybium solandri</i> (Cuvier, 1832)	Wahoo	N	PS
<i>Auxis rochei</i> (Risso, 1810)	Bullet tuna	N	HE
<i>Auxis thazard</i> (Lacepède, 1800)	Frigate tuna	N	PS
<i>Euthynnus alletteratus</i> (Rafinesque, 1810)	Little tunny	N	HE
<i>Katsuwonus pelamis</i> (Linnaeus, 1758)	Skipjack tuna	N	HE
<i>Orcynopsis unicolor</i> (Geoffroy Saint-Hilaire, 1817)	Plain bonito	N	HE
<i>Sarda sarda</i> (Bloch, 1793)	Atlantic bonito	N	HE
<i>Scomber colias</i> Gmelin, 1789	Atlantic chub mackerel	N	HE
<i>Scomber scombrus</i> Linnaeus, 1758	Atlantic mackerel	N	HE
<i>Scomberomorus commerson</i> (Lacepède, 1800)	Narrow-barred Spanish mackerel	L	PS
<i>Thunnus alalunga</i> (Bonnaterre, 1788)	Albacore	N	PS
<i>Thunnus thynnus</i> (Linnaeus, 1758)	Atlantic bluefin tuna	N	HE
Xiphiidae			
<i>Xiphias gladius</i> Linnaeus, 1758	Swordfish	N	PS
Istiophoridae			
<i>Kajikia albida</i> (Poey, 1860)	Atlantic white marlin	N	PS

(continued)

Table 1 (Continued)

	Common name	Origin	Reference*
<i>Tetrapturus belone</i> Rafinesque, 1810	Mediterranean spearfish	E	PS
Centrolophidae			
<i>Centrolophus niger</i> (Gmelin, 1789)	Rudderfish	N	PS
Stromateidae			
<i>Stromateus fiatola</i> Linnaeus, 1758	Blue butterfish	N	PS
Caproidae			
<i>Capros aper</i> (Linnaeus, 1758)	Boarfish	N	PS
PLEURONECTIFORMES			
Citharidae			
<i>Citharus linguatula</i> (Linnaeus, 1758)	Spotted flounder	N	HE
Scophthalmidae			
<i>Lepidorhombus boscii</i> (Risso, 1810)	Four-spot megrim	N	HE
<i>Lepidorhombus whiffiagonis</i> (Walbaum, 1792)	Megrim	N	HE
<i>Scophthalmus maximus</i> (Linnaeus, 1758)	Turbot	N	PS
<i>Scophthalmus rhombus</i> (Linnaeus, 1758)	Brill	N	HE
Bothidae			
<i>Arnoglossus imperialis</i> (Rafinesque, 1810)	Imperial scaldfish	N	PS
<i>Arnoglossus kessleri</i> (Schmidt, 1915)	Scaldback	N	PS
<i>Arnoglossus laterna</i> (Walbaum, 1792)	Mediterranean scaldfish	N	HE
<i>Arnoglossus rueppelii</i> (Cocco, 1844)	Rüppell's scaldback	N	HE
	Common name	Origin	Reference*
<i>Arnoglossus thori</i> (Kyle, 1913)	Thor's scaldfish	N	HE
<i>Bothus podas</i> (Delaroche, 1809)	Wide-eyed flounder	N	HE
Pleuronectidae			
<i>Platichthys flesus</i> (Linnaeus, 1758)	European flounder	N	PS
Soleidae			
<i>Buglossidium luteum</i> (Risso, 1810)	Solenette	N	PS
<i>Dicologlossa cuneata</i> (Moreau, 1881)	Wedge sole	N	HE
<i>Microchirus ocellatus</i> (Linnaeus, 1758)	Foureyed sole	N	HE
<i>Microchirus variegatus</i> (Donovan, 1808)	Thickback sole	N	PS
<i>Monochirus hispidus</i> (Rafinesque, 1814)	Whiskered sole	N	HE
<i>Pegusa lascaris</i> (Risso, 1810)	Sand sole	N	HE
<i>Solea aegyptiaca</i> (Chabanaud, 1927)	Egyptian sole	N	HE
<i>Solea solea</i> (Linnaeus, 1758)	Common sole	N	HE
<i>Synaptura lusitanica lusitanica</i> (de Brito Capello, 1868)	Portuguese sole	N	HE
<i>Synapturichthys kleinii</i> (Risso, 1827)	Klein's sole	N	HE
Cynoglossidae			
<i>Symphurus ligulatus</i> (Cocco, 1844)	Elongate tonguesole	N	HE
<i>Symphurus nigrescens</i> (Rafinesque, 1810)	Tonguesole	N	HE
TETRAODONTIFORMES			
Balistidae			
<i>Balistes capriscus</i> Gmelin, 1789	Grey triggerfish	N	HE
Monacanthidae			

