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Discrimination of the sardine stocks by using a morphometric and meristic analysis along the Moroccan Atlantic coast

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ABSTRACT

The variation of morphometric and meristic characters among three fishing areas of sardine was addressed considering the 300 specimenss from the Moroccan Atlantic coast, during the period from March 2017 to February 2018. The meristic count (Six characters) and morphometric character (fifteen characters) of each specimen were studied. The total length (TL) of all analysed specimens ranged from 135 to 249mm, while their weights ranged between 39.50g and 168.89g. Body length analysis showed a different value between males and females according to the fishing areas, Larache, Safi and Dakhla. For vertebrae analysis, three groups were compared according to their locations: the first one obtained from larache (TL average = 162.55 mm), the second was from Safi (TL average = 186.14 mm); whereas, the samples from Dakhla belonged to the third group (TL average = 231.78mm). The number of vertebrae for the three groups ranged between 48 and 51, with the most abundant vertebrae class of 50 vertebrae (37.70 %), whereas a minimal number of sardines (4.90 %) had 48 vertebrae. The number of dorsal fin rays (DFR) ranged from 16 to 18, and the average value was 17.11 ± 0.51. Statistical data processing, by uni- and multivariate methods allowed us to highlight significant differences for specimens among the different fishing areas.

INTRODUCTION

Stock identification is a multidisciplinary field of fisheries science involving genetics, biometrics, and life history studies **(Ihssen *et al*., 1981; Kumpf *et al*., 1987;**

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Pawson & Jennings, 1996 and **Begg *et al.*, 1999)**. A general definition of the term stock generally involves a group of individuals that sustains itself over time, but precise definitions vary among disciplines **(Booke, 1981)**. For example, morphometric variation can be used to discriminate "phenotypic stocks," defined as groups with similar growth, mortality, and reproductive rates.

Morphometric stock identifications have reflected the historical development of morphometric analysis, which has emerged as a complex discipline with applications in many biological fields of study (**Begg *et al.*, 1999** and **Mounir *et al.*, 2022**). It's has traditionally been used to describe the population structure of fishes in the family clupeidae. Conversely, morphological variation in fishes is often environmentally induced and may provide a good record of short-term population structuring, but morphology may be ineffective for studying the evolutionary patterns of population differentiation **(Leary & Allendrof, 1989)**.

Morphometric characters of fishes were found to be of taxonomic importance in sex, race and species identification by many investigators **(Oliveira & Almada, 1995; Mekkawy & Mohammad, 2011; Harabawy *et al.*, 2012** and **Safi, 2014)**. The meristic characters were also found to be valid in sex, race and species identification **(Villaluz & MacCrimmon, 1988; Mekkawy, 1991; Turan, 2006; Mekkawy & Mohammad, 2011; Mustać & Sinovčić, 2010; Abbaspour *et al.*, 2013** and **Mahmoud *et al.*, 2016)**.

We examined the population structure of sardines to isolate intraspecies variability existing within the *Sardina pilchardus* species from a biological perspective, using morphometric and meristic parameters, between three sites located on the Moroccan coastline from north to south: Larache, Safi and Dakhla, for a rational management of this resource.

This study is made due to the total absence of reliable and exploitable information concerning the morphometric and meristic characteristics of Moroccan Atlantic sardines. The comparative study was carried out using fifteen morphometric and meristic variables. Incorporating a morphological analysis has allowed us to reconcile apparent discrepancies in the structuring of sardine populations, our results therefore provide a discrimination of three stocks of sardine in the Moroccan Atlantic coast.

MATERIALS AND METHODS

1. Sampling

Samples of *S. pilchardus* were sampled from three different areas in the Moroccan Atlantic coast throughout the period between 2017 to 2018. The studied areas were selected based on many characteristics such as the geographical distance between them and the oceanographic proprieties of the areas used by the Food and Agriculture

Organization (**FAO, 2003**) (**Figure 1**). The samples were stored in the laboratory. Each individual was wrapped in plastic film immediately after collection to avoid damage, and was put in the freezer at -20 °C. 360 specimens were used for morphological evaluation.

