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RESEARCH ARTICLE

Seasonal and size-dependent variability in diet of *Scomber colias* (Gmelin, 1789) of the Atlantic Coast of the Northwest Africa

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Abstract

Atlantic chub mackerel *Scomber colias* is one of the major fisheries resources in the North African Atlantic coast that has an important role in energy transfer in the marine ecosystem. We conducted quantitative and qualitative analyses for the diet of Chub mackerel, collected between Cape Barbas (22°N) and Cape Bojador (26°30'N). Sampling was carried out during the warm and cold seasons of 2008. Stomach contents of 475 specimens were collected and analyzed. In terms of Index of Relative Importance (IRI), Crustaceans (IRI=62.3%), especially Copepods was the most important prey. Secondary, Teleosts (IRI=32.88%), especially small pelagic fishes (Engraulidae, Clupeidae, Scombridae, Myctophidae) and Mollusks (IRI=4.79%) mainly composed of gastropods. Other groups: Annelids, Appendicularians, Cheatognaths, Radiolarians and Hydrozoans were a minority, in terms of abundance and biomass and were considered as accidental preys. *Scomber colias* seemed to shift its prey from Copepods to fish at threshold size ranging from 21 to 24 cm (FL). Results from the visual analyses with geographic information system suggested the spatio-temporal variation of dietary composition. Significant statistical relationships ($p<0.05$) between diet composition, size classes and seasons were confirmed as well as their horizontal and vertical variations. Spatio-temporal difference of the marine environment and available prey derived the difference in the functional relationship of the *Scomber colias* depending upon the different gulp sizes as it grows.

INTRODUCTION

The Canary current ecosystem, located off the Northwest coast of Africa, is one of the major current ecosystems in the world. It is one of the most productive zones along the eastern boundary of the Atlantic Ocean with important fisheries potential due to upwelling activity that enhances the lower trophic productions. In this area, primary production exceeds 300 $gCm^{-2}y^{-1}$(Carr, 2002; Carr and Kearns, 2003) and its spatial and temporal dynamics depend from seasonal and permanent upwelling (Nieto *et al.*, 2012). Based on this high production, various commercially and socio-economically important fisheries take place in this area such as small pelagic fishes including sardine, chub mackerel, horse mackerel, sardinella and anchovy (Boëly and Fréon, 1979). Small pelagic fishes are the major target in the fisheries in the Northwest coast of Africa. Over the last decade, total catch has been fluctuating around an average of 1.8 million tones (FAO, 2012).

Chub mackerel is a geographically widespread and commercially important species, but its taxonomic status is still controversial although phylogenetic data support the recognition of Atlantic *Scomber colias* and Pacific *Scomber japonicus* as separate species. For FAO, Atlantic chub mackerel was commonly known as *Scomber japonicus*, *c*osmopolitan, inhabiting the warm and temperate transition waters of the Atlantic, Indian, Pacific oceans and adjacent seas, (http://www.fao.org/fishery/species/3277/en). Recent genetics studies confirmed that *S. japonicus* and *S. colias* were genetically distinct (Infante *et al*., 2006; Catanese *et al*., 2010; Cheng *et al*., 2011). Also, according to fishbase data (www.fishbase.org), *Scomber japonicus (*Houttuyn, 1782) is distributed in the Indo-Pacific Ocean : anti-tropical, absent from the Indian Ocean except for South Africa, replaced by *Scomber colias* (Gmelin,1789) in the Atlantic ocean.

S. colias is one of the important small pelagic species in the study area. The average catch during the last decade was estimated at around 69000 tons with a pic of approximately 115 000 tons recorded in 2012 for Moroccan fisheries (FAO, 2012). It plays an important role as conveyor of energy flows among trophic levels in the marine food web of the Northwestern African water. It is not only a target species for fisheries but also for many predators such as mega fauna including tunas (*Katsuwonus pelamis*, *Xiphias gladius*), marlins, sailfish and dolphins (Hernández and Ortega, 2000). As a predator of other small pelagic fishes during their early life stages, *S. colias* can play a major role in their population dynamics (Cury *et al*., 2000). Hence, its diet analysis is an important research topic to undertake for further understanding of species interaction and the potential impacts on the marine ecosystem.

The purpose of the present study is to examine the diet of Atlantic chub mackerel, *S.colias*, on the western coast of the North Africa, between 26°30'N and 22°N, with a qualitative and quantitative determination of the food, based on the seasonal analysis of stomach contents. Dietary opportunism has been discussed for this species in the North African coast, but the dependency and response to seasonally available prey compositions have not sufficiently been investigated. The analysis of spatio-temporal feeding characteristics of *S.colias* of the study area will contribute to conceptualize local food web, then to partially understand the structure and functional relationships of the ecosystem.

Material and Methods

Study area and data collection

The present study is carried out between Cape Bojador (26°N30') and Cape Barbas (22°N) along the Atlantic coast of Northwest Africa (Fig 1). In this area, the continental shelf widens southward to reach its maximum width at around 25°N where upwelling activity becomes permanent with variable intensity along the year (Nieto *et al*., 2012). The stomach samples used to characterize the diet of *S. colias* were collected in 2008 during the acoustic surveys carried out on board the Moroccan R/V "Al Amir Moulay Abdallah" in June and November and on board the Russian R/V"Atlántida"in July-August. These surveys were conducted over continental shelf and shelf edge up to 200 m isobaths to assess the pelagic fish abundance and biomass.

Trawling is processed,whenever distinctive fish schools are detected by scientific echosounder, with Japanese pelagic trawl, using panels of type O.B (Al), 1.44 m² (216.4 kg). Sampling protocol consists on taking 10 to 15 of caught individuals of *S.colias* each trawled station depending on its availability (Fig 1, Tab 1) and immediately freezing them in -20°C (Ferraton *et al*., 2007) for later laboratory analysis.

In the laboratory, sampled individuals were measured (FL to the nearest 1cm) and the pyloric sections of their stomachs were extracted and fixed in 5% buffered formalin. Then, for each station sample, stomachs were opened and their contents were extracted, weighed to the nearest 0.01 g and then pooled according to fish length classes (4 cm class width). For large preys or weakly filled stomachs, the whole sample was examined. Then, the pooled stomach contents were diluted to 100 ml and then three sub-samples of 5 ml were examined using a binocular loupe to identify and count zooplankton preys. Each prey was identified to the lowest possible taxonomic level depending on digestion state, counted individually and weighed (fresh weight to the nearest 0.001 mg).The average of the three sub-samples was calculated to represent each size class diet and then standardized to number per 100 ml.

