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Comments on estimates of natural mortality of jumbo squid *Dosidicus gigas*

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by

Juan Arguelles, Jimena Mendoza, Elizabeth Roncal-Herrera, Jorge Csirke

Instituto del Mar del Perú (IMARPE)

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SUMMARY

This document presents the values of natural mortality in *D. gigas* carried out to date, and shows the great variability of these estimates, which are associated with the methods used, periods and areas. In addition, since this parameter has an influence on potential yield, optimal capture, among others, it is emphasized that its estimation must be as robust as possible, and in the case of giant squid, the existence of population subgroups must be considered. Likewise, it is mentioned that given the semelparous nature of *D. gigas*, post-spawning mortality should be considered more important than natural mortality in structured population models.

Comments on estimates of natural mortality of jumbo squid *Dosidicus gigas*

In most methods of population assessment of fishing resources, the estimation of the number of specimens that die from natural causes is of the utmost importance. Its estimation should be as precise as possible, given that this parameter has an influence in the potential yield, optimal catch between others (Martínez-Aguilar et al., 2010). However, since natural mortality can vary due to various factors such as age, cannibalism, diseases, post-spawning stress, hunger, senescence, and interspecific or intraspecific competition, its estimation is one of the most difficult. So, different methods have been applied to estimate natural mortality using different sources of information such as fishing information (catch-analysis methods), life history parameters (Life history methods). Furthermore, natural mortality can vary by area, depending on the density of predators, competitors, and environmental factors (Megrey, 1989; Sparre et al., 1989).

For convenience, and in the absence of solid information on its variability, in stock assessment, it is common to assume that natural mortality is a constant value. This assumption is based on the concept that natural mortality falls rapidly from very high values for the egg and larval stages to a relatively constant level at maturity age (Caddy, 1996). What Caddy mention must be correctly interpreted paying particular attention to the expression "relatively constant". What happens is that, at the level of the egg and larvae, for a few days or weeks, natural mortality is very high (and variable), with mortality values that can exceed 99% in the early stages (days) of life. What would correspond to an M during the adult stage that is reached in a few days, then decreasing to lower values as the survivors grow and become stronger and more resistant. Then, compared to the mortality of eggs and larvae, the mortality of adult or larger specimens is lower and relatively less changing (i.e., relatively more constant). But, that it varies less than that of eggs and larvae, does not make the M of adults a constant. Above all, if the M of adults of different sizes or ages could be compared, and between different environmental conditions, food availability, presence of predators, cannibalism, etc.

Most squid are semelparous species and generally have a reproductive period during the year. However, as has been observed by Cordue et al. (2018), in Peruvian waters there is no time during the year when adults are absent from the population, this means that this species can spawn at any time of the year, although they generally have a high spawning season between October and January (Tafur et al. 2001, 2010). This should be taken into account in any population assessment model, since after spawning comes post-spawning mortality (semelparous mortality), which should be considered more important than mortality during the adult stage (Cordue et al. 2018).

The consequence of these two aspects of their biology (semelparous and year-round spawning) is that the biomass of the adult jumbo squid is constantly renewed. However, it is necessary to clearly distinguish semelparity from the fact that spawning is observed throughout the year, as well as the way in which each one affects (or modifies) the population structure. Semelparity is an intrinsic biological characteristic of the species (i.e., each and every one of the specimens of the species dies after reproducing, if they reproduce at all). While the occurrence of spawning throughout the year is, rather, an adaptation or population response to possible changing environmental conditions, in some years. Also, it is not that all the specimens spawn throughout the year, but rather, fractions of the population spawn (and die) at different times of the year (and possibly in different areas), thus producing several cohorts in some years with some interannual variability.

It is very difficult to estimate and/or have robust estimates of M, even in species that show less variability in their life histories. And it is even more difficult in the case of the jumbo squid, due to all the complexities of its life cycle that we know about, and others that we probably ignore.