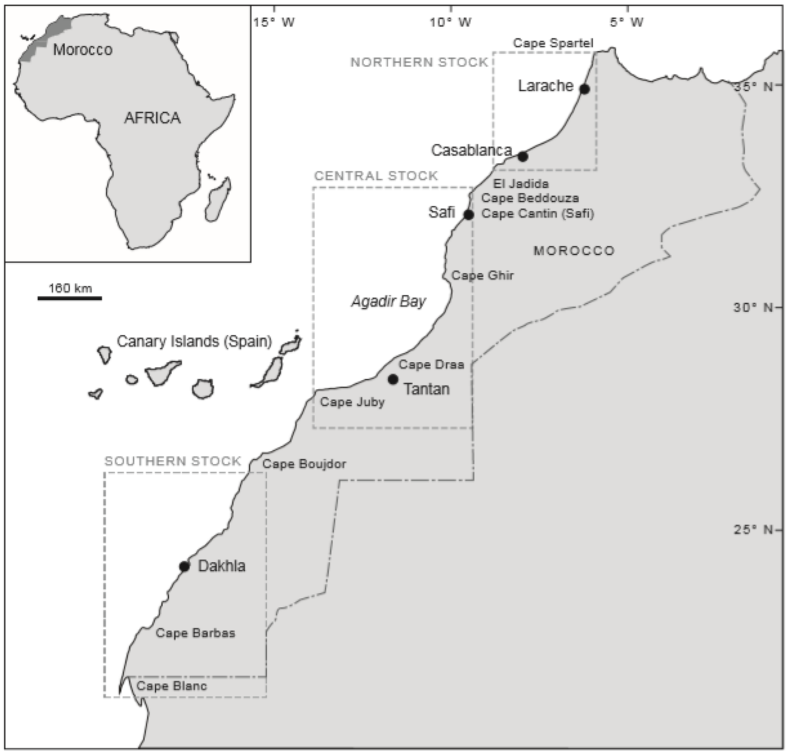

Figure 1. Sampling areas and delimitation of areas of three stocks of Atlantic Moroccan European sardine *S. pilchardus* (Mounir *et al.,* 2019).

2. Morphometry

The morphometric measurements were implored to determine taxonomic variations among the populations of fish, for this study 150 specimens were conducted.

2.1. Meristic characters

Four numeric characteristics were taken into account: number of gills rakers on the first left branchial arch: The number of gills rakers was determined with the naked eye in adults and under a binocular magnifier in young individuals. For it to be considered, a gill must be able to hold a needle pressed down along the gill arch, number of rays of both dorsal and anal fins and the number of vertebrae. The distribution of each character is described by its mean, mode and limits.

2.2. Morphometric characters

We recorded 15 straight-line measurements using an ichtyometera: total length (Lt), standard length (Ls), fork length (Lf) pre-pectoral length (LPP), post-pectoral length (Lpp) diameter of the orbit (Do), pre-orbital length(Po), post-orbital length (po), body height (BH), height of caudal peduncle (Hcp), body thickness (Bt), pre-dorsal length (lpd), pre-anal length (Lpa), maxillary length (Lm) and cephalic length (Lc) **(Figure 2)**.