Prey groups in stomach contents were categorized based on their general size, mobility and habitat. To identify important prey groups in the diet of *S. colias*, an Index of Relative Importance (IRI) (Pinkas *et al*., 1971) is used. This index is an integration of percentages in numbers, weights and frequency of occurrence of the various preys found in the stomach as follows:

$$IRIi = \%FOi \times (\%Wi + \%Ni)$$

Where i refers to a taxa or prey group, *%FOi* its frequency of occurrence, defined as the number of stomachs in which each item occurs and expressed as a percentage of the total number of full stomachs examined, $\%W$ and $\%N$ are respectively the weight and number percentages of the prey group with respect to the total.

The IRI was expressed as a percentage as follows:

$$\%IRI = (IRI/\sum_i IRIi) \times 100$$

Data analysis

In our analyses, three parameters potentially influencing the diet composition of *S. colias* were focused. These parameters, size class, location and trawling depth of the trawled stations, were analyzed according to two (warm and cold) seasons, representing different marine environmental conditions. We visually and statistically compared the %IRI, as the relative importance of prey groups, and the horizontal distribution patterns using statistical test for these aspects. For visual analysis in spatial and temporal changes in diet, the observations were plotted over map platform of geographic information system (GIS) using ArcGIS version 10 (ESRI) software. Diet comparisons were made for both the dominant prey group and also for the remaining prey groups. For statistical tests, we applied Permutation MANOVA (Legendre and Anderson, 1999) to test dependency of prey composition in terms of abundance and biomass upon factors including seasons, location of the feeding grounds (stations), trawling depth and size classes, (permutation= 100000 times, α=0.05 level).The combination of the size classes and trawling depth was also tested.

To examine statistical difference among %IRI by season, size classes of *S. colias* and vertical distribution, we used Fisher's exact test for the all possible combinations (α=0.05 level). All statistical analyses and data manipulations were performed using the open source software R version 2.15.3.

Results

Diet composition

A total of 475 specimens ranging from 13 to 29 cm (FL) were analyzed in this study. The samples collected in the warm season (June, July and August) were characterized by dominance of individuals with size classes ranging from 17 to 24 cm. In the cold season (November), a dominant size classes was 17 - 20 cm (Fig 2).Of the stomachs sampled, 92% had identifiable food. The stomach contents of *S. colias* consisted of several prey species belonging to following taxa: Crustaceans, Teleosts, mollusks and another groups of low abundance, grouped under "others" (annelids, appendicularians, chaetognaths, radiolarians and hydrozoans) (Tab 2).

In terms of relative importance of prey groups, %IRI, crustaceans were the dominant prey group (59.18%) dominated by copepods (Tab 3). The group of fishes, including multiple families such as Engraulidae, Clupeidae, Scombridae and Myctophidae, was also a major prey (32.88%). The Mollusks accounted for less than 5% dominated by gastropods, and were considered as complementary preys. Appendicularians, Radiolarians, Annelids, Hydrozoans and Chaetognaths were a minority of the stomach content, abundance and biomass in diets and were considered as accidental prey for this species.

Seasonal variation

Overall, prey group composition was dominated by copepods in terms of abundance, and the fishes are dominant preys in terms of weight in the warm season (Fig 3a). In the cold season, the diet composition was generally dominated by zooplanktons especially by copepods in abundance and small crustaceans in terms of weight (Fig 3b).

In terms of abundance, and during both seasons, copepods were dominant and distributed over all the study area (Fig 4a, 4b). The other prey group's composition have changing spatial patterns depending upon seasons. During the warm season, the gastropods and amphipods were observed in north of the 25°N, while small crustaceans and shrimp-like nektons were observed in south of the 25°N (Fig 4c). The cold season is marked by the fact that gastropods were not dominant as much as in the warm season (Fig 4d).

On the other hand, in terms of weight, fishes became prominent in the composition of prey groups especially in southern part in the warm season, while in the north part of the study area is characterized by a diversity of preys marked by the presence of gastropods and shrimps like nektons (Fig 5a). In the cold season, fish prey group was not as remarkable as in the warm season and the main prey group was crustaceans (Fig 5b).

Diversity of prey groups, in terms of abundance and weight, statistically tested using "Permutation MANOVA", showed highly significant variable ($p<0.05$) depending on season, size, station and trawling depth layers - more than 50 m or less - (Tab 4A; 4B). Moreover, diet analysis in terms of biomass of prey showed that combination of size classes with trawling depth is significant while it is not significant in terms of abundance.

Focusing on the diet analysis, based on the % IRI index and for both seasons, the copepods are the overall dominant prey group excepting for large size class (25-29 cm) where fish group prey are dominant (Fig 6). The warm season is characterized by the dominance of Gastropods for size less than 24 cm in the north of 25°N. In the south of 25°N, Gastropods prey group is replaced by shrimp-like nektons and/or small crustaceans with the appearance of fishes and eggs for predator size greater than 21 cm. In the cold season, the diet is dominated overall by crustaceans essentially copepods, shrimp-like nektons and small crustaceans.

The overall vertical diet composition, in terms of %IRI, showed difference in all size classes and both seasons (Fig 7) excepting for the 21-24 cm size class in cold season where almost no vertical difference was observed. Gastropods were observed mainly for depth greater than 50 m in warm season and the amphipods groups were only observed in depths less than 50 m in the cold season.

The result of comparisons of % IRI among combinations of seasons, size classes and depth layers (Tab 5) shows that excepting two combinations, all the other combinations were statistically significant (p <0.05). The %IRI of *S. colias* in 17-20 cm were not statistically different in the two seasons (p=0.45). Also, the %IRI for the 21-24 cm size class was not statistically different (p=0.45) compared in the two depth layers.

Table 1: Number of stomachs collected

Season	Number of stations	Number of stomachs
Warm (June, July-August 2008)	24	352
Cold (November 2008)	9	123
Total	33	475

Table 2: Categorized prey plankton and nektons in stomach content of *S. colias*

Prey type	Groups	Abbreviation	Prey items
Crustaceans	Copepods	CO	*Copepoda (Calanidae, Euchetidae, Eucalanidae, Acartidae, Paracalanidae, Corycaeidae, Temoridae,Unidentified)*
	Shrimp-like nektons	SN	*Decapoda (Larvae, Zoes, penaeidae)* *Euphausiacea* *Mysidacea*
	Amphipods	AP	*Amphipoda*
	Small Crustaceans	SC	*Cladocera* *Ostracoda* *Epicarides(Larvae, Isopoda)* *Larvae* *Ostracoda* *Unidentified*
Teleosts	Fish	FS	*Engraulidae, Clupeidae, Scombridae, Myctophidae*
	Fish Larvae	FL	*Engraulidae Larvae, Unidentified*
	Fish Eggs	FE	*Clupeidae eggs* *Engraulidae eggs* *Scombridae eggs* *Fish eggs*
Molluscs	Gastropods	GP	*Pteropods*
	Other Molluscs	OM	*Cephalopoda (Loligo sp., Squilla sp.)* *Bivalvia*
Others	Annelida Appendicularians Cheatognaths Radiolaria Hydrozoans	Others	*Polychaeta* *Siphonophora*

