SPRFMO

6th Meeting of the Scientific Committee

Puerto Varas, Chile, 9 - 14 September 2018

SC6-SQ04

Diet and feeding of jumbo squid (*Dosidicus gigas*) in the southern Humboldt upwelling system

C. Bruno & S. Núñez

DIET AND FEEDING OF JUMBO SQUID (*Dosidicus gigas*) IN THE SOUTHERN HUMBOLDT UPWELLING SYSTEM

C. Bruno & S. Núñez
Departamento de Pesquerías. Instituto de Investigación Pesquera. P.O. Box 350, Talcahuano, Chile. cbruno@inpesca.cl, snunez@inpesca.cl.

SUMMARY

The trophic spectrum of 2,672 jumbo squid (Dosidicus gigas) individuals collected by scientific observers onboard fishing vessels in coastal waters of central-south Chile was analyzed. The analysis of diet was carried out during 2014-2017 on a size range between 35-99 cm MDL. A total of 28 prey items (13 fish, 10 crustaceans, 5 mollusks) were determined, with higher values of relative importance index for crustaceans (mainly euphausiids= 14.5%), fishes (*Diaphus* sp.= 8.1, *Lampanyctus* sp.= 4.6%, Teleostei indeterminate= 3.9%, *Merluccius gayi*= 3.2%), and mollusks (*D. gigas*= 44.6%).

Trophic diversity was higher during 2014-2015 (H'= 1.706-1.484) according to the occurrence of 19-20 preys, while less diversity values (H'= 0.814-0.878) were observed during 2016-2017 due to a lower number of preys (7), dominated by common hake and jumbo squid (cannibalism), describing a generalist trophic behavior during 2014-2015.

Cluster analysis of preys showed that the smaller size-group (G1, ≤50 cm MDL) consumed crustaceans (mainly euphausiids), the intermediate size-groups (G2-G3, 51-70 cm MDL) mainly predated on myctophiids and squids, and the large-size groups (G4-G5, >70 cm MDL) consumed squids (cannibalism) and fish (especially myctophiids).

INTRODUCTION

The diet of the cephalopods and particularly of Family Ommastrephidae, places them within higher trophic levels (Velasco *et al*. 2001), showing high energetic requirements due to their high growth rates (Boyle & Boletzky 1996), and exhibiting an opportunistic trophic behavior on a wide variety of prey (Rodhouse & Nigmatullin 1996). In marine ecosystems, populations of cephalopods can respond rapidly to natural or anthropogenic environmental changes, observing strong interannual fluctuations in population size (Beddington *et al*. 1990).

The jumbo squid (*D. gigas*) has been described as an active predator mainly on copepods, amphipods, euphausiids, pelagic shrimp, heteropods, squids, and fish, including cannibalism (Nigmatullin *et al*. 2001, Markaida & Sosa-Nishizaki 2003, Nigmatullin *et al*. 2001). This species shows diet changes during ontogeny, feeding on zooplankton (juveniles) and fish and cephalopods (adults) (Nigmatullin *et al*. 2001). Changes in the trophic spectrum have also been observed with the size increasing cannibalism (Markaida & Sosa-Nishizaki 2003), and diet can also fluctuate seasonally and geographically (Cubillos *et al*. 2004). Likewise, it has been shown that specimens

of jumbo squids between 20 and 40 cm MDL exhibit a daily feed ratio of 3.9 g/day, which implies removing annually 1.42 times their own biomass.