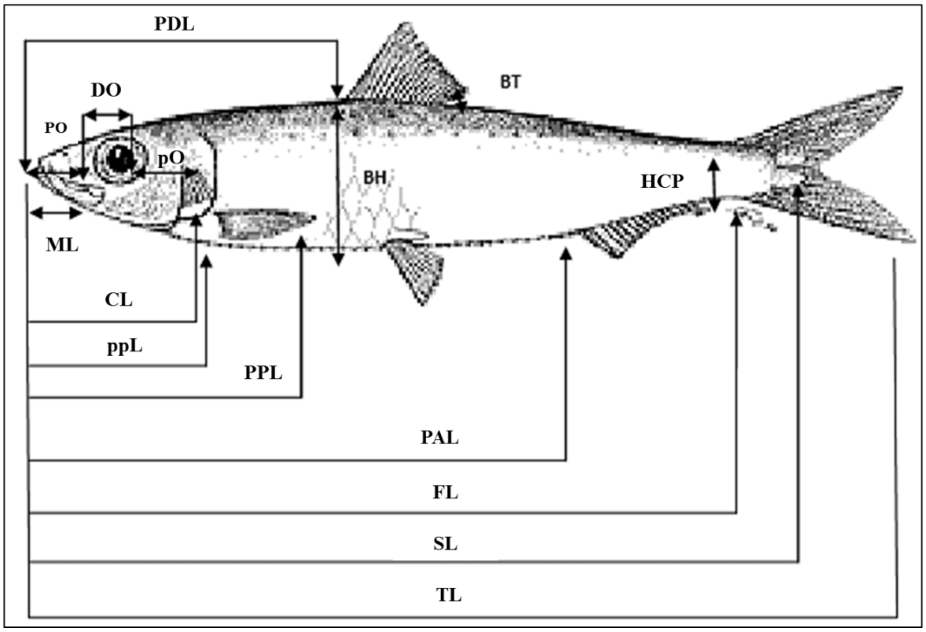

Figure 2. Morphometric measurements taken on each sample of *S. pilchardus*: total length (**TL**), standard length (**SL**), fork length (**FL**) pre-pectoral length (**PPL**), post-pectoral length (**ppL**) diameter of the orbit (**DO**), pre-orbital length (**pO**), post-orbital length (**PO**), body height (**BH**), height of caudal peduncle (**HCP**), body thickness (**BT**), pre-dorsal length (**PDL**), pre-anal length (**PAL**), maxillary length (**ML**) and cephalic length (**CL**).

3. Data analyses

There are 2 common problems in morphometric studies: size and allometry. The former may confound the interpretation of shape changes because morphometric variables usually carry both information about size and shape simultaneously **(Zelditch *et al.*, 2003)**. The latter is an important factor affecting shape variation ontogenetically **(Berry & Shine 1980; Lindeman, 1999** and **Shine, 2005)**. For this reason, linear variables are usually transformed with a method that removes size and allometric effects.

$$Z = Y \times (X_0/X)^b$$

Y : variable to being transformed.

X_0 : mean standard length.

X : standard length of each specimen.

b : allometric coefficient.

Z is the new variable that we used in our statistical analyses.

RESULTS

1. Meristic characters

The left branchial arch contains between 38 and 42 lower gill rakers (LR) with a mean of 39.05 in Larache, while in the specimens from Safi and Dakhla it varied from 56 to 60 and between 64 to 70 with mean of 58.09 and 67.07 respectively. The dorsal fin ray counts (DFR) ranged from 15 to 16 with a mean of 16.27 for sardines from Larache and from 16 to 17 with a mean of 17.22 in Safi and from 16 to 18 with a mean of 17.82 in Dakhla. The number of anal fin rays (AFR) in specimens from Larache ranged from 16 to17 with a mean of 17.05 while in the specimens from Safi and Dakhla it varied from 17 to18 with mean of 17.45 and 17.95 respectively. Slight differences were obtained from the vertebrae counts from the three locations (Larache: 50.42±0.07, Safi: 50.85±0.63 and Dakhla: 51.02±0.08) **(Table 1)**.

Table 1. Average values (mm), for meristic characters of *S. pilchardus* from the Moroccan Atlantic coast.

	Larache Mean ±S.D.	**Safi** Mean ± S.D.	**Dakhla** Mean+-S.D.
Number of GR	39.05±14.03	58.09±43.01	67.07±8.75
number of DFR	16.21±0.04	17.22±0.48	17.82±0.02
number of AFR	17.05±0.04	17.45±0.02	17.95±0.07
number of vertebrae (V)	**50.42±0.07**	**50.85±0.63**	**51.02±0.08**

(GR: gill raker**, DFR:** dorsal fin rays**, AFR:** anal fin rays and **V:** vertebrae number**)**

2. Morphometric characters

The morphometric measurements of the fish are shown in Table 2. Sardines from Dakhla were rather larger than those from Safi and Larache with mean lengths of 234.70, 185.22 and 165.58 mm, respectively. These differences were reflected in all the other morphometric characters.

