Received: 6 September, 2012

Vertical and horizontal behaviour of silky, oceanic white tip and blue sharks in the western Indian Ocean

John Filmalter [1], Fabien Forget [1], Francois Poisson [2], Anne-Lise Vernet [3], Pascal Bach [1], Laurent Dagorn [1]

[1] IRD, UMR 212, B.P. 171, Av. Jean Monnet, 34203 Sète Cedex, France
[2] Ifremer, UMR 212, B.P. 171, Av. Jean Monnet, 34203 Sète Cedex , France
[3] Orthongel Nouvelle criée bureau 10 - Ep 127 - 29181 Concarneau Cedex - France

Abstract

The vertical and horizontal behaviour of silky, oceanic whitetip and blue sharks in the western Indian Ocean was investigated through the use of pop-up archival tags (PATs) and smaller miniPATs. Tags were deployed from 2009 to 2012 under the MADE (www.made-project.eu), ISSF bycatch research projects (www.iss-foundation.org) and the project Contrat Avenir from the French fleet organization ORTHONGEL. Strong differences were found between the vertical behaviour of juvenile silky sharks tagged around drifting FADs and larger individuals caught on pelagic longlines. Oceanic whitetips displayed similar vertical behaviour to large silky sharks while blue sharks spent far more time at greater depths than the other two species. All three species displayed large horizontal movements.

Introduction

The silky shark *Carcharinus falciformis*, the oceanic whitetip shark *Carcharhinus longimanus* and the blue shark *Prionace glauca* are the three most commonly captured pelagic sharks species in all of the world's tropical and subtropical oceans (Clarke et al. 2006). These species often form part of targeted pelagic shark fisheries but are generally taken in their greatest numbers as bycatch in tuna and swordfish fisheries. In general pelagic longline fleets are believed to be responsible for the major component of fishery induced mortality for these species (Gilman 2011), but tropical tuna purse seine fleets using FADs have also been recognised a source of mortality for the juvenile portion of silky shark populations (Romanov 2002, Amandè et al. 2008). Developing an understanding of the vertical and horizontal behaviour of these species is an important first step towards their effective management. Furthermore as these behavioural characteristics strongly influence their vulnerability to capture such information is critical in the development of mitigation measures against their incidental capture in future.
Very little is known about these behavioural parameters in the western Indian Ocean and for the silky and oceanic whitetip sharks in particular the same is true throughout their global distribution range.

In this study data from pop-up archival tags (MK-10 PAT and MiniPAT, Wildlife Computers) were used to investigate both the vertical and horizontal behaviour of these three species.

Materials and methods

Tagging of sharks took place during multiple chartered research cruises and commercial fishing trips on longline, tuna purse seine and dedicated research vessels in areas of the western Indian Ocean including the Seychelles, La Reunion, Mayotte and the Mozambique Channel. These cruises were conducted between April 2009 and April 2012. Sharks were either captured using standard tuna long line gear rigged with wire traces, by handline or during purse seining operations. Data from 35 silky sharks (87 – 235 cm TL), 2 oceanic whitetip sharks (170 – 183 cm TL) and 7 blue sharks (142 – 220 cm TL) were analysed. For silky sharks separate analyses were conducted for small silky sharks (n = 28, 87 – 155 cm TL) tagged around drifting FADs and larger individuals (n = 8, 154 – 235 cm TL) tagged from long line vessels or captured with free-swimming schools of tuna by purse seine vessels.

For PAT tags, vertical data was summarised by the tags before being transmitted via the Argos satellite system. Summaries were calculated as histograms of depth frequencies over 6 hour periods. MiniPAT tags transmitted vertical data as time series, with 5-minute intervals between data points. To allow for comparison, time series data were summarised into 10 m bins.

Horizontal behaviour was assessed through the estimation of locations from light level collected by the tag. Geo-location estimates were derived using the Iknos-walker package coded in MatLab (see Tremblay et al. 2009). This package derived 50 possible locations on a daily basis and used a maximum speed limit of 4 km per hour for blue sharks, and 10 km per hour for silky and oceanic whitetip sharks.

As horizontal and vertical data were not always available from each tag the number of individuals in each species for which the two analyses were conducted was not always equal.

Results

<u>Vertical analysis</u>

Vertical data was obtained for 27 small silky sharks monitored for 3 – 101 days (mean = 38 days). All individuals were tagged at drifting FADs and tended to spend the majority of their time at depths < 20 m (Fig. 1). Occasional deeper dives beyond 80 m were observed but these were consistently brief and generally infrequent.

