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Predation of sea turtles by South American sea lion (*Otaria byronia*) and its relationship with overfishing in northern Chile

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ABSTRACT

The disruption of a new food chain in the South American sea lion (SSL, *Otaria byronia*), with predation on green sea turtles (GST, *Chelonia mydas*) is reported for Northern Chile, probably from "nutritional stress" as result of anchovy (*Engraulis ringens*) overfishing, its fundamental food, with implications that cross multinational barriers in the South Pacific due to the shared nature of the resource. From 2011 an increase in carcasses of GST turtles with damages attributable to attacks by larger predators was observed on beaches of Arica (18°28´S), for which a necropsy study for signs attributable to predation, was carried out between November 2013 and May 2019. Jointly, direct observations of SSL attacks were made between Arica (18°28´S) and Iquique (20°13´S), that document predation of GST by SSL. 195 strandings including 179 *Chelonia mydas*, 15 *Lepidochelys olivacea* y 1 *Eretmochelys imbricatea* were recorded. 96.01% were strandings, 2.23% concentrated in drift, 1.12% as ghost fishing and 0.56% by fishermen from a gillnet.

The necropsies of 14 carcasses in stage 1 and 2, showed damage attributable to interaction (alive or dead) with predators and/or scavengers. Most part of the observed injuries (tears of breakage and detachment of skin, muscles, internal structures such as the trachea, esophagus, stomach and part of the intestines, heart and liver) were attributable to SSL attacks and agree with the direct observations. Attacks by sharks or killer whales, and death by immersion or health problems could not be confirmed. The effect of this new feeding strategy of the SSL casts a shadow of uncertainty

Depredación de tortugas marinas por el lobo marino sudamericano (*Otaria byronia*) y su relación con la sobreexplotación pesquera en el norte de Chile

Author's contributions:

All authors greatly contributed to the manuscript.

DC: coordination, sampling activity, data analysis, and manuscript writing.

WS: conceptualization, and manuscript writing.

PS: conceptualization, and manuscript reviewing.

RB: sampling, data analysis.

TR: sampling, data analysis.

MA: sampling.

KP: sampling.

Competing interests

The authors declare that they have no competing interests.

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about the success of the green sea turtle population recovery program of northern Chile started in 2012. The results also suggest the need for evaluation of anchovy management programs and standards and the incorporation of an ecosystem approach to management plans, including the trophic needs of top depredators of the system.

Key words: fishery resources, depredation, sea turtle, South American sea lion.

RESUMEN

Se reporta una nueva estrategia de alimentación del lobo marino sudamericano (LMS, *Otaria byronia*) con depredación de tortugas verdes (TMV, *Chelonia mydas*) en el norte de Chile, resultado de un probable "estrés nutricional" por sobreexplotación de anchoveta (*Engraulis ringens*), su alimento principal, con implicancias que atraviesan barreras multinacionales del Pacífico sur por el carácter compartido del recurso. Desde 2011 se observó en Arica (18°28′S) un incremento de varamientos de tortugas con daños atribuibles a depredación y para lo cual se desarrolló entre 2013 y 2019 un estudio de necropsias para la evaluación de signos atribuibles a depredación. Conjuntamente se realizaron entre Arica (18°28′S) e Iquique (20°13′S) observaciones directas de ataques de LMS, que documentan la depredación de TMV. Se estudiaron 195 cadáveres: 179 *Chelonia mydas*, 15 *Lepidochelys olivacea* y 1 *Eretmochelys imbricata*. 96,01% de los cadáveres correspondieron a varamientos, 2.23% boyantes, 1.12% pesca fantasma y 0,56% recuperadas por pescadores de redes agalleras.

La necropsia de 14 cadáveres en estados 1 y 2 mostró daños atribuibles a interacción (vivas o muertas) con depredadores y/o carroñeros. Las lesiones observadas fueron atribuibles a ataques de LMS y concuerdan con las observaciones directas. No se confirmaron ataques de tiburones o ballenas asesinas, ni muerte por inmersión o problemas de salud. Esta nueva estrategia de alimentación arroja incertidumbre sobre el éxito del programa de recuperación de la población de TMV del norte de Chile iniciado en 2012. Los resultados imponen la necesidad de evaluación de programas y normas de manejo de la anchoveta y la incorporación de un enfoque ecosistémico, incluyendo requerimientos tróficos de los depredadores tope del sistema.

Palabras clave: recursos pesqueros, depredación, tortuga marina, lobo marino sudamericano.

