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Preliminary report of "Pacific Tuna and Ecosystem Research Cruise Project" in 2024

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Summary:
This document reports the preliminary results of a research survey investigating the survival and recruitment processes of three main tropical tuna (skipjack, yellowfin and bigeye) in their early life stages and their relationship with oceanographic conditions in the tropical-subtropical region. The survey was conducted using the R/V Kaiyo-Maru in the central and western Pacific Ocean in 2024. The cruise consisted of two main legs. The first leg (Leg 1) from Harumi in Tokyo to Pohnpei during 4 September and 1 October. It was set to survey an area spanning 170°E–170°W along the equator. The second leg (Leg 2) from Pohnpei to Saipan from 4 to 21 October. It surveyed a north-south line on the 150–160°E and 0–15°N. The oceanographic conditions within the research area exhibited the typical characteristics of an equatorial divergence region along the east-west Leg 1 transect and a transition towards the North Pacific subtropical gyre along the south-north Leg 2 transect. A total of 677 tuna larvae were collected as a result of on-board sorting, using ring net, bongo net and MOHT. A further 196 juveniles tuna were collected using a mid-water trawl at different depths. The number of larvae and juveniles collected was clearly greater on Leg 2 than on Leg1. In addition, a stratified collection was conducted using a NORPAC net and a VMPS to clarify the zooplankton that could be the food of tuna larvae. The vertical distribution and densities of zooplankton and micronekton were measured acoustically using three equipment with different frequencies: WBAT, AZFP and TAPS. This research cruise obtained biological samples, oceanographic data and acoustic data from the central and western Pacific Ocean. This information will help to clarify the dynamics and functions of the early life stages of larval tuna in marine ecosystems as well as the recruitment processes in this area. We also plan to conduct a similar survey in 2025, at the same time of the year and in the almost same area as in 2024.

Keywords: Tuna and tuna like fishes, Larval survey, International collaborative research, Pacific Ocean, Climate changes

Introduction

The tropical and subtropical regions in the central and western Pacific Ocean are important fishing grounds for many countries as well as being a major spawning ground for tropical tuna species such as skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*). Understanding the early survival and ecology of tropical tuna species in this area is essential for investigating the recruitment process and population dynamics. For this reason, larval and juvenile fish surveys have been conducted mainly by Japanese research vessels for some time. Early research into the early life ecology and the spawning habitats of those tuna species in this area was conducted from the 1950s to the 1980s (Matsumoto, 1958; Nishikawa et al., 1985). Several research projects on this topic were subsequently carried out from the 1990s to the 2010s. These research cruises have produced many reports on tropical tuna species from the larval to juvenile stages (e.g. Chow et al., 2003; Tanabe and Niu, 1998; Tanabe et al., 2017; Kiyofuji et al., 2019). However, many aspects remain unknown due to the wide range of their spawning areas.

The new research project, the "Pacific Tuna and Ecosystem Research Cruise Project", began in 2024 in collaboration with the FRA, the SPC and the IRD (Tawa et al., 2024). The main objectives of this research project are (1) to describe spatial and vertical distribution of larvae and juvenile skipjack, yellowfin and bigeye tuna, and its relationship with oceanographic features and the biological environment; and (2) to improve our understanding of the early survival and recruitment process in the Pacific Ocean. The detailed cruise and research plans for this project were reported at WCPFC-SC20 (Tawa et al., 2024).

This document reports on the preliminary results of the first cruise conducted in autumn 2024 as part of the new research project. While most of the results are limited to provisional information obtained on board the vessel, but some also include the results of analyses conducted on land.

Materials and Methods

The first leg (Leg 1) from Harumi in Tokyo to Pohnpei took place from 4 September to 1 October. It was set to survey an area spanning 170°E–170°W along the equator. The second leg (Leg 2) from Pohnpei to Saipan took place from 4 to 21 October. It surveyed a north-south line on the 150–160°E and 0–15°N (**Fig. 1**). A total of 16 monitoring stations were set up each leg. There are two types of station: "long" and "short", defined by the time spent on station. Intensive observations, were conducted both at the long station (red star in **Fig. 1**) for three days and at the short station for one day (solid circle in **Fig. 1**); long station differ from short station by including midwater trawl. The details of the monitoring stations and research contents are shown in **Table 1**.

