Double tagging juvenile silky sharks to improve our understanding of the behavioural ecology: preliminary results

John D. Filmalter[1,2], Laurent Dagorn[2] and Marc Soria[3]

[1]South African Institute for Aquatic Biodiversity (SAIAB), Private Bag 1015, Grahamstown 6140, South Africa
[2]Institut de Recherche pour le Développement (IRD), PO Box 570, Victoria, Mahé, Seychelles
[3]Institut de Recherche pour le Développement (IRD), Parc Technologique Universitaire, 2 rue Joseph Wetzell, PO Box 172, 97492 Sainte Clotilde cedex, La Réunion, France

Corresponding author: John Filmalter, email: jdfilmalter@gmail.com

Abstract

The behaviour of two juvenile silky sharks *Carcharhinus falciformis*, both while they were associated with drifting FADs and while not associated, was investigated through double tagging with acoustic transmitters and miniaturized PAT tags. Sharks were caught and tagged around drifting FADs in the Mozambique Channel. Drifting FADs were equipped with satellite-linked acoustic receivers, to monitor the fine scale behaviour of sharks while at FADs. Both sharks remained associated with the drifting FADs for several days (at least 7.8 and 10.0 d respectively). During their association both sharks undertook nocturnal excursions away from the FAD, during which deep dives were often observed. Vertical behaviour was found to change once the sharks were believed to have left the FAD, with the depth of the nocturnal dives increasing considerably.

Introduction

The behaviour of juvenile silky sharks *Carcharhinus falciformis*, both at and away from FADs, is being studied within the European project, MADE, to provide fundamental information required to investigate possible spatial and technical mitigation methods. One of the research protocols used in the project involves double tagging juvenile sharks with both acoustic transmitters and miniaturized pop-up archival tags. Here we report on the results of the first two sharks double tagged in this way within the framework of the project.

Materials and methods

During March 2010 two juvenile silky sharks were equipped with both acoustic transmitters (Vemco, V13P) and miniaturized pop-up archival tags (Wildlife Computers, MiniPAT). The sharks were caught using baited handlines around two drifting FADs in the northern Mozambique Channel. Sharks were lifted onboard using a knotless scoop net and placed ventral side up in a padded cradle, the head was covered with a damp cloth and the gills aerated using a hose pumping clean sea water. The acoustic tags were implanted into the peritoneal cavity of the sharks, using standard surgery techniques. The point of incision was closed with two independent sutures. The sharks were then flipped over and a small hole drilled through the base of their dorsal fin. A threaded nylon bolt was passed through this hole, over which a nylon eye was passed to which the tether of the miniPAT was secured. A large stainless steel washer was placed over the bolt on the opposite side of the fin. Finally two stainless steel lock nuts were tightened on either end of the bolt to secure the attachment system. The entire tagging operation lasted roughly five minutes after which the sharks were released directly at the FAD.

A satellite linked acoustic receiver (Vemco, VR4-Global) was attached to the FAD before the tagging operation commenced. The receiver relayed information on the sharks' presence at the FAD and their swimming depth at pre-defined intervals via the Iridium satellite system.

The miniPATs were activated upon entering the water and recorded the swimming depth of the shark as well as water temperature and light level to allow for geolocation. MiniPATs were programmed to automatically release from the sharks after 100 days at liberty. Once they had popped up they relayed time-series data on depth (sampled every five minutes) along with all other standard summarized information from PAT tags.

