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## Trabajo de Fin de Máster del Máster Universitario en Acuicultura (UB-UAB-UPC), Curso 2013-2014

Biology and trophic ecology of *Notacanthus bonaparte* and *Polyacanthonotus rissoanus*  
(Pisces: Notacanthidae) in the Balearic Basin.  
(Western Mediterranean).

Trabajo realizado en:

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Trabajo Final de Máster

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## RESUMEN

En este estudio se examina la estructura poblacional, biología, composición de la dieta y la ecología trófica de *Notacanthus bonaparte* y *Polyacanthonotus rissoanus* en la Cubeta Balear (Mediterráneo Occidental) a escala estacional y en profundidades desde los 579 hasta los 2174. El Centro de Gravedad (CoG) calculado situó la población de *N. bonaparte* en el talud intermedio (942m) y a *P. rissoanus* a (1680m), el talud inferior. Los individuos de mayor talla encontrados a mayor profundidad, coincidiendo con los altos valores del índice hepatosomático (GSI) sugieren que el periodo reproductivo en ambas especies se relaciona con la migración de los adultos hacia aguas mas profundas. El periodo reproductivo en *N. bonaparte* se produciría a finales del verano y durante otoño. Por otro lado el periodo reproductivo de *P. rissoanus* ocurriría durante los meses de verano. La dieta de *N. bonaparte* estaba basada en principalmente en organismos sésiles de tipo bentónico, como actinias, el coral *Isidella elongata* y equinodermos. Se observaron algunas diferencias en la composición de la dieta en relación a la profundidad y se observaron ligeras diferencias en las presas consumidas según la estacionalidad, en relación a los periodos de homogenización y estratificación. La diversidad de la dieta ( $H'$ ) y la *fullness* ( $F$ ) muestra correlación con variables ambientales, con una importante relación con los niveles de clorofilas en superficie y las descargas de ríos de dos a tres meses antes de la recolección de las muestras. Esto pone de manifiesto la importancia del aporte de materia orgánica de origen costero y desde la superficie para los recursos alimenticios de *N. bonaparte*. La dieta de *P. rissoanus* se basaba en crustáceos y poliquetos epibentónicos y suprabentónicos, revelando a ésta especie como un predador eurifágico. Su dieta se componía principalmente de poliquetos del género *Harmothoe* y crustáceos del género *Apseudes*. No se encontraron diferencias apreciables en la composición de la dieta en relación a la profundidad. Tampoco cambios en la dieta relacionado con los periodos de homogenización y estratificación, dado el ambiente mas profundo y estable que ésta especie habita. Se encontraron valores experimentales inesperadamente altos en la actividad de la enzima lactato deshidrogenasa, comparados con los de otras especies de peces del mar profundo.

## ABSTRACT

This study examines the population structure, biology, diet composition and feeding ecology of *Notacanthus bonaparte* and *Polyacanthonotus rissoanus* in the Balearic Basin (north-west Mediterranean) from depth of 579 to 2174 m and at seasonal scale. Centre of Gravity (CoG) situate *N. bonaparte* population at the middle slope (942m) and at the lower slope (1680m) for *P. rissoanus*. Bigger size individuals at deeper depth coinciding with high values of gonadosomatic index (GSI) suggested that the reproductive event in both species is related with adults migration to deeper waters. Reproductive season for *N. bonaparte* occurs to the late summer and autum. For *P. rissoanus* reproduction occurs during summer. *N. bonaparte* diet based mainly in sessile benthic organisms as actinians, *Isidella elongata* corals and echinoderms. Some differences in the diet composition in relation to depth ranges was observed. Few differences in items consumed by seasonality in relation to stratification and homogenization periods was observed. Diet diversity ( $H'$ ) and fullness ( $F$ ) of this species was correlated with environmental variables, showing an important relation with chlorophyll values and river discharges two and three months before sample collection. It shows the influence of coastal and surface fall of organic matter in *N. bonaparte* diet source. Diet

of *P. rissoanus* was based on epibenthic and suprebenthic crustaceans and polychaetes, revealing this species as an euryphagic predator. Diet was mainly composed of polychaetes of the *Harmothoe* genus and crustaceans of the *Apseudes* genus. Not appreciable differences in diet composition in relation to depth was observed. Not appreciable seasonal changes in the diet related with homogenization or stratification periods was observed, given the more deeper and more stable environment where this species inhabits. Lactate dehydrogenase activity values obtained by experimental procedures showed high values as expected for this species compared to other deep sea fish species.

## INTRODUCTION

The deep Mediterranean has been considered as a natural laboratory (Margalef, 1985), where temperature and salinity remains stable under 150m. A characteristic feature of the Mediterranean deep-sea megafauna is the numerical importance (in terms of abundance and number of species) of decapod crustaceans which together with fish, are the dominant taxa in deep Mediterranean assemblages (Cartes, 1993). Fish assemblages on the Western Mediterranean slope was described as upper (350-650m), middle (1000-1425m) and lower slope (1425-2250m) (Stefanescu et al., 1993; 1994).

Food input to the deep-sea can be in large seasonal pulses of phytodetrital material that occur weeks to months after phytoplankton blooms in the surface waters (Billett et al., 1983; Lampitt, 1985; Tyler, 1988; Smith et al., 1994). This is the case of the deep Mediterranean Sea, where, despite it is considered a fairly constant physical environment (Hopkins, 1985), marked temporal oscillations in food availability and resource use for deep-sea species have been observed (Cartes & Carrasón, 2004; Fanelli & Cartes, 2008). These ought to drive the biological cycles of deep-sea species, thus reproduction timing responds to the natural fluctuations in environmental factors (Gage & Tyler, 1991) both at a seasonal (Tsikliras et al., 2010) or bathymetric scale. The relationship between biological cycles and food availability on the middle slope of the NW Mediterranean Sea has been well established for macrofaunal groups (Cartes and Sorbe, 1996; 1998; Cartes, 1998) and for deep-sea shrimps, whose biological cycles were related to vertical fluxes of organic matter reaching bathyal depths (Puig et al., 2001; Cartes et al., 2008). Nonetheless this issue remains largely unexplored in deep-sea benthopelagic fish (Drazen, 2002; Papiol 2013).

Notacanthidae family is represented by two species in the Mediterranean Sea, Shortfin spiny eel (*Notacanthus bonaparte*) and Smallmouth spiny eel (*Polyacanthonotus rissoanus*). (Lozano Cabo, 1952; Gallego & Ibañez, 1974; Sulak et al., 1984; Stefanescu et al 1992a, b; D'Onghia, 2004). Anatomy and phylogeny of notacanthid fish have been described and revised (McDowell, 1973; Greenwood, 1977; Sulak et al., 1984). The characteristic shape and anatomy of these fishes difficult retention by commercial deep-water trawls (Gordon et al., 1996; Cartes et al., 2009a).

*Notacanthus bonaparte* coexists with *Polyacanthonotus rissoanus* down to 1900m depth in the Catalan Sea (Stefanescu et al., 1992a). The diet of *N. bonapartei* has been studied in the Atlantic, ranging depths from 250 to 2500m (Coggan et al, 1998). In Mediterranean waters, only on the upper slope (until 800m) (Lozano Cabo, 1952; Macpherson, 1981). It reveals this species as a generalized benthic feeder whose diet seems to be based in ophiuroids, hydrozoans and briozoans. (Lozano Cabo, 1952; Macpherson, 1981; Coggan et al, 1998).

The diet of *P. rissoanus* has been studied in the Atlantic, ranging depths from 250 to 3000m. (Coggan et al, 1998). And in the Mediterranean between 1000 and 2250m depth (Carrassón & Matallanas; 2002). It show this species as a benthopelagic feeder, consuming crustaceans and polychaetes as a preferential prey. (Coggan et al, 1998; Carrassón & Matallanas; 2002).

This marked differences in trophic diversity and feeding strategy could avoid competition between both species ( Carrassón & Matallanas; 2002). Also the presumable selective diet of *N. bonaparte* allows this species to exploit resources hardly consumed by other deep-sea fishes in the Mediterranean (Carrassón & Cartes; 2002).

For the better understanding of the role of Notacanthids in Mediterranean deep-sea ecosystems more information is needed. In this context, the objectives of this study were: I) get an accurate description of the diet of the two species inhabits in the Balearic basin (deep Mediterranean); II) to give insights on the population structure and the trophic ecology of both species in the entire bathymetric range at seasonal scale; III) To link this information with changes in food availability and environmental variables.

