

Biodiversity Studies for Sustainable Lagoon: Thermophilic and Tropical Fish Species vs. Endemic Commercial Species at Mellah Lagoon (Mediterranean, Algeria)

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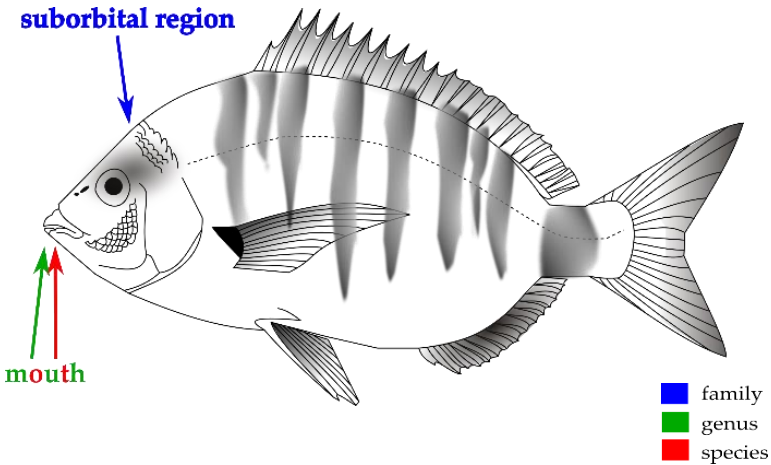
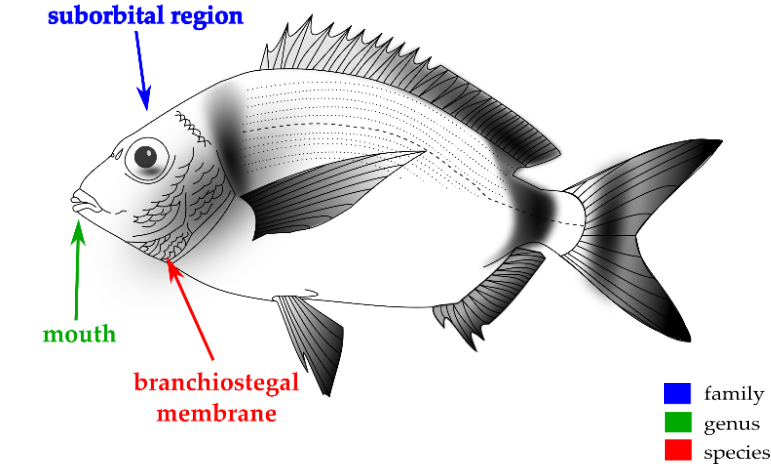
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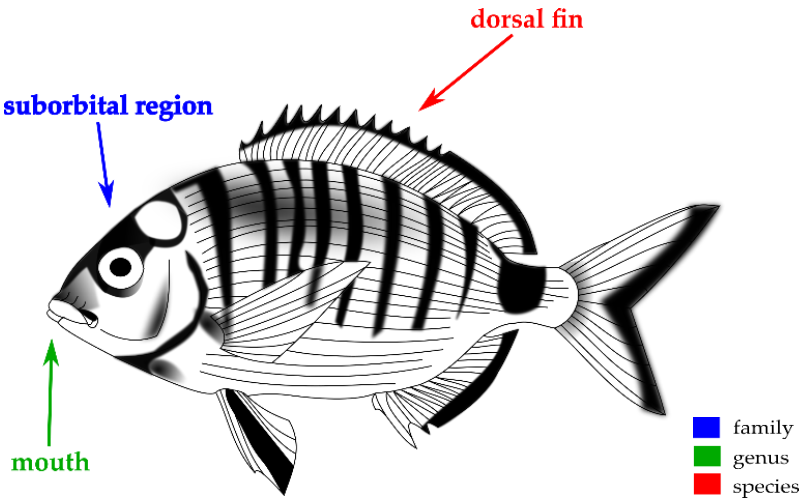
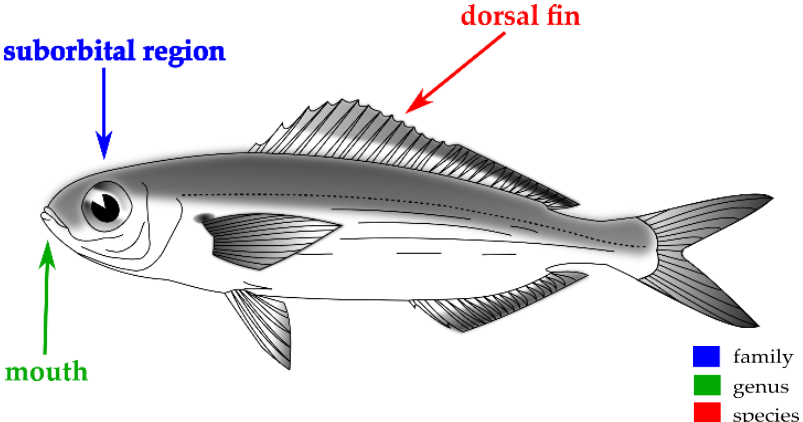
† These authors contributed equally to this work.

