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ARTICLE

Feeding ecology of the planehead filefish *Stephanolepis hispidus* (Pisces: Monacanthidae), in the Canary Islands area

Ecología trófica de *Stephanolepis hispidus* (Pisces: Monacanthidae), en el área de las Islas Canarias

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Resumen. Se examinó la ecología alimentaria de *Stephanolepis hispidus*, en aguas de las Islas Canarias. El estudio se basó en el contenido estomacal de 823 ejemplares de 8,9 cm a 25,9 cm de longitud total (LT), capturados mensualmente en trampas para peces entre febrero de 1998 y junio de 1999. Aproximadamente el 27,2% de los peces mostraron estómagos vacíos. Esta proporción varió significativamente entre los sexos, pero no entre las clases de tamaño o las estaciones evaluadas. La dieta de *Stephanolepis hispidus* se compone principalmente por hidrozooos, anfípodos, equinodermos y algas. Gastrópodos, decápodos y lamelibranquios fueron presas secundarias. De acuerdo con el cambio de la ontogenia, los individuos de pequeño tamaño (<12,9 cm LT) se alimentan principalmente de pequeños crustáceos (anfípodos e hidrozooos), mientras que los especímenes de gran tamaño consumen equinoideos, algas, crustáceos y lamelibranquios. Hidrozooos y algas son más importantes en la dieta durante la primavera, y los anfípodos fueron más importantes en invierno. Los erizos de mar aumentan en verano y otoño. Los valores del índice de Morisita indicaron superposición de la dieta entre individuos de las clases de tallas más pequeñas y más grande que 12,9 cm LT ($S=0,77$). Asimismo, la variación estacional en la superposición de la dieta fue alta durante invierno ($S=0,95$) y primavera ($S=0,93$), pero fue relativamente menor en otoño ($S=0,68$). Los resultados indicaron que la alimentación de la especie abarca un estrecho rango de presas con algún grado de selectividad y se compone principalmente por macroinvertebrados.

Palabras clave: Amplitud de nicho trófico, Atlántico Centro-Oriental, composición de la dieta, cambios ontogenéticos

Abstract. The feeding ecology of the planehead filefish, *Stephanolepis hispidus*, in waters of the Canary Islands was examined. The study was based on the stomach contents of 823 specimens, from 8.9 cm to 25.9 cm in total length (TL), caught monthly in fish traps from February 1998 to June 1999. Approximately 27.2% of the fish showed empty stomachs. This proportion varied significantly between sexes but not among size classes or the evaluated seasons. The food composition of planehead filefish was composed mainly of hydroids, amphipods, echinoids and algae. Gastropods, decapods and lamelibranchs were secondary prey. According to the observed ontogenetic shift, small-sized individuals (< 12.9 cm TL) fed primarily on small crustaceans (amphipods and hydroids), whereas large-sized specimens consumed echinoids, algae, and lamelibranchs. Hydroids and algae were more important in spring, and amphipods were more important in winter. Echinoids increased in summer and autumn. The values of Morisita's index indicated diet overlapping between individuals of length classes smaller and larger than 12.9 cm TL ($S=0.77$). Likewise, the seasonal variation in the diet overlapping was high during winter ($S=0.95$) and spring ($S=0.93$) but was relatively lower in autumn ($S=0.68$). The results indicated that the diet of planehead filefish was characterized by a narrow range of prey items with some degree of selectivity and was composed mainly of macroinvertebrates.

Key words: Trophic niche breadth, eastern central Atlantic, diet composition, ontogenetic changes

INTRODUCTION

The Monacanthidae family is distributed worldwide and includes approximately 102 species in 32 genera of marine filefishes (Nelson 2006). Most species inhabit tropical and subtropical shallow waters usually associated with rocky shores, coral reefs, and muddy and sand bottoms

(Nelson 2006). Monacanthid fishes show varied feeding habits, from herbivorous to carnivorous. For example, *Oxymonacanthus longirostris* is coralivorous (Barlow 1987, Kokita & Nakazono 2001); *Rudarius ercodes* and *Stephanolepis cirrhifer* are omnivorous (Kawase &

Nakazono 1995, 1996; Akagawa & Okiyama 1997); *Cantherhines macrocerus* and *Eubalichthys bucephalus* are spongevorous (Randall & Hartman 1968, Kawase 2008); *C. pardalis* is an herbivorous species (Kawase & Nakazono 1994); and other monacanthids feed on small invertebrates and benthic organisms (*e.g.*, Clements & Livingston 1983, Lindholm 1984, Peristiwady & Geistdoerfer 1991, Kokita & Mizota 2002, Zouari-Ktari *et al.* 2008, El-Ganainy & Sabrah 2013).

Stephanolepis hispidus (Linnaeus, 1766), is a benthic species that inhabits rocky and sandy areas in waters shallower than 50 m depth, from New England to Brazil (in the western Atlantic) and from the Madeira Islands to Angola (in the eastern Atlantic) (Tortonese 1986, Robin *et al.* 1986, Harmelin-Vivien & Quéro 1990). In the Canary Islands area, *S. hispidus* is the most abundant monacanthid, and it has a relatively high occurrence in fish landings, representing over 20.3% of the total catch of benthic-demersal species target by small-scale trap fishing (Mancera-Rodríguez 2000, Mancera-Rodríguez & Castro-Hernández 2004). In this small-scale fishery, the planehead filefish was a by-catch species until the end of the 1970s. However, it became a target species in the early 1980s, and in the 1990s, it showed signs of overfishing (Aguilera-Klink *et al.* 1994). Almost coincident with the increase in the fishing pressure of predatory species of urchins, the shallow rocky areas of most of the islands have suffered the effects of a blight of sea urchin (*Diadema antillarum*) (Aguilera-Klink *et al.* 1994, Hernández *et al.* 2008, Clemente *et al.* 2010). This blight is less significant in less exploited fishing areas near the island of El Hierro (Canary Islands) (Clemente *et al.* 2010).

