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Progress on Japan's Biological Sampling of Three Billfish Species caught in the North Pacific from 2019 to 2024¹

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Abstract

In 2020, Japan, the United States, and Taiwan initiated International Billfish Biological Sampling Program (IBBS) to accurately estimate the key life history parameters, such as maturity and growth, of three billfish species—swordfish, striped marlin, and blue marlin—across the North Pacific Ocean. This working paper summarizes the current progress of the biological sampling undertaken by Japan and the number of samples shared with the United States and Taiwan. The total number of gonads, otoliths, and fin rays collected by Japan from swordfish and striped marlin in the western North Pacific Ocean between January 2019 and November 2024 has reached the predetermined target. However, swordfish samples were biased towards females, and striped marlin samples were highly biased in terms of length bins and sampling locations. The number of swordfish gonad samples per length bin analyzed by Japan, including samples provided by the United States and Taiwan, is relatively evenly collected, although some bins do not reach the target. On the other hand, striped marlin otolith and fin ray samples have significantly fewer small and large specimens. Additionally, there are a few large geographic areas where very few samples of either swordfish or striped marlin have been collected. A more efficient sampling plan will be required to collect effectively these missing samples in the future.

Introduction

The ISC Billfish Working Group (BILLWG) formally launched the International Billfish Biological Sampling (IBBS) project in 2020. The project aims to enhance stock assessments of swordfish (*Xiphias gladius*), striped marlin (*Kajikia audax*), and blue marlin (*Makaira mazara*) by improving estimates of biological life history parameters, such as maturity and growth, across the North Pacific Ocean (Kinney et al., 2020). Japan, the United States, and Taiwan are participating in the project, following a standardized protocol for billfish sample collection. However, the progress report on Japanese biological sampling from April 2024 (Kai and Ishihara, 2024) highlights challenges in achieving the target number of samples per length bin across regions (eastern, central, and western) and ensuring random sampling in time and space. These difficulties arise due to differing seasonal migrations by sex and size class, as well as biases in the operational areas of the fishing fleets.

This working paper summarizes the current progress of biological sampling undertaken by Japan and the number of samples shared with the United States and Taiwan. Future sampling plans are also discussed.

Materials and Methods

Japan independently initiated the sampling of gonads, otoliths, dorsal or anal fin rays, and muscle tissues from swordfish, striped marlin, and blue marlin in January 2019, with lens sampling added in February 2023. For each sampled billfish, fishing information such as capture date and location (latitude and longitude) was recorded. Additionally, eye fork length (EFL, in cm) and body weight were measured. Sampling was generally conducted without regard to sex or body size.

Gonad samples were preserved in 10% formalin whenever possible, with the remainder frozen at -40°C . Gonads collected by Kesen-numa longline vessels from July 2023 to November 2024 were fixed using ALTFiX. When fixative was unavailable, samples were frozen. Gonad weights were recorded whenever feasible. Otolith samples were extracted from the head in the laboratory and preserved in 70% ethanol. Two to three rays, including the longest, were collected from the dorsal and anal fins, cleaned, and dried. Muscle samples (~ 0.1 – 0.2 grams) were excised using a clean scalpel and preserved in Urea buffer. Additionally, tissue pieces ($\sim 5 \times 5 \times 5$ cm cubes) were collected and frozen at -40°C . Lens samples were also gathered and stored frozen at -40°C .

The exchange of billfish biological samples among Japan, the United States, and Taiwan commenced in April 2023. Japan provided blue marlin gonad, otolith, and dorsal fin ray samples to Taiwan, as well as striped marlin gonad and swordfish otolith and anal fin ray samples to the United States. In return, Japan received swordfish gonads, striped marlin otoliths, and dorsal fin rays from both Taiwan and the United States. For samples with body length recorded in lower jaw fork length (LJFL) rather than eye fork length (EFL), LJFL was converted to EFL using a linear regression equation (Su et al., 2005).

