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Food consumption rates in fishes of the Río de la Plata and southwest Atlantic coast (Uruguay)

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Abstract. Food consumption rates (Q/B) were estimated for 20 fish species of the Río de la Plata and southwest Atlantic Ocean during June 2009, by using empirical models (Model I and II). Differences were found among classes, orders, families, species and habitat use.

Key words: ichthyofauna, trophic models, Uruguayan coast, Atlantic Ocean, Q/B

Resumen. Tasas de consumo de alimento en peces del Río de la Plata y costa del Atlántico suroccidental (Uruguay). Se estimaron las tasas de consumo de alimento (Q/B) para 20 especies de peces del Río de la Plata y océano Atlántico suroccidental durante junio 2009, mediante la aplicación de modelos empíricos (Modelo I y II). Diferencias en Q/B fueron encontradas entre clases, ordenes, familias, especies y usos del hábitat.

Palabras clave: ictiofauna, modelos tróficos, costa uruguaya, Océano Atlántico, Q/B

Ecosystem models representing the trophic structure and functioning have been developed to interpret field data and provide fisheries management advice. Such models assist the understanding of ecosystem functions incorporating ecological processes among populations (Pauly *et al.* 1990, Plagányi 2007). In this sense, the estimation of food consumption rates (FCR) of fishes is essential for both the understanding of trophic relationships and the application of multispecies models. Polovina (1984), showed that one of the most important parameters required in ecosystem trophic models is the amount of food ingested (Q) by a population over a specific period of time (conventionally a year) relative to its biomass (B), or Q/B. To calculate the consumption rate of fishes, Palomares & Pauly (1998) and Pauly *et al.* (1990), proposed empirical regression models (here referred as "Model I" and "Model II", respectively) which relate the form of the caudal fin (Aspect radio, A_r) with the food consumption rate. Many commercially important marine fishes of Uruguay are both distributed and develop their feeding and reproductive activities in the Río de la Plata and Atlantic Ocean coast. However, no studies exist for the FCR of these species in the area. Therefore, the aim of this study was to estimate the FCR of 20 fish species of the Río de la Plata and Atlantic coast of Uruguay and analyse this variability in terms of taxonomic and habitat use differences.

The study area comprised the estuarine zone of the Río de la Plata and the Uruguayan coast of the Argentine-Uruguayan Common Fishing Zone (AUCFZ) (33°50'-36°20' S; 53°00'-57°10' W) (Fig. 1), with a bathymetric range between 6 and 44 m. Samples were obtained during June 2009 (winter) from the fishing research vessel "Aldebarán" using a bottom trawl type "Engel" 472/160 with a minimum mesh size of 60 mm between knots. Temperature of the sampling area was recorded. Fishes were identified to the species level according to Carvalho-Filho (1992), Cousseau & Perrotta (2000), Fisher *et al*. (2004) and Nion *et al*. (2002), measured to the total length (cm) and photographed. Q/B values were estimated using Palomares & Pauly (1998) Model (Model I: $Q/B = 10^{(7.964 - 0.204 \log W_\infty - 1.965 T' + 0.083 Ar + 0.532 h + 0.398 d)}$) and Pauly *et al*. (1990) Model (Model II: $Q/B = 10^{6.37} * 0.0313^{T'} * W_\infty^{-0.168} * 1.38^{P} * 1.89^{HD}$), where *Q/B* is the consumption/biomass rate (year $^{-1}$), W_∞ is the asymptotic weight (g) of the population compiled from the literature (Milessi 2008, Colonello 2009, Haimovici & Velasco 2000, Froese & Pauly 2008), *T'* corresponds to: 1000/ (T(°C)+273), where T(ºC) is the water temperature registered in each fishing tow. A_r is the aspect ratio of the caudal fin which is defined as $A_r = S_1^2/S_2$, where S_1 is the height of the caudal fin (mm) and S_2 is the surface area (mm²) extending to the narrowest part of the caudal peduncle. This calculation was obtained from the digital analysis of photographed specimens. The processing of images was performed using ImageJ software v1.42Q. For Model I, *h* and *d* are binary variables that define whether the predator is herbivorous (h = 1, d = 0), detritivore (h = 0, d = 1) or carnivore (h = 0, d = 0). For Model II, *P* is the type of food (1 for top predators or zooplanktivores and 0 for other types of food) and *HD* is a factor that expresses the species diet (1 for herbivores and detritivores, and 0 for species of carnivores). Q/B average values (± standard deviation) were calculated for each fish species (Table 1).