INTRODUCTION

Overfishing and bycatch have been among the leading anthropogenic threats to marine mammals worldwide for more than 15 years (Estes *et al*., 2009), depleting their food supplies by reducing fish populations by 50% and 90% (Estes *et al*., *op. cit.*; Myers & Worm, 2003). Likewise, it has been recognized more than two decades ago that the exploitation of marine ecosystems has caused the rapid depletion of top predators around the world (Jackson & Sala, 2001; Myers & Worm, 2003). This is often attributed to bycatch and unsustainable catch rather than direct exploitation (Lewison *et al*., 2004), increasing the depletion of food resources due to overfishing (Bearzi *et al*., 2006), which has been noted as an important factor. in this ecological problem. According to Rosen & Trites (2000), overfishing leads to a lower supply of the usual prey for the main predators, generating "nutritional stress" due to lack of food, which leads to a dietary adjustment to alternative prey of lower nutritional value (Muck & Fuentes, 1987).

Predation of sea turtles outside their nesting areas has been poorly documented and is not considered an important element in the global priority program for sea turtle research developed by Hamann *et al*. (2010). However, there are indications that in sea turtles the risk of predation may play an important role, aside from reproduction and foraging, in driving the pattern of movements (Heithaus *et al*., 2008).

At the level of the eastern South Pacific, the priority lines of action of the sea turtle conservation program of the Permanent Commission of the South Pacific (CPPS) does not contemplate this situation either, even though they mention the importance of predation by sea lions in Chile in the same year. In relation to fisheries both global and regional programs, refer to mortality due to bycatch in different types of fisheries, and in the case of the southeastern Pacific, the capture of turtles by the artisanal sector for the commercialization of meat and products stands out. This activity is carried out mainly on the coast of Peru (Quiñones, 2017).

Regarding the effect of fishing on sea turtles (Gilman & Bianchi, 2010; Peckham *et al*., 2007), there are protection programs that mainly identify activities aimed at mitigating bycatch in ecological, economic, and social terms. They include the design and establishment of protection areas (Witt *et al*., 2008), educational programs and work with communities (Marcovaldi *et al*., 2005), technological changes and adjustments to fishing legislation (Tsamenyi & Jit, 2011), but the persistent controversies over ecosystem services need changes to achieve a transformation towards a sustainable future (Costanza *et al*., 2017).

Mainly during the earliest stages, sea turtles are subject to predation by a wide range of predators, including birds, crabs, Serranidae fish (Witzel, 1981), wild canids (Brown & MacDonald, 1995; Méndez-Rodríguez & Álvarez-Castañeda, 2016) and feral cats (Engeman *et al*., 2019). In its adult state, there are known cases of attacks by sharks, crocodiles, killer whales and jaguars (Guilder, 2015; Ortiz *et al*., 1997; Troëng, 2000). Fertl & Fulling (2007) report interactions of turtles with 22 species of marine mammals, including 16 species of cetaceans, and predation of turtles by the Hawaiian monk seal (*Monachus schauinslandi*), the Mediterranean monk seal (*Monachus monachus*), the Australian fur seal (*Neophoca cinerea*) and the crushing death of elephant seals (*Mirounga leonina*) on turtle nesting beaches in Australia. Regarding attacks on turtles by cetaceans, there is only one history of predation by killer whales (*Orcinus orca*) (Pitman & Dutton, 2004; Sarti *et al*., 1994).

Of all mentioned cases, the majority are related to reproductive events on spawning beaches and occasional predations involving *Dermochelys coriacea*, *Lepidochelys olivacea* and *Caretta caretta* (Fertl & Fulling *op. cit.*). Reports made by Guerra *et al.* (2007) confirmed the attacks of South American sea lions (SSL) (*Otaria byronia*) on *Chelonia mydas* (GST). The confirmed attacks have occurred in the Antofagasta Region: Bahía Mejillones del Sur (23°05'S), Ensenada Constitución (23°24'S), Puerto de Antofagasta (23°35'S) decimating completely the local populations.

It should be considered that the previous sectors, together with Bahía Salado (27°41'S), Bahía Chipana (21°19'S) and Bahía Arica (18°28'S) represent feeding areas of green sea turtles with relatively stable and permanent concentrations of turtles along the Chilean coast (Álvarez-Varas *et al.*, 2017; Salinas & Sielfeld, 2007; Veliz *et al.*, 2014). For this reason, the massive mortality due to LMS attack can have serious consequences on the population dynamics of turtles and the success of their future conservation.

This article identifies a new feeding strategy for the South American sea lion (SSL) with predation on green sea turtles (GST), probably resulting from overfishing of anchovy. Considering its consequences for the conservation of sea turtles, the need to apply an ecosystem approach to fishing is highlighted, crossing multinational barriers in shared resources of the Southeast Pacific, such as anchovy. This study was based on the analysis of sea turtles stranded on the northern coast of Chile (10°22'S-19°39'S), with signs of attack characteristics attributable to larger predators involving South American sea lions. The increase of the number of cases is analyzed in relation to the exploitation of fishing resources in the northern part of Chile. The form of turtle attack by South American sealions on *Chelonia mydas* observed between 2013 and 2019 is also described.