The macroinvertebrate-eating carnivorous fish (*e.g.*, balistids, sparids and labrids) act as a controlling force on the *D. antillarum* populations and others echinoids through predation (McClanahan 1995, Sala & Zabala 1996, Sala 1997, Tuya *et al.* 2004, Clemente *et al.* 2010). *S. hispidus* plays a similar role in the control of juvenile sea urchin populations (Clemente *et al.* 2010), but knowledge about the feeding ecology of this species has been poorly studied. Soares *et al.* (1993) presented data regarding the diet of the species off the coast of Brazil. Clements & Livingston (1983) studied the diet of juveniles (2-8 cm TL) off Florida. There are some studies on the juvenile fish communities associated with *Sargassum*, also in Florida and the Gulf of Mexico (Dooley 1972, Gorelova & Fedoryako 1986, Coston-Clements *et al.* 1991, Casazza 2008, Ballard & Rakocinski 2012). In the Canary Islands, some preliminary data were reported by Moreno (1999) for fish ranging between 3 cm and 11 cm TL.

This study hypothesized that *S. hispidus* plays a role in the control of sea urchin populations through predation and that larger fish consume more echinoids. Therefore, the objectives of the study were a) to determine the ontogenetic and seasonal changes in the diet, and b) to establish the importance of sea urchin prey in the diet of *S. hispidus* in the Canary Islands (central-eastern Atlantic).

MATERIALS AND METHODS

Eight hundred and twenty-three (823) specimens of the planehead filefish (*S. hispidus*) were obtained monthly from the small-scale fishery of Gran Canaria Island (28°00'N, 15°30'W) from February 1998 to June 1999. The specimens ranged between 8.9 and 25.9 cm TL. The fish were caught commercially in 30-mm mesh traps installed in neritic waters between 3 m and 100 m of depth. The total length (TL), wet weight (W), eviscerated weight (EW), and stomach content weight (SCW) of each fish were recorded in the Laboratory of Fisheries (Faculty of Marine Sciences) of the University of Las Palmas de Gran Canaria, Spain. The stomach contents were preserved in 70% ethanol and subsequently analyzed under a stereomicroscope. The prey items were identified to the lowest possible taxonomic level on the basis of their digestion state (many items could be identified only to order). The analysis of the diet was obtained by sex, seasons and length classes.

The vacuity index (VI) was expressed as: $VI = (Se/St) \times 100$, where (Se) is the number of empty stomachs and (St) the total number of stomachs examined. The variation of VI was tested by a chi-square test of a contingency table with the number of empty stomachs (Sokal & Rohlf 1981).

A cumulative prey curve was used to assess the sample size sufficiency of *S. hispidus* stomachs containing identifiable prey for the entire datasets. An adequate sample size was assumed if the resulting curve approached an asymptote and displayed a reduction in variability (Ferry & Cailliet 1996). The mean and standard deviation of the cumulative number of novel prey was calculated, and the sufficiency of sample size was statistically assessed using the linear regression method of Bizzarro *et al.* (2007).

The degree of digestion of each stomach with food in the sample was valued on a subjective scale, where I was fresh food item, II a barely digested food item, and III a half-digested food item. For each stomach examined, the wet weight was determined for each prey category on a

precision scale of 0.001 g. The contribution of each prey item to the overall diet of *S. hispidus* was quantified by the frequency of occurrence (%F), its contribution in weight (%W) (Hyslop 1980), and the alimentary importance index (%IA) (Kawakami & Vazzoler 1980).

The frequency of occurrence was expressed as $\%F_i = (N_i/NS) \times 100$, where (%F_i) is the frequency of occurrence of the *i*th food item; (N_i) is the number of stomachs in which the *i*th item is found; and (NS) is the total number of stomachs with food in the sample.

The contribution in wet weight (%W) was expressed as $\%W_i = (W_i/WS) \times 100$, where (%W_i) is the weight percentage of the *i*th food item; (W_i) is the weight of prey *i*; and (WS) is the total weight of all prey.

The alimentary importance index (IA) was calculated using a formula modified from Kawakami & Vazzoler (1989):

$$\%IA_i = \frac{(\%F_i) * (\%W_i)}{\sum (\%F_i) * (\%W_i)}$$

where (%IA_i) is the index of alimentary importance of the *i*th food item; (%F_i) is the frequency of occurrence of the *i*th food item; and (%W_i) is the contribution in weight of the *i*th food item.

Prey species were categorized in decreasing order according to their percentage IA contribution, and then cumulative %IA was calculated. In this order, the %IA of first prey was gradually added to obtain 75%, and these items were the main food. This calculation was continued until it reached 90%, and these items were called secondary prey. The other items were accidental.

We analyzed %IA data by means of a non-parametric multivariate analysis of variance (NPMANOVA) (Anderson 2000, 2001; McArdle & Anderson 2001) to detect the differences between seasons and length classes. The analysis was based on Bray-Curtis distances, with 999 permutations used. The differences in the rates of consumption (IA) of each food category by sex, seasons or length were compared by the Mann-Whitney test (Zar 1999). All of these non-parametric tests were performed using PAST software (Copyright Hammer & Harper Oslo, Norway) (Hammer *et al.* 2001). To evaluate the size related variations in food habits, specimens were placed in 1-cm length classes.

Trophic niche breadth for the utilization of food resources was calculated using the %IA values according

to the Levin's Measure of Niche Breadth (Krebs 1999):

$$Bi = 1/\sum p_i^2$$

where, *p* is the prey item of a determined species and *i* is the number of prey items. To standardize this measure of niche breadth on a scale of 0 to 1, Levins' measure of standardized niche breadth was calculated:

$$B = Bi - 1/n - 1$$

where, *B* is Levins' standardized niche breadth, *Bi* is Levins' measure of niche breadth, and *n* is the number of prey items.

