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Ecology and Conservation of Sea Turtles in Chile

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ABSTRACT. – **Chilean marine habitats have supported sea turtle species since prehistorical times. Although information exists regarding their contemporary distribution and ecological role in the region, it is diffuse. This study aims to bring such data together and provide an up-to-date review of the ecology and conservation status of sea turtles in Chile. Detailed available data largely reflect interactions between *Dermochelys coriacea* and *Caretta caretta* with oceanic fisheries. Newspaper and local studies have reported the regular presence of *Chelonia mydas* and *Lepidochelys olivacea* in certain locations in northern Chile during the past decade. The latter species were particularly abundant in the area around a thermal discharge from a water-cooled power plant (Mejillones Bay, 23°S) in the Antofagasta Region, and accounts included several reports of negative interactions between these species and sea lions (*Otaria flavescens*). Sea turtles found in Chilean waters are probably juveniles or subadults. No estimates have been made regarding the potential of the Chilean waters as feeding grounds or the relative importance of putative food items for sea turtles. Sea turtles are clearly present in Chilean waters, but we know little about factors that drive variation in their abundance. As such, there is a need for further exploration of the ecology of sea turtles in this region.**

KEY WORDS. – **Reptilia; Testudines: Cheloniidae; *Dermochelys coriacea*; *Chelonia mydas*; *Caretta caretta*; *Lepidochelys olivacea*; Humboldt Current Large Marine Ecosystem; Southeast Pacific Ocean**

Studies of the ecology of wide-ranging migratory species require extended and expensive surveys conducted across often-vast areas encompassing the distributional range of the target species. Hence, it can be difficult to successfully characterize their ecology, especially toward the limits of their distribution, where the probability of encountering individuals can be markedly reduced. Such observations extend to the sea turtle species that inhabit Chilean waters, located in the southeast Pacific Ocean. Sea turtles have been present in this region since prehistorical time, and modern records exist for at least the past 2 centuries. Records of sea turtles feeding in some coastal bays in northern Chile (e.g., Guerra-Correa et al. 2007) and telemetry studies have highlighted the role of the southeast Pacific as migratory routes and potential feeding grounds (Ortiz and Moreno 2008; Bailey et al. 2012a, 2012b). However, there has been little scientific and public interest in conducting follow-up studies, or systematic surveys to characterize sea turtle ecology in the region.

Chile has a long coastline (6435 km) and wide territorial waters that form the eastern boundary of the South Pacific Gyre, part of the Humboldt Current Large Marine Ecosystem (Fig. 1), one of the world's most productive fishing areas (Montecino and Lange 2009). Four species of sea turtles can be found in this region: *Dermochelys coriacea, Chelonia mydas, Caretta caretta,* and *Lepidochelys olivacea* (Frazier 1990). These species are classified by the International Union for Conservation of Nature as vulnerable (*L. olivacea*), endangered (*C. caretta, C. mydas*), or critically endangered (*D. coriacea*), with evidence of significant population declines occurring during recent decades (Chaloupka et al. 2004). However, our understanding of their ecological niche in Chilean waters is either lacking or incomplete, reflecting an absence of information regarding their population structure or habitat use in the region (Comisión Permanente Del Pacífico Sur [CPPS] 2007; Azócar et al. 2011).

Worldwide, coastal, and terrestrial environments are increasingly at risk because the modification and degradation created by human coastal development (Lotze et al. 2006). This is a particular issue in Chile, where the construction of new energy production facilities along the coast (Fig. 1) and continued extraction of natural resources in support of economic development threaten coastal ecosystem function and may limit the suitability of coastal habitats that may support sea turtles. In Chile, 7 macroalgae species (*Durviella antartica, Gigartina skottsbergii, Gracilaria chilensis, Macrocystis*

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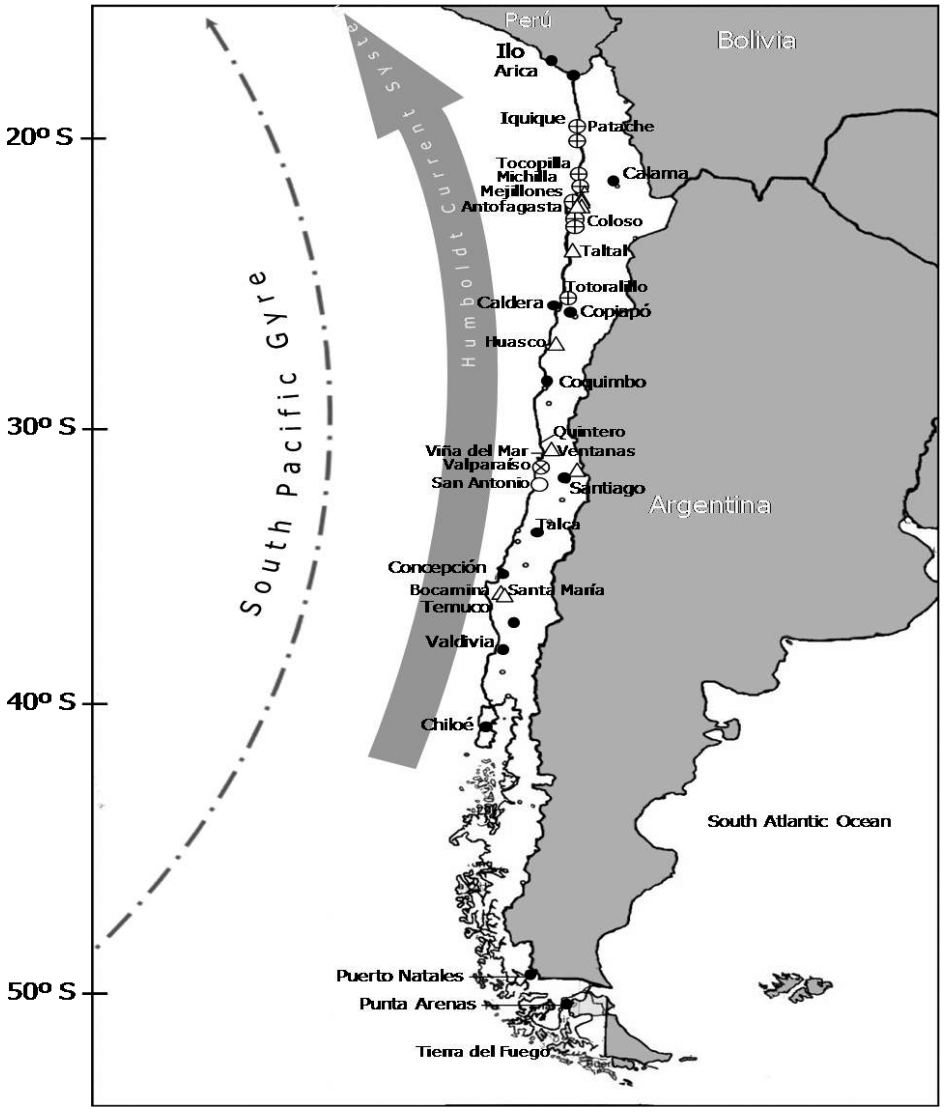


