Range extension of the Atlantic herring *Clupea harengus* (Clupeiformes: Clupeidae) southern part of the Northeast Atlantic Ocean

by

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**MATERIAL AND METHODS**

Five specimens of *Clupea harengus*, ranging from 28 cm and 30 cm in total length, were recorded in the waters of northern Spain from 2009 to 2018, at depths between 34 and 114 m (Tab. I). The first specimen was caught in 2009 by an artisanal fishing vessel using gill nets. The others were caught during the annual bottom-trawl surveys for the assessment of demersal and benthiic stocks (“Demersals” surveys), which are carried out every autumn on soft bottoms along the continental shelves of Galicia and the Cantabrian Sea by the *Instituto Español de Oceanografía*. Two specimens caught in 2009 and 2014 were examined. The morphometric and meristic characters were recorded in fresh following Whitehead (1985, 1986), and then the specimens were preserved in 70% ethanol and deposited in the fish collection of the Museo Luis Iglesias de Ciencias Naturais in Santiago de Compostela, with the reference numbers MNHUSC25163-1 and MNHUSC25163-2 (Fig. 1).

A muscle tissue sample from both specimens was submitted to DNA purification and sequencing of the standard 5′ barcoding region of the mitochondrial gene cytochrome c oxidase subunit I (COI), following procedures previously described (Barros-García et al., 2016). PCR amplification was carried out with Thermo Scientific Phire Green Hot Start II PCR Master Mix and primers FF2d (5′-TT cTccaccaaccacaa R GaYaTYGG-3′) and FR1d (5′-ACCTCAGGGTGTCCGAARAAYCARA-3′), obtaining 652 nucleotides-long DNA barcodes. Specimen and collection data, sequences, and trace files are available on the Barcode of Life database (BOLD; http://www.boldsystems.org) in the project **Ichthyological note**

**Table I.** Location of records and data for specimens of *Clupea harengus* caught in northern waters of Spain.

<table>
<thead>
<tr>
<th>Date</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Depth (m)</th>
<th>TL (cm)</th>
<th>Weight (g)</th>
<th>Gear</th>
</tr>
</thead>
<tbody>
<tr>
<td>19/05/2009</td>
<td>42.4397</td>
<td>−8.9214</td>
<td>35</td>
<td>28</td>
<td>−</td>
<td>Gillnet</td>
</tr>
<tr>
<td>25/09/2014</td>
<td>43.2477</td>
<td>−9.1234</td>
<td>95</td>
<td>30</td>
<td>190</td>
<td>Trawl</td>
</tr>
<tr>
<td>05/10/2014</td>
<td>43.6689</td>
<td>−6.2747</td>
<td>135</td>
<td>28</td>
<td>155</td>
<td>Trawl</td>
</tr>
<tr>
<td>21/09/2018</td>
<td>42.6125</td>
<td>−9.2187</td>
<td>101</td>
<td>29</td>
<td>197</td>
<td>Trawl</td>
</tr>
<tr>
<td>07/10/2018</td>
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<td>−6.0793</td>
<td>114</td>
<td>28</td>
<td>164</td>
<td>Trawl</td>
</tr>
</tbody>
</table>

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The Atlantic herring *Clupea harengus* Linnaeus, 1758 is a pelagic clupeid, schooling, plankton-feeding species that inhabits the coastal areas from inshore to well offshore waters, at depths to 200 m (Whitehead, 1986). This target species has been crucial for food security and economic development in northern Europe landed annually in the last years (FAO, 2010-2019).

This species is distributed on both sides of the North Atlantic Ocean. In the western Atlantic, it ranges from Labrador to Cape Hatteras; in the eastern Atlantic, from the northern part of the Bay of Biscay to Greenland, and to the East into the Barents Sea (Whitehead, 1985, 1986). In the northeastern Atlantic, a large number of intraspecific groups (races, stocks, and populations) are distinguished by their spawning grounds and sea conditions. It is targeted by fisheries in the coastal areas from inshore to well offshore waters, at depths to 200 m (Whitehead, 1986). This target species has been crucial for food security and economic development in northern Europe landed annually in the last years (FAO, 2010-2019).

