



Observations of Oceanic Whitetip Sharks, *Carcharhinus longimanus*, a globally threatened species, in the Papahānaumokuākea Marine National Monument (central Pacific)

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Abstract

Oceanic Whitetip Sharks (*Carcharhinus longimanus*) were observed and recorded in surface waters of the Papahānaumokuākea Marine National Monument (PMNM) in the Northwest Hawaiian Islands during launch and recovery of remotely operated vehicle dives in 2025, 2016, and 2015. Video from a forward-looking camera facilitated an assessment of shark presence at dive sites. Observations of *C. longimanus* occurred at or shallower than 50 m and in the northwest region of the Monument during dives in Spring 2025. Only observations of single sharks at single dive sites occurred during the summer 2015 and late-winter early-spring 2016 cruises. In all cases observations were brief, with the highest MaxN values of 3. Associated species included small-sized forage fishes and other piscivores. These observations provide a foundation for addressing the non-random nature of the distribution of oceanic whitetip sharks in the PMNM, the largest U.S. Marine National Monument, and offer insights for future surveys that span the entirety of PMNM.

Key words: ichthyology, elasmobranchs, ROV, video, distribution, MaxN, ocean exploration, marine protected area, Northwest Hawaiian Islands

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Introduction

Highly migratory pelagic predators are often keystone species within marine ecosystems, representing critical targets for conservation. However, effective management is a significant challenge given the wide distributions, large movement rates, and low population sizes of pelagic predators that limit direct observational data (Block et al. 2011). Additional challenges arise when such species occur within spatially extensive and remote marine protected areas (MPAs), where significant knowledge gaps remain regarding the influence of management on the demographics of species and their functional role in moderating ecological interactions, community structure, and species diversity. Simple information on patterns of occurrence within a MPA can aid development of questions regarding population and community processes, aid in developing assessment approaches to refine management policy and alternatives, and focus conservation attention.

The Oceanic Whitetip Shark, *Carcharhinus longimanus* (Poey, 1861), occurs in epipelagic waters in tropical and subtropical regions of the global ocean. Molecular data demonstrating genetic structure in *C. longimanus* (Ruck et al. 2024) suggests that there are two distinct populations: one in the Atlantic, and a second in the Indo-Pacific that is considered to represent a single interbreeding population. *C. longimanus* are considered highly migratory yet may demonstrate site fidelity: recent satellite telemetry revealed *C. longimanus* movements across distances of more than 1,600 to 7,800 km (Burkhardt et al. 2025), with several individuals returning to their original tagging areas. Evidence from stable isotopes suggests that there is limited sexual differentiation in behavior, with males and females sharing similar trophic positions, movement patterns, and feeding strategies (Shen et al. 2022, 2024). While recent work has greatly advanced our understanding of *C. longimanus* behaviors, additional research on population structure and movement patterns is needed to reveal the environmental and genetic factors driving differences within populations and across ocean basins. Population declines over the past several decades led to the protection of *C. longimanus* as a threatened species throughout its range under the United States Endangered Species Act in 2018 (NMFS 2025).

