Diet and feeding strategy of the blackspot seabream (*Pagellus bogaraveo*) in Moroccan waters of the Strait of Gibraltar

[1]Meryeme Khoukh, [1]Nadia Berday, [2]Meryem Benziane, [2]Mohammed Malouli Idrissi

[1] Agronomic and Veterinary Institute Hassan II, Madinat Al Irfane, Rabat, Morocco; [2] National Institute for Fisheries Research (INRH), Regional Centre of Tangier, Tangier, Morocco. Corresponding author: M. Khoukh, khoukh.meryeme@gmail.com

Abstract. The diet composition of 756 specimens of blackspot seabream (*Pagellus bogaraveo*) was studied in Moroccan waters of the Strait of Gibraltar through a random and monthly sampling of commercial catches landed in the Port of Tangier (35°47'N-5°48'W). Feeding activity of *P. bogaraveo* was studied based on the vacuity index (%VI) and the total fullness index (TFI). Data analysis of the stomach contents was made by four methods: frequency of occurrence, the numerical abundance, the gravimetric composition and the graphical method. The food coefficient (Q) and the index of relative importance (IRI) were used for prey classification. In order to detect variability factors in the diet of *P. bogaraveo*, a non-parametric multivariate analysis of variance (NP-MANOVA) applied to four factors (sex, season, size and sexual maturity) was carried out. Results showed that *P. bogaraveo* is a carnivorous predator that feeds mainly on crustaceans and fish, but also on cephalopods, echinoderms, algae and sponges. Crustaceans and fish were the two preferred prey, while other prey groups were accidental. The classification of prey revealed that crustaceans and fish formed the main prey (IRI>200), cephalopods were secondary prey (IRI=23.3), while the other groups of prey were occasional (0.21<IRI<8.89). The trophic intensity was greater in young individuals (23-28 cm TL) and its maximum was recorded in autumn and spring coinciding with the end of the reproduction period. The diet of *P. bogaraveo* showed a significant variation with ontogenetic development (juveniles/adults) and according to the seasons with more prey diversification in juveniles and during spring. Graphical analysis revealed that *P. bogaraveo* has a double feeding strategy: specialization strategy for crustaceans and generalization strategy for fish and other preys.

Key Words: crustaceans, feeding activity, Moroccan waters, predator, stomach content.

Introduction. The blackspot seabream *Pagellus bogaraveo* is a demersal fish belonging to the family Sparidae. This benthopelagic species is found in the Northeast Atlantic and the Mediterranean, between the continental shelf and the slope (Whitehead et al 1986) and inhabits rocky, sandy and muddy bottoms in the Mediterranean and Atlantic, reaching depths of up to 800 m (Fischer et al 1987b; Spedicato et al 2002). Due to its high commercial value and the increasing demand from external markets (Burgos et al 2013), *P. bogaraveo* represents a main targeted fishery species in the strait of Gibraltar with a local production that amounted to 105 tons in 2021. This species was classified as a priority species for management in the Mediterranean (FAO 2018) due to its overexploitation status and its decreasing abundance (Sanz-Fernández et al 2018). The ecological and socioeconomic interest of *P. bogaraveo* has prompted several authors to study its biology and especially the reproductive cycle (Sánchez 1983; Krug 1998; 1990; Lechekhab et al 2010; Gil 2006; Micale et al 2011; Khoukh et al 2021). The sustainable exploitation of this fishery in Morocco requires a better knowledge of the species biology and ecology, including aspects on its diet and feeding strategy, which had never been investigated in Moroccan waters. Diet studies of *P. bogaraveo* are limited in the Mediterranean and available information belongs to the Ionian Sea (Mytilineou et al 2013), the central Mediterranean (Capezzuto et al 2021), the Algerian coast (Meziani 2003) and the Spanish coasts of the Strait of Gibraltar (Polonio et al 2008). The blackspot seabream's diet has also been studied outside the Mediterranean, especially in the Azores (Morato et al 1998; Morato et al 2001). Understanding fish species diet does not only provide information on the behavior of the predator, but can also explain differences in growth, migrations and even some aspects of reproduction (Wootton 1990). These studies contribute to understanding the trophic behavior and the ecological role of species and constitute the basis for interpreting species interaction in multispecies trophic models (FAO 2010).

The present study is the first attempt to investigate the diet composition and feeding strategy of a commercially important species *P. bogaraveo* in the Moroccan waters of the strait of Gibraltar. It aims, as well, to study the main variation factors of *P. bogaraveo* feeding activity and to compare feeding habits of this species in different regions within and outside the Mediterranean Sea.

Material and Method

Description of the study area. This study was conducted on the Moroccan Mediterranean coast, precisely in the Strait of Gibraltar (Figure 1). The Strait of Gibraltar represents an ecological corridor between the Atlantic Ocean and the Mediterranean Sea. It is marked by an important biodiversity, a high degree of endemism (Coll et al 2010) and the passage of many migratory species due to its variable depth ranging from 80 to 1200 m (Zahraoui 1997). Fishing activity in this area is strongly affected by weather conditions, mainly by the high rainfall (90 days per year) and the alternation of two main winds ("east" and "west"), which limits the fishing fleet activity in the area. Tangiers port (35°47′N-5°48′W) occupies a privileged position in the strait and represents the main landing port of the Moroccan coastal and artisanal fleet operating in the area.

