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RESEARCH NOTE

Preliminary analysis of the feeding habits of batoids from the genera *Mobula* and *Myliobatis* in Northern Peru

Análisis preliminar de los hábitos alimentarios de batoideos pertenecientes a los géneros *Mobula* y *Myliobatis* en el Norte de Perú

Javier Jesús Coasaca-Céspedes[1,2], Eduardo Segura-Cobeña[1,3,] Rebeca Montero-Taboada[4], Adriana Gonzalez-Pestana[1,5], Eliana Alfaro-Córdova[1,2], Joanna Alfaro-Shigueto[1,2]* and Jeffrey C. Mangel[1,6]

[1]ProDelphinus, José Gálvez 780-E, Lima 18, Perú
[2]Carrera de Biología Marina, Facultad de Ciencias Veterinarias y Biológicas, Universidad Científica del Sur, Panamericana Sur, Km 19, Lima, Perú
[3]Programa de Magister en Ecología Marina, Facultad de Ciencias, Universidad Católica de la Santísima Concepción, Alonso de Ribera 2850, Concepción, Chile
[4]School of Marine Life Science, Department Ecology, Ocean University of China, 5 Yushand Road, Shinan District, Qingdao, China
[5]James Cook University, Townsville, QLD, 4811, Australia
[6]Centre for Ecology and Conservation, School of Biosciences, University of Exeter, Cornwall Campus, Penryn, Cornwall TR10 9EZ, United Kingdom
*Corresponding autor: Joanna Alfaro-Shigueto: jas_26@yahoo.com

Abstract.- This study provides baseline information on the feeding habits of five batoid species from the genera *Mobula* and *Myliobatis* sampled from the small-scale driftnet fishery in northern Peru. The diets of *Mobula mobular*, *Mobula munkiana* and *Mobula thurstoni* consisted mainly of euphausiids. Dietary niche breadth indicated a pelagic feeding behaviour of a specialist and a trophic level of a secondary predator for both *M. mobular* and *M. munkiana*. In contrast, *Myliobatis chilensis* and *Myliobatis peruvianus* consumed mostly gastropods and crustaceans. Dietary niche breadth indicated a feeding behaviour of a benthic specialist and a trophic level of a secondary predator for *Myliobatis chilensis*.

Key words: Feeding habit, trophic level, niche breadth, devil rays, eagle rays

INTRODUCTION

Devil rays (Mobulidae) are distributed in tropical, subtropical and temperate coastal waters (Couturier *et al.* 2012). These rays are filter feeders whose preys are small fishes and zooplankton crustaceans (Notarbartolo di Sciara 1988). In Peru are found Mobula species included in the Red List of the International Union for Conservation of Nature (IUCN) such as *Mobula mobular* (Bonnaterre, 1788), *Mobula munkiana* (Notarbartolo di Sciara, 1987) and *Mobula thurstoni* (Lloyd, 1908), with the first listed as Endangered (Notarbartolo di Sciara *et al.* 2015) and the other two as Near Threatened (Bizzarro *et al.* 2006, Walls *et al.* 2016). By contrast, eagle rays (Myliobatidae) are generally associated with sandy-muddy bottoms (Samamé *et al*. 1985) and are considered benthic consumers, feeding mainly on crustaceans and gastropods (Jacobsen & Bennett 2013). In this region, there are two species of eagle rays, *Myliobatis chilensis* (Philippi, 1892) and *Myliobatis peruvianus* (Garman, 1913), both of which are listed as Data Deficient by the IUCN (Lamilla 2006a, b). The objective of this study was to describe the diet composition of these five batoid species in Northern Peru, through the analysis of their stomach contents.

MATERIALS AND METHODS

Sampling was conducted at one northern Peru fishery landing site (Fig. 1): San José, during a moderate El Niño Southern Oscillation (ENSO) in 2015 (SENAMHI 2015). Stomachs were collected during fishing trips of the small-scale driftnet fishery. The sampled devil ray species were *M. mobular*, *M. munkiana* and *M. thurstoni*. For eagle rays, the species sampled were *M. chilensis* and *M. peruvianus*. Stomach contents of devil rays were sieved through a 300 µm mesh, weighed (± 0.0001g) and counted using the standardised method APHA/AWWA/WEF (Samanez *et al.* 2014) in a Bogorov chamber. Stomach contents of eagle rays were sieved through a 500 µm mesh counted and weighed (± 0.1 g). Each prey item was identified to the lowest possible taxon. Additionally, prey items were also categorized into higher taxonomic groups based on Jacobsen & Bennett (2013) to improve comparability with other works. The percentages by weight (%W), number (%N), frequency of occurrence (%FO) and the percentage of the Pinkas *et al.* (1971) index of relative importance (%IRI) (Cortés 1997), a combination of the three previously mentioned indices, were calculated to quantify the importance of prey items in both genera diets.

