

## **JIMAR ANNUAL REPORT FOR FY 2008**

P.I./SPONSOR NAME: Dr John R. Sibert (for Drs. Musyl, Larsen, Malte & Brill)/Dr. Tom Schroeder

NOAA OFFICE (Of the primary technical contract): PIFSC

PROJECT PROPOSAL TITLE: Modeling the Eco-physiology of Pelagic Fishes and Sharks with Archival and Pop-up Satellite Archival Tags (PSATs)

FUNDING AGENCY: NOAA

NOAA GOAL (Check those that apply):

- ☒ To protect, restore, and manage the use of coastal and ocean resources through ecosystem-based management
- ☐ To understand climate variability and change to enhance society's ability to plan and respond
- ☒ To serve society's needs for weather and water information
- ☐ To support the nation's commerce with information for safe, efficient, and environmentally sound transportation

PURPOSE OF THE PROJECT (One paragraph):

We propose to use available data from archival and PSAT tags to develop IBMs (individual based models) to describe the eco-physiology of different species of large pelagic fishes and sharks. This project will complement data already collected on a number of pelagic species and will be linked to existing PFRP projects by Musyl, Brill, and Moyes. Thus the study will be a collaboration between the University of Hawaii/JIMAR/PFRP, VIMS/ National Marine Fisheries Service, and the Dept. of Zoophysiology, University of Aarhus, Denmark. Our ultimate goal is to develop model(s), which will be applicable to many different pelagic fish and shark species. Using these models we can evaluate the possible importance of specific oceanographic parameters in an unbiased fashion, which will allow for intra- and inter-species comparison. A second purpose of this study is to explore failure (or conversely success) scenarios in pop-up satellite archival tags (PSATs) attached to pelagic fish, sharks and turtles. Specifically, this aspect of the study is designed to look for explanatory variables in the context of PSAT retention rates, percentage retrieved satellite data (i.e. depth, temperature, geolocations), and tag failure. By examining several factors and information about PSATs attached to vastly different pelagic species, it is anticipated that certain patterns/commonalities may emerge to help improve our understanding of attachment methodologies, selection of target species and experimental design. Lastly, information derived from this study will

allow an unprecedented and critical appraisal of the overall efficacy of the technology.

**PROGRESS DURING FY 2008** (One-two paragraphs, including a comparison of the actual accomplishments to the objectives established for the period, and the reasons for the slippage if established objectives were not met):

At present, the PI is adding final information to the PSAT Performance and Literature Meta-analysis databases and completing the manuscript detailing this work (slated for submission July 2008). The PSAT database contains detailed information from 731 tags across 19 pelagic taxa (including 3 marine turtle species). It is anticipated that additional information will be added later when these data are publicly posted on the PFRP website (anticipated Fall 2008). Preliminary results indicate PSATs have an overall reporting rate of ca. 79% (577 tags reporting) but PSATs attached to certain deep-diving species (e.g. swordfish, bigeye thresher shark) have lower than expected reporting rates ( $\approx 30\%$ ). The authors believe pressure may play an important role in non-reporting tags. It is important to emphasize that non-reporting tags (21%) are not synonymous with mortality. The PI has organized failure and survival analysis of the database using Weibull, log-normal, and Kaplan-Mier procedures with specialized engineering software and other procedures in the R and SAS statistical packages. Another major analysis was added to the PSAT performance and reliability research which will considerably strengthen the overall analysis and conclusions. The PI has completed a meta-analysis examining reporting rates of 1433 PSATs provided in the peer-reviewed literature for 23 marine species from 53 papers that is included in the manuscript. According to the literature study, 1089 of 1433 tags reported (76%) which is similar to our results. Twelve species are common to both the PSAT and meta-data databases which will allow for comparative studies. Tagheads developed by the project are providing long term retention in pelagic fishes (e.g. swordfish, sailfish and marlin; up to 240 days).