In Chile, information about dietary habits and quantitative estimates of jumbo squid consumption has been scarce. Some authors have reported that jumbo squid diet consists of crustaceans, conger eels (*Genypterus chilensis* and *G. blacodes*), common hake (*Merluccius gayi*), sardine (*Sardinops sagax*), Jack mackerel (*Trachurus murphyi*) and squid (probably *Loligo gahi*), including cannibalism (Wilhelm 1951, Fernández & Vásquez 1995, Tascheri 2002, Arancibia *et al*. 2007) Likewise, Cubillos *et al*. (2004) determined spatial variations in the diet of *D. gigas*, dominated by horse mackerel (*T. murphyi*) in oceanic waters, and other fishes, *v g*., hake (*Merluccius gayi*), hake (*Macruronus magellanicus*)) and sea bream (*Epigonus crassicaudus*) in coastal zones. On the other hand, it has been observed that the consumption/biomass (Q/B) ratio in the oceanic zones is different seasonally: 1.12 (spring) and 3.71 (summer), and very similar in the coastal waters: 1.34 (winter) and 1.35 (spring).

Recent studies of the life history and population dynamics of jumbo squid show a broad trophic spectrum, with ~12 to 17 main preys in central and south-central Chile, respectively, confirming the consumption of different species of fish (mictophiids, common hake, anchovy, common sardine, Jack mackerel), as well as crustaceans (including euphausiids) and cephalopods (squids), verifying a strong contribution of cannibalism (Arancibia *et al*. 2016).

DATA AND METHODS

This working document summarized the information of diet and trophic behavior of jumbo squid obtained from the Monitoring Program of jumbo squid (*Dosidicus gigas*) developed by the Instituto de Investigación Pesquera (Inpesca, Fisheries Research Institute). The sampling of jumbo squid for stomach content analysis was carried out by scientific observers aboard industrial fishing vessels between January 2014 and August 2017. Fishing trawls were carried out between 35°30'S and 38°30'S, and between 20 and 40 nm from the coast (**Figure 1**). The number of collected jumbo squids specimens per year was 1451 (2014), 373 (2015), 513 (2016) and 335 (2017).

The analysis of jumbo squid diet was based on the methodology described by Markaida (2011) and Markaida & Sosa.Nishizaki (2003). The relationship between both the stomach content and body weight was determined by the gut fullness index (Rasero *et al*. 1995), and a qualitative scale of digestion was also applied (Jackson *et al*. 1998). The occurrence frequency of prey was determined following to Hyslop (1980), and the relative importance index (Pinkas *et al*., 1971, modified by Arancibia *et al*., 1995) was used to evaluate the importance of prey in jumbo squid stomachs. On the other hand, the diet of jumbo squids was analyzed by range of predator sizes considering groups of 10 or 20 cm of mantle dorsal longitude (MDL). Likewise, the prey items were analyzed spatially and temporally according to Pennington *et al*. (1982). Finally, trophic heterogeneity was determined by the diversity index (Shannon-Wiener), assigning a euryphagic trophic behavior (high H' values) or stenophagic trophic behaviour (low H' values) according to Berg (1979).

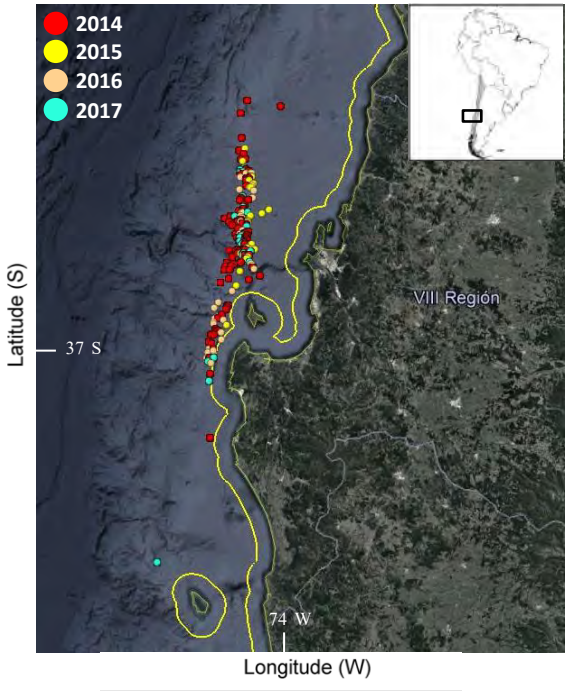

Figure 1. Fishing sets of jumbo squids in coastal waters of central-south Chile during 2014-2017 (from Instituto de Investigación Pesquera).