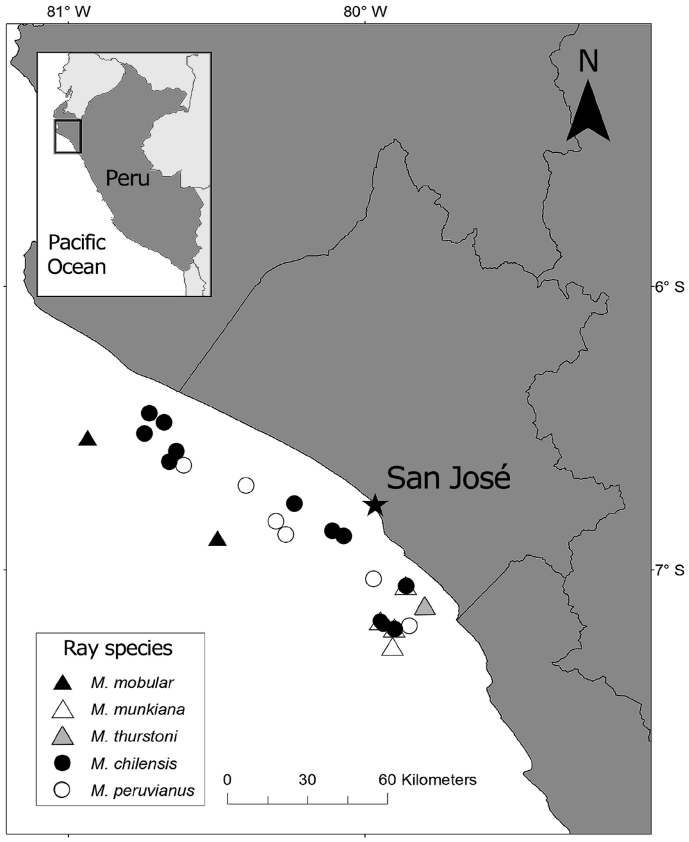

Figure 1. Study area (Northern Peru) indicating the sampling locations / Área de estudio (Norte de Perú) indicando los puntos de muestreo

To evaluate the quality of samples, the asymptotic Clench's curve was used to relate the number of samples to the number of prey species found (Clench 1979). First, the correlation coefficient was estimated to test if the data fit the model (Jiménez-Valverde & Hortal 2003). A coefficient near to 1 indicates that the data fist to the model. Then, the slope was estimated to test if the number of samples was sufficient. Values lower than 0.1 indicate that the sample number is enough (Soberón & Llorente 1993).

Differences in feeding habits among species were tested using one-way semi-parametric permutation multivariate analyses of variance test (PERMANOVA) using prey abundance and weight information. Then, a non-parametric post-hoc test SIMPER was used to identify the prey responsible for the variability. Niche breadth was determined using the Levin's standardised index (β_i) (Krebs 1999) with prey identified to the lowest possible taxon. The trophic level (T_L) was calculated using the formula given by Christensen & Pauly (1992) with the trophic levels of prey proposed by Cortés (1999) and Ebert & Bizzarro (2007) (Table 1).

RESULTS AND DISCUSSION

For the genus *Mobula* a total of 93 stomachs were analysed of which 60.2% (56) had contents. For this genus, 31 prey items were found (Table 2), with euphausiids as the most common prey. Only two of the three devil ray species, *M. mobular* and *M. munkiana* had a correlation coefficient near to 1 which means that the data fit the Clench's model. Additionally, these two devil ray species had slopes lower than 0.1 (b= 0.04 and 0.07, respectively) indicating that the sampling effort was adequate, representing 70 and 50% of the diet of *M. mobular* and *M. munkiana,* respectively (Fig. 2A and B). Thus, as *M. thurstoni* had a low sample size, its diet will only be described. For this species the principal prey found was the cosmopolitan *Nyctiphanes simplex,* as Notarbartolo di Sciara (1988) and Gendron (1992) describe in their studies, followed by *Stylocheiron* sp. and *Euphausia eximia* (Table 2). There are two possible explanations for the observed predominance of euphausiids: 1) *M. thurstoni* may have a preference for euphausiids, or 2) the main prey composition and disposition in the feeding area were euphausiids rather than other zooplankton groups. More samples would be required to develop a more accurate diet description.

