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Population characteristics of the Atlantic chub mackerel (Scomber colias Gmelin, 1789) in the northwestern Atlantic coast of Morocco

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Abstract

The Atlantic chub mackerel (Scomber colias) is a pelagic fish species which strongly support fisheries along Moroccan Atlantic coasts. However, despite commercial landings which have increased over the last decades in Morocco, biological information on this species remain scarce at the national scale. The present study was therefore conducted to examine the reproductive biology of S. colias in Atlantic coasts of Morocco. A total of 432 specimens were collected from Safi fishing harbor between March 2023 and February 2024, including 207 females and 225 males. The results showed that gonadosomatic index peaked during the colder months, while the spawning season occurred between December and March. Maximum hepatosomatic index values were recorded in June, at 1.13 ± 0.41 for females and 1.33 ± 1.32 for males. The overall body condition factor ranged from 0.71 to 0.91 in both sexes. Finally, size at first maturity was estimated at 18.26 cm for males and 19.31 cm for females. These preliminary findings provide crucial baseline data that may inform sustainable management practices and support conservation efforts of Atlantic chub mackerel populations in Moroccan marine waters.

I. Introduction

The Atlantic chub mackerel Scomber colias (Gmelin, 1789) is a pelagic fish species belonging to the Scombridae family, characterized by a fast-growing and early maturing of individuals. Specimens can reach a maximum length of 50 cm and an age of 13 years (Castro and Santana, 2000). This species colonizes the warm and temperate Atlantic coastal waters and surrounding seas, including the Mediterranean, Black and Adriatic Seas, generally on the continental shelf at depths of between 0 and 300 m (Collette and Nauen, 1983; Castro and Santana, 2000). Its geographical range extends from the Bay of Biscay in the northern part of the eastern Atlantic to South Africa. However, this species is also located along the U.S. coast from Massachusetts to Florida, in the Bahamas, the Gulf of Mexico, and in southern Venezuela, Brazil, Uruguay, and Argentina (Castro and Santana, 2000).

The central and southern regions of Morocco are identified as key areas for the concentration of Atlantic chub mackerel along the northwest African coast. In Moroccan waters, S. colias is a significant fishery resource, with fishing activities carried out using capture seiners, artisanal fleets, and commercial trawling vessels, including Refrigerated Sea Water vessels. The Atlantic chub mackerel fishery has significant socioeconomic importance in Morocco, being one of the most valued commercial fish throughout its habitat, and providing food and job opportunities for many locals. Indeed, catches were 380 000 tons, representing about 16 % of the overall catch of small pelagic fish within the country (ICES, 2020). However, the fishing pressure directed at this species in Morrocan waters negatively affect the biomass, resulting in the stock on populations being extensively exploited (Derhy et al., 2022). For instance, despite the increasing demand by consumers, the annual catches of key small pelagic fish species in the region decreased from 2.8 million tons in 2019 to 2.6 million tons in 2020 (FAO, 2020). This reduction is mainly related to fishing activities occurring during the spawning season, which provokes unintended mortality of juveniles, contributing therefore to the decline in the stock biomass of S. colias. However, despite its significant economic weight and the extent of the Moroccan marine coastlines, studies on the biological characteristics and spatial variability of this species remain limited. To date, scientific efforts on Atlantic chub mackerel at the national level have been limited in time and geographical coverage, and are far from commensurate with the species' socio-economic and nutritional importance. Only a few studies have focused on certain aspects of the species biology, including diet, age, growth, reproduction, morphometry and exploitation rates, highlighting variations between the Mediterranean and Atlantic populations. (Bouzzammit and El Ouizgani, 2019; Techetach et al., 2021; Bouzzammit et al., 2022). More accurate and up-to-date biological information is needed to assess the status of populations and their biological characteristics, in order to plan more appropriate and dynamic management over time and space.

The current study aimed to examine a wide range of biological parameters of S. colias including sex ratio, size at first maturity, spawning season and stages of maturation in northwestern coasts of Morocco. Specimens were caught from the central zone of the Atlantic stock, located between Safi city (32°.19'N, 9°W) and Cap Boujdour (26°.07'N, 14°.30'W). By providing actualized data, our findings may contribute to better understand the population dynamics of S. colias and its biological features during seasons in NW Moroccan waters.

II. Methods

a. Sampling

A total of 432 individuals of Atlantic chub mackerel, caught by purse seine, were collected from commercial catches landed at the port of Safi city from March 2023 to February 2024 (Figure 1). 36 specimens were sampled three times a month. The fish was transported to the laboratory in isothermal containers filled with ice. In the laboratory, morphometric data was recorded for each individual, such as total length (TL, cm) and total weight (TW, g). After dissection, the sex was identified macroscopically while the gonad weight (GW, g) and liver weight (LW, g) were measured to the nearest 0.01 g.