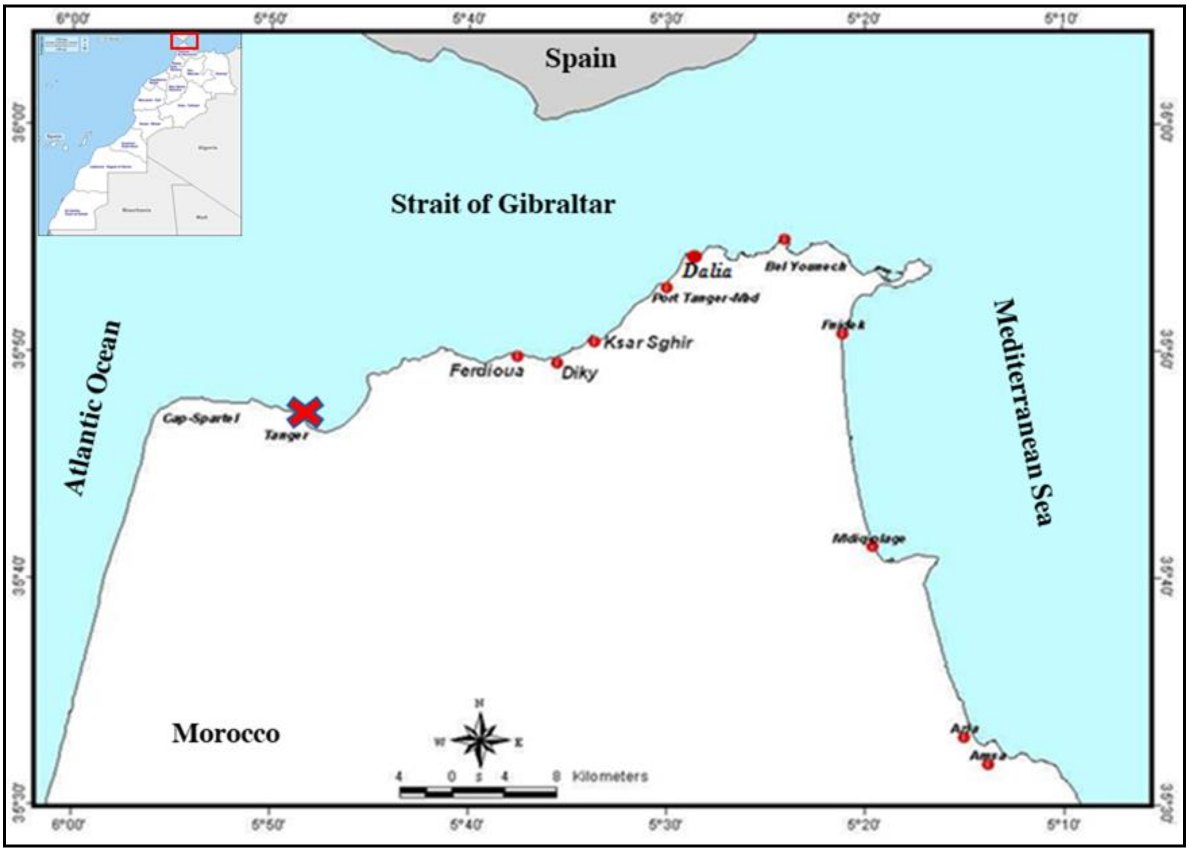

Figure 1. The location of *Pagellus bogaraveo* sampling port, Tangier, Morocco.

Sample collection. 756 specimens of *P. bogaraveo* (Sparidae) were collected between July 2018-June 2019 from landed catches of long-line and artisanal fishing vessels in the port of Tangier (35°47′N-5°48′W). For each individual, data on total length (LT), total weight (Wt), sex and month of capture were recorded. Sex was assigned by macroscopic observation of gonads and considering the following sexual features: males presented only testicles; females presented a single ovarian tissue and hermaphrodites displayed an ovotestis structure. Individuals were classified as juveniles/adults according to their size (total length) and considering the length at first sexual maturity of the species previously reported in Khoukh et al (2021)(L_{50}=31.5 cm). Juveniles were defined as individuals with TL below L_{50} and adults as individuals with TL equal or above the L_{50}.

Stomach content analysis. Full stomachs were collected and stored by immediate freezing at -18°C. In the laboratory, stomachs content was poured into a Petri dish and weighted (Wc). Prey were identified, counted and weighed. Each prey was determined to the lower possible taxonomic level, using a binocular microscope and the following identification keys: Fischer et al (1987a), Fischer et al (1987b), Conway (2015), the World Register of Marine Species (http://www.marinespecies.org) and algabase (https://www.algaebase.org/) websites. Food items in a state of advanced digestion were recognized by their undigested remains (crustacean appendages, scales, mandibles, vertebrae or fish otoliths) and fish otoliths were identified based on Campana (2004) and Tuset et al (2008).

Feeding activity. The feeding activity of *P. bogaraveo* was studied using the vacuity index (%VI) (Hureau 1970). Seasonal variation of the VI allowed the identification of low and intense feeding activity periods. This index is expressed by the following equation:

$$\%VI=Se/N \times 100$$

Where: Se - number of empty stomachs; N - total number of stomachs analyzed.

In addition, in order to assess the degree of stomachs fullness, a classification scale (0% to 100%) was established based on visual assessment. The determination of prey's digestion status was carried out by visual observation. An evaluation was assigned according to a scale of 1 to 4 (Table 1), corresponding to the respective levels of digestion (from not very affected to very degraded and not recognizable material).

Table 1

Digestion degree of prey ingested by *Pagellus bogaraveo*

Scale	*Status of prey*	*Level of digestion*
1	No digestion	Prey in intact state (100% intact)
2	50-75% intact	Partial digestion
3	<50% intact	Extensive digestion with well-digested remains
4	Prey remains	Some remains of prey, complete digestion

Total fullness index (TFI) was used to assess stomach filling from a quantitative perspective. It was calculated for each stomach containing food items following the equation modified by Bozzano et al (1997), expressed as follows:

$$TFI=(Wc \times 10^4)/Wt$$

Where: Wc - the weight of stomach contents; Wt - the total body weight of each individual.

Diet composition. Several methods were used in the analysis of *P. bogaraveo* diet: the frequency of occurrence (FO), the numerical abundance, the gravimetric composition and the graphical method (Table 2). The graphical method of Amundsen et al (1996) is based on a two-dimensional representation of the prey-specific abundance (Pi) and FO of the different prey items in the predator's diet. This method was used to describe *P. bogaraveo* feeding strategy and prey importance by analyzing the distribution of points along the diagonals and axes of the graph. Prey with low specific abundance and moderate to high occurrence show a generalist population, prey with high specific abundance and high occurrence indicate a specialized population, while prey with high specific abundance and low occurrence indicate specialization by individuals. The equations are expressed as:

$$Pi = (\sum S_i / \sum S_{ti}) \times 100$$

$$FO = 100 \times (n_i / n)$$

Where: Pi - the prey-specific abundance; Si - the number of prey species i; Sti - the total number of preys in stomachs containing prey i; FO - the frequency of occurrence of prey i.