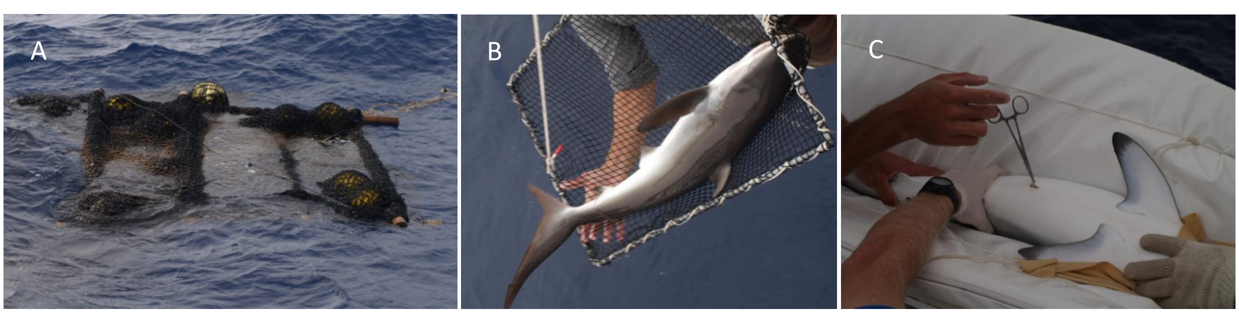

Figure 1: A) A drifting FAD, B) Lifting a juvenile *C. falciformis* aboard for tagging, C) Surgically implanting an acoustic tag into a juvenile *C. falciformis*.

Results

Silky shark #SIL1

Acoustic tag data:

The first shark tagged measured 71cm FL. It was detected briefly at the FAD (25 min) by the VR4-Global acoustic receiver, directly after being released and then left for an extended period (1.7 d). Once the shark returned to the FAD it remained closely associated for 8.7 d after which point the receiver stopped working, probably due to a fishing set, and the removal of the receiver.

During the time the shark was detected by the receiver, it undertook several short (2-6 h) excursions away from the FAD, all of which occurred during night hours. While associated with the FAD the shark remained within 60 m of the surface (average depth 12 m, SD 7 m). A clear rhythmic pattern was observed in the vertical behaviour while at the FAD. Typically the shark would be close to the surface at dawn and gradually move deeper as midday approached. After noon it would move gradually back up towards the surface until dusk, generally staying within the upper 20-30m during the day. After dusk it either left the FAD or remained close to the surface or undertook several rapid dives to depths between 30 and 60 meters.

PAT data:

The miniPAT remained on the shark for 19 days before releasing prematurely, likely a result of attachment failure. Once the tag popped up all summary data collected during the deployment period was successfully transmitted to the ARGOS system. This included a complete time series of depths recorded every five minutes. This time series data showed that the shark resumed 'normal' vertical behaviour shortly after release once tagging was completed. The depths recorded by both the acoustic receiver and the MiniPAT were found to correspond very well. As the miniPAT time series was continuous the vertical behaviour could be monitored during excursions away from the FAD. It was found that the shark undertook several deeper dives during these excursions reaching depths of up to 93 m. After the acoustic receiver stopped functioning, the shark showed a change in vertical behaviour, often spending prolonged periods (minutes-hours) at or very close to the surface, for the majority of the night, and undertaking a few rapid 'bounce' dives to depths of up to 160 m.