Figure 1. Principal locations associated with sea turtle records from Chilean waters. Also, core thermoelectric power plants (△), and coal unloading harbors (⊕) located on coastline.

pyriphera, M. integrifolia, Lessonia berteorana, L. spicata, L. trabeculata, and *Sarcothalia crispata*) are extracted from littoral areas (from the intertidal down to 40-m depth), and exported to international markets for the production of alginic acid, alginates, and natural polymers (Subsecretaria de Pesca y Acuicultura [SUBPESCA] 2015). This sector has grown since landings of approximately 250,000 t/yr in 2000 to 450,000 t/yr in 2011 that correspond to 70,000 dry tons (González-Poblete et al. 2013). Power generation in coastal habitats may impact marine species (e.g., Poornima et al. 2005; Jiang et al. 2009; Cardoso-Mohedano et al. 2015). Chile has installed power generation plants with a total capacity of $>$ 18,000 megawatt, based mainly on hydroelectric plants (120 total), mostly located in the central-southern region, or thermal plants (241 total) that have a majority placed along the northern coastline of the country (Comisión Nacional de Energía, Estadísticas: Energía 2015).

Recent studies have revealed that sea turtle bycatch from Chilean longline, gillnet, and trawl fisheries are among the highest recorded worldwide (Wallace et al. 2010; Azócar et al. 2011). The risk of impact from these fisheries increases when the relationship between bycatch records and fishery observation effort is considered (i.e., bycatch rates are likely underestimated because of the limited on-board observer programs in small-scale fisheries; Wallace et al. 2010). Furthermore, the numerous small artisanal fisheries in the southeastern Pacific region still lack systematic monitoring and reporting, and it is therefore difficult to reliably estimate their impact on sea turtles and other migratory species (Alfaro-Shigueto et al. 2007, 2011).

This article aims to clarify current knowledge regarding sea turtles in Chilean waters and the likely impact of anthropogenic activities on sea turtles in this region. Furthermore, we focused on factors that may play a role on the temporal and spatial distribution, population

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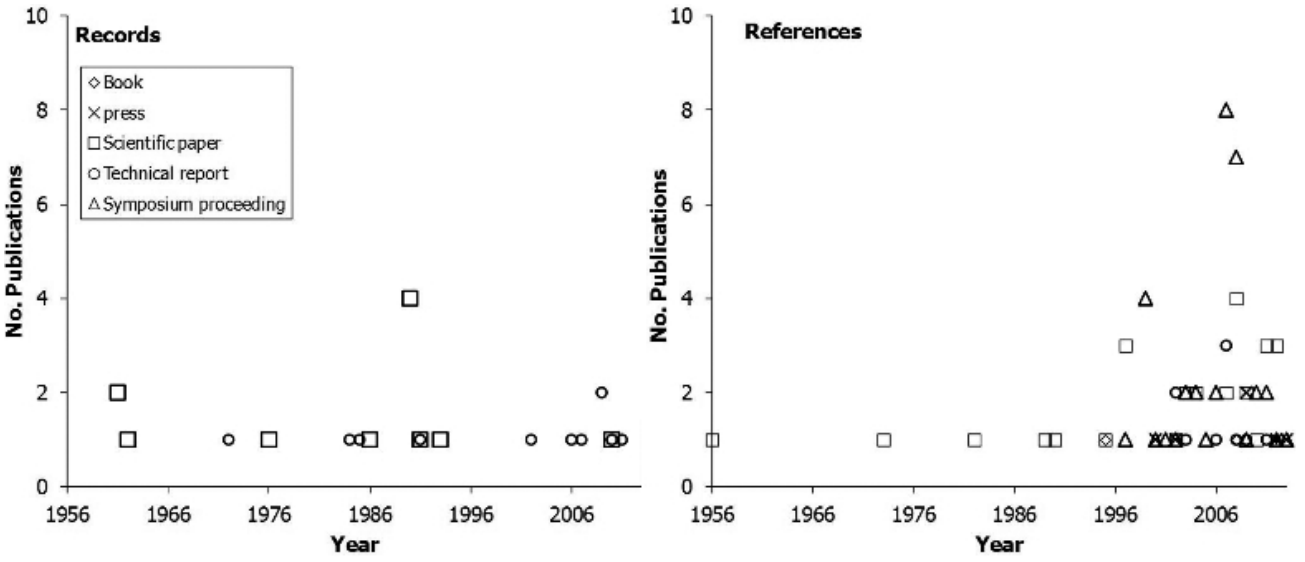


Figure 2. Grey and scientific publications including references or records of sea turtle presence in Chile.

dynamics, and insights into the ecological role and habitat requirements of sea turtles in this region.

