Ecological Indicators 79 (2017) 254–264

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

# Long-term trends in abundance of green sea turtles (*Chelonia mydas*) assessed by non-lethal capture rates in a coastal fishery

Berenice M.G. Silva[a], Leandro Bugoni[b], Bruno A.D.L. Almeida[a], Bruno B. Giffoni[a], Fernando S. Alvarenga[a], Luciana S. Brondizio[a], J. Henrique Becker[a,*]

[a] *Fundação Pró-TAMAR, Rua Antonio Athanásio da Silva, 273, Itaguá, 11680-000, Ubatuba, SP, Brazil*
[b] *Universidade Federal do Rio Grande – FURG, Instituto de Ciências Biológicas, Laboratório de Aves Aquáticas e Tartarugas Marinhas, Campus Carreiros, CP 474, Av. Itália, km 8, 96203-900, Rio Grande, RS, Brazil*

ARTICLE INFO

*Keywords:*
Atlantic Ocean
Fishing weir
Incidental capture
Population trend
Pound net
Turtle size

ABSTRACT

Sea turtle populations underwent severe decline in historical times, mainly through harvesting eggs and adults on nesting beaches. With the reduction of this threat in many areas, coupled with other conservation actions, some populations have demonstrated encouraging recovery, although remaining below their previous levels and undergone additional modern threats such as incidental capture in fisheries and pollution. Trends in sea turtle populations have usually been assessed through monitoring of females or nests on nesting beaches. Here we present data from a 22-year monitoring period for a juvenile green sea turtle *Chelonia mydas* mixed-stock in southeastern Brazil that were incidentally captured in passive non-lethal pound nets. A total of 3639 green turtles were captured in 5323 fishing days.pound$^{-1}$ with mortality rate of 2%. Captures occurred in all months, but bycatch rates, excluding recapture events, were higher in September and October, probably due to the recruitment of turtles migrating from southern areas, as well as recruits from the oceanic zone. Capture rates increased by 9.2% per year in the period from 1995 to 2016, in line with increasing source populations, particularly the main source contributor at Ascension Island, but also Trindade Island (Brazil) and Aves Island (Venezuela). Mean Curved Carapace Length of green turtles was higher during austral summer/early autumn and decreased markedly in May, probably due to the small-sized individuals that recruited to the study site. We show that the incidental capture of sea turtles in non-lethal fisheries, such as Brazilian pound nets, could also provide data on trends of populations nesting in distant places, and can contribute to the assessment of population status of sea turtles within Regional Management Units throughout the Atlantic Ocean.

## 1. Introduction

Populations of green sea turtles *Chelonia mydas* (Linnaeus, 1758) were estimated to have declined worldwide in historical times, and by 48–66% over the last three generations, with reductions recorded at 55% of the nesting sites (Seminoff, 2002). Comparison with historical information suggests that present day populations represent a tiny proportion of the total that once existed before European colonization, now regarded as ecologically extinct is some places (Jackson et al., 2001). The lack of reliable data on status and trends of sea turtle populations could impair both management strategies and recovery planning of threatened species (Chaloupka et al., 2008a; National Research Council, 2010); green sea turtles are listed as “vulnerable” in Brazil (MMA, 2014) and as “endangered” globally (IUCN, 2016).

Population trends for sea turtles have been determined traditionally through monitoring rookeries, usually by counting the number of nesting females, saturation tagging of females, or indirectly by counting the number of clutches or tracks on the beach (Broderick et al., 2006; Marcovaldi and Chaloupka, 2007; Pfaller et al., 2013; Bourjea et al., 2015). However, as for any long-lived vertebrate, it requires several years of monitoring to reliably detect population trends based on nesting ground data. Even though adult females may return to nesting grounds where they were born to lay their own eggs (Bjorndal et al., 2005), sea turtle species exhibit delayed maturity and individual turtles do not usually nest in every year. The need for assessing populations of both immature and mature sea turtles in the water to complement nesting assessments has been widely recognized (e.g. National Research Council, 2010). However, studies monitoring sea turtle populations based on juvenile stages in foraging grounds are scant (Bjorndal et al., 2005), and are usually based on capture-mark-recapture methods (e.g. Chaloupka and Limpus, 2001; Bjorndal et al., 2005). Some other approaches for identifying trends in sea turtle populations were through