Table 2

Quantitative methods used for the analysis of *Pagellus bogaraveo* diet

Method	*Equation*	*Terms of the equation*
Frequency of occurrence (%FO)	$\%FO = \left(\frac{n_i}{N}\right) \times 100$	ni: number of stomachs containing a given prey i; N: total number of non-empty stomachs
Numerical abundance (%N)	$\%\mathrm{N} = \left(\frac{n_p}{N_p}\right) \times 100$	np: number of individuals of a given prey; Np: total number of all prey
Gravimetric composition (%W)	$\%\mathrm{W} = (\mathrm{Wi} \times 100)/\mathrm{Wp}$	Wi: weight of a given prey i; Wp: total weight of all prey

Food preferences of P. bogaraveo. The two following methods were used to describe the food preferences of *P. bogaraveo*:

Hureau's method using the food coefficient (Q) (Hureau 1970):

Q=%N x %W

Where: %N and %W represent the percentage of preys in number and in weight, respectively. The interpretation of this index is as follows: preferred prey - Q>200; secondary prey - 20<Q<200; incidental prey - Q<20.

Pinkas et al (1970) method based on the index of relative importance (IRIi, and %IRIi) as modified by Hacunda (1981):

IRIi=(%N + %W) x %FO

$$\%IRI_i = 100 \times \frac{IRI_i}{\sum_{i=1}^{n} IRI_i}$$

Where: %N - the percentage of a prey in number; %W - the percentage of a prey in weight; %FO - the frequency of occurrence of a prey; IRIi - the index of relative importance of the prey i; n - the total number of food categories considered at a given taxonomic level. This index is interpreted as follows: main prey 200<IRI<20000; preferential prey 20< IRI<200; occasional prey IRI<20.

Statistical analysis. A Chi-square (χ2) test was used to test the variation in the vacuity index by month. Significance of variation in total fullness index (TFI) by season, sex, and size was tested by multifactor analysis of variance (ANOVA). In order to detect variability factors in the diet of *P. bogaraveo*, a non-parametric multivariate analysis of variance (NP-MANOVA) was performed on the food composition and applied on four factors: sex, season, sexual maturity (juveniles/adults) and size. For this, individuals were separated into 5 size classes: [23; 28[; [28; 33[; [33; 38[; [38; 43[; and >43 cm. Analyses were performed using R statistical software (R Core Team 2019).

Results and Discussion. Diet analysis was performed on stomachs of 756 individuals of *P. bogaraveo*. The size range of the sampled specimens varied between 22.9 and 55.6 cm TL (mean=31.54±4.68 cm) and the total weight ranged between 188 and 2311 g (mean weight = 471.7±251 g). The population consisted of 53% of hermaphrodites, 30% of gonochoric females (F), 14% of gonochoric males (M) and 3% of unsexed (und). The results showed that 610 of stomachs were empty with a very high vacuity index equal to 80.68%. Feeding activity showed a significant variation among months ($\chi 2=39.36$, $p<0.05$), with a maximum recorded in December when all examined stomachs were empty (%VI=100) and a minimum recorded in March (%VI=56.52) (Figure 2). Based on visual assessment, an average fullness frequency of 71.5% was found in non-empty stomachs throughout the year, with 72% of stomachs full in high degrees (60-100%) and 31 completely full; 7% half-full (50%) and 21% stomachs with a low degree of fullness (10-40%).

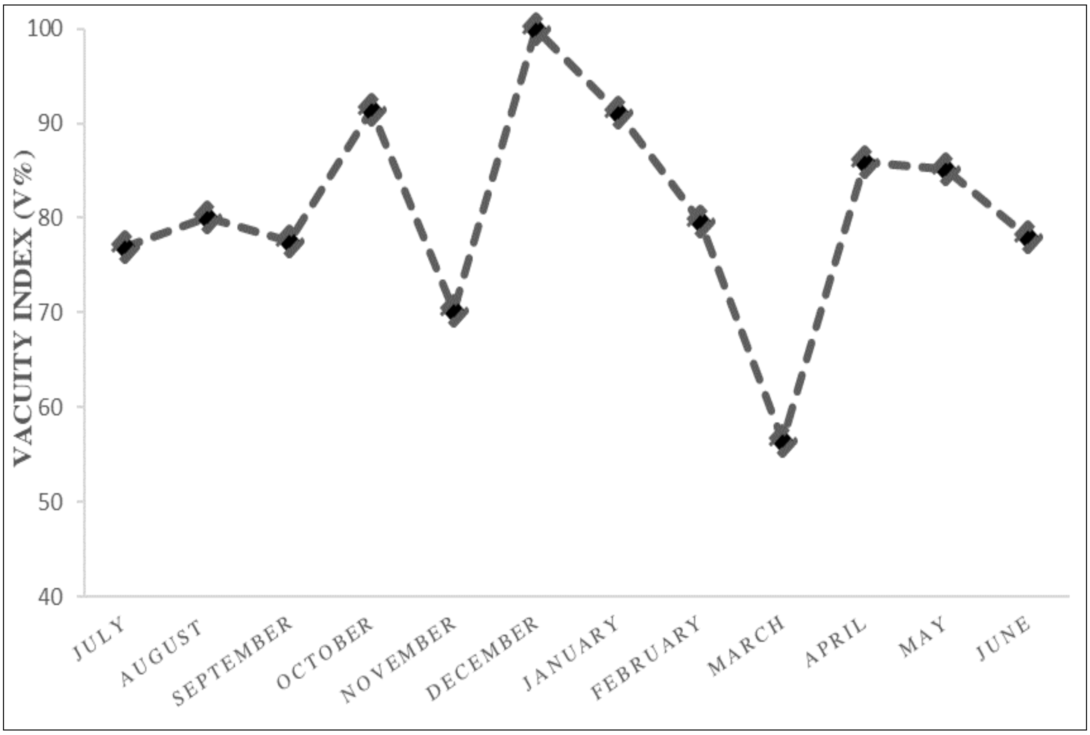

Figure 2. Monthly variations of vacuity index (V%) of *Pagellus bogaraveo* between July 2018 and June 2019.

Feeding intensity of *P. bogaraveo* showed a significant variability with season (p= 0.0612) and with size (p=0.0243), while the sex had no significant effect on feeding activity (p=0.1946) (Table 3). Indeed, a more marked feeding activity was observed in the youngest individuals (23-28 cm), who recorded a higher TFI than adults, in particular those of the last size class (>43 cm), whose TFI were minimal (TFI=54.06). On the other hand, we noted that the lowest TFI was observed in winter (TFI=39.92), while the feeding activity improved during the other seasons with a maximum recorded in autumn (TFI=140.00), then in spring (TFI= 121.26). Finally, the feeding activity of *P. bogaraveo* seemed important regardless of sex (94<TFI<141).