Table 3: Diet composition of *S. colias* in terms of (%FO), (%N), (%W) and (%IRI)

Groupes	Proies	% FO	% N	% W	% IRI
Crustaceans	*Copepods*	41.64	72.67	15.84	54.30
	Shrimp like nekton	73.36	5.58	5.69	3.98
	Amphipods	37.14	0.74	0.89	0.89
	Small Crustaceans	67.89	4.83	6.87	3.13
Teleosts Alpha=0.05	*Fish*	31.53	0.14	66.14	30.79
	Fish eggs	106.33	4.70	0.44	2.08
	Fish larvae	13.81	0.04	0.01	0.01
Molluscs	*Gastropods*	21.95	10.66	3.13	4.46
	Other molluscs	30.95	0.47	0.96	0.33
Others	*Appendicularians*	8.45	0.07	0.01	0.01
	Radiolarians	14.29	0.06	0.00	0.01
	Annelids	14.04	0.01	0.02	0.01
	Hydrozoans	6.98	0.02	0.00	<1%
	Cheatognaths	7.14	0.00	0.00	<1%

Table 4: Results from permutation MANOVA for the diversity of prey groups depending on season, trawling depth and size class of *S. colias*: A: in terms of abundance ; B: in terms of weight

A)

	df	SSE	MSE	*F*	R^2	p value
Season	1	0.52	0.52	21.27	0.08	0.001***
Station	28	4.60	0.16	6.72	0.67	0.001***
Trawling depth	2	0.42	0.21	8.54	0.06	0.002**
Size class	3	0.31	0.10	4.23	0.05	0.002**
Interaction trawling depth and size class	21	0.86	0.04	1.67	0.13	0.407
Signif. code :		*0 '***'*	*0.001 '**'*	*0.01 '*'*		

B)

	df	SSE	MSE	*F*	R^2	p value
Season	1	0.51	0.51	9.28	0.04	*0.001****
Station	28	8.17	0.29	5.35	0.65	*0.001****
Trawling depth	2	0.87	0.44	7.99	0.07	*0.001****
Size class	3	0.64	0.21	6.59	0.05	*0.002 ***
Interaction trawling depth and size class	21	2.13	0.10	3.94	0.17	*0.042 **
Signif. code :		*0 '***'*	*0.001 '**'*	*0.01 '*'*		

Table 5: Summary plot of Fisher's pairwise analyses among %IRI of season, size class and depth layer combinations. First letters of combinations indicates seasons (W: warm or C: cold). Second letter (or letters) indicates size class (S: 14-16 cm, SM: 17-20 cm, MM: 21-24 cm or L: 25-29 cm). Last letter indicates vertical depth layers (S: < 50 m, D: >= 50 m).

	WSD	WSS	CSMD	CSMS	WSMD	WSMS	CMMD	CMMS	WMMD	WMMS	CLD	CLS	WLD
WSS	<0.001	-	-	-	-	-	-	-	-	-	-	-	-
CSMD	<0.001	<0.001	-	-	-	Fail to reject	-	-	-	-	-	-	-
CSMS	<0.001	<0.001	<0.001	-	-	-	-	-	-	-	-	-	-
WSMD	<0.001	<0.001	<0.001	<0.001	-	-	-	-	-	-	-	-	-
WSMS	<0.001	<0.001	**0.455**	<0.001	<0.001	-	-	-	-	-	-	-	-
CMMD	<0.001	<0.001	0.001	<0.001	<0.001	0.031	-	Fail to reject	-	-	-	-	-
CMMS	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	**0.455**	-	-	-	-	-	-
WMMD	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-	-	-	-
WMMS	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-	-	-
CLD	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-	-
CLS	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-
WLD	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-
WLS	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	0.031	<0.001	<0.001

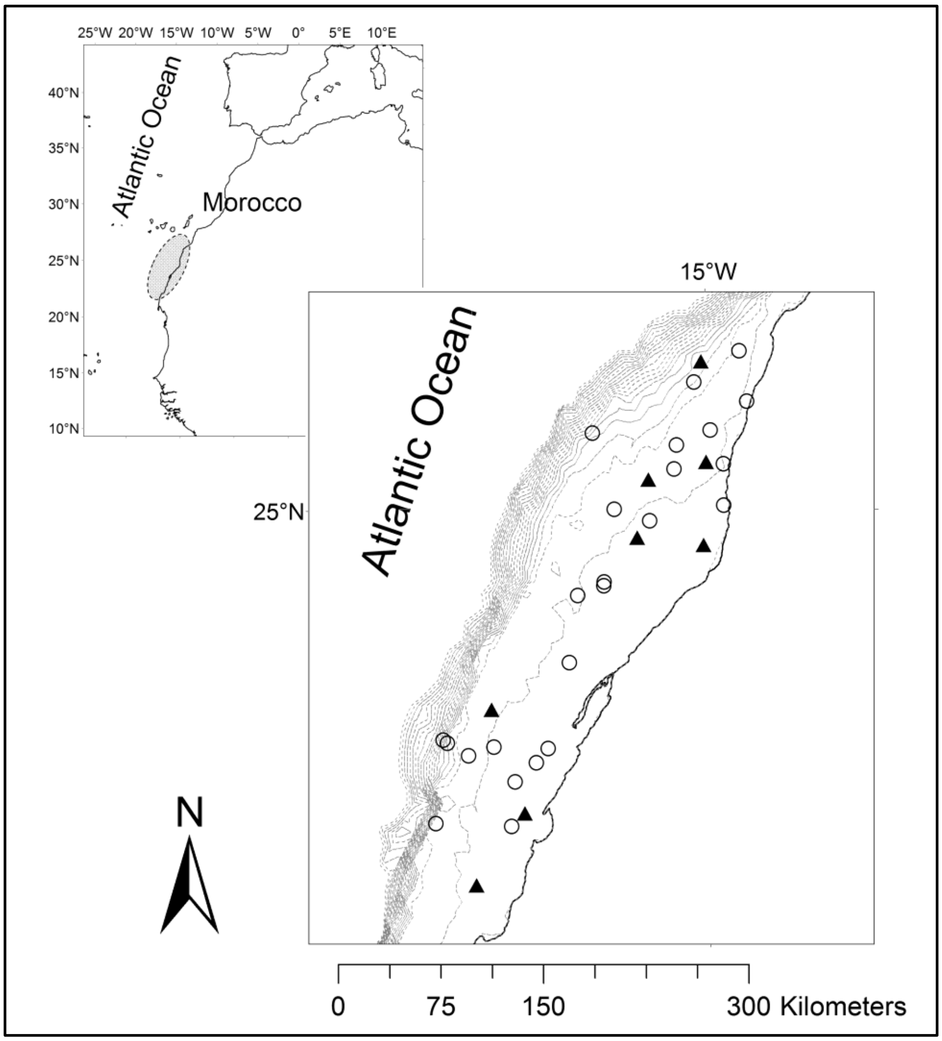

Figure 1: Study area and Sampling localities (**O**: Stations sampled in the warm season; ▲: Stations sampled in the cold season)

