Movements of swordfish (*Xiphias gladius*) in the northeastern Pacific Ocean as determined by electronic tags (2002-2019). [1]

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Abstract

An overview of the horizontal movements of swordfish (*Xiphias gladius*) tagged in the Eastern North Pacific (ENP) using electronic tags is provided in relation to existing stock boundaries for the period from 2002 to 2019. We summarize existing movement data published for swordfish tagged within the ENP (primarily off the U.S. West Coast n=120) and also provide preliminary data through January, 2020 from ongoing studies off southern California (n=16). These data suggest that: (1) swordfish movements do not directly follow the current boundaries used to differentiate ENP stocks; (2) trans-equatorial movements are limited; and (3) movements are confined to the area east of the Hawaiian Islands (163°W). Although these data provide insight towards a better understanding of swordfish movement patterns in the ENP, additional multi-year tagging tracks are necessary to establish more definitive regional stock boundaries for the purposes of stock assessment.

Introduction

In the North Pacific Ocean (NPO), the swordfish is currently managed as two stocks, the Western and Central North Pacific Ocean stock (WCNPO) and the Eastern Pacific Ocean stock (EPO). Delineation of the two stocks is based on previous genetic, catch per unit effort (CPUE), and distributional data, but has not incorporated tagging or movement data (ISC, 2008; ISC, 2009). The western boundary of the EPO stock has been presumed to be a diagonal line that extends from Baja California, Mexico (30°N) to the equator at 170°W (ISC, 2014; ISC, 2018). The southernmost boundary has been defined at the equator (ISC, 2018) or at 20°S (ISC, 2014). As noted in both the 2014 and 2018 WCNP assessments, stock structure continues to be a potential source of uncertainty for swordfish assessments in this region.

To date, movement and tagging data have not been formally included in the designation of stock boundaries for swordfish in the Eastern North Pacific (ENP) (ISC, 2008). This is due to the lack of long-term movement studies in the region and the difficulty of estimating horizontal position using available light-based geolocation methodologies (Dewar et al., 2011). Despite these difficulties, recent studies have focused on assessing swordfish horizontal movements using different tag technologies and geolocation methods (Sepulveda et al., 2019; Sepulveda et al., ongoing study).

This paper collates the body of existing and preliminary swordfish movement data within the ENP and presents the information within a management context.

Material and methods

Published tagging and movement data for swordfish within the ENP are detailed in Table 1. Additional preliminary data from active fin-mounted Argos transmitters (Figure 1) were also obtained and incorporated into the analyses (Sepulveda et al., ongoing study; Table 1). Data were plotted over existing ENP stock boundaries used by the ISC in both the 2014 and 2018 assessments of the WCNP stock using ArcGIS Pro version 2.4.0.

Estimated positions of tagged swordfish were either obtained directly from peer-reviewed publications (Sepulveda et al., 2018; Sepulveda et al., 2019; Abecasis et al., 2012) or estimated from published maps (Dewar et al., 2011). Data from Argos transmissions were analyzed based on protocols described in Sepulveda et al. (2019). Tags were excluded from the present analysis if the swordfish: (1) did not move a significant distance from the original tagging position (i.e., remained within the exclusive economic zone in which it was tagged), or (2) if there was any major uncertainty pertaining to the geolocation estimate.

Results and discussion

The data used to describe swordfish horizontal movements and distribution in the ENP were derived from 136 fish tagged in four studies spanning from September, 2002 to January, 2020 (Table 1). These data showed that swordfish tagged off southern California enter into, and spend significant time within, both the EPO and WCNP management units (Figure 2). More than half of the swordfish tagged within the Southern California Bight (SCB) exhibited movements into the EPO stock boundary area, while the more northern and western tag deployments (central California and Hawaii) largely resulted in WCNP affiliation.