Regarding preys digestion degree, overall, most of *P. bogaraveo* preys were in an advanced state of digestion with an average of 3.53 for all preys, which corresponds to prey in extensive or complete digestion (<50% intact) with well-digested remains. Indeed, prey in 50 to 80% of stomachs contained digested food at advanced stages 3 and 4, with stage 4 being the most represented (51%). Preys with partial digestion (stage 2) were only represented in 18% of individuals and intact preys (stage 1) were very rarely recorded (1%) (Figure 3).

Table 3
Evolution of the total fullness index (TFI) by size, sex and season in *Pagellus bogaraveo*

		TFI	*Number of stomachs*	*SD*
Size (cm)	[23 ;28[	151.58	27	132.42
	[28 ;33[	87.37	42	85.87
	[33 ;38[	102.24	20	88.20
	[38 ;43[	102.28	8	107.87
	>43	54.06	3	51.94
Sex	Females	110.64	35	109.20
	Hermaphrodites	94.46	52	80.96
	Males	141.33	10	115.15
Season	Autumn	140.00	12	152.29
	Summer	106.57	40	90.41
	Winter	39.92	12	32.73
	Spring	121.26	36	108.46

Note: SD - standard deviation.

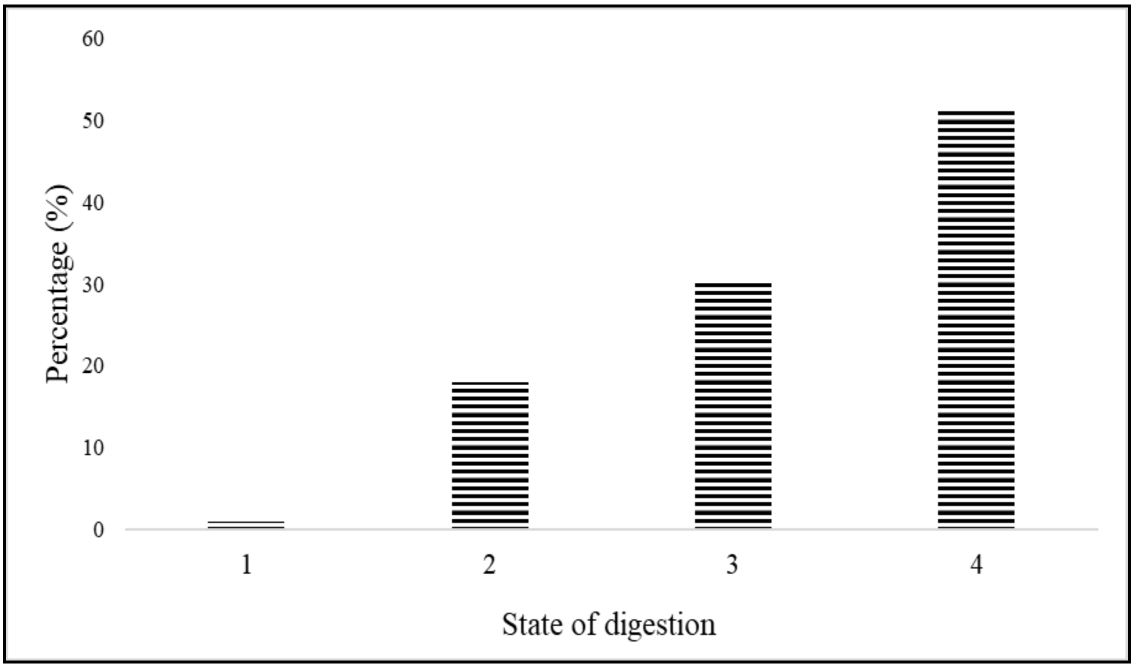

Figure 3. Digestion degree of prey found in the gut content of *Pagellus bogaraveo*. 1 - intact preys; 2 - partial digestion; 3 - advanced digestion; 4 - extensive or complete digestion.

Diet composition. 478 food items were identified in 100 full stomachs of *P. bogaraveo.* This species has a relatively wide food spectrum belonging to six zoological groups: bony fishes, crustaceans, cephalopods, echinoderms, algae and sponges (Table 4).

Table 4

Diet composition of *Pagellus bogaraveo* in the Strait of Gibraltar in terms of frequency of occurrence (%FO), percentage of number (%N), percentage of weight (%W), food coefficient (Q) and index of relative importance (IRI and %IRI)

Taxonomic group	*%N*	*%W*	*%FO*	*Q*	*IRI*	*%IRI*
Arthropoda Crustacea	67.99	13.10	79.00	890.82	6406.39	45.76
Isopoda	0.42	0.01	2.00	0.00	0.85	0.01
Amphipoda	1.26	0.06	4.00	0.08	5.27	0.04
Mysidacea	1.67	0.09	6.00	0.15	10.59	0.08
Euphausiacea	0.42	0.00	1.00	0.00	0.42	0.00
Decapoda	29.92	10.20	44.00	305.20	1765.20	12.61
Acanthephyridae						
Acanthephyra pelagica	0.63	2.07	3.00	1.30	8.09	0.06
Sergestidae						
Sergia robusta	16.95	5.01	20.00	84.84	439.05	3.14
Decapoda not identified	12.34	3.13	25.00	38.58	386.72	2.76
Crustacea not identified	34.31	2.73	39.00	93.82	1444.72	10.32
Echinodermata	0.42	0.13	2.00	0.06	1.11	0.01
Crinoidea Antedonidae	0.42	0.13	2.00	0.06	1.11	0.01
Algae	1.46	0.03	6.00	0.04	8.94	0.06
Phaeophyceae Dictyotaceae						
Rugulopteryx okamurae	1.46	0.03	6.00	0.04	8.94	0.06
Cephalopoda	1.05	5.41	5.00	5.66	32.30	0.23
Decapodiforme						
Sepiolidea *Rossia macrosoma*	0.63	1.58	3.00	0.99	6.62	0.05
Histioteuthidae *Histioteuthis* sp.	0.21	3.71	1.00	0.78	3.92	0.03
Cephalopoda not identified	0.21	0.13	1.00	0.03	0.33	0.00
Osteichthyes						
Teleosts	15.90	59.15	73.00	940.46	5478.62	39.13
Myctophidae *Myctophum punctatum*	0.21	0.38	1.00	0.08	0.59	0.00
Sternoptychidae *Argyropelecus* sp.	0.42	0.33	2.00	0.14	1.49	0.01
Fish not identified	15.27	58.44	70.00	855.39	5476.54	35.49
Porifera	0.21	0.00	1.00	0.00	0.21	0.00
Others	12.97	22.17	59.00	287.57	2073.33	14.81