(continued)

Table 1 (Continued)

	Common name	Origin	Reference*
<i>Stephanolepis diaspros</i> Fraser-Brunner, 1940	Reticulated leatherjacket	L	HE
Tetraodontidae			
<i>Lagocephalus lagocephalus</i> (Linnaeus, 1758)	Oceanic puffer	N	PS
<i>Lagocephalus sceleratus</i> (Gmelin, 1789)	Silver-cheeked toadfish	L	PS
<i>Lagocephalus suezensis</i> (Clark & Gohar, 1953)		L	PS
<i>Sphoeroides pachygaster</i> (Müller & Troschel, 1848)	Blunthead puffer	A	SH
Molidae			
<i>Mola mola</i> (Linnaeus, 1758)	Ocean sunfish	N	PS
<i>Ranzania laevis</i> (Pennant, 1776)	Slender sunfish	N	PS

* HE= Al-Hassan and Elsilini; 1999; PS = Present study; SH= Shakman *et al.*, 2017; EL= Elbaraasi *et al.*, 2013; BE= Ben Abdallah *et al.*, 2007.

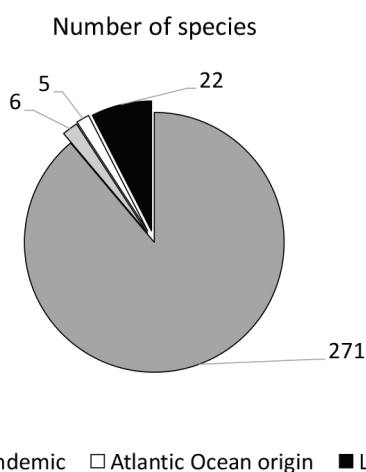


Fig. 3: Ichthyofauna of Libya: Number of species according to their geographical origin.

(continued from page 91)

eral of these species have caused significant ecological and socioeconomic impacts in the Mediterranean (Otero *et al.*, 2013; Katsanevakis *et al.*, 2014), but this phenomenon is probably underestimated in several countries of the southern Mediterranean rim (Coll *et al.*, 2013). Out of a total of 304 species registered by the present study, 22 (7%) were of Lessepsian origin. These are distributed in 8 total orders: Perciformes (11 species); Tetraodontiformes (3 species); Beloniformes and Clupeiformes (2 species), including the recently recorded species *Etrumeus golanii* (Shakman *et al.*, 2017); and Syngnathiformes, Atheriniformes, Aulopiformes, and Beryciformes (1 species). With respect to the most recent inventory (Shakman & Kinzelbach, 2007), the importance of Lessepsian fish species in Libya has significantly increased. According to our findings and by considering all survey locations, 1 species (*S. diaspros*) was reported as 'rare'; 3 species (*P. mento*, *S. rubrum*, *L. carinata*) were considered 'occasional'; 7 species (*A. forskalii*, *H. far*, *S. commerson*, *U. pori*, *P. rhomboidea*, *L. suezensis*, *L. sceleratus*) were

