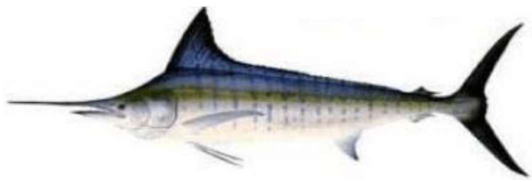
Review of horizontal migration of swordfish, striped marlin and blue marlin using electrical tags.[1]

*Akira Kurashima, *Hirotaka Ijima and *Yasuko Semba

*National Research Institute of Far Seas Fisheries, Fisheries Research and Education Agency 5-7-1, Orido, Shimizu, Shizuoka, 424-8633, Japan



This working paper was submitted to the ISC Billfish Working Group Intercessional Workshop, 30th January – 3rd February 2020, held in National Taiwan University, Taipei, Taiwan.

Abstract

The billfish is a highly migratory fish, and their stock assessment has been performed in each RFMOs. However, there is no consensus about their population structure although population structure is important for stock assessment. The information of horizontal movements is one of key factor for recognizing of population structure. In this study, horizontal movement pathways estimating by electrical tags about swordfish, striped marlin, and blue marlin were summarized for the purpose of clarifying the task of further study. Tagging studies of swordfish have been performed in the worldwide. In some individuals, return migration likes seasonal migration were observed but not return individuals also observed. Their pathways don't overlap among each research fields, i.e., the North west Pacific, the North east Pacific, the South west Pacific, off South Africa, and the North Atlantic. In striped marlin, tagging studies were limited in the East Pacific and the South Pacific, were not overlap among these areas. As well as swordfish, return and non-return migration was reported. In blue marlin, tagging studies was most limited than the other two species, and there was only report from the central Pacific and the Atlantic. In the Pacific, blue marlin showed widely migration beyond the equator. In the Atlantic, almost blue marlin in the Gulf of Mexico or the Caribbean Sea stay within this area, while widely migration observed in open water. These observed movements are narrow than range of genetic population structure in almost cases, they do not across each research field. More extended observations or tagging studies at boundary of previous studies area is necessary to resolve the actual population structure.

Introduction

The billfish is a highly migratory fish and important species as target of commercial fishery and sportfishing. Their stock assessment has been performed in each RFMOs. It is important to understand population structure for appropriate evaluation and effective management. There is some hypothesis about population structure, but not consensus has not been obtained in billfishes. For example, a single panmictic population to four subpopulations have been proposed in swordfish within the Pacific (Bartoo & Coan, 1989; Nakano, 1998; Hinton & Deriso, 1998; Sosa-Nishizaki & Shimizu, 1991; Chow & Takeyama, 2000; Hinton, 2003; Ichinokawa & Brodziak, 2008). In striped marlin, several stocks in a single panmictic population have been proposed (Shomura, 1980; Kamimura & Honma, 1958; Graves & McDowell, 1994; McDowell & Graves, 2008). In blue marlin, a single panmictic population have been proposed but Atlantic clade also observed with ubiquitous clade including worlds (McDowell et al., 2007; Chang et al., 2016). It needs to study the relationships among these clades and their population.

This working paper was submitted to the ISC Billfish Working Group Intercessional Workshop, 30th January – 3rd February 2020, held in National Taiwan University, Taipei, Taiwan.

Population structure was explained by various information. Among them, genetic research and tracking research are a useful to study to understand population structure. Genetic research is to be clear population structure beyond generations. On the other hand, tracking research is provided contact among each individual although limited information among a generation or several months. This information is direct evidence of relationships, existence of contact strongly supplements or rejects for other results of population analysis. Recently, detail of their movements is resolved gradually by the developments of electrical tags. Braun et al. (2015) summarized previous studies using pop-up satellite archival transmitting tags (PSATs) in billfishes, showed each release and pop-off position into a map. After them, the tagging study was advanced, and additional data about their movements have been accumulated about their movements.

In this study, we summarized horizontal movement pathways about stock assessment species in ISC, i.e. swordfish, striped marlin, and blue marlin, based on the previous reports using PASTs, archival tags, and Smart Position and Temperature tags (SPOT) for the purpose of considering the population unit and clarifying the task of further study.

Materials and Methods

The review of horizontal movements was performed, focusing on scientific papers and meeting document papers in which electric tags was used, i.e. archival tags, SPOT, and PSATs. Each movement pathways were traced from the figure in these reports and putted together on a single map per each species. Detailed information on locality of study, number of tags deployed, days at length (DAL) and body length or weight of billfish tagged were summarized by each study and species.