## **MATERIAL AND METHODS**

### **STUDY AREA AND SAMPLING COLLECTION**

All material were collected in the continental slope of the Catalan Sea in the Balearic basin (northwest Mediterranean). During 5 cruises in the framework of projects: BIOMARE, ANTROMARE and PRETREND, a total of 47 multidisciplinary (including trawl) surveys were carried out from 2008 to 2012. Cruises performed during winter and spring, summer and autumn, coinciding with seahomogenization and stratification periods (Table 1.).

The benthopelagic megafauna were obtained by trawling the seafloor using a semi-balloon otter trawl (OTSB14) (Merrett & Marshall, 1981). Hauls were performed on board of the oceanographic vessel *García del Cid*. OTSB-14 consists in a one-warp trawl with mesh-size at the cod end of 6 mm, the bridles are 8m long, the vertical height of the opening is 1,2 m and the horizontal opening is 13,5m (from a SCANMAR records; a control system made of different sensors that are placed on the doors and centre of the trawl net).

For environmental variables casts were performed with an SBE-32 CTD at the same locations as those where biological samples were collected. Temperature, salinity, oxygen concentration and turbidity were measured. Values were recorded for each CTD profile at 5 m above the sea bottom. Historical chlorophyll surface data were downloaded from radiometry satellite data from a National Aeronautics and Space Administration (N.A.S.A.) web page, Giovanni database, ([http://gdata1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance\\_id=ocean\\_month](http://gdata1.sci.gsfc.nasa.gov/daac-bin/G3/gui.cgi?instance_id=ocean_month)).

For historical river water discharges, capacity river were downloaded from *Agència Catalana de l'Aigua ( A.C.A )* and *Confederación Hidrográfica del Ebro ( CHEbro)* web pages ( <http://acaweb.gencat.cat/aca/appmanager/aca/aca/> , <http://www.chebro.es/> )

**Table 1.** Sampling data of *Notacanthus* and *Polyacanthonotus rissoanus* from B, Biomare; A, Antromare and PT, Pretrend cruises.

Station	Date	Depth (m)	Final situation	No. of specimens	
				<i>N. bon</i>	<i>P. riss</i>
B-051	24/02/2008	1094	41°06.898 N 02°26.180 E	5	—
B-052	24/02/2008	1296	41°07.648 N 02°36.072 E	2	3
B-053	25/02/2008	1656	40°57.992 N 02°32.801 E	—	1
B-054	25/02/2008	1503	41°01.403 N 02°31.627 E	1	0
B-055	26/02/2008	997	41°08.270 N 02°28.570 E	14	1
A-102	07/07/2010	631	41°10.580 N 02°23.760 E	8	—
A-103	08/07/2010	1000	40°58.790 N 02°07.720 E	23	—
A-104	08/07/2010	1024	40°58.419 N 01°57.940 E	57	—
A-105	10/07/2010	1269	40°55.270 N 02°09.500 E	10	2
A-106	10/07/2010	1308	40°52.940 N 02°00.560 E	7	1
A-107	11/07/2010	579	41°07.800 N 02°06.530 E	2	—
A-108	11/07/2010	580	41°07.800 N 02°06.490 E	8	—
A-109	12/07/2010	1744	40°38.220 N 02°02.140 E	2	—
A-110	12/07/2010	1794	40°28.870 N 02°06.080 E	4	—
A-112	13/07/2010	1400	41°06.139 N 02°34.900 E	1	—
A-115	17/07/2010	650	39°48.880 N 02°22.490 E	11	—
A-118	19/07/2010	1060	39°53.700 N 02°22.060 E	1	1
A120	20/07/2010	1609	40°05.860 N 02°05.090 E	2	3
A-121	20/07/2010	1477	40°06.330 N 02°13.720 E	—	1
A-122	21/07/2010	1900	40°20.290 N 02°43.120 E	1	—
A-124	22/07/2010	2198	41°53.166 N 02°11.286 E	2	21
A-201	18/06/2011	646	40°34.518 N 01°26.405 E	13	—
A-202	18/06/2011	642	40°35.349 N 01°26.590 E	2	—
A-203	18/06/2011	615	40°35.251 N 01°26.402 E	2	—
A-204	19/06/2011	627	40°54.570 N 01°35.123 E	2	—
A-205	19/06/2011	628	40°55.179 N 01°35.191 E	1	—
A-206	19/06/2011	648	40°54.509 N 01°35.298 E	3	—
A-207	20/06/2011	620	40°41.486 N 01°26.409 E	7	—
A-208	20/06/2011	632	40°41.381 N 01°26.424 E	17	—
A-210	22/06/2011	624	40°40.425 N 01°26.461 E	4	—
A-211	23/06/2011	1043	40°50.567 N 01°44.054 E	24	—
A-212	23/06/2011	1060	40°53.098 N 01°44.041 E	30	1
A-213	23/06/2011	1052	40°55.584 N 01°48.427 E	43	—
A-301	14/10/2011	661	41°05.315 N 02°11.535 E	10	—
A-302	14/10/2011	581	41°08.000 N 02°05.257 E	52	—
A-303	15/10/2011	1051	40°53.122 N 01°43.418 E	30	4
A-304	15/10/2011	1236	40°44.492 N 01°38.544 E	2	8
A-305	16/10/2011	1516	40°48.484 N 01°44.467 E	1	—
A-306	16/10/2011	1750	40°09.010 N 01°57.397 E	14	7
A-309	17/10/2011	1057	39°23.210 N 01°20.488 E	2	3
A-310	18/10/2011	1272	39°25.330 N 01°19.221 E	—	4
A-311	19/10/2011	1626	39°56.280 N 01°38.269 E	—	11
A-312	19/10/2011	1415	39°47.550 N 01°45.481 E	1	4
A-313	21/10/2011	1549	40°08.324 N 01°37.528 E	2	10
A-314	22/10/2011	1028	40°58.561 N 02°00.413 E	43	3
A-401	26/05/2014	1100	41°06.539 N 02°27.200 E	—	2
PT-01	03/05/2012	1014	41°08.988 N 02°28.885 E	2	11
PT-02	04/05/2012	2174	41°05.550 N 03°22.760 E	1	17
PT-03	05/05/2012	1389	41°03.470 N 02°31.840 E	—	7

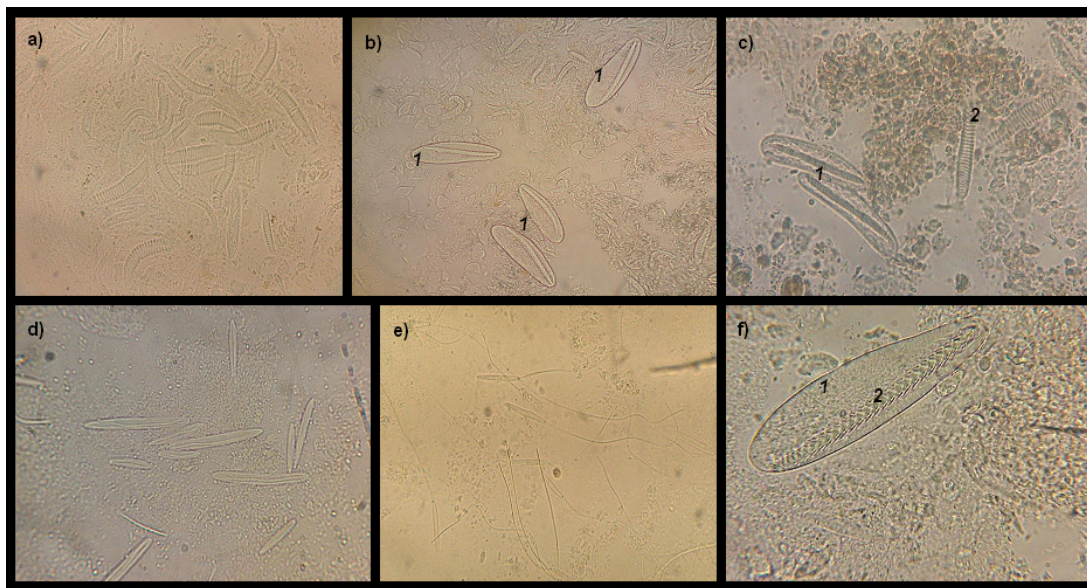
#### ANALYSES OF STOMACH CONTENT AND BIOLOGICAL PARAMETERS

A total of 469 *Notacanthus bonaparte* and 126 of *Polyacanthonotus rissoanus* were obtained. All the specimens, previously frozen on board after capture, were transported to the laboratory, for subsequent analyses.