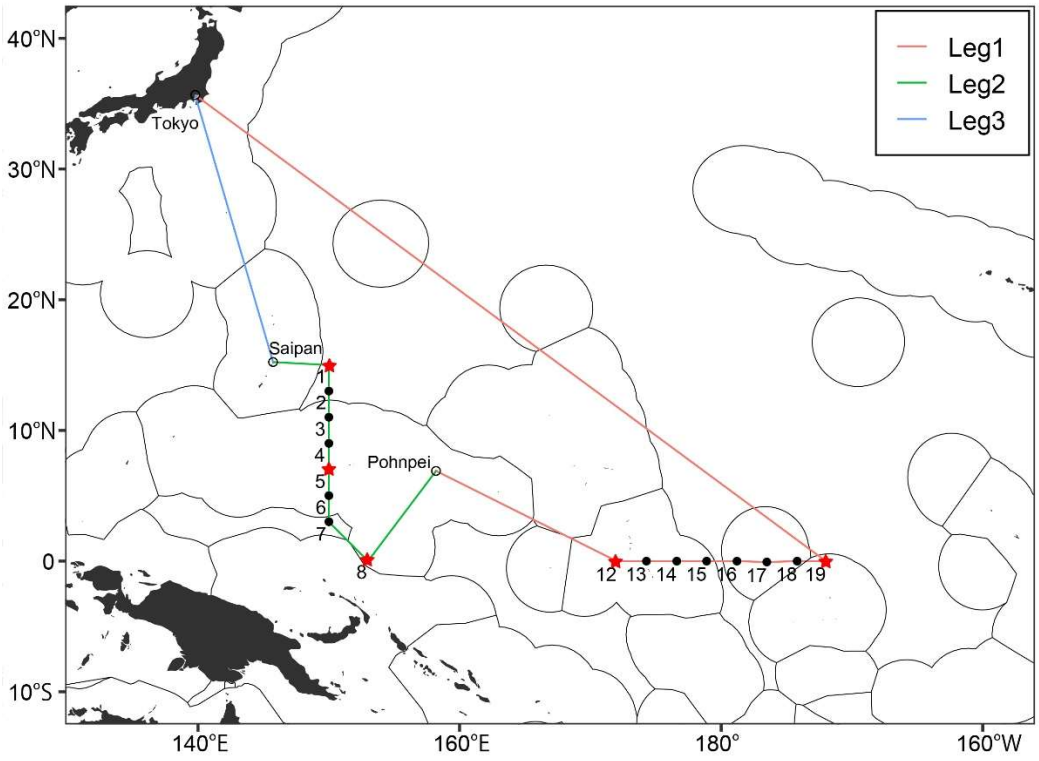


Figure 1 All monitoring stations of KY2405 cruise, where midwater trawling, zooplankton sampling, acoustic survey and oceanographic monitoring were conducted, and actual cruise track. There are two types of station: "long" (red star) and "short" (solid circle). Long station (three days) differ from short station (one day) by including midwater trawl. The red, green and blue lines indicate the first, second and third legs of the cruise, respectively. Monitoring started at station 19 and ended at station 1.

Table 1 Summary of research information at each station. Abbreviation: ln long station _1 indication day 1, _2d indicate day 2, _2n indicate night 2, _3 indicate day 3; SST, Sea Surface Temperature; CTD, Conductivity Temperature and Depth probe; RN0.3, Ring net with 0.334 mm mesh; RN1.0, Ring net with 1.0 mm mesh; MOHT, Matsuda-Oozeki-Hu Midwater Trawl; Norpac, twin-type North Pacific standard net; VMPS, Vertical Multiple Plankton Sampler; WBAT, WideBand Autonomous Transceiver; AZFP, Acoustic Zooplankton Fish Profiler; TAPS, Tractor Acoustic Profiling System.