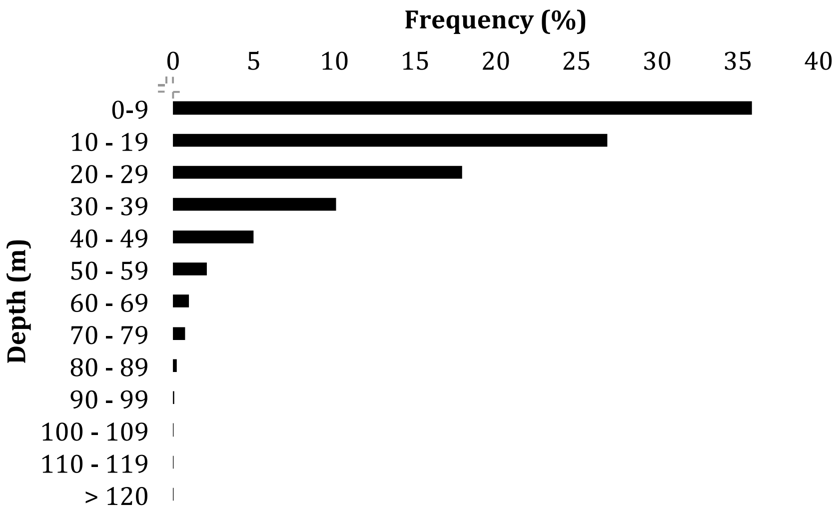

Figure 1 Average vertical distribution of juvenile silky sharks *Carcharhinus falciformis* tagged with miniPATs around drifting FADs in the western Indian Ocean (n = 27).

Data was obtained from tags on eight larger silky sharks, monitored for 8 -165 days (mean = 58 days). These sharks tended to spend more time at greater depths than the smaller individuals at FADs and typically spent the majority of their time between 50 and 150 m (Fig. 2).

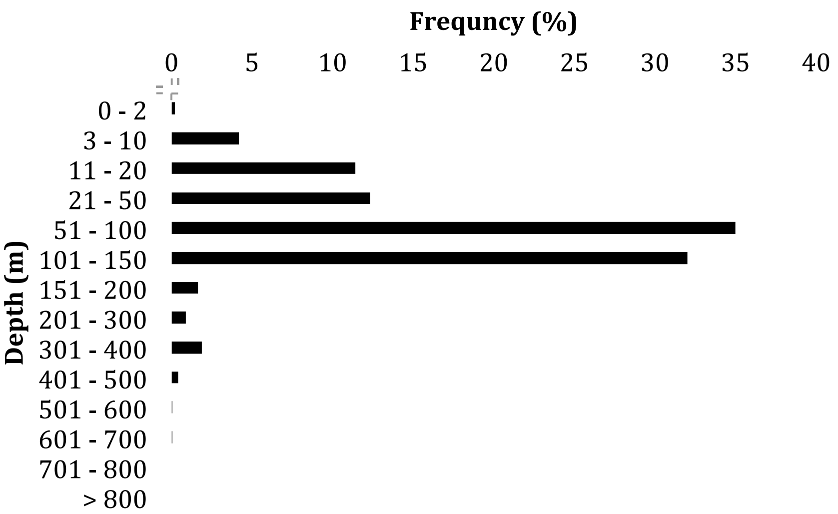

Figure 2 Average vertical distribution of large silky sharks *Carcharhinus falciformis* tagged with PATs and miniPATs from longline and purse seine vessels in the western Indian Ocean (n = 8).

The two oceanic whitetip sharks were monitored for 19 and 100 days. On average both individuals spent the majority of their time between 50 and 100 m (Fig. 3).

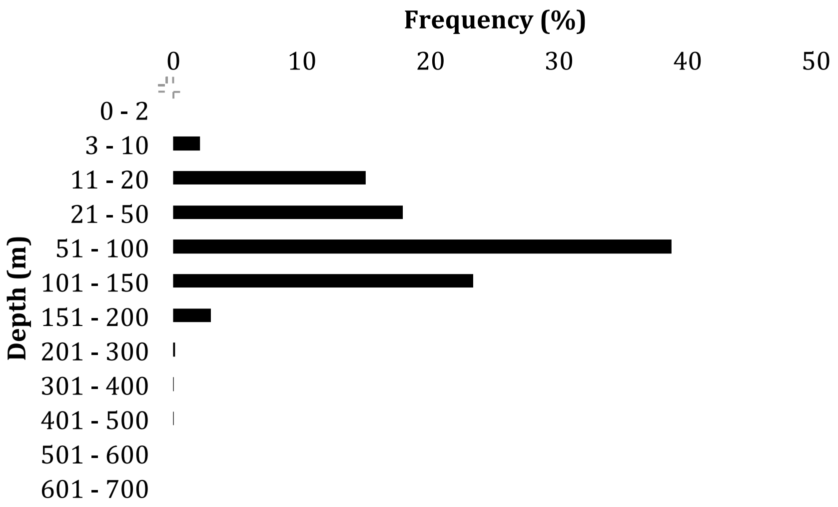

Figure 3 Average vertical distribution of two oceanic whitetip sharks *Carcharhinus longimanus* tagged with minPAT's and PAT's in the western Indian Ocean.