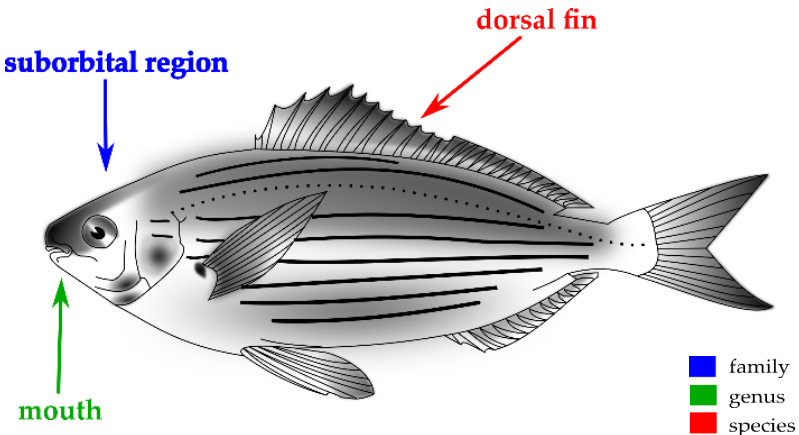
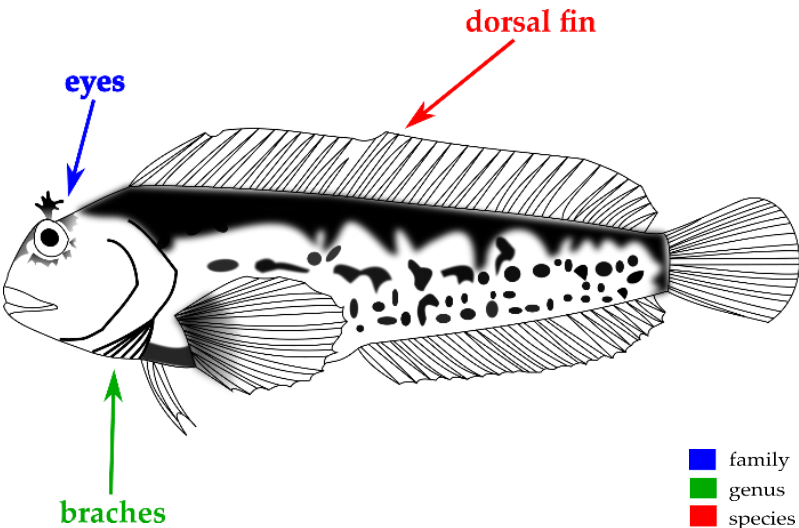
Table S1: Number and Total Length range (cm) of fish species caught in April 2018 and April 2021.

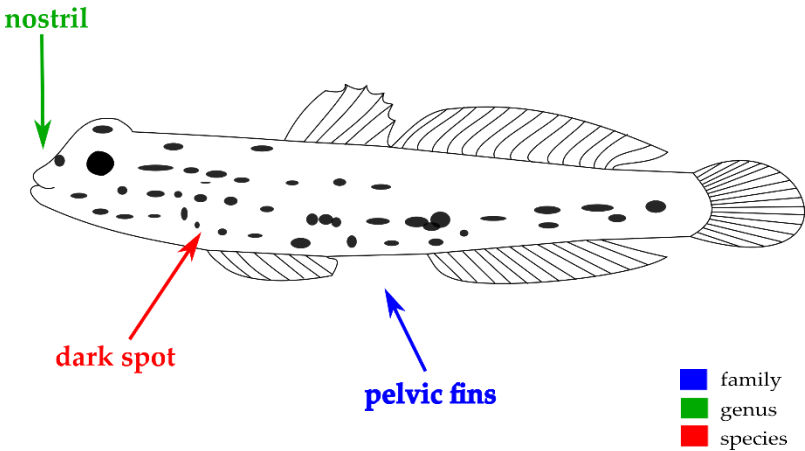
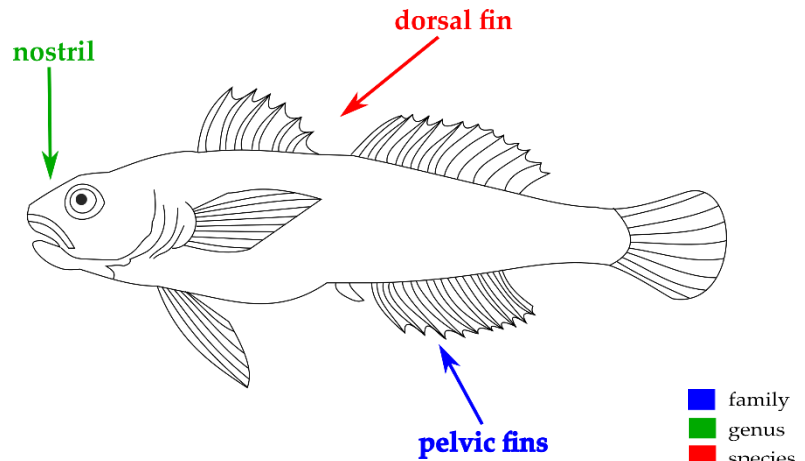
Scientific name	N. samples	N. samples	Tot. length range
	2018 (tot. 705)	2021 (tot. 656)	(cm)
<i>Anguilla anguilla</i>	11	14	45-110
<i>Apogon imberbis</i>	3	7	9-13
<i>Atherina boyeri</i>	7	9	13-15
<i>Belone belone</i>	8	5	27-53
<i>Lichia amia</i>	7	3	25-30
<i>Parablennius pilicornis</i>	28	19	15-19
<i>Conger conger</i>	15	12	34-80
<i>Aphanius fasciatus</i>	100	50	1-3
<i>Gobius cobitis</i>	32	21	10-15
<i>Gobius bucchichi</i>	21	22	5-10
<i>Gobius niger</i>	28	32	6-18
<i>Gobius paganellus</i>	25	13	9-11
<i>Coris julis</i>	6	6	7-18
<i>Simphodus tinca</i>	8	5	8-22
<i>Thalassoma pavo</i>	9	8	4-11
<i>Dicentrarchus labrax</i>	15	16	11- 30
<i>Chelon labrosus</i>	21	18	15-21
<i>Chelon aurata</i>	22	24	25-30
<i>Chelon ramada</i>	18	22	15-20
<i>Liza saliens</i>	7	9	19-22
<i>Mugil cephalus</i>	20	18	11-35
<i>Mullus surmuletus</i>	3	11	9-35
<i>Muraena helena</i>	12	16	28-90
<i>Gambusia holbrooki</i>	100	100	2-6
<i>Scorpaena scrofa</i>	4	6	9-35
<i>Serranus hepatus</i>	7	7	6-13
<i>Solea senegalensis</i>	27	25	7-18
<i>Boops boops</i>	18	20	11-20
<i>Diplodus puntazzo</i>	21	23	16-35
<i>Diplodus sargus</i>	16	25	11-18
<i>Diplodus vulgaris</i>	22	24	9-16
<i>Lithognathus mormyrus</i>	6	21	17-30
<i>Sarpa salpa</i>	16	14	12-18
<i>Sparus aurata</i>	8	10	8-16
<i>Oblada melanura</i>	5	5	12-27
<i>Hippocampus ramulosus</i>	7	4	7-10
<i>Syngnathus abaster</i>	22	12	5-12