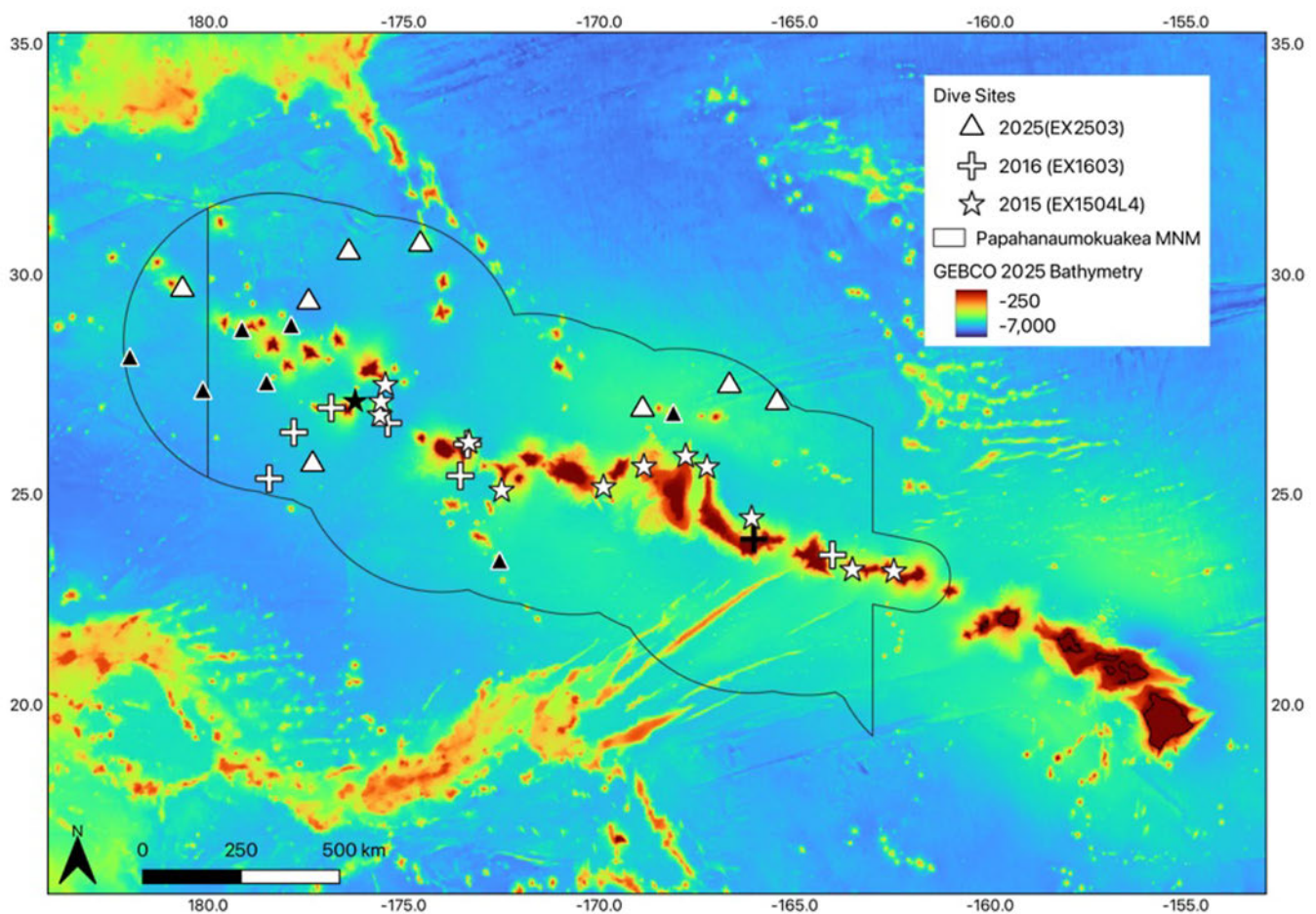


Figure 1. Map of ROV dive locations within the Papahānaumokuākea Marine National Monument from 2015 (star), 2016 (cross), and 2025 (triangle); presence of Oceanic Whitetip Sharks indicated by solid black fill.

The Papahānaumokuākea Marine National Monument (PMNM), designated in 2016, is located in the central Pacific Ocean, northwest of the main Hawaiian Islands (Fig. 1). PMNM is the largest highly protected area (*sensu* Sullivan-Stack et al. 2022) in the U.S. system, encompassing a region of more than 1.14 million km² (over 440,000 sq. miles) that contains diverse habitats, from atoll-reef island systems to the abyssal plains. Given the central importance of Papahānaumokuākea in Hawaiian cosmogonies and wayfinding stories (Kikiloi et al. 2017), the management of PMNM uniquely combines both natural and cultural elements to protect the region's diverse ecosystems and cultural heritage sites. Recognizing both the ecological and cultural values of the area, designation as the Papahānaumokuākea National Marine Sanctuary with overlapping boundaries to the PMNM was finalized in 2025.

Since the Monument was proposed and ultimately designated, several U.S. deep-sea exploration expeditions were conducted by the National Oceanic and Atmospheric Administration (NOAA) as part of their multi-year CAPSTONE and Beyond the Blue Campaigns. Using a remotely operated vehicle (ROV), video observations at the surface and in epipelagic waters were facilitated during descent and ascent and revealed the presence of *C. longimanus*. Here we report locations where *C. longimanus* were observed within PMNM, link these observations to their broader geographic distribution, and use the limited data currently available to develop hypotheses for assessing *C. longimanus* conservation within a large marine protected area.