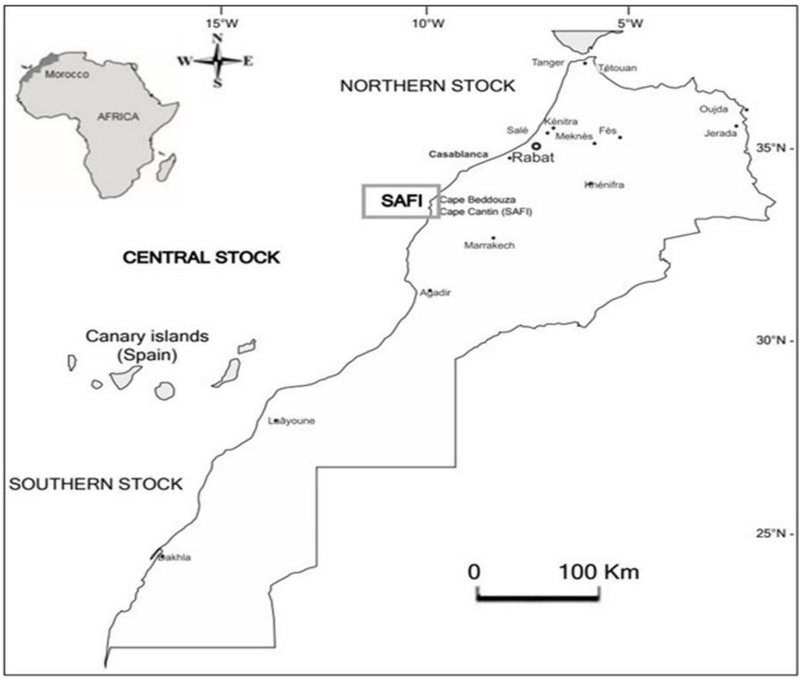

Figure 1: Geographic location of the sampling area of *S. colias* in the Atlantic coast of Morocco

b. Length-weight relationship

The majority of fish exhibit an allometric correlation between size and weight. Estimating the morphological changes induced by growth is highly beneficial in fisheries biology. It is converted into a species equation **(Le Cren, 1951)**:

$$TW = a \times TL^b,$$

where a: constant, and b: allometry coefficient.

c. Sex ratio

The sex ratio was determined using the following equation:

$$SR = M/F,$$

where F: number of females, and M: number of males.

d. Stages of sexual maturity

Sexual maturity stages were determined by direct observation of the gonads using various morphological parameters including size, color, and the volume they occupied within the abdominal cavity. According to **(Arriaga *et al.,* 1983)**, the macroscopic maturity scale includes five stages recognized in both males and females: stage I (immature), stage II (maturing virgin or recovering spent), stage III (maturation), Stage IV (spawning), and stage V (post-spawning).

e. Biological index

To assess the maturity of *S. colias* and the condition of specimens sampled, three indices were calculated: The gonadosomatic index (GSI), hepatosomatic index (HSI) and condition factor (K). The GSI serves as a dependable measure of reproductive activity in fish. It assesses fluctuations in gonadal weight relative to factors like body length, total body weight, or somatic weight, enabling the identification of the reproductive period. The GSI is determined by analyzing changes in gonad weight throughout the sexual cycle and is represented by the following formula:

$$GSI = (GW/TW\text{-}GW) \times 100$$

with GW: gonads weight, and TW-GW: total weight-gonads weight. The gonado-somatic index is used to determine the timing and duration of spawning (**Lahaye, 1980)**. All the energy required for gonad maturation comes from the lipid reserves stored in the liver. The HSI indicates the liver's energy reserves, essential for sexual maturation. It illustrates the fluctuations in liver mass during the sexual cycle, offering insights into energy distribution and physiological readiness for reproduction. The index is computed applying the subsequent formula:

$$HSI = (LW/TW\text{-}LW) \times 100$$

with LW: liver weight, and TW-LW: total weight-liver weight.

The K value was calculated using the formula **(Bouhali *et al.,* 2015)**:

$$K = (Wgt/TL^3) \times 100$$

where Wgt: gutted body weight, and TL: total length.

f. Size at first maturity

The size at which 50 % of individuals are sexually mature is known as the size at first sexual maturity (TL_{50}). To determine this size, samples were taken from the 1 cm size class and the number of individuals were recorded. The proportion of mature individuals (stages III, IV, and V) was subsequently determined for each size class. The correlation between size and the proportion of mature individuals was represented by a sigmoid logistic curve, mathematically expressed as follows **(King, 1995)**:

$$P = 1/\ (1 + e^{(-a(TL-TL_{50}))}),$$

where P is the proportion of mature fish for the total length, and a is a parameter of the model.

g. Data analysis

The sex ratio, GSI, and HSI data were analyzed using the Chi-Square test ($\chi 2$) to determine potential differences in the proportions of each sex. Variations in size during first maturity were evaluated applying Z values **(Gunderson, 1977)**. The differences were considered significant at $p < 0.05$. The statistical software SPSS version 20.0. was used for the data analysis.

III. Results

a. Population structure

The study population consisted of 207 female and 225 male individuals of *S. colias* . The overall length of the individuals varied between 15.5 and 26 cm, with an average of 20.55 ± 1.63 cm. Specifically, the length distribution for males ranged from 16.5 to 26 cm, with a mean of 20.55 ± 1.63 cm, while for females, it extended from 15.5 to 25 cm, with a mean of 20.5 ± 1.63 cm (Figure 2). A statistical analysis revealed no significant difference in the total length distribution between the sexes ($p > 0.05$), indicating similar size distributions for males and females. Regarding weight, the total body mass for males ranged from 35 to 132 g, with a mean of 71.39 ± 21.21 g, whereas for females, it ranged from 38 to 156 g, with a mean of 71.61 ± 21.36 g. Although there was a slight variation in the range of weights between the sexes, the means were closely aligned, suggesting that body mass did not differ substantially between males and females in this population.