Results and Discussion

Swordfish

The studies of movements in swordfish were performed in worldwide (Table1 and Fig.1). Although short-term movement dominated, long-term observation (over 300 days) were limited in several individuals (Takahashi et al., 2003, Abscal et al., 2015, Evans et al., 2012; 2014, Neilson et al., 2004, Tanaka & Yamaguti, 2017). According to previous results, the movement area doesn’t overlap among several areas, i.e., the North west Pacific, the North east Pacific, the South west Pacific, off South Africa, and the North Atlantic.

Return to release point after long distance migration were observed in several reports.

Takahashi et al. (2003) reported seasonal migration using an archival tag in the North west Pacific, i.e., migration among Oyashio area (summer) to subtropical area (winter). Evans et al. (2012; 2014), West et al. (2012), and Abscal et al. (2015) also reported similar migration patterns (see Blue line in Fig. 1). However, this behavior is not a typical pattern, because the non-return movement pattern is also observed (see Red line in Fig. 1). It is not clear whether they have seasonal migration.

Although the tagging studies of swordfish is most are enriched among billfishes, the amount of information is not enough to resolve population structure, because the days at liberty is limited. There is no study in the central Pacific and thus the boundary of each area is uncertain. Further, the tagging studies using electric tags in the Indian Ocean and the South Atlantic are not conducted at all, and so the movement among three oceans were not resolved.

A part of the result of the tagging study may be supported the genetic study. No movement was observed from the North Atlantic to the South Atlantic (Abscal et al., 2015). This is consistent with the results of the recently genetic population analysis (Smith et al., 2015). On the other hand, the genetic population structure in the Indo-Pacific has not been clarified, and it is unclear that swordfishes living each area consist of independent population.

Striped marlin

The studies of movements in striped marlin have only been performed in the South Pacific and the North East Pacific (Table2 and Fig.2). There is no long-term data of PSAT, and the longest case is 259 days (Domeier, 2006; Table 2). On the other hand, Domeier et al. (2018) have succeeded in obtaining the long-term observation (1.1 to 7.7 years) using archival tags.

However, the survey area is too narrow compared to their distribution. There is no confirmed overlap in the pathway among the South Pacific and the East Pacific at present. As well as swordfish, two migration patterns have been observed. Domeier (2006) observed the return pattern to release point (see Blue line in Fig. 2) and non-return pattern (see Red line in Fig. 2).

According to the recent genetic studies, the individuals of Oceania population appeared in the North west Pacific, and high gene flow among the East Australia (Pacific) and the West Australia (Indian Ocean) were estimated in the Oceania (Mamoozadeh et al., 2018). It is possible that they have more wide migration patterns than range observed by tagging study. Further tagging research is essential to resolve the population structure.

Blue marlin

The studies of movements in blue marlin were mainly performed in the Gulf of Mexico and northwestern Atlantic (outside the Gulf of Mexico). In the Pacific, there is only a report is limited in the central Pacific (Hawaii and Tahiti). Although short-term data are predominant, long-term data (maximum of 334 days) is also obtained (Table 3).

Different migration patterns were observed among the Pacific and the Atlantic (Fig. 3). In the Pacific, Carlisle et al. (2015) released tagged blue marlin from Hawaii and Tahiti, and they showed wide migration beyond the equator (i.e., from north to south movement) was observed.in Pacific widely. On the other hand, in the Atlantic, Karus et al. (2011) reported that most blue marlin released in the Gulf of Mexico stayed within the Gulf of Mexico or the Caribbean Sea.

From the perspective of genetic population structure, blue marlin genetically exhibits two separate clades, i.e., Atlantic clade and a ubiquitous clade including three oceans (Chang et al., 2016). These two patterns by tagging studies may reflect a difference of genetic population structure, however, coverage of tagging study is limited and needs to be improved especially in the Indian Ocean.

It is a little puzzling that movement across each Ocean has not been observed frequently in tagging study despite wide and continuous distribution in billfishes. It is possible that period of the observation is too short and thus we have not captured the large-scale movement among regions within the limited period at less than a year. More extended observations or tagging studies at intermediate points (for example, boundary among each migration area) of previous studies area is necessary to resolve the actual population structure in the future.

Reference

Abascal, F. J., Mejuto, J., Quintans, M., & Ramos-Cartelle, A. (2009). Horizontal and vertical movements of swordfish in the Southeast Pacific. ***ICES Journal of Marine Science***, 67(3), 466-474.