Materials and Methods

Video data used in this study were collected by the ROV *Deep Discoverer* operating from the NOAA Ship *Okeanos Explorer* on three separate cruises in 2015 (EX1504L4, Kennedy et al. 2019); 2016 (EX1603, Wagner et al. 2020); and 2025 (EX2503, cruise report in prep). *Deep Discoverer* is a dual-body ROV system with a 6,000 m rating (Kennedy et al. 2019). Imagery was recorded using an Insite Pacific Zeus Plus 3 HD camera with 2/3 inch 2,200,000 pixel 1080i sensors and a 5.2–52 mm zoom lens behind a corrected optical port. Video was recorded in PRORES 1080i format.

Continuous video was collected during each dive, including during vehicle launch, descent, ascent and recovery. During these launch and recovery intervals, the ROV is either stationary along the Z-axis (at the surface or at 50 m depth) or vertically moving through the water column at speeds of <1 m/sec and is being pulled ahead into the current by the ship at a speed of 0.1–0.5 kts (0.05–0.25 m/sec).

To characterize *C. longimanus* and associated taxa (i.e., apex predators, small forage fish) from ROV video obtained during launch and recovery windows, we used maximum number (MaxN) counts to estimate *C. longimanus* presence (Wilson et al. 2015). MaxN is the maximum number of individuals in any instantaneous field of view of the video camera during each observation period. This metric is used in remote-video observations as it is considered a robust and conservative estimate that is minimally impacted by repeated sightings (Langlois et al. 2020). We restricted our observation of *C. longimanus* to the top 50 m depth noting that no observations of this species have been made at depths beyond 50 m. The sharks were identified to species in both nearfield and far-field views from the HD camera, along with other apex and higher-trophic-level predators.

We used ROV-based measurements of environmental parameters to contextualize our observations in PMNM. *Deep Discoverer* is equipped with a Sea-Bird SBE 911+ conductivity-temperature-depth (CTD) system with dissolved oxygen (DO) sensors to characterize in-situ environmental conditions during each dive (Galvez et al. 2025). To represent near-surface conditions, we estimated temperature (°C), salinity (PSU) and dissolved oxygen (mg/liter) data from ROV-based CTDs by averaging measurements from the upper 10 m of each dive to account for potential variability resulting from the placement of sensors along the ROV body

Results

Observations from 37 dive sites from PMNM across three expeditions during 2015, 2016, and 2025 revealed that *C. longimanus* predominantly occur within the northwestern and western region of PMNM (Fig. 1), with most ROV-based observations being recorded during a single cruise in 2025 (Table 1). Across the two cruises and 21 dives conducted in 2015 and 2016, only one individual was observed each year (Table 2).