MATERIAL AND METHODS

Study area

The strandings study area extended from the border with Peru (18°22'S) to Caleta Camarones in Chile (19°14'S) however, direct observations of SSL attacks extended as far south as Caleta Pisagua (19°39'S; 70°13'W). (Fig. 1).

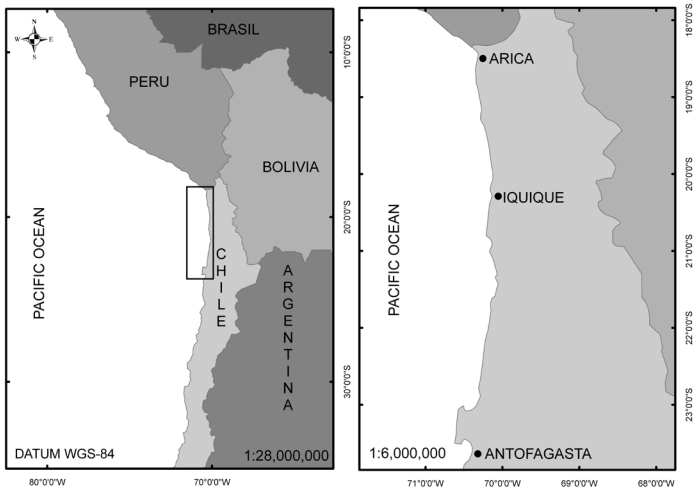

Fig. 1:
Study area

Strandings

According with the current regulations, the initial recognition of bodies must be carried out by the Investigative Brigade of Crimes Against the Environment and Cultural Heritage (BIDEMA) of the Chilean Investigative Police (PDI) and then the National Fisheries and Aquaculture Service (SERNAPESCA) that gives rise to an official database of strandings on the Chilean coast of SERNAPESCA. In the present case, the SERNAPESCA registry was used, and supplemented with registries and procedures carried out within the framework of the Sea Turtle Conservation Program funded by the Regional Government of Arica and Parinacota (Sielfeld, *et al.*, 2019).

Depending on the stranding type, the bodies were classified as washed up on the beach, floating, ghost fishing, and rescued by fishermen. According to Resendiz & Lara (2017) the following six states of decomposition were considered: class 1: fresh; class 2: specimens in incipient decomposition; class 3: corpse in an advanced state of decomposition; class 4: skeleton and carapace only, class 5: carapace only and class 6: bones only. Following Zárate (2013) for *Chelonia mydas* age classification the following categories were considered: adults (CCL≥80 cm), sub-adults (79cm ≤ CCL ≥65cm) and juveniles (CCL <65) (Zárate, 2013) and for *Lepidochelys olivacea* adults (CCL> 65 cm) and subadults (CCL <65 cm) (Barrientos & Ramírez, 2008).

The inspection of carcasses focused on the identification of possible causes of death, especially indications of predation by South American sea lions. For this, an external characterization of each specimen was carried out according to presence/absence of limbs and head/neck, external lesions: a) "tearing off skin and musculature", with irregular edges, b) "cuts", injuries with soft edges. In the same way, they were also characterized according to presence/absence of carapace and condition of the carapace/plastron. When it was possible and based on the external appearance of the soft parts of the specimens and shape of the plastron: concave, flat, convex, used to assign the turtles body condition as: poor, fair, good, following Thomson *et al.* (2009) equivalent to cachexic (emaciated), thin and norma categories scored by Work *et al.* (2015). No specimens with overweight were found.

When the decomposition of the carcass was incipient and/or of recent death (states 1 and 2 of Resendiz & Lara, 2017) and to exclude possible causes of endogenous death, a dissection and internal macroscopic examination were carried out, checking nutritional status (condition of muscle and adipose tissue), content of the digestive system (ingestion, plastics, feces, fecaloms and/or parasites). The inspecting of internal organs looked for signs of natural causes of death, infections, malformations, diseases and/or parasites, signs of drowning (foam in the respiratory system) and/or violent death (congestion of organs such as lungs or heart, hemorrhages, bruises, among others) following the protocols of Wolke & George (1981), Orós & Torrent (2001) and Flint *et al.* (2009). The anatomical nomenclature and organ recognition was based on the descriptions and macroscopic structures analyses of Wyneken (2001).