Additionally, a cluster analysis (group average) was performed on the standardized %IA values using the Bray-Curtis similarity index (Field *et al.* 1982) to describe the ontogenetic and seasonal variations of food habits using Biodiversity-Pro software (Scottish Association for Marine Science and The Natural History Museum, London, UK) (McAleece *et al.* 1997). The cluster analysis based on %IA values for the 11 length classes discriminated two main groups of length: group I (8.9-12.9 cm TL) and group II (fish greater than 12.9 cm TL).

The Morisita's diet overlapping index (Morisita 1959, Horn 1966, Krebs 1999) was calculated for each season to define the diet overlapping between groups I and II. The simplified Morisita's index is the following:

$$S_{I-II} = \frac{2 * \sum (IA_{iI} * IA_{iII})}{\sum IA_{iI}^2 + \sum IA_{iII}^2}$$

where IA_{iI} is the alimentary importance index of the *i*th food item in group I and IA_{iII} is the alimentary importance index of the same item *i* in group II.

Dietary overlap increases as the Morisita's index increases from 0 to 1. Overlap is generally considered to be biologically significant when the value exceeds 0.60 (Wallace 1981, Langton 1982).

RESULTS

The *Stephanolepis hispidus* sampled ranged from 8.9 cm to 25.9 cm TL and weighed between 12.4 g and 282.3 g. The mean total length was 15.7 ± 2.5 cm, and the mean total weight was 76.3 ± 37.1 g. The number of specimens per length class ranged between 22 and 145. The length

frequency distribution showed that the more abundant length classes were 15.0-15.9 cm TL and 16.0-16.9 cm TL with 145 and 143 specimens, respectively (Table 1).

VACUITY INDEX

The study was based on the stomach contents of 823 specimens, of which 224 were empty (27.2%) (Table 1). The proportion of empty stomachs did not change significantly between length classes ($\chi^2 = 7.24$, $P = 0.703$) or between analyzed seasons ($\chi^2 = 2.68$, $P = 0.748$). There were significant differences between sexes ($\chi^2 = 5.76$, $P = 0.016$).

VARIATION IN DIET COMPOSITION

The analysis of the cumulative prey curve indicated that it was necessary to have a relatively large number of stomachs ($n_{\min} = 486$) for a good description of the diet of *S. hispidus* (Fig. 1). Nine taxonomic groups (18 types of prey items) were frequently present in the stomach contents of *S. hispidus*: cnidarians, crustaceans,

echinoderms, algae, mollusks, polychaetes, fishes, foraminiferans, and sea sponges (Table 2). The food items were half digested in 45.4% of the stomachs analyzed. The contents were barely digested in 37.2% of the stomachs, and the food items were fresh in 17.4% of the stomachs. It should be taken into consideration that, as a consequence of the degree of digestion of prey, the determination to the level of species was not possible. Likewise, sand and shells were present in 70.4% of the stomachs analyzed and represented over 50% of the wet weight of the stomach contents.

The 3 diet indices indicated that planehead filefish mainly preyed on hydroids, gammarid amphipods, echinoids and algae. Gastropods, decapods and lamelibranchs were secondary prey, while polychaetes, ostracods, fishes, foraminiferans, cirripeds, sea sponges, cephalopods, polyplacophors, isopods, copepods and cumaceans were less frequent items in their stomach contents (Table 2).

Table 1. Number of specimens (Ns), number of specimens with prey in stomach (Nsp), vacuity index (VI), and Levin's Measure of Niche Breadth standardized (B) of *Stephanolepis hispidus* in the Canary Islands with regard to size-classes and seasons. Size-range (Ss) for each season / Número de ejemplares (Ns), número de ejemplares con alimento en el estómago (Nsp), el índice de vacuidad (VI), y Medida de Levin de amplitud de nicho estandarizada (B) de *Stephanolepis hispidus* en las Islas Canarias en relación con las clases de tamaño y las estaciones. Rango de tamaño (Ss) para cada estación

		Ns	Nsp	VI	Ss (cm)	B
Size class TL (cm)	< 10.9	26	20	23.1		0.23
	11.0-11.9	22	18	18.2		0.28
	12.0-12.9	52	40	23.1		0.24
	13.0-13.9	84	58	31.0		0.35
	14.0-14.9	116	86	25.9		0.33
	15.0-15.9	145	98	32.4		0.37
	16.0-16.9	143	96	32.9		0.36
	17.0-17.9	100	77	23.0		0.42
	18.0-18.9	67	52	22.4		0.35
	19.0-19.9	33	27	18.2		0.38
	> 19.9	35	27	22.9		0.31
Season	Winter 98	31	26	16.13	9.5-18.7	0.15
	Spring 98	129	91	29.46	9.0-19.5	0.26
	Summer 98	86	66	23.26	8.9-23.3	0.35
	Autumn 98	139	97	30.22	10.1-25.9	0.28
	Winter 99	190	140	26.32	9.1-25.0	0.20
	Spring 99	248	179	27.82	10.6-24.2	0.18

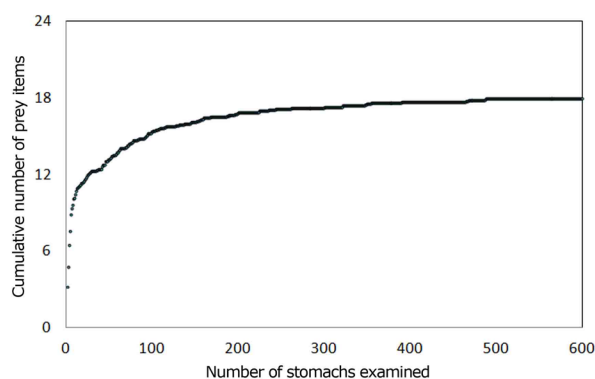


Figure 1. Cumulative prey curve as a function of sample size for all fish with stomach contents analyzed in the diet of *Stephanolepis hispidus* in the Canary Islands / Curva de acumulación de presas en función del tamaño de la muestra para todos los peces con contenidos estomacales analizados en la dieta de *Stephanolepis hispidus* en las Islas Canarias