Abascal, F. J., Mejuto, J., Quintans, M., García-Cortés, B., & Ramos-Cartelle, A. (2015). Tracking of the broadbill swordfish, *Xiphias gladius*, in the central and eastern North Atlantic. ***Fisheries Research***, 162, 20-28.

Abecassis, M., Dewar, H., Hawn, D., & Polovina, J. (2012). Modeling swordfish daytime vertical habitat in the North Pacific Ocean from pop-up archival tags. ***Marine Ecology Progress Series***, 452, 219-236.

Bartoo, N. W., & Coan Jr, A. L. (1989). An assessment of the Pacific swordfish resource. In: *Planning* *the Future of Billfishes: Research and Management in the 90s and Beyond*. ***Proceedings of the Second International Billfish Symposium***, Kailua-Kona, Hawaii, pp. 137-151.

Braun, C. D., Kaplan, M. B., Horodysky, A. Z., & Llopiz, J. K. (2015). Satellite telemetry reveals physical processes driving billfish behavior. ***Animal Biotelemetry***, 3(1), 2.

Carlisle, A. B., Kochevar, R. E., Arostegui, M. C., Ganong, J. E., Castleton, M., Schratwieser, J., & Block, B. A. (2016). Influence of temperature and oxygen on the distribution of blue marlin (*Makaira nigricans*) in the Central Pacific. ***Fisheries oceanography***, 26(1), 34-48.

Chen, H., Chang, C. H., Sun, C. L., Shao, K. T., Yeh, S. Z., & DiNardo, G. (2015). Population structure of blue marlin, *Makaira nigricans*, in the Pacific and Eastern Indian Oceans. ***Zoological Studies***, 55(33).

Chow, S., & Takeyama, H. (2000). Nuclear and mitochondrial DNA analyses reveal four genetically separated breeding units of the swordfish. ***Journal of Fish Biology***, 56(5), 1087-1098.

Dewar, H., Prince, E. D., Musyl, M. K., Brill, R. W., Sepulveda, C., Luo, J., Foley, D., Orbesen, E. S., Domeier, M., Nasby-Lucas, N., Snodgrass, D., Laurs, R. M., Hoolihan, J. P., Snodgrass, D., Block, B. A., & McNaughton L. M. (2011). Movements and behaviors of swordfish in the Atlantic and Pacific Oceans examined using pop-up satellite archival tags. ***Fisheries Oceanography***, 20(3), 219-241.

Domeier, M. L., Dewar, H., & Nasby-Lucas, N. (2003). Mortality rate of striped marlin (*Tetrapturus audax*) caught with recreational tackle. ***Marine and Freshwater Research***, 54(4), 435-445.

Domeier, M. L. (2006). An analysis of Pacific striped marlin (*Tetrapturus audax*) horizontal movement patterns using pop-up satellite archival tags. ***Bulletin of Marine Science***, 79(3), 811-825.

Domeier, M. L., Ortega-Garcia, S., Nasby-Lucas, N., & Offield, P. (2018). First marlin archival tagging study suggests new direction for research. ***Marine and Freshwater Research***, 70(4), 603-608.

Evans, K., Baer, H., Bryant, E., Holland, M., Rupley, T., & Wilcox, C. (2011). Resolving estimation of movement in a vertically migrating pelagic fish: does GPS provide a solution?. ***Journal of***

experimental marine biology and ecology, 398(1-2), 9-17.

Evans, K., Kolody, D., Abascal, F., Holdsworth, J., Maru, P., & Sippel, T. (2012). Spatial dynamics of swordfish in the south Pacific Ocean inferred from tagging data. ***WCPFC-SC8-2012/SA-IP-05.***

Evans, K., Abascal, F., Kolody, D., Sippel, T., Holdsworth, J., & Maru, P. (2014). The horizontal and vertical dynamics of swordfish in the South Pacific Ocean. ***Journal of experimental marine biology and ecology***, 450, 55-67.

Goodyear, C. P., Luo, J., Prince, E. D., Hoolihan, J. P., Snodgrass, D., Orbesen, E. S., & Serafy, J. E. (2008). Vertical habitat use of Atlantic blue marlin *Makaira nigricans*: interaction with pelagic longline gear. ***Marine Ecology Progress Series***, 365, 233-245.

Graves, J. E., & McDowell, J. R. (1994). Genetic analysis of striped marlin (*Tetrapturus audax*) population structure in the Pacific Ocean. ***Canadian Journal of Fisheries and Aquatic Sciences***, 51(8), 1762-1768.