Table 2. Percent number (%N), percent weight (%P) and percent frequency of occurrence (%FO) of identified prey categories from the stomach content of the 5 species of batoids. w/i: without identified / Porcentaje de número (%N), porcentaje de peso (%P) y porcentaje de frecuencia de ocurrencia (%FO) de las categorías de presas identificadas del contenido estomacal de 5 especies de batoideos. w/i: sin identificar

Prey Taxa	*Mobula mobular* (n= 30)				*Mobula thurstoni* (n= 3)				*Mobula munkiana* (n= 23)				*Myliobatis chilensis* (n= 36)				*Myliobatis peruvianus* (n= 7)			
	%N	%W	%FO	%IRI	%N	%W	%FO	%IRI	%N	%W	%FO	%IRI	%N	%W	%FO	%IRI	%N	%W	%FO	%IRI
Phylum Annelida																				
Class Polychaeta																				
Polychaeta w/i	0.01	0.12	1.19	0.01	0.01	0.01	8.33	0.01	-	-	-	-	-	-	-	-	-	-	-	-
Phylum Arthropoda																				
Class Hexanauplia																				
Copepoda w/i	0.75	0.20	2.38	0.10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Order Calanoida																				
Calanoida w/i	30.07	20.56	11.91	26.93	-	-	-	-	24.60	4.80	5.26	3.47	-	-	-	-	-	-	-	-
Family Calanidae																				
Calanus australis	0.02	0.05	1.19	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Calanus chilensis	0.49	0.11	1.19	0.03	2.06	0.01	8.33	1.04	-	-	-	-	-	-	-	-	-	-	-	-
Family Paracalanidae																				
Parvocalanus sp.	0.01	0.01	1.19	0.01	-	-	-	-	0.01	0.01	2.63	-	-	-	-	-	-	-	-	-
Family Cyclopoida																				
Cyclopoida w/i	0.05	0.01	3.03		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Class Malacostraca																				
Malacostraca w/i	41.28	0.65	7.14	13.38	-	-	-	-	0.01	0.01	2.63	0.01	7.50	12.72	11.11	9.07	-	-	-	-
Order Amphipoda																				
Amphipoda w/i	0.15	0.01	3.57	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Family Hyperiidae																				
Hyperiidae w/i	0.44	0.48	1.19	0.05	0.01	0.01	8.33	0.01	-	-	-	-	-	-	-	-	-	-	-	-
Family Platyscelidae																				
Platyscelidae w/i	0.05	0.01	1.19	0.01	-	-	-	-	0.01	0.01	2.63	-	-	-	-	-	-	-	-	-
Order Decapoda																				
Family Paguridae																				
Pagurus perlatus	-	-	-	-	-	-	-	-	-	-	-	-	22.50	1.09	3.70	3.53	-	-	-	-
Family Hippidae																				
Hippidae w/i	0.07	0.10	2.38	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Infraorder Brachyura																				
Brachyura w/i	0.02	0.01	1.19	0.01	0.01	0.01	8.33	0.01	0.01	0.01	2.63	0.01	-	-	-	-	-	-	-	-
Family Cancridae																				
Cancer porter	-	-	-	-	-	-	-	-	-	-	-	-	15.00	34.15	14.81	29.39	-	-	-	-
Order Stomatopoda																				
Stomatopoda w/i	0.01	0.02	2.38	0.01	-	-	-	-	0.01	0.01	2.63	0.01	2.50	1.08	3.70	0.54	-	-	-	-
Family Gonodactylidae																				
Gonodactylidae w/i	0.01	0.01	1.19	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Family Hemisquillidae																				
Hemisquilla sp.	0.01	0.01	1.19	0.01	0.01	0.74	8.33	0.37	-	-	-	-	-	-	-	-	-	-	-	-
Family Squillidae																				
Squilla parva	-	-	-		-	-	-	-	-	-	-	-	2.50	0.25	3.70	0.41	-	-	-	-
Squilla spp.	-	-	-		-	-	-	-	-	-	-	-	2.50	0.29	3.70	0.42	-	-	-	-