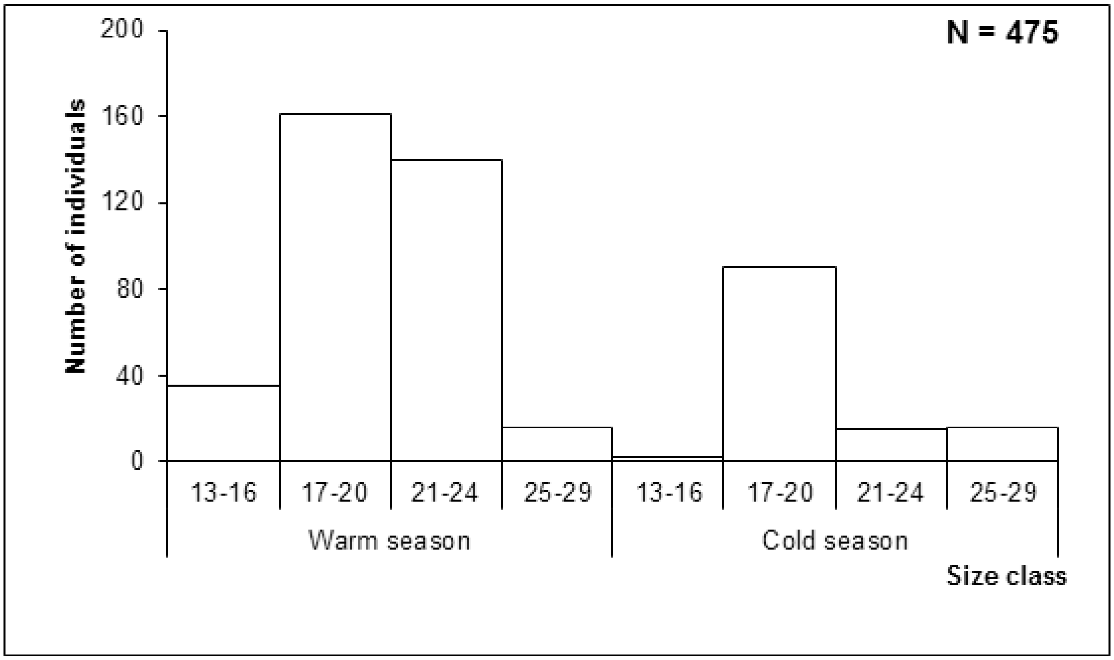

Figure 2: Length frequency distribution of individuals of *Scomber colias*

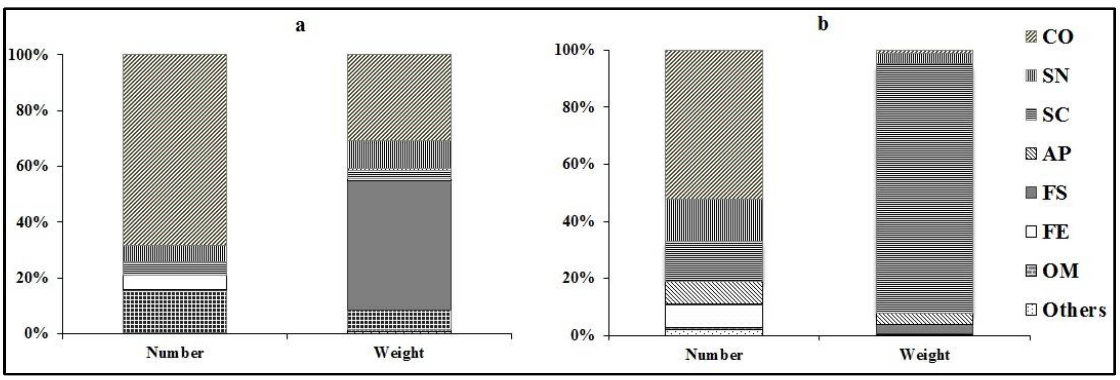

Figure 3: Overall seasonal comparison of prey group composition:
(**a**): warm season; (**b**): cold season

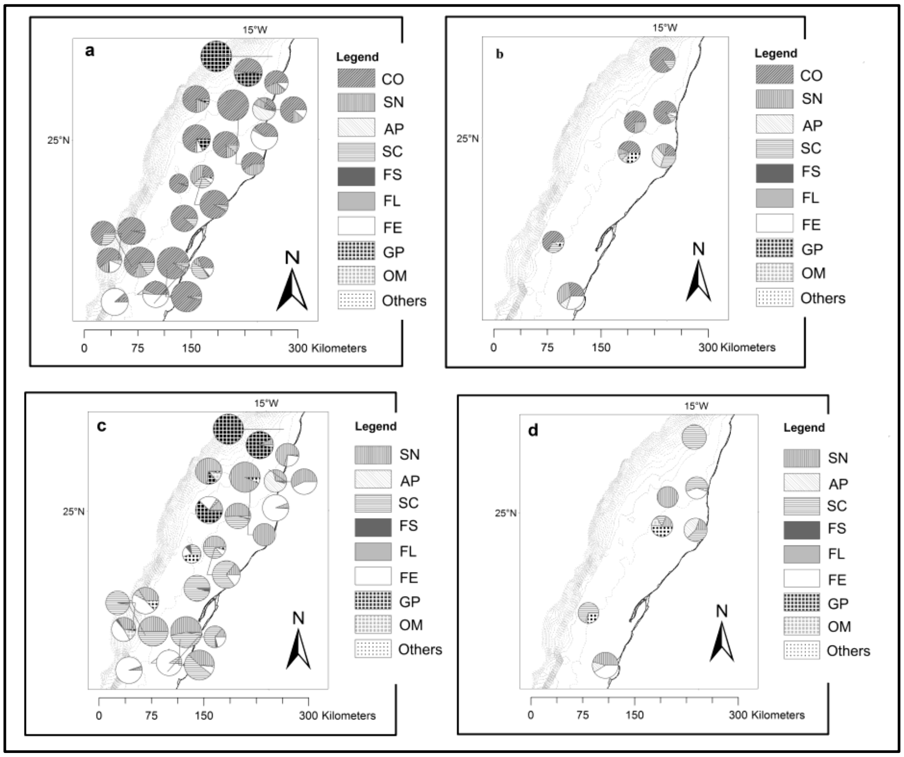

Figure 4: Spatial variability of the diet of *Scomber colias* based on the number of prey: **a**: all the prey, warm season; **b**: all prey cold season; **c**: all prey excluding copepods, warm season; **d**: all prey excluding copepods, cold season