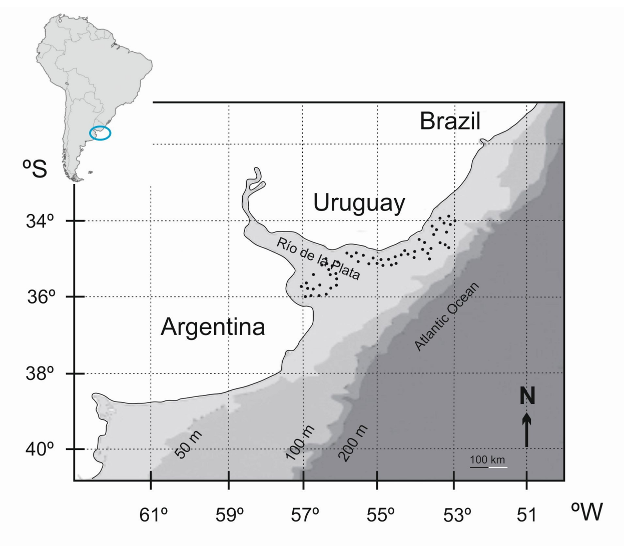

Figure 1. Study area showing the sampling stations (black circles) in the Río de la Plata and Atlantic coastal area of Uruguay, during June 2009.

Analyses of variance (ANOVA) were used to reveal the differences of Q/B among classes, orders, families as well as on the relationship between Q/B and habitat. A Cluster dendrogram was used to analyze the similarity between Q/B values of fish species (R mode), using the Bray-Curtis similarity coefficient and the Unweighted Pair Group Method with Arithmetic Mean. For the construction of the Cluster seven samples were selected randomly for each species to cope with the differences between numbers of samples. Software used for the statistical analysis was Past and Primer 6 (Clarke & Warwick 2001).

Five hundred and thirty individuals belonging to 20 carnivorous species, 13 families and seven orders within Chondrichthyes and Actinopterygii classes (Table I) were analyzed. Most specimens used in the analysis were adults. Food consumption rates differed significantly among classes (ANOVA; F = 40.52, $p < 0.05$), orders (ANOVA; F = 78.38, $p < 0.05$) and families (ANOVA F = 155.92, $p < 0.05$). However, post-hoc analysis showed that Rajiformes, Pleuronectiformes and Carchariniformes did not statistically differ and that some families can be grouped without significant differences. *Parona signata* (Carangidae) and *Mullus argentinae* (Mullidae) showed the highest A_r average values (3.56 and 2.10, respectively) in contrast with *Prionotus punctatus* (Triglidae) with the lowest A_r value (0.83). The species *Pomatomus saltatrix* (Pomatomidae) presented the lowest Q/B average value of 3.40 ± 0.27 year^{-1} and the highest average Q/B value was presented by *Engraulis anchoita* with 7.74 ± 0.59 year^{-1} (Table I). The cluster analysis showed three groups of species according to Q/B values. The family Engraulidae, represented by *Engraulis anchoita* (Ea) and *Lycengraulis grossidens* (Lg), was defined as one of the groups (Fig. 2). Significant differences in Q/B were found between species inhabiting different environments (ANOVA; F = 80,884, p <0.05). While demersal species showed the lowest values of food consumption (4.58 ± 0.07 year^{-1}), benthopelagic and pelagic organisms statistically did not differ (5.95 ± 0.14 year^{-1} and 5.79 ± 0.13 year^{-1}, respectively) (Fig. 3).