Data were obtained from 7 tags on blue sharks, which were monitored for 10 – 90 days (mean = 50 days). These sharks spent far more time at greater depths than the previous two species. Individuals typically occupied depths in excess of 100 m and regularly spend time at depths greater than 300 m (Fig. 4).

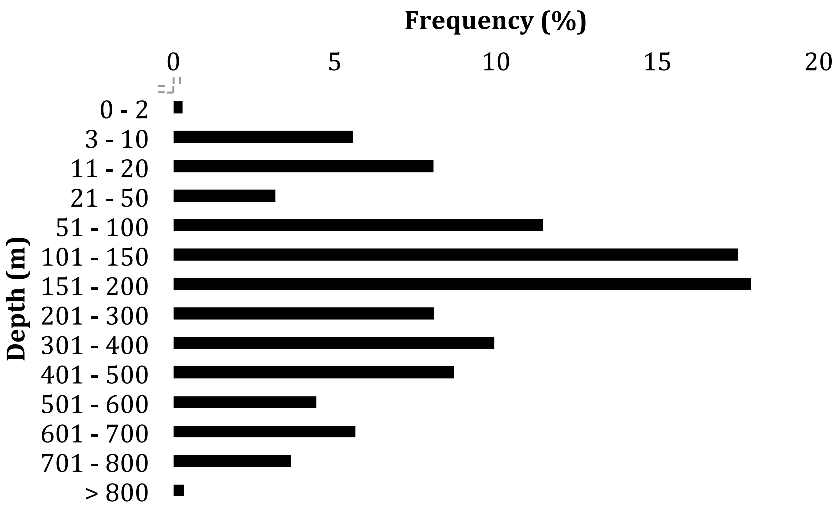

Figure 4 Average vertical distribution of seven blue sharks *Prionace glauca* tagged with PAT 's in the western Indian Ocean.

<u>Horizontal behaviour</u>

Data on horizontal movements was obtained for 26 small silky sharks that were tagged around drifting FADs at multiple locations below the equator in the western Indian Ocean. The overall distribution obtained from the light-based geolocation estimates indicate that these juveniles not only move great distances but also occupy virtually any area of the tropical pelagic environment (Fig. 5).

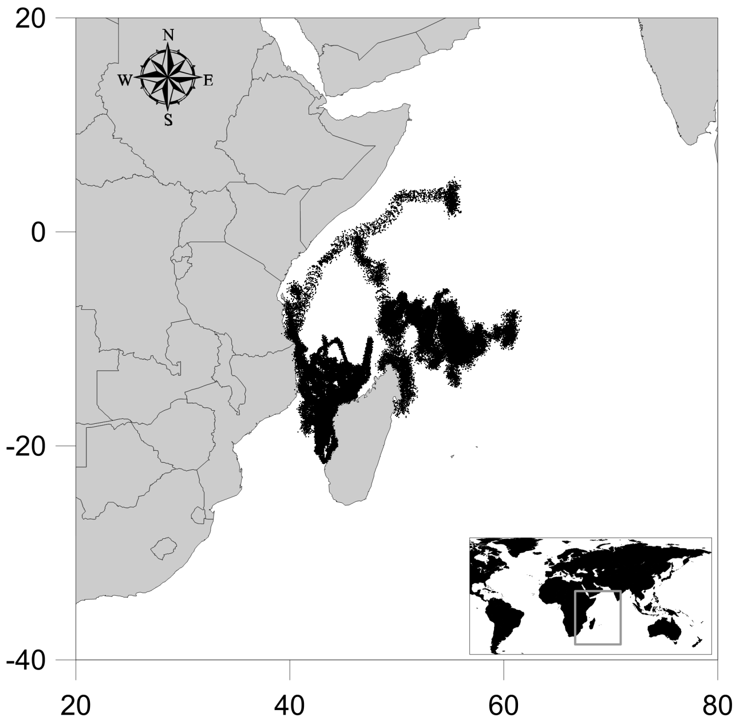

Figure 5 All geolocation estimates for 26 juvenile silky sharks *Carcharhinus falciformis* tagged at drifting FADs in the western Indian Ocean.