Results and Discussions

The current progress of biological sampling conducted by Japan

The number of samples for swordfish and striped marlin in 2024 ranked second, following 2023 (Table 1), reflecting continued intensified sampling efforts initiated after 2022. Size frequency distributions and sampling locations for the three billfish species with complete gonad, otolith, and fin ray samples are presented in Figures 1 and 2. However, the collection of blue marlin samples remains minimal. Notably, there is strong bias toward certain length bins and specific sampling locations.

The number of striped marlin samples from the western region is notably high, with certain length bins significantly exceeding target levels (Figure 1). Additionally, 73% of all samples were collected from specific areas of the East China Sea (Figure 2). Specimens smaller than 100 cm EFL and larger than 210 cm EFL were scarce in both the western and central regions. Efforts are currently focused on increasing the collection of striped marlins under 100 cm EFL in the southwestern North Pacific. Conversely, specimens over 210 cm EFL have only been sampled in the East China Sea (31° – 34°N , 127° – 129°E). Given the extensive sampling already conducted in the East China Sea, it is necessary to evaluate whether to continue sampling in this area or to shift efforts to other locations.

The number of swordfish samples met the target for most length bins; however, the sex ratio in the western region is heavily skewed toward females, with notably few male samples over 180 cm EFL (Figure 1). South of 30°N , the sex ratio is approximately 1:1, whereas north of 30°N , it is nearly 6:1 in favor of females (Figure 2). This disparity likely reflects the distinct seasonal

habitats of male and female swordfish (DeMartini et al. 2000), suggesting that a biased sex ratio may persist even with random sampling. Moving forward, sampling strategies must account for sex ratio disparities. Additionally, given that many female samples had immature ovaries, sampling near Ogasawara—where mature females are more commonly caught—commenced in December 2024 to address this gap.

Current status of biological samples from three countries collated by Japan

Japan has largely completed the provision of biological samples to Taiwan and the United States for those collected between January 2019 and August 2024 (Table 2). Taiwan primarily supplied samples from the western and central regions, while the United States focused on samples from the central and eastern regions (Table 3). Gonadal samples received from Taiwan were initially frozen and later preserved in formalin. The condition of these tissues will be assessed in future analyses.

The number of swordfish gonad samples collected by Japan, Taiwan, and the United States, including both fresh and frozen samples, largely met the length bin targets in the western and central regions (Figure 3). However, samples of males exceeding 200 cm EFL remain notably scarce across all regions, and the sex ratio in the western region is heavily skewed towards females. While swordfish gonads have been collected from a broad area in the North Pacific Ocean, certain regions remain unsampled (Figure 4). Notably, there is a significant lack of samples from areas between 20–30°N and 170–190°W, as well as 10–25°N and 120–170°W.

Otolith and fin ray samples from small (<100 cm EFL) and large (≥ 210 cm EFL in the western region, and ≥ 180 cm EFL in the central and eastern regions) striped marlins are severely underrepresented across all regions (Figure 5). Geographically, sampling in the western region was highly concentrated, while the eastern region exhibited more dispersed sampling (Figure 6). However, there is a notable scarcity of samples north of 31°N in all three regions, and even south of 30°N, certain areas remain unrepresented in each region.

References

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Table 1. Number of biological samples of three billfish species in the North Pacific Ocean collected by Japan from January 2019 to November 2024.

Species	Year	Gonad		Otolith	Dorsal fin	Anal fin	Muscle	Lens
		Raw	Frozen					
Blue marlin	2019	0	0	2	25	27	0	0
	2020	0	0	0	0	0	0	0
	2021	5	15	18	21	20	21	0
	2022	14	1	12	16	12	17	0
	2023	14	0	13	14	14	14	8
	2024	7	0	7	7	3	7	7
	Total	40	16	52	83	76	59	15
Striped marlin	2019	0	7	27	51	53	5	0
	2020	8	2	7	11	11	11	0
	2021	43	24	44	59	59	63	0
	2022	27	34	56	48	42	70	0
	2023	508	3	391	386	379	393	108
	2024	233	8	132	136	128	137	133
	Total	819	78	657	691	672	679	241
Swordfish	2019	0	78	44	18	36	61	0
	2020	2	39	42	41	32	42	0
	2021	69	11	78	78	50	81	0
	2022	29	10	20	16	14	21	0
	2023	374	33	294	85	286	294	215
	2024	157	21	139	40	137	139	139
	Total	631	192	617	278	555	638	354

Table 2. Number of biological samples of three billfish species in the North Pacific Ocean collected by Japan from January 2019 to November 2024 that were provided to Taiwan and the United States.