It has been observed that Q/B estimates for each studied species are influenced by the different parameters used in Model I. Some anatomical factors related to caudal fin type could be influencing the differences found between families and/or species. Palomares & Pauly (1998) concluded that aspect ratio can explain as much as 50% of the variance of Q/B values, used as a measure of the overall fish activity (Garcia & Duarte 2002). Pauly (1989) noted that fishes specialized in swimming showed higher values of A_r, while the lowest values corresponded to species

Table I. Taxonomic, biological attributes and estimated Q/B ratio of 20 fish species captured in the Río de la Plata and Atlantic coastal area of Uruguay, during June 2009. W_∞ = asymptotic weight (g), TL= total length (cm), A_r = aspect ratio of the caudal fin, T = average temperature (ºC), Q/B = consumption/biomass ratio (years $^{-1}$), S.D. = standard deviation of Q/B, N = number of captured specimens.

Taxonomy	Habitat	W_∞	TL		A_r	T	Q/B	S.D.	N
			min	max					
Chondrichtyes									
Rajiformes									
Rajidae									
Rioraja agassizii (Ra)	Demersal	3511.60	39.00	67.00	----	14.04	4.70	0.12	51
Atlantoraja castelnaui (Ac)	Demersal	12997.32	72.00	120.00	----	13.97	3.79	0.07	10
Sympterygia acuta (Sa)	Demersal	2534.90	47.00	62.00	----	14.96	5.15	0.11	13
Sympterygia bonapartii (Sb)	Demersal	4186.00	30.00	78.00	----	14.40	4.65	0.14	86
Carcharhiniformes									
Triakidae									
Mustelus schmitti (Ms)	Demersal	4360.50	45.00	84.00	----	14.20	4.57	0.12	93
Squatiniformes									
Squatinidae									
Squatina guggenheim (Sg)	Demersal	9302.30	33.00	91.00	----	14.27	4.04	0.11	71
Actinopterygii									
Pleuronectiformes									
Pleuronectidae									
Oncopterus darwini (Od)	Demersal	1418.60	20.00	27.00	----	13.62	5.38	0.19	7
Paralichthyidae									
Paralichthys isosceles (Pi)	Demersal	1000.00	20.00	29.00	----	13.56	5.70	0.02	8
Paralichthys patagonicus (Ppat)	Demersal	6151.20	17.00	90.00	----	13.80	4.25	0.13	43
Scorpaeniformes									
Triglidae									
Prionotus punctatus (Ppu)	Demersal	1290.44	11.50	43.00	0.83	13.11	3.47	0.33	8
Clupeiformes									
Engraulidae									
Engraulis anchoita (Ea)	Pelagic	50.68	9.00	16.00	1.43	13.72	7.74	0.59	18
Lycengraulis grossidens (Lg)	Pelagic	69.80	8.50	21.50	1.28	14.26	7.08	0.60	7
Perciformes									
Serranidae									
Dules auriga (Da)	Bentho-pelagic	196.27	13.00	17.50	1.61	13.82	5.98	0.28	15
Sciaenidae									
Cynoscion guatucupa (Cg)	Demersal	1876.54	16.00	39.00	1.24	13.92	3.50	0.27	18
Menticirrhus americanus (Mam)	Demersal	1857.01	26.00	44.00	1.29	13.26	3.57	0.24	7
Paralonchurus brasiliensis (Pb)	Demersal	291.13	16.50	23.00	0.96	13.28	4.83	0.27	8
Mullidae									
Mullus argentinae (Mar)	Demersal	242.30	16.00	24.50	2.10	13.83	6.50	0.78	14
Carangidae									
Parona signata (Psi)	Pelagic	2406.40	36.00	48.00	3.56	12.84	4.93	0.67	9
Stromateidae									
Peprilus paru (Ppar)	Bentho-pelagic	291.13	7.00	30.00	1.88	13.87	5.91	0.91	28
Pomatomidae									
Pomatomus saltatrix (Psa)	Pelagic	4544.37	12.50	46.00	1.99	13.83	3.40	0.27	15