Graves, J. E., Luckhurst, B. E., & Prince, E. D. (2002). An evaluation of pop-up satellite tags for estimating postrelease survival of blue marlin (*Makaira nigricans*) from a recreational fishery. ***Fishery Bulletin***, 100(1), 134-142.

Hinton, M. G. & Deriso, R. B. (1998). Distribution and stock assessment of swordfish, *Xiphias gladius*, in the eastern Pacific Ocean from catch and effort data standardized on biological and environmental parameters. ***NOAA'U chnical Report*** 142, 161.

Hinton, M. G. (2003). Status of swordfish stocks in the eastern Pacific Ocean estimated using data from Japanese tuna longline fisheries. ***Marine and freshwater research***, 54(4), 393-399.

Hoolihan, J. P., Luo, J., Richardson, D. E., Snodgrass, D., Orbesen, E. S., & Prince, E. D. (2009). Vertical movement rate estimates for Atlantic istiophorid billfishes derived from high-resolution pop-up satellite archival data. ***Bulletin of Marine Science***, 84(3), 257-264.

Holdsworth, J. C., Sippel, T. J., & Block, B. A. (2009). Near real time satellite tracking of striped marlin (*Kajikia audax*) movements in the Pacific Ocean. ***Marine Biology***, 156(3), 505-514.

Ichinokawa, M., & Brodziak, J. (2008). Stock boundary between possible swordfish stocks in the northwest and southeast Pacific judged from fisheries data of Japanese longliners. ***ISC/08/Special Session on Billfish Stock Structure,*** 4, 14.

Kamimura, T., & Honma, M. (1958). A population study of the so-called Makajiki (striped marlin) of both northern and southern hemispheres of the Pacific. I. Comparison of external characters. ***Rep. Nankai Reg. Fish. Lab***, 8, 1-11.

Kerstetter, D. W., Luckhurst, B. E., Prince, E., & Graves, J. E. (2003). Use of pop-up satellite archival tags to demonstrate survival of blue marlin (*Makaira nigricans*) released from pelagic longline gear. ***Fishery Bulletin***, 101(4), 939.

Kraus, R. T., Wells, R. D., & Rooker, J. R. (2011). Horizontal movements of Atlantic blue marlin (*Makaira nigricans*) in the Gulf of Mexico. ***Marine biology***, 158(3), 699-713.

Lam, C. H., Kiefer, D. A., & Domeier, M. L. (2015). Habitat characterization for striped marlin in the Pacific Ocean. ***Fisheries research***, 166, 80-91.

Lerner, J. D., Kerstetter, D. W., Prince, E. D., Talaue-McManus, L., Orbesen, E. S., Mariano, A., Snodgrass, D. & Thomas, G. L. (2013). Swordfish vertical distribution and habitat use in relation to diel and lunar cycles in the western North Atlantic. ***Transactions of the American Fisheries Society,*** 142(1), 95-104.

Loefer, J. K., Sedberry, G. R., & McGovern, J. C. (2007). Nocturnal depth distribution of western North Atlantic swordfish (*Xiphias gladius*, Linnaeus, 1758) in relation to lunar illumination. ***Gulf and Caribbean Research***, 19(2), 83-88.

McDowell, J. R., Carlsson, J. E., & Graves, J. E. (2007). Genetic analysis of blue marlin (*Makaira nigricans*) stock structure in the Atlantic Ocean. ***Gulf and Caribbean Research***, 19(2), 75-82.

McDowell, J. R., & Graves, J. E. (2008). Population structure of striped marlin (*Kajikia audax*) in the Pacific Ocean based on analysis of microsatellite and mitochondrial DNA. ***Canadian Journal of Fisheries and Aquatic Sciences***, 65(7), 1307-1320.

Mamoozadeh, N. R., McDowell, J. R., & Graves, J. E. (2018). Genetic population structure of striped marlin (*Kajikia audax*) in the Indian Ocean, with relationship to Pacific Ocean populations. ***IOTC-2018-WPB16-20***

Nakano, H. (1998). Stock status of Pacific swordfish, Xiphias gladius, inferred from CPUE of the Japanese longline fleet standardized using general linear models. ***US Nat. Mar. Fish. Serv., NOAA Tech. Rep. NMFS***, 142, 195-209.

Neilson, J. D., Loefer, J., Prince, E. D., Royer, F., Calmettes, B., Gaspar, P., Lopez, R., & Andrushchenko, I. (2014). Seasonal distributions and migrations of Northwest Atlantic swordfish: inferences from integration of pop-up satellite archival tagging studies. ***PLoS One***, 9(11), e112736.

