ISC6/06/MAR&SWO-WG/____

Biological Research Conducted by PIFSC During 2005-2006 in Support of Marlin and Swordfish Stock Assessments[1]

Robert L. Humphreys. Jr., Michael Musyl, and Edward E. DeMartini

Pacific Islands Fisheries Science Center
National Marine Fisheries Service, NOAA
Honolulu, Hawaii 96822-2396 U.S.A.

March 2006

[1] A working document submitted at the Fourth Meeting of the International Scientific Committee for Tuna and Tuna-Like species in the North Pacific Ocean (ISC), March 20-27, 2006, La Jolla, California, U.S.A. Document not to be cited without permission of the author(s).

Biological Research Conducted by PIFSC during 2005-2006 in Support of Marlin and Swordfish Stock Assessments[2]

Robert L. Humphreys. Jr., Michael Musyl, and Edward E. DeMartini

Pacific Islands Fisheries Science Center
National Marine Fisheries Service, NOAA
Honolulu, Hawaii 96822-2396 U.S.A.

At the Joint Intersessional Marlin and Swordfish Working Groups session of the International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean, held 29 August - 2 September 2005 in Shimizu, Japan, biological research plans were updated for marlin and swordfish. Several biological research topics were identified for further study that encompassed swordfish age and growth, movement, and stock structure. Age and growth studies centered on a production method that estimates age based on the enumeration of presumed annulus rings recorded within fin ray cross-sections. Movement studies examined movement patterns and inferred behaviors based primarily on the use of implanted electronic tags. Stock structure work required additional tissue and otolith samples of young swordfish from geographically distant nursery areas.

In this report we update and summarize: (1) the age and growth of juvenile to adult swordfish sampled from the Hawaii-based longline fishery that operates in the central North Pacific north of Hawaii; (2) assistance provided to a student researching age and growth of blue marlin hard parts collected off southern Japan; (3) updated information on movement patterns from recent PSAT tagging around Hawaii; (4) results and future potential of otolith elemental microchemistry conducted on otoliths from young-of-year swordfish; (5) updated results from at-sea PCR identifications of billfish eggs and larvae collected in plankton nets off Hawaii; and (6) published results that document the extent of shoaling of pelagic longline gear in the Hawaii-based commercial longline fishery.

Swordfish Age and Growth

A paper was completed on the age and growth of swordfish (*Xiphias gladius*) caught in the region of the Hawaii-based pelagic longline fishery. The study re-affirmed a major pattern observed for swordfish in other regions of the Pacific (off Taiwan and Chile) and in other oceans (Mediterranean, Western North Atlantic) -- namely, that females grow markedly faster than males after sexual maturity (Fig. 1) and that age-structured stock assessments therefore need to take into account gender differences. In addition, the paper showed that swordfish caught in the region of Hawaii's longline fishery grow appreciably faster than swordfish caught near Taiwan by that country's longline fishery (Fig. 2). As initially suggested by the results of a calibration exercise conducted in 2000-2002 that compared fin ray age readings among five Pacific ageing labs (CICESE, NTU Taiwan, NRIFSF, IFOP, and the PIFSC), this study has shown that the

[2] PIFSC Working Paper WP-06-003. Issued 15 March 2006.

growth of central North Pacific swordfish is as fast as that of swordfish caught off Chile (Fig. 2).