Dive No.	Date	Site Name	Latitude	Longitude	Min Seafloor Depth	Dive Time	Surface Observati on Time	MaxN	max tem	min tem	max DO	min DO	Notable pelagic taxa
1	11-Apr	Unnamed Seamount 01 (South of Murray Fracture Zone)	27.114 N	-165.4439 W	1687	7:44:19	0:19:20	0	21.864	21.560	7.232	7.174	
2	12-Apr	Murray Fracture Zone	27.50227 N	-166.66476 W	4719.6	10:09:03	0:31:31	0	22.715	21.445	7.240	0.000	swordfish
3	13-Apr	Unnamed Guyot 01 (Northeast of Volador Seamount)	26.8778 N	-168.0968 W	880.7	8:15:34	0:35:25	1	22.645	22.009	7.227	7.157	small forage sp.
4	14-Apr	Unnamed Seamount 02 (Northwest of Volador Seamount)	26.9598 N	-168.88486 W	1486.3	8:06:20	0:00:28	0	22.879	21.789	7.237	7.134	small forage sp.
5	17-Apr	Solide Seamount	30.6746 N	-174.5662 W	1111	7:57:05	0:32:16	0	18.024	18.022	7.773	7.757	
6	19-Apr	USS Yorktown	RESTRICTED		5148.2	10:09:53	0:36:25	0	19.777	19.766	7.488	7.475	
7	20-Apr	USS Yorktown	RESTRICTED		5154.1	10:01:39	0:33:00	0	19.680	19.673	7.511	7.492	
8	21-Apr	Midwater Site 01	29.3908 N	-177.4237 W	300	8:08:31	0:34:25	0	20.460	20.427	7.384	7.375	small forage sp.
9	22-Apr	Wentworth Seamount	28.8761 N	-177.8707 W	2026	8:11:24	0:35:24	1	20.426	20.250	7.396	7.371	pilot fish
10	23-Apr	Unnamed Seamount 03 (Northwest of Hōlanikū - Kure Atoll)	28.7794 N	-179.1267 W	1365.2	8:11:14	0:30:45	3	21.105	20.971	7.287	7.271	pilot fish, small forage sp.
11	24-Apr	Unnamed Seamount 04 (Northwest of Hōlanikū - Kure Atoll)	29.6711 N	179.3488 E	367.1	7:11:03	0:33:10	0	19.538	19.459	7.564	7.551	
12	25-Apr	Unnamed Seamount 05	28.1575 N	178.005 E	2253.3	7:51:51	0:29:55	1	22.972	22.772	7.053	7.030	pilot fish, small forage sp.
13	26-Apr	Deep Volcanic Dome - Extreme Western Papahānaumokuākea	27.4015 N	179.8723 E	4163.8	10:19:54	0:41:08	3	23.878	23.459	6.962	6.889	swordfish
14	27-Apr	Unnamed Seamount 06 (South of Hōlanikū - Kure Atoll)	27.5796 N	-178.5012 W	2229.3	8:08:34	0:30:00	3	23.904	23.559	6.940	6.906	Mako, dolphinfish, pilot fish, small forage sp.
15	28-Apr	Unnamed Seamount 07 (Southwest of Salmon Bank)	25.6926 N	-177.3213 W	2244	7:23:16	0:38:40	0	24.124	23.885	6.901	6.879	small forage sp.
16	30-Apr	Paul Seamount	23.4457 N	-172.5411 W	1737.9	8:02:33	0:31:30	1	26.162	26.159	6.695	6.685	

Table 1. Details of dive locations and presence of OWTs from 2025 cruise (EX 2503). Position is decimal degrees (USS *Yorktown* location protected). Minimum seafloor depth during each dive is in m. Total dive time is launch to recovery. Surface observation time is at 50 m depth to the surface (both in hh:mm:ss). Near surface oceanographic conditions (0–10 m depth) are maximum & minimum temperature (°C) and dissolved oxygen (mg ml⁻¹) as measured on ascent. MaxN is the maximum number of individual OWTs in an instantaneous field-of-view during the observation period.

