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**Progress on Taiwan's Biological Sampling of three  
Billfish Species caught in the Pacific**

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## Abstract

The International Billfish Biological Sampling (IBBS) program, launched by the ISC Billfish Working Group in 2020, aims to improve stock assessments of highly migratory billfish species by reducing uncertainties in key biological parameters. Taiwan has contributed to the program by collecting biological samples of blue marlin (*Makaira nigricans*), striped marlin (*Kajikia audax*), and swordfish (*Xiphias gladius*) from longline fishing vessels between 2020 and 2024. Samples include muscle tissue, fin spines, gonads, otoliths, vertebrae, and eyeballs, with muscle tissue being the most frequently collected. Spatial analysis showed distinct distribution patterns among species, with gaps noted in the Eastern Pacific. International sample exchanges began in 2023, enhancing collaboration among Taiwan, the United States, and Japan. Identified gaps in size and spatial coverage highlight the need for targeted sampling to better support stock assessments. This study demonstrates the importance of international cooperation in managing billfish populations.

## Introduction

The ISC Billfish Working Group (BILLWG) formally launched the International Billfish Biological Sampling System (IBBS) project in 2020, led by the U.S. National Oceanic and Atmospheric Administration (NOAA). The project aims to reduce uncertainties in key biological parameters required for stock assessments of highly migratory billfish species. Through collaboration between the United States, Japan, and Taiwan, the program seeks to establish a representative and spatially comprehensive biological sample repository for billfish, with broad coverage of size classes (Kinney *et al.*, 2020). This working report summarizes the current status of Taiwan's biological sampling efforts and the number of samples shared with the United States and Japan. Additionally, it discusses future sampling plans to further improve the representativeness and utility of the collected data for stock assessments.

## Materials and Methods

Taiwan has conducted biological sampling of Pacific swordfish (*Xiphias gladius*), striped marlin (*Kajikia audax*), and blue marlin (*Makaira nigricans*) aboard longline fishing vessels through the observers since 2020. The sampling program collects various biological samples, including muscle, fin spines, heads, vertebrae, and gonads. For each specimen, the biological measurements such as lower jaw fork length (LJFL in cm), body weight (in kg), and sex, along with capture location (latitude and longitude) are recorded. Otolith extraction was mainly conducted by laboratory staff, a smaller portion collected by observers during at-sea operations, and these were stored at room temperature in vials. From each fish, two to three spines, including the primary (longest) spine, were collected from both the dorsal and anal fins. Fin spine samples were stored by air-drying at room

temperature. Eyeballs, muscle tissue, and vertebral samples were preserved through freezer storage at  $-20^{\circ}\text{C}$ . The international exchange of billfish biological samples commenced in April 2023. Taiwan provided gonad, otolith, and dorsal fin samples of striped marlin to Japan and otolith and anal fin spine samples of swordfish to the United States. In return, Taiwan received gonad, otolith, and dorsal fin samples of blue marlin from Japan and the United States.

## Results and Discussions

Taiwan collected 149 samples of blue marlin, 176 samples of striped marlin, and 514 samples of swordfish during 2020 - 2024 in the Pacific Ocean. The spatial distribution of these samples is shown in **Figures 1-3**, with detailed sample counts provided in **Table 1**. More specifically, blue marlin samples were mainly collected in tropical and subtropical waters ( $20^{\circ}\text{N}$ - $20^{\circ}\text{S}$ ). Striped marlin samples were predominantly collected between  $20^{\circ}\text{N}$ - $40^{\circ}\text{N}$ , focusing on the Western and Central Pacific regions. Swordfish showed the most extensive coverage, spanning  $40^{\circ}\text{N}$  to  $40^{\circ}\text{S}$  with concentrations off Japan, the Central Pacific, and New Zealand waters. For all three species, muscle tissue was the most frequently collected biological sample, with collection rates of 82% (122/149) for blue marlin, 78% (138/176) for striped marlin, and 88% (451/514) for swordfish. Gonad and fin samples were also extensively sampled, although otolith samples were generally collected in smaller numbers, particularly for blue marlin (24 samples) and striped marlin (52 samples). Eyeball collection rates were relatively low: 13-26% across species (19 blue marlin, 34 striped marlin, and 134 swordfish samples). Vertebrae were the least collected tissue type, with only 11% collection rates for both blue marlin (17 samples) and swordfish (54 samples), while no vertebrae were collected from striped marlin.