METHODS

We conducted a literature review of studies available up until December 2013, examining primary and grey literature present in several databases: ISI Web of Knowledge (http://portal.isiknowledge.com/), Science Direct (http://www.sciencedirect.com/), Scielo (www.scielo.cl), and Google Scholar (http://scholar.google.cl/). The following combinations of key words in the title, abstract, or text content were used in the search: ''Sea Turtles'', Chile; ''Sea Turtles'', ''South eastern Pacific'', ''*Lepidochelys olivacea*'', Chile; ''*Caretta caretta*'', Chile; ''*Dermochelys coriacea*'', Chile; ''Southeast Pacific'', ''*Caretta caretta*''; ''Southeast Pacific'', ''*Dermochelys coriacea*''; ''*Chelonia mydas*'', ''South eastern Pacific''; ''Southeast Pacific'', ''*Lepidochelys olivacea*''. We also conducted these reviews with other combinations of words (''Tortugas marinas'', Chile; ''*Chelonia mydas*'', Chile; ''bycatch'', ''South eastern Pacific''; ''*Chelonia mydas*'', ''Southeast Pacific''; ''*Dermochelys coriacea*'', ''South eastern Pacific''; ''*Lepidochelys olivacea*'', ''South eastern Pacific''). We also searched using the Spanish equivalent, although results did not differ. This resulted in 123 documents published between 1956 and 2013, with a large increase in the period between 2007 and 2013 (Fig. 2). These were categorized as either references or records depending on whether they simply mentioned a location where > 1 sea turtle species were noted (i.e., reference), or whether they provided details on the number of individuals with a specific date and location of occurrence (i.e., record; see Fig. 2).

We also made formal requests to a number of Chilean governmental institutions (SUBPESCA, Servicio Nacional de Pesca, *Ministerio del Medio Ambiente*) for information on records, studies, and surveys regarding the presence of sea turtles in Chilean waters, under the framework of the Chilean Law on Transparency. Nongovernmental Organizations, universities, and sea turtle researchers were also consulted for information and details of current studies on sea turtles in Chile. Further information was obtained by examining Proceedings of the Annual Symposia on Sea Turtle Biology and Conservation between 1988 and 2013 (available at http://www.sefsc.noaa.gov/species/turtles/symposia.htm), and abstract books from Sea Turtle Symposia in the Eastern South Pacific (Fig. 3).

We identified 1655 records of sea turtles, most consisting of detailed bycatch ($n = 748$), encounter ($n = 230$), and strandings ($n = 160$), although many did not include information on defined interactions ($n = 489$) with turtles. Other sources of information reflected carapaces ($n = 11$) and embalmed specimens ($n = 5$) preserved in public collections, individuals included in satellite transmitter tracking studies ($n = 6$), catches, and anecdotal encounters ($n = 8$). Many observations were of unidentified individuals ($n = 58$), related to body damage or made by untrained observers. In general, records were dominated by *C. mydas* ($n = 765$) and *D. coriacea* ($n = 607$), followed by *L. olivacea* ($n = 139$) and *C. caretta* ($n = 86$), although bycatch records ($n = 749$) show the dominance of *D. coriacea* ($n = 569$; 76%) and *C. caretta* ($n = 81$; 11%) in offshore waters. In contrast, strandings and encounters ($n = 399$) close to the coast were dominated by *C. mydas* ($n = 334$; 84%) and *L. olivacea* ($n = 49$; 12%).

STATUS OF TURTLES IN CHILE

Historical Records of Sea Turtles from Chilean Waters

The first record of sea turtles from what are now Chilean waters dates from 1782 (Molina *in* Donoso-Barros 1962). However, it is likely that sea turtles have

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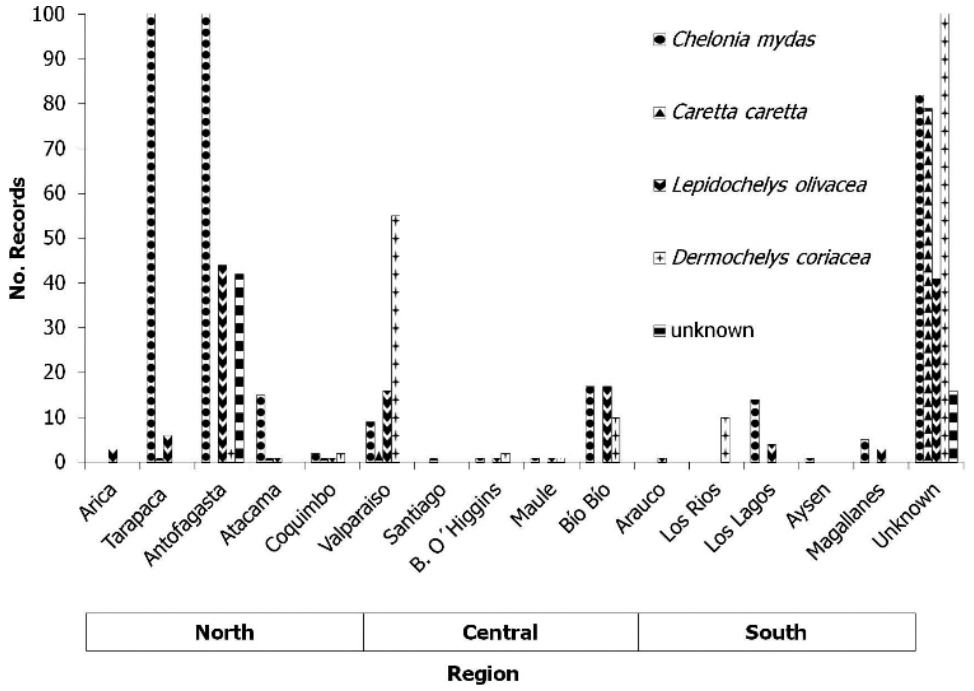


Figure 3. Records of sea turtles in Chile categorized by region.

been present in southern Peru and northern Chile since at least 5000 YBP (Frazier and Salas 1984; Frazier and Bonavia 1998). This is reflected by the existence of cave paintings (*Quebrada el Medano,* Antofagasta Region), as well as turtle remains (skulls and carapaces) recorded from archaeological sites in northern Chile (Frazier 1990; Frazier and Bonavia 1998; Berenguer 2009), providing evidence for the intentional capture of sea turtles for consumption, but also as funerary objects (Frazier 2005). Some researchers have even suggested that some beaches in northern Chile were used as nesting habitats (Ortiz and Moreno 2008).