Nation	Species	Sample	Total number of samples	Number of samples exchanged
Taiwan	Blue marlin	Raw gonad	40	36
		Otolith	52	52
		Dorsal fin	83	57
The United States	Striped marlin	Raw gonad	819	792
	Swordfish	Otolith	617	430
		Anal fin	555	539

Table 3. Number of swordfish gonads and striped marlin otoliths and dorsal fin ray samples from three countries collated by Japan.

Region	Nation	Swordfish		Striped marlin	
		Gonad		Otolith	Spine
		Raw	Frozen		
Western	Japan	498	126	602	626
	Taiwan	0	29	0	62
	US Hawaii	0	0	0	0
	Total	498	155	602	688
Central	Japan	136	49	57	68
	Taiwan	0	74	7	18
	US Hawaii	181	0	108	35
	Total	317	123	172	121
Eastern	Japan	0	19	2	2
	Taiwan	0	6	0	0
	US Hawaii	190	0	127	70
	Total	190	25	129	72

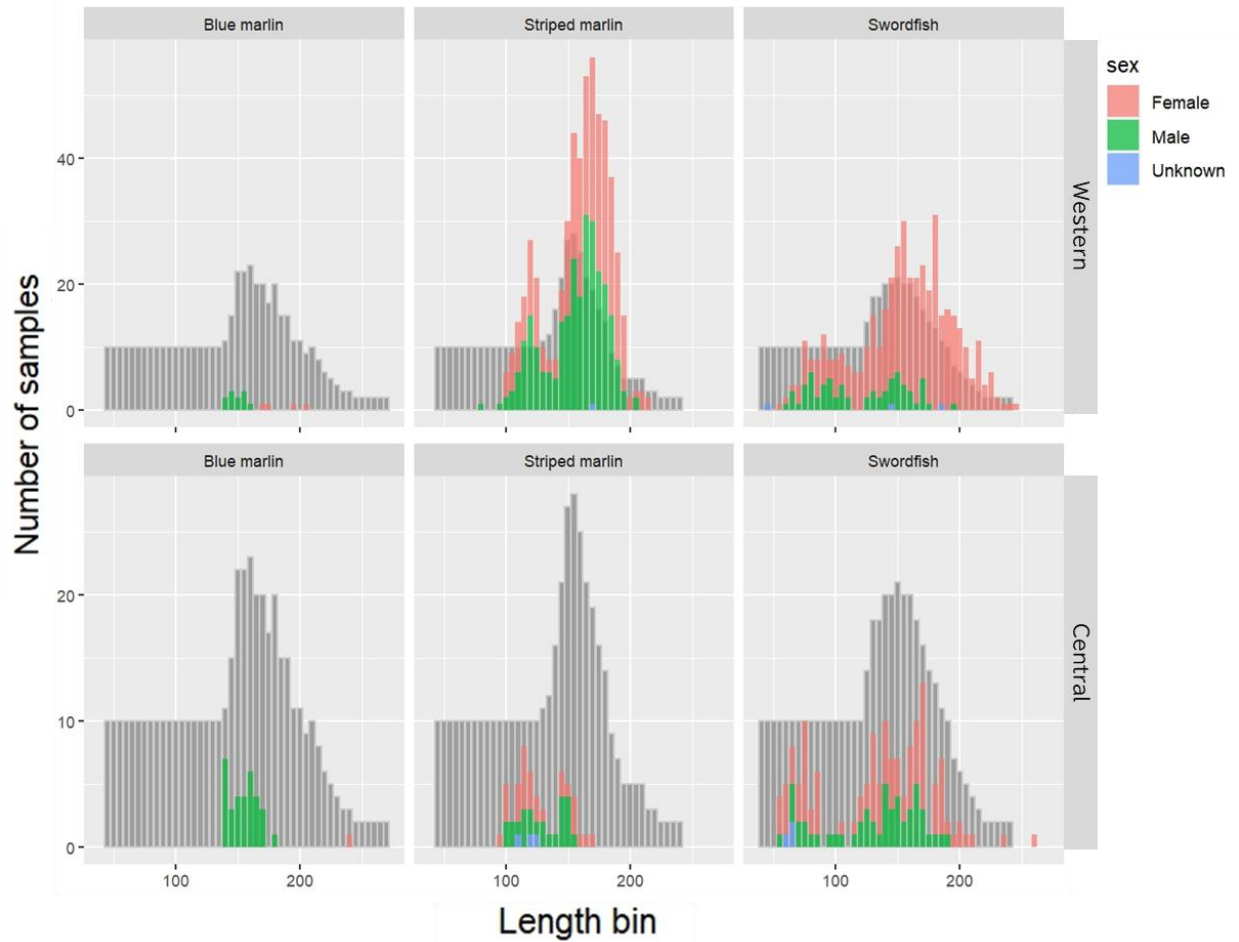


Figure 1. Size frequency distribution (5 cm bins) by sex (female, male, and unknown), including the corresponding targets (grey bars), for three billfish species collected by Japan in the western and central north Pacific Ocean from January 2019 to November 2024.