Leg	Station	Date	Lat	Lat_min	S/N	Lon	Lon_min	E/W	SST	CTD	Sampling gear	Acoustic gear
1	19_1	16-Sep	0	0.037	N	171	59.883	W	27.7	CTD	RN0.3, RN1.0, Trawl, Norpac	WBAT, AZFP
1	19_2d	17-Sep	0	0.019	S	172	0.078	W		CTD		WBAT, AZFP
1	19_2n	17-Sep	0	0.047	S	172	0.647	W	27.6	CTD	MOHT, Trawl	
1	19_3	18-Sep	0	0.045	N	172	2.817	W	27.6	CTD	Trawl, VMPS	
1	18	19-Sep	0	0.045	S	174	11.907	W	27.7	CTD	RN0.3, RN1.0 , Norpac, VMPS	WBAT, AZFP
1	17	20-Sep	0	4.946	S	176	29.894	W	28.8	CTD	RN0.3, Bongo, RN1.0, Norpac, VMPS	WBAT, AZFP
1	16	21-Sep	0	0.022	S	178	48.248	W	28.5	CTD	RN0.3, Bongo, RN1.0, Norpac, VMPS	WBAT, AZFP
1	15	22-Sep	0	0.013	S	178	54.002	E	28.6	CTD	RN0.3, Bongo, RN1.0, Norpac, VMPS	WBAT, AZFP
1	14	23-Sep	0	0.145	N	176	35.98	E	29.0	CTD	RN0.3, Bongo, RN1.0, Norpac, VMPS	WBAT, AZFP
1	13	24-Sep	0	0.164	N	174	17.938	E	29.2	CTD	RN0.3, Bongo, RN1.0, Norpac, VMPS	WBAT, AZFP
1	12_1d	25-Sep	0	0.017	S	171	59.844	E		CTD		WBAT, AZFP
1	12_1n	25-Sep	0	0.153	N	171	59.65	E	30.5	CTD	RN0.3, RN1.0, Trawl, Norpac	WBAT, AZFP
1	12_2	26-Sep	0	0.009	S	172	0.051	E	30.1	CTD	Bongo, Trawl	
1	12_3	27-Sep	0	2.263	N	171	57.384	E	30.0	CTD	Trawl, VMPS	
2	08_1	6-Oct	0	0.102	N	152	59.776	E	31.0	CTD	RN0.3, RN1.0, Trawl, Norpac	WBAT, AZFP, TAPS
2	08_2d	7-Oct	0	0.036	N	152	59.913	E		CTD		WBAT, AZFP, TAPS
2	08_2n	7-Oct	0	0.197	N	152	55.658	E	31.0	CTD	Bongo, Trawl	
2	08_3	8-Oct	0	0.019	N	152	56.98	E	30.9	CTD	Trawl, VMPS	
2	07	10-Oct	3	0.112	N	149	59.899	E	30.8	CTD	RN0.3, Bongo, RN1.0, Norpac, VMPS	WBAT, AZFP, TAPS
2	06	10-Oct	5	0.039	N	150	0.011	E	30.8	CTD	RN0.3, Bongo, RN1.0, Norpac, VMPS	WBAT, AZFP, TAPS
2	05_1	11-Oct	7	0.043	N	149	59.991	E	30.9	CTD	RN0.3, RN1.0, Trawl, Norpac	WBAT, AZFP, TAPS
2	05_2d	12-Oct	6	59.979	N	149	59.997	E		CTD		WBAT, AZFP, TAPS
2	05_2n	12-Oct	6	59.628	N	150	0.013	E	30.6	CTD	MOHT, Trawl	
2	05_3	13-Oct	6	59.763	N	150	2.508	E	30.6	CTD	Trawl, VMPS	
2	04	14-Oct	9	0.003	N	149	50.001	E	30.5	CTD	RN0.3, MOHT, RN1.0, Norpac, VMPS	WBAT, AZFP, TAPS
2	03	15-Oct	11	0.119	N	149	59.953	E	29.9	CTD	RN0.3, MOHT, RN1.0, Norpac, VMPS	WBAT, AZFP, TAPS
2	02	16-Oct	13	0.08	N	149	59.993	E	29.7	CTD	RN0.3, MOHT, RN1.0, Norpac, VMPS	WBAT, AZFP, TAPS
2	01_1d	17-Oct	15	0.054	N	149	59.919	E		CTD		WBAT, AZFP, TAPS
2	01_1n	17-Oct	14	59.998	N	149	59.947	E	29.7	CTD	RN0.3, RN1.0, Trawl, Norpac	WBAT, AZFP, TAPS
2	01_2	18-Oct	15	0.095	N	149	58.84	E	29.6	CTD	MOHT, Trawl	AZFP
2	01_3	19-Oct	15	0.975	N	149	57.599	E	29.6	CTD	Trawl, VMPS	