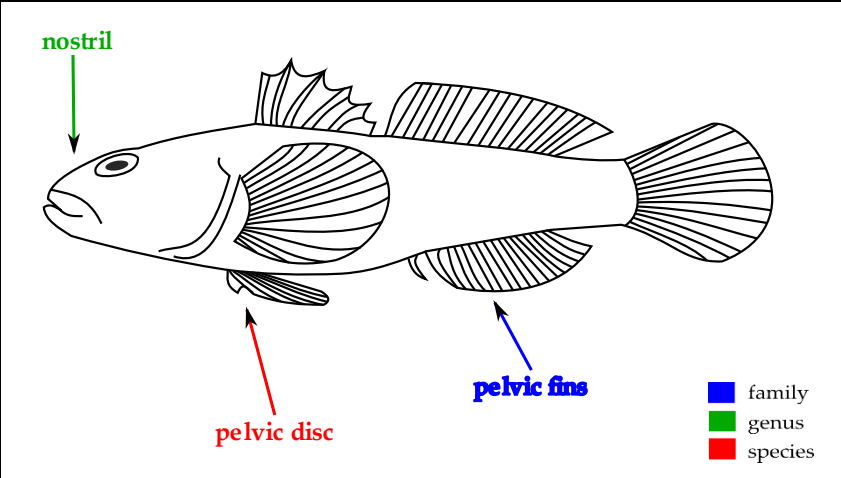
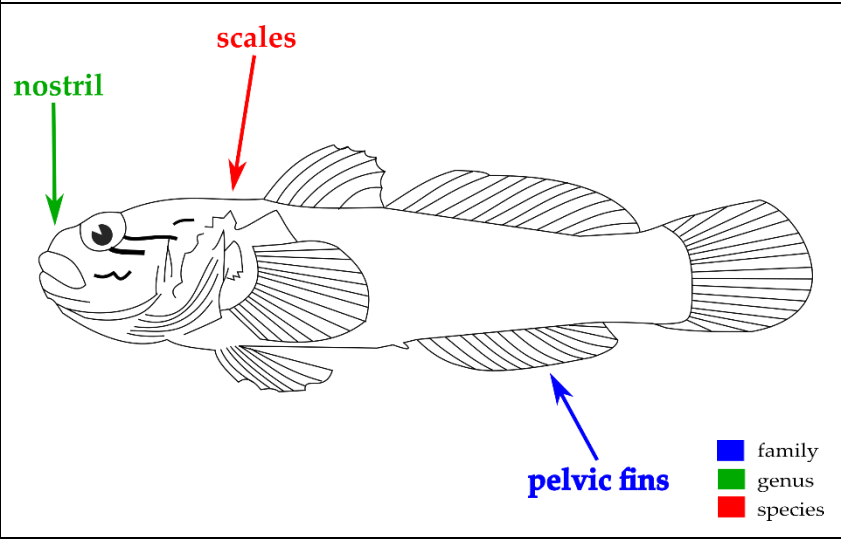
Table S2: Identification of species with high population density in Mellah Lagoon. The colored arrows indicate the main anatomical distinguishing characteristics pertaining to family, genus and species.

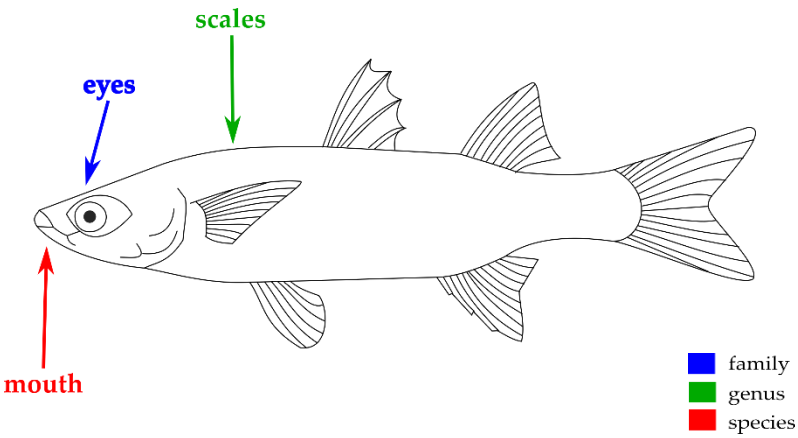
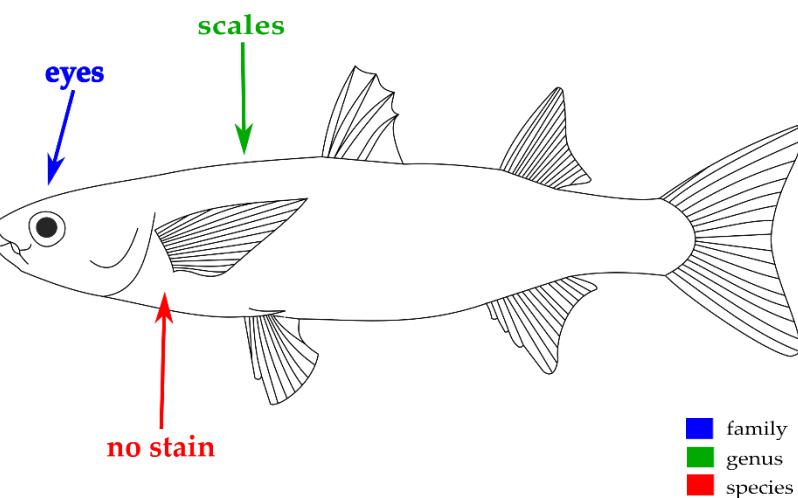
Schematic fish image	Family characteristics	Genus characteristics	Species characteristics
	Sparidae (family): snout and suborbital region scaleless, cheeks scaly; no supramaxilla; upper jaw never extending backward beyond a vertical line through middle of eye; premaxilla overlaps maxilla at distal tip; maxilla without scales	Diplodus (genus): Upper jaw with 8 to 12 medial incisors; no greatly enlarged pair of molars in jaw	puntazzo (species): Molars very rudimentary
	Sparidae (family): snout and suborbital region scaleless, cheeks scaly; no supramaxilla; upper jaw never extending backward beyond a vertical line through middle of eye; premaxilla overlaps maxilla at distal tip; maxilla without scales	Diplodus (genus): Upper jaw with 8 to 12 medial incisors; no greatly enlarged pair of molars in jaw	vulgaris (species): Nuchal band large, triangular; hind edge of branchiostegal membrane light coloured