The discriminant function analysis of transformed linear variables of the body shape showed differentiation among the three locations (Wilks' Lambda $p< 0.005$, and $\lambda < 0.50$) (**Figure 3**). The squared Mahalanobis distance for body variables was significant between individuals from different locations $p< 0.005$.

Table 2. Average values (mm), for morphometric and meristic characters of *S. pilchardus* from the Moroccan Atlantic coast.

Characters	Locations		
	Larache Mean ± SD*	Safi Mean ± SD*	Dakhla Mean ± SD*
TL	165.58±15.75	185.22±4.4	234.70±8.75
SL	145.95±13.72	185.98±7.07	210.84±8.15
FL	153.21±14.37	167±4.55	199.44±8.35
PAL	79.89±19.48	118±3.52	151.83±5.38
ppL	51.55±11.07	63.87±1.41	81.28±3.44
PPL	34.92±8.07	38.40±1.29	51.59±2.69
DO	7.73±1.53	10.15±2.08	13.02±1.58
ML	17.25±3.12	12.92±1.17	17.14±1.34
PDL	62.25±9.10	71.69±2.90	92.08±4.64
CL	31.98±4.76	20.71±0.83	27.52±1.40
BH	34.49±8.07	36.85±2.09	48.08±1.98
HCP	13.33±1.58	12.64±0.55	16.61±1.58
BT	5.91±1.68	19.39±1.41	23.49±3.18
pO	8.15±1.09	9.02±1.13	12.42±2.11
PO	6.92±1.23	8.43±2. 01	11.02±3.72

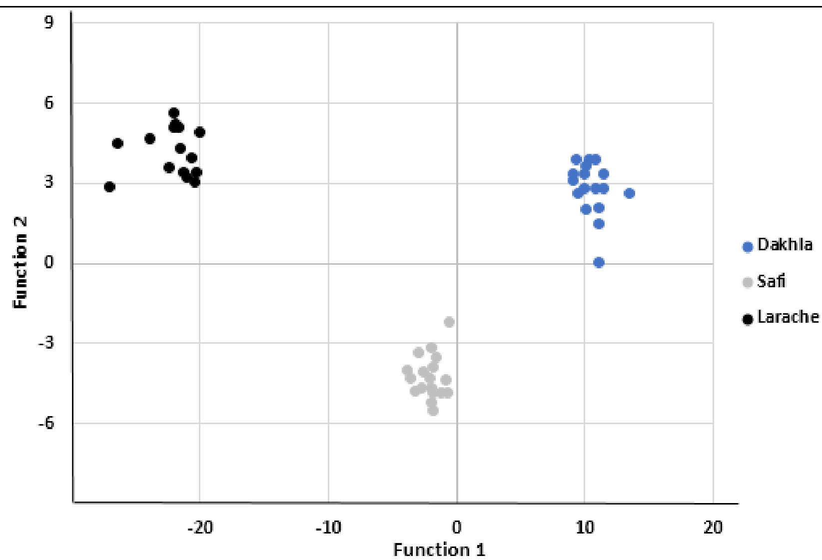

Figure 3. Discriminant Function Analysis of *S. pilchardus* populations based on the body shape measurements.

The comparison of the λ value of Wilks' showed a decrease in similarity from north to south. The highest degree of distinction between Larache and Dakhla confirm the existence of three stocks in studied areas (Table 3).

Table 3. Wilks' λ and *p* values between three locations among the Moroccan coast.

Locations	Wilks' λ	*P*	signification
Larache – Safi	0.28	0.00001	Hight signification
Safi – Dakhla	0.21	0.00001	Hight signification
Larache – Dakhla	0.096	0.00001	Hight signification

DISCUSSION

Morphometric and meristic characteristics are two powerful tools for identifying fish populations **(Ihssen *et al*., 1981** and **Melvin *et al*., 1992)**. Morphometric characteristics are progressive parameters that describe aspects of body form while meristic characteristics are related to discrete numbers that are serially repeated. Morphological plasticity is an adaptive response to the complex and different ecological conditions under which fish species exist **(Scheiner & Callahan, 1999)**. A mixture of environmental factors like temperature, salinity, dissolved oxygen, radiation, water depth and current flow influence morphological variations between the fish **(Vladycov, 1934; Smith, 1966; Lindsey, 1988** and **Turan, 2006)**. Other factors, such as reproduction and gonad development, may also influence the morphology of the fish.