Each specimen were defrosted and then measured to the nearest mm ( total length =TL ) and weighed to the nearest g ( total wet weight =TW ). After that, fish were dissected and the gonads and liver removed and weighed.

Stomachs, 279 for *N. bonaparte* and 108 for *P. rissoanus*, were dissected and the content examined under a stereoscopic binocular (X10 to 40) or microscope (X100 to X1000). Food items were identified to species or the lowest taxonomic level possible. Numbers and weights of food items were recorded using a 10<sup>-5</sup>g precision balance after drying with blotting paper to remove the surface moisture. Actinians in stomach content were found in some cases, as the complete organism, but sometimes only a gelatinous mass were found. In these cases actinian identification was possible by *cnidae* identification under the microscope (600-1000X). Spirocists and mastigophores found in gelatinous remains were compared with complete specimen *cnidae*. ( Fig. 1.).

**Figure 1.** Squashes of gelatinous stomach contents where actinian *cnidae* was observed at microscope. Spirocists (a) and (c,2) (600x). Mastigophores (b) and (c,1). Undischarged mastigophores (d) and discharged mastigophores (e). Detail of a mastigophore f) (1.000x), capsule (f,1), dart (f,2).



#### LACTATE DEHYDROGENASE ANALYSES

A portion of the muscle, about 0.5-0.3 g, was used for lactate dehydrogenase (LDH) activity determinations. The tissue was homogenised in a 50 Mm buffer phosphate pH 7.4 in a 1:5 (w:v) ratio using a polytron® blender. The homogenate was centrifuged at 10,000 g×30 min and the supernatant (S10) was used for biochemical determinations. For the LDH determination, 150 µl of NADH solution in phosphate buffer was mixed with 25 µl of 1:40 diluted sample and 50 µl of pyruvate solution in each microplate well. LDH activity was given by the amount of pyruvate consumed due to NADH oxidation at 340nm (Vassault, 1983). In both determinations, reading was carried out in triplicate in a microplate reader (TECAN Infinite 200) during 5 min at 25 °C. Activity was expressed in nmol/min/mg protein. Total protein content in the S10 fraction was determined by Bradford (1976) method using bovine serum albumin standard (BSA 0.1–1 mg/ml).

#### DATA ANALYSIS

Abundances and biomasses of both species were standardized to a common swept area of 1 ha (individuals / ha), according to the value proposed by Cartes *et al.* (2009a). It was assumed that specimens collected did not routinely travel upslope and downslope at the time-scaling of sampling and it were resident in the catching zone. The TL distributions of both species were plotted in relation

to depth in three strata, as upper slope; 350-650m (US), middle slope; 1000-1425m (MS) and lower slope 1425-2250m (LS). Winter, spring, summer and autumn seasonality, homogenization and stratification periods were considered in plots too. The centre of gravity (CoG) (Daget, 1977) was estimated to determine the depth of maximum occurrence in the two species.

Diet diversity based on the Shannon-Wiener  $H'$  index for any sample were calculated. Stomach fullness (F) was calculated using the total stomach content weight (CW); ( $F = (CW/TW) \times 100$ ) (Hyslop, 1980). The gonadosomatic index and hepatosomatic index were calculated, ( $GSI = (GW/TW) \times 100$ ); ( $HIS = (LW/TW) \times 100$ ) respectively, to describe fish physiological condition. Data were tested for normality using the Kolmogorov-Smirnov test. For data that did not satisfy the assumptions of normality non-parametric Kruskal-Wallis test were used to determine differences in biological indices by depth and season.

To identify changes in diet among seasonality and depth ranges, a one-way PERMANOVA was performed on the standardised and  $\ln(x+1)$ -transformed biomass data using Bray-Curtis similarity index. To illustrate observed similarities or dissimilarities (distances) between groups resulting from cluster analyses, multidimensional scaling (MDS) analysis was carried out on the same data matrix.

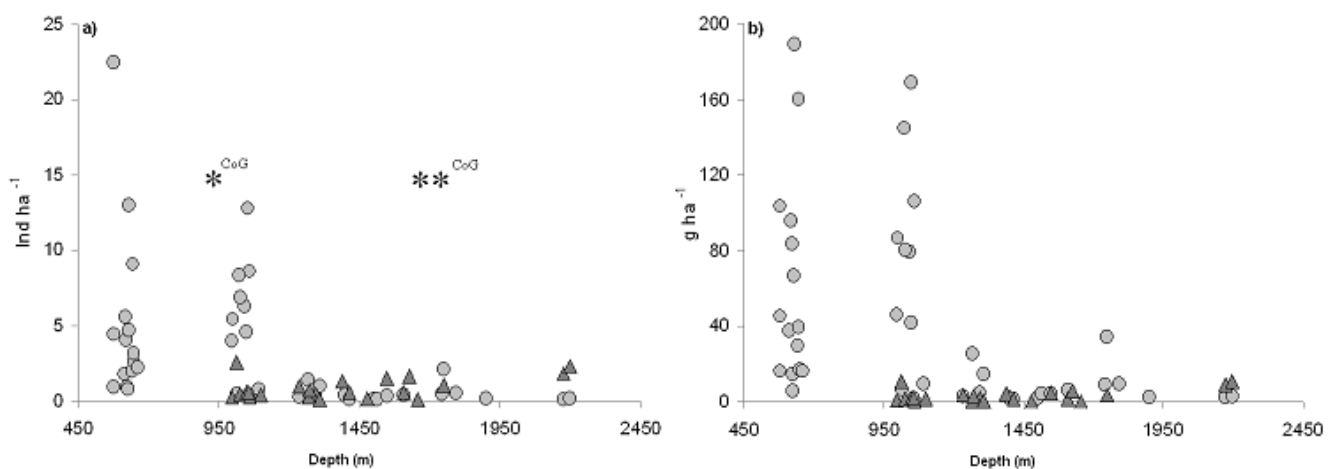
SIMPER analysis was performed to identify characteristic prey of each depth range and seasonal time to calculate the degree of similarity among depth ranges and season.

In order to identify which variables explained patterns of fullness and diet diversity the values of fullness were compared with environmental data by means of generalized linear models (GLM) and non-parametric Spearman rank correlation.

All statistical analyses were performed using PRIMER6 and PERMANOVA+ (Clarke and Warric, 1995), R 2.14.2 (<http://www.r-project.org/>) and STATISTICA 6.

