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Collecting information on the pelagic phase of marine turtles from at-sea observations: The case of purse seine fisheries in the Indian Ocean

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Abstract

Observations of turtles in the open-ocean are essential to complement the information collected at nesting sites and rookeries, especially during the 'lost years' of their surface-pelagic juvenile phase. We used a large dataset of observations at sea collected onboard Seychelles, Spanish and French purse seiners over the period 2003-2019 to describe the occurrence of five species of turtles in the Western Indian Ocean: green (*Chelonia mydas*), loggerhead (*Caretta caretta*), leatherback (*Dermochelys coriacea*), Olive ridley (*Lepidochelys olivacea*) and hawksbill (*Eretmochelys imbricata*). A total of 895 turtles were recorded by human observers, 487 turtles after having been caught in the purse seine and hauled onboard the vessels and 408 turtles swimming around or lying on floating objects. An additional 86 turtles were recorded from images collected by cameras deployed on some purse seiners but could not be identified at the species level. Information collected on the status of turtles indicates that the very large majority (>90%) hauled on deck were released alive. Size data show that most turtles observed in the open ocean were juveniles and that the ones caught in association with free swimming schools of tuna were smaller than the ones caught in schools associated with drifting floating objects, these latter representing the majority of the observations. Through the turtles' example, we aim to describe the availability of metadata and data standards widely used to share species occurrence data and key to foster collaborative science in the Indian Ocean and beyond.

Introduction

Marine turtles have been of major cultural, economic and nutritional importance to the people of the Indian Ocean for hundreds of years (Frazier 1980). Historical information available from trade statistics, literature and scientific studies showed that major declines occurred in turtle populations over the last centuries due to intense exploitation for meat, eggs, and other products such as calipee (Mortimer et al. 2011). Knowledge of the occurrence and movements of turtles is key to describing their home range and preferred habitat, improving our understanding of their complex demography, and eventually assessing the main factors affecting their survival (Polovina et al. 2000, Kobayashi et al. 2008). Over the last decades, data on turtle presence, relative abundance and seasonal dynamics related to spawning in the western Indian Ocean have been mainly collected from the monitoring of track counts and nesting activity (Frazier 1975; Le Gall & Hughes 1987, Lauret-Stepler et al. 2007, Mortimer et al. 2011, Bourjea et al. 2015, Derville et al. 2015). In addition, satellite telemetry showed some residency close to nesting beaches during several months in green (*Chelonia mydas*), loggerhead (*Caretta caretta*) and leatherback (*Dermochelys coriacea*) turtles and provided useful information on inter-nesting movements (Whiting et al. 2008, Harris et al. 2015).

Observations of turtles in the open-ocean are essential to supplement the information collected at nesting sites and rookeries, especially during the 'lost years' of the surface-pelagic juvenile phase (Carr 1987, Mansfield et al. 2014, Dalleau et al. 2014). Satellite tags deployed on green and loggerhead turtles showed that these species can make long-distance, longitudinal and latitudinal migrations within the tropical western Indian Ocean (Pelletier et al. 2003, Luschi et al. 2003, Dalleau et al. 2014, Christiansen et al. 2016). In this context, a valuable source of information on turtles in the open ocean may come from the observations of interactions with high sea fisheries (Bourjea et al. 2008). Although catch rates of turtles are low in the purse seine fishery (Bourjea et al. 2014) and much lower than in other high seas fisheries (Nel et al. 2013, Williams et al. 2018), it provides a good case study to showcase how valuable information can be inferred from observer programs as the fishery covers a large spatial extent of the western Indian Ocean, the observer coverage is high and is now complemented with Electronic Monitoring Systems (EMS) and the protocols of observation are comparable across purse seine fishing countries. Furthermore, the use of turtle bycatch in the purse seine fishery is non contentious as their survival rate is high (Bourjea et al. 2014, Ruiz et al. 2018).