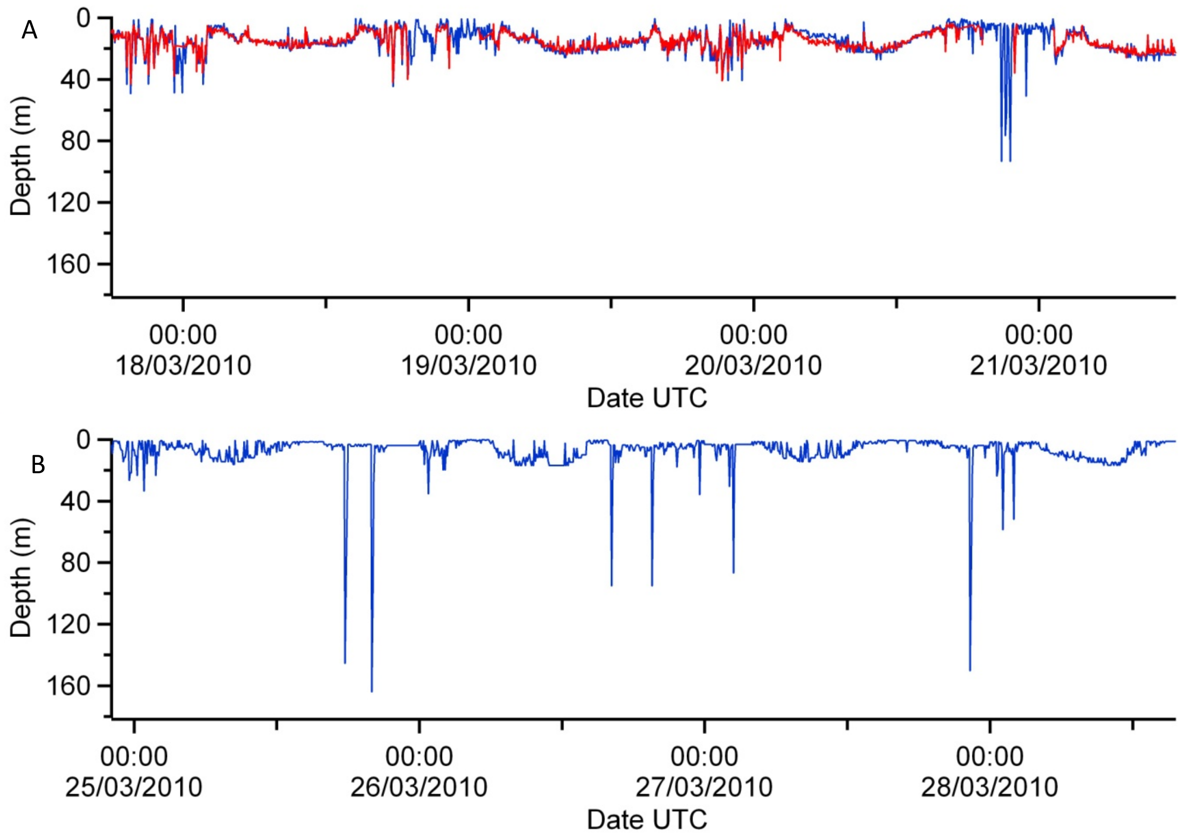

Figure 2: Samples of the verticals profiles of a 71 cm FL silky shark, *C. falciformis*, equipped with both a pressure sensitive acoustic transmitter and a miniaturized PAT. A) depicts data from both sources while the shark was associated with a drifting FAD equipped with an acoustic receiver (Red line = acoustic tag, blue line = PAT tag), B) depicts data from when the shark was believed to have left the FAD (or when the acoustic receiver stopped working).

During it's time at liberty it appears as if the shark never left the northern part of the Mozambique Channel, based on the rough light-based geolocation estimates obtained through Kalman filtering using SST data.

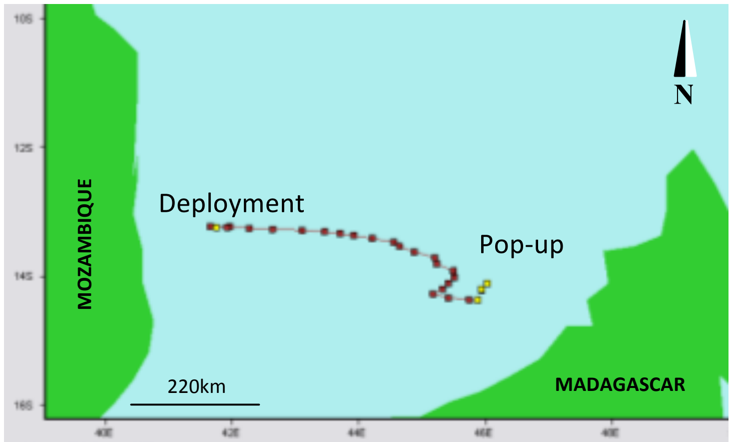

Figure 3 Most probable 19-day track of a 71 cm FL silky shark, *C. falciformis* tagged at a drifting FAD, with a PAT, based on light level geolocation methods derived using a Kalman filter approach with SST.

<u>Silky shark #SIL2</u>

Acoustic tag data:

The second shark tagged measured 90 cm FL. After being released once tagging was complete the shark was detected for 5 minutes by the acoustic receiver before it left the FAD for 0.5 d. Upon returning the shark remained closely associated with the FAD for 11.0 d after which point the receiver failed.

This second shark also undertook several short (1-7 hour) nocturnal excursions during its total period of association. While at the FAD the shark generally stayed within the upper 60m of the water column (average depth = 29 m, SD = 11 m) but some dives down to 100m were observed during both day and night time. A similar pattern to that of SIL1, in terms of vertical movements (shallower during the day, greater diving at night) was observed, however the magnitude of change in depth during the diel cycle was not as great as that observed in the smaller shark.