Preliminary data obtained from dorsal-fin-mounted Argos transmitters (Figures 1 & 3) support results from other published studies, and offer increased resolution on the movement paths of swordfish throughout the ENP. Of particular significance is the presence of multi-year, round-trip tracks that have greatly improved our understanding of the western and southern extent of swordfish tagged in this region. Because previous swordfish tag deployments provide only point-specific pop-up or recapture data, it is difficult to infer the overall extent of annual migration patterns or regional affiliations. Yet collectively, Figures 2 and 3 exhibit a lack of movements west of the Hawaiian Islands (~163°W) and south of the equator. The increased resolution and duration (<683 d) of tracks as determined by fin-mounted Argos transmitters also revealed that some swordfish transverse both management units over the course of their deployments and routinely exhibit seasonal site fidelity to their SCB release locations.

In summary, existing and ongoing tagging studies suggest that swordfish in the ENP do not exclusively adhere to the current WCNP and EPO stock boundaries used in ISC stock assessments; however, it is acknowledged that additional data are needed to better delineate such boundaries. The presented data do, however, suggest that there may be a potential east-west boundary as previously proposed by others (reviewed by Hinton and Bremer, 2007) and that the west coast of the United States is an important foraging ground for north Pacific swordfish. Although these data represent significant advancements towards understanding swordfish movements and stock delineation, we feel that inter-annual patterns will become more apparent upon the collection of longer-term data sets from ongoing deployments of additional fin-mounted Argos transmitters (Sepulveda et al., unpublished data). Additionally, ongoing research efforts to better characterize and evaluate the genetic population structure of tagged individuals using single nucleotide polymorphisms (SNPs) may be used in unison with tagging data to more definitively determine stock structure boundaries in the north Pacific.

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Table 1. Details for seven published swordfish tagging studies conducted in the central and eastern north Pacific from 1993–2019 along with an ongoing tagging study. *Datasets from 8 PSATs reported in Dewar et al. (2011) were also incorporated into Abecassis et al. (2012) study and movement data from all swordfish tagged with Argos transmitters reported on in Sepulveda et al. (2019; *n*=6) were included under Sepulveda et al. (ongoing study; *n*=16). All tagged swordfish from Carey and Robison (1981), Holts et al. (1984) and Sepulveda et al. (2010) exhibited minimal horizontal movements during the study period and were therefore not included. SCB=Southern California Bight; BCS=Baja California Sur; HI=Hawaii; PLCA=Pacific Leatherback Conservation Area off central California. WC=Wildlife Computers, PSAT=Pop-up satellite archival transmitter, mrPAT=Mark-report pop-up archival transmitter, DST=Cefas Data storage tag.

Study	Study Period	No. of individuals tagged	No. included	Pacific Deployment Region	Tag type	Max. Time at Liberty
Abecassis et al., 2012	Sept. 2002-Dec. 2008	28	28*	SCB;HI	WC MK-10 PSAT	180 d
Carey and Robison, 1981	Apr-May 1977	5	0	BCS	Acoustic transmitter	5 d
Dewar et al., 2011	Apr. 2001-Nov. 2006	24	16*	SCB; HI	WC MK-10 PSAT	150 d
Holts et al., 1994	Aug. 1993	1	0	SCB	Acoustic transmitter	1 d
Sepulveda et al., 2010	Nov. 2005-Nov. 2006	9	0	SCB	WC MK-10 PSAT	89 d
Sepulveda et al., 2018	Oct. 2012-Mar. 2014	11	11	PLCA	WC MK-10 PSAT	150 d
Sepulveda et al., 2019	Sept. 2012-Jun. 2019	65	65*	SCB; PLCA	WC MK-10, mrPAT, DST	240 d
Sepulveda et al., ongoing study	Nov. 2017-Jan. 2020	16	16*	SCB	Argos transmitters	683 d

Figure 1. Swordfish with an Argos transmitter (KiwiSat, Lotek Ltd) affixed to the leading edge of the dorsal fin prior to deployment off southern California. Argos position estimates generated during surface basking events have resulted in the collection of swordfish movement data spanning >683 d (Sepulveda et al., ongoing).