In this study, we build on the analysis of a large dataset of on-board observations of turtle bycatch throughout 1995-2011 (Bourjea et al. 2014) and updated for 2008-2017 (Ruiz et al. 2018) to present a general, reproducible methodology that aims to improving the description of biodiversity data collected from observations at sea. Firstly, we describe the component of the observer protocol that concerns the observations of turtles. Secondly, we summarize the main features of the turtle dataset, including some recommendations for improving the quality of future data to be collected from both human and EMS. Lastly, we suggest a set of stages in metadata and data processing to make the most of scientific observations following the FAIR (Findable, Accessible, Interoperable, and Reusable) guiding principles (Wilkinson et al. 2016).

Materials & Methods

Data sources

In the present study, we focus on the observations at sea collected onboard Seychelles, Spanish and French purse seiners between May 2003 and October 2019. Seychelles, Spain and France share the same observation protocol and data acquisition and management software for their fisheries observer programs onboard large-scale tuna purse seiners (Cauquil et al. 2015, Lucas et al. 2017, Ruiz et al. 2018). These observer programs were initially built from the methodology developed during the first SFA purse seine observer programme carried out during 1986-1993 and the EU-funded project "Les espèces associées aux pêches thonières tropicales" conducted during 1995-1996 (Sabadach & Hallier 1993, Stretta et al. 1996). Data presented in this paper include (i) the programs developed in the 2000s that were implemented by the French 'Institut de Recherche pour le Développement' (IRD), the Spanish institutes 'Instituto Español de Oceanografía' (IEO) and AZTI Foundation (Spain) within the framework of the EU Data Collection Framework, and (ii) voluntary, industry-funded programs that substantially extended the observer coverage from the mid to late 2010s (Goujon et al. 2017, Grande et al. 2019). Industry-funded programs are conducted in close collaboration between the industry and scientific institutes (IRD, IEO, AZTI and SFA). More recently, several purse seiners have been equipped with cameras and sensors to assess the performance of EMS as an alternative or complementary approach to human observations (Ruiz et al. 2017, Briand et al. 2018). EMS data collected during 2015-2018 onboard some Spanish and Seychelles-flagged vessels were included in the study to augment the dataset and illustrate the complementarity between different systems of data capture.

Data collection protocol

The overall observation protocol at-sea aims at collecting information on the purse seiner's fishing activities including their geographic positions, the fishing environment and the composition of catch retained onboard and discarded at sea. A specific form is used to record the size measurements of non-targeted species, including turtles for which the curved (L_{CC}) or straight (L_{SC}) carapace length should be taken to the lowest cm. L_{CC} should be measured with a tape measure and given preference over L_{SC} that are to be measured with a measurement board or a calliper. In the case of EMS, size measurements are visually estimated from the images and associated with some large uncertainty due to the distance to the camera, that do not permit an accurate calibration of the size measurement tool. The precision in size is considered to be of about 20 cm (B. Calvo, *pers. com.*). In addition, the presence and status of turtles around drifting floating objects has to be reported in the form used to describe the activities related to the use of buoys and floating objects, including man-made artificial fish aggregating devices (FADs). The status indicates the position of the turtle relative to the floating object (i.e. swimming around or lying on the object), whether it is entangled alive or dead, and whether is has been released by the crew when found entangled alive.

Data analysis

Firstly, a density map per 1 degree grid cells of the total number of turtles reported by the observers was built to assess the spatial extent of the observations over the study period. It is noteworthy that the density map does not account for sampling effort (e.g. days of observation) and only focuses on positive observations. Investigating the relative abundance of turtles from commercial catch rates and density of floating objects was beyond the scope of the present study. Secondly, a distribution map of the observations by species and school type was built for each type of observation, i.e. on the deck and at sea (Bourjea et al. 2014). Thirdly, the distribution of turtle size was investigated.