Table 2. Diet composition of *Stephanolepis hispidus* in the Canary Islands as percentage frequency of occurrence (%F), the percentage of wet weight (%W), and the alimentary importance index (%IA) for all stomachs sampled (n= 599) / Composición de la dieta de *Stephanolepis hispidus* en las Islas Canarias como porcentaje de frecuencia de ocurrencia (%F), porcentaje de peso húmedo (%W), y el índice de importancia alimentaria (%IA) para todos los estómagos muestreados (n= 599)

Items		%F	%W	%IA
Cnidaria	Hydrozoa	63.94	33.19	38.67
Crustacea	Amphipoda	42.57	16.97	17.02
	Decapoda	23.54	6.52	5.25
	Ostracoda	13.86	2.05	1.16
	Cirripeda	2.17	0.72	0.19
	Isopoda	1.00	0.12	0.01
	Copepoda	0.33	0.01	0.00
	Cumacea	0.17	0.00	0.00
Echinodermata	Echinoidea	36.89	11.61	11.68
Algae	Unidentified remains	38.40	10.40	10.03
Mollusca	Gastropoda	39.40	6.61	6.76
	Lamellibranchia	26.04	6.07	5.21
	Cephalopoda	0.33	0.17	0.16
	Polyplocophora	1.84	0.31	0.03
Polychaeta	Unidentified remains	28.38	3.10	2.48
Fish	Unidentified remains	3.34	1.14	0.76
Foraminifera	Unidentified remains	14.69	0.65	0.41
Porifera	Unidentified remains	1.67	0.35	0.18

FOOD IN RELATION TO SEX AND FISH LENGTH

Significant differences were found in the diet composition by sexes with regard to the %IA in relation to the contribution of echinoids (Mann-Whitney, $P= 0.019$), algae (Mann-Whitney, $P= 0.015$), and gastropods (Mann-Whitney, $P= 0.041$), which were higher in males (Table 3). The Mann-Whitney pairwise comparison test indicated differences between size group I (8.9-12.9 cm TL) and group II (fish greater than 12.9 cm TL), where individuals smaller than 12.9 cm TL consumed more gammarid amphipods (Mann-Whitney, $P < 0.001$), and fish larger than this length fed more on echinoids (Mann-Whitney, $P= 0.031$), algae (Mann-Whitney, $P= 0.005$) and lamelibranchs (Mann-Whitney, $P= 0.004$) (Table 3; Fig. 2).

The Levin's Measure of niche breadth increased with fish length and was higher in fish greater than 12.9 cm TL (Table 1), which indicated a tendency toward a more generalist feeding behavior with growth. The cluster analysis based on %IA values of length classes discriminated between two main groups, linked at 83.8% similarity: fish smaller and larger than 12.9 cm TL (with average similarities of 84.7 and 85.4%, respectively) (Fig. 3). The high similarity between both groups indicated that changes in diet composition with growth were slow and gradual. However, the NPMANOVA showed significant differences between the two groups ($F= 6.57$; $P= 0.0001$).

SEASONAL VARIATION IN DIET COMPOSITION

Planehead filefish exhibited seasonal variation in the relative importance of the IA index of their prey items. In spring, the diet was mainly composed of hydroids (%IA= 38.5 and 47.3 in 1998 and 1999, respectively). Amphipods were the main prey during the winter season (%IA= 57.9 and 38.5 in 1998 and 1999, respectively). In summer, the diet was mainly composed of amphipods (%IA= 33.8) and echinoids (%IA= 22.1), and in autumn, it was composed of echinoids (%IA= 32.1) and amphipods (%IA= 22.1). Algae were relatively frequent in spring and summer (Fig. 4).

The NPMANOVA showed significant differences between seasons ($F= 3.30$; $P= 0.0001$), and no significant differences between seasons of overlapping lengths ($F= -97.22$; $P= 0.5691$). However, the Mann-Whitney non-parametric test showed that planehead filefish exhibited a seasonal variation in the IA index of some food categories between the two previously defined length groups. In the spring of 1998, significant differences were found in the diet composition with regard to the %IA, as individuals smaller than 12.9 cm TL consumed more

Table 3. Variation in the alimentary importance index (%IA) of the different prey items in the diet by groups of length and sex of *Stephanolepis hispidus* in the Canary Islands / Variación del índice de importancia alimentaria (%IA) de las diferentes categorías de presas en la dieta por grupos de talla y sexo de *Stephanolepis hispidus* en las Islas Canarias

Food item	Juveniles	Adults	Mann-Whitney <i>P</i> -value	Sex		Mann-Whitney <i>P</i> -value
	< 12.9 cm TL	> 12.9 cm TL		Females	Males	
Hydrozoa	34.91	38.93	0.320	39.98	36.97	0.586
Amphipoda	45.37	13.00	< 0.001	18.35	15.27	0.110
Echinoidea	3.45	12.91	0.031	10.00	13.86	0.019
Algae	3.39	11.07	0.005	9.58	10.61	0.015
Gastropoda	3.71	7.20	0.082	6.16	7.55	0.041
Decapoda	3.93	5.41	0.313	5.88	4.33	0.711
Lamellibranchia	0.62	5.99	0.004	4.53	6.08	0.070
Polychaeta	2.78	2.42	0.936	2.78	2.10	0.449
Ostracoda	1.54	1.13	0.162	1.27	1.01	0.624
Fish	0.06	0.86	0.361	0.33	1.32	0.526
Foraminifera	0.22	0.43	0.389	0.45	0.35	0.024
Cirripeda	0.00	0.22	0.821	0.08	0.35	0.734
Porifera	0.00	0.20	0.218	0.31	0.00	0.298
Others	0.02	0.23		0.30	0.20	

