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Study on Migration Patterns of Yellowfin Tuna (*Thunnus albacares*) from Pop-up Satellite Archival Tags (PSAT) along the Indian EEZ

Kanhu Charan Sahu[1], Ansuman Das[2], M. K. Farejiya[3] and Kiran S. Mali[4]

[1,2,3,4]Fishery Survey of India (Hqs), New Fishing Jetty, Sassoon Dock, Colaba, Mumbai- 400 005.
E-mail: [1]charanksahu@gmail.com , [2]1006ansu@gmail.com, [3]farejiya@rediffmail.com , [4]kiransmali786@gmail.com

Abstract—*The Yellowfin tunas (Thunnus albacares) are highly migratory fishes occurring worldwide. The travel speed of Yellowfin Tuna made a challenge to study its migratory pattern. They can travel up to the speed of 75 km/hr. Tunas can cover around 4,000 km/ year. In the present study, healthy Yellowfin Tunas having minimum Fork Length (FL) of 98 cm and weight of 30 kg were taken for PSAT tagging purpose to understand their behaviour, habitat, selective ambient temperature and migration pattern along the Indian EEZ. The tags were tagged from onboard the Tuna longliner survey vessels of Fishery Survey of India viz. Matsya Drushti and Matsya Vrushti. A total of 13 nos. of PSATs were tagged to Yellowfin Tuna during January' 2012 to February' 2013. The Area of deployment of PSAT was Latitude 9°N-15°E and Longitude 70°E-81°E and the area of Pop-up of PSAT was Latitude 12°N-15°E and Longitude 71°E-82°E was recorded. The minimum and maximum pop-up time recorded by the Argos Satellite System was 08 days and 90 days respectively. Out of 13 nos. of tags, the data retrieved was only 7 nos. of tag. The PSAT tags were well equipped with the sensors like Light Sensor: GPS for study Position, Pressure Sensor: for Depth measurement and Temperature sensor. The tags were tagged to YFT and the data was collected from the Argos Satellite System as per the days at liberty of the PSAT. The results derived from the PSAT tag revealed that, the thermocline depth was traced between 50m-125m and the ambient temperature preferred by the species was between 25°-31°C. From the PSAT data it was observed that, the YFT covered the distance of 443.6 km. This study will certainly contribute in understanding the behaviour, habitat, selective ambient temperature and migration pattern of different migratory fish by using the electronic device, Pop-up Satellite Archival Tags (PSATs).*

Keyword*: PSAT, YFT, EEZ, Migration, Satellite, Sensor.*

1. INTRODUCTION

Human desire to understand the animal behaviour has come a long way. Initially researchers have tried to understand the physical behaviour, then it started to shift towards migratory behaviour. It was understood and found that large herbivore land animals used to migrate for food and water on seasonal changes affecting the availability of food. Subsequently it was also learned that animals including birds and fishes migrate for reproduction.

Particularly for aquatic animals such as fishes, understanding the behaviour and ecology of large pelagic fishes in their natural environment were limited. The constraint is their habitat (Oceanic province). With these constraints it could only possible to access a small portion of species behaviour. It's inevitable to devise novel technology to understand the behaviour of large pelagics such as Tuna and its allied species.

During early 20th Century Mark-recapture techniques employing external tags have been used extensively but this approach only provides deployment and retrieval locations with no data on fish's behaviour. In 1960, acoustic technologies were used for single individual tag for short period of time (up to 2 weeks). During 1980 longer duration tags were developed using passive acoustic techniques.

Satellite-linked archival tags are the latest development in telemetry research. Since the inception these tags have been increasingly deployed to understand horizontal and vertical behaviour movements, habitats, mortality, aggregation and feeding behaviour.

The Yellowfin tunas (*Thunnus albacares*) are highly migratory large pelagic fishes occurring in major oceans. The speed traveled by Yellowfin Tuna made a challenge to study its movements which can Travel 75 km/hr. It can cover around 4,000 km every year [1]. It is one of the least exploited resources of the Indian seas accounting for hardly 2% of the total marine fish catch of India, despite the ever increasing demand for tuna resources in the global market fetching high economic returns and foreign exchange [2-4].

Movements and behaviour are inherently coupled to species biology and ecology (e.g. trophic and environmental niches) and are directed by the physiological maintenance of homeostasis in the face of environmental variations [5]. Before understanding the PSAT tagging and its applications to study migration of Tunas, it is necessary to have brief overview of biological aspects of the species.

Tunas are obligate ram ventilator [6], they must swim constantly to move oxygenated water over their gills, which have structural modifications that enable respiratory and swimming efficiency benefits. In addition to that Tuna maintain the elevated eye and brain temperatures that facilitate cold water foraging without sacrificing visual and cognitive function [7, 8]. They pre-dominantly feed upon small pelagic fishes and cephalopods [9].