The importance of the main *P. bogaraveo* prey items expressed in relation to the different indices showed that its diet consisted mainly on crustaceans and teleosts as dominant preys (Figure 4). A dominance of fish over crustaceans was noted given the results of the gravimetric composition index (%W) due to the high proportion of fish bait in stomachs, while the numerical abundance (%N) revealed a dominance of crustaceans, since they represent numerous and small size preys. Crustaceans were present in 79% of stomachs (%FO=79) and bony fish were observed in 73 stomachs (%FO=73), while a lower occurrence was registered for the other groups.

Among crustaceans, decapods were the most important food items and were essentially represented by the two species *Sergia robusta* (Sergestidae; %FO=20) and *Acanthephyra pelagica* (Acanthephyridae; %FO=3). Isopods, amphipods, mysids and euphausiids were also reported in stomachs, but with a very low occurrence (1≤%FO ≤6). Among teleosts, unidentified fish, determined by vertebrae or scales were the most representative group (%W=58.44%) followed by two species, *Myctophum punctatum* (Myctophidae) and *Argyropelecus* sp. (Sternoptychidae) whose FO were 1% and 2% respectively. Cephalopods were represented by two species, *Rossia macrosoma* (Sepiolidae) and *Histioteuthis* sp. (Histiotheuthidae) with 3% and 1% FO, respectively. In addition, a single species of brown algae *Rugulopteryx okamurae* (Dictyotaceae) was observed (%FO=6) in addition to echinoderms (Antedonidae) and sponges, which were reported with lower frequency of occurrence (2 and 1%, respectively) (Table 4).

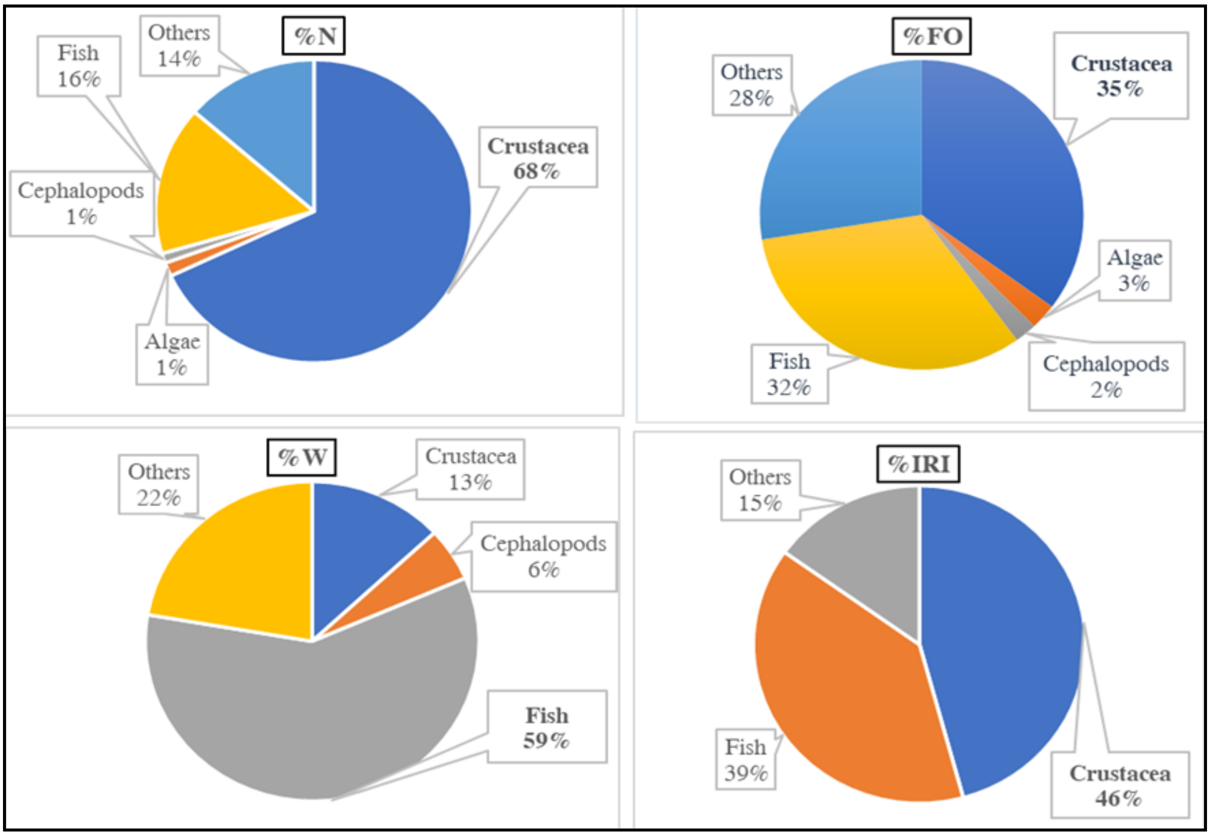

Figure 4. Importance of main prey groups for *Pagellus bogaraveo* in terms of frequency of occurrence (%FO), numerical percentage (%N), gravimetric percentage (%W) and index of relative importance (%IRI).

Food preference. According to their importance in the diet of *P. bogaraveo*, food items were classified into categories based on Q and IRI (Table 5). Results indicated that fish and crustaceans ranked first (Q>200) as two preferential preys, while echinoderms, cephalopods, algae and sponges were classified as accidental prey (Q<20). Based on the IRI index (Pinkas et al 1970), crustaceans (IRI=6406.39) represented primarily by decapods (IRI=1725.08) and specially *S. robusta* (IRI= 439.05) were the main ingested preys followed by teleost fishes (IRI=5478.62). According to this method, cephalopods were positioned as preferential prey (IRI=32.3), while algae, sponges and echinoderms were classified as occasional preys (IRI<20).