Dive No.	Date	Site Name	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Min Seafloor Depth (m)	Dive Duration (hh:mm:ss)	MaxN	temp max	temp min	DO.max mg.mL	DO.min mg.mL
1	27-Feb-2016	Ridge NE of Necker Island	23.57326	-164.02763	4292	2:18:00	0	23.7167	23.6	6.9958	6.98732
2	28-Feb-2016	Canyon N of FFS	23.94473	-166.03708	1405	5:18:00	1	22.5403	22.522	7.1359	7.11556
3	2-Mar-2016	S Pioneer Bank Ridge	25.42439	-173.54362	2357	4:57:00	0	22.0656	22.034	7.1409	7.12732
4	4-Mar-2016	Pinnacle N of Pioneer Bank	26.15336	-173.36317	1513	5:12:00	0	22.4655	22.345	7.0697	7.054
5	5-Mar-2016	Seamount E of Bank 9	26.64254	-175.39842	1757	5:19:00	0	21.5047	21.481	7.2117	7.19447
6	9-Mar-2016	Seamount W of Salmon Bank	26.9926	-176.84571	1293	8:52:00	0	19.6448	19.644	7.3881	7.38075
7	10-Mar-2016	Castellano Seamount	26.43077	-177.8011	2019	5:40:00	0	21.8835	21.809	7.129	7.11212
8	11-Mar-2016	Seamount SW of Castellano Seamount	25.35972	-178.43078	3987	3:19:00	0	22.661	22.468	7.0883	7.07744
1	2-Aug-2015	East Necker Seamount	23.2217167	-163.51767	-2217	7:59:30	0	27.1368	27.087	6.6693	6.66231
2	3-Aug-2015	North FFS Seamount	24.4352333	-166.095	-2459.9	8:03:44	0	27.4087	27.363	6.7037	6.68
3	4-Aug-2015	St. Rogation Rift Zone Ridge	25.6263667	-167.2392	-2150.5	8:07:49	0	27.396	27.353	6.6314	6.62567
4	5-Aug-2015	Maro Crater	25.16005	-169.8837	-3032.2	9:26:58	0	28.1042	28.1	6.5578	6.54811
6	7-Aug-2015	W Northampton Seamount	25.0816167	-172.48902	-1987.7	7:45:22	0	28.0592	28.051	6.5451	6.53739
8	9-Aug-2015	Bank 9 South	26.82195	-175.6066	-1378.1	8:20:01	0	28.1042	28.001	6.5289	6.51694
9	10-Aug-2015	E Salmon Bank	27.1404	-176.23273	-2282.2	8:14:35	1	27.6834	27.617	6.5876	6.57714
11	12-Aug-2015	Bank 9 North	27.1330333	-175.57085	-2137	8:01:26	0	27.9851	27.943	6.5158	6.50613
12	13-Aug-2015	SE Pearl & Hermes	27.5168833	-175.45938	-2791.2	10:06:24	0	28.1121	28.09	6.4975	6.48758
14	15-Aug-2015	N Pioneer Ridge	26.2011333	-173.3242	-1644.1	7:56:22	0	27.9642	27.904	6.5145	6.51179
16	17-Aug-2015	Gardner Terrace	25.63785	-168.8498	-1558.6	8:11:54	0	27.472	27.281	6.5808	6.56797
17	18-Aug-2015	E North Gardner	25.8804167	-167.78128	-2083.4	10:21:52	0	27.5138	27.459	6.5472	6.53884
18	20-Aug-2015	W Nihoa	23.1841333	-162.457	-1598.2	6:35:15	0	27.3593	27.335	6.6504	6.63761

Table 2. Details of dive locations and presence of OWTs from 2016 and 2015 cruises (EX 1603 and 1504L2) with site names from cruise reports (Wagner et al. 2020, Kelly et al. 2019). Positions in decimal degrees. Seafloor depth for each dive is in m. Total dive time is launch to recovery (hh:mm:ss). Near surface oceanographic conditions (0–10 m depth) are maximum & minimum temperature (°C) and dissolved oxygen (mg ml⁻¹) as measured on ascent. MaxN is the maximum number of individual OWTs in an instantaneous field-of-view during the observation period. Only 1 OWT was observed each year across all dives (no video from surface waters available for dives 5, 7, 10, 13, 15 in 2015 so deleted from the summary table).

The highest MaxN values of *C. longimanus* at each site was relatively low. The highest values (the maximum number of individuals in an instantaneous field of view) were recorded in 2025, where three sites in the westernmost region of PMNM had a MaxN of 3. The majority of observations were of solitary individuals (MaxN = 1) and most often co-occurred with forage fishes, alongside other apex and higher-trophic-level predators, within surface waters and the epipelagic zone.

Common forage fishes observed aggregating and dispersing around individual sharks included the Pilotfish *Naucrates ductor* and several genera of schooling fishes, likely *Decapturus*, *Atule*, and *Uraspis* (Figs. 2 & 3). Several other apex predators were also observed associating with the *C. longimanus*, including Common Dolphin *Coryphaena hippurus*, Swordfish *Xiphias gladius*, and the Pacific Shortfin Mako *Isurus oxyrinchus* (Fig. 4). While total observation time was limited, we observed no predation on other fishes.