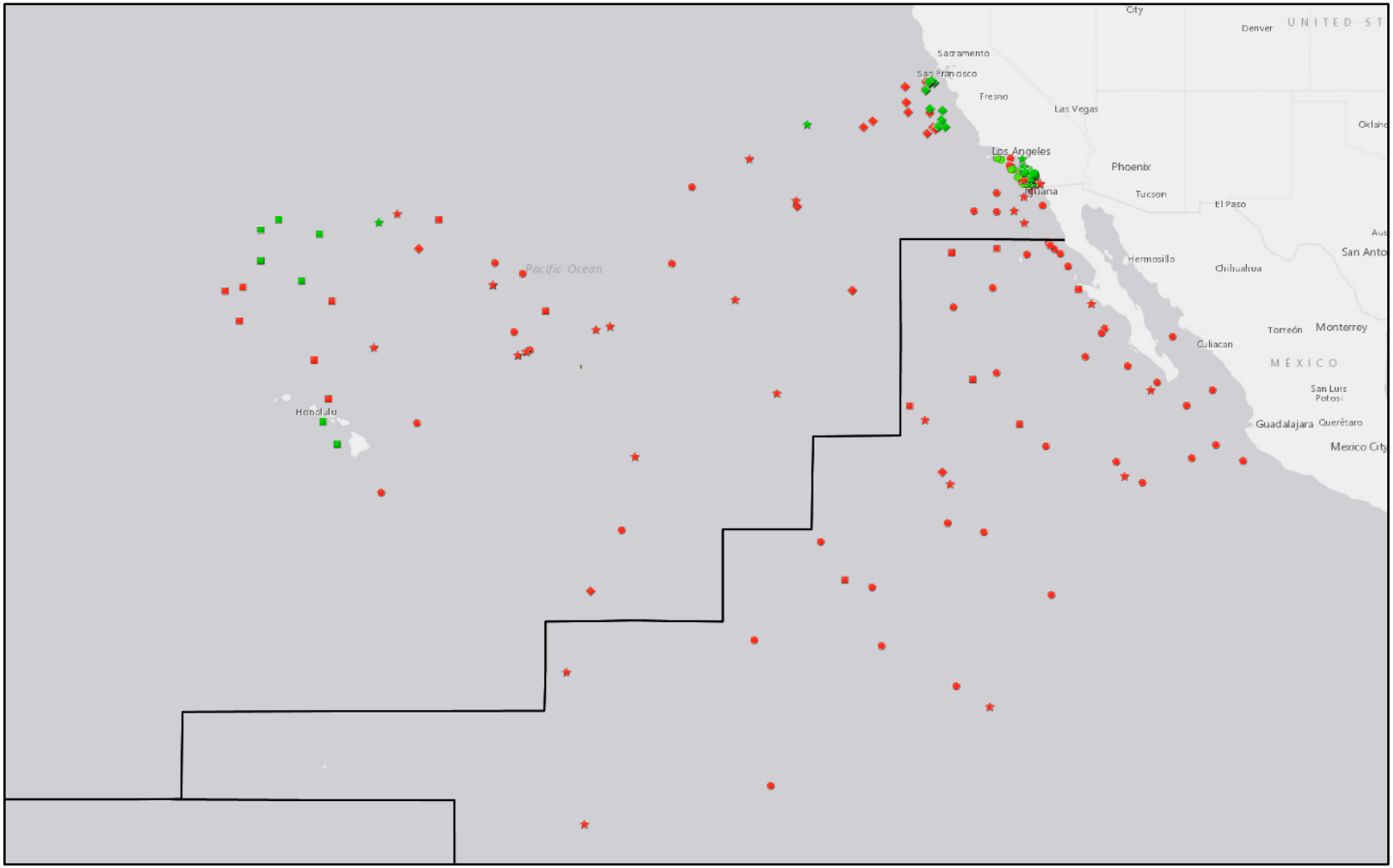

Figure 2: Electronic tag deployments (green symbols) and pop-up or recapture positions (red symbols) for 120 tagged swordfish—in relation to ISC swordfish stock boundaries —from tagging studies conducted in the eastern and central north Pacific (Dewar et al., 2011 [Squares]; Abecassis et al., 2012 [Stars]; Sepulveda et al., 2018 [Diamonds]; and Sepulveda et al., 2019 [Circles]).