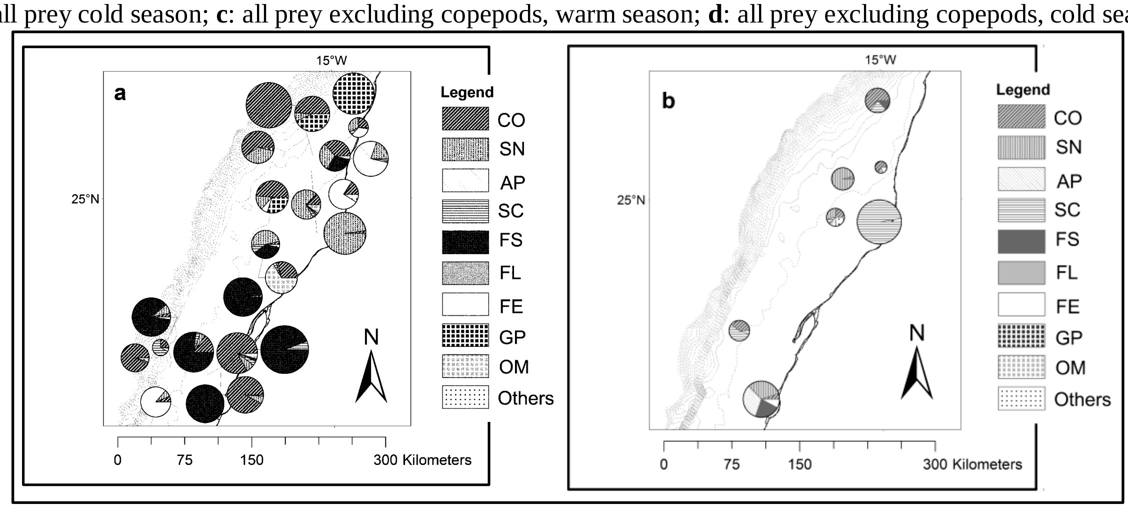

Figure 5: Comparison of prey composition in terms of weights: **a**: Warm season; **b**: cold seasons

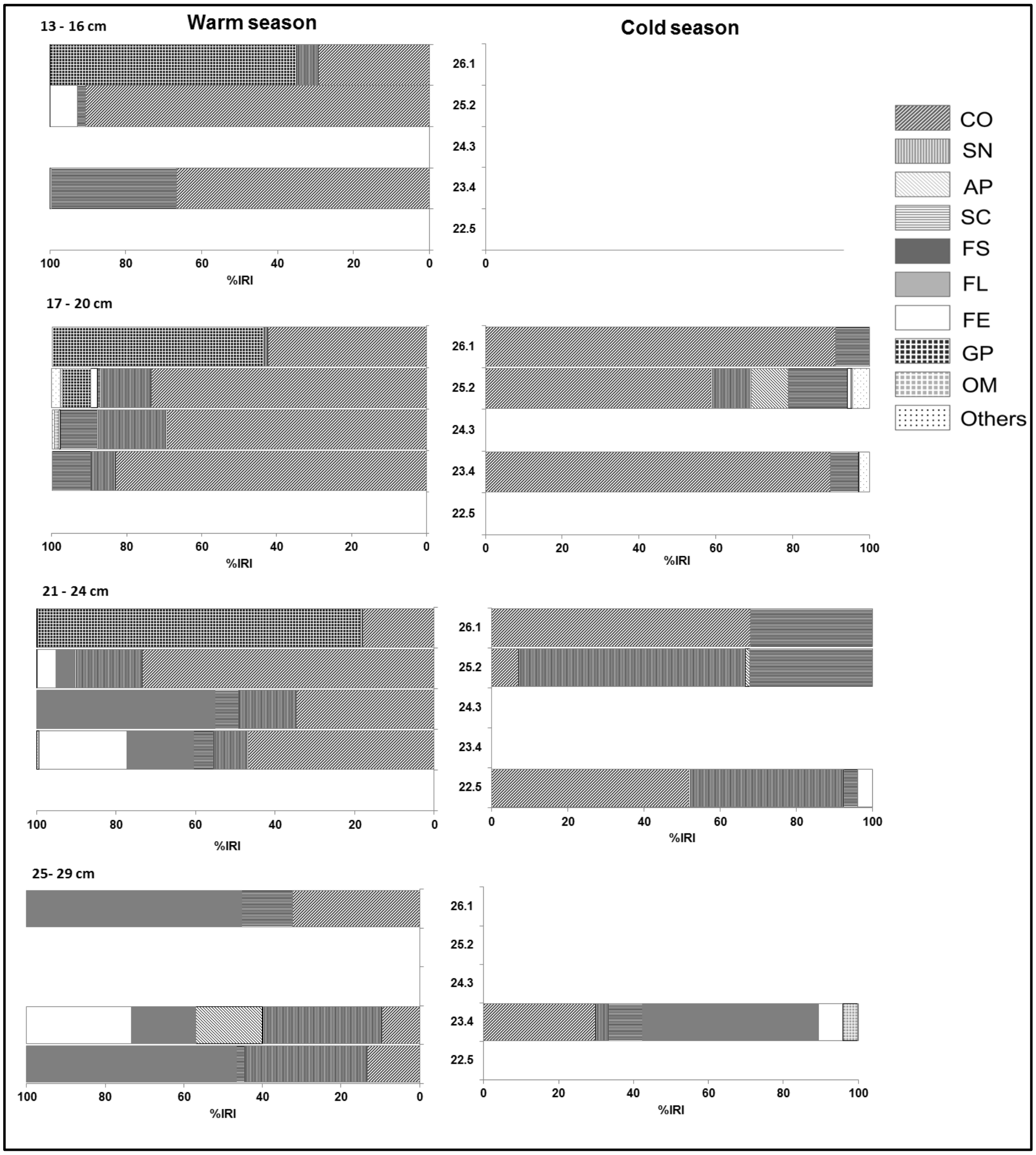

Figure 6: Comparison of binned %IRI into latitude classes among combinations of seasons and size classes