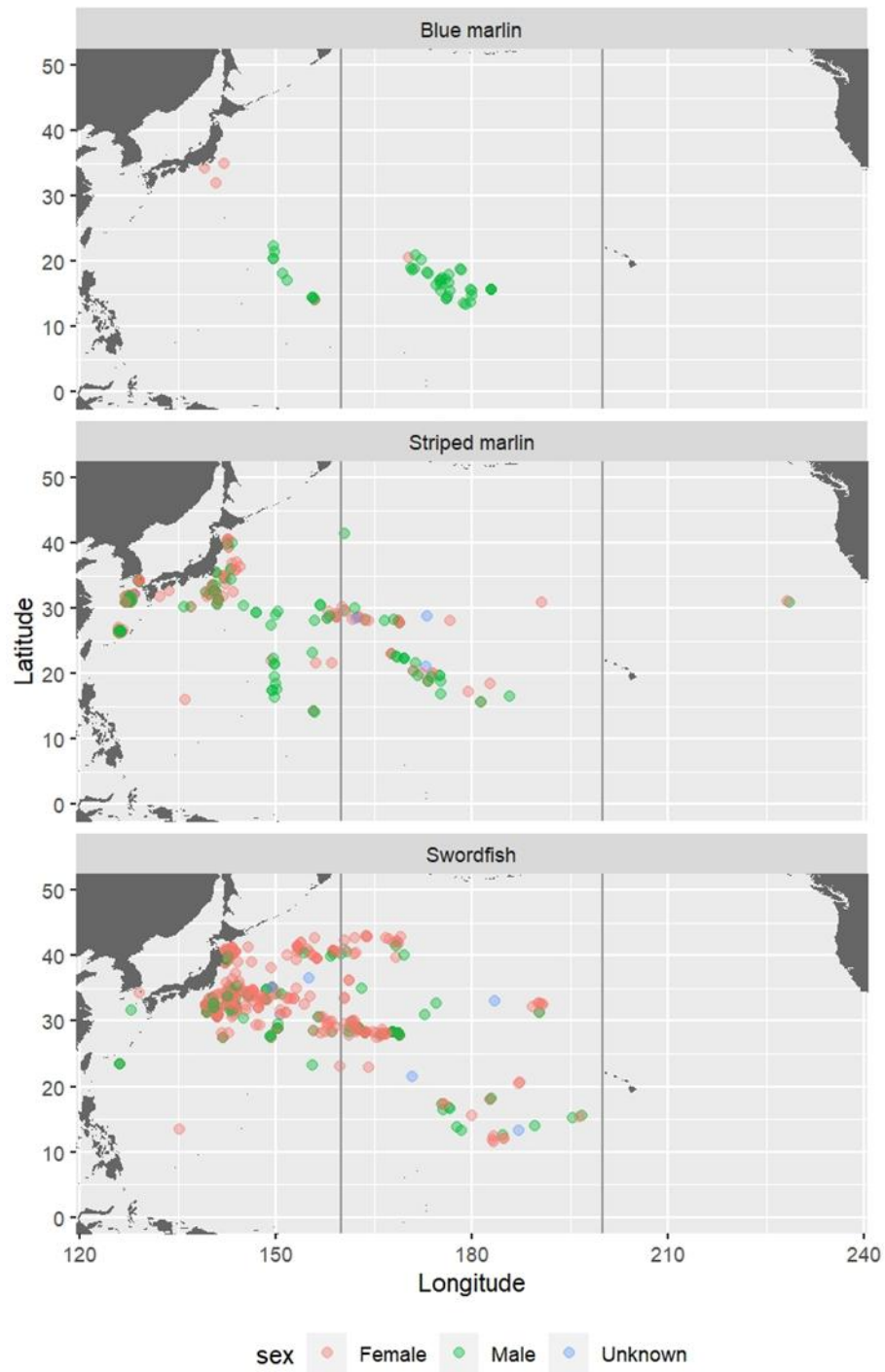


Figure 2. Sampling locations by sex (female, male, and unknown) for three species collected by Japan in the north Pacific Ocean from January 2019 to November 2024.