All observations of *C. longimanus* occurred near the surface (<50 m) in localities overlying seafloor bathymetries of a variety of depths and topographies. Across all sites, absolute water depth ranged from 360 to 5100 m, with the majority of sightings at the surface, overlying water depths between 880 and 4300 m. Given the limited observations available for 2015 and 2016 cruises, we parsed temperature, salinity, and dissolved oxygen observations from the top 10 m by the presence (n=60) or absence (n=78) of *C. longimanus* from 2025 dives to



Figure 2. Oceanic Whitetip Sharks, *Carcharhinus longimanus*, and associated fishes as viewed by the ROV HD camera within the Papahānaumokuākea Marine National Monument, including Pilotfish *Naucrates ductor* and other schooling fishes.



Figure 3. Schooling fishes associated with Oceanic Whitetip Sharks, *Carcharhinus longimanus*, including *Decapturus*, *Atule*, and *Uraspis*, within the Papahānaumokuākea Marine National Monument.

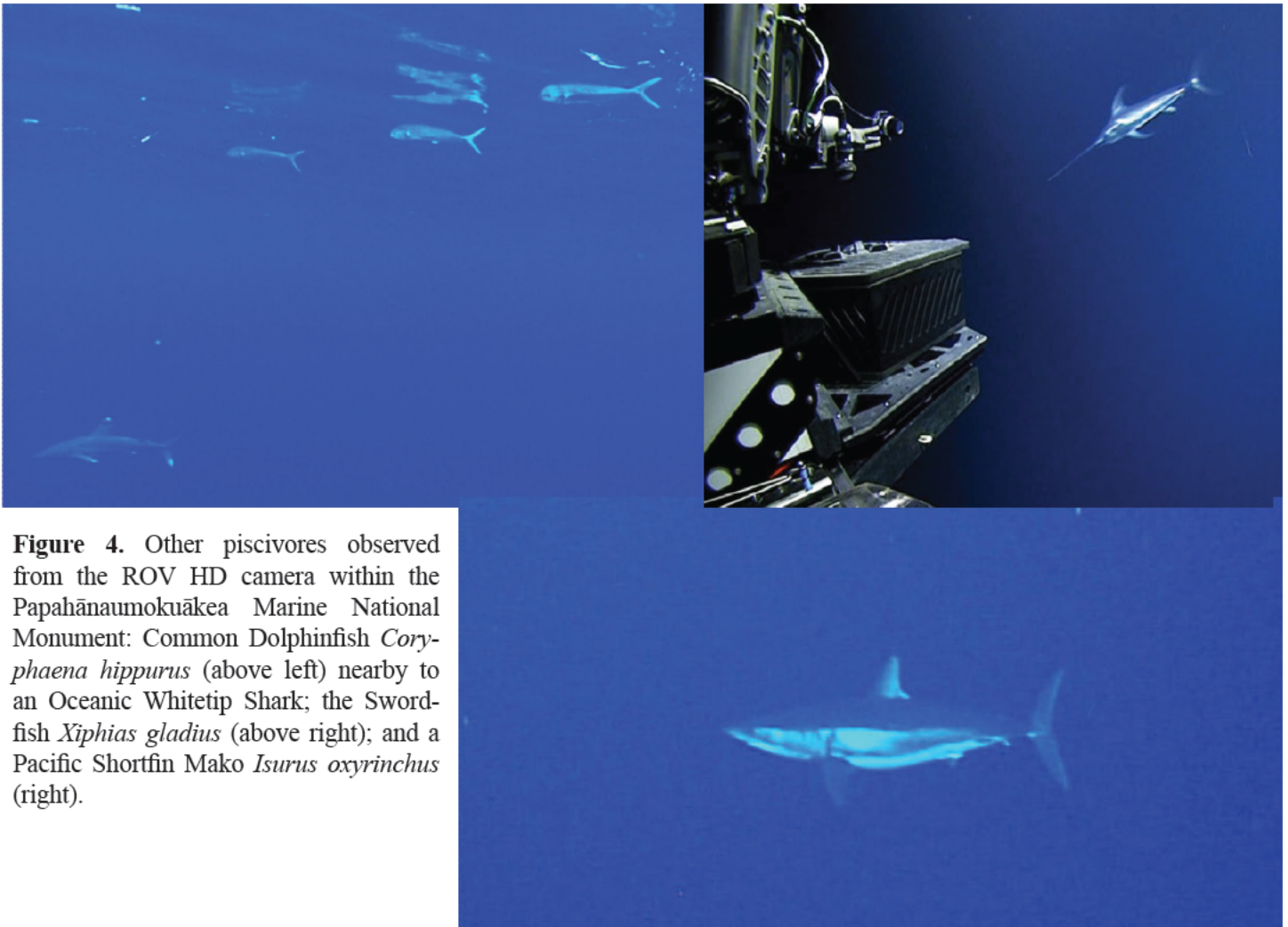