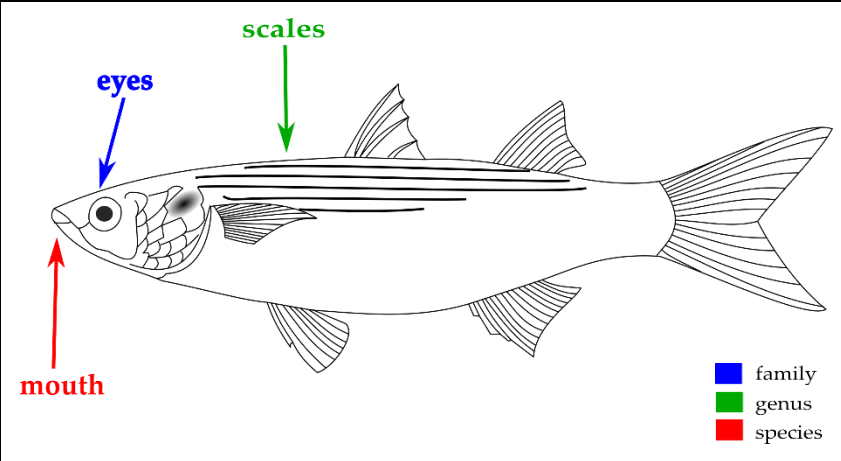
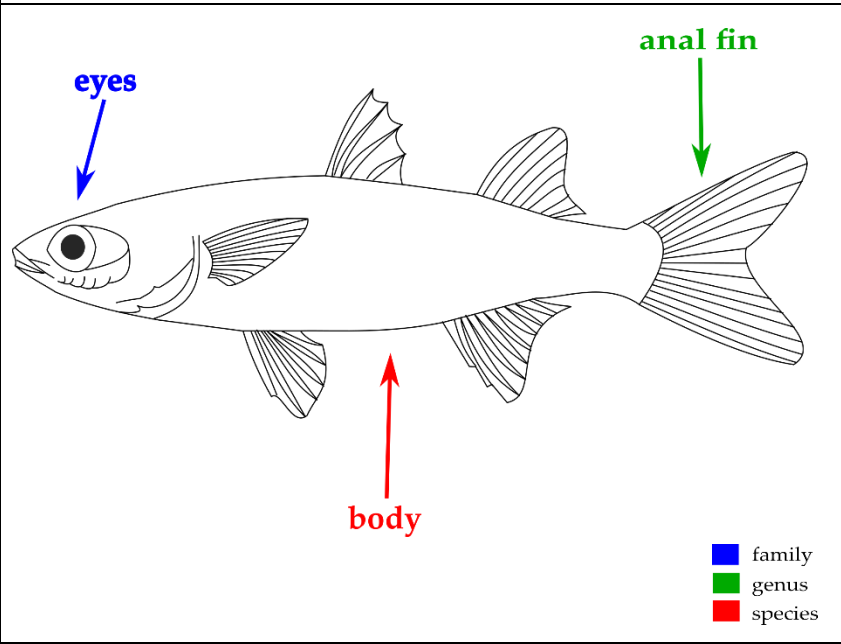
	<p>Sparidae (family): snout and suborbital region scaleless, cheeks scaly; no supramaxilla; upper jaw never extending backward beyond a vertical line through middle of eye; premaxilla overlaps maxilla at distal tip; maxilla without scales</p>	<p>Diplodus (genus): Upper jaw with 8 to 12 medial incisors; no greatly enlarged pair of molars in jaw</p>	<p>sargus (species): Peduncular bar saddle-shaped; lateral-line scales 57 to 71; dorsal-fin spines 11 or 12</p>
	<p>Sparidae (family): snout and suborbital region scaleless, cheeks scaly; no supramaxilla; upper jaw never extending backward beyond a vertical line through middle of eye; premaxilla overlaps maxilla at distal tip; maxilla without scales</p>	<p>Boops (genus): A single row of incisors in both jaws</p>	<p>boops (species): Dorsal fin with 13 to 15 spines; body fusiform</p>

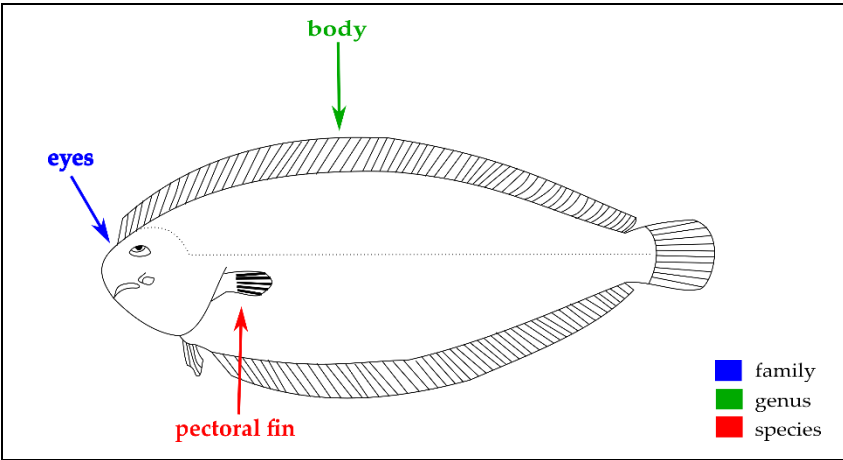
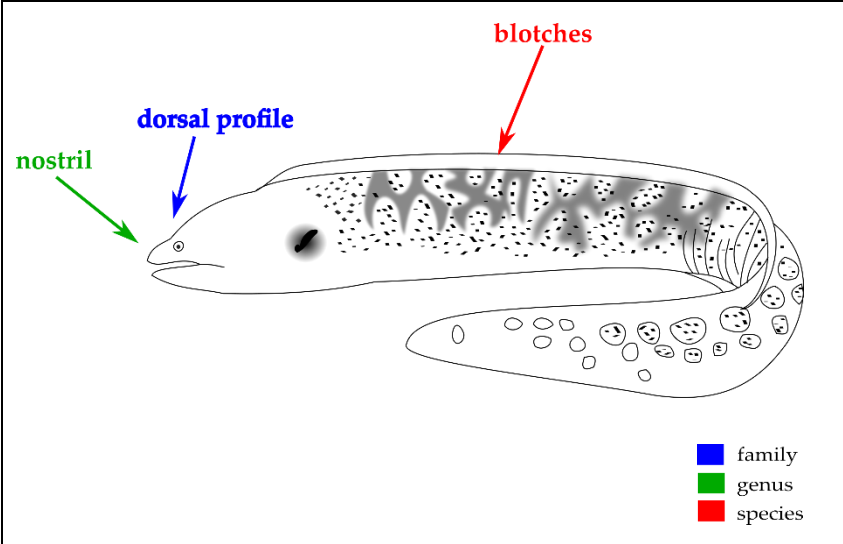
	<p>Sparidae (family): snout and suborbital region scaleless, cheeks scaly; no supramaxilla; upper jaw never extending backward beyond a vertical line through middle of eye; premaxilla overlaps maxilla at distal tip; maxilla without scales</p>	<p>Sarpa (genus): A single row of incisors in both jaws</p>	<p>salpa (species): Dorsal fin with 11 or 12 spines; body oblong</p>
	<p>Blenniidae (family): All species lack scales. Head usually with cirri or fleshy flaps on eye, dorsal and anal fins long, their spines usually flexible; dorsal fin occasionally high anteriorly, with fewer spines than segmented (soft) rays; 2 spines in anal fin</p>	<p>Parablennius (genus): Lateral line forming continuous tube anteriorly, with regularly spaced, short transverse Branches</p>	<p>pilicornis (species): Segmented dorsal-fin rays 20 to 22; segmented anal-fin rays 22 to 24; caudal vertebrae 28 to 30</p>