Currently, there is no widespread tradition of sea turtle consumption by Chileans, either of indigenous or European descent. However, discussions with fishermen from the northern region suggested that sea turtle meat is occasionally consumed, although artisanal fishers in the region usually avoid bycatch of these organisms in their nets, because they believe that killing a sea turtle is associated with bad luck, even if it is accidental (R.A. S.-D., *pers. obs.*).

Species Distribution

For this review, the northernmost records of sea turtles in Chile were from Arica (Tarapacá region, 18°27′S), and the southernmost record was located approximately 3800 km to the south in Tierra del Fuego (Magallanes and Antarctic Chilean region, 53°S; Gúzman and Campodónico 1973). However, one-third of the records from the past 50 yrs were related to *C. mydas* and *L. olivacea* from locations in the north of Chile (e.g., Antofagasta, Mejillones [Fig. 1; Guerra-Correa et al. 2007, 2008], or Salado Bay, Copiapó in the Atacama Region [Guerra-Correa et al. 2007; Tucker et al. 2013]). Importantly, trace-metal analysis of carcasses from the Antofagasta sector has revealed above-average concentrations of both arsenic and copper in *C. mydas* liver, likely reflecting industrial mining activity and subsequent heavy-metal pollution in the region (Plaza-Araya et al. 2010; Álvarez et al. 2013).

The presence of *C. mydas* in Mejillones Bay (Antofagasta Region) has been associated with the presence of thermal effluent from water-cooled power generation plants (Fig. 1) and several reports exist regarding negative interactions with resident sea lions (*Otaria flavescens*; Guerra-Correa et al. 2007; Kelez et al. 2008a, 2008b). Furthermore, there are multiple references to groups of up to 30 individuals of *C. mydas* in the area close to the fishing harbor in central Antofagasta, which during the early 2000s interacted with groups of sea lions consuming waste from the artisanal fishery fleet (Kelez et al. 2008a). Cárdenas and Stutzin (1985) noted that during the 1980s, *C. mydas* were sufficiently abundant in this area that fishermen often caught specimens and offered photographs for tourists. Approximately 400 km to the north of Antofagasta, dead *C. mydas* adults are commonly stranded (107 individuals during 2001–2007) year-round on an extended sandy beach located close to an upwelling cell at Chipana (Iquique, Tarapacá Region; Guerra-Correa et al. 2007).

Although present in Chilean waters, records of *L. olivacea* are extremely limited and are distributed from Arica (18°28′S) in the extreme north, to Quintero located

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on the central Chilean coast (32°S, Fig. 1; Brito 1997), with most records clustered in the northern regions of Iquique and Antofagasta. A single study has reported the presence of stranded specimens in poor condition, and suggested that decreases in Sea Surface Temperature associated with cooling of the Chile–Peru Current were linked with the presence of *L. olivacea* in Central Chile (Seminoff 2002).

Records of *D. coriacea* from Chilean waters are almost entirely of individuals captured as bycatch from either industrial or artisanal fishing vessels landing in harbors such as Algarrobo, San Antonio, or Talcahuano in Valparaiso Region, or Constitución in Maule Region. This highlights the use of Chilean offshore habitats by this species (Donoso and Dutton 2010), although limited sightings also exist from inshore waters, including Antofagasta (Sarmiento-Devia et al. 2014).

A limited number of confirmed records for *C. caretta* exist from Chilean waters, ranging from Arica (Donoso-Barros 1962), Caldera, and Coquimbo, all located in northern Chile, to Quintay close to Valparaiso (33°10′S), in central Chile (Brito 1997). Satellite monitoring data revealed that *C. caretta* specimens migrated from Peruvian waters (17°S) to Chilean oceanic waters (Mast et al. 2004; Guerra-Correa et al. 2007; Mangel et al. 2011). This is supported by the large number of bycatch records for this species from oceanic waters off northern Chile and southern Peru (Azócar et al. 2011). However, a lack of suitable data prevents the accurate description of the distribution of this species in Chilean waters.

In summary, it is apparent that *C. mydas* and *L. olivacea* are distributed in bays and specific locations in the northern coast of Chile, whereas *D. coriacea* and *C. caretta* are present in oceanic waters.

Origin of D. coriacea*,* L. olivacea*, and* C. mydas. — Individual *D. coriacea* and *L. olivacea* from Chilean waters have been associated with nesting populations in Mexico and Central America (Frazier 1990; Eckert and Sarti 1997). Small numbers of *D. coriacea* individuals tagged in Mexico and Costa Rica have also been recorded in different places along the Chilean coast. Individual sea turtles from Costa Rica were encountered in 1988 in Valdivia (40°S; Chandler 1991) and Coquimbo (30°S; Brito 1997). One *D. coriacea* tagged in Mexico was captured in 1988, close to Isla Mocha (33°30′S; Marquez and Villanueva 1993), with another individual encountered in 1992 in San Antonio (33°36′S). Similarly, several female *D. coriacea* fitted with satellite transmitters moved from Costa Rica to Chilean waters (Shillinger et al. 2008; Bailey et al. 2012b). *Dermochelys coriacea* migrate as far southwest as 37.6°S and 133.3°W in Chilean waters, encountering high-productivity areas associated with elevated rates of upwelling vertical transport, which is likely related to increased availability of food (Shillinger et al. 2011; Bailey et al. 2012a). Further evidence for movements of sea turtles between these 2 areas is provided by the reduction in the number of nesting females observed in Mexico beaches associated with mortality from bycatch in the Chilean swordfish fishery (Chandler 1991; Marquez and Villanueva 1993; Brito 1997; Eckert and Sarti 1997). Although these limited data show evidence for movement of individuals within the East Pacific, genetic evidence (mtDNA) indicates that some *D. coriacea* captured in Chilean waters had a western Pacific origin (Donoso et al. 1999).