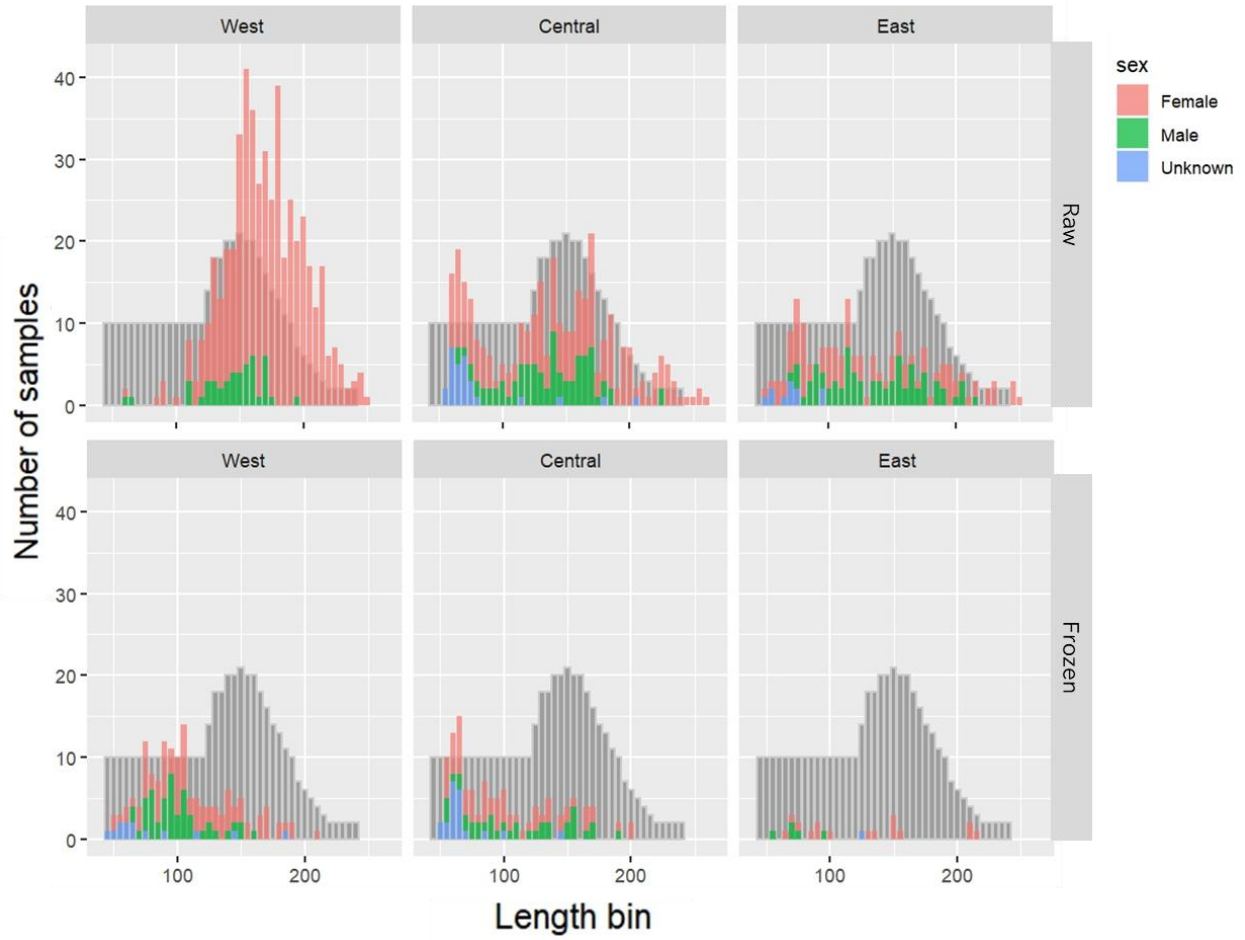


Figure 3. Size frequency distributions (5 cm bins) by sex (female, male, and unknown), preservation method (raw and frozen), and region (west, central, and east Pacific Ocean), including the corresponding targets (grey), for swordfish collated by Japan for gonad extraction.

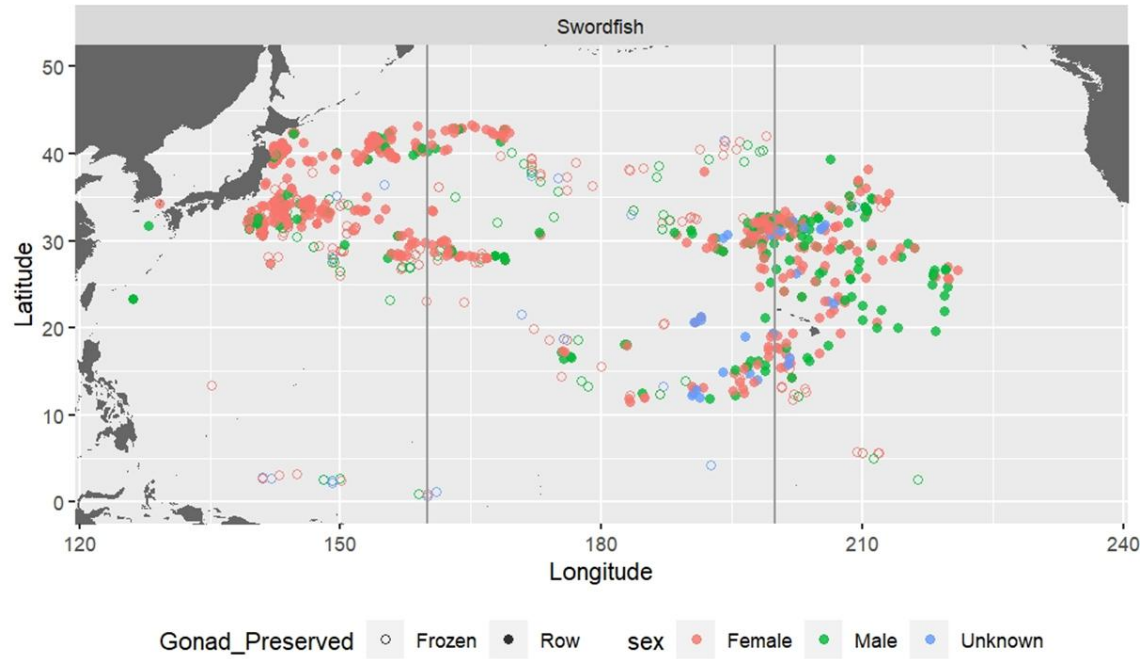


Figure 4. Sampling locations by sex (female, male, and unknown) and preservation method (frozen and raw) for swordfish collated by Japan for gonad extraction.