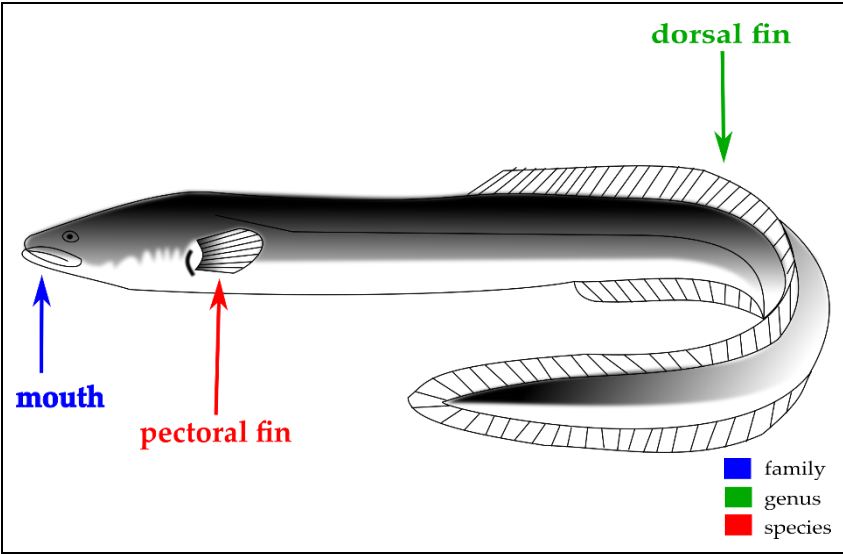
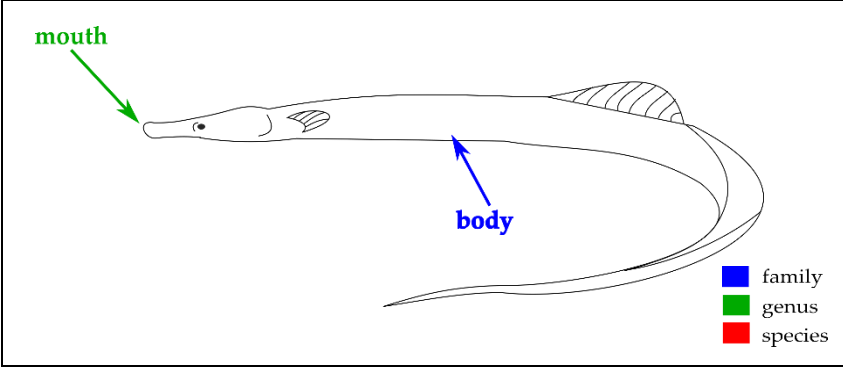
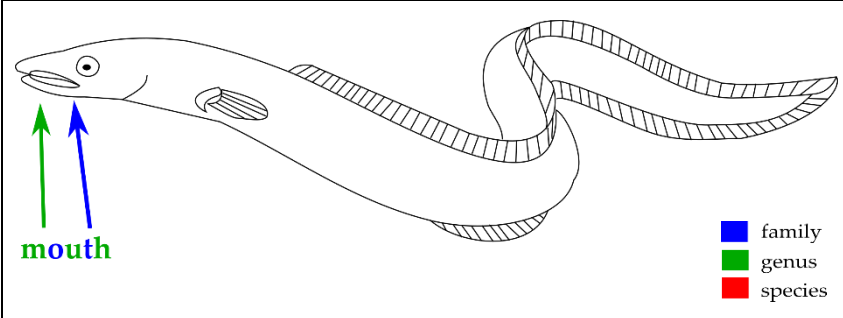
 <p>nostril</p> <p>dark spot</p> <p>pelvic fins</p> <p>family genus species</p>	<p>Gobiidae (family): Pelvic fins (1 spine and 5 soft rays) typically united into a simple disc, completed by an anterior transverse membrane between the spinous rays, or, if mostly separate, still connected by a low transverse membrane between the bases of the fifth soft rays</p>	<p>Gobius (genus): Anterior nostril rim with at least a lappet or thin process; uppermost pectoral rays more or less free; row 6i ends well above row</p>	<p>bucchichi (species): Scales in lateral series 50 to 56; body with longitudinal rows of small dark spots; pelvic disc complete</p>
 <p>nostril</p> <p>dorsal fin</p> <p>pelvic fins</p> <p>family genus species</p>	<p>Gobiidae (family): Pelvic fins (1 spine and 5 soft rays) typically united into a simple disc, completed by an anterior transverse membrane between the spinous rays, or, if mostly separate, still connected by a low transverse membrane between the bases of the fifth soft rays</p>	<p>Gobius (genus): Anterior nostril rim with at least a lappet or thin process; uppermost pectoral rays more or less free; row 6i ends well above row</p>	<p>niger (species): Nape scaled; first dorsal fin with spot in upper anterior corner, and middle rays more or less elongate; scales in lateral series 32 to 42</p>