For *C. mydas,* there are multiple records of specimens originally tagged in the Galápagos Islands, which were subsequently recaptured in Peruvian coastal waters (e.g., Green 1984). This could be interpreted as an indication of regular migration between the Galápagos Islands and Peruvian waters, but may possibly extend to the north of Chile. However, no record exists of tagged *C. mydas* from Chilean coastal areas (Brito 1997). It has been assumed that specimens recorded in Southern Chile originated from the Galápagos Islands (Frazier 1990). This is supported by analyses of frequency of mitochondrial DNA haplotypes from samples taken of Chilean bycatch green turtles (Seminoff 2002).

Origin of C. caretta. — According to current evidence, *C. caretta* originating from nesting beaches in Australia and New Caledonia cross the southern Pacific Ocean utilizing the Tasmania front (Mast et al. 2004; Mangel et al. 2011) in order to use feeding areas located off the coast of Peru, and subsequently return to the western Pacific (Alfaro-Shigueto et al. 2008; Boyle et al. 2009). This description is supported by genetic data, the lack of records of small-bodied individuals (i.e., < 70 cm) in Australian waters, the high frequency of juveniles captured as bycatch in Peruvian fisheries, and the absence of adult-sized individuals (> 70 cm) in the southeastern Pacific. In Chile, *C. caretta* is the second most frequently captured sea turtle in the swordfish fishery operating in waters of the south-central coast (Azócar et al. 2011), but numbers of records close to shore are very limited. Following this, *C. caretta* extends its distribution into northern Chilean waters, with individuals using the Chile–Peru coastal current to reach their feeding grounds in subtropical latitudes (Boyle et al. 2009).

Satellite monitoring of juvenile and adult *C. caretta* captured in waters off Peru clearly showed that they moved south through Chilean waters. Mangel et al. (2011) noted that this species is typically oceanic, and that movements into Chilean waters likely reflected temporary residence by the pelagic juvenile stage, prior to their return to breeding areas. Beyond this, data are lacking regarding potential relationships between the presence of *C. caretta* in Chilean waters with, for example, seasonal or interannual surface warming, behavior of the upwelling fronts, or temporary aggregations of jellyfish. As such, there is a pressing need for more *C. caretta* satellite surveys with juvenile individuals that coincide with traditional and nontraditional oceanographic measurements (e.g., dimethyl sulfide distribution; Endres and

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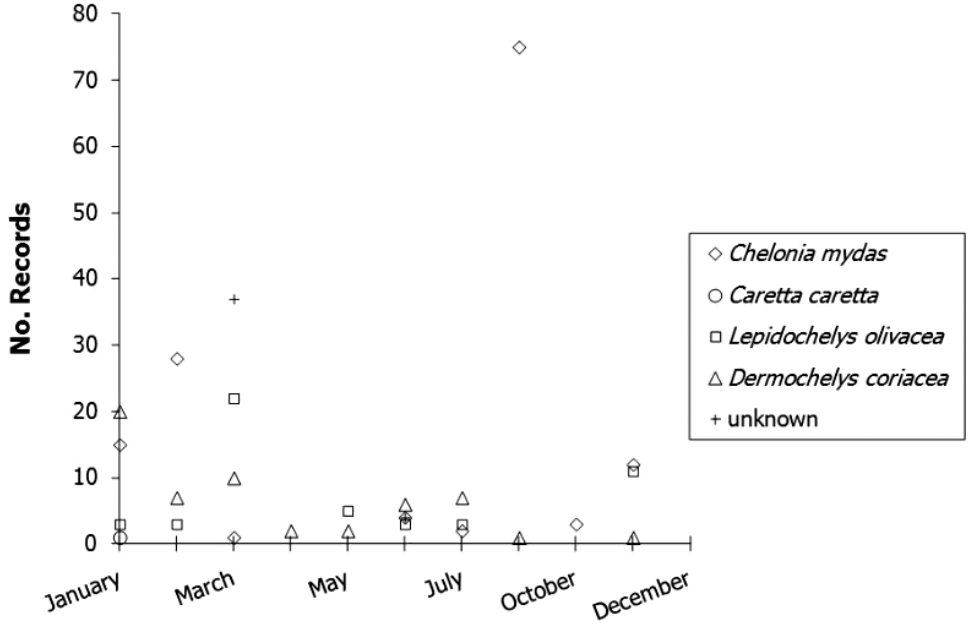


Figure 4. Records of sea turtles in Chile categorized by month of occurrence.

Lohmann 2012) that may increase our understanding of the factors driving the spatial and temporal distribution of *C. caretta* off Chilean coasts.

Temporal Distribution. — In terms of the temporal distribution of sea turtles in Chilean waters, our analysis showed that only 520 records included detailed temporal information (Fig. 4). Data for *C. mydas* included 28 records in the period December–February, as well as a record of 70 individuals in September, but this latter record was based on a newspaper reference regarding the estimated number of *C. mydas* consumed by sea lions at the port of Antofagasta (La Estrella de Antofagasta, 16 September 2009; available at http://www.estrellaantofagasta.cl). Similarly, *L. olivacea* also had 22 records in March and 11 in November 2009, with < 10 records associated with the remaining months of the year. Observations for *D. coriacea* and *C. caretta,* were limited to 10 records without any apparent seasonal trend.