The development of an oceanographic database (and associated tools) to examine/correlate movements patterns of PSAT tagged animals with various oceanographic parameters - on temporal and spatial scales (i.e. both horizontal and vertical vectors) is operational and PSAT information are now linked to this source ("IDENTIFICATION OF LARGE PELAGIC MARINE FISH HABITATS AND HABITAT UTILIZATION USING 'POP-UP' SATELLITE ARCHIVAL TAG AND OCEANIC SATELLITE REMOTE SENSING TECHNOLOGIES AND 'SODA' SIMPLE OCEAN DATA SIMULATION MODEL ANALYSES" BY R. Michael Laurs, David Foley, and Michael Musyl). Dr. David Sims (Marine Biological Association of the UK, School of Biological Sciences, Univ. Plymouth) and Dr. Diego Bernal (Univ. Massachusetts) are working with Musyl and colleagues to develop IBMs using PSAT data. Dr. Malte, Univ. Aarhus, plans to continue on the project (see Boyne et al. manuscript). Due to major knee surgery for PI Musyl in FY2007, the project was delayed.

**PLANS FOR THE NEXT FISCAL YEAR** (One paragraph):

Complete baseline research papers (outlined below) on horizontal and vertical movements of sharks, tunas, and billfish and performance of PSATs. Publicly post the PSAT Performance Database on the PFRP website (after paper detailing this work is submitted). Trials using sandbar sharks at VIMS are completed to map the EMF produced by PSAT and other electronic tags to document sharks' ability to perceive this EMF. It is anticipated that results from this study will provide insight into why some PSAT tags fail to report. Continue to explore and develop new analytical methods to use on PSAT data, particularly oceanographic information comparing vertical depth variability.

Tentative PSAT papers currently coordinated by Musyl and slated to be drafted in 2007/08:

- 1). Laurs, R.M., **M. Musyl** et al. Identification of large pelagic shark habitats in the central North Pacific using PSATs, satellite remote sensing, and SODA assimilation ocean models. Paper on oceanic white-tip, silky shark, blue shark and shortfin mako shark.
- 2). **M. K. Musyl**, R.W. Brill, R. M. Laurs, D. S. Foley, K. A. Bigelow and L. M. McNaughton. Post-release survivability and movements of blue shark (*Prionace glauca*), oceanic white-tip (*Carcharhinus longimanus*) and silky shark (*Carcharhinus falciformes*) released from longline fishing gear in the Central Pacific Ocean as Identified by Pop-up Satellite Archival Tags (PSATs).
- 3). Collaboration with Dave Sims examining PSAT data on white-tips, mako and silks using advanced modeling routines such as Levy-flight.
- 4). Long Term Survivability of Pacific Blue Marlin (*Makaira mazara*) released from sportsfishing boats in Hawaii Determined from Pop-up Satellite Archival Tags (PSATs) by Musyl, Moyes, Brill, West, Bright, McNaughton
- 5). Movements and migration corridors of Pacific Blue Marlin (*Makaira mazara*) in relation to oceanographic conditions Determined from Pop-up Satellite Archival Tags (PSATs) by Bigelow, Musyl, Brill, Laurs, Foley & McNaughton

LIST OF PAPERS PUBLISHED IN REFERRED JOURNALS DURING FY 2008, in the following format: (Author or authors with last name and initials, publication year: Article title. *Journal name*, volume, page range.) For example: Charney, J.G., and A. Eliassen, 1964: On the growth of the hurricane depression. *J. Atmos. Sci.*, 21, 68-75.