 <p>nostril</p> <p>pelvic disc</p> <p>pelvic fins</p> <p>family genus species</p>	<p>Gobiidae (family): Pelvic fins (1 spine and 5 soft rays) typically united into a simple disc, completed by an anterior transverse membrane between the spinous rays, or, if mostly separate, still connected by a low transverse membrane between the bases of the fifth soft rays</p>	<p>Gobius (genus): Anterior nostril rim with at least a lappet or thin process; uppermost pectoral rays more or less free; row 6i ends well above row</p>	<p>cobitis (species): Scales in lateral series 59 to 67; pelvic disc anterior membrane with large lateral lobes</p>
 <p>nostril</p> <p>scales</p> <p>pelvic fins</p> <p>family genus species</p>	<p>Gobiidae (family): Pelvic fins (1 spine and 5 soft rays) typically united into a simple disc, completed by an anterior transverse membrane between the spinous rays, or, if mostly separate, still connected by a low transverse membrane between the bases of the fifth soft rays</p>	<p>Gobius (genus): Anterior nostril rim with at least a lappet or thin process; uppermost pectoral rays more or less free; row 6i ends well above row</p>	<p>paganellus (species): Scales in lateral series 50 to 55 (46 to 59)</p>

 <p>eyes</p> <p>scales</p> <p>mouth</p> <p>family genus species</p>	<p>Mugillidae (family): Eyes often partly covered by adipose “eyefold” tissue. Mouth small or moderate in size, terminal or inferior, large, modified scales may be present above pectoral and pelvic fins (axillary scales) and below first dorsal fin</p>	<p>Chelon (genus): Scales either ctenoid or cycloid but without denticulations on hind margin; pectoral axillary scale rudimentary or absent</p>	<p>labrosus (species): Thick upper lip, its height substantially equal to the pupillary diameter, and provided with several rows of taste buds, corneas in adults</p>
 <p>eyes</p> <p>scales</p> <p>no stain</p> <p>family genus species</p>	<p>Mugillidae (family): Eyes often partly covered by adipose “eyefold” tissue. Mouth small or moderate in size, terminal or inferior, large, modified scales may be present above pectoral and pelvic fins (axillary scales) and below first dorsal fin</p>	<p>Chelon (genus): Scales either ctenoid or cycloid but without denticulations on hind margin; pectoral axillary scale rudimentary or absent</p>	<p>aurata (species): Scaling of the head finishing at the level of posterior nostrils; posterior edge of the preorbital sharp; no stain black in the armpit of the pectoral</p>

 <p>eyes</p> <p>scales</p> <p>mouth</p> <p>family genus species</p>	<p>Mugillidae (family): Eyes often partly covered by adipose “eyefold” tissue. Mouth small or moderate in size, terminal or inferior, large, modified scales may be present above pectoral and pelvic fins (axillary scales) and below first dorsal fin</p>	<p>Chelon (genus): Scales either ctenoid or cycloid but without denticulations on hind margin; pectoral axillary scale rudimentary or absent</p>	<p>ramada (species): lower lip with a high symphysial knob, folding up at hind end to obscure the upper lip</p>
 <p>eyes</p> <p>anal fin</p> <p>body</p> <p>family genus species</p>	<p>Mugillidae (family): Eyes often partly covered by adipose “eyefold” tissue. Mouth small or moderate in size, terminal or inferior, large, modified scales may be present above pectoral and pelvic fins (axillary scales) and below first dorsal fin</p>	<p>Mugil (genus): Maxilla straight, posterior tip not curved down; preorbital slender with straight anteroventral edge and a pointed posteroventral end adipose eyefold always extensive in adults; dentary symphysis pointed, usually less than 90° in adults, anal fin with III spines and 8 or 9 soft rays</p>	<p>cephalus (species): Thirty-six or more scales in longitudinal series; body depth at origin of first dorsal fin usually 24 to 28% standard length; body depth at origin of anal fin usually 20 to 24% standard length; head depth equal to or greater than head width at level of posterior of operculum; origin of fully erected second dorsal fin just posterior to vertical level of origin of anal fin</p>

	<p>Soleidae (family): Eyes on right side of body. Preopercle without free margin, embedded in skin</p>	<p>Solea (genus): Anterior nasal tube on eyed side short, not reaching beyond midpoint of lower eye; body and head without transverse wavy lines, but with more or less distinct black blotches</p>	<p>senegalensis (species): pectoral fin with black membrane and white rays</p>
	<p>Muraenidae (family): Typically, the dorsal profile above and behind the eye is steep; posterior nostrils above anterior portion of eye, usually as a simple hole with a raised rim, but sometimes tubular. No lateral line pores on body, but a reduced complement of lateral line pores on head, including typically 1 or 2 above and before gill opening</p>	<p>Muraena (genus): Posterior nostril with a tube</p>	<p>helena (species): colour yellowish brown, with large pale blotches including a rosette pattern of small brown dots</p>

 <p>Diagram of an eel (Anguillidae) showing its body shape, mouth, pectoral fin, and dorsal fin. The mouth is labeled with a blue arrow, the pectoral fin with a red arrow, and the dorsal fin with a green arrow. A legend indicates: blue square for family, green square for genus, red square for species.</p>	<p>Anguillidae (family): Lower jaw projects beyond upper; well-developed fleshy flanges on upper and lower lips.</p>	<p>Anguilla (genus): Teeth small, granular, in narrow to broad bands on jaws and vomer. dorsal fin begins well behind pectoral fins, somewhat in front of or above anus</p>	<p>anguilla (species): dorsal fin begins well behind pectoral fin, closer to anus than to pectoral-fin base; pectoral fin well developed. Small oval scales present, embedded in skin and arranged in a basket-weave pattern</p>
 <p>Diagram of a pipefish (Syngnathidae) showing its elongate body, mouth, and body shape. The mouth is labeled with a green arrow and the body with a blue arrow. A legend indicates: blue square for family, green square for genus, red square for species.</p>	<p>Syngnathidae (family): Body elongate to extremely so; encased in bony armour arranged into series of rings. Mouth small, toothless, placed at end of tubular snouts</p>		<p>Syngnathus abaster (genus characteristics): Mouth at end of tubular snout</p>
 <p>Diagram of a conger (Congridae) showing its body shape, mouth, and body shape. The mouth is labeled with a green arrow and the body with a blue arrow. A legend indicates: blue square for family, green square for genus, red square for species.</p>	<p>Congridae (family): Teeth on vomer (roof of mouth) typically in a triangular or oval, multiserial patch but may also be uniserial, branchiostegal rays long but not overlapping ventrally</p>	<p>Conger conger (genus characteristics): Teeth biserial on jaws, the outer row forming a conspicuous cutting edge</p>	