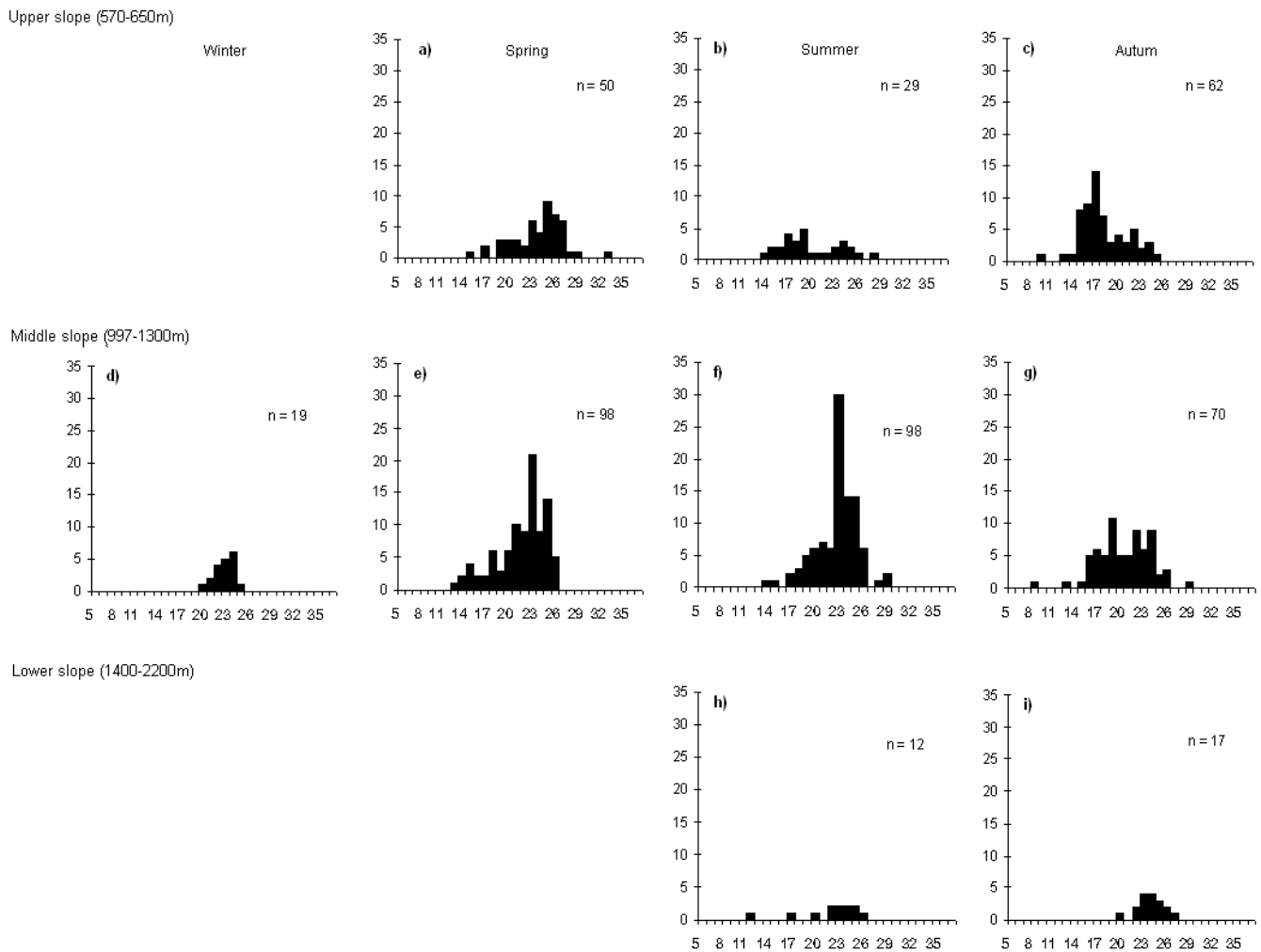
## RESULTS

From specimens of *Notacanthus bonaparte* obtained in 46 hauls, higher abundance and biomass was concentrated from 579 to 1050 m. Both, decrease sharply from 1200 to 2198m. Centre of gravity (CoG) calculated for the species showed 942 m as the preferent location for the population. (Fig. 2.)



**Figure 2.** Abundance (a) in terms of  $\text{ind ha}^{-1}$ , biomass (b)  $\text{g ha}^{-1}$  of *Notacanthus bonaparte* (○) and *Polyacanthonotus rissoanus* (▲). Centre of gravity (CoG) of *Notacanthus bonaparte* (\*) and *Polyacanthonotus rissoanus* (\*\*).



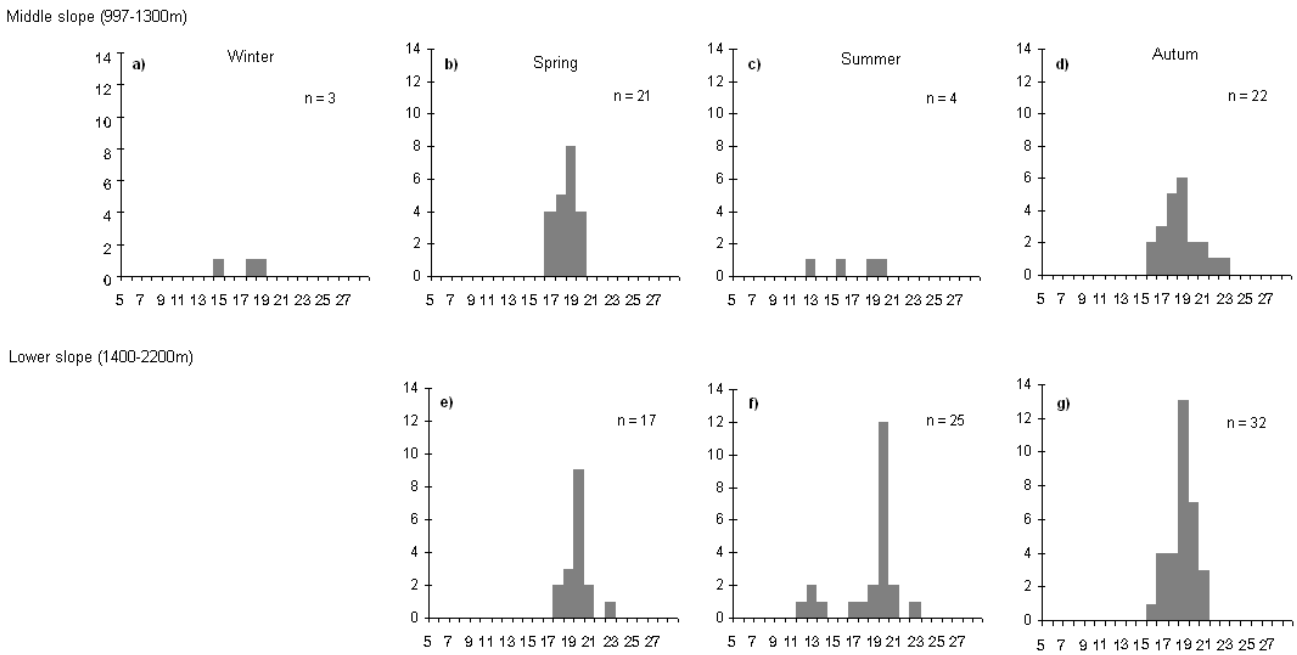


**Figure 3.** Seasonal total length distribution of *Notacanthus bonaparte* across three bathymetric ranges upper slope (570 to 650m), middle slope (997 to 1300m) and lower slope (1400 to 2200m).

From the total of individuals of *Polyacantonus rissoanus* were obtained in 23 hauls ranging depths from 997 to 2198m. No specimens were obtained at shallower depths. Abundance trended to increase with depth. Centre of gravity (CoG) calculated for this species locates preferent depth of the population in 1680 m. Both species coexists down to 2198m. (Fig. 2.)

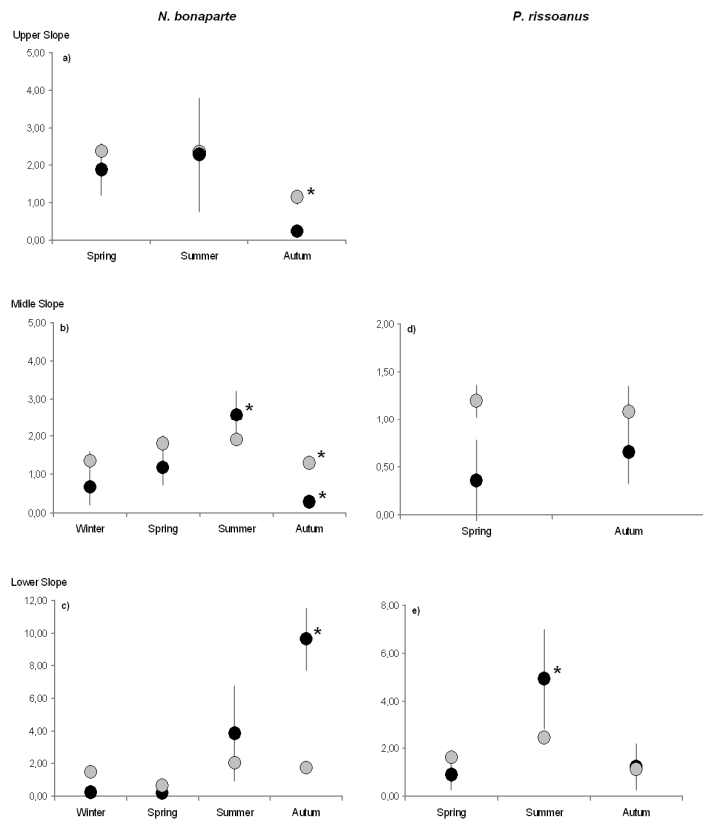
Modal size of *N. bonaparte* was 22 cm (TL). It was mainly observed at intermediate depths of the distribution range between 997 to 1300 m (Fig. 2. e – f.) along all year except in autum where a peak of smaller individuals ranging 16 to 18 cm (TL) appeared in frequency giving a bimodal population trend. (Fig. 3. g.)