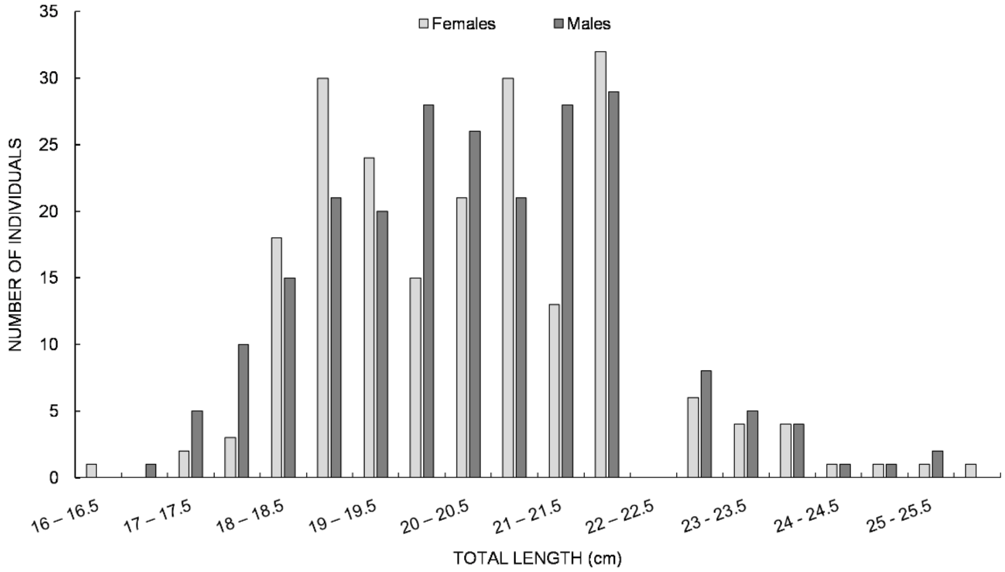

Figure 2: Distribution frequency of the total length (TL) in *S. colias* in the Atlantic coast of Morocco

b. Length-weight relationship

A significant relationship between length and weight ($p < 0.05$) (Figure 3). The correlation coefficient was 89 % and 91 % for males and females respectively, indicating a strong correlation between weight and size of *S. colias* in Safi area. The allometric coefficient (b) has a value much larger that 3 for both sexes, indicating that *S. colias* is weighty compared to its size (Table 1).

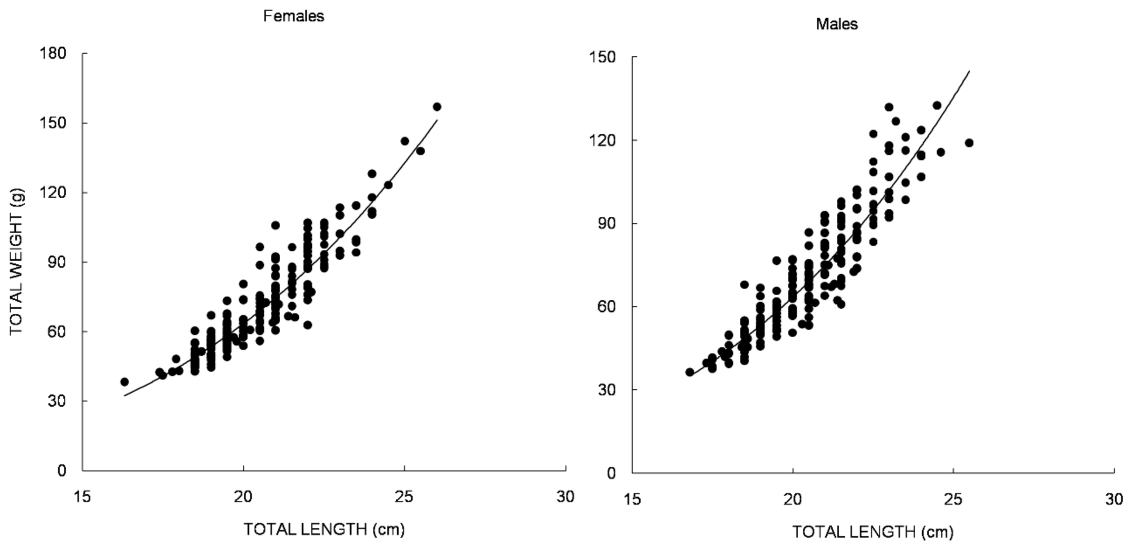

Figure 3: Length-weight relationship in females and males of *S. colias* in the Atlantic coast of Morocco

Table 1: Parameters of length-weight relationship for *S. colias* (N = number of fish; a = scaling coefficient; b = allometry coefficient; r = correlation coefficient)

Sex	N	a	b	r	Allometry
Males	207	0.0032	3.3055	0.89	
Females	225	0.0035	3.2751	0.91	Positive
All fish	432	0.0033	3.2910	0.90	

1. Sex ratio

The sex ratio of *S. colias* was calculated to be 1:1.08 (females to males), which approaches a ratio of 1:1 ($\chi^2 = 0.75$, $p > 0.05$). On a monthly basis, the sex ratio was especially near parity in June and July (1:0.1), as well as in October (1:0.80). As for monthly changes in sex ratio according to the studied months no significant differences between the males and females populations were noticed at all months apart from the month of May in which statistically significant differences emerged ($\chi^2 = 4$, $p < 0.05$) (Table 2). The seasonal analysis of the ratio of female-to-male appearance showed little fluctuation in the ratio of females to males throughout the year. Conversely, spring was also noted for a clear male bias ($p < 0.05$), with a significantly higher representation of males across the season (Figure 4).

