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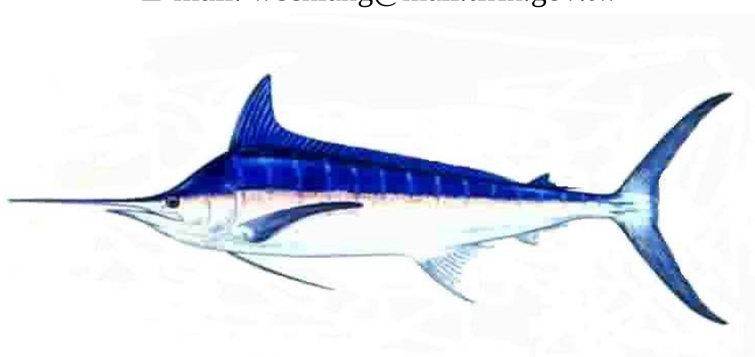
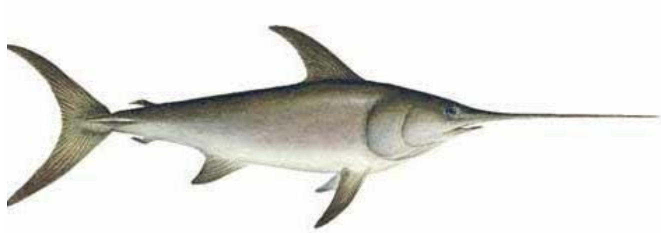
Multinational Pacific Billfish Tagging Program - Status of Electronic Tagging in Eastern Taiwan

Chiang, W.C.[1*], C.L. Sun[2], G. DiNardo[3], W.C. Su[4], M.K. Musyl[5], H.M. Hung[1], S.C. Chen[1], S.Z. Yeh[2], W.Y. Chen[1], and D.C. Liu[4]

[1]Eastern Marine Biology Research Center of Fisheries Research Institute, Taiwan
[2]Institute of Oceanography, National Taiwan University, Taiwan
[3] NMFS, Pacific Islands Fisheries Science Center, USA
[4]Fisheries Research Institute, Taiwan
[5]University of Hawaii, Joint Institute for Marine and Atmospheric Research Kewalo Research Facility/ NOAA Fisheries, USA

E-mail: wcchiang@mail.tfrin.gov.tw





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[4]Fisheries Research Institute, Taiwan

[5]University of Hawaii, Joint Institute for Marine and Atmospheric Research Kewalo Research Facility/ NOAA Fisheries, USA

E-mail: wcchiang@mail.tfrin.gov.tw

Summary

This program utilizes the local eastern Taiwan harpoon fishing fleet to deploy pop-up satellite archival tags (PSATs) on billfish to determine habitat and ecosystem characterizations, as well as data to advance the development of a multinational Pacific Ocean billfish tagging program. To date, a total of 27 PSATs have been harpooned on 2 striped marlin, 7 black marlin and 18 blue marlin in eastern Taiwan coastal waters. This program continues to deploy PSATs on marlin using harpoon vessels or longline vessels which will increase the data resources and help characterize marlin movements and habitat preferences in the northwest Pacific Ocean. The results from this program will help to parameterize a simulation model that can be used to develop a Pacific wide billfish tagging program.

Introduction

Istiophorid billfishes are highly migratory species that inhabit the tropical and subtropical, epipelagic waters of the world's oceans (Nakamura 1985). Billfish are often referred to as ‘rare event species’ based on the conspicuous lack of information on their movements and distribution patterns, as well as their basic life histories (Prince and Brown 1991). Commercial and recreational fishing activities have the potential to adversely affect the populations of large pelagic species (billfish, shark and tuna), whether they are target, incidental or bycatch species. Since commercial and recreational fishing generally remove the largest animals, substantial reductions in parental biomass (e.g. female blue marlin, *Makaira nigricans*, can release up to

13.5 x 10^6 eggs, Sun et al. 2009) of these long-lived, late-maturing predators over several decades could cause heritable changes in life-history traits such as body size, growth, and age-at-maturity (Law 2000, Conover 2007, Genner et al. 2009).

Tagging programs are often implemented to provide information on movement and data to estimate life history parameters to advance stock assessments. Given both the long-term commitment and high costs associated with the development, implementation and maintenance of tagging programs, it is imperative that such programs provide as much benefit as possible. The reasons for the observed deficiencies are usually associated with misspecifications at the design phase, and unrealistic assumptions associated with key requirements of tagging programs.

Commercial offshore fisheries in Taiwan harvest tuna and billfish that aggregate near Lanyu and Ludao Islands to forage and spawn. Coastal fisheries for longline fishing, harpooning, set nets and gillnets take advantage of the plentiful seasonal conditions to catch ~80% of all billfish captures in Taiwan. Pop-up satellite archival tags (PSATs) are used to elucidate movement patterns and habitat preferences of pelagic species and record information through numerous sensors such as pressure (depth), ambient sea temperature and light levels. Transmitter tags via radio signal or acoustics can easily and efficiently track fishes recording detailed data on short-term horizontal and vertical movements which can be correlated to real-time oceanographic factors. The billfish tagging project at the Eastern Marine Biology Research Center (EMBRC) of Fisheries Research Institute (FRI), in collaboration with National Taiwan University (NTU), has steadily developed and expanded to encompass a broad research program to provide essential information for the management and conservation of pelagic resources. The NOAA Pacific Island Fishery Science Center (PIFSC) entered into collaborations with FRI and NTU and the focus of the tagging program shifted to marlin. The program utilizes the local Taiwan harpoon fishing fleet to deploy pop up satellite archival tags (PSATs) on blue marlin, black marlin and striped marlin to determine habitat and ecosystem characterizations, as well as data to advance the development of a multinational Pacific Ocean billfish tagging program. The preliminary results of tagging program are presented.