* Corresponding author.
*E-mail address:* curupira@tamar.org.br (J.H. Becker).

http://dx.doi.org/10.1016/j.ecolind.2017.04.008
Received 13 December 2016; Received in revised form 3 April 2017; Accepted 5 April 2017
Available online 26 April 2017
1470-160X/ 

historical harvest data (e.g. Broderick et al., 2006; Weber et al., 2014), by counting stranded sea turtle carcasses (e.g. Chaloupka et al., 2008b; Monteiro et al., 2016) or on the basis of quantifying sea turtle bycatch rates (but see Epperly et al., 2007; Sasso et al., 2007; Casale et al., 2012). Strandings, despite being an important source of biological data and information on mortality causes (Epperly et al., 1996; Bugoni et al., 2001; Hart et al., 2006; Chaloupka et al., 2008b), are not a reliable indicator of mortality at sea, mainly because stranding probabilities are usually very low and highly variable in space and time, and usually do not exceed 10–20% of total mortality at sea (Epperly et al., 1996). Sea turtle carcasses stranded on the beach rarely present marks that clearly indicate death caused by fishery activities, sometimes as low as 1.2% of carcasses (Monteiro et al., 2016). Few studies have used in-water captures of live sea turtles to estimate population abundance (e.g. Chaloupka and Limpus, 2001; Bjorndal et al., 2005). This is probably because intentional capture programs are expensive and time consuming and require considerable logistical support (Bjorndal et al., 2005).

Incidental capture in fisheries could potentially be a useful source of information for monitoring sea turtle population trends (Chaloupka and Limpus, 2001; Casale et al., 2012). Bycatch in fisheries (sensu Hall, 1996) have been of limited utility for monitoring trends in sea turtle populations because substantial mortality occurs in most fisheries, such as in longline (Lewison et al., 2004; Sales et al., 2008, 2010), trawling (Poiner et al., 1990; Epperly et al., 1996), gill netting (Echwikhi et al., 2010; Fiedler et al., 2012); and also because capture rates vary depending on a fishing fleet's dynamics, such as gear type, size of the fishery, location of fishing grounds, and fishing duration. In addition, observer coverage in fisheries and quality/accessibility to data is limited (Rees et al., 2016). However, when fisheries are non-lethal for sea turtles (i.e. non-lethal bycatch, or "release", as defined by Hall, 1996) incidental capture is a potential tool for monitoring sea turtle population trends. Passive types of fixed fishing gear are used in coastal areas around the world (Nédélec and Prado, 1990), and these include pound nets, corrals, fences, barriers and weirs. In several of these fisheries sea turtle mortality is low because turtles are free to surface to breathe, particularly when the gear is open-roofed, and mesh size is small, making head or flipper entanglement a rare event (Oravetz, 1999; Harms et al., 2003; Gilman et al., 2010).

The green turtle is the most abundant sea turtle species in foraging grounds along the Brazilian coast (Almeida et al., 2011a) and at the Ubatuba coastal region: green turtles account for 98.4% of sea turtle records, including strandings and fisheries bycatch (Gallo et al., 2006). A large number of juvenile green turtles, and occasionally other species, are captured in the pound net fishery (stationary floating weirs) in Ubatuba, São Paulo state, southeastern Brazil, where they are able to surface inside the trap to breathe (Gallo et al., 2006). Long-term monitoring of pound nets in Ubatuba has been conducted by Projeto TAMAR, which has enabled data collection in partnership with fishermen at this important foraging ground for juvenile green turtles (Gallo et al., 2006).

Here we studied the non-lethal pound net fishery at Ubatuba, focusing on: 1) the usefulness in monitoring long-term abundance trends of green turtles; 2) the monthly variations in capture rates; 3) changes in turtle size between months and years; 4) the homogeneity of capture rates across the whole fishery by comparing capture rates among different fishing pounds.