One Mechanism that allows monitoring of horizontal and vertical movements of marine species is electronic tagging [10,11]. Previous electronic tagging studies have indicated that Yellowfin Tuna prefer to spend most of their time above the thermocline in the uniform temperature surface layer [12-15]. PSATs have been used to track movements of large pelagic fishes including tuna and shark and to study their habitat preferences [16-19].The PSATs can be deployed for comparatively long periods (months) extending well beyond the time it typically takes the fish to recover and resume normal behavior after capture [20]. The PSATs also have the advantage of being less dependent on fisheries than other tagging technologies, which require recapture [21]. PSATs need not be physically retrieved for data recovery. Instead the PSAT detaches from the fish on a pre-programmed data and then transfers stored data via the Argos Satellite System [12].

2. MATERIAL AND METHODS

The study area for the PSAT tagging was east coast and west coast of the Indian EEZ. PSAT tagging is an advanced tagging technique to understand migration pattern, growth and breeding of the migratory fishes such as tuna. A total 13 nos of Yellow fin tunas (*Thunnus albacares*) were tagged with PSAT tags on-board the Fishery Survey of India Tuna long liner survey vessel ***FB Matsya Vrushti*** in the Arabian sea of West Coast and ***FB Matsya Drushti*** in the Bay of Bengal of East Coast during 2011-12 and 2012-13. The healthy Yellowfin Tunas (YFT) having minimum Fork Length (FL) 98 cm were selected for tagging and taken onboard the vessels with the help of lifting device fitted with cradle. After taking the tuna onboard, it was covered with a wet cloth to its eyes. The PSAT was injected with an applicator specially designed for shooting near the second dorsal fin and it was then gently released to the sea. The released GPS position, length, weight was noted for further study. PSAT tag consists of sensor, antenna, a small buoy (Bulb like structure) and an umbrella tether, which collect data such as position of the fish, temperature, depth in a regular interval and would transmit recorded data to the Argos Satellite System whenever the tagged fish reaches the sea surface or the PSAT detach from the fish. On completion of the pop-up time (i.e. 4 to 12 months) the tag will be automatically detached from the fish body and due to the buoyancy of bulb attached with the tag, it will come to the sea surface spontaneously and keep the antenna upright above sea surface exposed in the atmosphere to enable the transmission with zero error. The details of the PSAT tagging are furnished in the figures (See Figures 1-4).

The data were collected from the Microwave Telemetry Inc. (MTI), USA, the supplier of the PSAT through INCOIS.

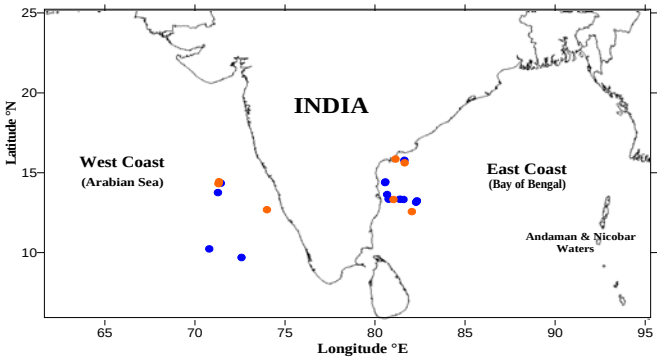

Fig. 1: Tagging and Pop up location of PSAT along the Indian EEZ

The tags are having the sensors like Light Sensor: GPS for study Position, Pressure Sensor: for Depth measurement and Temperature sensor. The tags were deployed to the YFT and the data was collected from the Argos satellite as per the days at liberty of the PSAT.

