Lat. Am. J. Aquat. Res., 44(2): 429-432, 2016
DOI: 10.3856/vol44-issue2-fulltext-25

Short communication

Assessing the trophic position of two sharks from the open waters of the southeastern Pacific Ocean

Sebastian A. Klarian[1], Augusto Cornejo[2], Pauline Sallaberry-Pincheira[1]
Patricio Barría[3] & Roberto Meléndez[†]
[1]Centro de Investigación para la Sustentabilidad CIS, Facultad de Ecología y Recursos Naturales
Universidad Andres Bello, Valparaíso, Chile
[2]Museo Nacional de Historia Natural, Santiago, Chile
[3]Instituto de Fomento Pesquero, Blanco 839, Valparaíso, Chile
Corresponding Author: Sebastian A. Klarian (s.lopez@uandresbello.edu)

ABSTRACT. Stable isotope analyses for shortfin mako (*Isurus oxyrinchus*) and blue sharks (*Prionace glauca*) were conducted to assess their trophic position in two periods of time (before 1980 and after 2000) in the Southeastern Pacific waters (SEP). Both sharks showed that their trophic position decreased over time ($P < 0.05$). Many factors could be involved in this change such as dietary shifts, prey availability, or indirect fishing effects in SEP waters.

Keywords: stable isotopes, sharks, top predators, trophic position, southeastern Pacific.

Evaluando los niveles tróficos de dos tiburones oceánicos del Océano Pacífico suroriental

RESUMEN. Para evaluar los niveles tróficos de los tiburones marrajo (*Isurus oxyrinchus*) y azulejo (*Prionace glauca*) en dos períodos de tiempo (previo a 1980 y posterior al 2000) en aguas del Pacífico suroriental (SEP), se realizaron análisis de isótopos estables. Ambos tiburones mostraron un descenso del nivel trófico en el tiempo ($P < 0{,}05$). Varios son los factores que pueden estar involucrados en este evento, como los cambios dietarios, la disponibilidad de las presas o los efectos indirectos de la pesquería en aguas del Pacífico suroriental.

Palabras clave: isótopos estables, tiburones, predadores tope, nivel trófico, Pacífico suroriental.

The trophic level or trophic position (TP) in worldwide oceans has been decreasing (Pauly *et al.*, 1998) mainly due to overexploitation of fisheries. Stevens *et al.* (2000) reviewed the possible effects of fishing and concluded that there are two major effects. The first is the direct impact related to reduction on the abundance and biomass, changes in the size-age structure, and also changes in the population parameters of species that are frequent in fisheries (Myers *et al.*, 2007; Block *et al.*, 2011). The second effect is indirect, and related to trophic interactions. Indirect effects are unnoticeable in the short term (Crowder *et al.*, 2008) with the entire food web significantly altered, involving shifts in feeding, meso-predator release, and prey switching in the ecosystem trophic cascades. Together with the food web alteration, large marine predators decrease their trophic level (Daskalov *et al.*, 2007). Sharks are particularly susceptible to fishing effects due to their life history patterns such as K selected strategy, slow growth, longevity, and low maturity rates (Baum *et al.*, 2003). Moreover, these predators play an important role in the ecosystems which they inhabit, because they preserve species diversity in the community and sustain ecosystem health largely by “top down” regulation (Baum *et al.*, 2009). For these reasons it is important to study how the TP of sharks changes over time and assess the role of fisheries in this change. Thus, the principal goal of this study was to compare the trophic position of two sharks *Prionace glauca* (Linnaeus, 1758) and *Isurus oxyrinchus* (Rafinesque, 1810) -both well known as top predators in the southeastern Pacific waters (SEP)-, in two periods of time.