The morphology of *S. pilchardus* may vary in different habitats since the composition of communities combined with the spatial scale of habitat types and landscapes may promote divergence within a species **(Wang *et al*., 2005)**. Morphological variability among spatially and ecologically separated fish populations may be induced by genetically manifested polymorphism or by phenotypic plasticity **(Wimberger, 1991 & 1992)**. Morphological characters, such as body shape and meristic counts, have long been used in stock identification **(Villaluz & McCrimmon, 1988; Haddon & Willis, 1995; Silva, 2003** and **Turan, 2004)**. In Morocco, information on the morphometric and meristic characteristics of this important fish is scanty despite its role in the country's scientific committee. The present study was therefore carried out to compare the morphological and meristic characteristics of *Sardina pilchardus* among the Atlantic coast.

We report morphological variation of body shape in *S. pilchardus* associated with developmental and historical factors. Our results support the hypothesis that at least part of the morphological variation in *S. pilchardus* is associated with variation between stocks; possibly as result of reduced gene flow between their populations. This was supported by both linear morphometry and meristic analyses. However, different analyses grouped individuals from different locations. Disparity between methods in stock variation could be related to differences in their sensitivity to shape variation **(Monteiro & Reis, 1999)** and the region of body shape that they recorded. Also, these results show that these methods could be complementary and should be used together.

The differences in the morphological and meristic characters of specimens are supposed to be in association with aquatic ecosystems from which they originated **(Cakić *et al*., 2002** and **Franičević *et al*., 2005). Naesje *et al*. (2004)** stated that the variation among populations of fish characters could be induced by ecological factors interacted with fundamental genetic roles.

The results of this study can be combined with information obtained from other morphological, chemical, and genetic studies to verify type identity. For instance, otolith chemistry can be used as a natural tag or chemical signature that explains the differences in the chemical compositions of the individual habitat and assesses relative distribution of the different stocks **(Campana & Thorrold, 2001; Rooker, *et al*., 2003** and **Mounir *et al*., 2021)**.

REFERENCES

Abbaspour, R.; Hedayatifard, M.; Sabet, H.R.A.; Hassanzadeh, H. and **Karimi, J.M. (2013).** Bioassessment of macrobenthic fauna of the Cheshmeh Kileh River, northern Iran. Am. Eurasian J. Agric. Environ. Sci., **13**(6): 747–753. https://doi.org/10.5829/idosi.aejaes.2013.13.06.73197

Begg, G.A.; Friedland, K.D. and **Pearce, J.B. (1999).** Stock identification and its role in stock assessment and fisheries management: an overview. Fish. Res., **43**(1–3): 1–8.

Berry, J.F. and **Shine, R. (1980).** Sexual size dimorphism and sexual selection in turtles (order Testudines). Oecologia, **44**: 185–191.

Booke, H.E. (1981). The conundrum of the stock concept – are nature and nurture definable in fishery science? Can. J. Fish. Aquat. Sci., **38**: 1479–1480.

Cakić, P.; Lenhardt, M.; Mićković, D.; Sekulić, N. and **Budakov, L.J. (2002).** Biometric analysis of *Syngnathus abastev* populations. J. Fish Biol., **60**(6): 1562–1569.

Campana, S.E. and **Thorrold, S.R. (2001).** Otoliths, increments, and elements: keys to a comprehensive understanding of fish populations? Can. J. Fish. Aquat. Sci., **58**(1), 30–38.

FAO (Food and Agriculture Organization of the United Nations). (2003). Report of the FAO Working Group on the Assessment of Small Pelagic Fish off North Africa, Agadir, Morocco, 31 March–10 April 2003. Fisheries Report No. 723. Rome: FAO

Franičevič, M.; Sinovčić, G.; Čikeś, V. and **Zorica B. (2005).** Biometry analysis of the Atlantic bonito, *Sarda sarda* (Bloch, 1753) in the Adriatic Sea. Acta Adriat., **46**(2): 213–222.