At shallowest depth range, between 579 to 650 m, bimodal size population trend was observed in summer (Fig. 3. b.) and size frequency in spring and autum was dominated by bigger (24 cm TL) and smaller (16 cm TAL) individuals respectively. (Fig. 3. a and c.) At deeper stations, from 1400 to 2200, individuals ranging 22 to 28 cm (TL) were observed. *N. bonaparte* population showed a marked trend, where bigger sizes tends to be found at deeper stations, while smaller ones were placed at shallower waters in summer and autum. Overall, higger number of individuals were found at middle depths (Fig. 3. h and i).



**Figure 4.** Seasonal total length distribution of *Polyacanthonotus rissoanus* across two bathymetric ranges, middle slope (997 to 1300m) and lower slope (1400 to 2200m).

For *P. rissoanus* modal size was 18 cm (TL). Not appreciable trend was found neither along depth nor season. Higger number of individuals was collected at the deepest station, from 1400 to 2250 m (Fig. 4. e – g.).



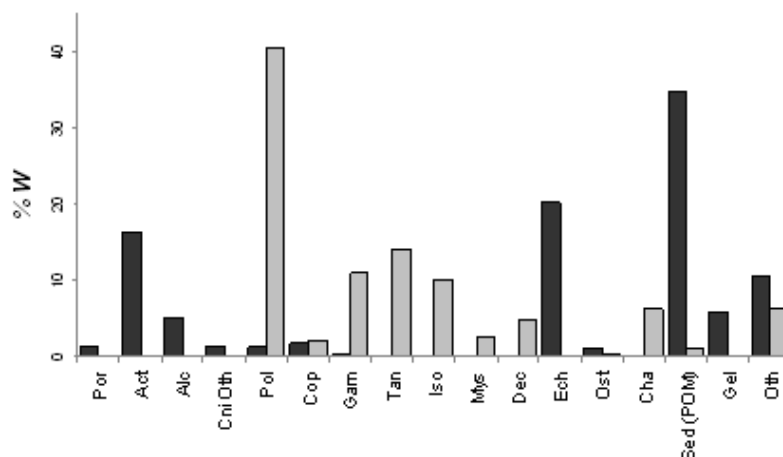
**Figure 5.** Seasonal variations of the gonadosomatic index (●) and hepatosomatic index (○) in *Notacanthus bonaparte* (a), (b) and (c) and *Polyacanthonotus rissoanus*. (d) and (e). Across three depth ranges, upper, middle and lower slope.

*N. bonaparte* hepatosomatic index showed an opposite trend to the gonadosomatic index in the lower slope (Fig. 5. c.) while it seems to be parallel in the upper and in the middle slope (Fig. 5. a and b.). No significant differences between depth in the hepatosomatic index were observed, K-W<sub>test</sub> (  $H_{2,362} = 1,84$   $p > 0.05$  ). Gonadosomatic index was significantly higher in lower slope than in other depths, K-W<sub>test</sub> (  $H_{2,23} = 29,87$   $p < 0.001$  ), i.e. specimens reached maturity when migrated deeper.

In the upper and middle slope HSI values were lower in autumn, K-W<sub>test</sub> (  $H_{2,111} = 52,25$   $p < 0.001$  ), K-W<sub>test</sub> (  $H_{3,220} = 31,03$   $p < 0.001$  ) but not showed differences in the lower slope, K-W<sub>test</sub> (  $H_{2,31} = 7,62$   $p > 0.05$  ). HSI was higher at upper and middle than lower slope always, in general GSI showed higher values in lower slope in autumn, K-W<sub>test</sub> (  $H_{2,30} = 14,49$   $p < 0.001$  ). Significant differences were observed between seasons in the middle slope, K-W<sub>test</sub> (  $H_{3,159} = 53,00$   $p < 0.001$  ) but no significant differences in the upper slope, K-W<sub>test</sub> (  $H_{2,30} = 14,49$   $p > 0.05$  ).

HSI in *P. rissoanus* showed an opposite trend to de GSI in the middle slope and parallel in the lower slope (Fig. 5. d and e.). Significant difference between depths was observed in both indices showing higher values in lower slope, HSI K-W<sub>test</sub> (  $H_{1,109} = 13,34$   $p = .0003$  ), GSI K-W<sub>test</sub> (  $H_{1,70} = 17,12$   $p < 0,001$  ). No seasonal significant difference in the HSI or GSI in the middle slope K-W<sub>test</sub> (  $H_{1,39} = 0,85$   $p > 0,05$  ), K-W<sub>test</sub> (  $H_{1,18} = 1,90$   $p > 0,05$  ). In the lower slope HSI showed higher values in summer K-W<sub>test</sub> (  $H_{2,69} = 38,01$   $p < 0,001$  ), GSI gave significant differences by season with higher values in summer too, W<sub>test</sub> (  $H_{2,,52} = 12,63$   $p < 0,05$  ).

From 279 *N. bonaparte* stomachs examined, 67 were empty, ( vacuity index = 24.01 % ). A total of 47 prey items were found in stomach contents, 14 of which were identified to species or genus level. ( Table 2. ). According to W%, the most abundant prey was cnidaria group ( 22.48% ) conformed by different species where actinians was showed as the most abundant prey ( 16.31% ) followed by the bamboo coral polypes ( Alcyonacea ) *Isidella elongata* ( 4.97% ), often found entire in guts. Next item in W% importance was echinodermata group (20.10%), conformed by *Penilpidia ludwigi* (9.71%) and *Hymenodiscus coronata* (2.31%) as the main species. Sediment and particulated organic matter (POM) represents 34.72% ( Figure 6.).

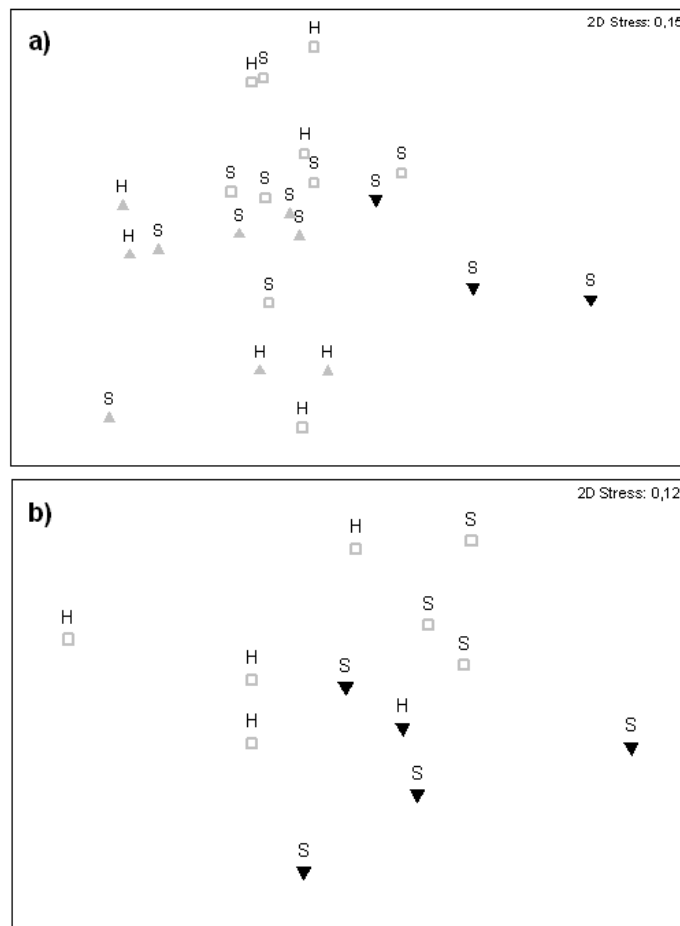


**Figure 6.** Prey contribution (% W) in *Notacanthus bonaparte* (■) and *Polyacanthonotus rissoanus* (□) diet of big groups. Poriphera (Por), actinaria (Act), alcyonacea (Alc), other cnidarians, (Cni Oth), polychaeta (Pol), copepoda (Cop), gammaridea (Gam), tanaidacea, isopoda (Iso), mysidacea (Mys), decapoda (Dec), echinodermata (Ech), osteichthyes (Ost), chaetognatha (Cha), sediment / particulated organic matter (Sed (POM)), gelatinous (Gel) and others (Oth).



