Diet of the Dusky finless skate *Gurgesiella furvescens* de Buen, 1959 (Chondrichthyes: Rajidae) from the continental shelf and slope of the north-central area of Chile

Dieta de la raya de profundidad Gurgesiella furvescens de Buen, 1959 (Chondrichthyes: Rajidae) de la plataforma y talud continental del área centro-norte de Chile

# Abstract

The Dusky finless skate *Gurgesiella furvescens* appears sporadically as part of the bycatch in the trawl fishery targeting benthic crustaceans on the continental shelf and upper slope of the north-central area of Chile (26ºS-33ºS). We have few antecedents about biological aspects of the *G. furvescens*, particularly those related to their feeding. In this paper, we determine the diet composition of *G. furvescens* and relationships between prey size and mouth size and between the weight of the prey and the bodyweight of the predator. We sampled 51 stomachs from individuals obtained from the bycatch of trawls targeting benthic crustaceans in 2013 and 2017. The stomach contents indicate that this skate is consuming mainly shrimp *Heterocarpus reedi*, secondarily deepwater shrimp *Haliporoides diomedeae*, and indeterminate crustaceans. The size of the prey was a linear function of the mouth size, as well as the weight of the prey was related with the bodyweight of the predator. Although squat-lobsters were abundant in the study area, the importance of the shrimp *H. reedi* and *H. diomedeae* in the diet of *G. furvescens* may be due to preference and/or selection of this kind of prey in deep waters.

**Key words**: skate, diet, prey, specialist feeder.

# Resumen

La raya de profundidad *Gurgesiella furvescens* aparece esporádicamente como parte de la captura incidental en la pesquería de arrastre dirigida a crustáceos bentónicos en la plataforma continental y talud superior de la zona centro-norte de Chile (26ºS-33ºS). Los antecedentes sobre aspectos biológicos de *G. furvescens* son pocos, particularmente aquellos relacionados con su alimentación. Nosotros determinamos la composición de la dieta de *G. furvescens* y las relaciones entre el tamaño de la presa y el tamaño de la boca, y entre el peso de la presa y el peso corporal del depredador. Se obtuvieron 51 estómagos de individuos obtenidos de la captura incidental de la pesca de arrastre dirigidas a crustáceos bentónicos entre 2013 y 2017. El contenido del estómago indica que esta raya consume principalmente camarón naylon *Heterocarpus reedi*, gamba *Haliporoides diomedeae* y crustáceos indeterminados. El tamaño de la presa fue una función lineal del tamaño de la boca, así como el peso de la presa se relacionó con el peso corporal del depredador. Aunque los langostinos son abundantes en el área de estudio, la importancia de *H. reedi* y *H. diomedeae* en la dieta de *G. furvescens* puede deberse a la preferencia y/o selección de este tipo de presas en aguas profundas.

**Palabras claves**: raya, dieta, presas, predador, especialista

# Introduction

Skates represent a diverse group, widely distributed around the world, from shallow to near 2000 m depth (Priede *et al*. 2006). More than 90% of elasmobranch species inhabit deep waters on the continental shelves and slopes (Compagno 1990). According to Bustamante *et al*. (2014), at least 30 cartilaginous fishes inhabit (or did inhabit) on the continental shelf off central Chile. Evidence suggests an overall increase in skate species richness with increasing latitude and shark species depth down to 500 m. Understanding the ecological factors that condition the role of elasmobranchs in deep-water ecosystems is possible by describing the feeding habits of these predators. Indeed, skates play an essential role in transferring energy of benthic and demersal trophic webs (Wheterbee & Cortés 2004, Ebert & Bizarro 2007). Although the degree of foraging specialization of the group varies from specialists to generalist species, many deepwater skates feed primarily on decapod crustaceans and secondarily teleosts, with polychaetes and amphipods being relevant prey groups too (Ebert and Bizarro 2007).