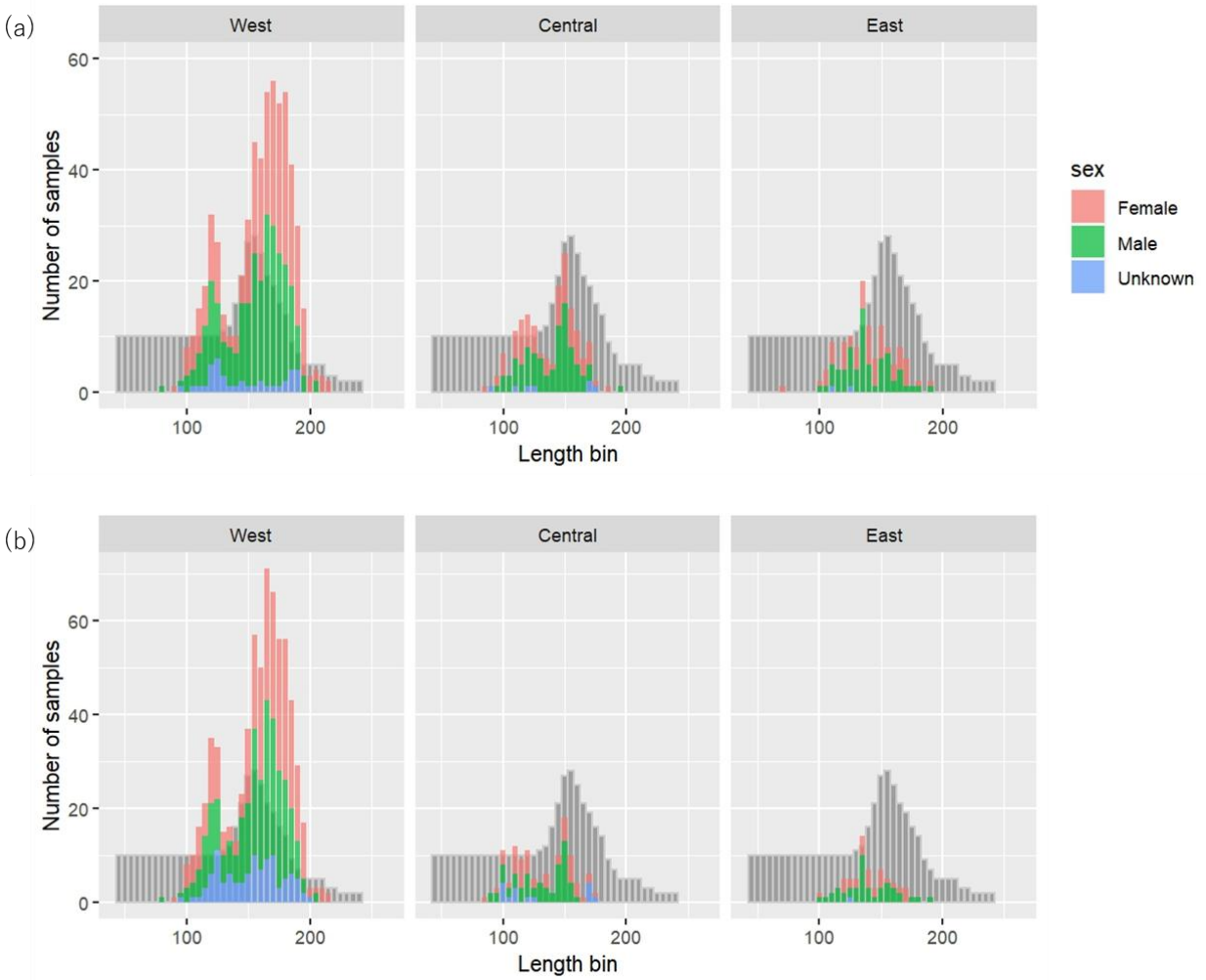


Figure 5. Size frequency distributions (5 cm bins) by sex (female, male, and unknown) and region (west, central, and east North Pacific Ocean), including the corresponding targets (grey), for striped marlin collated by Japan for (a) otolith and (b) anal fin ray extraction.

