The Moroccan Ichthyoplankton - A General Overview

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Morocco is one of the most important seafood producing countries. In consideration of its advantageous geographical location in addition to the biodiversity and richness that characterise these halieutic resources, the small pelagic fishes represent 75% of the halieutic harvest, with a domination of *S. pilchardus*. Regarding the sustainability and protection of the marine species, the study of ichthyoplankton is an essential and crucial step, through the use of classical identification techniques under binocular lenses combined with molecular biology tools based on genetic markers as well as an integrated image analysis system, the ZooScan. The present work is the subject of an overview of the study of ichthyoplankton on the two Atlantic and Mediterranean coasts of Morocco.

Keywords: *Biodiversity; ichthyoplankton; classical identification; genetic markers; ZooScan.*

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1. INTRODUCTION

Morocco is located in north-west Africa, between latitudes 21°-36°N and longitudes 1°-17°W, with two sea fronts that are part of the largest reserve of fish resources. Its long coastline overlooking the Atlantic Ocean with 2934 km extending between Cape Sparte and Cape Blanc, moreover the central area of this coast is subject to active seasonal upwelling in summer [1], at the southern coastal zone level, it is permanent during the whole year, supporting primary and secondary production [2] which gives this ecosystem a wealth of nutritional elements necessary for the development of marine species [3]. The Mediterranean coastline extends over 512 km from Saidia to Cape Sparte and presents a complex ecosystem particularly in the western part, it is a semi-closed sea with a biological biodiversity that gives rise to a large fishing activity [4]. This geographical position allows Morocco to be an important seafood producer and this contributes considerably to the country's national economy. More than 75% of Moroccan seafood is made up of small pelagic species and is dominated by *Sardina pilchardus* [5], the study of ichthyoplankton is an index for identifying the egg-laying areas of fish species. Any factor that affects this sector will have a direct impact on the country's national economy, which is why it is necessary to better understand the population dynamics of fish in order to guarantee the sustainability and durability of the Moroccan fishing resources. Several studies on the early life stages of fish have been carried out on the Moroccan Atlantic coastline, but little research has affected the Mediterranean coastline of the country.

2. IMPORTANCE OF STUDYING ICHTHYOPLANKTONS

Ichthyoplankton is a temporary zooplankton component, i.e. meroplankton [6] which represents the early life stages of fish. Their study is very important due to their sensitiveness to environmental changes, which gives them a bioindicator of the marine ecosystem's health and performance, as well as their taxonomic importance [7].

The study of early life stages of fish has a key contribution to the management and protection of fish communities by estimating the production of fish eggs and larvae and their spatial and temporal distribution, taking into consideration the mortality rates [8], The environmental

temperature and salinity are among the main abiotic factors influencing the survival and growth of fish larvae. The environmental hydrodynamics also play a role in larval transport to areas that are not suitable for the growth of these species; in fact, the higher the growth rate, the lower the mortality rate [9] and [10]. The nutritional richness of the environment and the predation are biotic factors that also influence the survival of larval stages [11]. Eggs are more susceptible to predation than larvae [12] as their transparency reduces their detectability to predators [13] although they may be victims of other species' predators, such as in the case of Hareng [14], which are sensitive to ultra-violet radiation and to pollution [15,16].

3. STATUS OF ICHTHYOPLANKTON IN MOROCCO

Few studies of ichthyoplankton have been carried out in the Moroccan Mediterranean, but the Atlantic coastline has been the subject of several studies. In the framework of Morocco-Russian co-operation a study was carried out in 1994 along the Atlantic coastline to determine the spatial distribution as well as the abundance and specific diversity of fish eggs and larvae during the reproductive period. 34 Taxonomic clusters were identified including the families of the following pelagic clusters: Clupeidae, Engraulidae, Carangidae, Scombridae and Trichuridae with an abundance of Sardine eggs and larvae [17]. In 1998 (March-July) two campaigns were carried out in the southern Atlantic between Cap Blanc and Cap Boujdour to assess the Hydrological Parameters and their importance on the distribution of ichthyoplankton, this assessment indicated a difference between the coastal and off-shore stations [18], during later years [19] have confirmed these results in their study, which indicates that the more the direction is offshore, the more the abundance of ichthyoplankton decreases, with a preference of larvae for the upper layers, they were able to identify 21 families with the most abundant taxon and that of the Clupeidae.

S. pilchardus presents the most abundant small pelagic fish in the north western Atlantic Ocean, its distribution between Cape Barbas and Cape Boujdour was determined and the natural mortality rates of European sardine eggs and larvae estimated at 83.5% and 21.4% per day respectively, the variability in sardine egg-laying population dynamics between the years 1990-2000 is explained by the warming of the oceans

during that period, which explains the relationship between the abundance of ichthyoplankton species and environmental parameters [20].