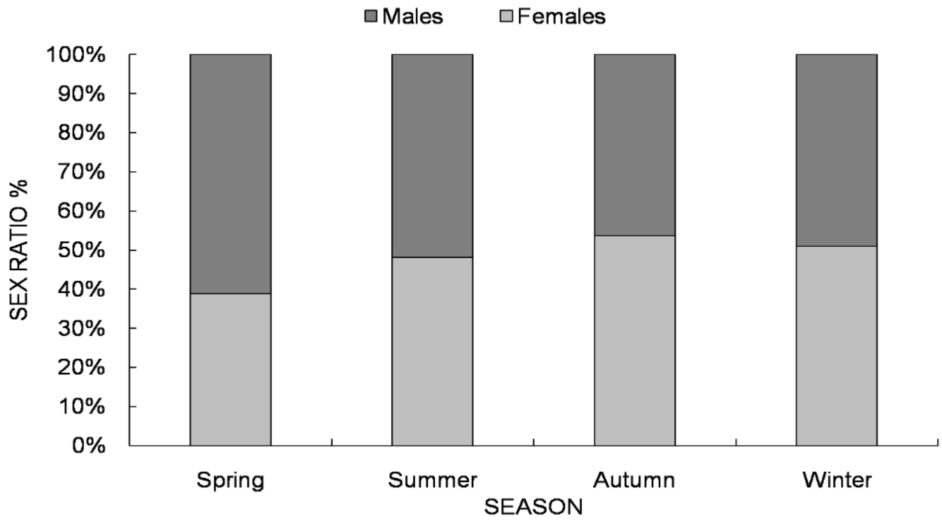

Figure 4: Seasonal evolution of the sex ratio of *S. colias* in the Atlantic coast of Morocco

Month	Number of specimens			SR	χ²	TL (cm)	TW (g)
	Females	Males	Total				
Mar	16	20	36	1.25	0.44	21.48 ± 1.81	73.07 ± 20.82
Apr	14	22	36	1.57	1.77	19.63 ± 1.72	58.14 ± 14.04
May	12	24	36	2.00	4.00*	21.18 ± 2.17	81.27 ± 27.73
Jun	13	23	36	1.77	2.77	21.83 ± 0.83	95.68 ± 12.08
Jul	21	15	36	0.71	1.00	21.39 ± 0.90	84.69 ± 16.87
Aug	18	18	36	1.00	0.00	20.04 ± 1.02	66.06 ± 11.96
Sep	16	20	36	1.25	0.44	20.21 ± 1.34	74.58 ± 21.05
Oct	20	16	36	0.80	0.44	21.04 ± 1.46	80.62 ± 18.39
Nov	22	14	36	0.64	1.77	20.39 ± 1.15	67.07 ± 14.72
Dec	18	18	36	1.00	0.00	21.15 ± 1.40	73.41 ± 17.85
Jan	21	15	36	0.71	1.00	19.07 ± 0.89	50.54 ± 5.49
Feb	16	20	36	1.25	0.44	19.01 ± 0.89	51.06 ± 9.71

Table 2: Monthly variation of the sex ratio, mean total length (TL), mean total weight (TW) of *S. colias*. * Significant difference $p < 0.05$

c. Stages of sexual maturity

Through macroscopic examination of the gonads of *S. colias*, five different stages of sexual maturity were identified (Figure 5). The seasonal distribution of these stages revealed that both sexes predominantly remained in stage I (immature) and stage II (maturing virgin) for the majority of the year (Figure 5). There was a particularly high proportion of females in stage I during the summer months, with a striking 71 % (July), 72 % (August) and 88 % (September) of the population in stage I. Lowest proportion of immature females (11 % in December) indicated progression to more mature stages during this period. Stage II, representing maturing virgins, exhibited smaller proportions but showed significant peaks in November (45 %) and April (36 %), reflected a period of growth in the cycle immaturity. A similar high percentage of stage I in males was observed between May and August, 83 % to 78 %, with 93 % peak in November. It indicates a lengthy period of immaturity behavior during these months. For females, stage III (mature virgin) occurred from February to March while for males it occurred from November to March. With respect to sex and stage, Stage IV (fully mature), which is indicative of reproductive readiness, only occurs in February for females and males in March. This period corresponds to the peak of reproductive activity, as evidenced by the highest rates of maturity and spawning stages for both sexes, particularly in February and March.