Large silky sharks (n = 7) were typically captured close to islands or seamounts, however, geolocation estimates indicate that tagged individuals undertook large movements both longitudinally and latitudinally (Fig.6).

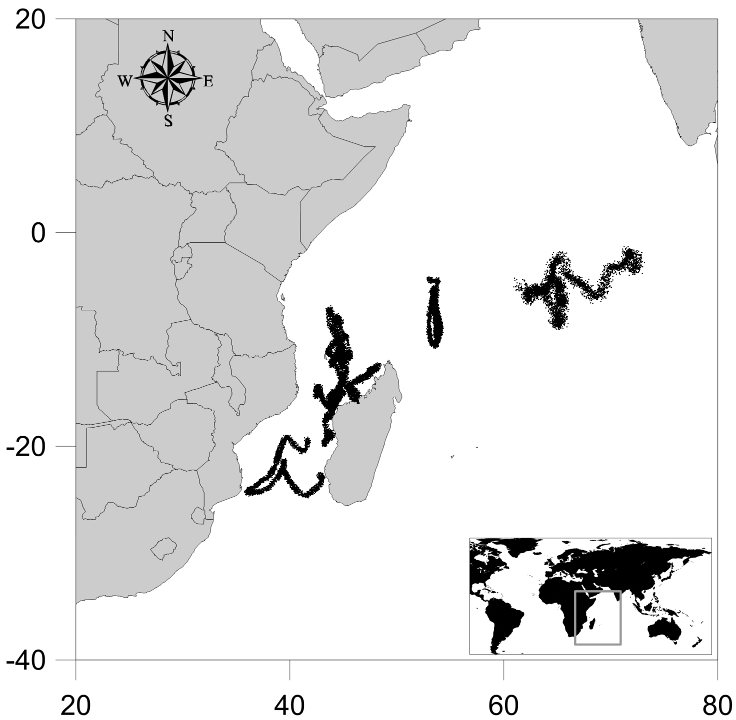

Figure 6 All geolocation estimates for seven large silky sharks *Carcharhinus falciformis* tagged with PATs in the western Indian Ocean.

Of the two oceanic white tip sharks for which horizontal data was obtained one tag remained attached for 100 days. This individual displayed extensive horizontal movement covering a distance of approximately 6500 km during the monitored period, moving from the Mozambique Channel up the African east coast off Somalia and heading back down towards the Seychelles. The second individual was only monitored for 19 days during which time it is estimated to have moved 1100 km in the south of the Mozambique Channel. Both results display the ability of these sharks to travel great distances in the pelagic environment (Fig. 7).

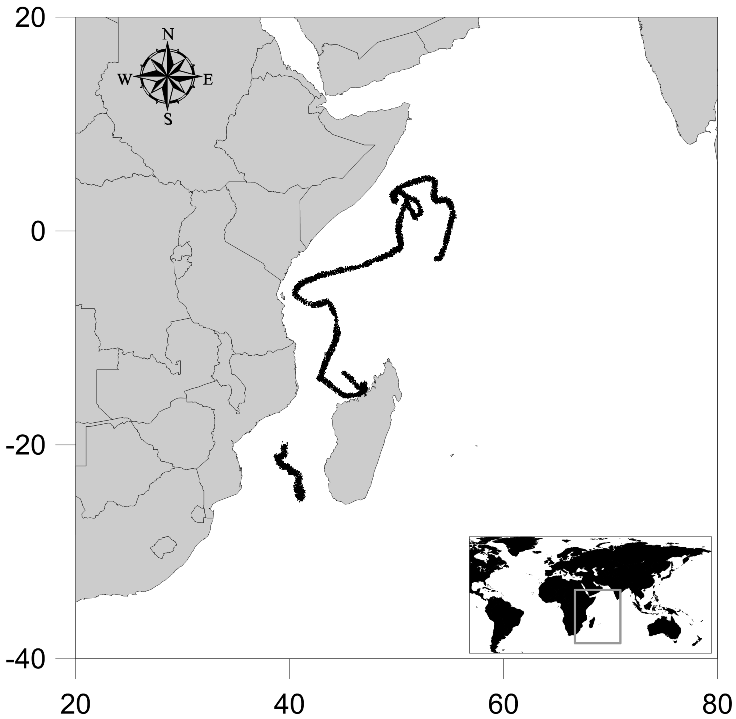

Figure 7 Horizontal movements of oceanic white tip sharks *Carcharhinus longimanus* (n = 2) tagged with PAT and MiniPAT's in the western Indian Ocean.