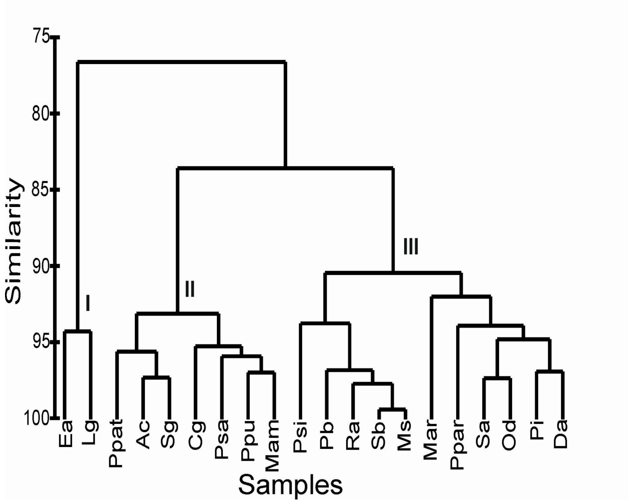

Figure 2. Similarity dendogram for 20 fish species of the Río de la Plata and Atlantic coastal area of Uruguay, during June 2009. The abbreviation (x- axis) refers to the species cited in Table I.

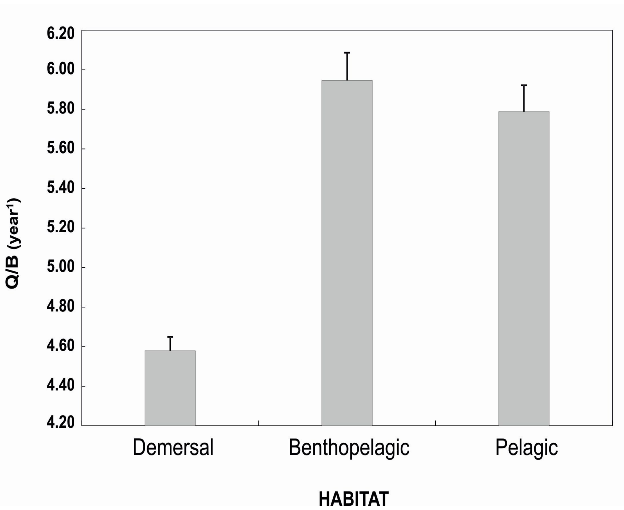

Figure 3. Mean ± SE of fish consumption rates (Q/B) associated with different habitats of the Río de la Plata and Atlantic coastal area of Uruguay, during June 2009.

of low swimming activity. Therefore, the low A_r values would result in low feeding intakes. Agreeing with this observation, the species *P. signata*, classified as a pelagic species, presented the highest A_r value. However, the second highest value was registered in *M. argentinae*, a demersal species. This contrast would indicate that the high activity seems not to be confined only to pelagic fishes (Garcia & Duarte 2002). Moreover, Jarre *et al.* (1991) suggested that high Ar values can occur in less active fishes that inhabit deep zones. In the study area, species belonging to the order Clupeiformes (*E. anchoita* and *L. grossidens*) showed the highest values of Q/B but no the highest values of A_r, although they are pelagic species. This finding points out that the estimation of Q/B could be strongly influenced by asymptotic weight ($W\infty$). On the other hand, the pelagic species *P. saltatrix* showed the lowest value of Q/B although it should have presented a higher consumption rate according to its habitat use. Thus, it should be stated that there is not always a clear relationship between food consumption and A_r. Also temperature has shown to double the effect produced by A_r (Palomares & Pauly 1998) and temperature could differently affect Q/B values. In this sense a rise in temperature values would cause an increase in Q/B values (Palomares & Pauly 1989, Pauly *et al*. 1990, Garcia & Duarte 2002, Donoso & Medina 2005). The analysis here presented was limited to June (winter season) so contrasts between different periods were not possible, however highest Q/B values could be expected to occur during the warmest seasons. Other factors cited as relevant in FCR are depth and type of feeding (Diaz de Astarloa & Fabre 2002, Rico 2000, Garcia & Duarte 2002). According to it, differences among orders could be related to organisms with benthic feeding habits (Gubiani *et al.* 2012). Finally, contrasting Q/B values were expected to found according to habitat use. In this sense, pelagic and benthopelagic species registered higher values than demersal species, probably linked to fish activity.

The data here presented provide a basis to evaluate the trophic interactions of species in the Río de la Plata and southwestern Atlantic coast, as well as the existing relationships between taxonomic groups, habitat use and food consumption rates. This study estimates for the first time the food consumption rate of fishes inhabiting the Río de la Plata and Uruguayan Atlantic coast, contributing to the biological knowledge of the most abundant fish species of this region and suggesting the existence of differences between species and between species with different habitat preferences.

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