This could support the suggestion that the presence of *C. mydas* and *L. olivacea* in Chilean waters is seasonal (Fig. 4), coinciding with occurrence of these species further north in southern Peru during December–February (Seminoff 2002). *Chelonia mydas* females nest every year in the Galápagos Islands, between December and March (Zárate et al. 2013). From this, it could be suggested that green turtles in Chile correspond to males and/or postnesting females. However, available size data indicate that most Chilean records of *C. mydas* are of juvenile or subadult individuals, which is in line with the life stage reported for feeding areas in southern Peru (Velez-Zuazo et al. 2014). It is likely that after hatching at the Galápagos Islands, *C. mydas* posthatchlings dispersal southward into oceanic waters off the Chilean coast and then move to feeding areas off southern Peru looking for abundant food that promotes fast growth (Velez-Zuazo et al. 2014). Studies compiled by Seminoff et al. (2002) showed that mean annual estimates of nesting females in Galápagos Islands were similar ($\sim$ 1400) between 1976–1982 and 1999–2000, and suggested that this stock of *C. mydas* had been stable. Hence, it is possible that the supply of individuals migrating to waters off northern Chile may be similarly constant. Also, the presence of *C. mydas* in Chilean waters may be supported by biotic factors such as the large regional seasonal blooms of the scyphozoan jellyfish *Chrysaora plocamia,* a preferred prey in Peruvian neritic waters (Quiñones et al. 2010), which in northern Chile also usually occur during summer (Óliva et al. 2010; see details in the ''Foraging Ecology'' section).

Conversely, it is suggested that *C. mydas* has the ability to overwinter in areas with abrupt temperature decrease during some seasons (e.g., Gulf of California), where the record of motionless individuals in crevices and caves in the littoral is common during winter (Ultsch 2006). As such, in agreement with Frazier and Salas (1984), *C. mydas* was likely present in Chilean coastal waters year-round but remain inactive during the cooler months. As has been noted previously (e.g., Frick et al. 2006), the potential seasonal or permanent presence of *C. mydas* in northern Chilean coasts highlights the need for a continuous quantitative monitoring of sea turtle abundance in this area.

In the same sense, seasonal patterns in the data for *C. caretta* and *D. coriacea* originating from fishery observers reflect patterns of seasonal fishing effort rather than a natural pattern in sea turtle populations in these waters. In this case, records including temporal data are limited. Clearly, there is no consensus regarding the temporal variability of sea turtles in this region.

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There are no confirmed records of hawksbill turtles (*Eretmochelys imbricata*) in Chilean continental waters, and it has been suggested that Chile is outside of its distribution range. However, the presence of this and the other 4 sea turtle species has recently been anecdotally reported from Easter Island, an offshore territory of Chile, located in the Pacific Ocean approximately 3600 km from continental Chile (Álvarez et al. 2012). Besides this recent addition, there is no direct evidence regarding the presence of the hawksbill sea turtle in Chile.

Oceanographic Features Associated with Turtle Presence. — The presence of sea turtles in Chilean coastal waters has been linked with oceanographic–atmospheric anomalies resulting from the El Niño Southern Oscillation (ENSO; Aranda and Chandler 1989), disorientation of individual turtles (Philippi 1899; Donoso-Barros 1962; Formas 1976; Ibarra-Vidal and Ortiz 1990), passage through Chilean waters as part of migration, or temporary residence reflecting utilization of resources provided by the region's ecosystems (e.g., food or shelter [Frazier and Salas 1982; Donoso and Dutton 2000; Frick et al. 2006; Guerra-Correa et al. 2007; Ortiz and Moreno 2008]). Potential migratory movements and the potential of Chilean waters as feeding grounds have already been referred in preceding sections. Regarding physiological abnormalities in sea turtle orientation and cues used to direct migration, the studies available do not provide details on the health status of stranded sea turtles; as such, it is difficult to comment on the role of putative physiological problems or disease associated with strandings on the Chilean coasts.

From an oceanographic point of view, superficial currents close to Chilean coasts and sea surface temperature vary both seasonally and interannually (Thiel et al. 2007). Such variation could modulate the proximity of the sea turtles to the coast or the time spent in these sectors. The presence of *C. mydas* in bays located along the northern Chilean coast has been related to the incursion of superficial warm, nutrient-poor equatorial water moving southward during strong El Niño events (e.g., $\sim$ 22,000 individuals in 1987; Frazier 1990). Antofagasta Bay, and in particular its central region, is recognized by local fishermen as a historical aggregation site for *C. mydas* and *L. olivacea*. Local-superficial circulation and the presence of Equatorial Sub-Surface Water (Cerda et al. 2010) transported southward from tropical latitudes to Northern Chile by the Gunter current, lead to the retention of surface waters in the bay, promoting warming (Escribano and Hidalgo 2001). This warming is reinforced during summer months (December–January), and can be accentuated during ENSO warm phases, when the thermocline outside of the bay is deeper and the upwelling influence is weaker (Ulloa et al. 2001; Escribano et al. 2004).

Such seasonal coastal warming could explain an increased presence of sea turtles originating from more equatorial latitudes, or a more intense and shallower activity rate by ''resident'' individuals, at the end of the each year. If the apparent seasonality reported in the presence of sea turtles in Antofagasta and Mejillones bays is not an artefact of selective reporting, this likely represents a response to the dynamics of surface warming during summer months and El Niño events. However, without the development of long-term monitoring, these hypotheses are reduced to speculation.