- 1). Malte, H., Larsen, C., **Musyl, M.**, Brill, R. (2007). Differential heating and cooling rates in bigeye tuna (*Thunnus obesus*, Lowe): a model of non-steady-state heat exchange, *Journal of Experimental Biology* 210, 2618-2626

- 2). Sims, D.W., E. J. Southall, N. E. Humphries, G. C. Hays, C. J. A. Bradshaw, J. Pitchford, A. James, M. Z. Ahmed, A. S. Brierley, M. A. Hindell, D. Morritt, **M. K. Musyl**, D. Righton, E. L. C. Shepard, V. J. Wearmouth, R. P. Wilson, M. J. Witt and J. D. Metcalfe. 2008. Scaling laws of marine predator search behaviour. *Nature* 451:1098-1103.
- 3). D.Bernal, C. Sepulveda, **M. Musyl**, and R. Brill. 2008. "The Eco-Physiology of Swimming and Movement Patterns of Tunas, Billfishes and Large Pelagic Sharks" in Fish locomotion- an Etho-Ecological Approach (P. Domenici and BG Kapoor, eds.)

#### Submitted/finished manuscripts

- 1). Jess Boye, H. Malte, **M. Musyl** and R. Brill. Transectional heat transfer in thermoregulating bigeye tuna (*Thunnus obesus*) - a two-dimensional heat flux model. *Journal Experimental Biology*.
- 2). A.Nielsen, J.R. Sibert, **M.K. Musyl**, S. Kohin. State space model for light based tracking of marine animals: validation on swimming and diving creatures. *Proceedings of San Sebastian Electronic Tagging Symposium (Fisheries Reviews)*.
- 3). J. Sibert, A. Nielsen, **M. Musyl**, B. Leroy, K. Evans. Systematic errors in estimating latitude from solar irradiance time series. *Proceedings of San Sebastian Electronic Tagging Symposium (Fisheries Reviews)*.
- 4). **M. Musyl**, R. Brill, M. Domeier, N. Nasby-Lucas, M. Lutcavage, B. Galuardi, F. Royer, L. M<sup>c</sup>Naughton, Y. Swimmer, S. Wilson and J. Liddle. A Study of Pop-Up Satellite Archival Tag (PSAT) Performance and Reliability in Marine Fisheries Research.
- 5). S. Beverly, B. D. Curran, **M. Musyl** and B. Molony. Effects of eliminating shallow set hooks from tuna longline sets on target and non-target species in the Hawaii-based pelagic tuna fishery
- 6). Heidi Dewar, Eric Prince, **Mike Musyl**, Richard Brill, Chugey Sepulveda, Jiangang Lou, David Foley, Joe Serafy, Michael Domeier, Nicole Nasby-Lucas, Derk Snodgrass, Michael Laurs, Barbara Block and Lianne M<sup>c</sup>Naughton. MOVEMENTS AND BEHAVIORS OF SWORDFISH IN THE ATLANTIC AND PACIFIC OCEANS EXAMINED USING POP-UP SATELLITE TAGS

OTHER PAPERS, TECHNICAL REPORTS, ETC.:

#### **PFRP Honolulu Talks 2007**

**M. Musyl**, R. Brill, M. Domeier, N. Nasby-Lucas, M. Lutcavage, B. Galuardi, F. Royer, L. McNaughton, Y. Swimmer, S. Wilson and J. Liddle. 2007. PSAT Meta Data analysis Project.

### **San Sebastian Talks 2007**

1). **M. Musyl**, R. Brill, M. Domeier, N. Nasby-Lucas, M. Lutcavage, B. Galuardi, F. Royer, L. McNaughton, Y. Swimmer, S. Wilson and J. Liddle. 2007. PSAT Meta Data analysis Project.

2). **M. Musyl**, R. Brill, M. Domeier, N. Nasby-Lucas, M. Lutcavage, B. Galuardi, F. Royer, L. McNaughton, Y. Swimmer, S. Wilson and J. Liddle. 2007. PSAT Performance Evaluation.

3). R. M. Laurs, D. G. Foley and **M. Musyl**. Identification of Pacific large pelagic fish habitats using “PSAT” archival tags, oceanic satellite remote sensing and “SODA” ocean assimilation model analyses.