Materials and methods

We deployed two model Mk10 PSATs from Wildlife Computers (WC, Redmond, WA, USA). Depth and temperature data were binned into the following intervals: 0–10 m, 10–25 m, 25–50 m, 50–75 m, 75–100 m, 100–150 m, 150–200 m, 200–250 m, 250–300 m, 300–400 m, 400–500 m, 500–600 m and >600 m; and 0–6 °C, 6–8 °C, 8–10 °C, 10–12 °C, 12–14 °C, 14–16 °C, 16–18 °C, 18–20 °C, 20–22 °C, 22–24 °C, 24–26 °C, 26–28 °C, 28–30 °C and >30 °C, respectively. Depth and temperature data were recorded every 60 s and the data summarized into successive four hour intervals commencing at 00:00 h (GMT). The programmed pop-up period was set to 180 days after deployment.

We also deployed models X-tags and PTT-100 PSATs from Microwave Telemetry (MT, Columbia, MD, USA). These unit recorded ambient water temperature and depth data every hour. The programmed pop-up period was set to 240 and 360 days after deployment. Sensors onboard can measure ambient water temperature from -4°C to 60°C (±0.176°C) and depth from 0 to 1296 m (±1.27 m). PSATs were rigged in a manner similar to that describe by Musyl and Mcnaughton (2007). Tether is made of monofilament line put together by stainless steel crimps matching the diameter of the line. Stainless steel ball bearing is used to reduce torque and precession of tag head and tag and the tag head is made of surgical grade nylon and plastic steel crimps (Musyl et al. 2011a, b).

PSAT is programmable to detect tag shedding or death of the animal, through the pressure (depth) sensor. When depth remains stable over a defined period, the PSAT initiates release and data transmission. In this study, PSAT was programmed to release if depth remained constant (+2 m) for 48 h. Release locations were estimated from global positioning systems on board the tagging vessels, while pop-up locations were estimated directly from ARGOS transmissions received from each tag. The PSATs also stored minimum and maximum depths and temperatures so that temperature-depth profiles could be generated. Raw light-level data were initially processed using the global positioning software WC-AMP (Wildlife Computers, Redmond, WA, USA) to estimate daily geolocations. We subsequently applied a sea surface temperature (SST) corrected (unscented) Kalman filter (Lam et al., 2008) to calculate most probable tracks (MPTs). The linear displacements from tagging to pop-up locations were determined using the Great Circle Distance and release locations were determined by GPS coordinates (Global Positioning System) at the set net complex. Pop-up locations were estimated by Doppler shift from the ARGOS transmissions of each PSAT. Only messages with location class of 1 or higher [< 1000 m RMS (root mean square error)], 2 [< 350 m] and 3 [< 150 m] were used to determine pop-up locations. Performance and reliability of PSATs in research are discussed in Musyl et al. (2011 b).

Given the limited temporal and spatial coverage of tags in the study, we categorized data into daytime and nighttime periods by calculating times of local dawn and dusk from http://aa.usno.navy.mil/. To further explore daytime and nighttime differences in the time series data collected from the MT tag, we firstly used one-sample Kolmogorov–Smirnov tests to compare distributions of ambient temperature (day, night, combined) and depth (day, night, combined) data to that of a normal distribution. Because all six tests indicated that data distributions were not normally distributed ($P < 0.01$), we used non-parametric two-sample Kolmogorov–Smirnov tests to compare daytime and nighttime temperature and depth distributions, and Mann–Whitney W-tests to compare differences in medians between daytime and nighttime data for depth and temperature (Zar, 1996). The time-at-depth and time-at-temperature data were aggregated into bins and were subsequently expressed as a fraction of the total time of observation for each fish. The $P < 0.05$ level was taken to indicate statistical significance.

The harpoon method involves the use of stainless steel leader material to secure the body of the tag to a flattened stainless steel harpoon tip. The stainless steel tip fits loosely into a notch at the end of the applicator pole (harpoon) and the tag body is loosely fastened to the harpoon pole (weight: 15 kg; length: 5 m) with rubber band. The tag is attached to the fish by impaling the tip into the dorsal musculature with the thrust of the harpoon. The harpoon tip lodges in the muscle or beneath the skin, allowing the harpoon pole to be withdrawn and the tag to trail alongside the body. This method has also been successfully used with free-swimming swordfish that have been harpooned from above as they swim at the surface (Carey and Robison, 1981).

Preliminary results

To date, a total of 27 PSATs have been harpooned on 2 striped marlin, 7 black marlin and 18 blue marlin using the two harpoon vessels (Long-Yu-Fa & Chi-Fu) in eastern Taiwan coastal waters. The captains have been harpooning for over 30 years. After harpooning a PSAT at the base of the dorsal fin, the black marlin jumped twice on the sea surface then swam away, which is a commonly observed behaviour. The marlin did not appear to be injured from harpooning procedure.

Eleven PSATs released prematurely after periods ranging about 21-155 d, one was pop-up on program for 240 d (Table 1). The tags' data have successfully transmitted from the Argos.

Future works

1. Continue with deployments of PSATs on marlin using harpoon vessels or longline vessels to

increase the data resources and characterize marlin movements and habitat preferences in northwest Pacific Ocean. If possible using data from this project (and others) data link ongoing PSAT tagging projects in the Central Pacific.

2. Improve fisheries population dynamics models for marlin by incorporating information on depth distribution, oceanographic conditions, and specific gear vulnerability.
3. Provide data to parameterize a simulation model that can be use to develop a Pacific wide billfish tagging program.

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Table 1. Details for set up, release, pop-up from 27 PSATs deployed on striped marlin, black marlin and blue marlin PTT: platform transmitter terminal.

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