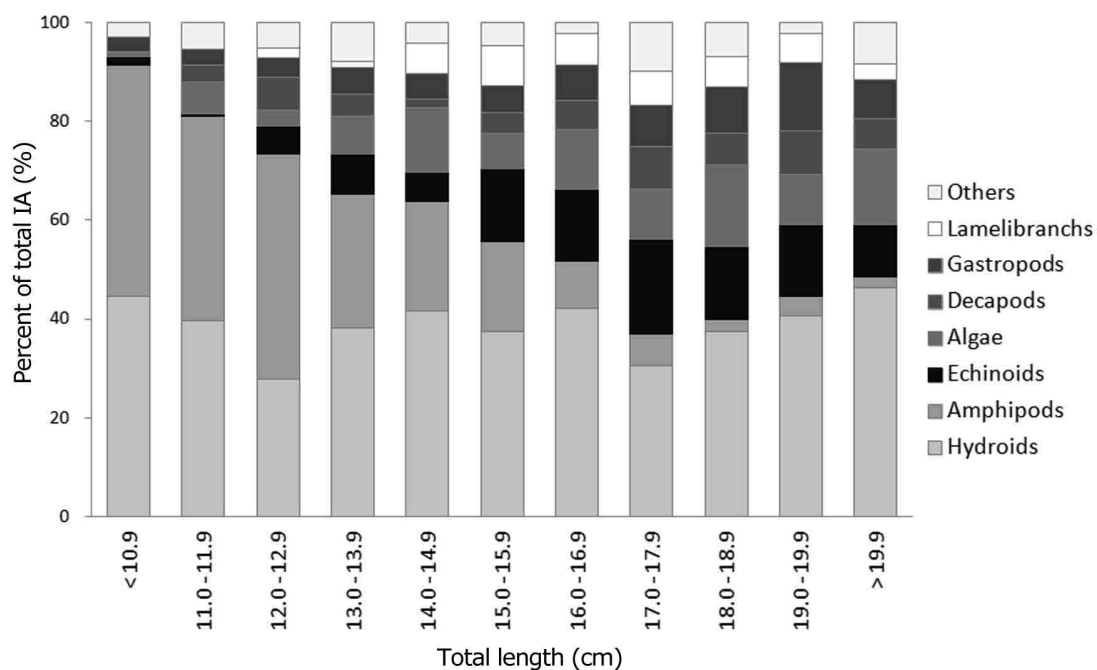


Figure 2. Frequency of the major prey groups in the diet of *Stephanolepis hispidus* by length classes in the Canary Islands (n= 599) / Frecuencia de los principales grupos de presas en la dieta de *Stephanolepis hispidus* por clases de talla en las Islas Canarias (n= 599)

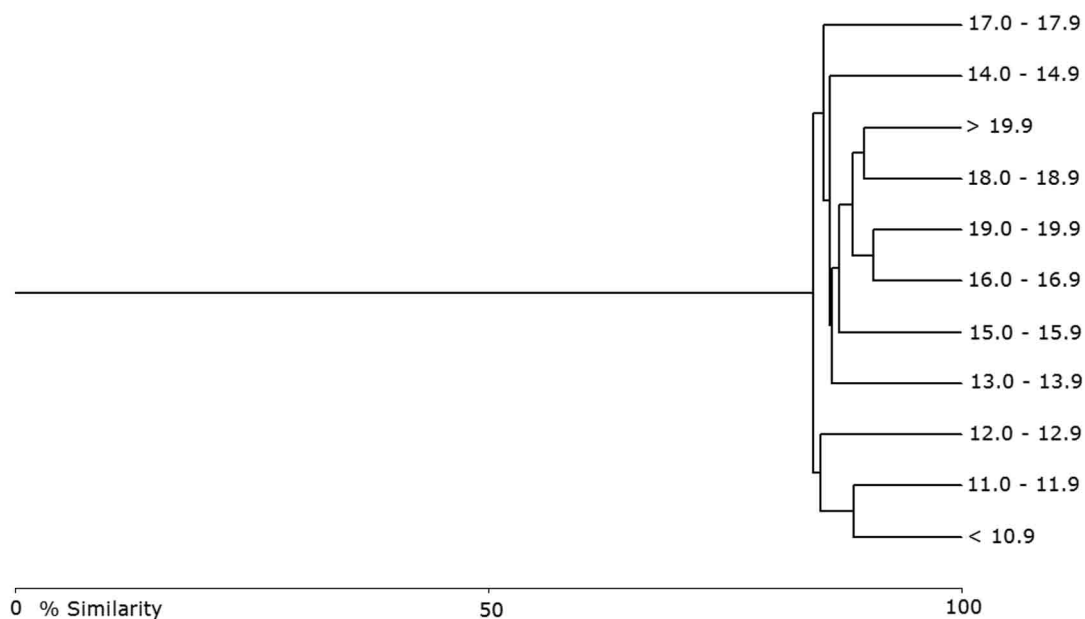


Figure 3. Dendrogram based on alimentary importance index (%IA) values by length classes of *Stephanolepis hispidus* in the Canary Islands / Dendrograma basado en valores índice de importancia alimentaria (%IA) por clases de talla para *Stephanolepis hispidus* en las Islas Canarias