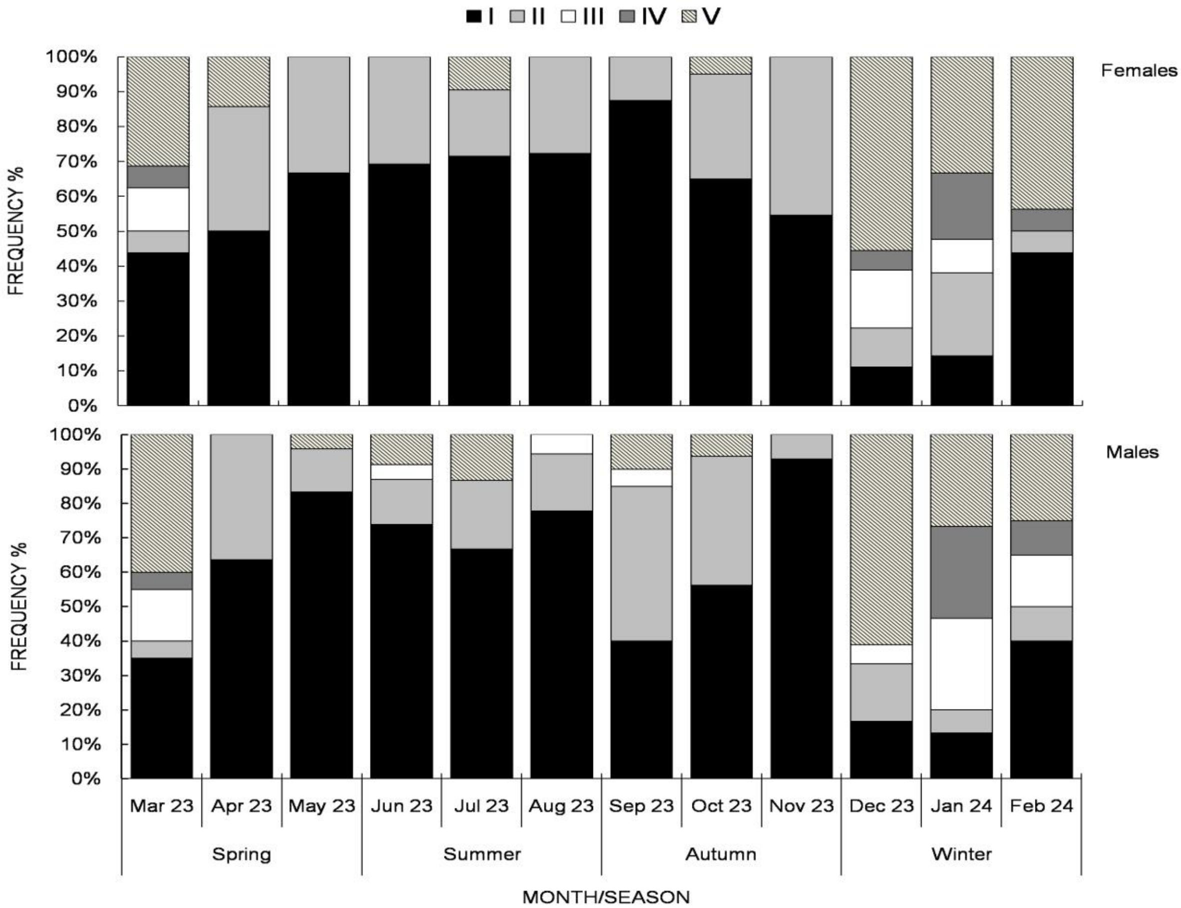

Figure 5: Monthly variation of sexual maturity stages for females and males of *S. colias* in the Atlantic coast of Morocco

d. Biological index

Both sexes demonstrated a comparable pattern in the evolution of the GSI (Figure 6). The monthly variations in the mean GSI ranged from 0.29 ± 0.14 to 1.28 ± 1.57 in females and from 0.30 ± 0.19 to 1.36 ± 1.60 in males (Figure 6). The GSI began increasing in November, reaching its peak in February for both males and females. Afterward, it gradually declined from March onward, hitting its lowest levels in June. Similarly, the HSI followed a comparable pattern, with elevated values observed during two distinct periods: May to June and September to October. The highest recorded HSI values occurred in September, measuring 1.18 ± 0.29 for females and 1.33 ± 1.32 for males. In contrast, the lowest values were observed in April, with females at 0.52 ± 0.14 and males at 0.54 ± 0.17 (Figure 6). After summer, the HSI showed a gradual decline but remained relatively stable, indicating a depletion of energy reserves following the spawning season. Statistical analysis using the χ^2 test found no significant differences in the monthly trends of GSI and HSI between males and females ($p > 0.05$). Both indices exhibited a consistent and synchronized pattern across sexes, highlighting the shared physiological and reproductive dynamics of *S. colias* (Figure 6). The condition factor ranged from 0.72 to 0.92 in females and from 0.71 to 0.91 in males. The highest values were observed in June, while the lowest occurred in March. Temperature fluctuations likely play a role in influencing reproductive cycles and energy storage. Warmer summer temperatures may contribute to improved body condition (as indicated by higher K values) and increased energy reserves (HSI), whereas colder winter temperatures could stimulate spawning, leading to a rise in GSI.