Saito, H., & Yokawa, K. (2005). Vertical distribution pattern of striped marlin estimated using pop-up tag data. ***ISC/05/MAR&SWO-WGs/13***.

Saito, H., & Yokawa, K. (2006). Use of pop-up tags to estimate vertical distribution of Atlantic blue marlin (*Makaira nigricans*) released from the commercial and research longline cruise during 2002 and 2003. ***Collective Volume of Scientific Papers ICCAT***, 59, 252-64.

Saito, H., Takeuchi, Y., & Yokawa, K. (2004). Vertical distribution of Atlantic blue marlin obtained from pop-up archival tags in the tropical Atlantic Ocean. ***Collective Volume of Scientific Papers ICCAT***, 56(1), 201-211.

Sedberry, G., & Loefer, J. (2001). Satellite telemetry tracking of swordfish, *Xiphias gladius*, off the eastern United States. ***Marine biology***, 139(2), 355-360.

Sepulveda, C. A., Aalbers, S. A., Heberer, C., Kohin, S., & Dewar, H. (2018). Movements and behaviors of swordfish *Xiphias gladius* in the United States Pacific Leatherback Conservation Area. ***Fisheries Oceanography***, 27(4), 381-394.

Shomura, R. S. (1980). Summary report of the Billfish Stock Assessment Workshop; Pacific Resources: Honolulu Laboratory, Southwest Fisheries Center, Honolulu, Hawaii, 5-14 December 1977.

Sippel, T. J., Davie, P. S., Holdsworth, J. C., & Block, B. A. (2007). Striped marlin (*Tetrapturus audax*) movements and habitat utilization during a summer and autumn in the Southwest Pacific Ocean.

Fisheries Oceanography, 16(5), 459-472.

Sippel, T., Holdsworth, J., Dennis, T., & Montgomery, J. (2011). Investigating behaviour and population dynamics of striped marlin (*Kajikia audax*) from the southwest Pacific Ocean with satellite tags. ***PLoS One***, 6(6), e21087.

Smith, B. L., Lu, C. P., García-Cortés, B., Viñas, J., Yeh, S. Y., & Bremer, J. R. A. (2015). Multilocus Bayesian estimates of intra-oceanic genetic differentiation, connectivity, and admixture in Atlantic swordfish (*Xiphias gladius* L.). ***PloS one***, 10(6), e0127979.

Sosa-Nishizaki, O., & Shimizu, M. (1991). Spatial and temporal CPUE trends and stock unit inferred from them for the Pacific swordfish caught by the Japanese tuna longline fishery. ***Bulletin of the National Research Institute of Far Seas Fisheries***, 28, 75-89.

Takahashi, M., Okamura, H., Yokawa, K., & Okazaki, M. (2003). Swimming behaviour and migration of a swordfish recorded by an archival tag. ***Marine and Freshwater Research***, 4(4), 527-534.

Tanaka, Y., & Yamaguti, K. (2017). Horizontal and vertical movement of a swordfish in the Northwestern Pacific Ocean. ***NIPPON SUISAN GAKKAISHI***, 83(6), 961-970.

Prince, E. D., Cowen, R. K., Orbesen, E. S., Luthy, S. A., Llopiz, J. K., Richardson, D. E., & Serafy, J. E. (2005). Movements and spawning of white marlin (*Tetrapturus albidus*) and blue marlin (*Makaira nigricans*) off Punta Cana, Dominican Republic. ***Fishery Bulletin***, 103(4), 659-669.

West, W. M., Kerwath, S. E.,Silva, C., Wilke, C. G., Marsac, F. (2012). Horizontal and vertical movements of swordfish tagged with pop up-satellite transmitters in the south-west Indian ocean, off south Africa. ***IOTC-2012-WPB10-16***

Table 1 Previous study of swordfish using electric tags.