The Dusky finless skate, *Gurgesiella furvescens* de Buen (1959), has a distribution from the Galápagos in Ecuador to Valparaíso in Chile (Lamilla & Saez 2003). The southern boundary of the *G. furvescens* distribution ends at 35ºS, which is coincident with the limit of the Peruvian biogeographic province (Pequeño & Lamilla 1993, Sielfeld & Vargas 1996, Bustamante *et al*. 2014). McEachran & Compagno (1979) point out a distribution between 400 and 960 m depth, while Yañez & Barbieri (1974) found the species between 351-600 m at 33ºS (Valparaíso), and Sielfeld & Vargas (1996) found *G. furvescens* between 300 and 600 m depth. In general, the biological aspects of the genus Gurgesiella are poorly known, and *G. furvescens* is a scarcely studied species (Lamilla 2004). According to McEachran & Compagno (1979), the maturity size is at 50.9-52 cm body length in males, and from 55.2 to 56.8 cm body length in females. Ñacari *et al*. (2018) described a new species of monogenean parasite of the deep-sea skate *G. furvescens*. In the Atlantic, there are two species *G. atlantica* (Bigelow & Schroeder 1962) and *G. dorsalifera* (McEachran & Compagno 1980). Rincón *et al*. (2008) described the trophic spectrum of *G. dorsalifera* in southern Brazil. The analysis of stomach contents revealed apparent opportunistic predation on juveniles of *Urophycis brasiliensis*, followed by mysidaceans, unidentified teleosts, copepods, and decapod crustaceans.

In Chile, *G. furvescens* is occasionally caught as bycatch in the trawl fisheries of benthic crustaceans (Acuña *et al*. 2005, Queirolo *et al*. 2011, Bustamante *et al*. 2014). The trawl fisheries are targeting two squat-lobsters (*Cervimunida johni* and *Pleuroncodes monodon*), the shrimp *Heretocarpus reedi*, and occasionally the deepwater shrimp *Haliporoides diomedeae* (Arana *et al*. 2003, Acuña *et al*. 2014). There is no published information about the diet of *G. furvescens*, and the objective of this paper was to study the diet of *G. furvescens* and the relationships between prey size and mouth size of the predator, as well as the weight of the prey and the body weight of the predator.

# Materials and Methods

## Study area and sampling

The study area was located on the slope and continental shelf off north-central Chile (Fig. 1), with fishing tows obtained between 25.5ºS to 33ºS on board of trawlers (22 m length, Table 1). The vessel FOCHE was fishing for red squat-lobster (*Pleuroncodes monodon*) and yellow squat-lobster (*Cervimunida johni*), while the second vessel (Isla Orcas) and third vessel (Lonquimay) targeted the shrimp (*Heterocarpus reedi*). The study area has a narrow continental shelf and a steep slope, the reason why the samples were obtained close to the coast at depths between 180 and 511 m (Table 1, Fig. 1). Once captured, the specimens of the Dusky finless skate were immediately refrigerated and transported to the Universidad Católica del Norte, Coquimbo laboratory. Each individual, as sex-identified and measured the body length (0.1 cm), disk size (0.1 cm), disk length (0.1 cm), mouth size (0.1 cm) and the total body weight (0.1 g). Classifying the specimens as juvenile or mature. The degree of clasper calcification and the development of testes and reproductive ducts determined the stage of maturity (immature or mature) of the males. In contrast the, maturity stage for females was determined by the uterus condition, the oviduct glands and the ovarian follicles according to Ebert (2005).

## Stomach contents analysis

We removed the stomach and analyzed their contents. The degree of filling of each stomach concerning the ingested food was quantified. The preys found in each stomach were separated, weighed (after drying the excess of surface water with paper, 0.01 g), identified to the lowest taxonomic level, and specimens of each taxon were counted and measured. We measured the size of the crustaceans as the total length (0.1 cm).

We traced the cumulative number of pooled stomachs versus the average cumulative number of the main prey species to determine whether we sampled a sufficient number of Dusky finless skate (Ferry & Caillet 1996, Cortés 1997). We computed the cumulative prey curve as a function of the number of stomachs with the BiodiversityR package (Kindt and Coe 2005) for the software and language R (R Core Team, 2019), analyzing the relative importance of preys in the diet was analyzed according to the following equation:

where , , and are the frequency of occurrence, the number in percentage, and the wet weight (of all prey including hard parts) (Pinkas *et al*. 1971). We expressed the values in percentage to allow comparisons with other studies, (, Cortés 1997). Also, we calculated the feeding coefficient () according to:

where and were previously defined, according to Braga & Braga (1987), when , the feeding has a preference, the feeding has secondary preys, and the feeding is supported by rare preys.