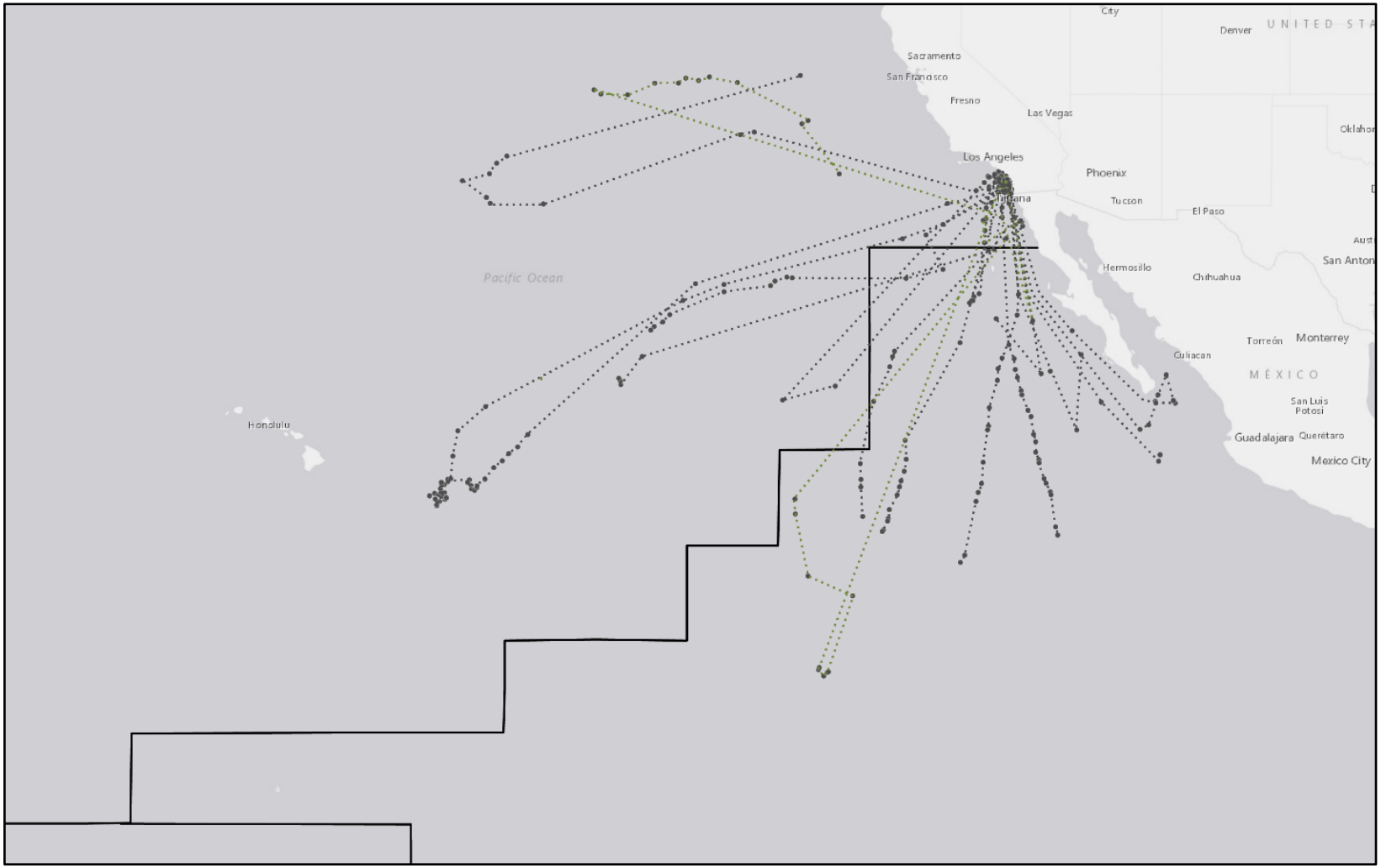

Figure 3: Preliminary movement data from 16 swordfish affixed with dorsal-fin mounted Argos transmitters between November, 2017 and January, 2020, with individual tracks (dotted lines) up to 683 days at liberty (Sepulveda et al., 2020). Solid black lines depict current ISC swordfish stock boundaries.