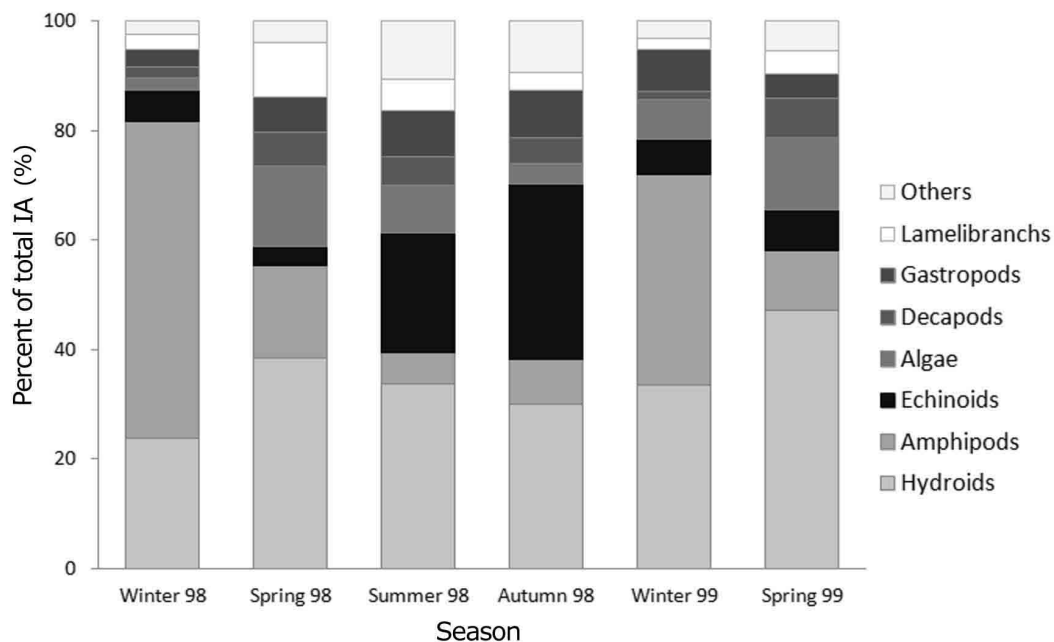


Figure 4. Seasonal variation of *Stephanolepis hispidus* diet in the Canary Islands based on the alimentary importance index (%IA) values of the major prey groups (n= 599) / Variación estacional de la dieta de *Stephanolepis hispidus* en las Islas Canarias sobre la base de los valores del índice de importancia alimentaria (%IA) de los principales grupos de presas (n= 599)

gammarid amphipods (Mann-Whitney, $P=0.002$), less algae (Mann-Whitney, $P=0.041$), and less lamelibranchs (Mann-Whitney, $P=0.011$). In autumn, the individuals smaller than 12.9 cm TL consumed more gammarid amphipods (Mann-Whitney, $P<0.004$), and in winter 1999, more decapods (Mann-Whitney, $P=0.014$) and gammarid amphipods (Mann-Whitney, $P=0.028$) (Table 4).

The cluster analysis revealed the presence of two major food or diet groups (linked at 71.7% similarity; Fig. 5) according to seasons. Group I was that of the winter season, where the amphipods were the predominant prey in the stomach contents (Fig. 4). However, in group II, algae and equinoids were more dominant in the diet. Group II was also composed of two well-defined subgroups (average similarity 74.1%): one that is categorized by a spring diet, where the presence of algae and mollusks were more dominant (average similarity 83.5%), and one that was a summer–autumn diet in which equinoids were highlighted (average similarity 83.5%) (Figs. 4 and 5). On the contrary, the Levin's Measure of niche breadth was less in winter ($B=0.15$ and 0.20 in 1998 and 1999, respectively) and spring 1999 ($B=0.18$). It increased in spring 1999 ($B=0.26$) and autumn ($B=0.28$) and obtained the maximum value for summer ($B=0.35$) (Table 1). The trophic niche breadth indicated a tendency toward a more generalist feeding in summer and autumn.

The Morisita's index showed a high diet overlapping between both length groups (I and II) ($S=0.77$). This diet

overlapping peaked during winter 1998 ($S=0.95$) and spring 1999 ($S=0.93$), with both groups feeding mainly on hydroids and amphipods. In spring 1998 ($S=0.82$) and summer 1998 ($S=0.77$), the diet overlapping was relatively high, as group II showed a decrease in the consumption of amphipods and an increase in the consumption of echinoids, algae, decapods and lamelibranchs. During the winter of 1999, this index was lower ($S=0.69$), with a greater consumption of amphipods and decapods by group I and hydroids, lamelibranchs and gastropods by group II. The lowest value of the Morisita's index was obtained in autumn 1998 ($S=0.68$), with a greater consumption of amphipods and polychaetes by group I and echinoids, algae, lamelibranchs, gastropods and ostracods by group II.

DISCUSSION

The diet of *S. hispidus* was dominated by relatively few prey items, and this species could be considered a macroinvertebrate feeder. The diet of this fish in the Canary Islands (central east Atlantic) was composed of invertebrates and benthic organisms, mainly hydroids, gammarid amphipods, echinoids and algae. Also mollusks (gastropods and lamelibranchs) and decapods were eaten regularly but as secondary prey. The high proportion of sand and shells in the stomach contents of planehead filefish indicated that this species mainly fed on organisms they ingest while stirring up the sediments.

Table 4. Seasonal variation in the alimentary importance index (%IA) of the different prey items in the diet of two main groups of length of *Stephanolepis hispidus* in the Canary Islands / Variación estacional en el índice de importancia alimentaria (%IA) de las diferentes categorías de presas en la dieta de los dos grupos principales de la longitud de *Stephanolepis hispidus* en las Islas Canarias

Food item	Winter 98		Spring 98		Summer 98		Autumn 98		Winter 99		Spring 99	
	I	II	I	II	I	II	I	II	I	II	I	II
Hydrozoa	26.56	22.72	27.38	36.66	57.22	29.81	39.88	28.45	20.72	39.99	51.47	47.01
Amphipoda	70.05	52.15 *	57.88	27.24	12.67	4.43 *	32.71	5.95 *	45.85	14.18	12.05	10.50
Echinoidea	1.38	6.94	1.64	9.28	9.21	24.01	9.81	34.44	0.01	3.75	3.55	7.84
Algae	1.74	2.27 *	2.86	9.55	0.29	10.17	0.16	4.13	12.12	14.95	1.55	13.71
Gastropoda	0.21	4.78	6.14	8.82	6.43	8.75	0.63	9.83	1.92	6.79	1.09	4.59
Decapoda	0.03	2.71	0.61	2.22	0.00	6.33	5.81	4.39 *	15.51	5.34	11.55	7.01
Lamelibranchia	0.00	4.72 *	0.12	3.15	1.53	6.34	0.22	3.42	3.08	10.66	0.48	4.31
Polychaeta	0.00	3.42	3.17	2.93	10.53	4.68	9.60	2.61	0.00	0.44	0.56	3.05
Ostracoda	0.00	0.24	0.00	0.12	1.88	0.41	0.34	3.24	0.00	1.82	12.79	0.50
Others	0.03	0.03	0.19	0.03	0.25	5.07	0.85	3.55	0.79	2.08	4.91	1.48