Corresponding editor: Oscar Sosa

To compare TP in two different times, samples were separated into two periods: before 1980 (BE-80) and after 2000 (AF-00). Historical data confirms that open ocean fisheries began in 1990 (Cerna, 2009). For the AF-00 period a total of 100 individuals of *P. glauca* and *I. oxyrinchus* were collected from the bycatch of long-line swordfish industrial fishing between 21ºand 35ºS, 78º and 118ºW during 2013. The total length (TL) was measured on board the vessels and muscle tissues from dorsal parts were taken and frozen at -20°C. On the other hand, tissues from 19 specimens of the Museo Nacional de Historia Natural, Chile (MNHN) (see Appendix S1) were used to study TP before 1980 (BE-80) (Kaehler & Pakhomov, 2001). Considering that the preservation method can affect the isotope ratios, a correction was made following Kelly *et al.* (2006). All tissues were put in a 2:1 chloroform-methanol solution for lipid extraction. The isotope composition was analyzed at the "Laboratorio de Análisis Isotópico LAI", Universidad Andrés Bello UNAB, Viña del Mar, using an Eurovector elemental analyser coupled to a Micromass Isoprime isotope ratio mass spectrometer. Stable isotope ratios were reported in the δ notation as the deviation from standards (Pee Dee Belemnite for $\delta^{13}C$ and atmospheric N for $\delta^{15}N$), therefore $\delta^{13}C$ or $\delta^{15}N = [(R_{sample} / R_{standard}) - 1] \times 10^3$, where R is $^{13}C/^{12}C$ or $^{15}N/^{14}N$, respectively. Typical precision of the analysis was ±0.5‰ for $\delta^{15}N$ and ±0.2‰ for $\delta^{13}C$. TP was estimated using raw ^{15}N values and calculated by this equation (Post, 2002): $TP_{shark} = \lambda + [\delta^{15}N_{shark} - \delta^{15}N_{base1}]/\Delta_n$. *Cubiceps pauciradiatus* a plankton feeder which is widely distributed in the SEP area was selected as TP $base_1$ (TP = 3.5). The mean enrichment of $\delta^{15}N$ per trophic level (TDFs) for sharks was taken from Malpica-Cruz *et al.* (2012), which provides a robust approximation and a trustworthy value (TDFs = 3.5). The TPs were compared using a PERMANOVA + SIMPER analysis (Zar, 2010). All statistical analysis and mathematical calculations were performed with R statistical software (R Development Core Team, 2011).

Means of $\delta^{15}N$ and $\delta^{13}C$ are summarized in Table 1. With the $\delta^{13}C$ value it is possible to infer some aspects of the sharks' habitat. Thus, both sharks presented values of epipelagic predators and did not show diffe-

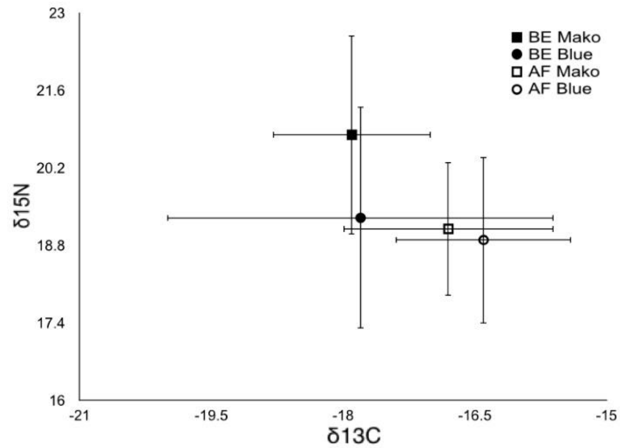

Figure 1. $\delta^{15}N$ and $\delta^{13}C$ Bi-plot of blue and shortfin mako sharks before 1980 (BE) and after 2000 (AF).

rences between BE-80 and AF-00. The TP found for blue shark in BE-80 was 3.8 while for AF-00 was 3.7. When the TP before and after were compared, the blue shark showed significant differences (P = 0.002). On the other hand, the TP found in shortfin mako sharks was 4.2 for BE-80 and 3.7 in AF-00. Like blue sharks, the *I. oxyrinchus* samples showed statistical differences (P < 0.001) between the two periods of time.

The stable isotope method constitutes a robust approach, as it is regularly used to trace energy flow pathways through food webs (Cabana & Rasmussen, 1996) and recently to assess historical trophic positions (Doubek & Lehman, 2014). Our results indicate that *P. glauca* and *I. oxyrinchus* had a higher TP before swordfish long-line fisheries began to operate (Fig. 1). Blue sharks showed a small decrease in comparison with individuals of shortfin mako. The latter could involve changes in their feeding strategy and shifts on prey consumption. This is a biological concern, since if these top predators change their TP; consequently the entire ecosystem changes its mean TP. For example, Polovina *et al.* (2002) found an increase in the trophic level of meso-predators because the apex predator changed its trophic level. Cox *et al.* (2002) proposed that change in the TP of a top predator is one of the most important effects when their diet changes, causing an

Table 1. Mean trophic position (TP) of the studied sharks before (BE-80) and after (AF-00) the long-line fishery began. n: number of samples, *P*-values are from Permanova analysis.