Haddon, M. and **Willis, T.J. (1995).** Morphometric and meristic comparison of orange roughy (*Hoplostethus atlanticus*: Trachichthyidae) from the Puysegur Bank and Lord Howe Rise, New-Zealand, and its implications for stock structure. Mar. Biol., **123**: 19–27.

Harabawy, A.S.; Mekkawy, I.A. and **Alkaladi, A. (2012).** Identification of three fish species of genus Plectorhynchus from the Red Sea by their scale characteristics. Life Sci. J., **9**(4), 4472–4485.

Ihssen, P.E.; Booke, H.E.; Casselman, J.M.; McGlade, J.M.; Payne, N.R. and Utter, F.M. (1981). Stock identification: materials and methods. Can. J. Fish. Aquat. Sci., **38**:1838–1855.

Kumpf, H.E.; Vaught, R.N.; Grimes, C.B.; Johnston, A.G. and **Nakamura, E.L. (1987).** Proceedings of the Stock Identification Workshop. NOAA Technical Memorandum NMFS-SEFC-199. Washington DC: U.S. Department of Commerce.

Leary, R.F. and **Allendrof, F.W. (1989).** Fluctuating asymmetry as an indicator of stress: Implications for conservation biology Trends Ecol. Evol. **4**: 214–217.

Lindeman, P.V. (1999). Growth curves for *Graptemys*, with a comparison to other Emydid turtles. Am. Midl. Nat., **142**:141–151.

Lindsey, C.C. (1988). Factors controlling meristic variation. In: Hoar WS, Randall DJ, editors. Fish Physiology. San Diego: Academic Press. pp. 197–274.

Mahmoud, U.M.; Mehanna, S.F. and **Mohammad, A.S. (2016).** Sexual dimorphism of morphometrics and meristics of *Carangoides bajad* (Forsskål, 1775) and *Caranx melampygus* (Cuvier, 1833) from the Southern Red Sea, Egypt. Int. J. Sci. Res., **1**(5): 448–456. https://doi.org/10.21275/v5i1.nov152695

Mekkawy, I.A. and **Mohammad, A.S. (2011).** Morphometrics and meristics of the three Epinepheline species: *Cephalopholis argus* (Bloch and Schneider, 1801), *Cephalopholis miniata* (Forsskal, 1775) and *Variola louti* (Forsskal, 1775) from the red sea, Egypt.

Mekkawy, I.A.A. (1991). Multivariate analysis of the morphometric and meristic characteristics of the Nile charcoid fish, *Alestes nurse* (Ruppel, 1932) from the Nile in Egypt. Assiut Vet Med J.

Melvin, G.D.; Dadswell, M.J. and **McKenzie, J.A. (1992).** Usefulness of meristic and morphometric characters in discriminating populations of American shad (*Alosa sapidissima*) (Osteichthyes: Clupeidae) inhabiting a marine environment. Canadian Journal of Fisheries and Aquatic Sciences, **49**: 266–280.

Monteiro, L.R. and **Reis, S.F. (1999).** Principios de morfometria geométrica. Ribeirao Preto: Holos Editora, 189 pp.

Mounir, A.; Alahyane, H.; Znari, M.; El Mghazli, H.; Chouikh N. (2022). Spatial variability of linear growth of *Sardina pilchardus* (Walbaum, 1792) from the Moroccan Atlantic coast by using otolithometry. Egypt J Aquat Biol Fish **26**(2), 61-76.

Mounir, A.; Znari, M.; Elmghazl, H. and **Alahyane, H. (2021).** Status stock and Sustainable Management Measures for Moroccan Sardines. Sustainable Marine Structures, **3**(2): 50–58.