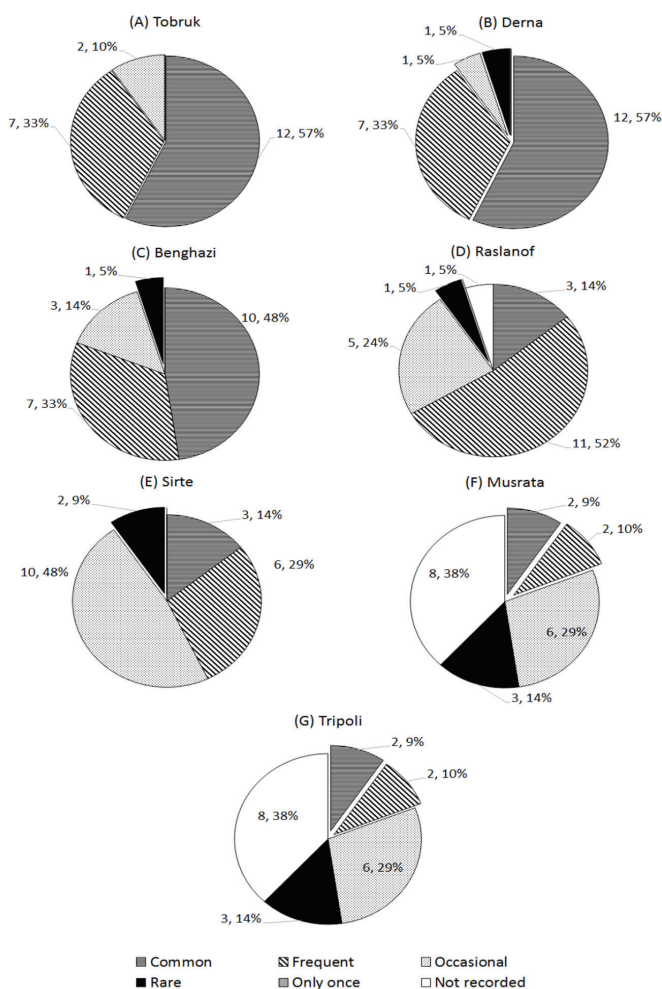


Fig 4. Abundance of Lessepsian fishes along the study locations in Libya. The percentage of Lessepsian fishes distributed in each class of abundance (defined in six different ranks) is calculated for each location.

'frequent'; and 10 species (*S. lessepsianus*, *H. punctatus*, *S. luridus*, *S. rivulatus*, *S. obtusata*, *S. pinguis*, *A. djedaba*, *U. moluccensis*, *C. crenidens*, *F. commersonii*)

were indicated as ‘common’. Remarkably, the common lionfish *Pterois miles* was not recorded by the present investigation. Taking into account the efforts posed in this study in terms of the number of surveys and the number of interviewed fishermen, it is highly probable that this species was unnoticed because it is very rare along the Libyan coast. Indeed, despite some punctual observations of the lionfish that have been recently reported to the west of Libya (from Tunisia and southern Italy, see Azzurro *et al.* 2017), to the best of our knowledge, the species has not been reported on the Mediterranean coast of Egypt. Considering the increasing success of the lionfish and its rapid geographical expansion, further investigation is needed to detect its expected occurrence and spread.

One other important result of this study was that the occurrence and abundance of Lessepsian fish in Libya are unevenly distributed across the different geographical sectors (Table 2, Fig 4). Indeed, 98% of the reported Lessepsian species occurred on the eastern coast, 91% on the central coast, and only 56% in the western sector. These differences, which are well represented by the *Lessepsian score* (Fig 5a), produced a clear west-east gradient, with a higher representation (in terms of both distribution and abundance) of Lessepsian fish along the eastern coast than along the western coast. Interestingly, the cluster obtained by the ranked abundances (Fig 5b) perfectly matched the geographical arrangement of survey locations across the western, central and eastern

coasts of the country. Therefore, at least three assessment areas, corresponding to the eastern, central and western sectors of the country, should be considered in monitoring programs, which focus on the distribution and abundance of Lessepsian species. Considering the rapid evolution of the Lessepsian phenomenon along the Libyan coast and the longitudinal gradients, monitoring activities should be ideally performed on all these subsectors on a periodic basis. Recent studies provide increasing evidence on the effectiveness of involving local communities in order to provide a complementary knowledge to traditional surveys and enforce early detection systems (e.g., Azzurro *et al.*, 2018). In this regard, we provided a good example to show how local stakeholders, especially small-scale fishermen, can be involved in the process of knowledge building. The used approach, which combined fishermen knowledge with field surveys, was of great help in filling large information gaps along the Libyan coast, and its use can be certainly advised, especially in data-poor coastal ecosystems (Beaudreau & Levin, 2014), such as the southern Mediterranean Sea.

Nevertheless, some groups of small and cryptic species with no commercial importance such as gobiidae, blennidae, trypterigidae and gobiesocidae remain underrepresented in this study, and further investigation is expected to enrich our knowledge of fishes along the Libyan coast.