Table 2 continued / Continuación Tabla 2

Prey Taxa	*Mobula mobular* (n= 30)				*Mobula thurstoni* (n= 3)				*Mobula munkiana* (n= 23)				*Myliobatis chilensis* (n= 36)			
	%N	%W	%FO	%IRI	%N	%W	%FO	%IRI	%N	%W	%FO	%IRI	%N	%W	%FO	%IRI
Order Euphausiacea																
Euphausiacea w/i	0.63	0.66	1.19	0.07	-	-	-	-	-	-	-	-	-	-	-	-
Family Euphausiidae																
Euphausiidae w/i	0.06	0.03	1.19	0.01	-	-	-	-	11.30	22.42	15.79	11..94	-	-	-	-
Euphausia eximia	0.66	0.32	2.38	0.01	20.52	26.25	8.33	23.39	0.08	0.03	2.63	0.01	-	-	-	-
Euphausia mucronata	12.54	48.91	15.48	42.49	-	-	-	-	-	-	-	-	-	-	-	-
Euphausia spp.	6.20	17.68	11.91	12.70	1.11	0.66	8.33	0.88	47.33	51.47	31.58	69.98	-	-	-	-
Nyctiphanes simplex	5.50	6.46	7.14	3.82	35.36	37.25	8.33	36.30	0.52	2.73	5.26	0.38	-	-	-	-
Nyctiphanes sp.	0.97	3.50	1.19	0.24	3.58	1.99	8.33	2.78	16.15	18.22	18.42	14.20	-	-	-	-
Stylocheiron sp.	0.01	0.02	2.38	0.01	37.29	33.07	8.33	35.20	-	-	-	-	-	-	-	-
Phylum Chaetognatha																
Chaetognatha w/i	0.05	0.07	1.19	0.01	-	-	-	-	-	-	-	-	-	-	-	-
Phylum Chordata																
Subphylum Tunicata																
Appendicularia	0.01	0.01	1.19	0.01	0.01	0.04	8.33	0.03	0.01	0.32	2.63	0.02	-	-	-	-
Class Actinopterygii																
Superclass Pisces																
Pisces (Ova)	0.01	0.01	2.80	0.01	0.01	0.01	8.33	0.01	0.01	0.01	5.26	0.01	-	-	-	-
Infraclass Teleostei																
Teleostei w/i	-	-	-	-	-	-	-	-	-	-	-	-	5.00	0.62	7.41	1.68
Family Engraulidae																
Engraulis ringens	-	-	-	-	-	-	-		-	-	-	-	5.00	2.97	7.41	2.38
Family Merluciidae																
Merluccius gayi	-	-	-	-	-	-	-	-	-	-	-	-	5.00	19.13	7.41	7.21
Family Paralychthidae																
Paralychthys sp.	-	-	-	-	-	-	-	-	-	-	-	-	2.50	4.13	3.70	0.99
Family Congriidae																
Xenomystax atrarius	-	-	-	-	-	-	-	-	-	-	-	-	2.50	2.18	3.70	0.70
Phylum Mollusca																
Class Gastropoda																
Gastropoda w/i	0.01	0.01	2.38	0.01	-	-	-	-	-	-	-	-	20.00	9.10	29.63	34.80
Family Naticidae																
Naticidae w/i	0.01	0.01	2.38	0.01	-	-	-	-	-	-	-	-	-	-	-	-