4). O. Maury, B. Faugeras, A. Nielsen, **M. Musyl**, J. Gunn, J. Hampton, J-C Poggiale, J. Sibert. Mechanistic modeling of bigeye tuna vertical movements: a state-space approach using archival tagging data and the unscented Kalman filter.

5). Y. Swimmer, M. Chaloupka, L. McNaughton and **M. Musyl**. Bayesian hazard regression modeling of factors affecting post-release mortality of loggerhead sea turtles caught in pelagic longline fisheries.

### **Expeditionary**

**M.K. Musyl, Chief Scientist**, FBSAD Longline Cruise on the NOAA RV *Oscar Elton Sette* 9 June to 4 July, 2008

### **Outreach**

Representative for JIMAR/PFRP and NMFS at 2007 Hawaiian International Billfish Tournament (HIBT), invited to deliver talk to anglers and coordinated “Science Night”

GRADUATES (Names of students graduating with MS or PhD degrees during FY 2008; Titles of their Thesis or Dissertation): None.

AWARDS (List awards given to JIMAR employees or to the project itself during the period): None.

PUBLICATION COUNT (Total count of publications for the reporting period and categorized by NOAA lead author and Institute (or subgrantee) lead author and whether it was peer-reviewed or non peer-reviewed (not including presentations):

	JI Lead Author	NOAA Lead Author	Other Lead Author
Peer Reviewed			3
Non-Peer Reviewed	3	1	2

#### PERSONNEL:

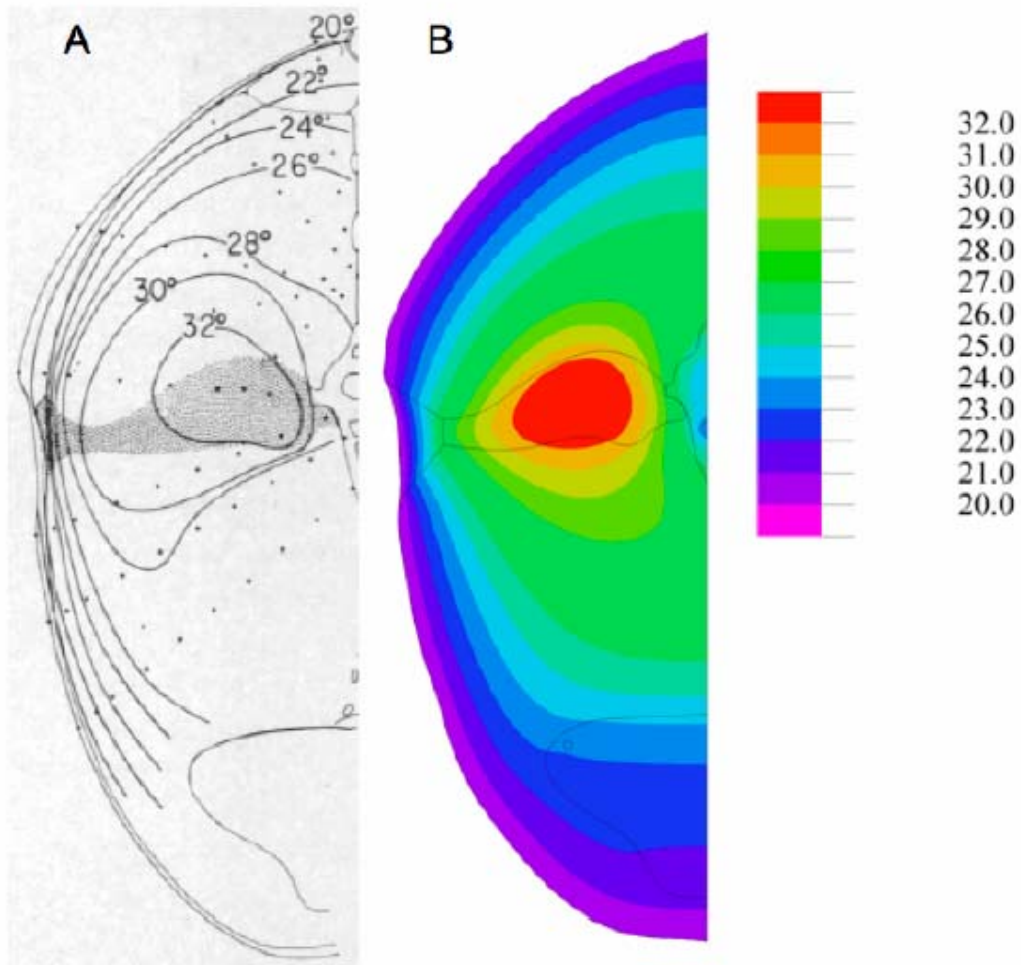
For projects that awarded subcontracts in the fiscal year, please provide the number of supported postdocs and students from each subgrantee.