## 2. Material and methods

### 2.1. Study area

Ubatuba (23°26′S; 45°04′W) is located on the northern coast of the state of São Paulo, southeastern Brazil. The Ubatuba coastline is about 140 km long, with several bays, rocky shores and about 100 small beaches (Fig. 1). Many beaches are occupied by traditional communities, for which artisanal fishing is the main source of income. Average yearly precipitation is 2616 mm with over 200 mm per month from October to April and average monthly air temperatures between 17.7 °C in July and 24.7 °C in February (Estado de São Paulo, 1996). Monthly mean sea surface temperatures reach maximum value of 28.6 °C in February and minimum of 21.9 °C in July (Valentim et al., 2013). Waters comprises the South Atlantic Central Water (SACW), Tropical Water (TW), and Coastal Water (CW), with stratification in summer (CW predominating in the upper 20 m near the coast, TW offshore, and SACW deeper offshore), and no stratification in winter (Castro-Filho et al., 1987). Tourism is the main economic activity, followed by small scale fishing using purse seine, gillnets and trawlers, among others, which targets mainly sardine, white croaker, blue runner and shrimp (Ávila-da-Silva et al., 2016).

### 2.2. Fishery description

Pound nets were introduced in Brazil's southeastern region by a Japanese fisherman in the early 1920s (Mussolini, 1980; Seckendorff et al., 2009), and first recorded at Ubatuba in 1942. The gear has varied little since then, although some sites now have made specific adaptions to the gear. In Brazil pound net fishing occurs from Rio de Janeiro to Santa Catarina states (Seckendorff et al., 2009). Pounds are typically installed in bays 8–15 m deep. The nets extend from the surface to the seabed, which allows fish to be caught throughout the water column (Gallo et al., 2006). Pounds are constructed from nets with mesh size 3–10 cm, and comprise two main pieces: a guide fence (barrier) maintained in a vertical position by ballast weights at the bottom and by floats at the top. This net is perpendicular to the shore and will direct any fish swimming parallel to the coast towards the entrance of the trap; the other part is the trap itself, an elliptical chamber where the fish are trapped and kept alive until removal (Seckendorff et al., 2009) (Fig. 2). Fish and turtles enter actively, but once inside are unable to find the exit again. In historical times when fish were abundant, traps were emptied 4–6 times a day (Mussolini, 1980), but now usually 2–3 times a day. Traps are left set in the same place and stay fishing for 24 h a day. Historically, fish collection required two small canoes, a tiny one used to block the entrance with two fishermen onboard, and another with two fishermen onboard that maneuvered along the net, lifting it upward and forcing fish into a small area, where they could be selected according to species, size and commercial value, or discarded. In good weather pound nets usually remain set for 8–12 days, and are then removed for maintenance (cleaning debris and algae, repairs and dyeing; this camouflages the net and reduces biofouling). Traps are not deployed in bad weather, usually worst in the winter months, and so the fishing season occurs mainly from September to May. Fishing pounds have been located at the same points for decades, built near rocky shores protected from waves and always in waters over 6 m depth.

### 2.3. Data gathering

Interviews with fishermen indicated that the pound net fishery was suitable for long-term monitoring, because the pounds were static, there was a daily fishing routine, and sea turtle bycatch was high (Gallo et al., 2006). Monitoring occurred in two ways: 1) during winter when pound nets were used infrequently, fishermen were visited every two weeks to check if the gear was deployed; 2) during the fishing season researchers visited the pounds whenever a sea turtle had been captured. Fishermen contacted the researchers and kept the turtles aside for measurement and tagging procedures. As captures of sea turtles were frequent, it was possible to monitor continually all pounds for fishing effort, and also note when traps were removed and redeployed, so unmonitored periods were noticed and recorded. Due to intense involvement of fishermen with the project means we are confident that turtle captures or fishing effort had not been omitted by fishermen or overlooked by researchers.