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

Abdelaziz Mounir\textsuperscript{1,2}, Nawal Hichami\textsuperscript{1,2,3}, Nor-eddine Chouikh \textsuperscript{4}, Majid Mounir \textsuperscript{5}, Mohammed Znari \textsuperscript{1,2}, Mouna El qendouci \textsuperscript{6}, Hassan Alahyane \textsuperscript{1}

\textsuperscript{1} Laboratory "Water, Biodiversity & climate change ", Department of Biology, Faculty of Sciences, Semlalia, Cadi Ayyad University, Marrakech, P.O. Box2390, 40000, Morocco.
\textsuperscript{2} The Natural History Museum of Marrakech, Research Centre on Biodiversity, Cadi Ayyad University, Bd Allal El Fassi, Marrakech, Morocco.
\textsuperscript{3} Laboratory of Biotechnology & Sustainable Development of Natural Resources. Polydisciplinary Faculty of Beni Mellal, Sultan Moulay Slimane University, Mghila PO Box. 592, Beni Mellal 23000. Morocco.
\textsuperscript{4} Department of Environmental Engineering, Higher School of Technology Khénifra, B.P. 170, Sultan Moulay Slimane University, Morocco.
\textsuperscript{5} Department of Food Science and Nutrition Hassan II Institute of Agronomy and Veterinary Medicine, PO Box 6202, Madinat Al-Irfane, Rabat instituts, Rabat, Morocco.
\textsuperscript{6} Laboratory of Biodiversity, Ecology and Genome, Faculty of Science, Mohammed V University of Rabat, Morocco.

*Corresponding Author: mnraziz1980@gmail.com

**ARTICLE INFO**

**Article History:**
Received: Nov. 16, 2021
Accepted: June 29, 2022
Online: July 30, 2022

**Keywords:**
Morphometric characters; Meristic counts; Vertebrates number; Discrimination.

**ABSTRACT**

The variation of morphometric and meristic characters among three fishing areas of sardine was addressed considering the 300 specimens 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 249 mm, while their weights ranged between 39.50 g and 168.89 g. 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 = 231.78 mm). 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 \textit{et al.}, 1981; Kumpf \textit{et al.}, 1987;
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 & Allendorf, 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
Discrimination of the sardine stocks in the Moroccan Atlantic coast (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).](image)

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 ichtyometer: 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.

\[ Z = Y \times \left( \frac{X_0}{X} \right)^b \]

Y : variable to being transformed.
X₀ : 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 to 17 with a mean of 17.05 while in the specimens from Safi and Dakhla it varied from 17 to 18 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.

<table>
<thead>
<tr>
<th></th>
<th>Larache</th>
<th>Safi</th>
<th>Dakhla</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of GR</td>
<td>39.05±14.03</td>
<td>58.09±43.01</td>
<td>67.07±8.75</td>
</tr>
<tr>
<td>number of DFR</td>
<td>16.21±0.04</td>
<td>17.22±0.48</td>
<td>17.82±0.02</td>
</tr>
<tr>
<td>number of AFR</td>
<td>17.05±0.04</td>
<td>17.45±0.02</td>
<td>17.95±0.07</td>
</tr>
<tr>
<td>number of vertebrae (V)</td>
<td>50.42±0.07</td>
<td>50.85±0.63</td>
<td>51.02±0.08</td>
</tr>
</tbody>
</table>

(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 λ < 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.

<table>
<thead>
<tr>
<th>Characters</th>
<th>Locations</th>
<th>Larache Mean ± SD*</th>
<th>Safi Mean ± SD*</th>
<th>Dakhla Mean ± SD*</th>
</tr>
</thead>
<tbody>
<tr>
<td>TL</td>
<td>165.58±15.75</td>
<td>185.22±4.4</td>
<td>234.70±8.75</td>
<td></td>
</tr>
<tr>
<td>SL</td>
<td>145.95±13.72</td>
<td>185.98±7.07</td>
<td>210.84±8.15</td>
<td></td>
</tr>
<tr>
<td>FL</td>
<td>153.21±14.37</td>
<td>167±4.55</td>
<td>199.44±8.35</td>
<td></td>
</tr>
<tr>
<td>PAL</td>
<td>79.89±19.48</td>
<td>118±3.52</td>
<td>151.83±5.38</td>
<td></td>
</tr>
<tr>
<td>ppL</td>
<td>51.55±11.07</td>
<td>63.87±1.41</td>
<td>81.28±3.44</td>
<td></td>
</tr>
<tr>
<td>PPL</td>
<td>34.92±8.07</td>
<td>38.40±1.29</td>
<td>51.59±2.69</td>
<td></td>
</tr>
<tr>
<td>DO</td>
<td>7.73±1.53</td>
<td>10.15±2.08</td>
<td>13.02±1.58</td>
<td></td>
</tr>
<tr>
<td>ML</td>
<td>17.25±3.12</td>
<td>12.92±1.17</td>
<td>17.14±1.34</td>
<td></td>
</tr>
<tr>
<td>PDL</td>
<td>62.25±9.10</td>
<td>71.69±2.90</td>
<td>92.08±4.64</td>
<td></td>
</tr>
<tr>
<td>CL</td>
<td>31.98±4.76</td>
<td>20.71±0.83</td>
<td>27.52±1.40</td>
<td></td>
</tr>
<tr>
<td>BH</td>
<td>34.49±8.07</td>
<td>36.85±2.09</td>
<td>48.08±1.98</td>
<td></td>
</tr>
<tr>
<td>HCP</td>
<td>13.33±1.58</td>
<td>12.64±0.55</td>
<td>16.61±1.58</td>
<td></td>
</tr>
<tr>
<td>BT</td>
<td>5.91±1.68</td>
<td>19.39±1.41</td>
<td>23.49±3.18</td>
<td></td>
</tr>
<tr>
<td>pO</td>
<td>8.15±1.09</td>
<td>9.02±1.13</td>
<td>12.42±2.11</td>
<td></td>
</tr>
<tr>
<td>PO</td>
<td>6.92±1.23</td>
<td>8.43±2.01</td>
<td>11.02±3.72</td>
<td></td>
</tr>
</tbody>
</table>

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).
Discrimination of the sardine stocks in the Moroccan Atlantic coast

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

<table>
<thead>
<tr>
<th>Locations</th>
<th>Wilks’ λ</th>
<th>P</th>
<th>signification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larache – Safi</td>
<td>0.28</td>
<td>0.00001</td>
<td>Hight signification</td>
</tr>
<tr>
<td>Safi – Dakhla</td>
<td>0.21</td>
<td>0.00001</td>
<td>Hight signification</td>
</tr>
<tr>
<td>Larache – Dakhla</td>
<td>0.096</td>
<td>0.00001</td>
<td>Hight signification</td>
</tr>
</tbody>
</table>

**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


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.


Discrimination of the sardine stocks in the Moroccan Atlantic coast