Measurements of body length and weight for all sampled specimens of each species are presented in **Table 2**. The average length and weight of blue marlin were 182.7 cm LJFL and 44.1 kg, respectively; for striped marlin, 185.1 cm LJFL and 39.3 kg; and for swordfish, 124.9 cm LJFL and 27.2 kg. **Figure 4** illustrates the annual size distributions (length and weight) of three billfish species from 2020 to 2024. The length distributions showed that swordfish generally centered around 100-150 cm, while blue marlin typically peaked around 180-200 cm and striped marlin ranged from 150-200 cm. Weight distributions suggested that most swordfish concentrated between 20-50 kg, blue marlin peaked between 40-60 kg, and striped marlin primarily fell between 30-50 kg. All species exhibited right-skewed weight distributions, with some individuals reaching 150-200 kg.

**Figure 5** shows the size-frequency distribution (in 5 cm bins) by sex for three billfish species across three regions of the North Pacific (Western:  $<160^{\circ}\text{E}$ ; Central:  $160^{\circ}\text{E} - 160^{\circ}\text{W}$ ; and Eastern:  $>160^{\circ}\text{W}$ ). Most biological samples were obtained from the

Western and Central Pacific regions. The eastern Pacific ( $>160^{\circ}\text{W}$ ) had notably fewer samples across all species. Striped marlin samples in the eastern Pacific were primarily between 180-200 cm LJFL, while swordfish showed scattered size distributions. This suggested the sampling gaps, particularly in the eastern Pacific, and highlighted the need for increased sampling effort in this region, especially for swordfish over 150 cm LJFL and striped marlin either below 150 cm LJFL or above 210 cm LJFL.

## **References**

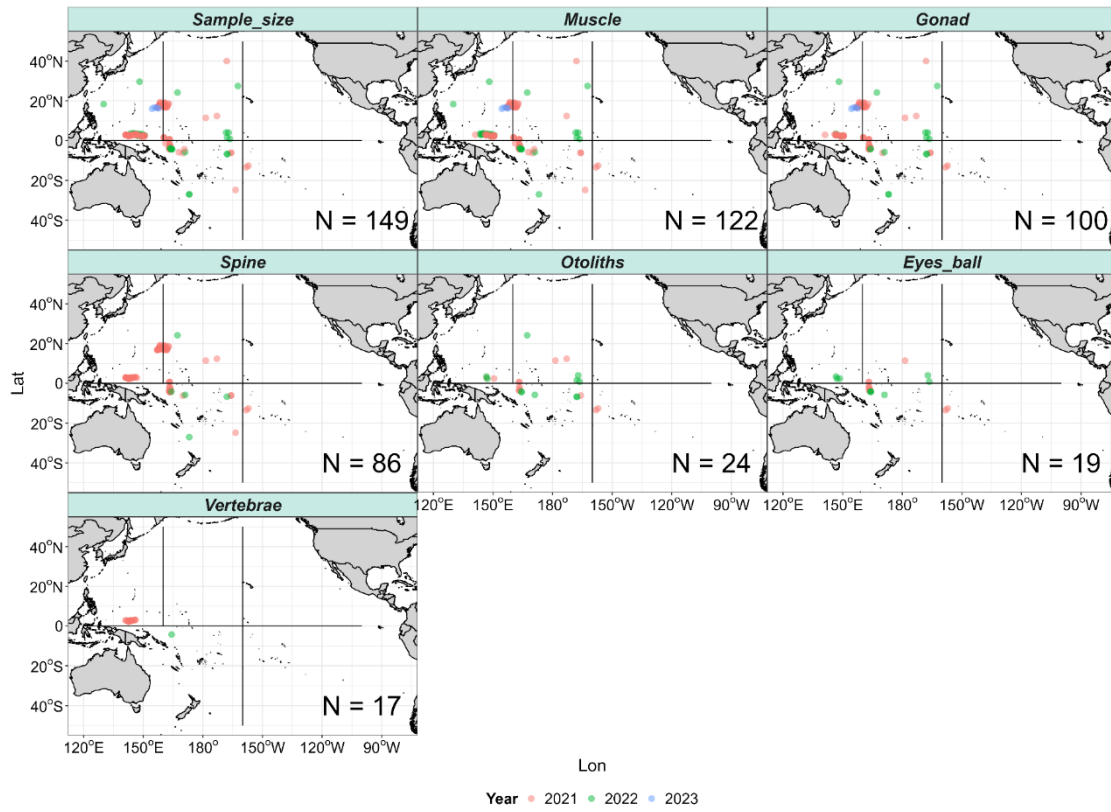
- Kinney, M.J., Chang, Y.J., Ijima, H., Kanaiwa, M., Schemmel, E., and O'Malley, J. 2020. Length-based proportional sampling for life history research: establishing uniform sampling for North Pacific billfish species. ISC/20/BILLWG-02/01.
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**Table 1.** Annual observer sampling summary of three billfish species by various parts from 2020 to 2024. Species codes: BUM = blue marlin, MLS = striped marlin, SWO = swordfish. Tissue categories include total sample size (number of specimens) and counts of collected muscle, gonad, fin spine, otolith, eye, and vertebrate samples.