We performed a quantile regression to establish the relationships between the prey size and the mouth size, as well as between the prey weight and the body weight of the predator. Quantile regression is a technique we prefer (Scharf *et al*. 1998) because we are interested in the border of the relationships. We used the algorithms described in the “quantreg” package for the language R, using 90% as a quantile that describes the border of the relationships.

# Results

The body length of the collected specimens fluctuated between 20.3 and 64.5 cm, with a mean of 41.3 cm total length and a standard deviation of 11.7 cm (). Of the total number of individuals, 29 are females, 15 females were immature, 8 maturing, and 6 mature. In the case of males, 11 specimens were immature and 11 mature.

The diet analysis showed that 100% of the stomach had contents (), from which 44.5% classified as full, and 55.5% was half-full. Decapod crustaceans were the main prey items in the stomach contents and represented by the shrimp *Heterocarpus reedi*, and the deep-sea shrimp *Haliporoides diomedeae* and the rest were indeterminate crustaceans. According to the quantitative analysis, from a total of 64 prey specimens, *H. reedi* contributed with 76.56%, identifying the same importance for mass and frequency of occurrence. Indeterminate crustaceans contributed with 12.5%, which were not possible to identify because they were very digested. *H. diomedeae* represented 9.38% of the diet, and 1.6% was due to an indeterminate mollusk (Table 2). According to the feeding coefficient (), the preferred prey of Dusky finless skate was *H. reedi*. The deep-sea shrimp *H. diomedeae* was secondary in the stomach contents.

The stomach contents revealed a very narrow trophic spectrum represented by only three main prey items and a rare prey represented by the indeterminate mollusk. Therefore the cumulative prey curve reached an asymptote after 25 stomachs (Fig. 2). Thus, the sample size was sufficient to describe the diet of the Dusky finless skate.

The 90% quantile regression between prey size and mouth size showed a clear linear border, as well as the relationship between the prey weight in the stomach contents and the body weight of the predator (Fig. 3). The average relationship between prey size and mouth size (, ). Besides, the average weight of preys as a function of body weight showed a linear relationship described by (, ).

# Discussion

Acuña *et al*. (2005) and Bustamante *et al*. (2014) reported that *G. furvescens* was in the by-catch of the benthic crustaceans fisheries, with low frequency. Indeed, in terms of relative frequency, Bustamante *et al*. (2014) reported a depth range between 362 and 484 m and a latitudinal range between 29.4 and 32ºS in 2006. In our results, the presence of *G. furvescens* was low in the trawl nets, but the samples collected allow us to report wide, deep distribution from 179 to 511 m, as well as covering a higher latitudinal range than previously described (*i.e.*, from 25.5°S to 33°S). On the other hand, the maximum size reported for *G. furvescens* was 56.8 cm by Lamilla (Pers. Comments and unpublished data), but in the current study we found 5 larger individuals, the largest being 64.5 cm. Also, McEachran & Compagno (1979) mentioned that the male individuals of *G. furvescens* reach maturity between 50.9 and 52.0 cm of total body length, this time, there is an individual of 48.6 cm already mature, and in the case of females, individuals mature from 44.3 cm.

The number of specimens was low (), but this number seems to be enough to study the diet of *G. furvescens*. Indeed, the stomach contents revealed a minimal number of preys represented by *Heterocarpus reedi*, *Haliporoides diomedeae*, and indeterminate crustaceans. The latter were digested and probably parts of either *H. reedi* or *H. diomedeae*. The Dusky finless skate seems to be more associated with the depth range of *H. reedi*, in which this prey is much more abundant. Although *G. furvescens* was also caught in the bycatch of squat-lobsters (*Cervimunida johni* and *Pleuroncodes monodon*), these crustaceans were not present in the stomach contents. Besided, we should mention that we found no more than one or two specimens in the stomach contents.