Table 5

Classification of ingested food items by *Pagellus bogaraveo* from the Moroccan coasts of the Strait of Gibraltar according to Hureau (1970) and Pinkas et al (1970)

Method	*Classification*	*Type of prey*	*Reference*
Food coefficient (Q)	Preferential	Fish, crustaceans (Decapoda)	Hureau (1970)
	Secondary		
	Accidental	Echinoderms, cephalopods, algae, sponges	
Index of relative importance (IRI)	Main prey	Crustaceans (Decapoda), fish	Pinkas et al (1970)
	Preferential prey	Cephalopods	
	Occasional prey	Algae, sponges, echinoderms	

Note: Q - food coefficient; IRI - index of relative importance.

Feeding strategy. Graphical analysis of *P. bogaraveo* feeding strategy confirmed that crustaceans are an important and dominant prey in the diet of this species, followed by teleosts (Figure 5). The feeding strategy of this predator indicated a specialization towards crustaceans (positioned in the upper right quadrant) and in particular decapods (Pi>50%), and a generalization strategy for fish and other prey, which seemed to be occasional. The Amundsen diagram showed that the majority of prey were in the lower left part of the diagram, indicating that this species feeds on many less important preys including cephalopods, echinoderms, algae and sponges. Teleost fish represented the only prey in the lower right part of the diagram, indicating that this resource was most frequently consumed under a generalization strategy (Pi<50%). Furthermore, *P. bogaraveo* presented a trophic niche of medium width since most of the preys were identified as rare with Pi values lower than 50%. *P. bogaraveo* showed, on the other hand, a high specialization for crustaceans, which represented the most important prey, given the high percentage of their specific abundance (Pi=73%) and frequency of occurrence (%FO=79).

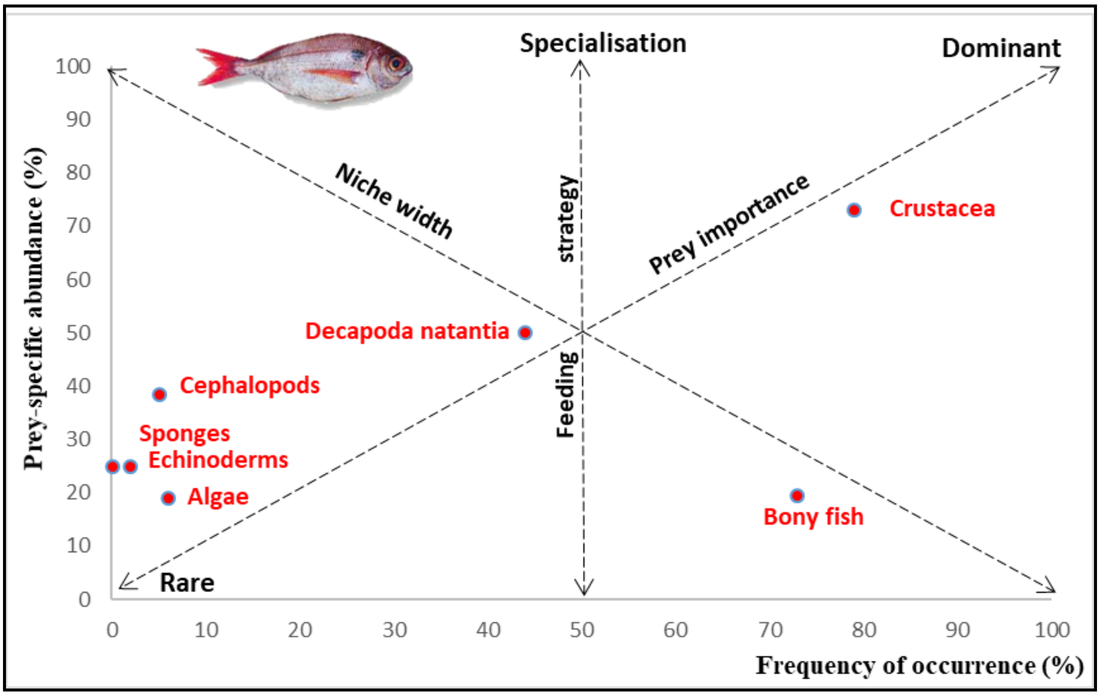

Figure 5. Feeding strategy of *Pagellus bogaraveo* in the Strait of Gibraltar.

Dietary variation in P. bogaraveo. Statistical analysis revealed that *P. bogaraveo* diet varied significantly with the season (p=0.040) and with the sexual maturity (juveniles/adults)(p=0.075), the effect of sex (p=0.757) and size (p=0.264) being insignificant. In terms of qualitative and quantitative composition, juveniles (TL< 31.5 cm) presented the most diversified diet (Figure 6). In contrast, adult specimens (TL ≥ 31.5 cm) had a narrower dietary spectrum based mainly on crustaceans (FO=83%) and fish (FO=61%). On the other hand, spring was the season when the diet of *P. bogaraveo* were the most diversified, while the lowest diversification was noted in autumn with specifically fish and crustaceans as observed prey (Figure 7).