Collaborative Support for Age & Growth Study of Blue Marlin

Tamaki Shimose, doctoral student at the University of Ryukyus, Okinawa, Japan, visited the PIFSC's WestLAB facility for a two-week period (27 February-11 March 2006) to learn aging techniques and protocols used by Life History Program (LHP) staff in their hard parts based age and growth study of swordfish. Mr. Shimose is currently conducting an age and growth study of blue marlin, *Makaira nigricans*, based on hard part samples collected from specimens off Yanoguni Island, in the southernmost territorial waters of Japan. Blue marlin age estimates are based on the enumeration of presumed annulus rings visible in thin cross-sections of the fifth spine within the first dorsal fin. The appearance of these annulus rings can range from well delineated to diffuse and can be complicated by the occurrence of annuli that appear to split into doublets and triplets along their lateral-most extent within a section. A subsample of 50 blue marlin cross-sections, from fish of both sexes and a range of sizes, were digitized and analyzed by LHP staff. Protocols used to enumerate and detect annulus rings in swordfish, particularly the outermost annulus, were applied to the 50 digitized blue marlin sections. Tentative results indicate that the first annulus appears to be deposited approximately 8 mm from the focus of the section. Otoliths of blue marlin were also processed for age analysis via transverse and rostral sections of the sagittal otolith. One of three prepared otoliths was serially photographed under an SEM and the presumed daily microincrements enumerated. Tentative results indicate that a 50 kg specimen was approximately 1-year old. Future collaborations with Mr. Shimose on blue marlin age and growth are anticipated.

Update of Results From PSAT Tagging

Popup satellite archival tags (PSATs) are capable of recording vertical and horizontal movements of fish by recording pressure (depth), geolocation (based on changing light levels), and ambient temperature. PSAT tags release and transmit data to a satellite when their pre-programmed pop-off date is reached. PSAT tags also release and transmit data if no pressure change is recorded for four consecutive days (tag is presumed to have been "shed" by the fish and is free-floating) or if the tag reaches a depth of 1200 m (the fish is presumed to have died and sunk to this depth). PSAT tags are attached to a barbed nylon dart tip with heavy monofilament line and implanted into the fish's dorsal musculature using a long wooden tagging pole.

A collaborative effort by five research organizations (Stanford University, NMFS SEFSC, JIMAR, VIMS, and NMFS, PFEL) report the results of 22 successful PSAT tag deployments on swordfish across the Western Atlantic, Central Pacific, and Eastern Pacific. Virtually all swordfish displayed a diurnal pattern of inhabiting deeper habitat (200 -1000 m depths) during daylight hours and significantly shallower depths (0 to 500 m) at night. This diurnal movement pattern was consistent across all three locations. Depth variations on this

diurnal pattern were also recorded, particularly instances of "basking" behavior recorded from each area. Further data analysis and collaboration is on-going.

Michael Musyl and colleagues report on the results from 39 PSATs attached to blue marlin, primarily off the Kona coast of the Island of Hawaii. Although the programmed pop-off dates were set at eight months after tagging, average attachment duration was 76 days. Blue marlin spent the majority of time at depths <50 m and rarely at depths below the thermocline. No clear diurnal depth differences were observed. The predominant net movement from the Kona coast was to the east with no fish exhibiting significant westward movement. Future plans include attempts to tag blue marlin in the periphery of their range to better establish whether migratory corridors exist.

Elemental Composition of Swordfish Otoliths

A collaborative study with Steve Campana (Bedford Institute of Oceanography, Nova Scotia, Canada) found detectable differences in the otolith elemental composition of juvenile swordfish collected from geographically distant sites. Results of the study were recently published in Humphreys, Campana, and DeMartini (2005). The importance of elemental composition differences is their potential to serve as natural markers embedded in the portion of adult otoliths formed during juvenile development. Such markers could help determine the origins and interchange of adults captured on the major swordfish fishing grounds, typically at higher latitudes than juvenile swordfish inhabit. Otolith trace element concentrations were determined in this study using isotope dilution-inductively coupled plasma mass spectrometry (ID-ICPMS); assays were conducted at the National Research Council Laboratory in Ottawa, Canada. Juvenile swordfish specimens were collected within a narrow swath of longitude (160 - 165^{o} W); latitudinal sites within this swath included equatorial waters (0 -1^{o} N, n=12), waters immediately south of Hawaii (17^{o} N, n=2), west of the main Hawaiian Islands (22^{o} N, n=7)), and in temperate waters north of Hawaii (31^{o} N, n=2). Concentrations of Mg, Zn, and Pb displayed similar concentration levels among these latitudinal sites. The concentrations of Sr and Ba, however, varied significantly with greater latitudinal separation. The concentration of Sr declined with increasing latitude while Ba concentrations showed the reverse trend. Discriminant analysis showed that Sr and Ba concentrations differed significantly between the two sites with the larger sample sizes in this study; the Equator (0-1^{o}N) and the site adjacent to the main Hawaiian Islands (22^{o}N). These results point out the potential promise of the technique. Other lines of investigation are needed before this technique can be used to attempt the assignment of individual adults to their nursery area of origin. To effectively sample only the core area of the sagittal otolith corresponding to the juvenile nursery area, a probe based mass spectrometry technique using laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) sampling will be employed. The PIFSC has secured a contract with the LITER facility of Old Dominion University to use their LA-ICPMS instrument for these analyses.