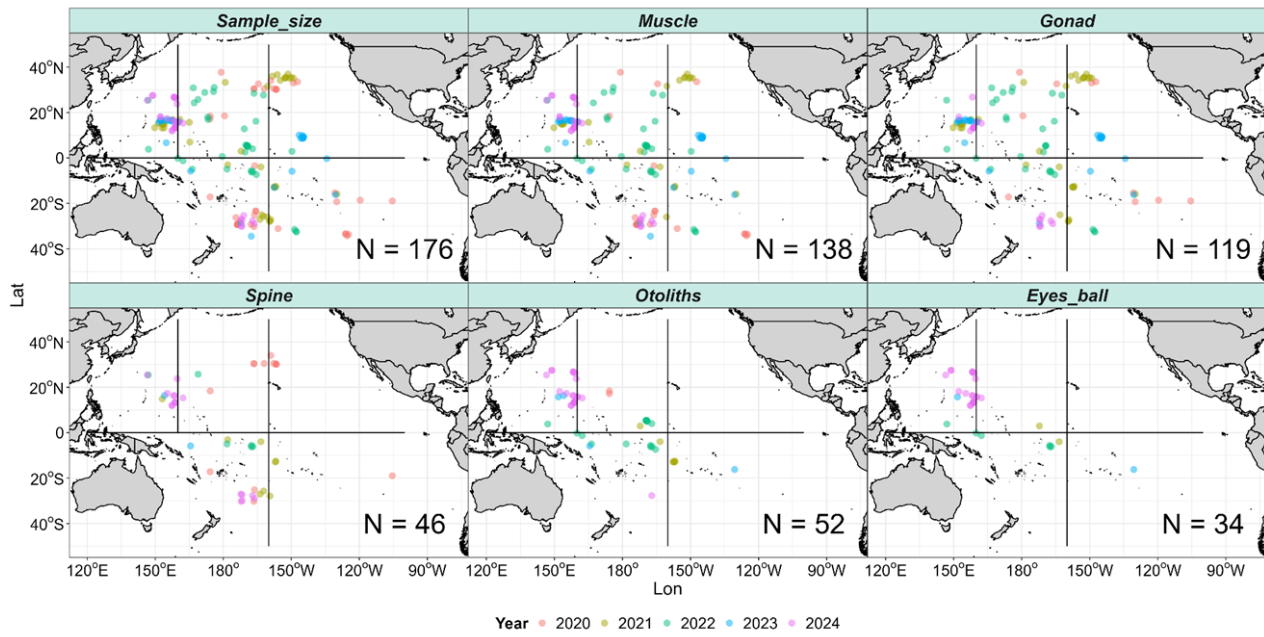
<b>Year</b>	<b>Sample size</b>	<b>Muscle</b>	<b>Gonad</b>	<b>Spine</b>	<b>Otolith</b>	<b>Eyes ball</b>	<b>Vertebrates</b>
<b>BUM</b>							
2021	105	84	79	81	13	10	16
2022	40	34	17	5	11	9	1
2023	4	4	4	0	0	0	0
Total	149	122	100	86	24	19	17
<b>MLS</b>							
2020	39	22	10	13	2	0	0
2021	39	22	34	8	6	2	0
2022	35	33	29	6	15	6	0
2023	31	31	29	2	4	2	0
2024	32	30	17	17	25	24	0
Total	176	138	119	46	52	34	0
<b>SWO</b>							
2020	126	103	103	84	66	0	0
2021	200	178	126	146	130	43	18
2022	150	133	68	126	129	64	27
2023	38	37	18	30	33	27	9
Total	514	451	315	386	358	134	54