Reference	Tag types	Locality	NT	DAL	Size
Sedberry & Loefer., 2001	PSATs	N. W. Atlantic (Gulf of Mexico)	29	29-100	71-183 cm (LJFL)
Takahashi et al., 2003	Archival Tag	N. W. Pacific (Japan)	1	345	190 cm (EFL)
Loefer et al., 2007	PSATs	N. W. Atlantic (S. Caroline)	15	5-123	81-183 cm (LJFL)
Abscal et al., 2010	PSATs	E. Pacific (N. Chile)	21	3-166	140-220 cm (LJFL)
Dewar et al., 2011	PSATs	N. W. Atlantic (Caribbean)	9	15-120	11-77 kg (BW)
	PSATs	C. Pacific (Hawaii)	30	5-245	20-135 kg (BW)
	PSATs	E. Pacific (Mexico)	23	10-106	45-114 kg (BW)
Abecassis et al., 2012	PSATs	E. Pacific (Mexico)	43	10-180	45-140 kg (BW)
West et al., 2012	PSATs	Indian Ocean (S. Africa)	11	1-91	140-220 cm (LJFL)
Evans et al., 2011	PSATs	S. Pacific (E. Australia)	10	4-57	50-240 kg (BW)
Evans et al., 2012	PSATs	S. Pacific (E. Australia)	54	59-302	50-200 kg (BW)
	PSATs	S. Pacific (New Zealand)	19	67-236	56-130 kg (BW)
	PSATs	W. Pacific (Polynesia)	13	44-312	53-108 kg (BW)
	PSATs	W. Pacific (Cook Islands)	9	99-351	65-130 kg (BW)
	PSATs	E. Pacific (Chili)	21	49-166	76 kg (BW)
Lerner et al., 2013	PSATs	N. Atlantic (Florida)	10	1-133	109-249 cm (LJFL)

Table 1 continued.

Reference	Tag types	Locality	NT	DAL	Size
Evans et al., 2014	PSATs	S. Pacific (E. Australia)	55	41-362	50-200 kg (BW)
	PSATs	S. Pacific (New Zealand)	19	67-236	56-130 kg (BW)
	PSATs	W. Pacific (Polynesia)	13	44-312	53-108 kg (BW)
	PSATs	W. Pacific (Cook Islands)	9	99-351	65-130 kg (BW)
	PSATs	E. Pacific (Chili)	21	49-166	43-78 kg (BW)
Neilson et al., 2014	PSATs	N. W. Atlantic (S. Carolina)	12	31-123	81-152 cm (LJFL)
	PSATs	N. W. Atlantic (Canada)	17	77-411	124-263 cm (LJFL)
	PSATs	N. Atlantic	9	57-135	109-208 cm (LJFL)
Abscal et al., 2015	PSATs	N. Atlantic	21	2-365	135–215 cm (LJFL)
Tanaka & Yamaguti, 2017	PSATs	N. W. Pacific (Ogasawara)	18	11-300	20-200 kg (BW)
Sepulveda et al., 2018	PSATs	E. Pacific (California)	13	2-150	75-148 kg (BW)

NT; number of tags, DAL; days at liberty, EFL; eye-fork length, LJFL; lower jaw-fork length, BW; body weight.

Table 2 Previous study of striped marlin using electric tags**.**

Reference	Tag types	Locality	NT	DAL	Size
Domeier et al., 2003	PSATs	E. Pacific (Baja California)	80	3-93	41-84 kg (BW)
Saito &Yokawa, 2005	PSATs	E. Pacific (Mexico)	5	9-32	-
Domeier, 2006	PSATs	S. Pacific (E. Australia)	24	Max:134	45.5-130 kg (BW)
	PSATs	E. Pacific (New Zealand)	34	Max:226	54.6-159.1 kg (BW)
	PSATs	E. Pacific (Mexico)	130	Max:259	40.9-81.8 kg (BW)
	PSATs	E. Pacific (California)	17	Max:153	40.9-79.6 kg (BW)
	PSATs	E. Pacific (Ecuador)	33	Max:134	40.9-100.0 kg (BW)
	PSATs	E. Pacific (Panama)	3	-	79.6-102.3 kg (BW)
	PSAT	E. Pacific (Costa Rica)	1	62	81.82 kg (BW)
	PSATs	C. Pacific (Hawaii)	6	Max:122	22.7-36.4 kg (BW)
Sippel et al., 2007	PSATs	E. Pacific (New Zealand)	5	22-60	70-140 kg (BW)
Holdsworth et al., 2008	SPOT &PSATs	E. Pacific (New Zealand)	26 /22	0.5-110.6	60-110 kg (BW)
Sippel et al., 2011	SPOT &PSATs	E. Pacific (New Zealand)	28*	15-133	70-110 kg (BW)
Domeier et al., 2018	Archival Tags	E. Pacific (Mexico)	10	400-2795	150-228 cm (LJFL)

* including Holdsworth et al. (2008), NT; number of tags, DAL; days at liberty, LJFL; lower jaw-fork length, BW; body weight.