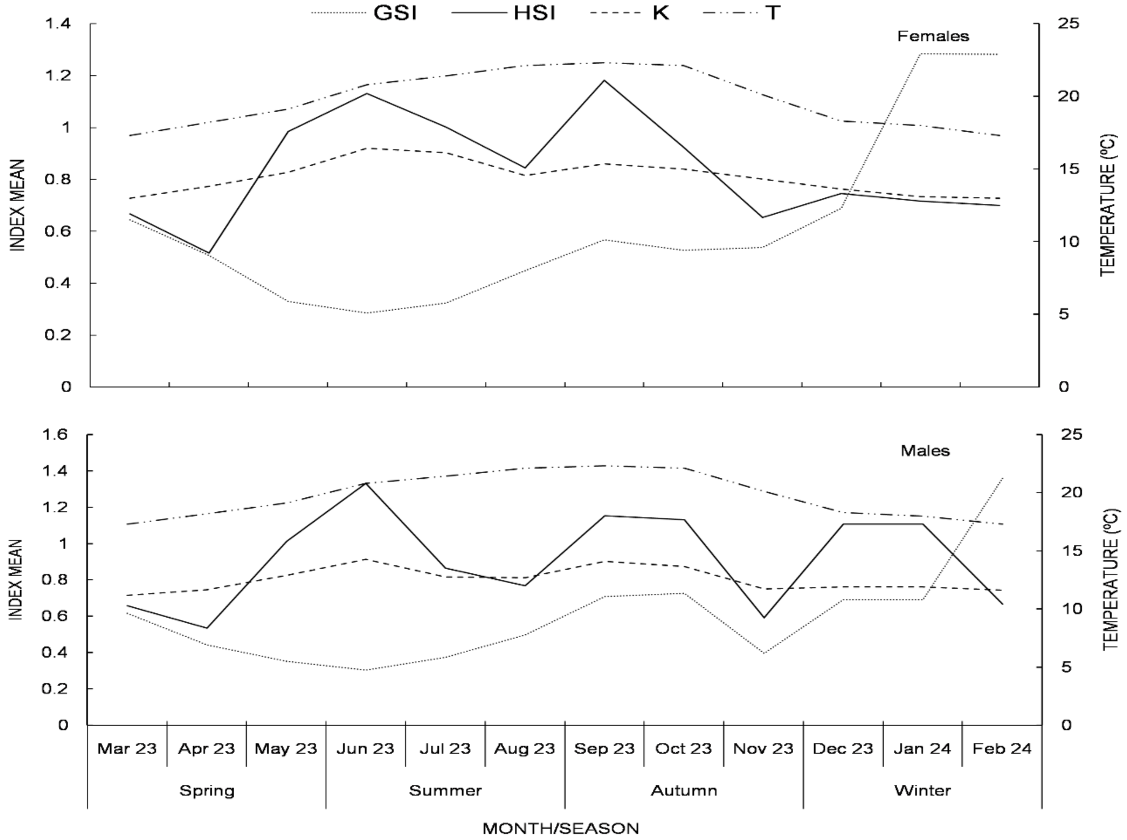

Figure 6: Monthly variation of GSI, HIS and K for females and males of *S. colias* and evolution of water temperature in the Atlantic coast of Morocco

e. Size at maturity estimates

The maturity curve showed a significant fit to the observed data ($\chi 2 = 3.89$, $p < 0.05$ for males; $\chi 2 = 39.86$, $p < 0.001$ for females; $\chi 2 = 15.51$, $p < 0.001$ for the whole sample). The smallest mature specimens measured 17.5 cm for both sexes. The size at first maturity was 18.26 cm for males, 19.31 cm for females, and 18.98 cm for the combined sexes (Figure 7), with no significant difference between sexes of the Atlantic chub mackerel ($Z = 0.72$; $p > 0.05$).

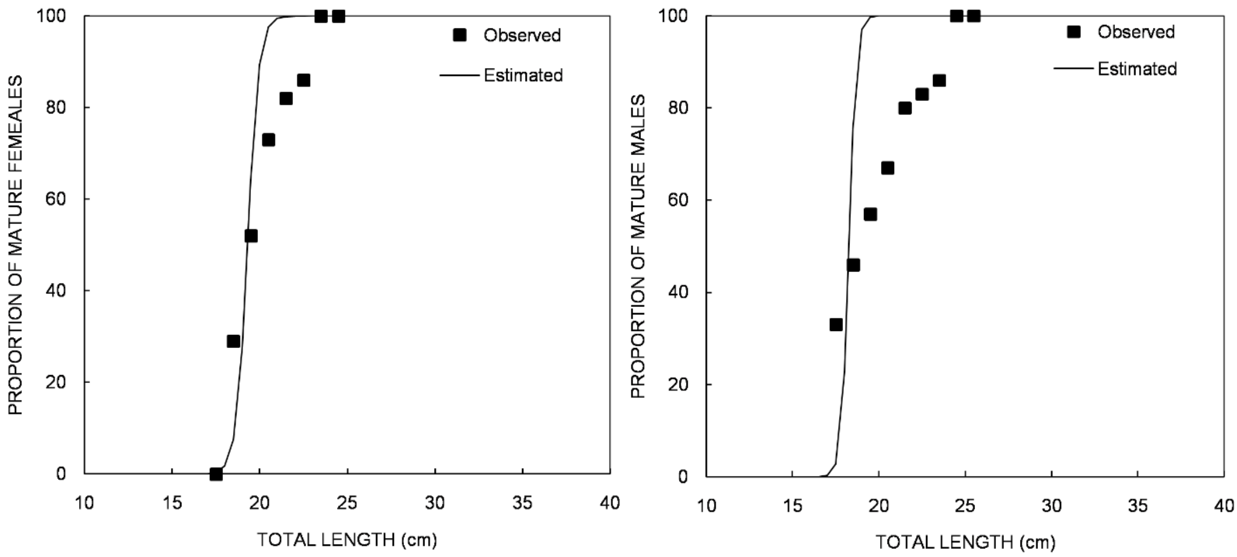

Figure 7: Maturity ogive for females and males of *S. colias* in the Atlantic coast of Morocco