**Table 2.** Summary statistics of lower jaw fork length (LJFL, cm) and weight (kg) measurements for three billfish species sampled by observers from 2020 to 2024. Species codes: BUM = blue marlin, MLS = striped marlin, SWO = swordfish. Statistics include sample size, mean, standard deviation (SD), maximum (Max), and minimum (Min) values for each measurement type.

	<b>Species</b>	<b>Sample size</b>	<b>Mean</b>	<b>SD</b>	<b>Min</b>	<b>Max</b>
<b>LJFL (cm)</b>	BUM	149	182.7	25.3	136	284
	MLS	176	185.1	32.4	88	254
	SWO	514	124.9	48.5	53	280
<b>Weight (kg)</b>	BUM	149	44.1	25.1	15	200
	MLS	176	39.3	22.7	4	136
	SWO	514	27.2	35.7	1	200

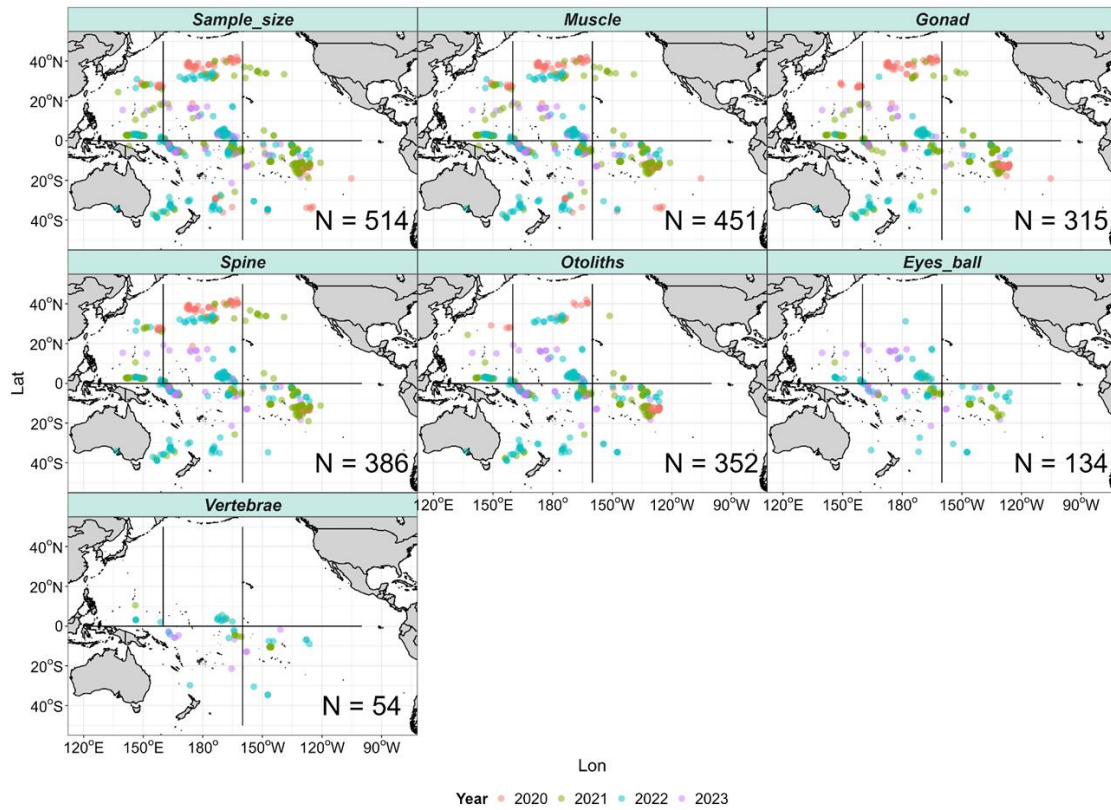


**Figure 1.** Spatial distribution of blue marlin biological samples (muscle, gonad, spine, otoliths, eyes, and vertebrae) collected by Taiwanese observers in the Pacific Ocean from 2021 to 2023.