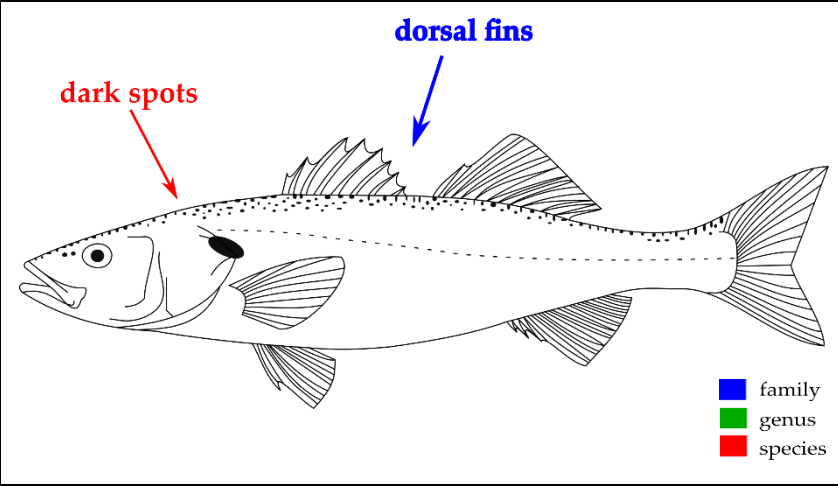
 <p>dark spots</p> <p>dorsal fins</p> <p>family genus species</p>	<p>Moronidae (family): Rear edge of opercle with 2 flat spines but no horizontal ridge; mouth terminal, slightly protrusile; rear end of maxilla exposed, not slipping under preorbital bone; no supramaxilla. Two separate dorsal fins, the first with 8 to 10 slender spines, second dorsal fin with 1 spine, 9 to 14 soft rays</p>	<p><i>Dicentrarchus labrax</i> (species characteristics): Adults uniform silvery; juveniles silvery with several faint dark spots scattered over the body; vomer tooth patch crescentic, no median posterior extension</p>
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Table S3. Applications of Mediterranean fish for Sustainable Development Goals.

SCIENTIFIC NAME	HUMAN FEEDING USE	RESTOCKING USE	AQUACULTURE AND VALLICULTURE	AQUARIOLOGY USE	ANIMAL FEEDING USE	MEDICAL USE
<i>Anguilla anguilla</i>	Taktaka et al. [98]	Rossi et al. [101]	Lovatelli and Holthus [111]	n.d.	Sila et al. [115]	n.d.
<i>Aphanius fasciatus</i>	-	Zogaris [102]	n.d.	Novak et al., [114]	n.d.	n.d.
<i>Apogon imberbis</i>	n.d.	Molinari and Bonel [103]	n.d.	AIAM [37]	n.d.	n.d.
<i>Atherina boyeri</i>	Dal Bosco et al. [99]	IUCN [34]	Cataudella and Bronzi [104]	n.d.	Gumus [116]	n.d.
<i>Belone belone</i>	Koral et al. [95]	n.d.	Rosenthal and Fonds [112]	n.d.	Wikipedia [35]	IRCCS HUMANITAS [38]
<i>Boops boops</i>	Benessere [36]	n.d.	n.d.	n.d.	Estefanell et al. [117]	Lassoued et al. [118]
<i>Chelon labrosus</i>	Zerunian [96]	Zerunian [96]	Cataudella and Bronzi [104]	n.d.	Iandoli and Trincanato [113]	n.d.
<i>Conger conger</i>	Wikipedia [35]	Molinari and Bonel [103]	n.d.	n.d.	n.d.	n.d.
<i>Coris julis</i>	Wikipedia [35]	Molinari and Bonel [103]	n.d.	AIAM [37]	n.d.	n.d.
<i>Dicentrarchus labrax</i>	Zerunian [96]	Zerunian [96]	Lovatelli and Holthus [119]	n.d.	n.d.	IRCCS HUMANITAS [38]
<i>Diplodus puntazzo</i>	Benessere [36]	n.d.	Iandoli and Trincanato [113]	n.d.	n.d.	n.d.
<i>Diplodus sargus</i>	Benessere [36]	Santos et al. [105]; Pereira et al. [106]	Iandoli and Trincanato [113]	n.d.	n.d.	n.d.
<i>Diplodus vulgaris</i>	Benessere [36]	Molinari and Bonel [103]	n.d.	n.d.	n.d.	n.d.
<i>Gambusia holbrooki</i>	n.d.	AIAD [107]	n.d.	Novak et al. [114]	n.d.	n.d.
<i>Gobius bucchichi</i>	n.d.	n.d.	n.d.	Wikipedia [35]	Wikipedia [35]	n.d.
<i>Gobius cobitis</i>	Wikipedia [35]	n.d.	n.d.	n.d.	n.d.	n.d.
<i>Gobius niger</i>	Zerunian [96]	n.d.	n.d.	Wikipedia [35]	n.d.	n.d.
<i>Gobius paganellus</i>	Wikipedia [35]	n.d.	n.d.	Wikipedia [35]	n.d.	n.d.
<i>Hippocampus ramulosus</i>	-	-	-	-	-	-
<i>Lichia amia</i>	Benessere [36]	n.d.	n.d.	n.d.	n.d.	IRCCS HUMANITAS [38]
<i>Lithognathus mormyrus</i>	Wikipedia [35]	n.d.	n.d.	n.d.	n.d.	n.d.
<i>Liza aurata</i>	Benessere [36]	n.d.	Cataudella and Bronzi [104]	n.d.	Iandoli and Trincanato [113]	n.d.
<i>Liza ramada</i>	Zerunian [96]	n.d.	Lovatelli and Holthus [119]	n.d.	Iandoli and Trincanato [113]	n.d.