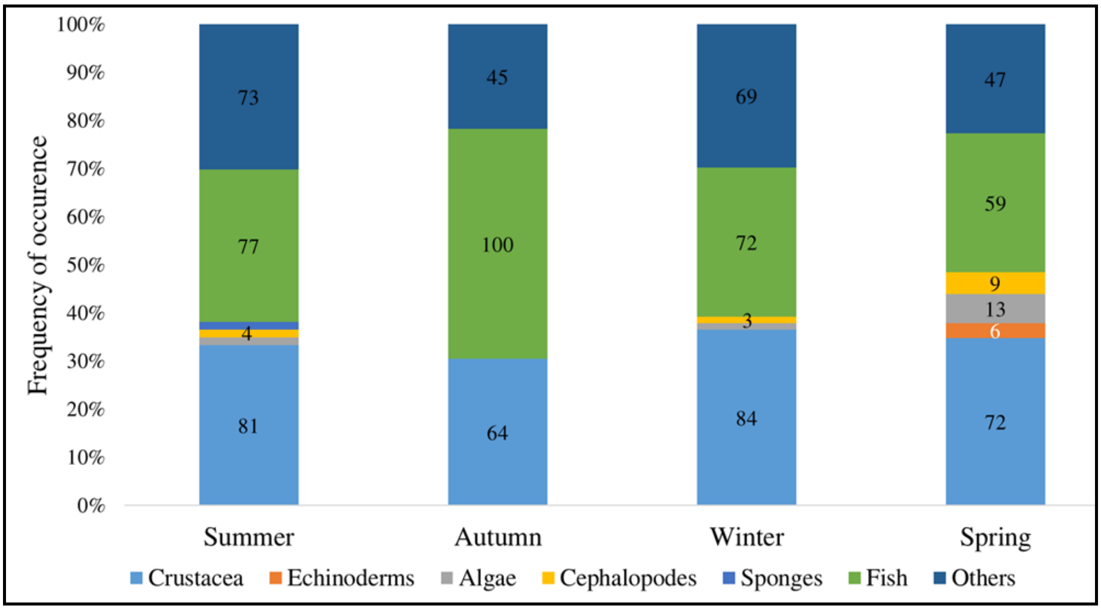

Figure 6. Seasonal dietary variation of *Pagellus bogaraveo* based on frequency of occurrence (%FO).

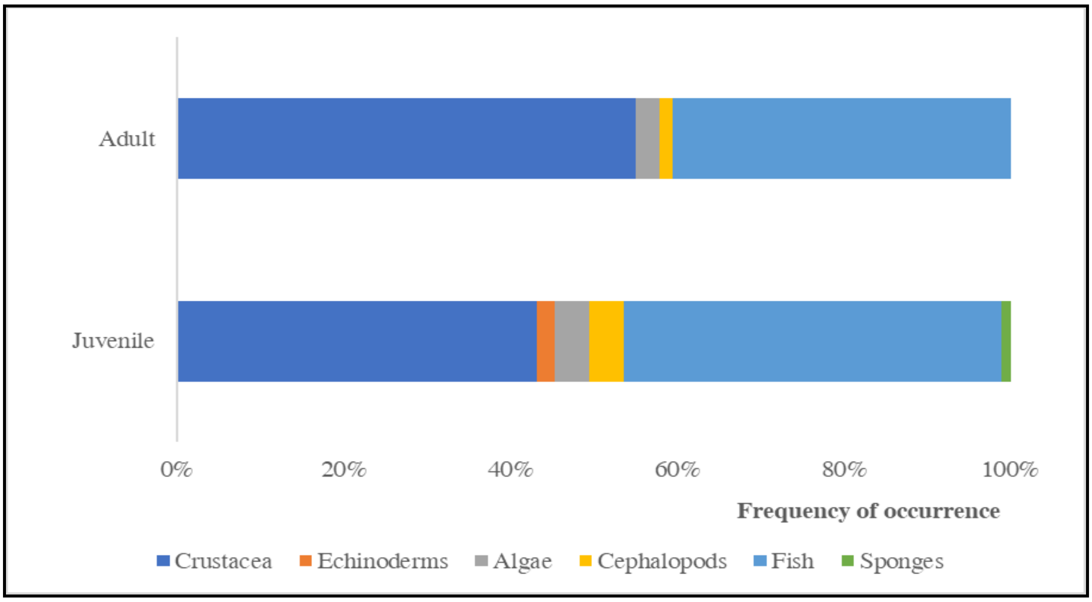

Figure 7. Diet composition of *Pagellus bogaraveo* juveniles and adults based on frequency of occurrence (%FO).

According to this study, *P. bogaraveo* is a euryphagous carnivorous predator with high species diversity (fish, crustaceans, cephalopod molluscs, echinoderms, algae and sponge) and with a preference for benthic crustaceans and bony fish. Similar feeding habits were described by several authors in the Mediterranean (Meziani 2003; Polonio et al 2008; Mytilineou et al 2013; Capezzuto et al 2021) (Table 6). In the central Mediterranean (Capezzuto et al 2021), crustaceans were also described as the main food items of *P. bogaraveo*. In the Spanish waters of the Strait of Gibraltar (Polonio et al 2008), crustaceans of the decapod group have also been observed at the top of prey groups, in particular the species *S. robusta* in addition to other prey groups especially fish (Stomiiformes and Myctophiformes), cephalopods and algae. The dominance of teleosts in the diet of *P. bogaraveo* has also been reported from the Azores (Morato et al 1998, 2001), eastern Ionian Sea (Mytilineou et al 2013; Anastasopoulou et al 2018) and in the central Mediterranean (Capezzuto et al 2021). However, crustaceans played a very low importance in the diet of *P. bogaraveo* in the Azores (Morato et al 2001), where a high consumption of Thaliaceae as a second important prey was reported. Furthermore, while the feeding strategy of *P. bogaraveo* showed a clear specialization on crustaceans in the Strait of Gibraltar, its diet was based almost exclusively on fish (IRI=93.1%) in the deep waters of the eastern Ionian Sea, where decapods had lower contribution as secondary prey and were mainly represented by *Aristaeomorpha foliacea* (Mytilineou et al 2013). Furthermore, a significant occurrence of annelids, not reported in this work, was reported in Algerian coasts (Meziani 2003), which may be linked to the habitat type (Capezzuto et al 2021). Thus, richness and diversity of the Mediterranean environment made the behavior of *P. bogaraveo* change according to the degree of preference for a specific prey. Moreover, geographical changes in prey's availability may explain the differences in *P. bogaraveo* diet observed outside the Strait of Gibraltar.

Regarding feeding activity of *P. bogaraveo*, a high number of empty stomachs was also observed in various areas (Morato et al 1998, 2001; Olaso et al 2002; Polonio et al 2008; Mytilineou et al 2013), which may be explained by the sampling period. The capture in this case can coincide with a period of end of digestion, a pre-trophic period, or a real fast of the species. Furthermore, the passivity of the fishing gear (bottom longline) adopted in the majority of these studies (Morato et al 1998, 2001; Polonio et al 2008; Mytilineou et al 2013) suggests that fish fed to satiety react little to bait odor and escape capture (Lokkeborg et al 1995). Otherwise, *P. bogaraveo* showed a low feeding activity throughout the year, in particular during the winter period (December-February), which coincides with the reproduction period of the species in the study area (Khoukh et al 2021). Results from this study showed that the trophic activity of *P. bogaraveo* slows down during the spawning period (winter) to increase during the post-spawning period (spring), where the minimum value of %VI was recorded in response to the resumption of normal trophic activity.