This working paper was submitted to the ISC Billfish Working Group Intercessional Workshop, 30th January – 3rd February 2020, held in National Taiwan University, Taipei, Taiwan.

Table 3 Previous study of blue marlin using electric tags.

Reference	Tag types	Locality	NT	DAL	Size
Graves et al., 2002	PSATs	N. E. Atlantic (Bermuda)	9	5	125-425 lb (BW)
Kerstetter et al., 2003	PSATs	N. Atlantic	9	6-35 (h)	120-350 lb (BW)
Saito et al., 2004	PSATs	C. Atlantic	12	8-180	70-200 kg (BW)
Prince et al., 2005	PSATs	N. E. Atlantic (Dominica)	1	40	58.97 kg (BW)
Saito & Yokawa, 2006	PSATs	C. Atlantic	12	6-32	70-200 kg (BW)
Goodyear et al., 2008	PSATs	N. W. Atlantic	40	2-93	36-227 kg (BW)
	PSATs	N. E. Atlantic	5	15-154	82-181 kg (BW)
	PSATs	C. Atlantic	5	4-44	45-363 kg (BW)
Karus et al., 2011	PSATs	N. W. Atlantic (Gulf of Mexico)	42	4-334	45-250 kg (BW)
Carlisle et al., 2015	PSATs	C. Pacific (Hawaii)	29	9-180	45-136 kg (BW)
	PSATs	C. Pacific (Hawaii)	5	115-181	57-318 kg (BW)
	PSATs	C. Pacific (Tahiti)	7	5-243	45-125 kg (BW)

NT; number of tags, DAL; days at liberty, BW; body weight.

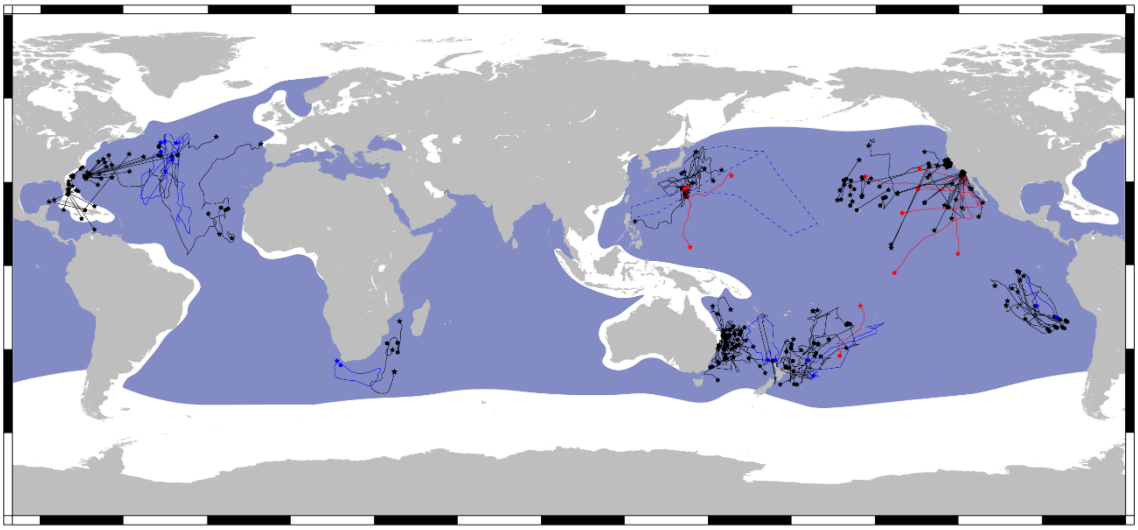


Fig. 1 Horizontal movement of swordfish. Circles show release points, Stars pop-off points. All lines were traced each pathway from figure of following reports, Sedberry & Loefer (2001), Takahashi et al. (2003), Abscal et al. (2009; 2015), Dewar et al. (2011), Abecassis et al. (2012), West et al. (2012), Evans et al. (2011; 2012; 2014), Loefer et al. (2007), Lerner et al. (2013), Tanaka & Yamaguti (2017), and Sepulveda et al. (2018). Red lines show non-return individuals, blue line return individuals, break line indicate the individual estimated two pathways. Blue mask show distribution of swordfish.