RESULTS AND DISCUSSION

A total of 2,672 jumbo squids stomachs collected during 2014-2017 were analyzed, verifying a 65.5% of stomachs with gastric content (Figure 2). A high number of stomachs was analyzed during 2014 (n= 1451), while during 2015-2017 a significantly lower number was analyzed (n= 335-513). A highest percentage of stomachs with content (>70%) was also observed in 2014 and 2015, and lower percentages (<40%) was observed in 2016-2017. Likewise, a high percentage (>90%) of empty or almost empty stomachs was observed during 2014-2017 (Figure 3).

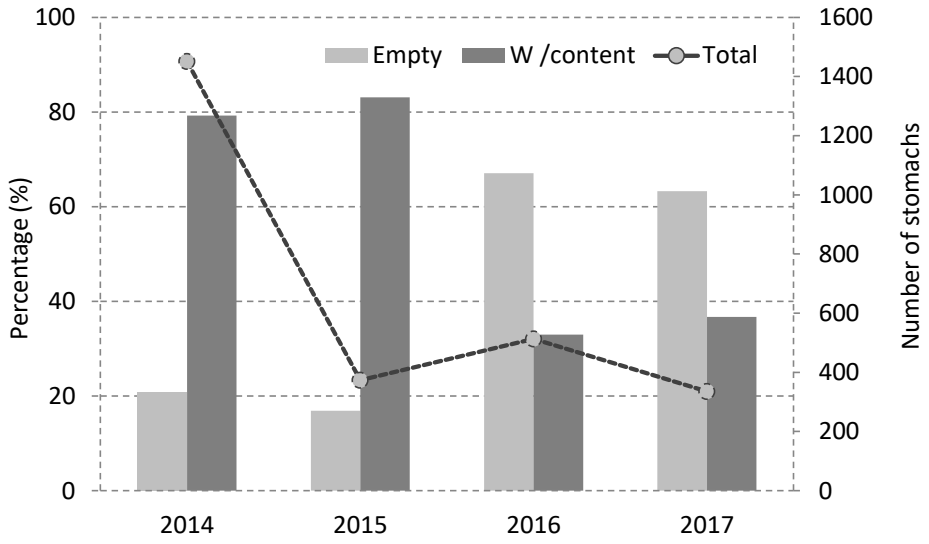

Figure 2. Number of stomachs of jumbo squids (empty and with contents) analyzed for 2014-2017 period.

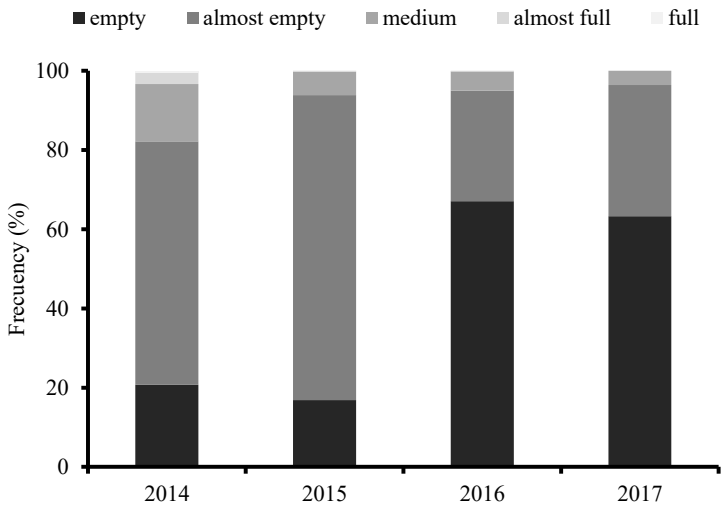

Figure 3. Gut fullness of jumbo squid stomachs collected in the coastal region of central-south Chile during 2014-2017 (n=2672).