Figure 4. Other piscivores observed from the ROV HD camera within the Papahānaumokuākea Marine National Monument: Common Dolphinfish *Coryphaena hippurus* (above left) nearby to an Oceanic Whitetip Shark; the Swordfish *Xiphias gladius* (above right); and a Pacific Shortfin Mako *Isurus oxyrinchus* (right).

assess whether observations are correlated with key environmental parameters. Analysis of variance reveals that sites with *C. longimanus* had significantly higher temperatures (mean 22.7°C vs 21.1°C; $F=27.51$, $p<0.001$) and salinity values (mean 35.3 vs 35.1 PSU; $F=31.6$, $p<0.001$) than sites without *C. longimanus*. Dissolved oxygen was not significantly different across sites (mean 7.09 vs 7.23 mg/liter; $F=1.59$, $p=0.210$) (e.g. Fig. 5).

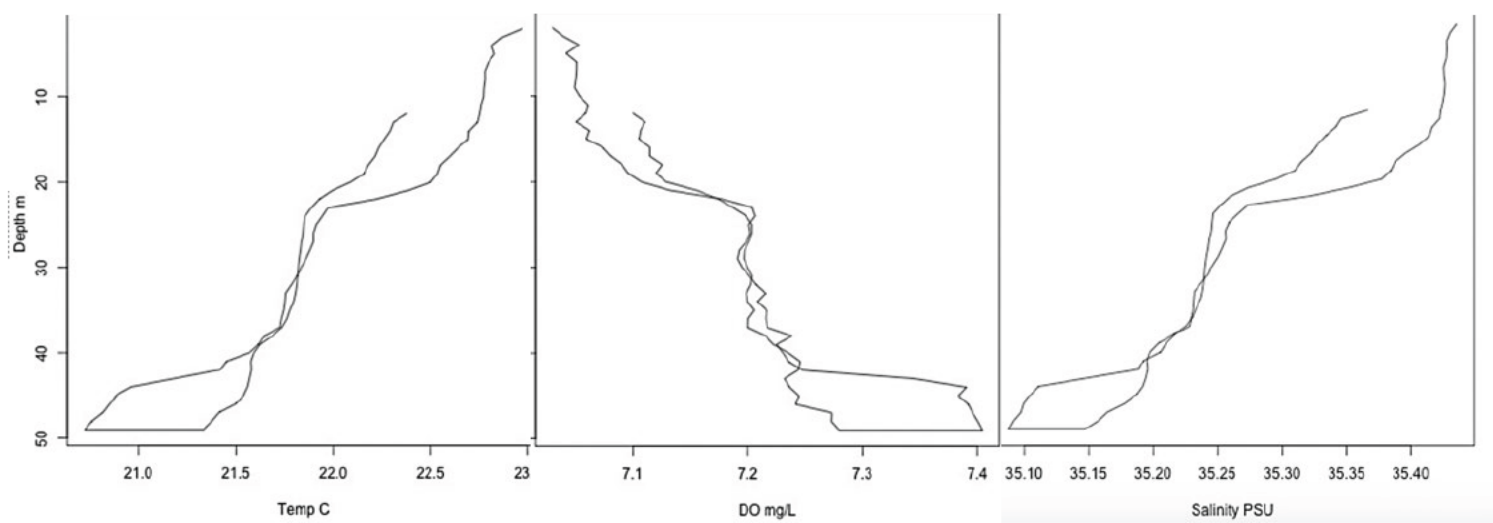


Figure 5. Examples of temperature, oxygen, and salinity profiles through the top 50 m of the water column within the Papahānaumokuākea Marine National Monument during dive 12 from 2025 cruise. Lines to surface (top of graph) are for ascent at end of dive. Lines beginning at 10 m are from descent and start of data acquisition.