PAT data:

The miniPAT on the second shark remained attached to the animal for the full deployment period of 100 days. After releasing on time, 58% of the depth time series data was successfully received by the ARGOS satellite system. As the data are transmitted in messages containing three hours of depth data sampled at five minute intervals, and not all time series messages were successfully received, several gaps remained in the time series after the tag's battery had been exhausted. Despite these gaps a significant amount of data was collected on the vertical behaviour of this individual.

This second shark did not show such clear changes in vertical behaviour during nocturnal excursions from the FAD although a single deep dive was observed during one excursion where the shark descended rapidly to 140 m before returning to the FAD. After the acoustic receiver stopped functioning the sharks vertical behaviour was not observed to change significantly (Mean depth = 29 m, SD = 18 m) apart from the depth to which it dived at night. Several dives beyond 150 m were observed, with the deepest dive reaching 297 m.

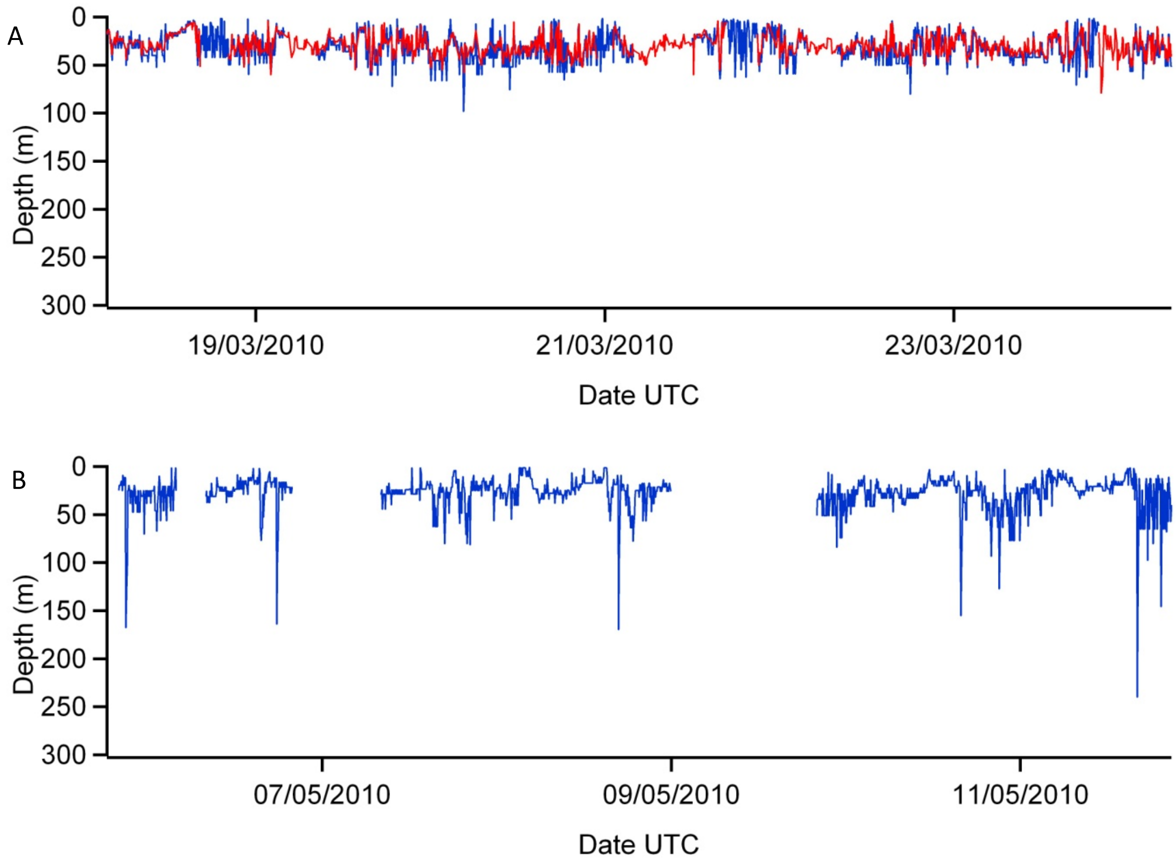

Figure 4: Samples of the vertical profiles of a 90 cm FL silky shark, *C. falciformis*, equipped with both a pressure sensitive acoustic transmitter and a miniaturized PAT. A) depicts data from both sources while the shark was associated with a drifting FAD equipped with an acoustic receiver (Red line = acoustic tag, blue line = PAT tag), B) depicts data from when the shark was believed to have left the FAD (or when the acoustic receiver stopped working).