Table I shows the jumbo squid prey composition during 2014-2017, highlighting 13 taxa of fish (especially myctophids), 10 crustaceans and 5 taxa of mollusks. In addition, Table I also shows the relative importance index of jumbo squid preys for 2014-2017, revealing a diet composed by crustaceans (mainly euphausiids= 14.5%), fishes (*Diaphus* sp.= 8.1, *Lampanyctus* sp.= 4.6%, Teleostei indeterminate= 3.9%, *Merluccius gayi*= 3.2%), and mollusks (*D. gigas*= 44.6%), coinciding with observed by Arancibia *et al*. (2016). On the other hand, Figure 4 shows a Fullness Weigth Index (FWI) of jumbo squid stomachs showing a low interannual variability ~0.1 and 0.2 (n = 2007).
An estimate of the daily food ration was made for 2014 (n = 1451), as a fraction of body weight, showing values between 1.9 and 3.8% of the predator weight, similar to that reported by Cubillos *et al*. (2004) and Arancibia *et al*. (2007).

Table I. Frequency (number and weight) and Relative Importance Index (RII, %) of preys in jumbo squid stomachs collected in the center-south region of Chile during 2014-2017. Jumbo Squid Monitoring Program (Inpesca).

	Preys	%F	% N	%W	%RII
Teleostei	*Vinciguerria lucetia*	0.3	1.1	0.1	0.1
	Mictophidae	1.1	2.7	0.7	0.8
	Notoscopelus sp	0.1	0.2	0.0	0.0
	Lampanyctus sp	1.8	10.7	0.4	4.6
	Lampadena sp	0.0	0.0	0.0	0.0
	Diaphus sp	1.6	21.4	0.7	8.1
	Hygophum sp	0.1	0.1	0.0	0.0
	Teleostei indeterm.	4.2	2.3	7.1	3.9
	Coelorhynchus sp	0.0	0.0	0.0	0.0
	Merluccius gayi	2.4	3.2	5.9	3.2
	Engraulis ringens	0.1	0.1	0.0	0.0
	Strangomera bentincki	0.7	3.3	1.9	1.0
	Normanichthys crockeri	0.7	9.9	0.5	1.8
Crustacea	Euphausiacea	4.2	14.4	1.8	14.5
	Mysis larvae	0.6	11.3	0.0	1.6
	Megalopa	0.2	0.1	0.0	0.0
	Crustaceans eggs	0.0	9.1	0.0	0.0
	Hyperidea	0.8	0.3	0.0	0.1
	Gammaridea	0.0	0.1	0.0	0.0
	Stomatopoda (juveniles)	0.6	1.7	0.1	0.3
	Pleurodoncodes monodon	0.1	0.0	0.0	0.0
	Decapoda	3.8	1.7	1.3	1.8
	Crustacea indeterm.	21.5	0.0	13.5	3.2
Mollusca	*Dosidicus gigas*	25.9	6.0	37.7	44.6
	Todarodes filiippovae	0.2	0.0	0.8	0.2
	Gonatus antarticus	0.0	0.0	0.0	0.0
	Indeterminate	0.1	0.0	0.1	0.0
	Cephalopoda indeterm.	40.5	0.4	27.3	10.2