Results

Observations

A total of 895 turtles were observed by human observers in the Seychelles, Spanish and French purse seine fishery of the Indian Ocean during 2003-2019 (Table 1). On the deck, 487 turtles, of which 129 could not be identified, were observed after having been caught in the purse seine and hauled onboard the vessels. At sea, 408 turtles, of which 170 could not be identified, were observed swimming around or lying on floating objects. An additional number of 86 turtles were observed on deck from the dataset of images collected from EMS. Due to the general poor quality and resolution of the images and position of the cameras, all turtles recorded from EM could not be identified by the dry observers.

Table 1. Number of turtles observed in the Seychelles, Spanish and French purse seine fishery of the Indian Ocean during 2003-2019 through interactions with the fishing gear (N_I) and in association with drifting floating objects (N_F).

Institute	**Flag**	**Period**	$\mathbf{N_I}$	$\mathbf{N_F}$
HUMAN				
SFA	Seychelles	Jul 2015-May 2019	81	27
AZTI	Spain	May 2003-Jul 2019	103	91
IEO	Spain	Sep 2003-Sep 2019	95	145
IRD	France	Jan 2006-Oct 2019	122	184
ELECTRONIC				
AZTI	Seychelles|Spain	Sep 2015-Dec 2018	86	-

About 94% of the turtles brought on deck were released alive. Most turtles observed around or on the floating objects were alive, i.e. 357 out of 408. Many turtles were however found entangled in the components of the FADs structure, with 51 observed dead throughout the whole study period. New FAD designs have been developed in the Indian Ocean purse seine fishery over the last decade to reduce the risks of entanglement and maximize the probability of survival through the adoption of good practices guidelines (Franco et al. 2009, Poisson et al. 2014, Grande et al. 2019). Assessing the effects of the implementation of new design on the rates of entanglement is beyond the scope of the present study and would deserve further analysis.

Spatial distribution

Turtles were observed all over the western Indian Ocean, spanning the fishing grounds of the purse seine fishery, from the south of the Mozambique Channel at 20°S to the Gulf of Oman at almost 17°N (Fig. 1). Most turtles were observed in the vicinity of or lying on drifting floating objects, i.e. for more than 96% of the observations. The floating objects appear to be used as resting spots for turtles but they might also be used as indicators of local enrichment through fronts that would be sought for feeding during their pelagic phase (Carr 1986). Furthermore, 31 turtles were caught in association with free swimming tropical tunas that can swim at sustained speeds of 4–6 knots and burst speeds up to 13–14 knots (Magnuson 1973). Turtles generally cruise at lower speeds (0.8-1.2 knots) but they can sustain speeds of around 4-5 knots (Eckert 2002) which seems consistent with their association with free swimming tuna schools.