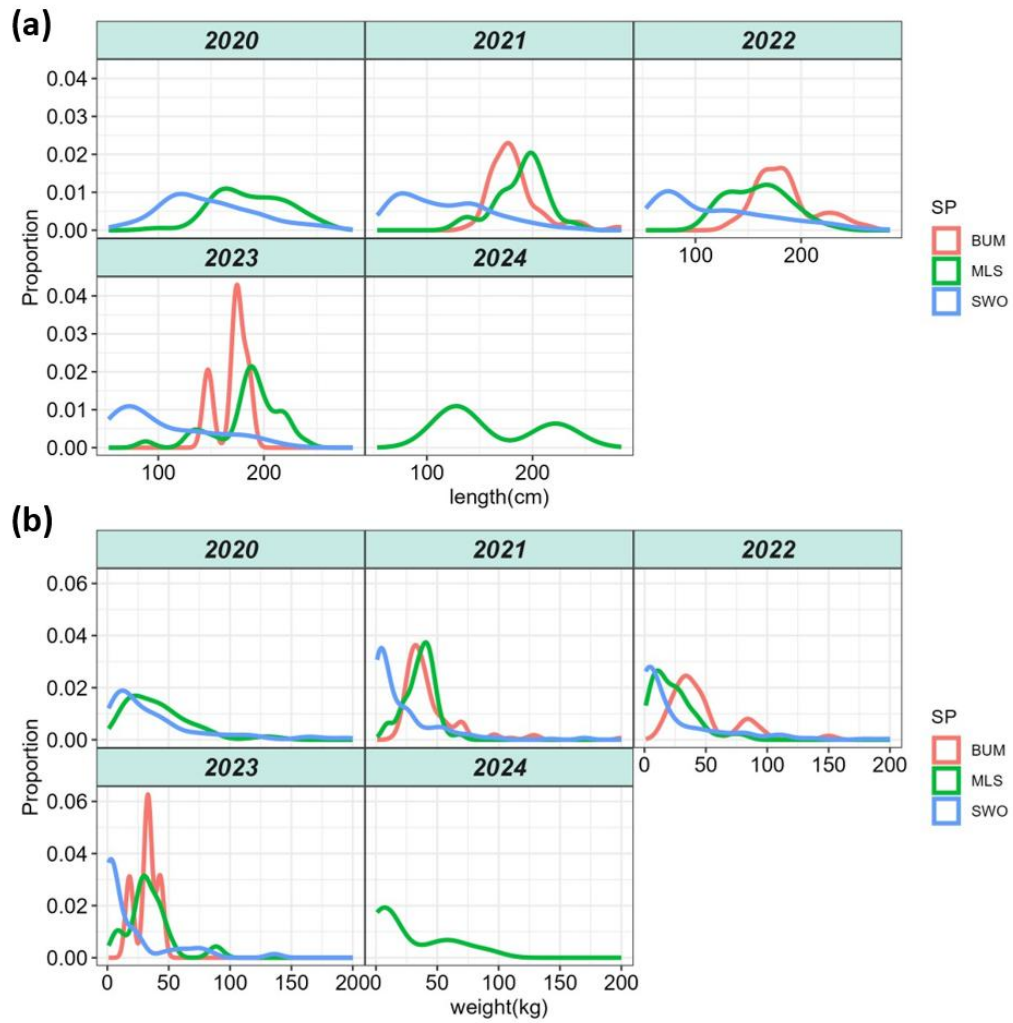


**Figure 2.** Spatial distribution of striped marlin biological samples (muscle, gonad, spine, otoliths, and eyes) collected by Taiwanese observers in the Pacific Ocean from 2020 to 2024.

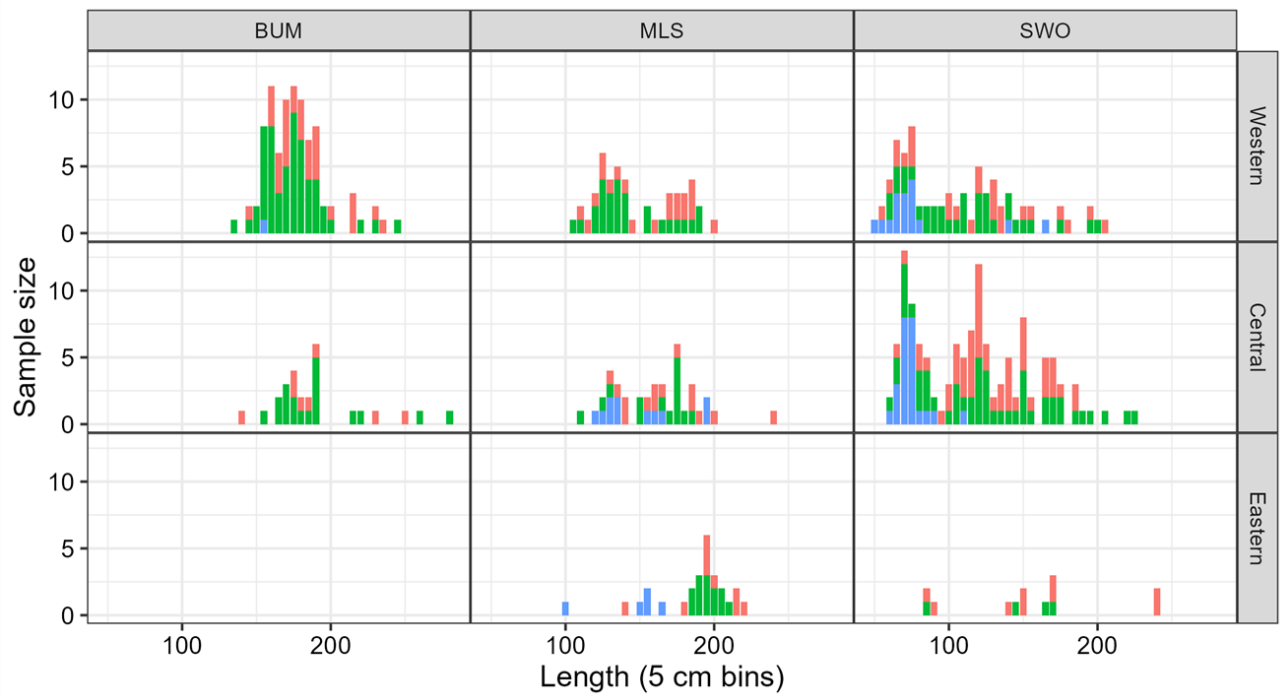




**Figure 3.** Spatial distribution of striped marlin biological samples (muscle, gonad, spine, otoliths, eyes and vertebrae) collected by Taiwanese observers in the Pacific Ocean from 2020 to 2023.



**Figure 4.** Length (a) and weight (b) distributions of blue marlin, striped marlin, and swordfish collected through Taiwanese observer sampling.



**Figure 5.** Size frequency distribution (5 cm bins) by sex (female, male, and unknown) for three billfish species collected by Taiwanese observers in the North Pacific Ocean.