The feeding coefficient () revealed a strong preference for *H. reedi*. Probably *G. furvescens* is a specialist predator based on *H. reedi*. Besides, considering the low number of specimens per stomach, probably the energy requirement of *G. furvescens* could be likely low. *H. reedi* is an abundant and available prey for *G. furvescens* and probably enough to meet its energy requirements. The depth range between the prey and the predator is overlapped, but the latitudinal distribution of *H. reedi* extends to 37º10’S (Acuña *et al*. 2013), south of the latitudinal boundary of *G. furvescens* (Pequeño & Lamilla 1993, Sielfeld & Vargas 1996). In this context, the southern limit of the distribution cannot be explained by its preference for feeding *H. reedi*. The ratio between prey size and the mouth size of the predator was close to 1.47 at the 90% quantile. Because a prey tends to be larger than mouth size, probably shrimps are sucked by *G. furvescens*. According to Wilga *et al*. (2007), elasmobranchs specializing in suction-feeding are likely limited to bottom associated prey and because of their small gape may have a diet restricted to relatively small prey. In addition, the ratio between weight of preys and body weight tend to be constant, suggesting that large skates tend to eat larger preys.

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# Literature cited

**Acuña E, JC Villarroel, A Cortes & M Andrade. 2005**. Capítulo 11. Fauna acompañante en pesquerías de arrastre de crustáceos de Chile: Implicancias y desafíos desde la perspectiva de la Biodiversidad. In: Biodiversidad Marina: Valoración, Usos y Perspectivas ¿Hacia dónde va Chile? Figueroa E (Ed.), Editorial Universitaria. pp. 395-425.

**Acuña E, R. Alarcón, H Arancibia, A Cortés, L Cubillos & L Cid. 2014**. Evaluación directa de langostino colorado y langostino amarillo entre la II y VIII Regiones, año 2013. Informes Técnicos FIP. FIP/IT Nº 2013-02, 384 p.

**Acuña E, R. Alarcón, H Arancibia, A Cortés, L Cubillos & L Cid. 2015**. Evaluación directa de camarón nailon entre la II y VIII Regiones, año 2013. Informes Técnicos FIP. FIP/IT Nº 2013-01, 261 p.

**Arana P, M Ahumada & A Guerrero. 2003**. Distribución y abundancia de la gamba *Haliporoides diomedeae* (Crustacea: Decapoda: Penaeidae) frente a la costa central de Chile. Investigaciones marinas, Valparaíso 31: 57-71. <http://dx.doi.org/10.4067/S0717-71782003000200006>

**Braga FM de S & AM de S Braga. 1987**. Estudo do hábito alimentar de *Prionotus punctatus* (Bloch, 1797) (Teleostei, Triglidae), na região da Ilha Anchieta. Estado de São Paulo, Brasil. Revista Brasileira de Biologia 47:31-36.

**Bustamante C, C Vargas-Caro & MB Bennett. 2014**. Biogeographic patterns in the cartilaginous fauna (Pisces: Elasmobranchii and Holocephali) in the southeast Pacific Ocean. PeerJ 2:e416 <https://doi.org/10.7717/peerj.416>

**Compagno LJV. 1990**. Shark exploitation and conservation. In: Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of the fisheries. Pratt HL, SH Gruber & T Taniuchi (Ed). NOAA Technical Report NMFS 90, pp. 397-414.

**Cortés E. 1997**. A critical review of methods of studying fish feeding based on analysis of stomach contents application to elasmobranch fishes. Canadian Journal of Fisheries and Aquatic Science 54: 726-738.

**De Buen F. 1959**. Notas preliminares sobre la fauna marina preabisal de Chile, con descripción de una familia de rayas, dos géneros y siete especies nuevas. Boletín Museo Nacional de Historia Natural, Chile, 27(3): 171-201.

**Ebert DA. 2005**. Reproductive biology of skates, Bathyraja (Ishiyama) along the eastern Bering Sea continental slope. Journal of Fish Biology 66: 618-649. <https://doi.org/10.1111/j.0022-1112.2005.00628.x>

**Ebert DA & JJ Bizarro. 2007**. Standardized diet compositions and trophic levels of skates (Chondrichthyes: Rajiformes: Rajoidei). In: Ebert DA & JA Sulikowski (Ed) Biology of Skates. Developments in Environmental Biology of Fishes 27. Springer, Dordrecht. <https://doi.org/10.1007/978-1-4020-9703-4_8>

**Ferry L & G Caillet. 1996**. Sample size and data analysis: are we characterizing and comparing diet properly? In: Feeding, ecology and nutrition in fish. MacKinlay D & K Shearer (Ed). Symposium Proceedings, American Fisheries Society, San Francisco. pp. 71-80.