Mounir, A.; Ewague, A.; Znari, M. and **El Mghazli, H. (2019).** Discrimination of the phenotypic sardine *Sardina pilchardus* stocks off the Moroccan Atlantic coast using a morphometric analysis. Afr J Mar Sci **41**(2): 137–144. https://doi.org/10.2989/1814232X.2019.1597765

Mustać, B. and **Sinovčić, G. (2010).** Morphometric and meristic parameters of Sardine (*Sardina pilchardus*, walbaum, 1792) in the Zadar fishing area. Ribar. Croat. J. Fish., **68**(1), 27–43.

Naesje, T.F.; Vuorinen, J.A. and **Sandlund, O.T. (2004).** Genetic and morphometric differentiation among sympatric spawning stocks of whitefish (*Coregonus lavaretus* L.) in Lake Femund, Norway. J. Limnol., **63**(2), 233–243.

Oliveira, R.F. and **Almada, V.C. (1995).** Sexual dimorphism and allometry of external morphology in *Oreochromis mossambicus*. J. Fish Biol., **46**(6), 1055–1064.

Pawson, M.G. and **Jennings, S. (1996).** A critique of methods for stock identification in marine capture fisheries. Fish. Res., **25**: 203–217.

Rooker, J.R.; Secor, D.H.; Zdanowicz, V.S.; De Metrio, G. and **Relini, L.O. (2003).** Identification of Atlantic bluefin tuna (*Thunnus thynnus*) stocks from putative nurseries using otolith chemistry. Fish. Oceanogr., **12**(2): 75–84.

Safi, A. (2014). Study of some morphometric and meristic characters of striped piggy fish, *Pomadasys stridens* (Forsskal, 1775) from Karachi Coast, Pakistan. J. Zool. Stud., **1**(4), 1–6.

Scheiner, S.M. and **Callahan, H.S. (1999).** Measuring natural selection on phenotypic plasticity. Journal of Evolution, **3**: 1704–1713.

Shine, R. (2005). Life-history evolution in reptiles. Annu. Rev. Ecol. Evol. Syst., **36**:23–46.

Silva, A. (2003). Morphometric variation among sardine (*Sardina pilchardus*) populations from the northeastern Atlantic and the western Mediterranean. ICES J. Mar. Sci., **60**: 1352–1360.

Smith, G.R. (1966). Distribution and evolution of the North American catostomid fishes of the subgenus *Pantosteus*, genus *Castostomus*. Michigan: Miscellaneous Publications.

Turan, C. (2004). Stock identification of Mediterranean horse mackerel (*Trachurus mediterraneus*) using morphometric and meristic characters. ICES J. Mar. Sci., **61**(5), 774–781.

Turan, C.; Oral, M.; Ozturk, B. and **Duzgunes, E. (2006).** Morphometric and meristic variation between stocks of Bluefish (*Pomatomus saltatrix*) in the Black, Marmara, Aegean and northeastern Mediterranean Seas. Fish. Res., **79**:139–147

Villaluz, A.C. and **MacCrimmon, H.R. (1988).** Meristic variations in milkfish *Chanos chanos* from Philippine waters. Marine Biology, **97**: 145–150.

Vladycov, V.D. (1934). Environmental and taxonomic characters of fishes. Transaction of Royal Canadian Institute, **20**: 99–140.

Wang, L.; Lyons, J.; Rasmussen, P.; Seelbach, P.; Simon, T.; Wiley, M.; Kanehl, P.; Baker, E.; Niemel, S. and **Stewart, P.M. (2005).** Watershed, reach, and riparian influences on stream fish assemblages in the Northern Lakes and Forest eco-region, U.S.A. Can. J. Fish. Aquat. Sci., **60**: 491–505.

Wimberger, P.H. (1991). Plasticity of jaw and skull morphology in the neotropical cichlids *Geophagus brasiliensis* and *G. steindachneri*. Evolution, **45**: 1545–1561.

Wimberger, P.H. (1992). Plasticity of fish body shape. The effects of diet, development, family and age in two species of *Geophagus* (Pisces, Cichlidae). Biol. J. Linn. Soc., **45**:197-218.

Zelditch, M.L.; Sheets, H.D. and **Fink, W.L. (2003).** The ontogenic dynamics of shape disparity. Paleobiology, **29**: 139–156.