From the characteristics of the damage and wounds, the eventual participation of predators, such as sharks (type and form of bite, cutting of tissues), SSL (teeth marking, mainly canines and tear of integumentary and muscle tissue), killer whales (form of perforations by teeth), scavengers (*Larus dominicanus*, *Cathartes aura*) (mainly in advanced decomposing corpses with extraction of eyes, intervertebral muscles in the neck, remains of viscera) and anthropic effects (evidence of boat collisions, death by drowning, crushing and injuries in by catch, external lacerations due to mishandling and trauma caused by the presence and/or extraction of hooks) was evaluated.

Through the network of collaborators of the sea turtle conservation project and voluntary observers (artisanal fishermen, diving company "Pisagua Sumergido", photography company "Mar en Sepia"), a surveys of the fishermen and a field monitoring program was made. Verbal reports and photographic records of interactions between sea turtles and SSL. Each sea lion/sea turtle interaction was described and characterized. This information was used to interpret the injuries found in the stranded sea turtles.

RESULTS

Strandings

195 stranded turtles were recorded between November 2013 and August 2019, of which 62.57% were concentrated in the years 2017 and 2018 (42 and 79 individuals respectively). The years 2013, 2016 and 2019 showed only 3, 2 and 5 records respectively (Fig. 2a). These events occurred in different places on the coastline of the Port of Arica, grouped into 8 zones (Table 1) (Fig. 3). The sectors that concentrated the highest number of strandings were Las Machas Beach (46.37%) and Chinchorro Beach (29.60%). 96.01% (172 individuals) of the carcasses were found stranded on the coast, 2.23% (4 individuals) as drift, 1.12% (2 individuals) as ghost fishing and 0.56% (1 individuals) recovered by fishermen from a gillnet.

91.79% (179 ind.), 7.69% (15 individuals) and 0.51% (1 ind.) corresponded respectively to *Chelonia mydas, Lepidochelys olivacea* and *Eretmochelys imbricata*. The specimen of the species *E. imbricata*, represents the first record hawksbill turtle for continental Chile (Salinas *et. al., in prep.*).

For *Chelonia mydas*, 6 individuals (3.35%), 57 individuals (31.84%) and 116 individuals (64.80%) were determined as males, females and indeterminate respectively. 68 individuals (37.99%) were classified as adults, 63 individuals (35.20%) as sub-adults and 41 individuals (22.91%) as juveniles. 7 specimens could not be classified. The curve carapace length (CCL) fluctuated between 30 cm and 120 cm (mean 76.13 cm and SD = 16.00) (Fig. 4).

Of 15 *L. olivacea*, 5 individuals (33.33%) were adults, 2 individuals (13.33%) subadults and 8 individuals (53.33%) juveniles. All adult specimens were classified as females. The curve carapace length (CCL) was 30-112 cm (mean 71.00 cm and SD = 24.67). The only specimen of *E. imbricata* (45.4 cm CCL) was classified as juvenile.

During the 2013-19 period, strandings were mainly concentrated between August and November, accumulating 67.60% (121 individuals) of the total strandings, distributed in 35, 28, 21 and 37 stranded individuals for the months of August, September, October and November respectively (Fig. 2b).

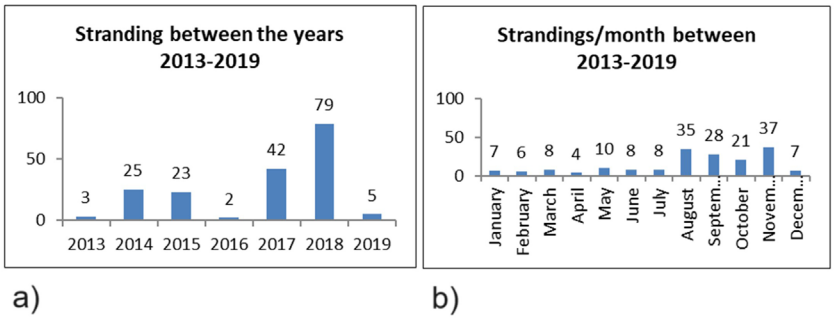

Fig. 2:
a). Stranding in the Arica and Parinacota Region between november-2013 and august-2019.
b) Monthly strandings for the same period.