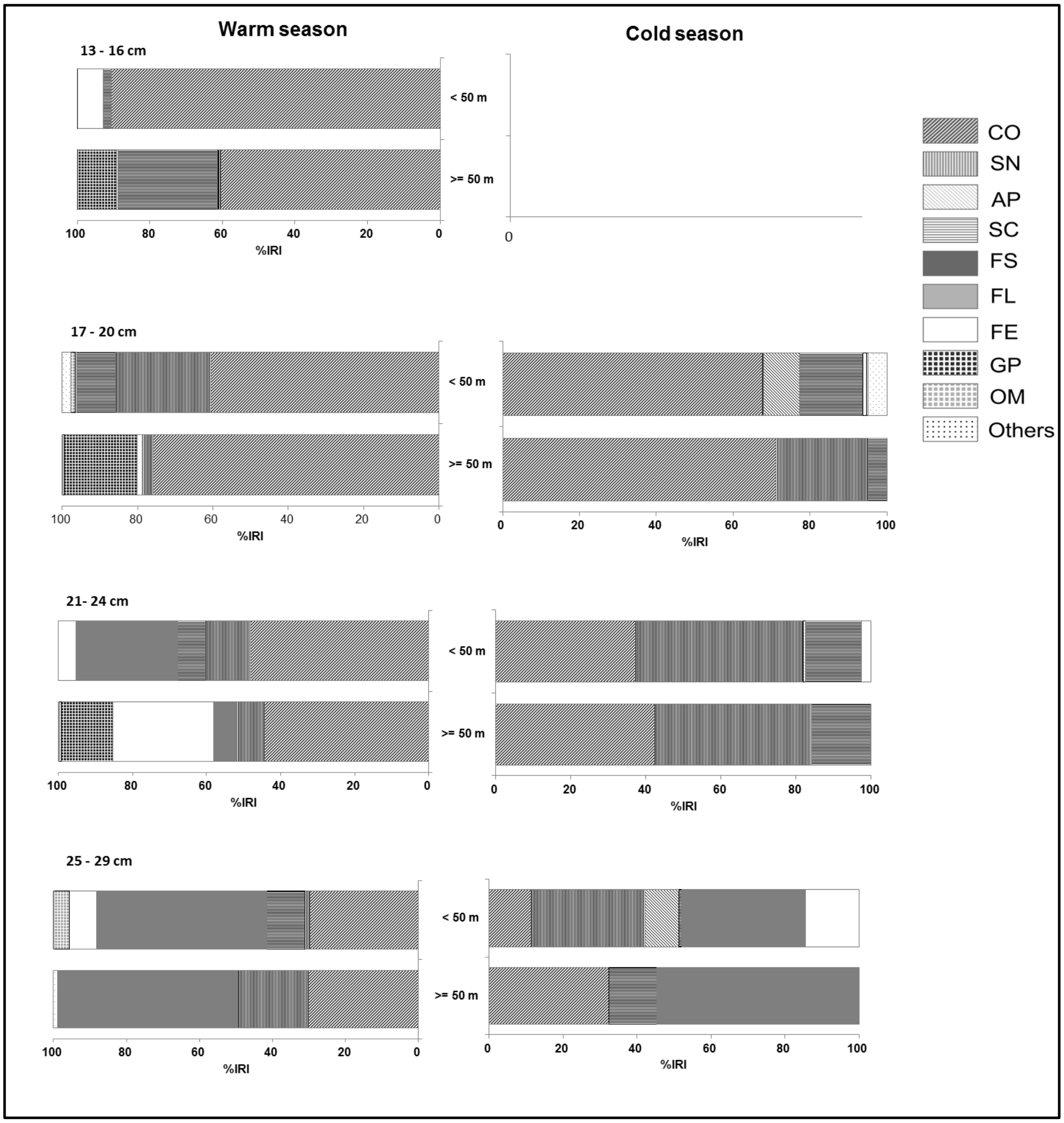

Figure 7: Comparison of binned %IRI into depth layers among combinations of seasons and size classes

Discussions

Diet of *S. colias* was highly diverse in the composition of prey groups and species according to the data collected in 2008. Examined stomach contents expressed in %IRI, showed that its diet is mainly composed of diverse zooplanktons including various crustaceans dominated by copepods. Secondary group was fish, followed by mollusks (mainly gastropods). The remaining groups had a wider variation in %IRI values depending on time and location.

The copepods were the most dominant group in terms of abundance for all seasons. In terms of biomass, fish group was dominating in the diet in warm season, while small crustaceans dominated in the cold season. The Atlantic coast of the North Africa, including the study area, is characterized by year-round upwelling (Mittelstaedt, 1983; Nieto *et al*., 2012) that transports micro-nutrients and cold waters from bottom to the surface. High densities of phytoplankton and zooplanktonespeciallycopepods in the area, depend upon the enhanced primary production based on the nutrient rich water in the area between 21°N and 26°30'N (Estrada, 1980; Rodríguez *et al*., 2001). The high abundance of copepods in diet of *S. colias* observed off shore near Dakhla (24°N) may indicates high availability of those zooplankton preys in the highly productive waters from the upwelling, extended to shelf edge, in this area Makaoui *et al*., 2005).

Seasonal variability of the composition and diversity of prey groups were also observed in our analyses. In the warm season, we observed various prey groups including gastropods, especially in northern part of the study area, amphipods, fish eggs, small and large crustaceans and fishes as the dominant prey group in terms of weight. Yet in the cold season, gastropods were absent over the area. Also in terms of biomass, composition of the diet became simplified with dominance of small crustaceans. It was suggested in Nykjær and Van Camp (1994) that the difference in community structure between the cold and warm seasons is related to hydrological conditions. The seasonally and spatially difference in prey composition of *S. colias* depends most likely on the difference in availability of specific preys in the area. The study area is under influence from a productive and permanent coastal upwelling with a seasonally variable intensity: high in summer and low in winter (Makaoui *et al*., 2005; Benazzouz *et al*., 2014). In fact, combination of seasonal variability of upwelling intensity and nutrients availability with other environmental factors such as temperature determines the spatio-temporal variability of primary and secondary production including zooplankton preys. Feeding of *S. colias* is highly sensitive to environmental conditions changes, such as temperature and chlorophyll concentration (Sanchez-Velasco and Shirasago, 2000).

Diet of *S. colias* included not only zooplanktons but also fish eggs in all size classes in both seasons. Spatial match between the ichthyoplankton, including fish eggs and zooplanktons were explained from physical transports and biological synchronization of spawning in ambient area (Berraho *et al*., 2005). The spatial patchiness and trend in the distribution of early life phase of the fishes, especially small pelagic fishes, highly influence to the natural mortality over the area (McGurk, 1986). The study area includes spawning grounds of small pelagic fishes, namely *Sardina pilchardus* and *Engraulis encrasicolus. S.colias* predation upon the other small pelagic fishes, especially for the early life stages, combined with other hydroclimatic effects may have a major impact on small pelagic fluctuations and need to be investigated.