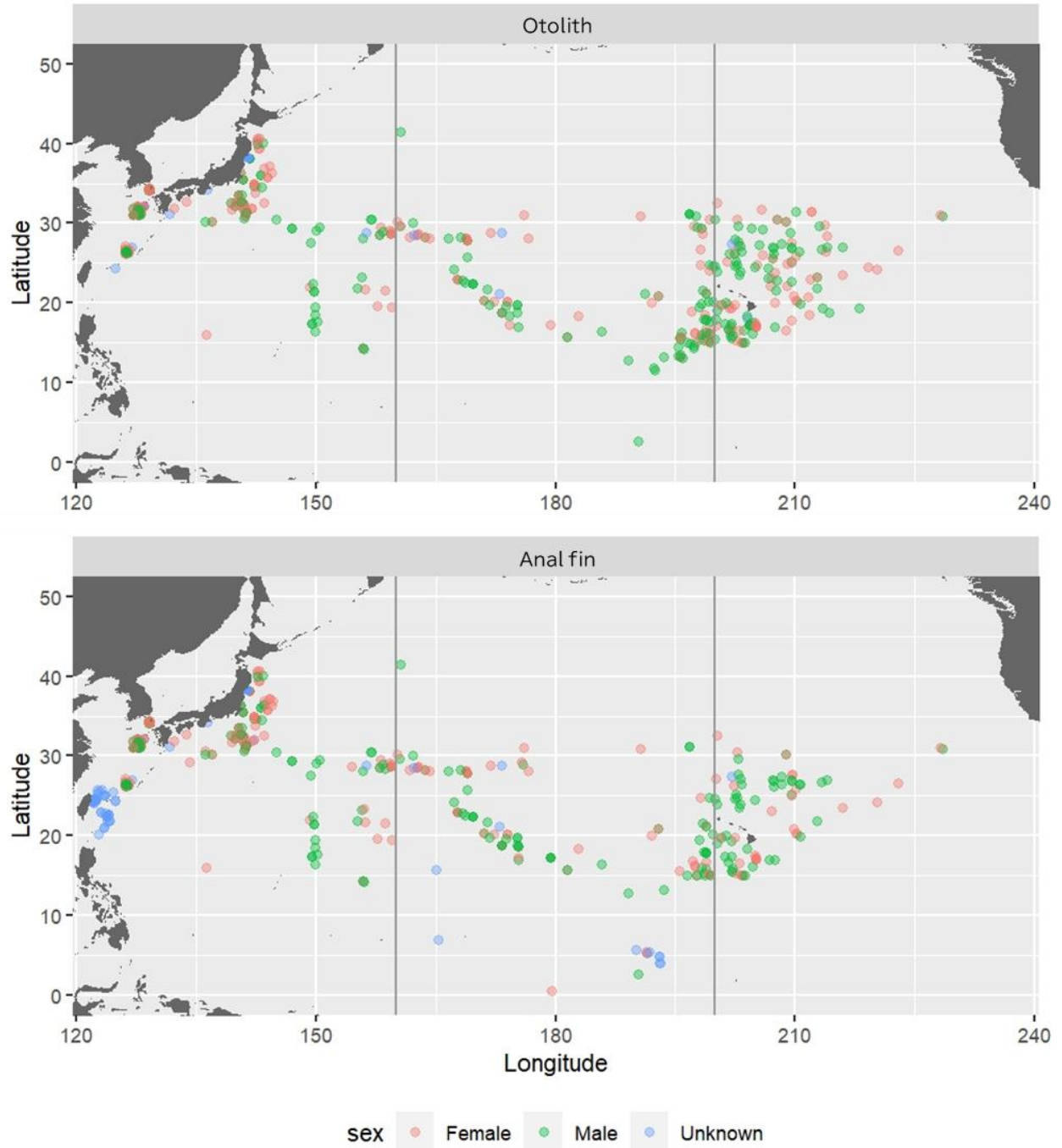


Figure 6. Sampling locations by sex (female, male, and unknown) for swordfish collated by Japan for (a) otolith and (b) anal fin ray extraction.