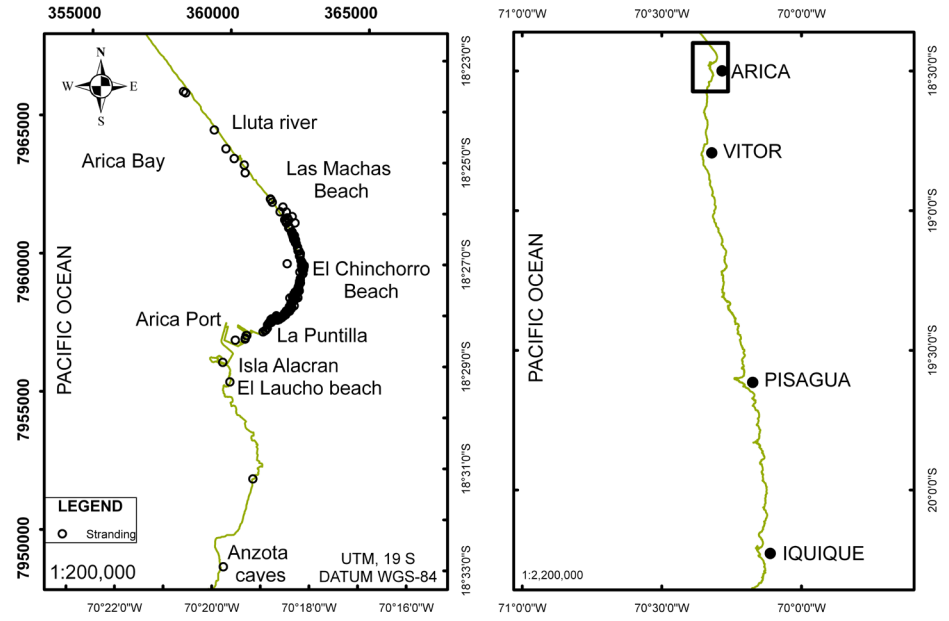

Fig. 3:
a) Sea turtle stranding sites in the Arica and Parinacota region.
b) Sea turtle and South American sea lion interaction sites in northern Chile.

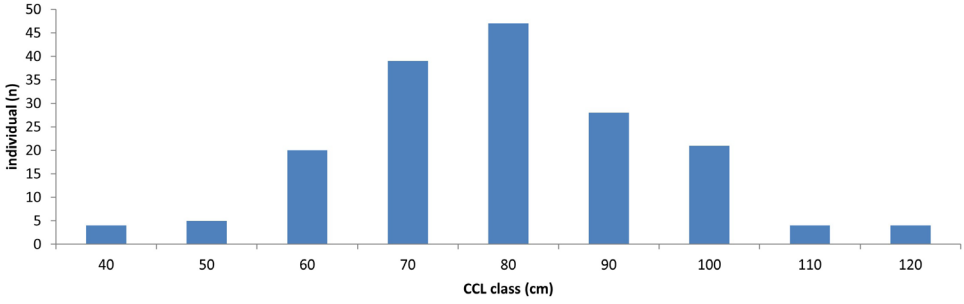

Fig. 4:
Size distribution (Curved Carapace Length) of stranded sea turtles between 2013 and 2019 in the Arica and Parinacota Region, Northern Chile.

Year	Species	a	b	c	d	e	f	g	h	TOTAL
2013	*Ch. mydas*					2	1			3
2014	*Ch. mydas*		1	1	1	8	11			25
	L. olivacea						2			2
2015	*Ch. mydas*					6	4			23
	L. olivacea					7	4	1		12
	E. imbricata					1				1
2016	*Ch. mydas*						2			2
2017	*Ch. mydas*	2		2	11	13	13		1	42
2018	*Ch. mydas*	3	3	2	8	16	45		1	79
	L. olivacea					1				1
2019	*Ch. mydas*		1				4			5
TOTAL		5	5	5	20	54	86	1	2	195

Table 1.
Species of sea turtles stranded between 2013 and 2019 in the respective stranding areas of the Arica coastline: a. south of Arica; b. port of Arica; c. Miramar beach; d. La Puntilla; e. Chinchorro beach; F. Las Machas beach; g. Lluta river mouth; h. at sea.

External physical examination

Due to the state of decomposition of the carcasses, 4 ind. (2.24%) were classified in state 1 and 19 ind. (10.62%), 153 ind. (85.47%) and 3 ind. (1.67%) in states 2, 3 and 4 respectively. Of the 179 individuals studied, 4 ind. (2.24%) did not present their carapace, 6 ind. (3.35%) had a broken and / or wounded carapace and 169 ind. (94.41%) presented the carapace intact.

72 ind. (40.22%) presented head, however in 15 cases the skull was disarticulated from the vertebral column and held by skin flaps and cervical musculature. The remaining 107 ind. (59.78%) did not present their skull. Of the 57 ind. with the skull articulated with the cervical spine, 43 ind. did not show external damage (tears, cuts, blows) in the cephalic/cervical area, while the remaining 14 ind. showed tears of skin and muscles in that sector. The 43 individuals without external damage in their cephalic/cervical region, did not lose their fins and only one of them presented a tear-type wound in one of them. Likewise, 2 individuals did not present their carapace and two showed wounds and/or breakage in it. Therefore, 38 individuals (21.23%) were found intact and without signs of scavenging (Table 2).