Predator's size dependency of relative importance of the prey groups in the diet was also observed. The importance of the prey groups in the diet began to be shifted from crustacean preys to fishes and fish eggs in the large size class from 21 cm. Observed seasonal difference of size classes with presence of fishes in the diet was probably from both availability of the fish preys in the area and size-dependent response to the available preys. Though *S. colias* in this region may be assumed as opportunistic predator depending upon the available preys (Robert *et al*., 2008), its prey selectivity was explained as a function of size, morphology and the availability of preys in the environment (Main, 1985; Piet, 1998) as well as the capability of predator to hunt them. Thus, as proposed by Karpouzi & Stergiou (2003) and Karachle & Stergiou (2011) mouth gape could be a good indicator of piscivory in fishes, as well as an indicator of ontogenetic shift in the feeding habits of a given species. Energetic requirements for capturing the preys also change depending on their physiological changes (e.g., reproduction, growth). In the area, at least for the period of study, the threshold of the prey switching from crustacean prey to larger fish preys was observed between 21 and 24 cm with seasonal variability. This threshold size is corresponding to the first maturation size suggesting that may be reproduction is driving this prey switching.

Spatial variation of prey diversity and composition of relative abundance indicated that *S. colias* is opportunistic predator in the study area. Gastropods were observed only in the warm season at north of Dakhla, especially important near bottom. Amphipods were a minority or almost absent in the diet composition especially in cold season. Fish was dominant prey and sustained the diet of *S.colias* over the steep shelf in the study area especially for sizes larger than 21 cm. On the other hand, *S. colias* diet is highly depending on small zooplankton prey for sizes less than 21 cm before shifting the prey to nektons. When major prey is scarce in the habitat, *S.colias* probably switches preys to the other abundant prey as the other opportunistic predatory fishes (Hernandez and Santana del Pino, 1995; Garrido and Murta, 2011). This species most likely responds to availability of prey with selection of adequate sizes to their own body size and inevitability from its scarcity.

Our results are in agreement with those in the neighboring waters in Canary Islands area. The stock of *S. colias* in the Canary Island feeds on three types of preys: copepods, mysids and fish. Its feeding preference is influenced by habitat, seasonal fluctuations of food availability and the behavioral pattern of the preys (Garcia-Rodriguez and Aurioles-Gamboa, 2004; Diaha et al., 2010). In Egyptian Mediterranean waters, the major food items for *S. colias* were fishes, crustaceans and annelids, and diet composition was changing according to the size and season. Sever *et al*., (2006) ; Rizkalla and Faltas, (1997) noted that the species fed on zooplankton and various prey groups including cephalopods and small pelagic fishes, especially anchovy and sardines. Then, necessary food in take of *S. colias* is a function of the body weights depending upon the growth at its life history (Nakayama *et al*., 2003).

As a conclusion based on the results of our study, we got the following results: firstly, *S. colias* is a size-dependent opportunistic predator in the Atlantic coast of Northwest Africa. Various populations over the world were defined as opportunistic predators with selection of preys depending on the given biological and environmental conditions. Those observations are comparable to our findings in the feeding ecology of *S. colias*. Secondly, the diet of this species is also function of the prey availability depending upon the hydro climatic and environmental conditions. In the Gulf of California, chub mackerel has been defined as a facultative carnivore that also feeds on phytoplankton though it prefers zooplanktons and micronektons as preys with variability depending on seasonal changes of

oceanographic environment (Molina *et al*., 1996). In the north Atlantic coast of Morocco (north of 33°N), the food spectrum of *S. colias* depended upon the season and size (Wahbi *et al*., 2011). Considering the seasonal
dynamics of upwelling system and variety of the life history of preys for the given species diversity in the Atlantic coast of North Africa including study area, variation of the diet and importance of the prey for *S. colias* is function of seasons and both latitudinal location and layer's depth of the feeding grounds.
In consequence, the diet and associated ecological characteristics including bioenergetics and trophic status are probably highly variable in this region. Moreover, the interannual variability of the upwelling scenario in the region most likely influences to the diet and those ecological aspects depending on the year and climate scenarios. Unfortunately, our observations are not sufficient to validate our concluding hypotheses in the spatio-temporal dynamics of diet against the environmental variability. Also, quantification of the impact on the ecosystem, for example, predation effect to the other species may be conducted. Cumulative integrated monitoring efforts and further trophic analyses are being conducted in the Atlantic coast of North Africa and expected to be published in a next paper.

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References

Benazzouz, A., Mordane, S., Orbi, A., Chagdali, M., Hilmi, K., Atillah, A., LluísPelegrí, J., Hervé, D. (2014). An improved coastal upwelling index from sea surface temperature using satellite-based approach – The case of the Canary Current upwelling system. Cont. ShelfRes. 81, 38–54. doi:10.1016/j.csr.2014.03.012

Berraho, A., Ettahiri, O., Letourneur, Y., Orbi, A., Yahyaoui, A. (2005). Importance des paramètres hydrologiques dans la distribution des oeufs et des larves des petits pélagiques du sud de l'Atlantique marocain. Cybium 29, 21–31.

Boëly, T., Fréon, P. (1979). Les ressources pélagiques côtières, in : Les ressources halieutiques de l'Atlantique centre-est. I. Les ressources du Golfe de Guinée de l'Angola à la Mauritanie, FAO Doc. Tech. Pêches, 186, 1, 13-78.

Carr, M.E. (2002). Estimation of potentiel productivity in Eastern Bouandary Currents using remote sensing. Deep-Sea Res. II, 49: 59 – 80.

Carr, M.-E., Kearns, E.J. (2003). Production regimes in four Eastern Boundary Current systems. Deep Sea Res. Part II Top. Stud. Oceanogr., The US JGOFS Synthesis and Modeling Project: Phase II 50, 3199–3221. doi:10.1016/j.dsr2.2003.07.015

Catanese, G., Manchado, M., Infante, C. (2010). Evolutionary relatedness of mackerels of the genus Scomber based on complete mitochondrial genomes: Strong support to the recognition of Atlantic Scombercolias and Pacific Scomberjaponicus as distinct species. Gene 452, 35–43. doi:10.1016/j.gene.2009.12.004

Cheng, J., Gao, T., Miao, Z., Yanagimoto, T. (2011). Molecular phylogeny and evolution of Scomber (Teleostei: Scombridae) based on mitochondrial and nuclear DNA sequences. Chin. J. Oceanol. Limnol. 29, 297–310. doi:10.1007/s00343-011-0033-7

Cury, P., Bakun, A., Crawford, R.J.M., Jarre, A., Quiñones, R.A., Shannon, L.J., Verheye, H.M. (2000). Small pelagics in upwelling systems: patterns of interaction and structural changes in "wasp-waist" ecosystems. ICES J. Mar. Sci. J. Cons. 57, 603–618. doi:10.1006/jmsc.2000.0712

Diaha, C.N., N'da, K., Soro, Y.(2010). Régime alimentaire de Scomberomorustritor (Cuvier, 1831) dans le Golfe de Guinée. Int. J. Biol. Chem. Sci. 4. doi:10.4314/ijbcs.v4i3.60482

Estrada, M. (1980). Phytoplankton biomass and production in the upwelling region of NW Africa. Relationships with hydrographic parameters. Mar. Biol. 60, 63–71. doi:10.1007/BF00395607

FAO (2012). Science and Management of Small Pelagics, FAO Fisheries and Aquaculture Proceedings. No. 18, FAO. 606 pp.