Geolocation data from tags deployed seven blue sharks showed that these sharks regularly undertake extensive movements in both the longitudinal and latitudinal planes (Fig. 8).

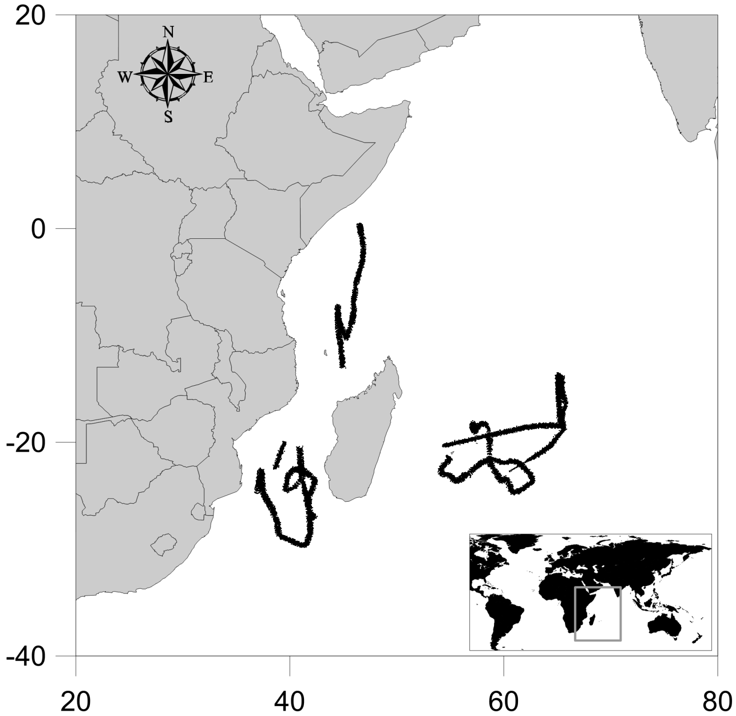

Figure 8 Horizontal movements of blue sharks *Prionace glauca* tagged with PATs (n = 7) in the western Indian Ocean.

Discussion

Strong differences were observed between the vertical distribution of small and large silky sharks. This difference between sizes could be an artefact of the behavioural response of juveniles to associate with drifting objects (tunas are known to swim in shallower depths when associated with floating objects than when being unassociated, e.g. Schaefer and Fuller 2010), where as larger individuals and adults occur far less frequently in such aggregations. Alternatively this difference may reflect physiological or dietary shifts, which occur later in the species ontogeny. Nevertheless, irrespective of the causes behind these differences, the results presented here highlight the vulnerability of these two size classes to both purse seine and longline gears. Results for adults are comparable with individuals tagged in the Pacific Ocean (Musyl et al. 2011), showing a preference for epipelagic waters (Musyl et al. 2011).

Similar to silky sharks, the depth range occupied by oceanic whitetip sharks overlaps directly with both purse seine and longline gears. Oceanic white tip sharks mainly occupy the first 150 m, which is slightly deeper than the data obtained for the same species in the Pacific Ocean (Musyl et al. 2011). The blue shark appears to spend far more of its time greater depths. Similar results have been obtained for this species in the Pacific Ocean (Musyl et al. 2011), however blue sharks in this study appear to occupy slightly deeper waters more regularly than those in the Pacific Ocean.

The horizontal movements observed for all three species clearly show extended movements. Such results should be combined with catch data (see Amandè et al. 2011) to examine if spatial measures could be efficient for the conservation of these species.

References

Clarke, S., M. K. McAllister, E. J. Milner-Gulland, G. P., Kirkwood, C. G. J. Michielsens, D. J. Agnew, E. K. Pikitch, H. Nakano, and M. S. Shivji (2006). Global estimates of shark catches using trade records from commercial markets. Ecol. Let. 9:1115–1126.

Musyl MK, Brill RW, Curran DS, Fragoso NM, McNaughton LM, Nielsen A, Kikkawa BS, Moyes CD (2011). Postrelease survival, vertical and horizontal movements, and thermal habitats of five species of pelagic sharks in the central Pacific Ocean. Fish Bull 109(4)341-368.

Schaefer KM, Fuller DW (2010). Vertical movements, behavior, and habitat of bigeye tuna (Thunnus obesus) in the equatorial eastern Pacific Ocean, ascertained from archival tag data. Mar Biol 157:2625-2642

Tremblay Y, Robinson PW, Costa DP (2009). A Parsimonious Approach to Modeling Animal Movement Data. PLoS ONE 4(3): e4711. doi:10.1371/ journal.pone.0004711