The next steps in this research will be to analyze otoliths of juvenile swordfish from distant geographic nursery sites in the western and eastern North Pacific and to evaluate the temporal consistency of the geographically associated patterns. Collaborative efforts to collect otoliths, led by Kotaro Yokawa (National Research Institute of Far Seas Fisheries) and Michael

Hinton and Ed Everett (Inter-American Tropical Tuna Commission) have now provided juvenile head samples from waters off Japan, from the area near the International Dateline, and from off Ecuador. These additional sampling sites will allow us to evaluate other, more distant juvenile sites to determine whether otoliths of juvenile swordfish from these sites contain unique, geographically associated, otolith elemental compositions. Evaluation of temporal stability of elemental fingerprints will be conducted by testing samples over several years from the same nursery area(s). Currently, otolith samples collected adjacent to the main Hawaiian Islands over several years are available to address this topic.

At-Sea Identification of Swordfish Eggs Collected from Plankton Tows Using a Species-Specific PCR Assay

Colleagues at the NMFS Southwest Fisheries Science Center and the Scripps Institution of Oceanography have developed a species-specific multiplex PCR assay capable of identifying the early life stages of swordfish included amongst the five Indo-Pacific species of Istiophoridae that co-occur in Hawaiian waters. This single-step multiplex PCR assay allows identification of billfish species at-sea within 3 hours of sample acquisition (Hyde et al. 2005). On five recent collection cruises (during 2003-2005) conducted off the Kona coast of the Island of Hawaii, surface plankton collections of swordfish, blue marlin, and shortbill spearfish have been verified using the multiplex PCR assay. Eggs of these species were primarily collected within 3-6 nmi off the Kona coast and overlapped with the larval distribution of these species in the area. All captured eggs were in an advanced stage of development and, under microscopic examination, many of the embryos displayed twitching and other movements. Initial attempts to raise these eggs have been unsuccessful, with no hatched larvae surviving beyond 2 days post-hatch. During the most recent cruise (May 2005), larvae of striped marlin were identified for the first time; no egg stages have been collected for this species.

Shoaling of Pelagic Longline Gear in the Hawaii Commercial Fishery

Bigelow et al. (2006) reported evidence of significant shoaling of commercial longline gear in the Hawaii fishery based on field data recorded by temperature-depth recorders (TDRs) attached to longline gear. When compared with catenary algorithms used to predict fishing depths, the TDR data indicated that for shallow sets targeting swordfish, longline gear sets reach ~50% of their predicted depths. For deeper longline sets targeting tuna, gear sets reach ~70% of their predicted depths. Efforts to explain these differences based on environmental effects were limited by the coarse resolution of available environmental datasets; finer scale environmental data are needed. Longline gear shoaling will need to be considered in future stock assessments both in efforts to standardized CPUE and in determining the vertical distribution of catch.

Literature Cited

Bigelow, K., M. Musyl, F. Poisson, and P. Kleiber. 2006. Pelagic longline gear depth and shoaling. Fish. Res. 77:173-183.

Humphreys, R. Jr., S. Campana, and E. DeMartini. 2005. Otolith elemental fingerprints of juvenile Pacific swordfish *Xiphias gladius*. J. Fish Biol. 66:1660-1670.

Hyde, J., E. Lynn, R. Humphreys Jr., M. Musyl, A. West, and R. Vetter. 2005. Shipboard identification of fish eggs and larvae by multiplex PCR, and description of fertilized eggs of blue marlin, shortbill spearfish, and wahoo. Mar. Ecol. Prog. Ser. 286:269-277.