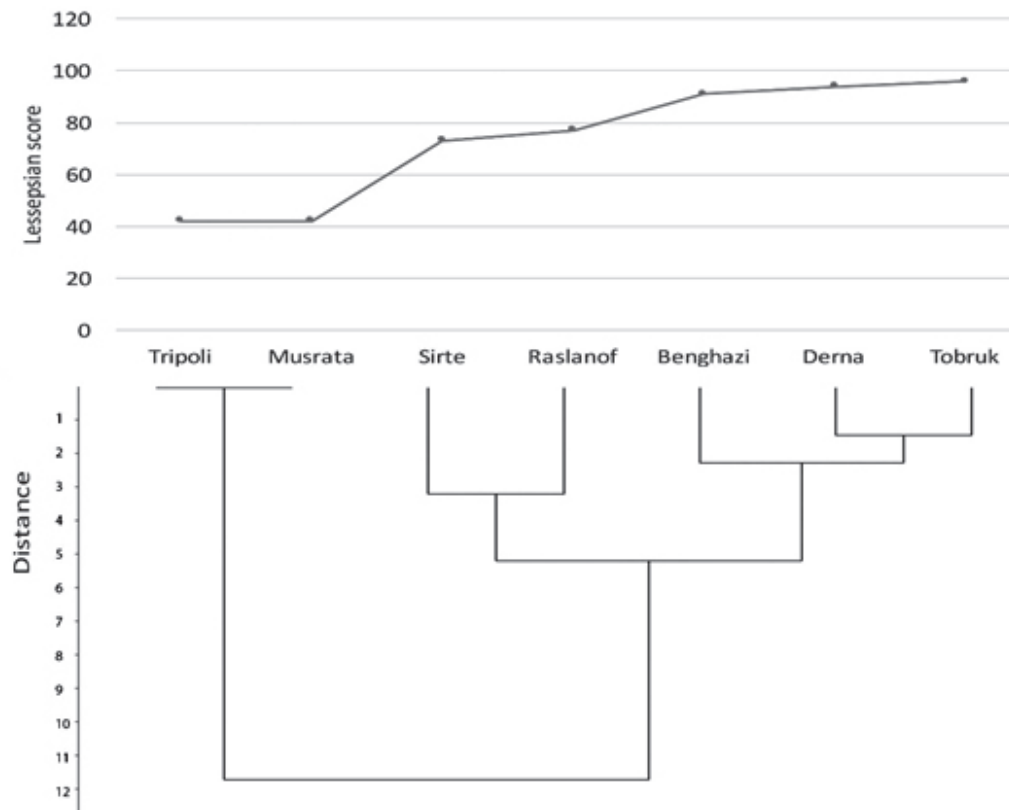


Fig. 5: A upper) Lessepsian score according to survey locations. An east-west gradient is apparent; B lower) Cluster representation of survey locations according to the ranked abundance of Lessepsian species and based on Euclidean distances: Eastern, central and western survey locations clustered together.

Table 2. Abundance of Lessepsian fish species on the Libyan coast estimated by both scientific surveys and interviews with local fishermen.

Species	Eastern Region			Mid Region		Western Region	
	Tobruk	Derna	Benghazi	Raslanof	Sirte	Musrata	Tripoli
<i>A. forskalii</i>	frequent	frequent	frequent	occasional	occasional	rare	rare
<i>S. lessepsianus</i>	common	common	common	frequent	frequent	rare	rare
<i>P. mento</i>	frequent	frequent	occasional	occasional	occasional	-	-
<i>H. far</i>	common	common	frequent	frequent	occasional	occasional	occasional
<i>S. rubrum</i>	frequent	frequent	occasional	occasional	occasional	-	-
<i>H. punctatus</i>	common	common	common	frequent	occasional	-	-
<i>L. carinata*</i>	occasional	occasional	occasional	-	rare	-	-
<i>S. luridus</i>	common	common	common	common	common	common	common
<i>S. rivulatus</i>	common	common	common	common	common	common	common
<i>S. flavicauda*</i>	common	common	common	occasional	occasional	occasional	occasional
<i>S. chrysoaenia*</i>	common	common	common	frequent	occasional	occasional	occasional
<i>S. commerson</i>	frequent	frequent	frequent	frequent	frequent	frequent	frequent
<i>A. djedaba</i>	common	common	common	frequent	frequent	occasional	occasional
<i>U. pori</i>	frequent	frequent	frequent	occasional	occasional	-	-
<i>U. moluccensis</i>	common	common	common	frequent	frequent	occasional	occasional
<i>C. crenidens</i>	common	common	common	frequent	frequent	occasional	occasional
<i>P. rhomboidea</i>	common	common	frequent	frequent	frequent	-	-
<i>F. commersonii</i>	common	common	common	common	common	frequent	frequent
<i>S. diaspros</i>	occasional	rare	rare	rare	rare	rare	rare
<i>L. suezensis*</i>	frequent	frequent	frequent	frequent	occasional	-	-
<i>L. sceleratus</i>	frequent	frequent	frequent	frequent	occasional	-	-

*For species with difficult taxonomical identification, estimation was based on scientific surveys only.

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