On the other hand, the seasonal variations in the diet composition of *P. bogaraveo* were significant and revealed a change in food preferences towards some taxa, particularly in spring with the appearance of cephalopods and algae and the decrease in the proportion of fish and crustaceans consumed during this season. Crustaceans were consumed more in summer and winter, while fish consumption dominated in autumn. On the other hand, algae, sponges, and echinoderms were classified as accidental or occasional prey regardless of the season. This seasonal variation can be linked mainly to the heterogeneity of food resources at seasonal and annual scales. The availability of food in the environment in combination with other physiological factors such as temperature could influence the overall feeding performance of fish (Behrens & Lafferty 2007).

Although crustaceans and fish remain the taxa sought by all size classes, the diet of *P. bogaraveo* varied, as well, in relation to sexual maturity, where juveniles (TL<31.5 cm) presented the most diversified diet and were less selective for food than adults (TL>31.5 cm). This may be explained by the ontogenetic niche changes that the species undergoes while increasing in size. Young individuals of *P. bogaraveo* live near the coast, while large individuals live at greater depths (Spedicato et al 2002). This implies an increase in the average size of prey consumed and induces better selectivity for food in adult stage. The same finding was reported by Polonio et al (2008), who concluded a more piscivore tendency in larger adults of *P. bogaraveo* (TL>40 cm).

Table 6

Values for frequency of occurrence (FO), percentage of number (%N), percentage of weight (%W) and index of relative importance (IRI and %IRI) for prey items observed in stomachs of *Pagellus bogaraveo* in various areas (1998-2021) (+: presence; -: absence)

Author/Area	*Morato et al (2001)*			*Meziani (2003)*		*Polonio et al (2008)*			*Mytilineou et al (2013)*			*Capezzuto et al (2021)*		*Present study (2024)*			
	Azores			*Algerian coasts*		*Strait of Gibraltar- Spain*			*Ionian Sea*			*Central Mediterranean*		*Strait of Gibraltar- Morocco*			
	FO	*%N*	*IRI*	*FO*	*%N*	*FO*	*%N*	*IRI*	*FO*	*%N*	*%IRI*	*FO*	*%N*	*FO*	*%N*	*IRI*	*%IRI*
Teleosts	+	+	+	67	20	33.33	47.74	2503.93	54.84	51.28	93.13	+	+	73	15.90	5478.62	39.13
Myctophidae	11.7	9.6	320.2	-	-	3.41	0.85	11.58	+	+	+	1.69	0.06	1	0.21	0.59	0
Sternoptychidae	1.8	1	6.0	-	-	6.3	1.77	15.75	+	+	+	0.85	0.06	2	0.42	1.49	0.01
Not identified	41.4	50	2.062.8	59	15	5.51	1.56	25.4	+	+	+	63.56	2.78	70	15.27	5476.54	35.49
Crustacea	+	+	+	+	+	78.22	50.25	8999.69	+	+	+	+	+	79	67.99	6406.39	45.76
Decapoda	0.9	0.5	0.9	8	2.08	60.1	40.14	5538.53	6.45	7.69	0.86	1.69	0.31	44	29.92	1765.20	12.61
Mysidacea	-	-	-	6	1.67	9.97	4.78	57.93	-	-	-	-	-	6	1.67	10.59	0.08
Isopoda	-	-	-	6	1.67	-	-	-	-	-	-	13.56	1.28	4	0.42	0.85	0.01
Amphipoda	0.9	0.5	0.5	20	26.25	-	-	-	-	-	-	22.88	22.63	6	1.26	5.27	0.04
Euphausiacea	-	-	-	-	-	0.26	0.05	0.01	3.23	2.56	0.13	3.39	0.19	1	0.42	0.42	0.00
Not identified	3.6	1.9	16.5	41	7.92	0.26	0.05	0.02				38.14	3.09				
Cephalopoda	1.8	1	7.9	2	0.83	2.89	0.55	12.02	+	+	+	4.24	0.19	5	1.05	32.30	0.23
Sepiolidea	-	-	-	-	-	-	-	-	3.23	2.56	0.31	0.85	0.03	3	0.63	6.62	0.05
Histioteuthidae	-	-	-	-	-	1.31	0.25	4.03	3.23	2.56	0.17	-	-	1	0.21	3.92	0.03
Echinoderms	9.9	17.7	198.8	4	2.92	-	-	-	-	-	-	+	+	2	0.42	1.11	0.01
Algae	0.9	0.5	0.4	-	-	1.05	0.2	0.69	-	-	-	-	-	6	1.46	8.94	0.06
Sponges	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.21	0.21	0.00

Conclusions. This study has successfully documented the feeding strategy and diet of *P. bogaraveo* in the Moroccan waters of the Strait of Gibraltar. Given its high consumption of teleosts, the trophic level of *P. bogaraveo* places it in the category of euryphagous carnivorous predators with a preference for decapods, fish and cephalopods. The species can also occasionally consume other prey such as algae, echinoderms and sponges and its diet varies according to the seasons and sexual maturity. Furthermore, we concluded that *P. bogaraveo* has a double feeding strategy: a specialization towards crustaceans and a generalization towards fish and other prey. For better explaining the feeding behavior of the species in the study area, studies on the availability of food resources in this area are necessary to provide detailed information on the abundance of the different preys. In addition, enhancing studies on the diet of *P. bogaraveo* in the study area is recommended, especially by optimizing sampling conditions through the use of unbaited fishing gear, the staggering of fishing operations over a 24-hour period and taking into account depth to better understand the daily feeding activity of this predator. Finally, these results are of great importance for decision-makers for the good governance and sustainable management of this species in Morocco.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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Authors:
Meryeme Khoukh, Agronomic and Veterinary Institute Hassan II, Madinat Al Irfane, 6202 Rabat, Morocco, e-mail: khoukh.meryeme@gmail.com
Nadia Berday, Agronomic and Veterinary Institute Hassan II, Madinat Al Irfane, 6202 Rabat, Morocco, e-mail: n.berday@gmail.com
Meryem Benziane, National Institute for Fisheries Research (INRH), Regional Centre of Tangier, 5268 Tangier, Morocco, e-mail: me.benziane@gmail.com
Mohammed Malouli Idrissi, National Institute for Fisheries Research (INRH), Regional Centre of Tangier, 5268 Tangier, Morocco, e-mail: malouli@inrh.ma

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