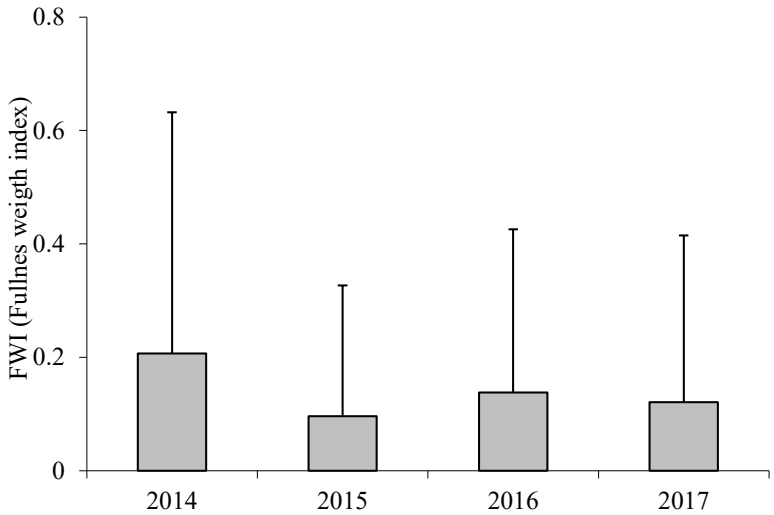

Figure 4. Fullness weight index (FWI) of jumbo squid stomachs collected in the coastal region of central-south Chile, during 2014-2017 (n= 2007). Vertical bars= standard deviation.

Table II shows the annual diversity and dominance index determined during 2014-2017. Diversity values were higher during 2014-2015 (H'= 1.706-1.484) according to 19-20 preys, while they were lower (H'= 0.814-0.878) during 2016-2017 due to a lower number of preys (7) dominated by common hake and jumbo squid (cannibalism).

The comparison of frequency (in weight) for three most important prey categories of *D. gigas*, *i e*., fish, cephalopods and crustaceans during 2014-2017 (Figure 5), showed: a) the domain of cephalopods (*D. gigas*) (>60% contribution) with low inter-annual variability, b) higher contribution of fish during 2016-2017, and c) an increase of crustaceans in 2014 (~20%).

Table II. Index of diversity (Shannon-Wiener) and dominance of *D. gigas* preys during 2014-2017 off central-south Chile.

	Diversity	Dominance
2014	1.706	0.238
2015	1.484	0.302
2016	0.814	0.572
2017	0.878	0.531

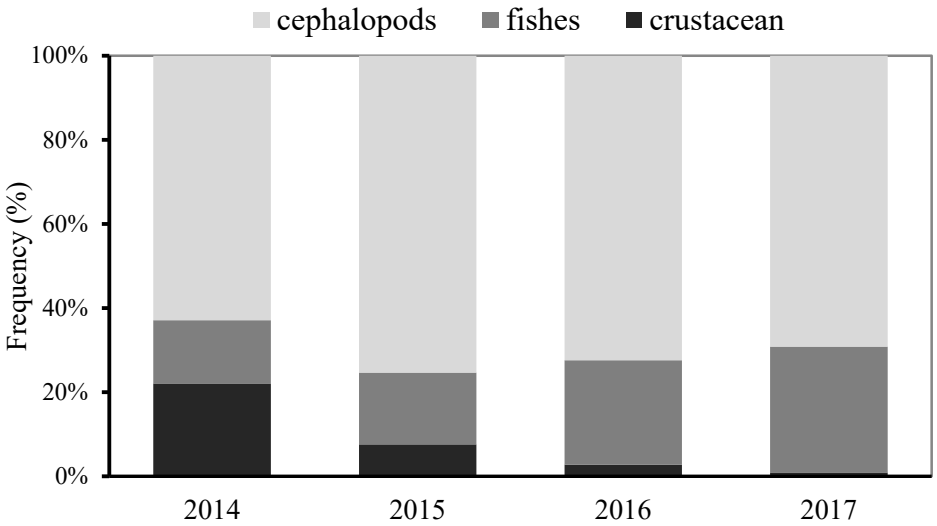

Figure 5. Contribution of cephalopods, fishes and crustaceans in jumbo squid diet for specimens collected during 2014-2017.