In the case of *D. gigas* in the Gulf of California, Martínez-Aguilar et al. (2010) have estimated annual values of natural mortality between 128 and 283 for the egg stages, between 84 and 136 per year for paralarvae, decreasing rapidly in the juvenile (33-44), subadult (13-14) and adult stages. (4.7-5.2). In addition, in the case of semelparous species, such as squid; this natural mortality should rise sharply after spawning. However, most estimates of natural mortality in Dosidicus gigas report a single value, which should be representative of its adult stage, values that vary from 0.6 to 5.2 year-1, depending on the method used (Table 1).

Table 1. Values of natural mortality and longevity of Dosidicus gigas. Updated from Martínez-Aguilar 2010.

M	Longevity	References
0.60-1.56 year^{-1}	1.3-3.0 years	Erhardt et al. 1983
0.48-1.80 year^{-1}		Morales-Bojórquez et al. 1997
4.80 year^{-1}		Hernandez-Herrera et al. 1998
	1.0 years	Masuda et al. 1998
4.80 year^{-1}		Morales-Bojórquez et al. 2001
	1.0-2.0 years	Nigmatullin et al, 2001
4.80 year^{-1}		Morales-Bojórquez, Nevarez-Martinez 2002
	0.7-2.0 years	Markaida-Aburto et al. 2003
	1.0-1.3 years	Filauri 2005
1.02-1.95 year^{-1}		Nevarez-Martinez et al. 2006
4.70-5.20 year*		Martinez-Aguilar et al. 2010
	1.73 years	Liu et al. 2013
	1-2 years	Arkhipkin et al. 2015
0.20 month^{-1}		Cordue et al. 2018

*value valid for the adult stage

Furthermore, this single value of M for adults does not distinguish by population subgroup. The large differences in estimates of M (values between 0.6 and 5.2 per year) could be due to belonging to different groups evaluated, estimation methods, periods, and areas. For example, the smallest values of M have been estimated using methods that use life history parameters. While the highest values have been derived from assessment models. Therefore, taking into account that natural mortality is extremely important in population models, its estimation should consider all possible variables, for example, population subgroups that occur in the same year, but in different areas (coastal - oceanic).

References

Arkhipkin A, Argüelles J, Shcherbich Z, Yamashiro C. 2015. Ambient temperature influences adult size and life span in jumbo squid (*Dosidicus gigas*). Canadian Journal of Fisheries and Aquatic Sciences. 72(3): 400-409. (https://doi.org/10.1139/cjfas-2014-0386)

Caddy JF. 1996. Modelling natural mortality with age in short-lived invertebrate populations: definition of a strategy of gnomonic time division. Aquatic Living Resources 9: 197-207.

Cordue P, Arguelles J, Csirke J, Tafur R, Ttito K, Lau L, Perez M, Torrejon J, Grados D, Mariategui L, Valdez C, Saldarriaga M. 2018. A stock assessment method for jumbo flying squid (Dosidicus gigas) in Peruvian waters and its possible extension to the wider SPRFMO Convention area. Paper present to the 6th Meeting of the Scientific Committee of the South Pacific Regional Fisheries Management Organization. Puerto Varas, Chile, 9-14 September 2018.

Erhardt NM, Jacquemin PS., Garcia BF, Gonzalez DG, Lopez BJM, Ortız CJ, Solıs NA, 1983. On the fishery and biology of the giant squid Dosidicus gigas in the Gulf of California, Mexico. In: Caddy, J.F. (Ed.), Advances in Assessment of World Cephalopods Resources. FAO Fisheries Technical Paper, 231, pp. 306– 340

Filauri-Valencia N. 2005. Patrón de crecimiento y estructura poblacional del calamar gigante (Dosidicus gigas, Orbigny 1835) en la región central del Golfo de California. Tesis de Maestría. Posgrado en Ciencias del Mar y Limnología. Universidad Nacional Autónoma de México, México, DF. 74p