The presence of sea turtles in several northern Chilean bays has also been associated with the discharge of warm-water effluent from coastal power plants (Guerra-Correa et al. 2008). In Mejillones Bay, 3 power plants discharge $>$ 500,000 m^3 of heated water each day (E-CL, Environmental Department, *pers. comm.,* August 2013). During recent decades, this was suggested as the main factor driving the presence of *C. mydas* and *L. olivacea* inside the bay (Guerra-Correa et al. 2008), and resembled reports for sea turtles in San Diego Bay, California, USA (Turner-Tomaszewicz et al. 2012). However, although these (and new) plants are operating, sea turtles have not been observed recently in these sites (E-CL, *pers. comm.,* August 2013). In turn, this apparent disappearance is ascribed to the negative interactions between sea turtles and sea lions (*Otaria flavescens*) from close colonies, or domesticated individuals in fishing ports (Guerra-Correa et al. *in* Kelez et al. 2008a).

Demography: Sizes, Life-Stages, and Biomass

The majority of records examined in this review did not report the size and/or sex of individual sea turtles. However, from those limited records (n = 10) with information on size, we estimated a mean ($\pm$ standard deviation, range) straight carapace length of 49 cm ($\pm$ 46; 60–150 cm) for *C. mydas*, and of 113 cm ($\pm$ 69; 12–200 cm, n = 19) and average mass of 457 kg ($\pm$ 243, n = 9) for *D. coriacea*. Although limited, these size estimates indicate that the individuals of both *C. mydas* and *D. coriacea* found in Chilean waters were juveniles or subadults, according to the mean size (curved carapace length [CCL] = 85 $\pm$ 5.5 cm) of nesting females of *C. mydas* in the Galápagos Islands (Zárate et al. 2013), or the mean size (CCL = 120–165 cm) of nesting females of *D. coriacea* in Mexico or Costa Rica (Eckert et al. 2012). Unfortunately, existing data were not suitable to produce similar estimates for the other sea turtle species in Chilean waters.

Although data on *C. caretta* population structure are not available from Chilean waters, the mean CCL of specimens encountered from interactions with East Pacific Tuna Fisheries and artisanal fisheries off Peru, was approximately 50 cm—a length corresponding to juvenile specimens (Alfaro-Shigueto et al. 2004; Alava 2008) according to those descriptions by Dodd (1988; i.e., juvenile: 10–40 cm).

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Foraging Ecology

We found several records of *C. mydas* feeding on macroalgae and annelids in the north region of Chile close to Antofagasta (Guerra-Correa et al. 2007) and Copiapó (Tucker et al. 2013). Specifically, there are gut content records of *C. mydas,* including *Macrocystis piryfera* (Formas 1976), *Durvillaea antartica, Glossophora kunthii, Gymnogongrus furcellatus, Plocamiun violaceum* (Troncoso 1990), *Ulva* sp., *Lessonia* sp., *Chaetomorpha* sp. (Guerra-Correa et al. 2007), and *Porphyra columbina* (Brito 1997). There are also records of individual *C. mydas* from Antofagasta consuming fish and mollusc debris discharged from the city's main artisanal harbor (Kelez et al. 2008a). These observations agree with that observed in other feeding areas (e.g., Seney and Musick 2007; Arthur and Balazs 2008), where *C. caretta* or *C. mydas* feed mainly on dominant components of neritic communities (e.g., macroalgae, crustaceans, and molluscs). These groups are abundant in Chilean coastal habitats (Lancellotti and Vasquez 2000), highlighting the need for suitable studies using long-term (e.g., stable isotope analysis) and short-term (e.g., stomach content analysis) approaches to estimating the relative importance of benthic and pelagic taxa in the diet of sea turtles in these localities.

Dermochelys coriacea is characteristically identified as consumers of gelatinous zooplankton, including Cnidaria, Ctenophore, and Urochordata. Eckert et al. (2012) described 19 prey classes counting 18 species and 11 genera of Cnidarians, Ctenophores, Scyphozoa, and Siphonophores. They also refer to several records of fishes and invertebrates that are consumed occasionally. From this list, 2 taxa (*Aequorea* sp. and *Cyanea* sp.) and 4 species (*Aequorea minima, Chrysaora plocamia, Cyanea rosea,* and *Physalia physalis*), are present in Chilean waters (World Register of Marine Species; http://www.marinespecies.org/). *Chrysaora plocamia* is found in locations that overlap spatially with specific coastal sites in northern region of Chile where *D. coriacea* adults have been recently sighted (Sarmiento-Devia et al. 2014).

Fisheries Interactions

The Chilean industrial pelagic longline fishery for the swordfish (*Xiphias gladius*) operates between December and February in the Chilean Economic Exclusive Zone, between 180°–70°W and 17°–39°S in waters of 2000- to 3000-m depth. It is estimated that 4% of gear set by this fishery results in sea turtle bycatch (Donoso and Dutton 2010). Even though the industrial longline fleet has gradually declined from the 1980s, it maintains a significant impact on these species (*D. coriacea* bycatch rates: 0.022 turtles/1000 hooks; *C. caretta* bycatch rates: 0.0014 turtles/1000 hooks; GloBAL Project data), especially in areas where fishing effort from several fleets overlaps (Azócar et al. 2011).

Bycatch of *D. coriacea* juveniles and adults (CCL measured on board: 61–190 cm, $n = 14$; lengths visually estimated in the water: 80–200 cm, $n = 73$) are distributed throughout the whole Chilean fishing region (Frick et al. 2006; Guerra-Correa et al. 2007; Kelez et al. 2008a, 2008b; Azócar and Saavedra-Nievas 2010). Along the Chilean coastal zone, records of *D. coriacea* are reported from Caldera (27°5′S) to Ancud in Chiloe Island (41°5′S, Fig. 1; Brito 1997). These represent the 93% of all types of records (strandings, encounters, active catch, etc.) of regional data for this species. Records are centered on fishing ports (i.e., San Antonio, Concepción, and Valparaíso) where the artisanal swordfish fishery was historically concentrated during the late 1980s (Frazier and Brito 1990; Brito 1997), and are maximized in waters with temperatures between 15.2° and 23.4°C (Donoso and Dutton 2011). In 1989, a total annual capture of 250 individuals, mainly of adults, was estimated for the port of San Antonio. However, this estimate was indirectly calculated based on the number of artisanal vessels and the mean number of encounters with sea turtles per boat (Frazier and Brito 1990).