Species	BE-80				AF-00				*P* value
	$\delta^{15}N$	$\delta^{13}C$	TL (cm)	n	$\delta^{15}N$	$\delta^{13}C$	TL (cm)	n	
Prionace glauca	19.3 ± 2.0	-17.8 ± 2.2	3.8 ± 0.6	9	18.9 ± 1.5	-16.4 ± 1.0	3.7 ± 0.46	50	0.002
Isurus oxyrinchus	20.8 ± 1.8	-17.9 ± 0.9	4.2 ± 0.3	10	19.1 ± 1.6	-16.8 ± 1.2	3.7 ± 0.45	50	<0.001

alteration in the ecosystem community, predator-prey size and age structure. In this study we found evidence that shortfin mako and blue sharks changed their diet consumption over time with a probable break after 1980, showing changes in their TP, possibly as a consequence of the fluctuations in population dynamic parameters of their most important prey.

ACKNOWLEDGEMENTS

This work was funded by IFOP-SUBPESCA Fishery Research fund 2013 SRAM-2013: "Situación de Recursos Altamente Migratorios".

REFERENCES

Baum, J.K. & B. Worm. 2009. Cascading top-down effects of changing oceanic predator abundances. J. Anim. Ecol., 78: 699-714.

Baum, J.K., R.A Myers, D.G. Kehler, B. Worm & S. Harley. 2003. Collapse and conservation of shark populations in the Northwest Atlantic. Science, 299: 389-392.

Block, B.A., I.D. Jonsen, S.J. Jorgensen, A.J. Winship, S.A. Shaffer, S.J. Bograd, E.L. Hazen, D.G. Foley, G.A. Breed, A.L. Harrison, J.E. Ganong, A. Swithenbank, M. Castleon, H. Dewar, B.R. Mate, G.L. Shilinger, K.M. Schafer, S.R. Benson, M.J. Weise, R.W. Henry & D.P. Costa. 2011. Tracking apex marine predator movements in a dynamic ocean. Nature, 475: 86-90.

Cabana, G. & J.B. Rasmussen. 1996. Comparison of aquatic food chains using nitrogen isotopes. Proc. Natl. Acad. Sci. USA, 93: 10844-10847.

Cerna, J.F. 2009. Age and growth of the swordfish (*Xiphias gladius* Linnaeus, 1758) in the southeastern Pacific off Chile (2001). Lat. Am. J. Aquat. Res., 37(1): 59-69.

Cox, S., T. Essington, J. Kitchell, S. Martell & C. Walters. 2002. Reconstructing ecosystem dynamics in the central Pacific Ocean, 1952-1998. II. A preliminary assessment of the trophic impacts of fishing and effects on tuna dynamics. Can. J. Fish. Aquat. Sci., 59: 1736-1747.

Crowder, L.B., E.L Hazen, N. Avissar, R. Bjorkland & C. Latanich. 2008. The impacts of fisheries on marine ecosystems and the transition to ecosystem-based management. Ann. Rev. Ecol. Evol. System., pp. 259-278.

Received: 24 March 2015; Accepted: 1 April 2016

Daskalov, G.M., A.N. Grishin, S. Rodionov & V. Mihneva. 2007. Trophic cascades triggered by overfishing reveal possible mechanisms of ecosystem regime shifts. Proc. Natl. Acad. Sci. USA., 104: 10518-10523.

Doubek, J.P. & J.T. Lehman. 2014. Historical trophic position of *Limnocalanus macrurus* in lake Michigan. J. Great Lakes. Res., 40: 1027-1032.

Kaehler, S. & E.A. Pakhomov. 2001. Effects of storage and preservation on the delta C-13 and delta N-15 signatures of selected marine organisms. Mar. Ecol. Prog. Ser., 219: 299-304.

Kelly, B., J.B. Dempson & M. Power. 2006. The effects of preservation on fish tissue stable isotope signatures. J. Fish Biol., 69: 1595-1611.

Malpica-Cruz, L., S.H. Herzka, O. Sosa-Nishizaki & J.P. Lazo. 2012. Tissue-specific isotope trophic discrimination factors and turnover rates in a marine elasmobranch: empirical and modelling results. Can. J. Fish. Aquat. Sci., 69: 551-564.