A total of 108 stomachs were examined for *P. rissoanus*, 27 were empty, ( vacuity index = 25 % ). Overall 40 prey items were found in stomach contents, 27 of which were identified to species or genus level. ( Table 2. ). The main abundant prey according to W% (Table .), was Polychaetes ( 40.40% ) dominated by *Harmothoe sp.* ( 31.97 % ) as the main item. Tanaids ( 14.02% ) with *Apseudes sp.* ( 13.58 % ), isopods ( 10.11% ) with *Munnopsurus atlanticus* ( 7.28% ) and *Ilyarachna longicornis* ( 2.48% ) were the next prey items in W% importance in *P. rissoanus* diet. (Fig. 6.).

The nMDS plot for *N. bonaparte* ( Fig. 7. a. ) showed a trend where samples seem to be clustered by zones. Lower slope samples were situated at the right of the plot area, clearly separated from the rest. Upper slope samples were located in the lower and left side of the plot area, and middle slope samples rather in the upper side of the plot area.



**Figure 7.** nMDS plot of *Notacantus bonaparte* (a) and *Polyacanthonotus rissoanus* (b) of diet similarity from stomach contents based on Bray Curtis similarity  $\text{Log}(x+1)$ . Data points are identified by depth; upper slope ( $\Delta$ ), middle slope ( $\square$ ), lower slope ( $\blacktriangledown$ ); and seasonality; homogenization (H) and stratification (S).

Data analysis using PERMANOVA test gave significant differences between samples according depth range ( *pseudo* -  $F_{1,23} = 1.80$ ,  $p = 0.004$ ). Pairwise comparison gives significant differences between lower slope and upper slope ( $t = 1.42$ ,  $p = 0.02$ ) and lower and middle slope ( $t = 1.39$ ,  $p = 0.029$ ) respectively. Test between middle and upper slope showed values near of the significance ( $t = 1.25$ ,  $p = 0.104$ ).

PERMANOVA test gave significant differences between seasons ( *pseudo* -  $F_{1,23} = 1.867$ ,  $p = 0.026$  ).

For *P. rissoanus* nMDS plot ( Fig. 7. b.) showed an aggregation trend of samples in relation to depth stations and homogenization / stratification season. PERMANOVA test gived almost significant differences between upper and lower slope ( *pseudo* –  $F_{1,12} = 1.5999$ ,  $p = 0.0663$ ) and for homogenization / stratification time test was not significative ( *pseudo* –  $F_{1,12} = 1.34$ ,  $p = 0.159$ ). The low n ( due to the fact we are working with a rare species) was an inconvenient.

**Table 3.** Results of SIMPER analysis: average similarity of diets by depth; upper slope (a), middle slope (b) and lower slope (c); and seasonality; homogenization (d) and stratification (e) of *Notacanthus bonaparte*

Species / Item	Average Similarity	Contribution %	Cum.%
a) Upper Slope			
Average similarity: 13,41			
Actinaria	10,9	81,32	81,32
<i>Peryphilla peryphilla</i>	1,3	9,71	91,03
Fecal pellets	0,43	3,24	94,28
Scales	0,24	1,8	96,08
b) Middle Slope			
Average similarity: 9,49			
Teleostei und.	4,3	45,27	45,27
<i>Penilpidia ludwigi</i>	3,35	35,25	80,52
Actinaria	0,99	10,45	90,97
<i>Isidella elongata</i>	0,32	3,37	94,34
Scales	0,27	2,84	97,18
c) Lower Slope			
Average similarity: 9,35			
<i>Hymenodiscus coronata</i>	8,31	88,84	88,84
Teleostei und.	1,00	10,65	99,49
d) Homogenization			
Average similarity: 7,73			
Fecal pellets	2,7	34,96	34,96
Actinaria	2,18	28,19	63,15
<i>Penilpidia ludwigi</i>	2,12	27,44	90,59
Gelatinous	0,33	4,27	94,86
Teleostei und.	0,29	3,69	98,55
e) Stratification			
Average similarity: 9,93			
Actinaria	5,58	56,23	56,23
Teleostei und.	2,59	26,1	82,33
<i>Hymenodiscus coronata</i>	0,46	4,68	87,01
Scales	0,44	4,43	91,43
Vegetal remains	0,3	3,03	94,46
<i>Isidella elongata</i>	0,14	1,43	95,9

According to the SIMPER results, the most typifying taxon in the *N. bonaparte* diet was actinians, with bathymetric variations. In the upper slope it gives the main contribution (81.32 %) followed by the scyphozoan *Peryphilla peryphilla* (9.71 %). At the middle slope prey contribution showed a bigger diversified diet, where actinians was present again followed by, bamboo coral, *Isidella elongata*. The main consumed preys were rests of fishes of unidentified teleosts followed by *Penilpidia ludwigi* holothurians. Diet in the lower slope showed *Hymenodiscus coronata*, asteroidea, as the taxon mostly fed. (Table 3. a – c.)

Seasonal SIMPER results in relation to stratification / homogenization time were shown actinians again as a common prey in both seasons. A trend to consume organic remains during stratification and alive sessile organisms in homogenization time was observed. (Table 3. d and e.).

**Table 4.** Results of SIMPER analysis: average similarity of diets by depth; middle slope (a) and lower slope (b); and seasonality; homogenization (c) and stratification (d) of *Polyacanthonotus rissoanus*

Species / Item	Average Similarity	Contribution %	Cum.%
a) Middle Slope			
Average similarity: 17,51			
<i>Harmothoe sp.</i>	15,63	89,29	89,29
<i>Apseudes sp.</i>	0,85	4,83	94,12
<i>Racotrophis caeca</i>	0,54	3,09	97,2
b) Lower Slope			
Average similarity: 21,97			
<i>Munnopsurus atlanticus</i>	10,38	47,26	47,26
<i>Harmothoe sp.</i>	10,37	47,19	94,45
<i>Polychaeta und.</i>	1,07	4,88	99,33
c) Homogenization			
Average similarity: 18,61			
<i>Harmothoe sp.</i>	14,02	75,32	75,32
<i>Apseudes sp.</i>	1,77	9,54	84,85
<i>Racotrophis caeca</i>	1,13	6,1	90,95
<i>Munnopsurus atlanticus</i>	0,9	4,86	95,81
d) Stratification			
Average similarity: 17,81			
Species	Average Similarity	Contribution %	Cum.%
<i>Harmothoe sp.</i>	12,68	71,19	71,19
<i>Polychaeta und.</i>	2,82	15,86	87,05
<i>Munnopsurus atlanticus</i>	2,17	12,16	99,21

Overall *P. rissoanus* SIMPER results showed that the main ingested taxon by these species were polychaetes, especially from the genus *Harmothoe sp.* followed by suprabenthic-epibenthic crustaceans. In the lower slope *Munnopsurus atlanticus* isopoda took more importance. Seasonally SIMPER showed that *P. rissoanus* still preyed on polychaetes, but crustaceans contributed to the diet similarity in homogenization period. (Table 4.).

**Table 5.** Results of Spearman correlation test for *Notacanthus bonaparte* and *Polyacanthonotus rissoanus*. Surface chlorophyll values one (*Chl1*) two (*Chl2*) and three (*Chl3*) months before the sampling collecting, River discharges at the same time (*RrOff0*), one (*RrOff1*) two (*RrOff2*) and three (*RrOff3*) months before sampling collecting, latitude (*LAT*), longitude (*LONG*) and turbidity (*Turb*).

	<i>Chl1</i>	<i>Chl2</i>	<i>Chl3</i>	<i>RrOff0</i>	<i>RrOff1</i>	<i>RrOff2</i>	<i>RrOff3</i>	<i>LAT</i>	<i>LONG</i>	<i>Turb</i>
<i>N. bonaparte</i>										
a) <b>Full</b>										
<b>p</b>	0,046	0,543	0,652	0,430	0,541	0,413	0,461	-0,111	-0,277	-0,193
<b>n</b>	24	24	24	24	22	22	22	23	23	24
<b>p-value</b>	ns	0,0061*	0,0006*	0,0358*	0,0093*	0,056*	0,0308*	ns	ns	ns
b) <b>H'</b>										
<b>p</b>	-0,127	-0,128	-0,169	0,087	-0,043	-0,015	0,08	0,115	-0,159	0,411
<b>n</b>	24	24	24	24	22	22	22	23	23	24
<b>p-value</b>	ns	ns	ns	ns	ns	ns	ns	ns	ns	0,0462*
<i>P. rissoanus</i>										
c) <b>Full</b>										
<b>p</b>	0,425	0,446	0,268	-0,266	-0,272	-0,191	-0,358	0,463	0,416	-0,360
<b>n</b>	18	18	18	16	16	16	16	18	18	17
<b>p-value</b>	ns	ns	ns	ns	ns	ns	ns	0,0527	ns	ns
d) <b>H'</b>										
<b>p</b>	0,287	0,378	0,306	0,081	0,019	0,025	0,025	2,345	0,451	0,069
<b>n</b>	18	18	18	16	16	16	16	18	18	17
<b>p-value</b>	ns	ns	ns	ns	ns	ns	ns	0,0322*	0,059	ns

\*p < 0,05 ns, p>0,05

Spearman correlation test on fullness data revealed that *N. bonaparte* fullness (*F*) (Table 5. a.) was positively correlated with surface chlorophyll levels from two and three months before. Positive correlation was seen between fullness and river discharges from one to two months before. On the other hand *N. bonaparte* diet diversity (*H*) (Table 5. b.) was positively correlated with turbidity near the bottom.