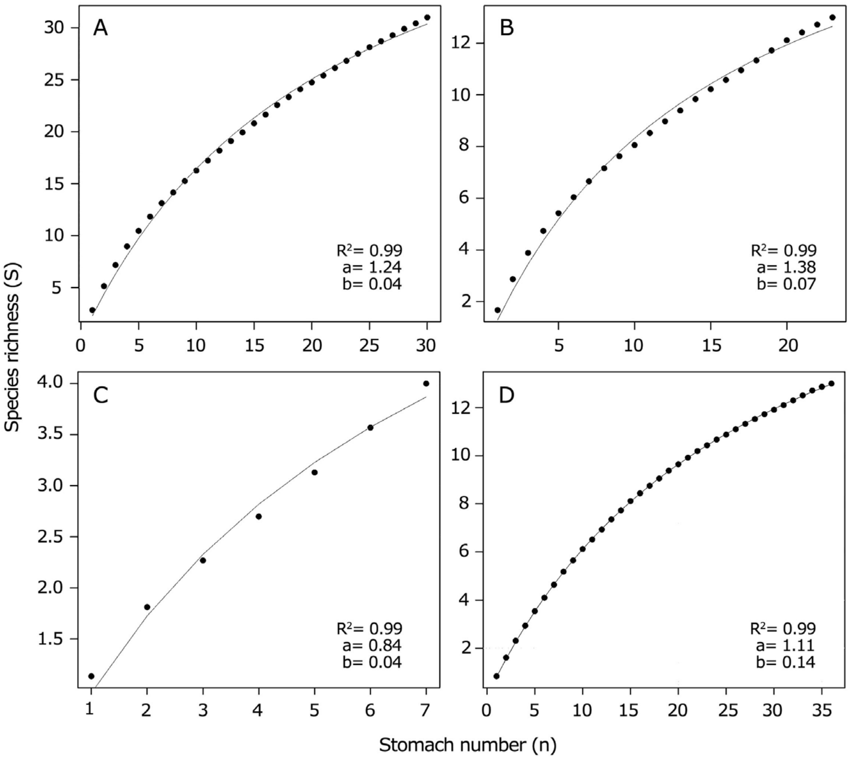

Figure 2. Asymptotic Clench's curve for prey accumulation. The points correspond to the observed data, the lines to expected data, 'a' is the intercept and 'b' is the slope of the line. A) *Mobula mobular*, B) *Mobula munkiana*, C) *Myliobatis chilensis*, D) *Myliobatis peruvianus* / Curva asintótica de Clench para la acumulación de presas. Los puntos corresponden a los datos observados, las líneas a los datos esperados, 'a' es el intercepto y 'b' la pendiente. A) *Mobula mobular*, B) *Mobula munkiana*, C) *Myliobatis chilensis*, D) *Myliobatis peruvianus*

Significant differences were found between the two devil rays ($P < 0.05$) in both prey abundance and weight (Tables 3 and 4). For *M. mobular*, the SIMPER revealed a high percentage in abundance and weight for the prey items Euphausiacea (83.1 and 82.5%, respectively) and Calanoida (12.9 and 16.1%, respectively). While for *M. munkiana*, the same test resulted in lower values to the prey item Euphausiacea in abundance and weight (56.2 and 56.7%, respectively) but higher values for the prey item *Nyctiphanes* sp. (21.5 and 20.4%, respectively). Although *N. simplex* is one of the most abundant euphausiid species in Peru (Nakazaki & Ayón 2012), *M. mobular* did not have *Nyctiphanes* species as its main prey, but rather the euphausiid *Euphausia mucronata* (Table 2). This is likely due to differences in the spatial distributions between devil ray species. *Mobula mobular* individuals were mostly captured in northern and oceanic waters, in contrast to the other two species of devil rays (Fig. 1), and the zones may have differences in prey availability due to the different distributions between euphausiid species (Ayón & Girón 1997). A larger sampling effort in quantity and time would allow for a comparison between zones. It is noteworthy that for *M. munkiana* there was a high presence of digested items that could only be identified to the level of Euphausiacea, which was another marked difference in comparison with the other mobulids.

Table 3. Results of the PERMANOVA test comparing the feeding habits of the species *Mobula mobular* and *Mobula munkiana* with the ABUNDANCE prey data / Resultados de la prueba PERMANOVA comparando los hábitos alimentarios entre las especies *M. mobular* y *M. munkiana* con datos de ABUNDANCIA de las presas

Source	df	SS	MS	Pseudo-F	*P*(perm)	Permutations
Species	1	10080	10080	3.13	0.029	999
Residuals	34	$1.09e^7$	322.3			
Total	35	$1.19e.^7$				

df= degree of freedom, SS= sum of squares, MS= mean squares, *P*(perm)= *P*-value from permutations

The trophic levels (T_L) were 3.29 and 3.26 for *M. mobular* and *M. munkiana,* respectively. They are surpassed by other congeners such as *Mobula japanica* (T_L 3.48) [now *M. mobular* (White *et al.* 2018)], and *M. thurstoni* (T_L 3.43) from the Gulf of California, where their only prey was *N. simplex* (Sampson 2007). However, Sampson (2007) evaluated the trophic level using stable isotopes, while in this study we used stomach contents. Additionally, there was an absence of mysids, benthic crustaceans, in the

Table 4. Results of the PERMANOVA test comparing the feeding habits of the species *Mobula mobular* and *Mobula munkiana* with the WEIGHT prey data / Resultados de la prueba PERMANOVA comparando los hábitos alimentarios entre las especies *M. mobular* y *M. munkiana* con datos de PESO de las presas