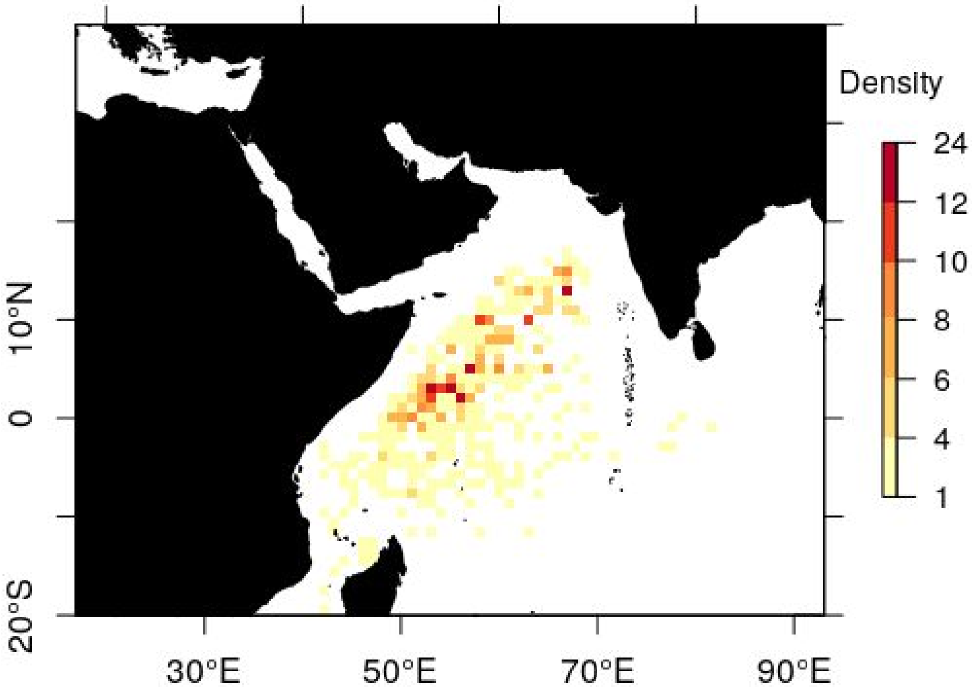

Fig. 1. Density distribution (1 degree grid cells) of marine turtles observed in the Seychelles, Spanish and French purse seine fishery during 2003-2019.

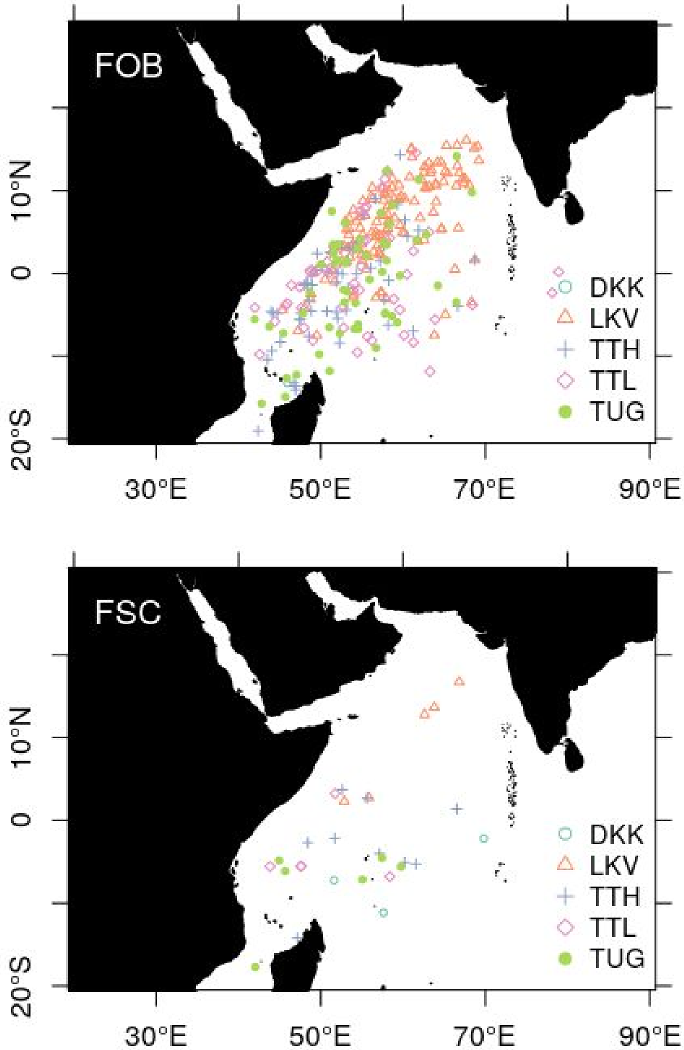

Fig. 2. Distribution of marine turtles by species observed in the Seychelles, Spanish and French purse seine fishery during 2003-2019 on (a) floating objects (FOB) and (b) free swimming schools (FSC). DKK = Dermochelys coriacea; LKV = Lepidochelys olivacea; TTH = Eretmochelys imbricata; TTL = Caretta caretta; TUG = Chelonia mydas.

Olive ridley (n = 163) predominated in the observations for which species was identified (n = 358) and were mainly found north of the Equator (Fig. 2a). They were followed by hawksbills (n = 72), greens (n = 64) and loggerheads (n = 55), while leatherbacks were very rare with only 4 observations reported over the time period. Interestingly, 3 of the 4 observations of leatherback turtles were made on free swimming schools (Fig. 2b).