At present, no students or post-docs are paid by the project. A \$13,000 services contract was written to Dr. R. Michael Laurs for FY 2006 to enable him to continue work on developing the oceanographic database with Dave Foley of JIMAR. Laurs recently retired from NOAA, thus the impetus to contract him to provide continuous services/data specifically crafted for the project. Joe Liddle, Assoc. Prof. Mathematics at University of Alaska-Southeast, was awarded a \$24,000 services contract in FY2008 to assist with analysis of the PSAT Performance and Reliability data (including literature meta-data analysis). Both contracts have, or shortly will be expired with completion of the projects.

#### IMAGES AND CAPTIONS (We will also be including images for the annual report.

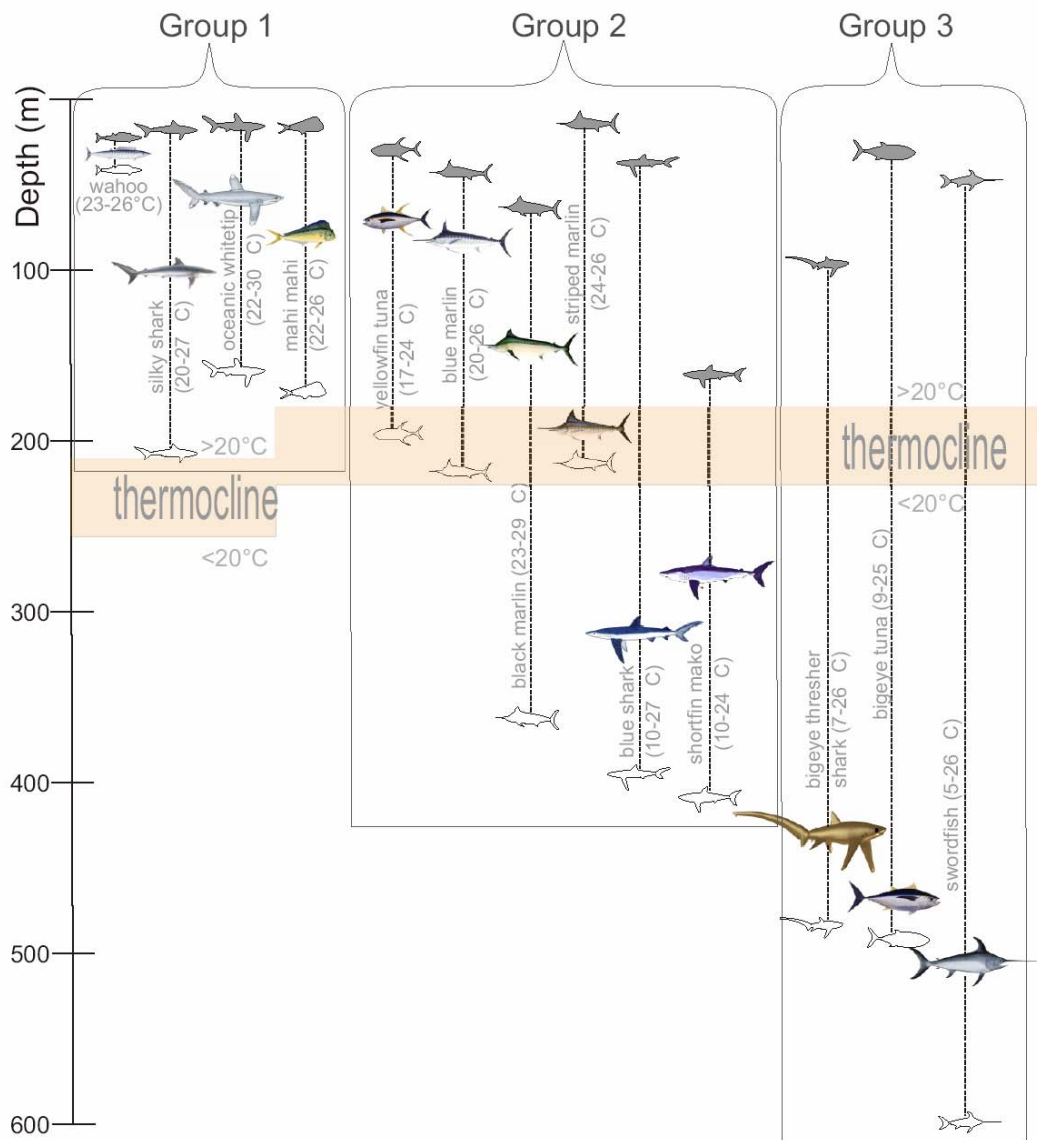
Please send two of your best high-resolution, color images (photo, graphic, schematic) as a **JPEG or TIFF (300 dpi)** with a caption for each image. If you do not have an electronic version of the image, a hardcopy version may be dropped off at the JIMAR office located in the Marine Sciences Building, Room 312):