Table I. – Location of records and data for specimens of *Clupea harengus* caught in northern waters of Spain.
Range expansion of *Clupea harengus*  

**RESULTS**

A dot distribution map was created based on georeferenced data reported in online marine biogeographic databases (GBIF, 2019) showing the records in the north of Spain (Fig. 2).

The body is elongated and highly depressed, its height 4.6 times in the standard length; mouth large, reaching posteriorly to the midline level of the eye; lower jaw projecting; snout greater than eye diameter, 0.7 times in eye; eye large, 4.4 and 4.7 times in head; no median notch on the upper jaw; operculum smooth, without radiating bony striae; pelvic fins inserted posterior to the dorsal fin origin; scales large and cycloid; colour bright silver, darker on the back with no distinctive dark spots on the body or fins. The main morphometric and meristic characters are showed in table II.

Molecular analysis identifies the two specimens tested as belonging to the species *Clupea harengus*, as they unambiguously group with other sequences of the same species, the mean distance between all of them being 0.3%. The average distance separating this cluster from that formed by sequences of its sister species *C. pallasii* is 1.5% and the distance from the group formed by barcodes of *S. pilchardus* is greater than 17%. The two sequences of *C. harengus* under analysis differ only in two nucleotide positions.

**DISCUSSION**

Meristic and biometric measures are in agreement with previous diagnoses and descriptions of *Clupea harengus*. So far, this species was not reported south of the estuary of the River Garonne (France) (GBIF, 2019). Therefore, the present records confirm its presence on the northern coasts of Spain, establishing the southernmost record in the eastern Atlantic Ocean at 42.4397°N-8.9214°W, in Galician waters.
The fish species composition in the North of Spain includes groups of boreal and subtropical origin. Although Lusitanian species represents the majority of the fish fauna in the region, there is also a minor group of warm- and cold-water adapted species inhabiting these waters (Bañón et al., 2010). Although the occurrence of new warm-water fishes related to global warming is the most common phenomenon in this area (Bañón et al., 2017), the presence of new cold-water fishes also occurs, but less frequently. *Clupea harengus* is the last cold-water adapted species added to the list of Spanish distributed fishes. Other species such as the beaked redfish *Sebastes mentella* (Travin, 1951 (Fernández-Zapico et al., 2012) and the northern wolffish *Anarhichas denticulatus* Krøyer, 1845 (Rodríguez-Cabello et al., 2015) have also been recently reported in the north of Spain for the first time, both establishing new southern limits of distribution.

The causes of the current presence of *C. harengus* could be related to climate variations. Indeed, the distribution of some pelagic fishes, such as *S. pilchardus* and *C. harengus*, have shown pronounced latitudinal distributional responses to seasonal change of sea temperatures in the historical records from the northeast Atlantic Ocean, in relation with alternations of cycles of warm and cold periods (Heath et al., 2012). Dynamics of abundance and migrations of populations of *C. harengus* in the eastern North Atlantic vary in synchrony with the warm (positive) and cool (negative) phases of the Atlantic Multidecadal Oscillation (AMO). It is during negative AMO phases when good recruitment and large incoming year classes occur, that will form the basis of the herring fishery in the following years (Alheit et al., 2014). There are hints of a transition to a relatively cold period at this moment in the north Atlantic (McCarthy et al., 2015). The AMO index has been decreasing in the last years and, during the 2014-2016 period, it has become marginally negative, with an average sea surface temperature anomaly of about –0.1°C (Frajka-Williams et al., 2017). Therefore, a colder period seems to favor the abundance and the migration of *C. harengus* in the eastern North Atlantic, and could be the cause of this apparent expansion to the south. If this hypothesis is true, and a progressive cooling occurs in the next years in the North Atlantic Ocean, a greater presence of *C. harengus* could be expected in the northern waters of Spain.

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REFERENCES