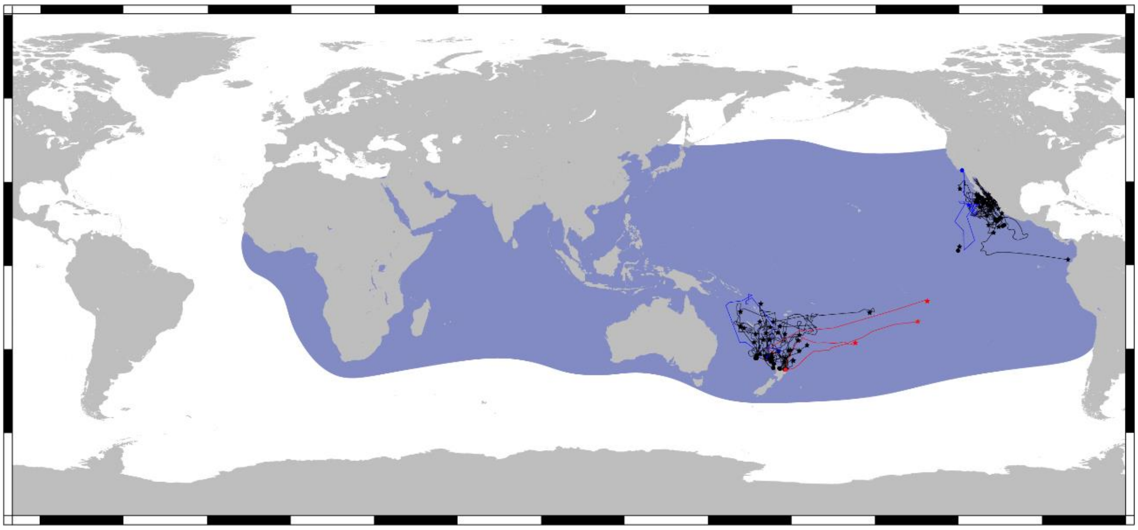


Fig. 2 Horizontal movement of striped marlin. All lines were traced from figure of following reports, Domeier et al. (2003; 2018), Saito & Yokawa (2005), Domeier (2006). Sippel et al. (2007; 2011), Holdsworth et al. (2008). Red lines show non-return individuals, blue line return individuals. Blue mask show distribution of striped marlin.

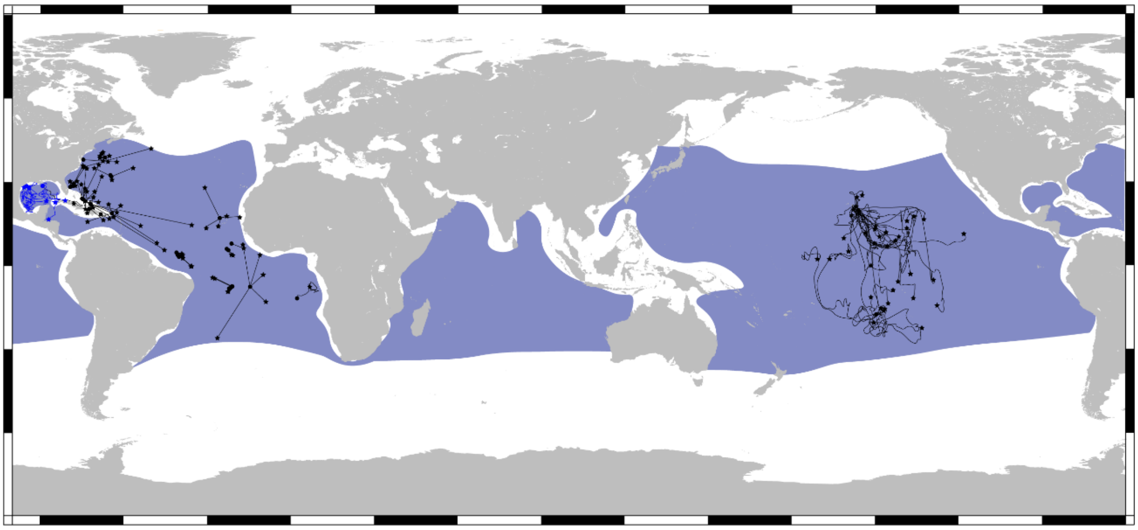


Fig. 3 Horizontal movement of blue marlin. All lines were traced from figure of following reports, Graves et al. (2002), Saito et al. (2004), Prince et al. (2005), Saito & Yokawa (2006), Goodyear et al. (2008), Hoolihan et al. (2009), Karus et al. (2011), Kerstetter et al. (2013), Carlisle et al. (2015). Blue lines show the movements of individual staying in the Gulf of Mexico and the Caribbean Sea. Blue mask show distribution of blue marlin.