Ferraton, F., Harmelin-Vivien, M., Mellon-Duval, C., Souplet, A. (2007). Spatio-temporal variation in diet may affect condition and abundance of juvenile European hake in the Gulf of Lions (NW Mediterranean). Mar. Ecol. Prog. Ser. 337, 197–208. doi:10.3354/meps337197

Garcia-Rodriguez, F.J., Aurioles-Gamboa, D. (2004). Spatial and temporal variation in the diet of the California sea lion (Zalophuscalifornianus) in the Gulf of California, Mexico. Fish. Bull. 102, 47–62.

Garrido, S., Murta, A.(2011). Interdecadal and spatial variations of diet composition in horse mackerel Trachurustrachurus. Journal of Fish Biology 79, 2034–2042.

Hernández, J.J.C., Ortega, A.T.S. (2000). Synopsis of Biological Data on the Chub Mackerel:

ScomberJaponicusHouttuyn, 1782. Foor and Agriculture Organization of the United Nations.
Hernandez, J.J.., Santana del Pino, A.(1995). Feeding preferences of Scomberjaponicus in the Canary Islands area. Scientia Marina, 59,325–333.
Infante, C., Blanco, E., Zuasti, E., Crespo, A., Manchado, M. (2006). Phylogenetic differentiation between Atlantic Scombercolias and Pacific Scomberjaponicus based on nuclear DNA sequences. Genetica 130, 1–8. doi:10.1007/s10709-006-0014-5
Karachle, P.K., Stergiou, K.I. (2011). Mouth Allometry and Feeding Habits of Some Mediterranean Fishes. ActaIchthyol. Piscat. 41, 265–275. doi:10.3750/AIP2011.41.4.02
Karpouzi, V.S., Stergiou, K.I. (2003). The relationships between mouth size and shape and body length for 18 species of marine fishes and their trophic implications. J. Fish Biol. 62, 1353–1365. doi:10.1046/j.1095-8649.2003.00118.x
Legendre, P., Anderson, M.J. (1999). Distance-Based Redundancy Analysis: Testing Multispecies Responses in Multifactorial Ecological Experiments. Ecol. Monogr. 69, 1. doi:10.2307/2657192
Main, L.K. (1985). The influence of prey identity and size on selection of prey for two marine fishes. J. Exp. Mar. Biol. Ecol. 88:145–152.
Makaoui, A., Orbi, A., Hilmi, K., Zizah, S., Laarissi, J., Talbi, M. (2005). L'upwelling de la côte atlantique du Maroc entre 1994 et 1998. C. R. Geoscience 337, 1518–1524.
McGurk, M. (1986). Natural mortality of marine pelagic fish eggs and larvae: role of spatial patchiness. Mar. Ecol. Progr. Ser. 34:227-242.
Mittelstaedt, E. (1983). The upwelling area off Northwest Africa—A description of phenomena related to coastal upwelling. Prog. Oceanogr. 12, 307–331. doi:10.1016/0079-6611(83)90012-5
Molina, R.E., Maurique, F.A., Velasco, H.E. (1996). Filtering apparatus and feeding of the Pacific mackerel (Scomberjaponicus) in the Gulf of California. CalCOFl Rep., 37: 251-256.
Nakayama, S., Masuda, R., Shoji, J., Takeuchi, T., Tanaka, M. (2003). Effect of prey items on the development of schooling behavior in chub mackerel Scomberjaponicus in the laboratory. Fish. Sci. 69, 670–676. doi:10.1046/j.1444-2906.2003.00673.x
Nieto, K., Demarcq, H., McClatchie, S.(2012). Mesoscale frontal structures in the Canary Upwelling System: New front and filament detection algorithms applied to spatial and temporal patterns. Remote Sensing of Environment 123, 339–346.
Nykjær, L., Van Camp, L. (1994). Seasonal and interannual variability of coastal upwelling along northwest Africa and Portugal from 1981 to 1991. J. Geophys. Res. Oceans 99, 14197–14207. doi:10.1029/94JC00814
Piet, G. (1998). Ecomorphology of a size-structured tropical freshwater fish community. Environmental Biology of Fishes 51 (1): 67–86.
Pinkas, L., Oliphant, M.., Iverson, I.L.K. (1971). Food habitats of albacore, bluefin tuna, and bonito in California waters. Fish. Bull., 152: 1-139.
Rizkalla, S., Faltas, S.N. (1997). Feeding Habits of Chub Mackerel (Scomberjaponicus) in Egyptian Mediterranean Waters. IKAU: Mar .Sci . , vol. 8, pp . 127-136.
Robert, D., Castonguay, M., Fortier, L. (2008). Effects of intra- and inter-annual variability in prey field on the feeding selectivity of larval Atlantic mackerel (Scomberscombrus). J. Plankton Res. 30, 673–688. doi:10.1093/plankt/fbn030
Rodríguez, J.M., Barton, E.D., Eve, L., Hernández-León, S. (2001). Mesozooplankton and ichthyoplankton distribution around Gran Canaria, an oceanic island in the NE Atlantic. Deep Sea Res. Part Oceanogr. Res. Pap. 48, 2161–2183. doi:10.1016/S0967-0637(01)00013-9
Sanchez-Velasco, L., Shirasago, B. (2000). Larval Feeding of Scomberjaponicus (Pisces: Scombridae) in the Gulf of California and Its Relation to Temperature and Chlorophyll Satellite Data.
Sever, T.M., Bayhan, B., Bilecenoglu, M., Mavili, S. (2006). Diet composition of the juvenile chub mackerel (Scomberjaponicus) in the Aegean Sea (Izmir Bay, Turkey). J. Appl. Ichthyol. 22, 145–148. doi:10.1111/j.1439-0426.2006.00705.x
Wahbi, F., Errhif, A., Ettahiri, O., 2011. Cycle de reproduction et variabilité du régime alimentaire du maquereau *Scomber japonicus* (Houttuyn, 1782) débarqué au port de Casablanca. In S. Garcia, M. Tandstad & A.M. Caramelo, eds. Science and Management of Small Pelagic, Fisheries and Aquaculture proceedings, FAO, 18: 127-138.