Of the 122 individuals (107 without head + 15 with disarticulated skull) that presented external damage types tears in the head/neck area, 70 individuals (57.38%) also presented damages in their extremities (tears and/or cuts) and 55 individuals (30.73%) had at least one dismembered fin at the level of the pelvic and/or scapular girdle, with wounds and/or tears in the skin and/or muscles.

Internal physical examination

Due to the advanced state of decomposition of most of the carcasses, only 15 internal examinations were carried out on specimens classified in categories 1, 2 and 3. (Table 2). Of these, 14 corresponded to *Chelonia mydas* (12 females and 2 males) and 1 specimen corresponded to *Eretmochelys imbricata* (female). All the specimens showed signs of attack by scavengers and/or predators (*pre* or *post mortem*), with the exception of an injured one, who later died in rehabilitation, and an *Eretmochelys imbricata* individual with no detectable cause of death.

The examinations did not reveal signs of previous symptoms or diseases that could have caused their death, as well as injuries caused by fishing gear or signs of drowning. In the cases in which the bodies conserved the digestive system (n =10), it presented abundant food remains, consisting of *Austromenidia regia* eggs (1.8-2.7 Kg / turtle) and to a lesser extent algae (*Ulva, Enteromorpha, Glossophora, Pterosiphonia* and others). No fecaloms and/or intestinal parasites or associated were observed, except for one individual with a piece of a polyethylene bag (size approximately 70 cm^2), located in the final part of the small intestine and without an apparent obstruction in that area. In general condition of the carcasses was considered good, except for the individual *Eretmochelys imbricata*, which was emaciated.

Of the 14 necropsies performed on green sea turtles, all presented signs of interactions (alive or dead) with predators/scavengers. Lesions attributable to South American sea lion attack were mainly tears, consisting of breakage and detachment of the skin and muscles, accompanied in some cases by internal structures such as the trachea, esophagus, stomach and part of the intestines, heart and liver, as evidenced in the photographs. Likewise, the heart and lungs (when present) were hemorrhagic or congested in 5 cases, which could indicate violent death of the animals.

Direct observation of interaction with the South American sea lion (SSL)

Information was collected on six interactions between South American sea lions and sea turtles in the Arica and Tarapacá regions (Table 3), and an interaction with the Peruvian pelican (*Pelecanus thagus*) (Fig. 6). In all cases the SSLs were identified as subadult/adult males. Regarding the form of attack, in the six cases studied (Figs. 5-11), it consisted of taking the turtle by the neck, raising it to the surface and whipping it on it with violent movements of head. SSLs do not have cutting teeth, so the strong side lash eventually leads to tearing of the skin and musculature of the neck and fins. Due to the characteristics of a significant number of stranded turtles, this tear of the gular region and neck also leads to evisceration that involves the trachea, esophagus, digestive system, heart, and liver.

Table 2. Results of the internal physical examination carried out on corpses of sea turtles stranded on the coastal edge of Arica.

Date	Corpse condition	Sex	Species	Digestive system				Respiratory system		Heart	Liver	Kidneys	Tumors
				Esophagus	Intake	Obstructions	Plastic	Trachea and bronchi	Lung				
11-11-2014	3	Female	*Ch.mydas*	Normal	algae	No	No	Normal	Normal	Normal	Normal	Normal	Yes
11-11-2014	3	Female	*Ch.mydas*	Normal	algae	No	No	Normal	Normal	Normal	Normal	Normal	Yes
11-11-2014	3	Female	*Ch.mydas*	Normal	algae	No	No	Normal	Normal	Normal	Normal	Normal	No
27-11-2014	3	Female	*Ch.mydas*	Normal	No	No	No	Normal	Normal	Normal	Normal	Normal	No
20-03-2016	1	Female	*E. imbricata*	Normal	No	No	No	Normal	Normal	Normal	Normal	Normal	No
12-09-2017	3	Female	*Ch.mydas*	Normal	Fish eggs & algae	No	Yes	Normal	Normal	Normal	Normal	Normal	No
27-07-2018	3	Female	*Ch.mydas*	Normal	Fish eggs & algae	No	Yes	Normal	Normal	Normal	Normal	Normal	No
04-08-2018	3	Female	*Ch.mydas*	Absent	no stomach	No	No	Absent	Hemorrhagic	Normal	Normal	Normal	No
04-08-2018	3	Female	*Ch.mydas*	Normal	Fish eggs & algae	No	No	Normal	Normal	Normal	Normal	Normal	No
08-08-2018	3	Female	*Ch.mydas*	Absent	no stomach	No	Yes	Absent	Hemorrhagic	Absent	Fatty liver. Right lobe absent.	Discolored.	No
22-08-2018	3	Female	*Ch.mydas*	Absent	Fish eggs & algae	No	No	Absent, bronchi normal	Congested	Congested	Normal	Normal	No
24-08-2018	3	Male	*Ch.mydas*	Absent	Fish eggs & algae	No	No	Absent, bronchi normal	Normal	Normal	Normal	Normal	No
31-08-2018	3	Male	*Ch.mydas*	Absent	Fish eggs & algae	No	No	Absent, bronchi normal	Congested	Congested	Congested	Congested	No
03-09-2018	3	Female	*Ch.mydas*	Absent	Fish eggs & algae	No	No	Absent, bronchi normal	Congested	Normal	Congested	Congested	Yes
01-03-2019	3	Female	*Ch.mydas*	Absent	no stomach	No	No	Absent, bronchi normal	Normal	Absent	Normal	Normal	No