Figure 6. Shows a cluster analysis of *D. gigas* preys categorized by size, observing three major groups. The smaller size-group (G1, ≤50 cm MDL) consumed crustaceans (mainly euphausiids), the intermediate size-groups (G2-G3, 51-70 cm MDL) mainly predated on myctophiids and squids, and the large-size groups (G4-G5, >70 cm MDL) consumed squids (cannibalism) and fish (especially myctophiids).

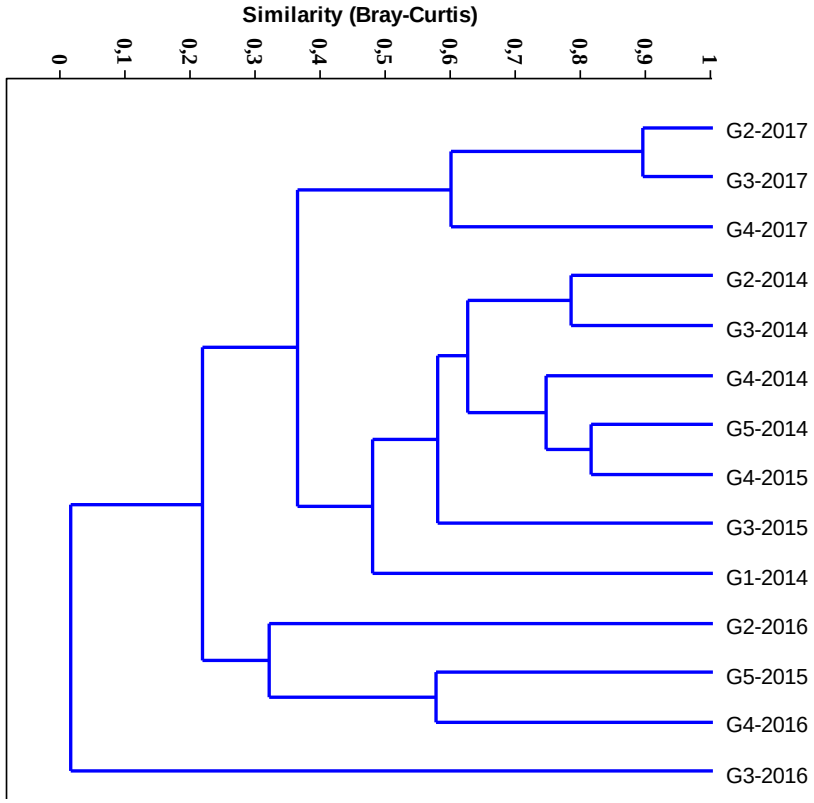

Figure 6. Classification tree (dendrogram) for *D. gigas* preys categorized by size-class. (G1= ≤ 40-50 cm MDL, G2= 51-60 cm, G3=61-70 cm, G4 =71-80 cm and G5≥81 cm MDL).

REFERENCES

Arancibia, H., L. Miranda, S. Núñez, G. Vásquez & E. Yánez. 1995. Determinación de las relaciones tróficas en el recurso jurel. En: Arancibia, H., L. Vilugrón y D. Arcos (Eds.). Estudio biológico pesquero sobre el recurso jurel en la zona centro-sur, V a IX Regiones. Informe Final, Proyecto FIP 018-93. Organismo ejecutor: Instituto de Investigación Pesquera VIII Región S.A.

Arancibia, H., M. Barros, S. Neira, U. Markaida, C. Yamashiro, L. Icochea, C. Salinas, L. Cubillos, Ch. Ibáñez, R. León, M. Pedraza, E. Acuña, A. Cortés & V. Kesternich. 2007. Informe Final Proyecto FIP 2005-38. Análisis del impacto de la jibia en las pesquerías chilenas de peces demersales. Universidad de Concepción / Universidad Católica del Norte, 299 p. + Anexos

Arancibia H., M. Barros, S. Neira, R. Alarcón, A. Gretchina, A. Yáñez, C. Ibáñez, L. Cisternas, A. Zúñiga, C. Bruno, N. Alegría, E. Acuña y A. Cortés. 2016. Informe Final Proyecto FIP 2013-18. Historia de vida y dinámica poblacional de jibia en aguas nacionales. Universidad de Concepción / INPESCA / UCN, 386 p. + Anexos.