I= fish with TL of 8.9-12.9 cm, II=fish with TL greater than 12.9 cm. Asterisk indicates group with significantly different Mann-Whitney P -value <0.05

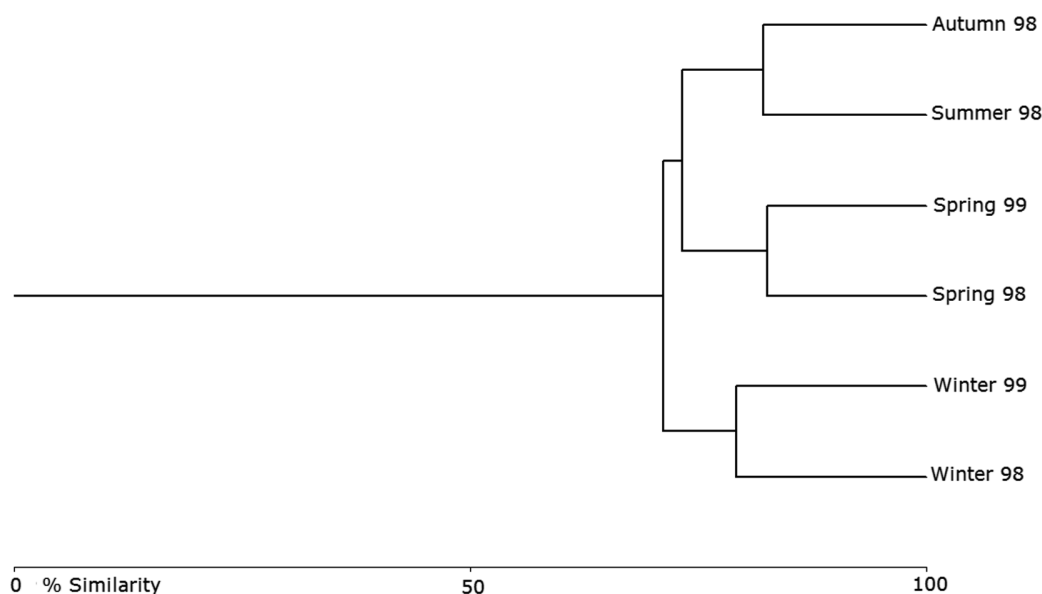


Figure 5. Dendrogram based on alimentary importance index (%IA) values of *Stephanolepis hispidus* diet showing classification by season into main groups / Dendrograma basado en los valores del índice de importancia alimentaria (%IA) por estación de los grupos principales de la dieta de *Stephanolepis hispidus*

The hydroids consumed by the fish were in all of the length ranges available for this study and in all seasons. Hydroids were the most important food item in the diet of *S. hispidus* in this area. This coincided with data reported by Dooley (1972) and Stachowicz & Lindquist (1997), who mentioned that hydroids were consistently found in the guts of planehead filefish caught in pelagic *Sargassum*, while other prey occurred sporadically. Likewise, Hutchinson (2005) studied the predator-prey relationships between *S. hispidus* and shrimp in the pelagic *Sargassum* communities and found that the planehead filefish employed optimal foraging strategies, selecting smaller shrimp first and then larger ones.

Planehead filefish have a relatively small mouth, which can be opened extensively without losing its sharp power (Gregory 1933, Tortonesi 1986). The jaws and teeth are adapted for feeding on hard shell invertebrates (Keenleyside 1979, Last 1983) and for biting off the fronds of algae (Keenleyside 1979). However, the ingested algae (mainly *Caulerpa prolifera*) may be eaten by *S. hispidus* as a consequence of feeding on epibiontic fauna, such as hydroids, gammarid amphipods or gastropods. In this way, Last (1975) also concluded that vegetable items found in the stomach contents of leatherjackets

(*Maushenia australis*, *M. freycineti*, *Penicipelta vittiger* and *Acanthaluteres spilomelanurus*) were ingested accidentally when feeding on amphipods. Similarly, Peristiwady & Geistdoerfer (1991) found that *M. tomentosus* appeared to bite seagrasses and algae together with attached or closely associated organisms, and seagrasses and algae retained their original structure after passing through the gut. Bell *et al.* (1978), Conacher *et al.* (1979) and Wressnig & Booth (2007, 2008) found similar observations for others Monacanthid species in a *Posidonia* spp. seagrass habitat.

In the Canary Islands, Moreno (1999) found that juveniles (3-11 cm TL) of *S. hispidus* fed mainly on amphipods, decapods, mollusks and algae. Similar results were reported by Clements & Livingston (1983) in the waters of Florida for juvenile fish (2-8 cm total TL), where gammarid amphipods, plant matter, lamelibranchs, polychaetes and copepods were the main food items. Additionally, Soares *et al.* (1993) found that this species fed mainly on amphipods (Gammaridae and Hiperiidae) and polychaetes, and foraminiferans, ophiuroids, diatoms, mollusks, ostracods, copepods and hydroids were secondary prey items. Casazza (2008) found that the diet of juveniles (< 6.5 cm of standard length, SL) was

mainly composed of copepods, cnidarians, and amphipods in the *Sargassum*, and Casazza & Ross (2008) found mostly lobate ctenophores. Ballard & Rakocinski (2012) found that juveniles often fed on hydroids and bryozoans associated with *Sargassum* and also on polychaetes, crustaceans and zooplankton.

Others species of monacanthids had similar diets. The diet of *S. diaspros* consisted of a wide variety of items, with crustaceans, mollusks, algae, and echinoderms (particularly sea urchins) being the dominant food items and sea sponges, hydroids, foraminifera, fish and bryozoans the secondary food items (Zouari-Ktari *et al.* 2008, El-Ganainy & Sabrah 2013). Peristiwady & Geistdoerfer (1991) reported that the food of *Monacanthus tomentosus* in Indonesia consisted primarily of gastropods, sea grasses, sponges, algae, amphipods and sedentary polychaetes. Bell *et al.* (1978) and Kim *et al.* (2013) found that the black scraper, *Tamnaconus modestus*, in the southern sea of Korea fed on hyperiid amphipods, gastropods, ophiuroids, and algae.