For *P. rissoanus*, Spearman correlation test showed a positive correlation in diet diversity (*H*) (Table 5. d.) and latitude. Near significance values of fullness and diet diversity with latitude and longitude suggest some relationships between trophic indicator and geographic patterns variables.

**Table 6.** Generalized global models, nGLM performed on fullness (*F*) and diversity (*H*) values of *Notacanthus bonaparte* and *Polyacanthonotus rissoanus*.

	Variable	Estimate	Explained deviance	Residual deviance	% expl. deviance	<i>p</i>
<i>N. bonaparte</i>						
a)	<b><i>F</i></b>		<b>AIC: -264.96</b>		<i>Df</i> = 22	
	NULL			0,00001712		
	<b><i>Chl2</i></b>	0,002714	0,00000475	1,23728E-05	27,7	0.00057
	<b><i>LONG</i></b>	-0,002065	0,00000347	8,8993E-06	20,3	0.0032
	<b><i>Chl3</i></b>	0,001594	0,00000221	6,6863E-06	12,9	0.019
	<b><i>RrOff</i></b>	0,000003	0,00000103	5,6572E-06	8,3	0,1
	<b>TOTAL</b>				<b>60,9</b>	
b)	<b><i>H</i></b>		<b>AIC: 39.862</b>		<i>Df</i> = 24	
	NULL			6,0544		
	<b><i>Chl1</i></b>	-3,3815	1,0722	4,98223	17,7	0.024
	<b><i>T</i></b>	2,4944	0,7172	4,26506	14,4	0.06
	<b>TOTAL</b>				<b>32,1</b>	
	Variable	Estimate	Explained deviance	Residual deviance	% expl. deviance	<i>p</i>
<i>P. rissoanus</i>						
c)	<b><i>F</i></b>		<b>AIC: -153.65</b>		<i>Df</i> = 16	
	NULL			0,000103		
	<b><i>Chl0</i></b>	0,000054	0,0000491	0,000054	47,5	0.0005
	<b>TOTAL</b>				<b>47,5</b>	
d)	<b><i>H</i></b>		<b>AIC: 32.238</b>		<i>Df</i> = 16	
	NULL			7,186		
	<b><i>turb</i></b>	5,84437	1,5004	5,68554	20,9	0.0025
	<b><i>Depth</i></b>	0,00014	1,2084	4,47713	16,8	0.029
	<b><i>Chl2</i></b>	0,85989	1,1008	3,37632	15,3	0.034
	<b>TOTAL</b>				<b>53,0</b>	

The GLMs performed on fullness data revealed that fullness of *N. bonaparte* was positively correlated with surface chlorophyll values two and three months before and diet diversity with chlorophyll values one month before. Fullness was negatively correlated with longitude. Both models explained 60.9% and 32.1% of the total system variation (Table 6. a and b.).



The GLMs performed for *P. rissoanus* for fullness was positively correlated with surface chlorophyll values at the same month of sampling collection. Diet diversity was positively correlated with turbidity, depth and surface chlorophyll values two months before sample collection. The two models explained the 47.5% and the 53% variation for fullness and diversity respectively (Table 6. c and d.).

**Table 7.** Mean values and SD of lactate-dehydrogenase (LDH) activities of *Notacanthus bonaparte* and *Polyacanthonotus rissoanus*.

	Size cm (TL)	Depth (m)	LDH
a) <i>N. bonaparte</i>			
	16 - 18	631	5,24 ± 0,70
	"	1024	8,75 ± 3,58
	"	1053	6,40 ± 1,57
	21 - 22	1024	3,72 ± 3,72
	"	1053	5,08 ± 0,89
b) <i>P. rissoanus</i>			
	16 - 17	1000	7,56 ± 3,91

LDH mean activities (in nmol / min / g prot ) ranged from 5.24 to 8.75 in smaller *N. bonaparte* individuals (16-18 cm, TL) and from 3.72 to 5.08 in bigger ones (21-22 cm, TL) (Table 7. a.).

For *P. rissoanus* LDH mean activities was 7.56 (in nmol / min / g prot ) (Table 7. b.).

## DISCUSSION

Notacanthidae is a well-represented family in the Mediterranean deep sea, in terms of abundance and biomass ( Stefanescu et al., 1992a ). In the North Eastern Atlantic Notacanthidae they are usually among the 10 most abundant species when relative abundance is considered (Gordon et al., 1996 ). *Notacanthus bonaparte* and *Polyacanthonotus rissoanus* are dominant among the notacanthids and their depth ranges overlap, their population densities peak in different depth zones. In the Mediterranean bathymetric distribution, is considered to be located at depths greater than 1000m. *N. bonaparte* optimum depth range is located at depths around 1400 m and greater than 1600 m for *P. rissoanus*. Both species coexists down to 1900m (Stefanescu et al., 1992a). Our results revealed a similar tendency with distributions of *N. bonaparte* and *P. rissoanus* coexisting down to 2200m. Population overlap from around 1000 m to 2200m. Based on CoG, *N. bonaparte* population peak appears at 942m, situating the species maximum abundance at the middle slope. *P. rissoanus* CoG situate the species population peak at 1680 m depth.

Frequency sizes by depth seems to show a clear trend to found bigger individuals at deeper stations and smaller ones at shallowest stations in *N. bonaparte*. This trend was not clear in *P. rissoanus*, only with a slight change in the modal size in spring and summer. Inmature fish are usually restricted to shallower depths contributing to the bigger deeper trend found in several deep-water species. (Gordon et al., 1996, Stefanescu 1992b). This can be due to ontogenic migrations. These migrations trough the continental slope could be linked to reproduction patterns. In the Mediterranean

Sea deep-sea fishes, both seasonal and continuous reproduction has been observed (Massutí et al., 1995; Papiol, 2013). Under natural conditions, reproduction in fishes is timed by changes in the external environment (Bromage, 1995). Seasonal reproduction takes place in response to natural fluctuations in environmental factors (Gage & Tyler, 1991), such as food availability and temperature, that have important consequences for the energy allocated to somatic growth and reproduction because of their effect on metabolism and surplus energy (Wootton, 1990). Our biological results on notacanthids suggest this. Thus, hepatosomatic index (HSI) and gonadosomatic index (GSI) changes by season shows that reproductive event in both species mainly occurs at concrete season. GSI in *N. bonaparte* at upper slope showed in general lower values, lowest values were found in autumn at the same season when a bimodal trend in population size distribution with a peak of smaller individuals was observed. Overall, in the middle slope GSI values increased. A peak in summer was given and again lowest values were shown in autumn, coinciding again with a bimodal population trend perceived in size population structure. Highest GSI values occur in the lower slope during autumn. Both index seems to be parallel at the upper and at the middle slope but opposite in the lower slope. This pattern agrees with the bigger-deeper described by other authors (Gordon et al., 1996, Stefanescu 1992b). According to our results reproductive event for *N. bonaparte* could occur probably during the end of summer and autumn by the migration of bigger individuals to the deeper part of the slope.

Reproductive event in *P. rissoanus* seems to be linked too with the migration through the slope. During summer just a few individuals were caught at lower slope, at the same time, high number of individuals occurs in the lower slope that together with the higher values of GSI at these depth and season, would indicate a recruitment of reproductive specimens. Reproductive event for *P. rissoanus* seems to be situated at the lower slope during summer months.