Berg. J, 1979. Discussion of methods of investigating the food of fishes, with reference to a preliminary study of the prey of *Gobiusculus flavescens* (Gobiidae).Marine Biology 50, 263-273 .

Boyle P. R; S. V. Boletzky.1996. Cephalopod populations: definition and dynamics. Biological sciencies.

Cubillos L, Ibáñez CM, González C, Sepúlveda A (2004) Pesca de jibia (*Dosidicus gigas*) con red de cerco entre la V y X Regiones, año 2003 (Project research). Inst Invest Pesq VIII Region, Talcahuano (Chile), pp 48.

Fernández F, Vásquez JA (1995) La jibia gigante *Dosidicus gigas* (Orbigny, 1835) en Chile: analisis de una pesquería efímera. Estud Oceanol 14:17–21

Jackson G.D., J.F. McKinnon, C. Lalas, R. Ardern & N.G. Buxton. 1998. Food spectrum of the deepwater squid *Moroteuthis ingens* (Cephalopoda: Onychoteuthidae) in New Zealand aters. Polar Biology 20: 56-65

Markaida. U. 2001. Biología del calamar gigante *Dosidicus gigas* Orbigny, 1835 (cephalopoda: ommastrephidae) en el Golfo de California, México. Tesis para obtener el grado de Doctor en Ciencias. Centro de Investigación Científica y de Educación Superior de Ensenada. División de Oceanología, Departamento de Ecología. 426 pp

Markaida U, Sosa-Nishizaki O (2003) Food and feeding habits of jumbo squid *Dosidicus gigas* (Cephalopoda: Ommastrephidae) from the Gulf of California, Me´xico. J Mar Biol Assoc UK 83:1– 16

Nigmatullin ChM, Nesis KN, Arkhipkin AI (2001) A review of the biology of the jumbo squid *Dosidicus gigas* (Cephalopoda: Ommastrephidae). Fish Res 54:9–19

Pinkas L, Oliphant MS, Iverson IL (1971) Food habits of albacores, bluefin tuna and bonito in California water. Calif Fish Game 152:1–105

Pennington, M., R. Bowman & R. Langton. 1982. Variability of the weight of stomach contents of fish and its implications for food studies. En: M. Cacilliet y A. Simenstad (eds.). Gutshop 81. Fish food habits studies. Proceedings of the Third Pacific Workshop Washington Sea Grant Publication. University of Washington: 2-7.

Tascheri, R. 2002. Antecedentes biológicos y evaluación preliminar de la presencia de merluza común en estómagos de jibia (*Dosidicus gigas*). Reporte Técnico noviembre de 2002, Instituto de Fomento Pesquero, Valparaíso, 10 p.

Rodhouse PG, Nigmatullin ChM (1996) Role as consumers. Philos Trans R Soc Lond 351:1003–1022.

Rasero, M., A.F. Gonzalez, B.G. Castro & A. Guerra. 1996. Predatory relationships of two sympatric squid, *Todaropsis eblane* and *Illex coindetii* (Cephalopoda: Ommatrephidae) in Galician waters. Journal of the Marine Biological Association of the United Kingdom, 76: 73 - 87.

Velasco, F., I. Olaso & F. Sánchez. 2001. The role of cephalopods as forage for the demersal fish community in the Southern Bay of Biscay. Fisheries Research 52: 65-77.

Wilhelm O (1954) Algunas observaciones acerca de las mortandades de jibias (*Dosidicus gigas* D' Orb.), en el litoral de Concepción. Rev Biol Mar 4:196–201.