Size data

The full compliance with the sampling protocol for measuring turtles is difficult to assess but some pictures and anecdotal evidence suggest that size data may mix straight and curved carapace lengths, at least in the case of the Seychelles observer program. Here, we assumed that the size measurements made by the observers were taken in curved carapace length to depict the general size pattern observed. In particular, we find that turtles caught on free swimming schools are all juveniles and significantly smaller than the ones caught on floating objects (Table 2). Most turtles caught on FOBs are also juveniles but the largest individuals, with the exception of leatherbacks (n = 3), have a length larger than the thresholds considered for adults (Table 2). Note that a more stringent data screening combined with some validation procedure for each dataset is required to confirm the patterns observed which have to be considered as preliminary.

Table 2. Mean and maximum individual curved carapace length (cm) by species and school type derived from size measurements collected at sea by observers. FOB = Tuna school associated with a drifting floating object; FSC = Free swimming tuna school. L_{CC} *thresholds: DKK = 145 cm; LKV = 70 cm; TTH = 91 cm; TTL = 112 cm; TUG = 91 cm.*

School type	Scientific name	n	Mean length	Max length
FOB	*Caretta caretta*	44	60	110
FOB	*Chelonia mydas*	48	56	104
FOB	*Dermochelys coriacea*	1	105	105
FOB	*Eretmochelys imbricata*	54	44	109
FOB	*Lepidochelys olivacea*	141	51	105
FSC	*Caretta caretta*	4	42	46
FSC	*Chelonia mydas*	5	35	60
FSC	*Dermochelys coriacea*	2	100	130
FSC	*Eretmochelys imbricata*	8	34	55
FSC	*Lepidochelys olivacea*	5	44	54

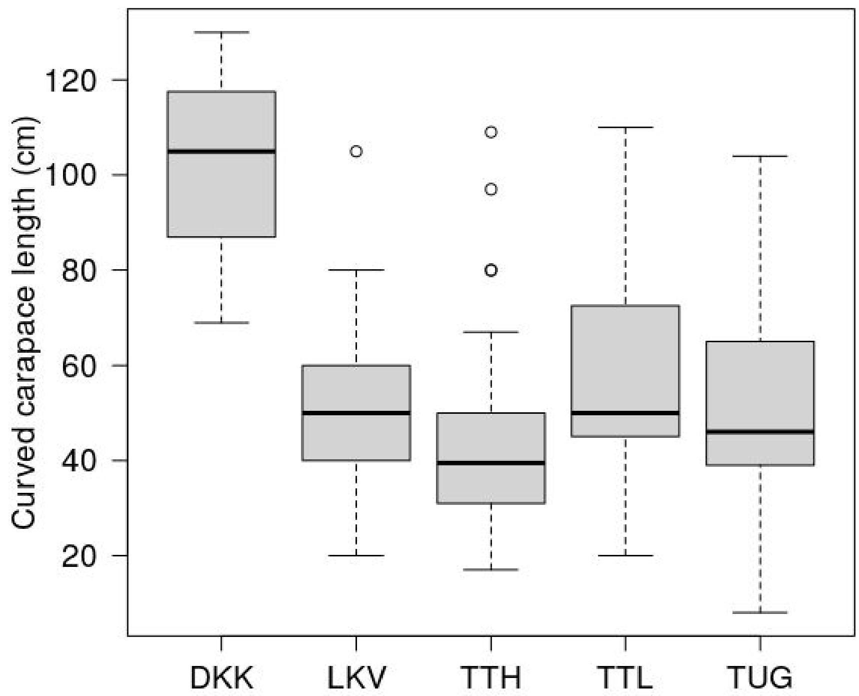

Fig. 3. Distribution of curved carapace length (cm) for the five species of turtles observed in the Seychelles, Spanish and French purse seine fishery during 2003-2019. DKK = Dermochelys coriacea; LKV = Lepidochelys olivacea; TTH = Eretmochelys imbricata; TTL = Caretta caretta; TUG = Chelonia mydas.