IV. Discussion

Length-weight relationships (LWRs) are commonly utilized to describe the growth patterns of a particular species **(Pauly, 1984)**. In fisheries science, LWRs for fish are crucial because they enable the estimation of biomass based on commercial length-frequency data **(Anderson and Gutreuter, 1983)**. In this study, the results of LWR analysis indicated a positive allometric growth pattern for all samples, with fish weight increasing at a faster rate than its length. The coefficient b was related to both length and weight, and it was expected to be higher in this context, which could be attributable to good environmental conditions and the availability of food. The coefficient of correlation r for LWR was high ($r \geq 0.8$), indicating that there was a clear relationship between length and weight. The same results were found by **Techetach *et al.,* (2021)** on the Moroccan Mediterranean coast and by other studies on the Mediterranean Sea, such as in the Hellenic Seas **(Kiparissis *et al.,* 2000)**, the Aegean Sea **(Moutopoulos and Stergiou, 2002)**, Izmir Bay **(Bayhan *et al.,* 2007)**, the Alboran Sea **(Velasco *et al.,* 2011)**, and Saros Bay **(Cengiz, 2012)**. However, isometric growth was reported by **Allaya *et al.,* (2013)** on the Tunisian coasts, **Čikeš Keč and Zorica (2013)** in the Adriatic Sea, and **Özaydın and Taşkavak (2006)** in Izmir bay. Variation in LWR parameters was related to variability resulting from geographical area, sampling methods, feeding, sex, sexual maturity, body size and condition of individuals **(Tesch, 1971; Ricker, 1975)**.

The sex ratio varies depending on whether the entire population or specific size classes are considered, and it also fluctuates over time, across seasons and years. In the present study, the overall sex ratio of 1:1.08 (females to males), being very close to 1:1. Typically, the sex ratio tends to be close to 1:1 for most species **(Nikolsky, 1963)**. This balanced sex ratio is significant, as future recruitment depends largely on the proportion of females in the population. However, our finding contrasts with that of **Techetach *et al.,* (2010)**, who reported a significant male bias, with a sex ratio of 0.79:1 (females to males) on Morocco's northern Atlantic coast of Morocco. In contrast, **Techetach *et al.,* (2019) and Bouzzammit *et al.,* (2022)** reported sex ratios of 1:0.49 and 1:0.86 (females to males), respectively, indicating a predominance of females. Similarly, a slight dominance of females over males was observed in the Canary Islands **(Lorenzo and Pajuelo, 1996)**. According to **Murua and Saborido-Rey (2003),** a female-biased sex ratio may confer a reproductive advantage, suggesting that variations in sex ratio may have a crucial importance in population dynamics and reproductive success.

According to the present results, the gathering of GSI data and the distribution frequency of gonadal maturity stages were found to be reliable indicators to define the spawning season of *S. colias* in the northwest Atlantic coast of Morocco. The reproductive cycle in this species is characterized by a well-defined spawning season, spanning from November to March. This conclusion is supported by a high proportion of individuals exhibiting mature gonads and elevated GSI values during this period **(Rizzo and Bazzoli, 2020)**. The presence of substancial number of fish in spawning condition, along with the peak of GSI values, provides strong evidence for the timing of the reproductive cycle. Moreover, the analysis of HSI reveals that the highest values preceded the GSI peak, suggesting the mobilization of hepatic energy reserves to support gonadal maturation and vitellogenesis **(Garcia-Diaz *et al.,* 2006)**. This inverse relationship between HSI and GSI patterns during the spawning period indicates a transfer of energy reserves from the liver to gonads, likely playing a critical role in supporting reproductive activities **(Nunes *et al.,* 2011)**. The inverse variation between HSI and GSI is also consistent with the idea that the liver's energy reserves are being reallocated to support gonadal development during the spawning season, as previously proposed in the amphidromous goby, *Sicyoterus lagocephalus* **(Teichert *et al.,* 2014)**. This energy transfer seems to be a crucial aspect of the reproductive biology of *S. colias*, allowing individuals to allocate energy for gamete production. The present study supports the notion that HSI is a reliable indicator of the liver's contribution to vitellogenesis, as suggested by previous research **(Rizzo and Bazzoli, 2020)**. According to the results obtained from the seasonal GSI and the distribution of developmental stages, the spawning season occurred from December to March. In Southwest Grand Canaria, *S. colias* spawn from December to March, with a peak in December and January **(Lorenzo and Pajuelo, 1996)**. On the North Moroccan coasts, spawning occurs during two periods throughout seasons: from December to March and from June to July **(Techetach *et al.,* 2010)**. In the Madeira Archipelago, spawning was observed to occur from January to April, with a peak in February-March **(Vasconcelos *et al.,* 2012)**. However, in Portuguese waters, **Nunes *et al.,* (2019)** suggested that the peak of spawning occurs from February to March, and from February to June. On the other hand, the spawning activities of *S. coilas* exhibits variability along the Atlantic coast, with studies suggesting a latitudinal influence on its reproductive timing. A research conducted in the Azores Islands indicates that the spawning period extends from March to July-August **(Carvalho *et al.,* 2002)**, while a study by **Navarro *et al.,* (2021**) suggests a slightly shorter spawning season, from March to July, with a peak occurring in June. A comprehensive analysis by **ICES (2020)** further supports the notion of a variable spawning period across different regions, emphasizing the significance of environmental factors such as sea temperature, oceanographic currents, upwelling, and food availability in shaping the reproductive patterns of *S. colias*. These findings are consistent with earlier research conducted by **Wootton (1990)**, which identified temperature as a critical factor influencing spawning. Furthermore, studies by **Collette and Nauen (1983)** suggest that water temperatures between 15-20 °C serve as a key for the initiation of spawning activities in Atlantic chub mackerel, underscoring the complex interplay between environmental variables and reproductive behavior in this species.