Preliminary analysis of the light level data recorded by the miniPAT used to derive geolocation estimates suggest that the shark spent some time in the Mozambique channel before moving northwards and towards the African coast. When the tag released from the shark it was between the islands of Pemba and Zanzibar, off the coast of Tanzania, approximately 1050km NE of its tagging locating, in Mozambique channel.

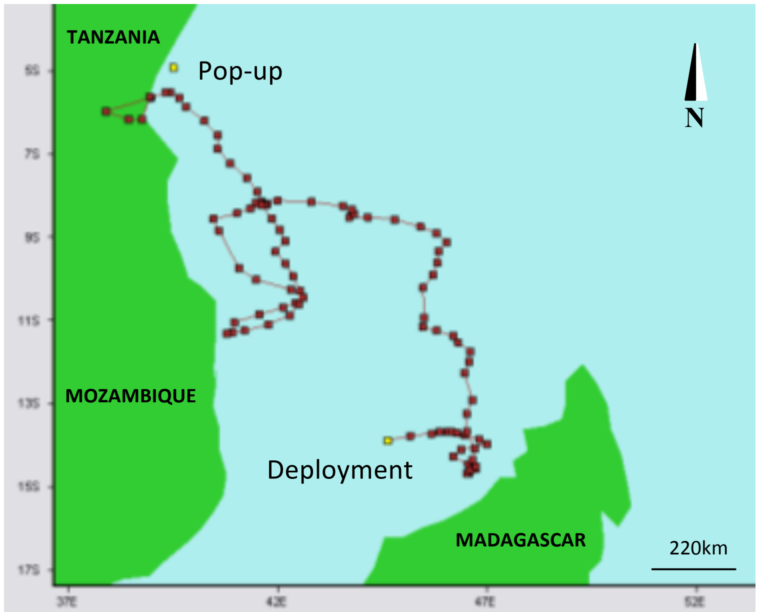

Figure 5: Most probable 100-day track of a 90 cm FL silky shark tagged at a drifting FAD based on light level geolocation methods derived using a Kalman filter approach with SST.

Discussion

Association of juvenile silky sharks with FADs

Both of the juvenile silky sharks presented here showed similar behaviour when associated with a drifting FAD. The initial departure after release is likely a response to the stress induced through the capture and tagging process, and has already been observed on previous silky sharks also equipped with acoustic transmitters around FADs (Filmalter et al., 2010). Both sharks were monitored at their respective FADs for similar periods of time, these residence periods are amongst the longest recorded for this species (Filmalter et al. 2010) as well as for other species associated with drifting FADs (Dagorn et al. 2007, Schaefer & Fuller 2010). The fact that both acoustic receivers failed before the sharks naturally departed the FAD makes interpretation of the results complicated. Information from the purse seine fleet suggests that the FAD at which the first silky shark was tagged, was fished on the date the receiver stopped recording. The fact that the tagged shark was not reported by the crew, but even more so, that the miniPAT released several days after that date, shows that the shark survived the set. Either the shark was not encircled (because it was on an excursion away from the FAD) or was fished but released by the crew. Similar observations have been recorded for other acoustically tagged silky sharks in the past (Filmalter et al. 2010).

Both sharks exhibited some excursions away from FADs. These were short and nocturnal, similar to what was observed on sharks previous tagged around FADs (Filmalter et al. 2010).