In the Deep-sea megafauna, in terms of abundance and number of species, decapod crustaceans together with fish, are the dominant taxa in deep Mediterranean assemblages (Cartes, 1993). Main abundant species of deep-sea fishes diets and food resource is based on crustaceans, other fishes and cephalopods (Carrassón & Cartes, 2002). Previous studies that attempt to describe *N. bonaparte* diet, reveals this species as a generalized benthic feeder whose diet seems to be based on ophiuroids, hydrozoans and bryozoans. (Lozano Cabo, 1952; Macpherson, 1981; Coggan et al., 1998). Our results show the species diet based mainly (in weight) on sessile benthic organisms but diet in this case is based on cnidarians as actinians at the upper and middle slope and bamboo coral *Isidella elongata* and, echinoderms as *Penilpidia ludwigi* at the middle slope too, at the lower slope asteroidean *Hymenodiscus coronata* was the main prey. Cnidarians identification presents some difficulties, it kind of prey seems to be quickly digested and it normally appears as formless mass, identification only is possible by microscope (600-1000X) observation and cnidae identification. *N. bonaparte* is revealed as a specialized predator consuming a range of prey hardly exploited by other deep-sea species fish in the area (Carrassón & Cartes, 2002). Bamboo coral is considered as a deep-sea species that provide an habitat to invertebrates along the continental slope. *N. bonaparte* has been described as a fish species associated to facies of *Isidella elongata* but not described as a consumer of this coral (Maynou & Cartes, 2011). *Isidella elongata*, together with other suspension feeders (*Desmophyllum cristagalli* and *Gryphus vitreus*), is mainly distributed in the Balearic basin over the middle and lower continental slope, between two depositional areas of sediment and particulate organic matter occupied by deposit feeders (holothurians and *Brissopsis lyrifera*: Cartes et al., 2009). Studies on trophic webs in the area suggest the belt occupied by *I. elongata* is rich in near bottom zooplankton (Cartes et al., 2009b). The

main food source for deep-corals ( Sherwood et al., 2005). In addition to the direct impact or damage by the mechanical action of trawling, deep-water coral reefs are also negatively impacted by the resuspension of off bottom sediments (Rogers, 1999; Fossa et al., 2002). In addition to this area from our data is reasonable to think that anthropogenic impact as bottom trawling could affect directly *N. bonaparte* population.

Previous studies described *P. rissoanus* as a euryphagic predator, with a wide variety of prey. *P. rissoanus* is a more conventional species in terms of prey exploited / consumed. Consuming small epibenthic and suprabenthic crustaceans and polychaetes, and occasionally other groups such as Priapulida, Gastropoda and Foraminifera, (Carrassón & Matallanas; 2002). Our results agree with this, but our data reveals differences in prey proportions where polychaetes from genus *Harmothoe* were the most consumed followed by crustaceans of the genus *Apseudes* in all depths.

The Mediterranean Sea is characterised by annual thermal stability of the water mass ( Hopkins, 1985). However, important temporal fluctuations are associated with pulses of food to bathyal depths. These changes derive on one hand from seasonal changes of primary production (Estrada, 1991) and the variable vertical flux of particles (Miquel et al., 1994; Cartes et al., 2002). In the Catalan Sea, primary production peaks during a late winter surface bloom, whereas there is a deep chlorophyll maximum in open waters during stratified period (Estrada, 1991). A homogenised water column is present in winter and early spring, with most downward flux occurring in those mixed waters. Stratification of the water column is usual from April to November, and is associated with much lower vertical particle fluxes (Miquel et al., 1994). On the other hand, changes in advective fluxes, such as those that generate nepheloid layers in submarine canyons, also seem to play an important role in variations of organic matter input in the deep-sea. The submarine canyons are contact zones between the circalitoral and bathyal communities (Reyss, 1971), and in the study area they channel significant amounts of sediment and associated organic matter across the slope (Palanques et al; 2006) enhancing the food supply (Vetter and Dayton, 1998) in depocenters. Those become local hotspots of secondary production. Additionally, advective fluxes move up sediment layers causing resuspension of organic matter from the bottom. The advective flux of organic matter and the physical conditions in the canyons vary in relation to river discharges of continental run-off (Canals et al., 2006; Palanques et al., 2006). *N. bonaparte* diet not seems to show great changes in the main preys consumed, as actinians, but during the stratification period coinciding with the fall of organic matter through the water column food items as vegetal remains increases, at the same time fullness correlation with river discharges, surface chlorophyll levels two and three months before and latitude would indicate not negligible influence of coastal and surface fall organic matter in the *N. bonaparte* diet source. Comparatively *P. rissoanus* not shows appreciable seasonal changes in the diet related with homogenization or stratification periods, probably because it lives deeper in a more stable environment, than occupied by *N. bonaparte*.

Lactate dehydrogenase (LDH) is an important glycolytic enzyme involved in the supply of energy demand under oxygen-limiting conditions and LDH activity in white muscle reflects the anaerobic power generating capacity during burst swimming (Childress & Somero, 1979). LDH activity has been associated with the species locomotory performance as a quick response of energy demands under low oxygen conditions, also in benthic species from deep-sea environments (Drazen & Seibel, 2007). On

the other hand, exists a negative relation between LDH activities and depth. In general low LDH activities for deep-sea fishes has been recorded in comparison of species from shallowest waters. Our results showed a high LDH activity for notacanthids compared with other Mediterranean and Atlantic species ranging similar and bigger depths (Table 8.). *Mora moro* has high LDH values, it could be expected in a fish on a diet based on mobile preys as crustaceans, cephalopods and other fishes. (Dallarés et al., 2014). *P. rissoanus*, with a diet based on polychaetes and crustaceans, species with intermediate swimming capacity (Cartes & Sorbe, 1999), presents surprisingly high LDH values. *N. bonaparte* LDH values are completely unexpected for a species based on consuming sessile organisms which a priori would not need to powerful swimming ability.

**Table 8.** Comparison of lactate-dehydrogenase (LDH) activities of different deep-sea fish species from Mediterranean Sea and Atlantic.

Species	Fam.	mean depth (m)	LDH $\mu\text{mol}/\text{min}/\text{g prot}$	Source	Area
<i>Anoplopoma fimbria</i>	Anoplopomatidae	875	0,955	Somero et al., 1983	Atlantic
<i>Nezumia bairdi</i>	Macrouridae	1112,5	0,049	"	"
<i>Coryphaenoides rupestris</i>	Macrouridae	1255	0,113	"	"
<i>Dichrolene intranegra</i>	Ophidiidae	1340	0,460	"	"
<i>Coryphaenoides acrolepis</i>	Macrouridae	1645	1,510	"	"
<i>Antimora rostrata</i>	Moridae	1662,5	0,353	"	"
<i>Coryphaenoides carapinus</i>	Macrouridae	1995	0,041	"	"
<i>Bathysaurus agassizi</i>	Bathysauridae	2233,5	0,324	"	"
<i>Halosaurus macrochir</i>	Halosauridae	3339,5	0,132	"	"
<i>Coryphaenoides armatus</i>	Macrouridae	3350	0,299	"	"
<i>Coryphaenoides leptolepis</i>	Macrouridae	3463,5	0,028	"	"
<i>Alepocephalus rostratus</i>	Alepocephalidae	1200	1,696-2,359	Koenig, Solé 2014	Balearic Basin
<i>Coelorhynchus mediterraneus</i>	Macrouridae	1350	0,641-1,089	"	"
<i>Bathypterois mediterraneus</i>	Chirophthalmyidae	1350	0,785	"	"
<i>Lepidion lepidion</i>	Moridae	1470	0,226-,0,293	"	"
<i>Mora moro</i>	Moridae	1143	2,390-5,173	Dallarés et al, 2014	Balearic Basin
<i>Notacanthus bonaparte</i>	Notacanthidae	902	3,72-8,75	Present study	Balearic Basin
<i>Polyacanthonotus rissoanus</i>	Notacanthidae	1000	7,56	"	"

In conclusion, both species coexists in the continental slope down to 2198m. Populations overlap but present different population peaks, situating *N. bonaparte* (942m) at the middle slope and *P. rissoanus* (1680m) at the lower slope. Both species seems to perform migrations to deeper water in reproduction time. *N. bonaparte* is shown as a selective benthic feeder consuming a range of prey hardly exploited by other deep-sea species *P. rissoanus* is shown as a euryphagic predator consuming small epibenthic and suprabenthic preys. *N. bonaparte* food resource shown a clear dependence of organic matter apportion from coastal inputs and surface fall, not so for *P. rissoanus*.

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