In the Mediterranean and in a context of preservation of fish species that are subject to exploitation have combined classical

identification techniques with molecular biology tools (Barcoding) by using the mitochondrial markers COX1, 16S rRNA and Cytochrome b between April and May 2014 [21], the main species identified are: *Boops boops* (Linnaeus, 1758) 48%, *Engraulis encrasicolus* (Linnaeus, 1758) 7% and *Pagellus acarne* (Risso, 1827) 7%.

Fig. 1. Fish eggs and larvae [22]

Table 1. Simple methods for ichthyoplankton sampling

Study area	Net type	Mesh size (µm)	Type of haul	References
Moroccan Atlantic	Bongo 20cm	417 µm	Oblique	(Berraho et al., 1996) [17]
Moroccan South Atlantic	Bongo 20cm	417 µm	Oblique	(Berraho et al., 2005) [18]
Atlantic Coast of Morocco	Bongo 20cm	300 µm	Oblique	(Abdelouahab et al., 2016) [20]
Atlantic Coast of Morocco	Bongo 50cm	180 µm	Oblique	(Abdelouahab et al., 2017) [19]
Gulf Tunisia	Bongo 47cm	300 µm	Horizontal	(Zarrad et al., 2004) [23]
Gulf Tunisia	Bongo 60cm	335 µm	Oblique	(Zarrad et al., 2003) [24]
California Current	Bongo 60cm	505 µm	Oblique	(Aceves et al., 2018) [25]
English Channel as well as the Southern Bight of the North Sea	Bongo 2m	1.6 mm mesh size except the last meter which was 500 µm	Oblique	(Di Pane et al., 2019) [26]
Hypersaline bay of the Colombian Caribbean	Bongo 30 cm	300-500 µm	Horizontal	(GallegoZerrato and Giraldo, 2018) [27]

Table 2. Methods of extracting DNA from ichthyoplankton

DNA extraction method	Reference
The phenol / chloroform / isoamyl (PCI) method	(Quinteiro et al., 1998) [28]
The Chelex100 Resin method (Biorad)	(Jérôme et al., 2003) [29]
REExtract-N-Amp TM Tissue PCRKit (Sigma Aldrich)	(Pappalardo et al., 2015) [30]
Magnetic bead kit (ChargesSwitchw Forensic DNA Purification Kit, Invitrogen, Carlsbad, USA)	(Lelievre et al., 2010a) [31]

4. SAMPLING AND IDENTIFICATION

Any study of ichthyoplankton is based on the appropriate choice of sampling and identification methods depending on the objective to be achieved. There are several strategies for the capture of fish eggs and larvae among the most commonly used:

In general the visual identification of ichthyoplankton is a difficult task due to the small size of eggs and larvae, it is done under a binocular lens which is mainly based on morphological criteria [22], however in some cases it is problematic, particularly for species of proximate size diameter [32]. The molecular tool allows the uncertainties of the classical technique to be unveiled, specific genetic markers are often used [33,34], sample fixation plays a key role in the efficiency of DNA extraction [35].

In addition to the molecular tool, there is a new technology based on an image analysis system the ZooScan [36] it is a means which makes it possible to obtain data quickly on the taxonomy, distribution, and mapping of spawning areas for ichthyoplankton species [37] were able to produce distribution maps of flounder, whiting, cod, sole, plaice, and broom by classical identification and ZooScan to compare the two methods in the east of the English Channel and the southern North Sea.

5. RESULTS AND DISCUSSION

The study of ichthyoplankton presents a crucial component for the understanding of fishing fluctuations and plays a significant role in the management and sustainability of the Moroccan halieutic resource. The distribution of fish eggs and larvae is regulated by spatio-temporal variations and environmental factors, such as temperature and salinity, besides global warming causes an increase in water temperature, in addition changes in ocean salinity and acidity thus impact the abundance and distribution of marine species stocks [38]. The main preoccupation in the study of the early life stages

of fish is the adequate choice of tools to ensure a better identification and therefore a reliable mapping of spawning and nursery areas for the larval development of the main species of ichthyoplankton.

Molecular techniques have been developed in order to resolve the doubts of the classical method using genetic markers, the fixation and conservation of samples plays a major role in the success of species determination [39] whether to provide an easier visual identification through the good conservation of pigments, or for the conservation of genetic material against degradation, methods based on the use of magnetic bead kits seem to be relevant for a better extraction of DNA [31,35] furthermore the new integrated image analysis system is considered as an efficient and rapid technique in the measurement and classification of ichthyoplankton species [37]. The ZooScan and the molecular tool are complementary methods to visual identification and can in no way replace the classical technique. In Morocco, few studies have targeted the Mediterranean coast, which is distinguished by its biodiversity in terms of marine species [4].

6. CONCLUSION

It is still vulnerable to the overexploitation that affects these halieutic resources. not to mention the negative effects of climate change, which makes this coast more vulnerable, which is why it is necessary to further develop hydrological and biological knowledge with a view to protecting the Moroccan Mediterranean ecosystem.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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