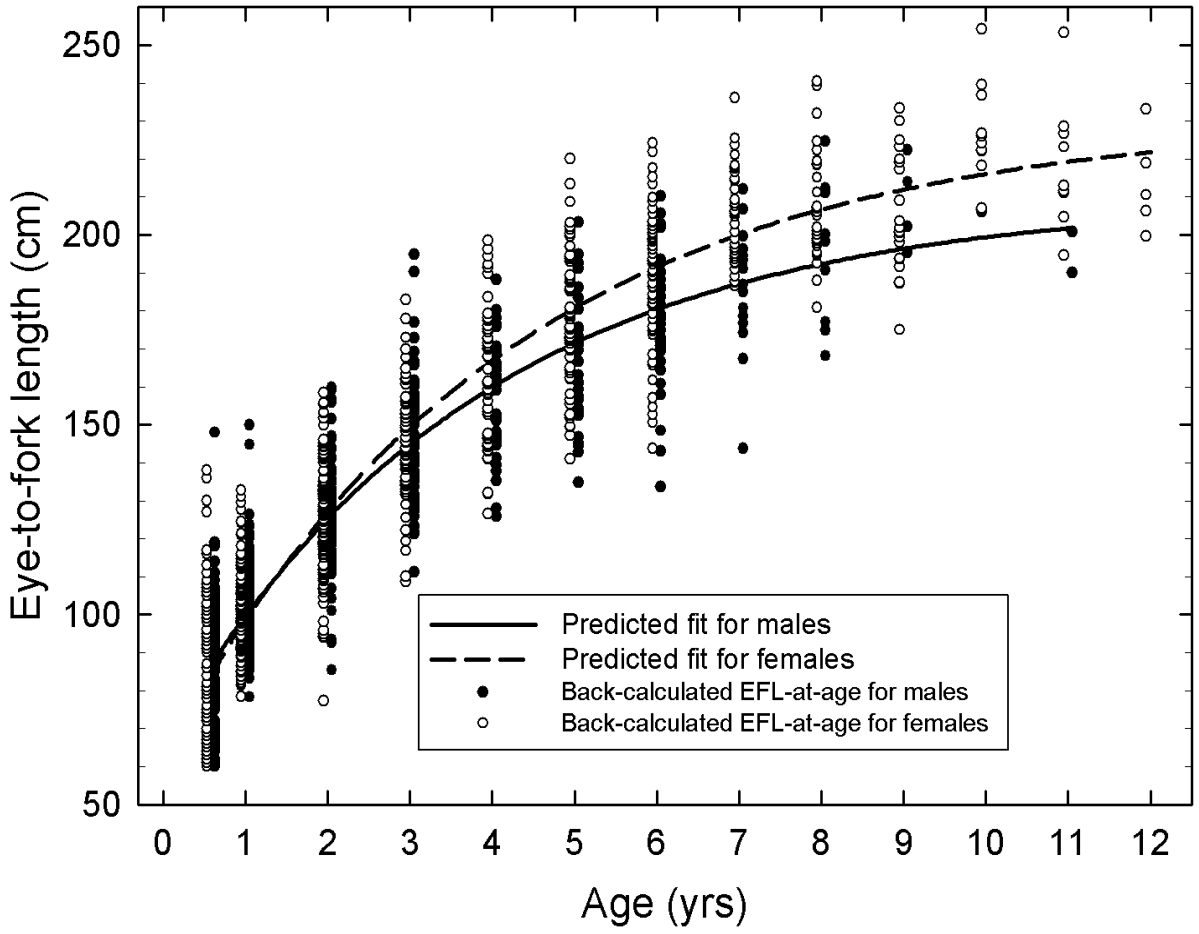

Figure 1. Sex-specific age-length plots of swordfish collected from the Hawaii-based pelagic longline fishery. Age estimates are based on annulus readings from cross sections of the third anal spine.