Figure1



Caption 1: Plots of the isotherms in bigeye tuna. Cross-sections of the recorded isotherms (A) and the isotherms predicted by the model (B). The thermal distribution (A) as observed by Carey and Teal (1966). The isotherms are hand drawn and estimated on the basis of thermistors readings (black dots in the figure). The simulated heat transfer expressed as isotherms by the mathematical model (B) indicates close agreement and thus a role for the heat conserving abilities of the white muscle rete (from Boyne et al.).

Figure2



Caption 2: Representative vertical dive profiles for pelagic fishes. Fish images represent the average depth (combined night and day) for each species. Gray-filled fish outlines represent the depth at which each species spent 95% of the time during the night. Open outlines represent the depth at which each species spent 95% of the time during the day. Values next to the common name show the temperature ranges encountered by each species. Orange shaded bar represents the thermocline, defined as depth range in which the water column is separated into the upper uniform-temperature surface layer (i.e., water above 20°C) and the cooler deeper waters (i.e., below 20°C). Group 1: fishes that spend the majority of their time in the upper uniform-temperature surface layer. Group 2: Fishes that undertake short excursions below the thermocline. Group 3: Fishes that



make frequent excursions below the thermocline. Figure modified from Musyl et al. (2004). Wahoo (*Acanthocybium solandri*), silky shark (*Carcharhinus falciformis*), oceanic whitetip (*Carcharhinus longimanus*), mahimahi (*Coryphaena hippurus*), yellowfin tuna (*Thunnus albacares*), blue marlin (*Makaira nigricans*), black marlin (*M. indica*), striped marlin (*Tetrapturus audax*), blue shark (*Prionace glauca*), shortfin mako shark (*Isurus oxyrinchus*), bigeye thresher shark (*Alopias superciliosus*), the bigeye tuna (*Thunnus obesus*), and swordfish (*Xiphias gladius*)(from Bernal et al.).