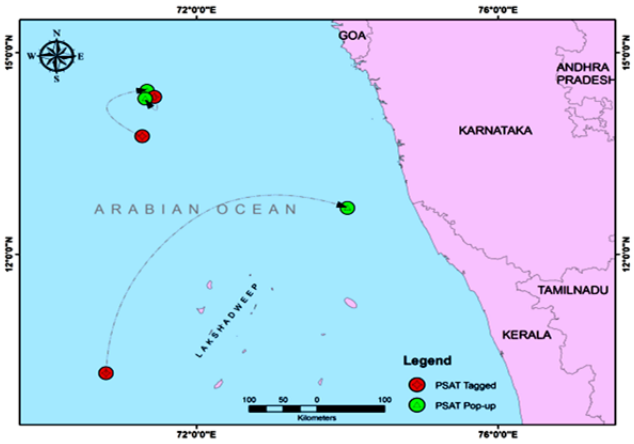

Fig. 2: Tagging and Pop up location of PSAT in the West Coast

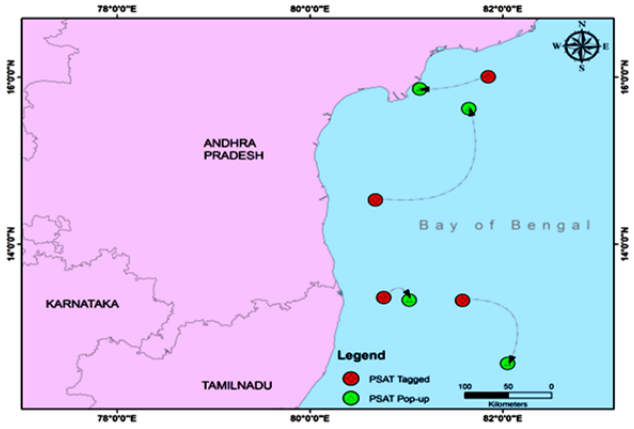

Fig. 3: Tagging and Pop up location of PSAT in the East Coast

Fig. 4: A view of Tagging of Yellow fin tuna on-board the vessel

3. RESULTS

During the year 2012-13, total 13 numbers of Yellowfin tuna (*Thunnus albacares*) were tagged with PSAT. The YFTs tagged were with fork length (cm) ranges from 98-164 with mean FL=132.38 cm. Body weight of the fishes were varies from 15-60 kg with mean body weight (MBW) = 34 kg. Out of 13 tags, seven (54%) popped up, one (8%) fish caught and five (38%) non-report. The tags implanted were programmed for various days at liberty (DAL) ranging from 120 days to 365 days. Two were 120 DAL, three were 180 DAL, four were 240 DAL, four were 365 DAL. Among these three 365 DAL tags and Two 240 DAL were non-report. Mean Dal was 246.2, while linear displacement (movement) between the release point of YFT and pop-up locations ranged from 13.46 km to 443.59 km. Mean distance covered (migration) was 128.21 km. Maximum depth covered by YFT was 227m and minimum depth covered was 50m with average depth 138.5. Temperature variation with respect to depth was observed. Maximum was 31.65°C and minimum 23°C. Mean temperature variation was 28°C. This result clearly shows thermocline depth zone. Corresponding depth and temperature variation is given in the figures (See figures 5 & 6)

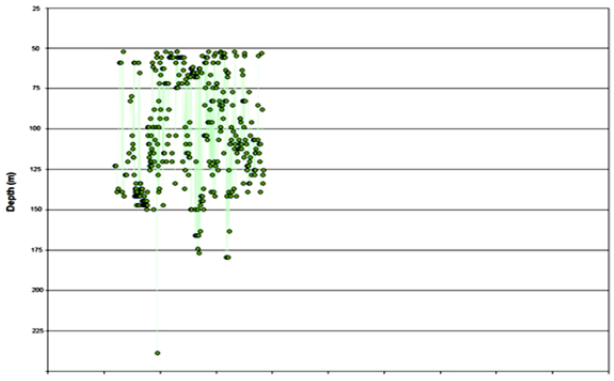

Fig. 5: Ambient Depth (m) prefered by YFT

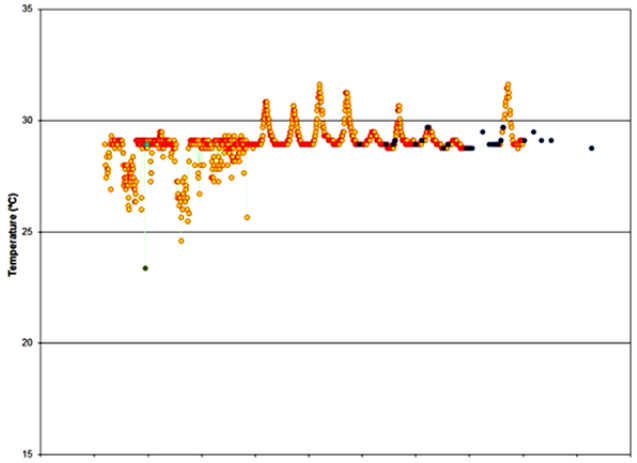

Fig. 6: Ambient Temperature (°C) prefered by YFT

4. DISCUSSION AND CONCLUSION

The behavior of pelagic fish largely influenced by environmental conditions, life history phase and species specific preferences. Analysis of archival data derived from PSAT suggests that the trauma and stress associated with capture and handling may influence the behavior of some tagged YFT. For example, sub-lethal injuries may occur from extensive jumping while the tag is implanted on the live fish, external abrasions after the fish is released into the natural habitat (Sea), sometimes poor PSAT anchor placement that impedes function or results in excessive bleeding or infection.

Though the DAL are of quite larger duration in all the tags but the successful pop-up tag data shows none of them continued beyond 50% of their DAL. In majority of cases it was observed that the tags were popped-up within 13.52% of its programmed DAL. This is a remarkable finding which gives further scope to study the cause behind it. There could be many factors such as error in programming, accidental encounter of the fish it's natural habitat, collision during movement in small size school, ulcer growth at the point of implant on the dorsal side of the fish, biofouling etc.

Out of 8 successful PSAT tags from the series of 13, 5 were from Bay of Bengal (east coast of Indian EEZ) and 3 were from Arabian Sea (west coast of Indian EEZ). The average distance covered by the tagged YFT in Bay of Bengal is 91.21 km and 177.53 km in Arabian Sea. The variation in migration pattern in both the sea might be due to multiple factor viz., variation I sea water temperature, food, breeding etc. While analyzing the above factors it reveals that this study opens new scope for further more studies on many aspects of PSAT tag and its utilization in migration and behavioural studies of Tunas and allied species.

5. ACKNOWLEDGEMENTS

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Note: Reference to commercial products, hardware, software etc. does not imply endorsement by the authors or their respective associated institutes.

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