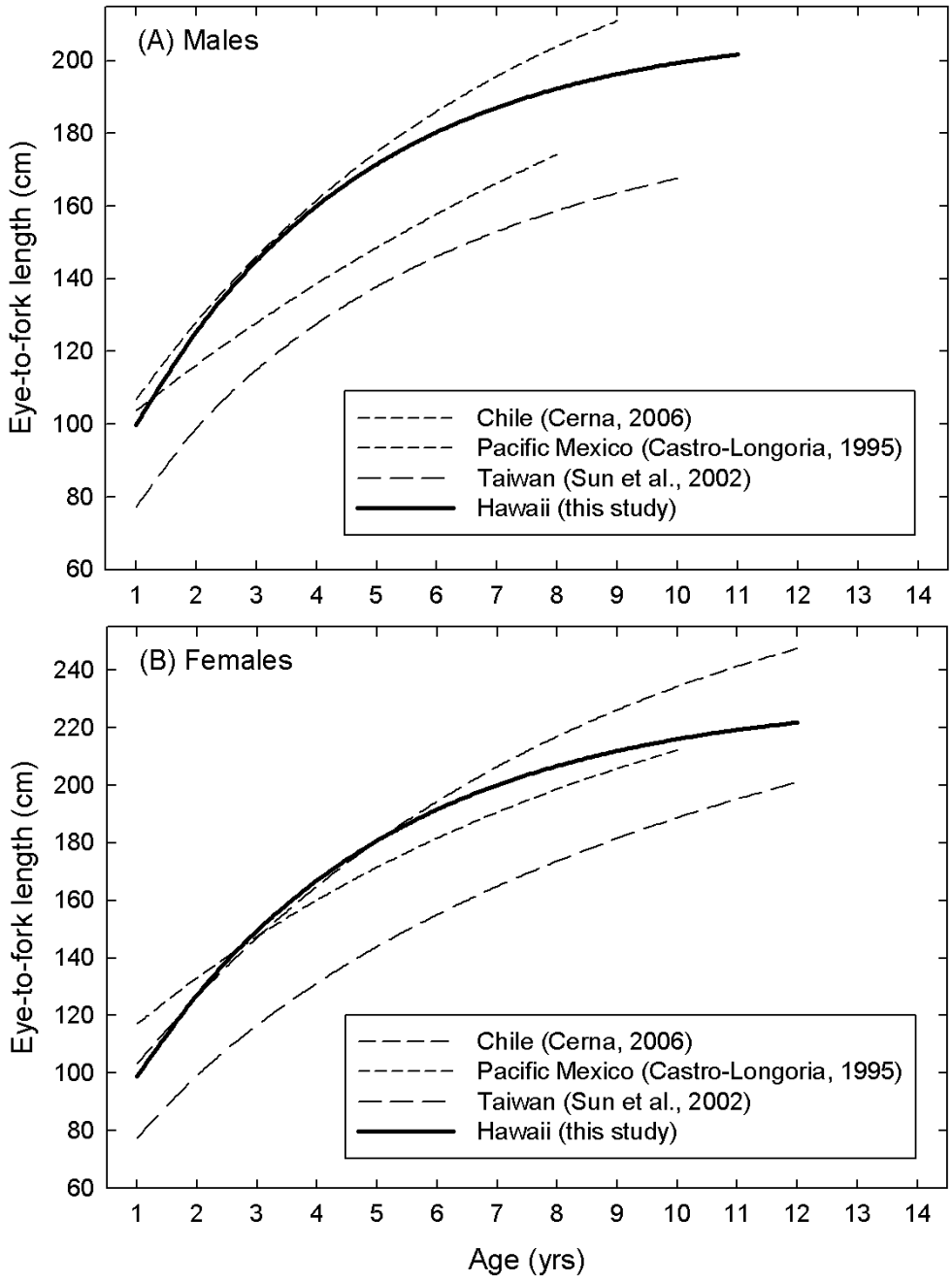

Figure 2. Comparison of age-length plots of swordfish determined from this study and three other geographically distant regions in the Pacific for males (A) and females (B), respectively.