<i>Liza saliens</i>	Wikipedia [35]	n.d.	Cataudella and Bronzi [104]	n.d.	Iandoli and Trincanato [113]	n.d.
<i>Mugil cephalus</i>	Zerunian [96]	Santos et al. [105]	Lovatelli and Holthus [111]	n.d.	Iandoli and Trincanato [113]	Rosa et al. [127]
<i>Mullus surmuletus</i>	[34, Wikipedia 35]	Molinari and Bonel [103]	n.d.	n.d.	n.d.	IRCCS HUMANITAS [38]
<i>Muraena helena</i>	Wikipedia [35]	Molinari and Bonel [103]	n.d.	n.d.	n.d.	n.d.
<i>Oblada melanura</i>	Wikipedia [35]	Molinari and Bonel [103]	n.d.	n.d.	n.d.	IRCCS HUMANITAS [38]
<i>Parablennius pilicornis</i>	n.d.	n.d.	n.d.	AIAM [37]	n.d.	n.d.
<i>Sarpa salpa</i>	Wikipedia [35]	Molinari and Bonel [103]	n.d.	n.d.	n.d.	n.d.
<i>Scorpaena scrofa</i>	Reale et al. [100]	Özgüla et al. [116]	n.d.	n.d.	n.d.	Reale et al. [100]
<i>Serranus hepatus</i>	Wikipedia [35]	n.d.	n.d.	Wikipedia [35]	n.d.	n.d.
<i>Symphodus tinca</i>	Wikipedia [35]	Molinari and Bonel [103]	n.d.	Wikipedia [35]	n.d.	n.d.
<i>Solea senegalensis</i>	Morais et al. [97]	Abate et al. [109]	Morais et al. [97]	n.d.	n.d.	n.d.
<i>Sparus aurata</i>	Wikipedia [35]	Santos et al. [105]	Lovatelli and Holthus [111]	n.d.	n.d.	IRCCS HUMANITAS [38]
<i>Syngnathus abaster</i>	n.d.	Rodríguez et al. [110]	n.d.	n.d.	n.d.	n.d.
<i>Thalassoma pavo</i>	n.d.	n.d.	n.d.	Wikipedia [35]	n.d.	n.d.
Abbreviations: n.d. not detected; - not recommended.						

Table S4: Fish Conservation Status of Mellah Lagoon and Population Density through the years (2006; 2017; 2018, 2021).

Scientific name	Family Order	Conservation status (IUCN)	Population density		
			Chaoui et al. 2006	Embarek et al. 2017	Our studies 2018, 2021
<i>Anguilla anguilla</i>	Anguillidae Anguilliformes	CR	HPD	HPD	HPD
<i>Apogon imberbis</i>	Apogonidae Perciformes	LC	LPD	n.d.	LPD
<i>Atherina boyeri</i>	Atherinidae Atheriniformes	LC	HPD	HPD	LPD
<i>Belone belone</i>	Belonidae Beloniformes	LC	LPD	n.d.	LPD
<i>Lichia amia</i>	Belonidae Perciformes	LC	LPD	n.d.	LPD
<i>Parablennius pilicornis</i>	Blenniidae Perciformes	LC	HPD	n.d.	HPD
<i>Conger conger</i>	Congridae Anguilliformes	LC	LPD	n.d.	HPD
<i>Aphanius fasciatus</i>	Cyprinodontidae Cyprinodontiformes	LC	HPD	HPD	LPD
<i>Gobius cobitis</i>	Gobiidae Perciformes	LC	HPD	n.d.	HPD
<i>Gobius bucchichi</i>	Gobiidae Perciformes	LC	HPD	n.d.	HPD
<i>Gobius niger</i>	Gobiidae Perciformes	LC	HPD	n.d.	HPD
<i>Gobius paganellus</i>	Gobiidae Perciformes	LC	HPD	n.d.	HPD
<i>Coris julis</i>	Labridae Perciformes	LC	LPD	n.d.	LPD
<i>Simphodus tinca</i>	Labridae Perciformes	LC	LPD	n.d.	LPD
<i>Thalassoma pavo</i>	Labridae Perciformes	LC	LPD	n.d.	LPD
<i>Dicentrarchus labrax</i>	Moronidae Perciformes	LC	HPD	n.d.	HPD
<i>Chelon labrosus</i>	Mugilidae Mugiliformes	LC	HPD	n.d.	HPD
<i>Chelon aurata</i>	Mugilidae Perciformes	LC	HPD	HPD	HPD
<i>Chelon ramada</i>	Mugilidae Perciformes	LC	LPD	n.d.	HPD
<i>Liza saliens</i>	Mugilidae Perciformes	LC	LPD	HPD	LPD
<i>Mugil cephalus</i>	Mugilidae Perciformes	LC	HPD	HPD	HPD
<i>Mullus surmuletus</i>	Mullidae Perciformes	LC	LPD	n.d.	LPD
<i>Muraena helena</i>	Muraenidae Perciformes	LC	HPD	n.d.	HPD
<i>Gambusia holbrooki</i>	Poeciliidae Cyprinodontiformes	NA	HPD	n.d.	LPD
<i>Scorpaena scrofa</i>	Scorpaenidae Scorpaeniformes	LC	LPD	n.d.	LPD
<i>Serranus hepatus</i>	Serranidae Perciformes	LC	LPD	n.d.	LPD

<i>Solea senegalensis</i>	Soleidae Pleuronectiformes	n.d.	HPD	n.d.	HPD
<i>Boops boops</i>	Sparidae Perciformes	LC	HPD	n.d.	HPD
<i>Diplodus puntazzo</i>	Sparidae Perciformes	LC	LPD	n.d.	HPD
<i>Diplodus sargus</i>	Sparidae Perciformes	LC	HPD	HPD	HPD
<i>Diplodus vulgaris</i>	Sparidae Perciformes	LC	HPD	n.d.	HPD
<i>Lithognathus mormyrus</i>	Sparidae Perciformes	LC	HPD	n.d.	LPD
<i>Sarpa salpa</i>	Sparidae Perciformes	LC	HPD	n.d.	HPD
<i>Sparus aurata</i>	Sparidae Perciformes	LC	HPD	HPD	LPD
<i>Oblada melanura</i>	Sparidae Perciformes	LC	LPD	n.d.	LPD
<i>Hippocampus ramulosus</i>	Syngnathidae Syngnathiformes	NT	LPD	n.d.	LPD
<i>Syngnathus abaster</i>	Syngnathidae Syngnathiformes	DD	LPD	HPD	HPD
Abbreviations: CR, critically endangered; DD, data deficient; LC, least concern; NA, not applicable; NT, near threatened; HPD, High Population Density; LPD, Low Population Density; HPD , the most abundant species; n.d., not detected.					