Table 3. Registry of interactions of South American sea lion and sea turtles in the north of Chile.

ID	Date	Record	Coordinates	Species	Attacks (n)	Photo (n)
1	20-06-2017	Photographic	19°25'S/70°14'W	*Pelecanus thagus*	1	2
2	12-07-2017	Visual	18°27'55''S/70°18'32"W	*Chelonia mydas*	2	/
3	19-07-2018	Photographic	19°35'50''S/70°12'55"W	*Chelonia mydas*	3	3, 4 y 5
4	07-08-2018	Visual	18°44'S/70°21"W	*Chelonia mydas*	1	/
5	01-04-2019	Photographic	19°35'50"S/70°12'55"W	*Chelonia mydas*	1	6
6	17-06-2019	Photographic	19°35'50''S/70°12'55''W	*Chelonia mydas*	3	7
7	25-06-2019	Photographic	19°37'40''S/70°13'10''W	*Chelonia mydas*	3	8

Fig. 5: Green turtle with a healed wound on the throat, attributed to South American sea lion attack, captured during the monitoring campain at La Puntilla, Arica, 22-11-2014.

Fig. 6: South American sea lion attack on Peruvian pelican (*Pelecanus thagus*), 20-06-2017.

Fig. 7: Attack of a South American sea lion on *Chelonia mydas*, 19-07-2018. (Photography credits: Fernando Olivares, Mar en Sepia).

Fig. 8: Attack of a South American sea lion on *Chelonia mydas*, 19-07-2018.

Fig. 9: Attack of a South American sea lion on *Chelonia mydas*, 19-07-2018.

Fig. 10: Green sea turtle rescued from a South American sea lion attack (dead, still bleeding), Pisagua, Northern Chile, 01-04-2019 (Photography credits: Marcos Tobar, Pisagua Sumergido).

Fig. 11: Green sea turtle attacked by a South American sea lion at Pisagua Bay, Northern Chile, 25-06-2019. (Photography credits: Marcos Tobar, Pisagua Sumergido).

DISCUSSION

The here described South American sea lion attacks on green sea turtles endanger their conservation in the Southeastern Pacific, an aspect not adequately valued and not included in the global and regional conservation programs and strategies of this species, established by CPPS (2007) and Hamann *et al.* (2010).

This threat mainly affects pre and sub-adult green sea turtles from the feeding areas of Northern Chile, where the observed massive predation of individuals can lead to the elimination of local populations, as has been reported by Guerra *et al.* (2007) for Bay Mejillones del Sur (23°05'S) and Constitución Cove (23°24'S).

The protection of the green sea turtles is an urgent need due to their classification as "endangered species" according to the Red List of Threatened Species of the International Union for the Conservation of Nature (IUCN). Adding In this situation death by South American sea lion depredation to death by "by catch", it will lead to an important decline in the recruitment of mature females at nesting centers.

The here described cases of sea turtle predation are like the reports by Margaritoulis & Touliatou (2011) for the Mediterranean monk seal (*Monachus monachus*) on loggerhead turtles (*Caretta caretta*) where the triggering factor is overfishing of the resources that make up the usual diet of this species (Karavellas, 1995; Margaritoulis *et al.*, 1996).

This behavior responds to a "switch" or "diet adjustment" to alternative prey (Muck & Fuentes, 1987), determined by "nutritional stress" due to overfishing as described by Rosen & Trites (2000) for the Steller sea lion (*Eumetopias jubatus*) of the North Pacific.

A "surplus killing" by sea lions, as alternative hypothesis for their predation behavior, also known as "excessive killing", a behavior commonly exhibited by predators, such as species of bears, hyenas, foxes, felines and orcas (Gaydos *et al.*, 2005) is here rejected as cause of predation on sea turtles because it was not a generalized behavior, described for the SSL and because of the highly focused predation of turtles.