**Kindt R & R Coe. 2005**. Tree diversity analysis. A manual and software for common statistical methods for ecological and biodiversity studies. World Agroforestry Centre (ICRAF), Nairobi. ISBN 92-9059-179-X.

**Lamilla J & S Sáez. 2003**. Clave taxonómica para el reconocimiento de especies de rayas chilenas (Chondrichthyes, Batoidei). Investigaciones marinas, Valparaíso 31: 3-16.

**Lamilla J. 2004**. *Gurgesiella furvescens*. In: IUCN 2013. IUCN Red List of Threatened Species. Versión 2013.1

**McEachran J & LJV Compagno. 1979**. A further description of *Gurgesiella furvescens* with comments on the interrelationships of *Gurgesiellidae* and *Pseudorajidae* (Pisces, Rajoidei). Bulletin of Marine Science 29: 530-553.

**McEachran JD & LJV Compagno. 1980**. Results of the research cruises of FRV “Walther Herwig” to South America. LVI. A new species of skate from the southwestern Atlantic *Gurgesiella dorsalifera* sp. Nov. (Chondrichthyes, Rajoidei). Archiv fur Fischereiwissenschaft 31: 1-14.

**Ñacari L, F Sepulveda, R Escribano & M Oliva. 2018**. *Acanthocotyle gurgesiella* n. sp. (Monogenea: Acanthocotylidae) from the deep-sea skate *Gurgesiella furvescens* (Rajidae) in the south-eastern Pacific. Journal of Helminthology 92: 223-227. <http://doi.org/10.1017/S0022149X17000220>

**Pequeño G. & J Lamilla. 1993**. Batoideos comunes a las costas de Chile y Argentina-Uruguay (Pisces: Chondrichthyes). Revista de Biología Marina 28: 203-217. <https://revbiolmar.uv.cl/escaneados/282-203.pdf>

**Pinkas L, MS Oliphant & ILK Inverson. 1971**. Food habits of albacore, bluefin tuna, and bonito in Californian waters. Fishery Bulletin 152: 11–105.

**Priede IG, R Froese, DM Bailey, OA Bergstad, MA Collins, JE Dyb, C Henriques, EG Jones & N King. 2006**. The absence of sharks from abyssal regions of the world’s oceans. Proceedings of the Royal Society B, Biological Sciences 273: 1435-1441. <https://doi.org/10.1098/rspb.2005.3461>

**Queirolo D, K Erzini, CF Hurtado, E Gaete & MC Soriguer. 2011**. Species composition and bycatches of a new crustacean trawl in Chile. Fisheries Research 110: 149–159. <https://doi.org/10.1016/j.fishres.2011.04.001>

**Rincon G, T Vaske Jr., & CM Vooren. 2008**. Stomach contents and notes on the reproduction of the onefin skate *Gurgesiella dorsalifera* (Chondrichthyes: Rajidae) off Southern Brazil. Neotropical Ichthyology 6: 689-692. <http://dx.doi.org/10.1590/S1679-62252008000400019>

**Scharf FS, F Juanes & M Sutherland. 1998**. Inferring ecological relationships from the edges of scatter diagrams comparison of regression techniques. Ecology 79: 448-460. [https://doi.org/10.1890/0012-9658(1998)079[0448:IERFTE]2.0.CO;2](https://doi.org/10.1890/0012-9658(1998)079%5B0448:IERFTE%5D2.0.CO;2)

\*\*Sielfeld W & M Vargas. 1996\*. Composición y estructura de la ictiofauna demersal en la zona norte de Chile. Investigaciones marinas, Valparaíso 24: 3-17. <http://dx.doi.org/10.4067/S0717-71781996002400001>.

**Wetherbee BM & E Cortés. 2004**. Food consumption and feeding habits. In: Biology of sharks and their relatives. Musick JA, JC Carried & M Heithaus (Ed). CRC Press, Boca Raton FL, pp. 223-244.

**Wilga CA, PJ Motta & CP Sanford. 2007**. Evolution and ecology of feeding in elasmobranchs. Integrative and Comparative Biology 47: 55-69. <https://doi.org/10.1093/icb/icm029>

**Yáñez E & MA Barbieri. 1974**. Distribución y abundancia relativa estacional de los recursos disponibles a un arte de arrastre camaronero frente a la costa de Valparaíso (invierno 1973). Investigaciones marinas, Valparaíso 5: 137-156.