Discussion

The observations of the Oceanic Whitetip Sharks we report here were obtained via opportunistic sampling conducted across several months spanning a decade. Dive sites were not revisited, limiting our ability to interpret long-term patterns. ROV cameras consistently recorded high-resolution video during the 2016 and 2025 expeditions, but gaps were present in video logs from several descents during the 2015 expedition. In addition, the field of view of the camera is limited, even with wide-angle optics. We note, however, that individual sharks observed in the main ROV camera were also captured in other cameras across the dual-body ROV system. As a result, we interpret video and associated still images as *ad hoc* samples that provide an estimate of presence, rather than representing true presence-absence data. Thus, the patterns we note here, such as greater occurrences of *C. longimanus* in 2025 vs. dives a decade prior, are tentative, and could reflect either increases in abundance or some other undetermined factor. Despite the limiting factors precluding a robust assessment of population size, structure, and distribution, our observations can assist in guiding future research and management in PMNM.

The presence of small schooling fishes around and proximate to *C. longimanus* was frequent. This association may be analogous to the association of Round Scad *Decapterus punctatus* and Sand Tiger Sharks *Carcharias taurus* in the western North Atlantic (Coleman & Burge 2021), where sharks were interpreted as providing a refuge from predation for the scad when other predators were present and when fear responses were elicited. If so, it may expand the ecological role of *C. longimanus* beyond functioning solely as apex predators (*sensu* Dedman et al. 2024).

Our observation of more frequent occurrences in the northwestern portion of PMNM warrants future research effort. Oceanographic conditions within PMNM exhibit broad spatiotemporal variability, in part due to the region's location at the northern edge of the subtropical Pacific (Follett et al. 2021). The northernmost atolls in PMNM lie within a major ecological transition zone, where rapid changes to sea surface temperatures, nutrient availability, and chlorophyll concentrations are thought to drive seasonal variability in forage habitat for several migratory marine predators (Polovina et al. 2001, Baker et al. 2007, Polovina et al. 2008, Polovina et al. 2017). During fall-winter months, this transition zone reaches as far south as Kuaihelani (Midway Atoll; 28°N), driving increases in regional ocean productivity and resulting recruitment success for species such as Hawaiian Monk Seals *Neomonachus schauinslandi* (and ocean-feeding seabird populations (Polovina et al. 2008, Baker et al. 2007). In addition, individual islands and atolls within PMNM are known to drive localized upwelling of cool, nutrient-rich water enhancing phytoplankton biomass, a phenomenon known as the island mass effect (De Falco et al. 2022). Biological productivity is especially enhanced in the lee of islands (typically to the west of islands in both the Main and Northwestern Hawaiian Island chain).

It is possible that *C. longimanus*, like other migratory predators, track productivity gradients across PMNM. While our dataset is limited, most of our observations occurred during a single month (April 2025) when the transition-zone chlorophyll front reached ~28°N in latitude (NASA 2025). Higher densities of *C. longimanus* have been observed along the western leeward coastlines of the main Hawaiian Islands, peaking during the spring months (Scott et al. 2025), when heightened eddy activity drives localized upwelling (Lindo-Atichati et al. 2020). In the western Indian Ocean, higher probabilities of *C. longimanus* sightings occur during months when upwelling is strongest (Lopetegui-Eguren et al. 2022). The apparent preferences of *C. longimanus* for relatively cool, productive waters may drive the spatial patterns we observed within PMNM.

The interactions between mesoscale oceanographic processes that generate upwelling and eddy formation, leading to cooling surface waters, vs. larger-scale climate-driven increases in surface-water temperatures and coincident reductions of oxygen levels, would greatly affect prey availability for predators. Such climate-driven changes may compress the vertical and horizontal distribution of *C. longimanus*, which may increase the vulnerability of epipelagic sharks to overfishing and industrial activities such as mining (Hazen et al. 2012, Dedman et al. 2024). The increase in observations of *C. longimanus* in 2025 relative to previous deep-sea expeditions in PMNM highlights the need to evaluate whether conservation management is responsible for the apparent increased the population size of this threatened species. Assessments across the range of *C. longimanus* based on observed and reported catch appear to indicate reduced mortality since its designation as a protected species (Worm et al. 2024).

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