Myers, R.A., J.K. Baum, T.D. Shepherd, S.P. Powers & C.H. Peterson. 2007. Cascading effects of the loss of apex predatory sharks from a coastal ocean. Science, 315: 1846-1850.

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese & F. Torres. 1998. Fishing down marine food webs. Science, 279: 860-863.

Polovina, J., M. Abecassis, E. Howell & P. Woodworth. 2002. Increases in the relative abundance of mid-trophic level fishes concurrent with declines in apex predators in the subtropical North Pacific, 1996-2006. Fish. Bull., 107: 523-531.

Post, D.M. 2002. Using stable isotopes to estimate trophic position: models, methods, and assumptions. Ecology, 83: 703-718.

R Development Core Team. 2011. R: a language and environment for statistical computing. Vienna, Austria: the R Foundation for Statistical Computing. ISBN: 3-900051-07-0.

Stevens, J.D., R. Bonfil, N.K. Dulvy & P.A. Walker. 2000. The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. ICES J. Mar. Sci., 57: 476-494.

Zar, J. 2010. Biostatistical analysis. Prentice Hall, Englewood Cliffs, 931 pp.

Appendix S1. Specimens from the Museum of Natural History. PMNHN (specimen code from collection). *Pelvic fins were removed from the specimen, **Identification number was not legible on the record card.

Species (code)	Sex	Date	Zone caught	Size	PMNHN	From
Prionace glauca 39.5 MNHN	Female	1979	off Valparaiso, Chile	Small (39,5 cm LT)	B085-05	Bernardino Quijada Collection
Prionace glauca 45 MNHN	Male	1979	off Valparaiso, Chile	Small (45 cm LT)	B085-22	Bernardino Quijada Collection
Prionace glauca 45 MNHN(1)	Female	1979	off Valparaiso, Chile	Small (45 cm LT)	B085-45	Bernardino Quijada Collection
Prionace glauca 190 MNHN	Male	1913	off Valparaiso, Chile	Medium (190 cm LT)	288	Bernardino Quijada Collection
Prionace glauca 200 MNHN	Male	1913	off Valparaiso, Chile	Medium (200 cm LT)	289	Bernardino Quijada Collection
Prionace glauca 185 MNHN	Male	1913	off Valparaiso, Chile	Medium (185 cm LT)	287	Bernardino Quijada Collection
Prionace glauca 345 MNHN	Female	1979	off Valparaiso, Chile	Large (345 cm LT)	B085-37	Bernardino Quijada Collection
Prionace glauca 350 MNHN	Male	1979	off Valparaiso, Chile	Large (350 cm LT)	B085-46	Bernardino Quijada Collection
Prionace glauca 350 MNHN (1)	Male	1979	off Valparaiso, Chile	Large (350 cm LT)	B085-47	Bernardino Quijada Collection
Isurus oxyrinchus 120 MNHN	Female	1913	off Valparaiso, Chile	Small (120 cm LT)	250	Bernardino Quijada Collection
Isurus oxyrinchus 110 MNHN	Female	1913	off Valparaiso, Chile	Small (110 cm LT)	241	Bernardino Quijada Collection
Isurus oxyrinchus 120 MNHN (1)	Female	1913	off Valparaiso, Chile	Small (120 cm LT)	267	Bernardino Quijada Collection
Isurus oxyrinchus 220 MNHN	Male	1913	off Valparaiso, Chile	Medium (220 cm LT)	260	Bernardino Quijada Collection
Isurus oxyrinchus 250 MNHN	UNK*	1970	off Valparaiso, Chile	Medium (250 cm LT)	UKN**	Bernardino Quijada Collection
Isurus oxyrinchus 220 MNHN(2)	Male	1913	off Valparaiso, Chile	Medium (220 cm LT)	260	Bernardino Quijada Collection
Isurus oxyrinchus 300 MNHN	Male	1895	off Valparaiso, Chile	Large (300 cm LT)	279	Bernardino Quijada Collection
Isurus oxyrinchus 300 MNHN(4)	Male	1895	off Valparaiso, Chile	Large (300 cm LT)	280	Bernardino Quijada Collection
Isurus oxyrinchus 300 MNHN(3)	Male	1895	off Valparaiso, Chile	Large (300 cm LT)	282	Bernardino Quijada Collection
Isurus oxyrinchus 230 MNHN	Male	1913	off Valparaiso, Chile	Medium (230 cm LT)	251	Bernardino Quijada Collection