Our results for length at first maturity were compared with previously published data from several locations, as shown in Table 3. A potential source of bias during the estimation of length at first maturity is the use of macroscopic ovary staging without histological validation **(Hunter *et al.,* 1992)**. Therefore, any comparisons should take into account the specific methodological approaches used in the first maturity estimations. In our results, TL_{50} of *S. colias* was 18.26 cm for males and 19.31 cm for females. These length values were smaller than those obtained in M'diq Bay **(Techetach *et al.,* 2019)**. However, our findings align closely with the estimates from the central coastal area of Morocco **(Bouzzammit *et al.,* 2022)**. Generally, TL_{50} fluctuates between 18.26 and 25.59 cm **(Navarro *et al.,* 2014)**. The differences in the length at first maturity between regions is explained by many factors including food, temperature, genetic constitution, fishing pressure and selectivity, uptake of methods and type of maturity scale **(Trippel and Harvey, 1991)**. The present study showed that males attained sexual maturity at a smaller size than females. This trend was reported in many fish species due to varying energy allocation between sexes, with males allocating more energy to growth and females to reproduction **(Wootton, 1990)**.

Table 3: Size at first sexual maturity (TL_{50}, cm) of *S. colias* in different areas

Area	References	Males	Females	Combined	Gonad evaluation
Safi	Present study	18.26	19.31	18.98	Macroscopic
M'diq Bay	Techetach et al. (2019)	-	19.19	-	Microscopic
Larache	Techetach et al. (2010)	22.88	23.01	22.83	Macroscopic
Agadir	Bouzzammit et al. (2022)	20.82	21.08	-	Macroscopic
Bay of Biscay	Navarro et al. (2014)	24.73	25.59	25.54	Macroscopic
Portugal	Nunes et al. (2019)	19.15	22.64	20.57	Microscopic
Iberian waters	Navarro et al. (2021)	-	22.90	-	Macroscopic
Canary Islands	Jurado-Ruzafa et al. (2021)	18.79	19.44	19.00	Macroscopic

The size at first sexual maturity may provide information about the influence of fisheries on populations' stock **(ICES, 2012)**. An increase in the fishing mortality rate can affect the size distribution of the adult stock recruited to a fishery by decreasing the proportion for the large fish **(Lappalainen *et al.,* 2016)**. TL_{50} Analysis showed a downward trend. In fact, the reduction in stock biomass-usually as a consequence of high fishing exploitation-leads to a reduction in size at maturity **(Lojo *et al.,* 2022)**. The estimation of TL_{50} can be used to define the minimum landing size, which must be higher than TL_{50} to enable individuals to reproduce at least once in their lives. However, under the current Moroccan legislation for *S. colias* species, there are no regulations concerning the minimum landing size, which has direct detrimental repercussions on the sustainability of fisheries.

The differences between *S. colias* populations in various regions may be explained by several factors, including genetic, environmental and food availability-related hypotheses. From a genetic perspective, limited gene flow between populations may lead to distinct local adaptations, resulting in morphological and physiological differences such as size, maturation, and other phenotypic traits. In addition to genetic differences, environmental factors such as water temperature, salinity and oxygen levels may significantly influence metabolism and reproduction in individuals. On the other hand, the availability and food quality, which vary across ecosystems, play a critical role in growth and development of fish. In Morocco, the differences between Atlantic and Mediterranean coastal ecosystems are mainly influenced by distinct geographic and hydroclimatic factors. This is also evident along the Atlantic coast, where significant variations can be observed between the northern, central, and southern zones, due to specific environmental conditions and the availability of food resources in these regions.

V. Conclusion

This study highlights the importance of understanding the reproductive biology of *S. colias* and its temporal patterns in the Morocco Atlantic caost. As the current Moroccan legislation lacks specific regulations on minimum landing size, the availability of basic biological data becomes even more critical to prevent over exploitation of the stock. These findings are crucial for the effective management of fishery resources, as they fill an important gap by providing valuable information for decision-makers to develop sustainable management plans for *S. colias* fishery resources in the region.

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