Sharing turtles observations

The existence and accessibility of species occurrence datasets is essential to merge different biodiversity data sources so as to obtain a large, representative spatio-temporal coverage of species habitats and reduce costs of data collection. This is particularly relevant for species described by extended home range and migratory behavior such as turtles and tunas. Since 2009, the Taxonomic Data Working Group developed a standard data structure to store and share species occurrences called Darwin Core (tdwg.org/standards/dwc). The standard defines a suite of attributes and imposes constraints on labels and data types, i.e. data dictionary. This harmonized data format enables plugging the data to open repositories such as the Global Biodiversity Information Facility (GBIF; gbif.org). More recently, an extension entitled 'Extended Measurement Or Facts' has been added to include some characteristics of the occurrence data such as individual size measurements (https://tools.gbif.org/dwca-validator/extensions.do). Furthermore, a metadata standard, the Ecological Metadata Language (EML), describes some general metadata elements of the dataset that cannot be directly inferred from the data themselves, e.g. title, creator, keywords, etc. In the context of sharing occurrence datasets, EML is essential to track the origin of each dataset and describe the context of data collection, sampling protocols etc. for each constituent dataset. Some work is ongoing at IRD to produce the EML metadata and Darwin Core data for species caught in the French purse seine fishery and update datasets published on the GBIF in 2012 (ecoscope_observation_database), including the addition of turtles observations. Ideally, the approach should include all purse seine fleets included in the present document and extend to other purse seine fleets (Italy, Mauritius, Korea) and other fishing gears such as longline and gillnet that have been shown to catch more turtles than purse seine.

Conclusions & recommendations

Data improvement

In the case of interactions, about one fourth of the turtles could not be identified by observers, likely due to quick release of the turtles at sea by the crew. In addition, pictures available for some turtles' observations suggested that some misidentification might occur. In this context, it seems that a dedicated protocol specifying how size measurements and pictures should be systematically taken for subsequent validation would be useful to reduce the uncertainties associated with the observations. Additionally, some identification workshop could be conducted by turtles experts to increase the capacity of observers. In the case of Electronic Monitoring, the quality of the current images available in the purse seine fishery does not allow identifying the species. Collaboration with the purse seine industry calling for the collaboration of the crew to bring the turtle close to the camera would be instrumental to get good cues for species identification. Meanwhile, new EMS technology to soon be deployed on purse seiners is expected to result in improved species identification and size measurement through better image resolution and quality.

Data dissemination

Despite the accumulation of a large amount of scientific observations and information on marine turtles in the Indian Ocean over the last decades, very few data remain available to the public. In particular, few tracking data are available from open repositories (e.g. movebank, seaturtles, zoatrack, and oceantrackingnetwork) while very few occurrences of turtles are available from the GBIF, particularly in the open ocean (e.g. gbif.org/species/2442153). Sharing turtles observations in the open ocean has been shown to be of major interest for describing their preferred habitat in the eastern Pacific Ocean (Montero et al. 2016), with potential application to identify hotspots of bycatch for mitigation purpose (Howell et al. 2008).

Recommended steps

Observations collected from fisheries bycatch observer programs can provide invaluable information on the distribution of marine species, including some emblematic species such as turtles. For any dataset of observation, we recommend to follow the following steps:

1. Description and publication of the sampling protocol (e.g. protocols.io)

2. Production and publication of standard metadata (e.g. DataCite, Dublin Core, EML) to describe the main features of each dataset, e.g. context of development, lineage, keywords, contacts, etc.

3. Publication of merged species occurrences from all datasets complying with Darwin Core data format along with EML metadata through open data repositories assigning Digital Object Identifiers (DOI) such as GBIF (e.g. with the Integrated Published Toolkit of Robertson et al. (2014)) or cross-domain repositories such as zenodo or pangaea.

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