Bycatch of *C. caretta* (CCL = 47–84 cm, $n = 34$) is aggregated in the northern portion of the Chilean fishing area, in waters with temperatures between 16.8° and 22.1°C (Donoso and Dutton 2011). It is suggested that the local presence of *C. caretta* is associated with increases in primary production in offshore waters. An analysis of the bycatch between 2001 and 2005 revealed that most *C. caretta* captures occurred in 2001, during a La Niña period (the cold phase of ENSO; Donoso and Dutton 2010).

For *C. caretta,* interactions with tuna fisheries is also likely an issue: high-frequency interactions between specimens and fishing vessels have been reported by observers from the Inter-American Tropical Tuna Commission (IATTC) in waters off Peru, and to a lesser degree in waters off southern Ecuador, and have increased in the past decades (Alava 2008). Chilean waters support internationally important tuna fisheries; however, Chile is not a member or cooperating state of the IATTC. The IATTC has an objective to reduce bycatch associated with the tuna fishery operating in the eastern Pacific Ocean, as well as monitoring bycatch species (Mejuto et al. 2007).

There are relatively few records of *C. mydas* bycatch (< 100), and none for *L. olivacea* (Donoso and Dutton 2010). This is consistent with observed patterns in the artisanal fishing fleet of Peru, where *C. caretta* dominated bycatch figures, whereas *L. olivacea* and *D. coriacea* were captured in lower numbers (Alfaro-Shigueto et al. 2011).

Sea Turtle Conservation Efforts in Chile

Although sea turtle products have not been widely consumed or traded in Chile, the national government has prohibited hunting and trapping in agreement with the

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1975 CITES convention (*Decreto Supremo* 141-1975, 868-1981, and 225-1995; *Ministerio de Economía*). Also, concerns regarding sea turtle mortality associated with artisanal fisheries led the *Instituto de Fomento Pesquero* (IFOP) and NOAA-fisheries (USA) to initiate an onboard observer program in 2001 focused on main fishing areas of South-central Chile (Mast et al. 2004; Azócar et al. 2010). This explains why bycatch records increased since 1998, and why sea turtle records prior to this date were apparently low. This highlights the fact that the lack of clear trends of sea turtles in these waters reflects a lack of systematic surveys.

Furthermore, Chile is part of the Inter-American Convention for the Protection and Conservation of the Sea Turtle and of the Permanent Commission for the South Pacific, which is developing the *Programa Regional para la conservación de las Tortugas Marinas del Pacifico Sudeste* (Regional Program for the Conservation of South Eastern Pacific Marine Turtles) as part of the *Convenio para la Protección del Medio Marino y las Zonas Costeras del Pacifico Sudeste* (Agreement for the Protection of the Marine Environment and Coastal Zones of the Southeast Pacific, Lima of 1981). These international initiatives aim to ''recover sea turtle populations and their habitats in the Southeast Pacific by mitigating major threats across participative strategies based on the best socio-economic, biological and ecological information available'' (CPPS 2013:4) and ''taking into account the environmental, socioeconomic and cultural characteristics'' of every country (Inter-American Convention [IAC] 1994:2). Initially, IFOP examined the current understanding of the status of sea turtle populations in Chile, and identified several knowledge gaps (Azócar et al. 2010). However, Azócar et al. (2011) did not include the large amount of information available via alternative sources (including web sites and grey literature) that are included in the current study. Thus, there is an immediate need to develop our understanding of these species in the region, across complementation of basic information on distribution based on systematic monitoring.

Rescue centers for handling injured or stranded sea turtles have been implemented in Antofagasta (Guerra-Correa et al. 2008), Iquique, and Valparaíso. There are also a number of new research groups focused on the ecology and conservation of sea turtles in Chile: Tortumar-Chile, *Qarapara Tomachi*, Censo de la Vida Marina en Chile, among others.

Future Areas of Research

To date, no detailed studies have been conducted examining the population status of the different sea turtle species found in Chilean waters, beyond estimates based on bycatch in open oceanic waters. Although sea turtle movements from Central America into Chilean waters have been demonstrated, more long-term studies are needed to support a better understanding of their presence, population biology, and ecological function in the southeastern Pacific. As such, there is a clear need for the initiation of surveys detailing the presence of sea turtles in Chilean waters and their origin (e.g., through analysis of population genetics). Studies examining population dynamics should combine monitoring of known potential sea turtle hotspots (e.g., Antofagasta, Mejillones, Punta Chascos, and Arica) and measures of industrial fishery bycatch with periodic and systematic surveys of open ocean habitats, independent from the industrial fishery. Analyses of such monitoring correlated with oceanographic data (e.g., ENSO) would allow the examination of hypotheses regarding the influence of surface circulation processes in sea turtle migration and their use of Chilean coastal waters (Saba et al. 2008). Future work also should consider combined use of short-term (e.g., stomach contents) and long-term (e.g., stable isotope analysis, fatty acid analysis) measures of consumption and assimilation of prey to characterize the migration history and trophic ecology of the different sea turtles in Chilean waters.

Our analysis has shown that *C. mydas* dominate the records of sea turtle encounters from the Chilean coast. These records appear to be concentrated in the Austral summer (December–March) when trade winds and upwelling processes are more intense (Marín and Olivares 1999), enriching benthic communities (Taylor et al. 2008; Pacheco et al. 2011). Taken together, we suggest that the coastal waters of Chile represent more than a pathway for migrants and can be considered as seasonal feeding areas. However, this hypothesis requires further examination.

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