Vertical behaviour

Both independent data sets on vertical movement while the sharks were at the FAD correspond very well for both individuals. The vertical behaviour of each shark while associated was similar, with both animals remaining in the upper 50m of the water column for much of the time. The clear rhythmic pattern displayed by SIL1 was not as apparent for SIL2, which displayed greater vertical activity throughout the day. Both sharks did show deeper dives during their excursions away from the FAD at night, which could be interoperated as feeding forays, as has been done for tunas displaying similar behaviour around FADs (Holland et al. 1990, Dagorn et al. 2000).

Although we cannot definitively show that the sharks left their respective FADs after the receivers stopped working, both individuals showed a distinct change in the depth of their nocturnal forays after this point in time. Assuming these changes are in fact indicative of the sharks leaving the FAD such behaviour could be used in future to determine the amount of time that sharks spend associated with floating objects, as has been done for bigeye tuna (Schaefer and Fuller 2002, 2010). If the vertical behaviour of juvenile silky sharks appears to be different when individuals are associated to FADs or not, it would could assist considerably in the future study of this species with relations to FADs, as miniPAT (or any archival) tag data would be sufficient to estimate residence times of sharks at and away from FADs, with no need to equip FADs with acoustic receivers. As our preliminary results tend to demonstrate such vertical differences, more data are clearly required to validate these trends.

Horizontal behaviour of silky sharks

Both of these juvenile silky sharks appear to have remained relatively far off shore while they were tagged, which is contrary to the previously documented behaviour of juveniles of this species (Bonfil, 2008). It is difficult to say whether the second individual was associated with a FAD when it moved northwards out of the channel. However, FADs within the Mozambique Channel typically remain within gyres that move gradually southwards. The estimated distance that SIL2 traveled is 3700km which translates to an estimated average speed over ground of approximately 0.5 body lengths per second, roughly 1 knot. Similar values were estimated for the first shark, which also showed an average speed over ground of roughly 1 knot.

Conclusions

These are the smallest sharks ever double tagged with both acoustic transmitters and pop-up tags. The data from these two sharks alone have already provided promising results. It is noteworthy that both the satellite-linked acoustic receivers (Vemco, VR4-Global) and miniaturized MiniPAT (Wildlife Computers) were both new products that are still undergoing improvements. The failure of the acoustic receivers (likely due to fishing for one, but not explained for the second) prevented us from knowing the point in time at which each individual left the monitored FAD, with absolute certainty. More double tagging is planned in the coming year, although the presence of Somali pirates in the Indian Ocean affects the organization of off-shore tagging cruises considerably.

References

Bonfil, R. (2008) The Biology and Ecology of the Silky Shark, *Carcharhinus falciformis*, in: Camhi, M., Pikitch, E.K., Babcock, E.A., (Eds.), Sharks of the Open Ocean: Biology, Fisheries and Conservation. Blackwell Science. pp. 114–127.

Dagorn L., Pincock D., Girard C., Holland K., Taquet M., Sancho G., Itano D. & Aumeeruddy R. (2007) Satellite-linked acoustic receivers to observe behavior of fish in remote areas. Aquatic Living Resources, 20, 307-312

Dagorn, L., Josse, E., Bach, P. (2000) Individual differences in horizontal movements of yellowfin tuna (*Thunnus albacares*) in nearshore areas in French Polynesia, determined using ultrasonic telemetry. Aquat Living Resour 13:193–202

Filmalter, J.D., Dagorn, L, Cowley, P. and Taquet, M. (2010) First descriptions of the behaviour of silky sharks (*Carcharhinus falciformis*) around drifting FADs, in the Indian Ocean, using acoustic telemetry. IOTC-2010-WPEB-12.

Holland, K.N., Brill, R.W., Chang, R.K. (1990) Horizontal and vertical movements of yellowfin and bigeye tuna associated with fish aggregating devices. Fish Bull 88:493–507

Schaefer, K.M., Fuller, D.W. (2002) Movements, behavior, and habitat selection of bigeye tuna (*Thunnus obesus*) in the eastern equatorial pacific, ascertained through archival tags. Fish Bull 100:765–788

Schaefer K.M., Fuller, D.(2010) Vertical movements, behavior, and habitat of bigeye tuna (*Thunnus obesus*) in the equatorial eastern Pacific Ocean, ascertained from archival tag data. Mar Biol DOI 10.1007/s00227-010-1524-3.