Source	df	SS	MS	Pseudo-F	*P*(perm)	Permutations
Species	1	8689.2	8689.2	2.64	0.044	999
Residuals	34	$1.12e^{7}$	3296.5			
Total	35	$1.21e.^{7}$				

df= degree of freedom, SS= sum of squares, MS= mean squares, *P*(perm)= *P*-value from permutations

diet of devil rays in our study. This suggests that during 2015 those devil rays did not show the demersal feeding behaviour as described in other diet studies (McEachran & Notarbartolo di Sciara 1995, Hobro 2002, Sampson *et al.* 2010). A continuous evaluation of the behaviour of these species would help clarify this topic. Results from our study may indicate that most devil ray feeding activities take place in the pelagic zone or are directly related to the vertical movements of zooplankton in the water column.

For the genus *Myliobatis*, a total of 32 stomachs were analysed of which 94% (30) had contents. For this genus, 14 prey items were found (Table 2). Even though the correlation coefficients for both eagle ray species were near to 1, only *M. chilensis* had a slope lower than 0.1 (b= 0.04) indicating that it is the only eagle ray with adequate sampling effort, representing 58% of its diet (Fig. 2C and D). Thus, as *M. peruvianus* had a low sample size, its diet will be only described. For both eagle rays, it is important to highlight the high abundance of gastropods (Table 2), mainly for *M. peruvianus,* while for *M. chilensis* another important prey was the decapod, *Cancer porteri*. Crowder & Cooper (1982) suggested that the diet of a predator could look like specialist when a specific prey is abundant in the environment. Hence, a high abundance of gastropods and decapods ingested could be indicative of its high abundance in the environment. However, the 2015 moderate ENSO could have caused a decline in the recruitment of gastropods (Díaz & Ortlieb 1993, Ramos *et al*. 1999), so the fact that the diet of these eagle rays was dominated by gastropods and decapods could be indicative of their specialist behaviour.

In our study, a small proportion of pelagic teleosts and crustaceans were identified as prey for both eagle rays (Table 2). These results support previous studies that also reported the presence of demersal and pelagic prey as part of the diet of related demersal ray species (Torres 1978, Castañeda 1994, Gray *et al.* 1997, Jardas *et al.* 2004, Navarro-González *et al*. 2012) and benthic ray species (Coller 2012, Simental-Anguiano 2013). However, both Torres (1978) and Castañeda (1994) indicated a broader variety of benthic prey items, including polychaetes and bivalves. This behaviour of preying upon pelagic teleosts could be influenced by the morphology of large rays with large pectoral fins, which allows them to exploit both pelagic and benthic species (Rosenberger 2001) and act as trophic process linkers, controlling prey populations in pelagic and benthic ecosystems (Lundberg & Moberg 2003). The presence of a cephalopod from the order Teuthida in one stomach of *M. peruvianus* could be associated with this behavior and show versatility in its feeding diet. These results also suggest that both species of eagle rays could have overlapping diets, leading to competition when resources are scarce (Navarro-González *et al.* 2012). In addition, the vertical migrations of fish could be influencing the pattern observed in the diet of *Myliobatis*. However, since our sampling period was relatively short, it was not possible to assess temporal variations.

Finally, our results indicate that devil rays and eagle rays are secondary predators. Comparing their diet compositions, devil rays ingested lower tropic level prey (*i.e.*, zooplankton) than eagle rays (*i.e.*, gastropods and teleosts). Devil rays have a lower trophic level, T_L= 3.29 for *M. mobular* and T_L= 3.26 for *M. munkiana*, narrower niche breadth (β_i= 0.17 and 0.16, respectively) and their diets specialized, dominated by euphausiids (Table 2). The eagle ray *M. chilensis*, while still specialist (β_i= 0.50), seems to have a wider niche breathe than devil rays, feeding mainly upon gastropods and located in a higher trophic level (T_L= 3.62).

We recommend studying the diets of batoid species for longer periods, including during ENSO and non-ENSO periods, to assess for seasonal or even daily differences, and to contribute to an improved understanding of marine community dynamics. Studies of energy transfer along trophic chains would also help clarify the importance of each prey item in the diet of rays. Finally, we believe that our results are an important step toward better understanding the feeding habitats of devil rays and eagle rays in the eastern Pacific Ocean and can serve as a baseline for future studies.

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