In the case of the South American sea lion, the consumption of higher vertebrates is an infrequent and not generalized behavior, with reports of attacks to steamer ducks (*Tachyeres pteneres*) in the Falkland Islands, Magellanic penguin (*Spheniscus magellanicus*), rockhopper penguin (*Eudyptes chrysocome*) and gentoo penguin (*Pigoscelis papua*) on the Atlantic Patagonian coast and Staten Islands (Vaz-Ferreira, 1982).

Regarding the attacks on green sea turtles in Northern Chile, a relation with food availability factors it is highly probable, due to overfishing of anchovy (*Engraulis ringens*), an "essential food" in the South American sea lion diet in Northern Chile, with around 70% of the weight of the total intake and 80% by prey specimens consumed (Arias-Schreiber, 2000; Sepúlveda *et al.*, 2016; Sielfeld *et al.*, 2018).

Muck & Fuentes (1987) calculated an annual intake of 107.000–179.000 Tons/Year (80.000-134.000 Tons/Year, corresponding to fishes) by 49.230 otariids (fur seals + sea lions) off Peru (4°-14°S). For Northern Chile (18-23°S) Sepúlveda *et al.* (2016) concluded an annual food consumption of 106.544 Tons/Year by a population of 95.302 SSLs. Until now, no anchovy management plan has considered a quote reserved for otariids and other top predators.

Regarding the anchovy stock, it should also be taken in account that the total biomass and spawning biomass of the anchovy between Arica and Mejillones showed a decreasing trend from year 2006, with a fall in the recruitment rate and an increasing fishing mortality (IFOP, 2018; SUBPESCA, 2018), reaching a spawning biomass of only 235,298 Tons in 2017 (the lowest value in the 1999-2017 period). Based on this value and from 2014, this resource is defined as "overexploited" by the Chilean Fishing Service (SUBPESCA). Consequently, this also means a reduction in availability for the Sea Lions and other top predators of the system, situation here concluded as triggering mechanism for the switch to turtle predation.

It is also an aggravating factor in this situation that the annual fishing quotas authorized for a wide sector of Northern Chile (18°30'S to 26°00'S), is principally fished around Arica (18°23'S) and Mejillones (23°05'S), sectors also more affected by sea turtle predation (Guerra *et al.*, 2007; present data).

Regarding the here documented observations of attack of the South American sea lions, there are differences with respect to those described by Margaritoulis & Touliatou (2011) on the attack of the Mediterranean monk seal on loggerhead turtles. These authors describe the opening of the abdominal cavity by the seals through the soft tissues between the plastron and posterior fins, detachment of part of the plastron scutes. The consumption of the entrails

was described (Margaritoulis *et al.*, 1996). In other cases (Margaritoulis & Touliatou, *op. cit.*) the opening of the body cavity was through the neck and the esophagus, trachea and tongue were ingested. This last case agrees with the present observations, in that in many cases it also included the consumption of stomach and lungs.

CONCLUSIONS

1. The here described attacks on green sea turtles endanger seriously their conservation in the Southeastern Pacific by contributing, together with "by catch", to a recruitment reduction of spawning females in the breeding colonies of this species.

2. The way South American sea lions attack green sea turtles occurs from below and principally affecting the neck and throat region, tearing the esophagus, trachea, and part of the internal thoracic organs, giving no alternatives for survival and rehabilitation.

3. The overfishing of anchovy is the probable trigger for the unusual behavior in the South American sea lion and its new trophic chain disruption due to a dietary adjustment and should be part of new studies in this regard.

4. The situation found is reiterative in the region, with similar events in the Antofagasta region during 2007, which requires urgent attention and inclusion in the priority actions of the Sea Turtle Conservation Program of the Permanent Commission of the Southeast Pacific (CPPS).

5. In agreement with the provisions on ecosystem management of the fishing resources imposed by the Chilean Law of Fisheries and Aquaculture (Law 18,892, Article 1, State of Chile), the fisheries management programs and the fishing quotes for anchovy in the Southeastern Pacific should be reviewed regarding their effect on the ecosystem, mainly on top predators, their trophic dependence, and nutritional needs, including pinnipeds and sea turtles.

6. Due to the highly migratory nature of sea turtles and the anchovy stocks shared between Chile, Peru and Ecuador, and the agreements within the Convention for the Conservation of Migratory Species of Wild Fauna (Bonn Convention), a revision of the here presented problem and the consideration of trophic surpluses for top predators along the Humboldt current System should be discussed and agreed multinational.

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