In the Canary Islands, the low values of the vacuity index indicated that feeding intensity was high, independent of the growth stage or seasons of the year. However, the higher percentage of empty stomachs found in females may be related to the vulnerability of females to fish traps, staying there longer and consuming a greater amount of food items. However, in general, species of the Monacanthidae family have low values of the vacuity index (Peristiwady & Geistdoerfer 1991, Kwak *et al.* 2003, Kim *et al.* 2013).

As *S. hispidus* grows, it shows changes in the diet. Juveniles consumed more amphipods, and individuals larger than adults preyed more on echinoids, algae and lamelibranchs. The more diversified diet exhibited by the large specimens suggested that large individuals exploited a broader range of prey. This ontogenetic change was associated with morphological and maturational processes, particularly the increase in mouth size and the start of reproductive activity (Mancera-Rodríguez 2000, Mancera-Rodríguez & Castro-Hernández 2015). In this way, Ballard & Rakocinski (2012) also found ontogenetic shifts in the diet of juveniles of *S. hispidus* that appeared at a threshold length of approximately 30 mm SL, when the large size class began to feed on decapod crustaceans. The ontogenetic switch in feeding habits is a general phenomenon among fish as a result of increasing body size (Stoner & Livingston 1984, Castro & Hernández-García 1995, Labropoulou *et al.* 1997, Platell *et al.* 1997,

Morato *et al.* 2000, Schafer *et al.* 2002, Xue *et al.* 2005). The increase in the body and mouth size enables fish to capture a broader range of types and prey sizes and could reduce competition between smaller and larger individuals (Grossman 1980, Langton 1982, Harmelin-Vivien *et al.* 1989). The ontogenetic changes in diet were reported in other monacanthid species, such as *S. diaspros* (Zouari-Ktari *et al.* 2008, El-Ganainy & Sabrah 2013), *Monacanthus tomentosus* (Randall 1975, Bell *et al.* 1978, Peristiwady & Geistdoerfer 1991), and *Tamnaconus modestus* (Kim *et al.* 2013). In all of these studies, the food diversity increased with fish size.

Planehead filefish exhibited seasonal variation in the importance of the different food categories. The trophic niche breadth was less in winter, increased in spring and obtained the maximum value during summer and autumn, which indicated a tendency toward more generalized feeding during warmer months. Moreover, there was an important diet overlap between juvenile and adult planehead filefish during the year. Food specialization and trophic niche breadth are a result of the evolutionary development of the feeding behavior, morphology and mouth structure, which interact with the size, distribution and abundance characteristics of certain types of prey (Labropoulou *et al.* 1997). The observed seasonal changes in the relative importance of preferred prey can reflect the fluctuations of the available prey in the environment. However, prey availability is not only a function of its abundance in the habitat but also of its size, behavior, density and the relative abundance of the preferred prey items in exploited habitats (Moore & Moore 1976, Labropoulou *et al.* 1997, Piet *et al.* 1998, Gibson *et al.* 2002). However, the changes in the diet indicated that the planehead filefish exhibited some degree of selectivity in their feeding habits because they exploited relatively few items, mainly hydroids, gammarid amphipods, and echinoids.

Trophic ontogeny in planehead filefish proceeds as a continuum of dietary changes rather than by the distinct segregation of food resources between length classes. In this way, Labropoulou *et al.* (1997) found that large *Mullus surmuletus* were able to capture relatively larger prey, despite the morphological constraints such as the small mouth size. However, the morphological limitations imposed certain restrictions in the foraging behavior that frequently confined the diet to small benthic animals. In this way, juvenile *S. hispidus* seemed to be more dependent on hard substrates (reefs, etc.) or seagrass beds, where hydroids and gammarid amphipods were

abundant. On the contrary, adult fish were able to feed on many other items that were available not only near reefs or seagrass beds but also at sandy and muddy areas, where grooved burrowing urchins are frequently found (Pérez-Sánchez & Moreno-Batet 1991). Indeed, juveniles were more frequent in catches from shallower waters than adults (Mancera-Rodríguez 2000). It is likely that the previously described ontogenetic change and the significant increase in echinoid consumption during the summer and autumn may be related to the displacement of planehead filefish adults to deeper waters after spawning (Mancera-Rodríguez & Castro-Hernández 2015), where some species of sea urchins, such *Diadema antillarum*, increase in density in the Canary Islands (Tuya *et al.* 2007).

In the same way, the abundance of larger specimens of *S. hispidus* in catches of the small-scale fisheries of the Canary Islands increased as the catch depth increased. At depths shallower than 18 m, only 15.25% of the planehead filefish were larger than 17 cm in TL. However, at between 19 m and 27 m depths, the proportion of these large fish increased to 36.25%, and at between 28 m and 42 m depth, their proportion increased to 51.06% of the *S. hispidus* caught (Mancera-Rodríguez 2000). It is well known that most demersal fish species have a tendency to displace to deeper waters as fish become adults (Cushing 1976). Juvenile stages occur in shallower, warmer waters, while older fish are more frequently found at greater, colder depths, where they may benefit from the lower metabolic cost and greater longevity (MacPherson & Duarte 1991).

In conclusion, the planehead filefish exhibited some degree of selectivity in their feeding habits because they exploited relatively few items, mainly hydroids, amphipods, echinoids and algae. We found an ontogenetic diet variation where individuals greater than 12.9 cm consumed more echinoids, algae and lamelibranchs. We also found seasonal variations that showed an increased consumption of sea urchins in summer and autumn seasons, indicating that this fish species play an important role in controlling the populations of these invertebrates in the shallow rocky areas of the Canary Islands.

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