Hernandez-Herrera A, Moralez-Bohóquez E, Cisneros-Mata M, Nevarez_Martinez M, Rivera-Parra G. 1998. Management strategy for the giant squid (Dosidicus gigas) fishery in the Gulf of California, Mexico. CalCOFI Rep., Vol 39:212-218

Liu B, Chen X, Chen Y, Tian S, Li J, Fang Z, Yang M. 2013. Age, maturation, and population structure of the Humboldt squid *Dosidicus gigas* off the Peruvian Exclusive Economic Zones. (Presented at the 4th meeting of the Scientific Committee of the SPRFMO, The Hague, Netherlands, 10-15 October 2016 as document SPRFMO SC-04-19). Chinese Journal of Oceanology and Limnology. Vol. 31(1): 81-91.

Markaida-Aburto U, Quiñónez-Velázquez C, Sosa-Nishizaki O. 2003. Age, growth and maturation of jumbo squid Dosidicus gigas (Cephalopoda: Ommastrephidae) from the Gulf of California, Mexico. Fisheries Research 66(1): 31-47.

Martinez-Aguilar S, Diaz-uribe JG, Anda-Montañez JA, Cisneros-Mata MA. 2010. Natural mortality and life history stage duration for the jumbo squid (Dosidicus gigas) in the Gulf of California, Mexico. Using the gnomonic time division. Ciencia Pesquera. Vol. 18:31-42

Masuda S, Yokawa K, Yatsu A, Kawahara S. 1998. Growth and population structure of Dosidicus gigas in the southern Pacific Ocean. In Large pelagic squids (Ed. T. Okutani) 269 p. Japan Marine Fishery Resources Research Centre, Tokyo.

Megrey BA. 1989. Review and comparison of age structured stock assessment model from theoretical and applied points of view. In: E.F. Edwards & B.A. Megrey (eds.). Mathematical analysis of fish stock dynamics. American Fishery Society Symposium 6: 8-48.

Morales-Bojórquez E, Hernández Herrera A, Nevarez-Martínez MO, Díaz de León Corral AJ, Rivera Parra GI, Ramos Montiel A. 1997. Abundancia poblacional del calamar gigante (Dosidicus gigas) en las costas de Sonora, México. Oceánides 12(1):90-96.

Morales-Bojórquez E, Martínez-Aguilar S, Arreguín-Sánchez F, Nevárez-Martínez MO. 2001. Estimations of catchability at-length for the jumbo squid (Dosidicus gigas) fishery in the Gulf of California, Mexico. California Cooperation Oceanic Fishery Investigation Report 42: 167-171

Morales-Bojórquez E. Nevárez-Martínez MO. 2002. Stochastic estimation of the catchability and recruitment of the jumbo squid Dosidicus gigas (D'Orbigy, 1835) from the Gulf of California, Mexico. Ciencias Marinas 28(2): 193-204

Nevarez-Martinez M, Mendez-Tenorio F, Cervantes-Valle C, Lopez-Martinez J, Anguiano-Carrasco M. 2006. Growth, mortality, recruitment, and yield of the jumbo squid (Dosidicus gigas) off Guaymas, Mexico. Fisheries Research 79:38-47

Nigmatullin CM, Nesis KN, Arkhipkin AI. 2001. A review of the biology of the jumbo squid *Dosidicus gigas* (Cephalopoda: Ommastrephidae). Fisheries Research. 54: 9-19

Tafur R, Villegas P, Rabi M, Yamashiro C. 2001. Dynamics of maturation, seasonality of reproduction and spawning grounds of the jumbo squid Dosidicus gigas (Cephalopoda: Ommastrephidae) in Peruvian waters. Fish. Res. 54, 33–50

Tafur R, Keyl F, Arguelles J. 2010. Reproductive biology of jumbo squid Dosidicus gigas in relation to environmental variability of the Northern Humboldt Current System. Mar. Ecol. Prog. Ser. 400:127-141

Sparre P, Ursin E, Venema SC. 1989. Introduction to tropical fish stock assessment. Part1. Manual. FAO Fish. Tech. Pap. 306.1, 337