Oceanographic observations

Vertical observations of water temperature, salinity, dissolved Oxygen content and chlorophyll-a content were made using a CTD (SBE 911plus CTD, Sea-Bird) down to 1500m. Nutrients and chlorophyll-a samples were collected from Niskin-X bottles and were kept frozen until analyses on land. Nutrient concentrations were measured using a colorimetric method (QuAAtro39, BLTEC; Kodama et al., 2014), and chlorophyll-a concentrations were measured fluorometrically (Trilogy, Turner Designs; Welschmeyer, 1994; Suzuki and Ishimaru, 1990).

Echosounders used during the scientific cruise

Assessment of the amount and size of biological organisms was completed by acquiring active acoustic data, both continuously and in station. Several instruments were deployed during the survey, including a Simrad EK80 hull-mounted split-beam echosounder, an Acoustic Doppler Current Profiler (ADCP), and three profilers: the Tractor Acoustic Profiling System (TAPS), the Acoustic Zooplankton Fish Profiler (AZFP) and the WideBand Autonomous Transceiver (WBAT), see **Figure 2**. All acoustic instruments emit echos at a given frequency and record the backscattered intensity, modulated by the obstacles encountered in the path of the acoustic wave (e.g. living organisms).

Hull-mounted echosounders, EK80 and ADCP, sample large volumes over various depth ranges (down to 1000 m, depending on the frequency) and help describe large scale water column patterns (e.g. vertical structuration, diel vertical migrations, differences across various ecosystems…). ADCP specifically measures currents direction and velocity. Data with hull-mounted echosounders were collected continuously along the cruise.

Acoustic profilers (TAPS, AZFP, WBAT) were deployed in stations, lowered down by the side winch to acquire vertical profiles. Profilers are sent into layers at depth, as close as possible to individual organisms, for example, to count and identify them. AZFP and WBAT were deployed between the surface and 600 m depth and TAPS went only down to 200 m, due to its depth limitation. Their sampling range is small (40 m for WBAT, 1.3 m for TAPS and 30 m for AZFP), ensuring that only a small number of distinct organisms are sampled. A combination of hull-mounted echosounders and profilers sent into the water column allows for describing both the large scale and general ecosystems structure and identify what organisms are present at different depths.

According to the frequency they operate, echosounders observe different kinds of

organisms. Low frequencies (≤ 120 kHz) are adapted to micronekton (2-20 cm organisms) while high frequencies (> 120 kHz) are more suited for the study of zooplankton. Because of their operating frequencies, TAPS (265, 420, 700, 1100, 1850 & 3000 kHz) and AZFP (200, 455, 769 & 2000 kHz) mainly focus on zooplankton, WBAT (38 & 120 kHz) on micronekton and EK80 (38, 70, 120 & 200 kHz) on both targets. During the whole cruise (Leg 1 & 2 together), a total of respectively 21, 21 and 11 vertical profiles were acquired with the WBAT, the AZFP and the TAPS.

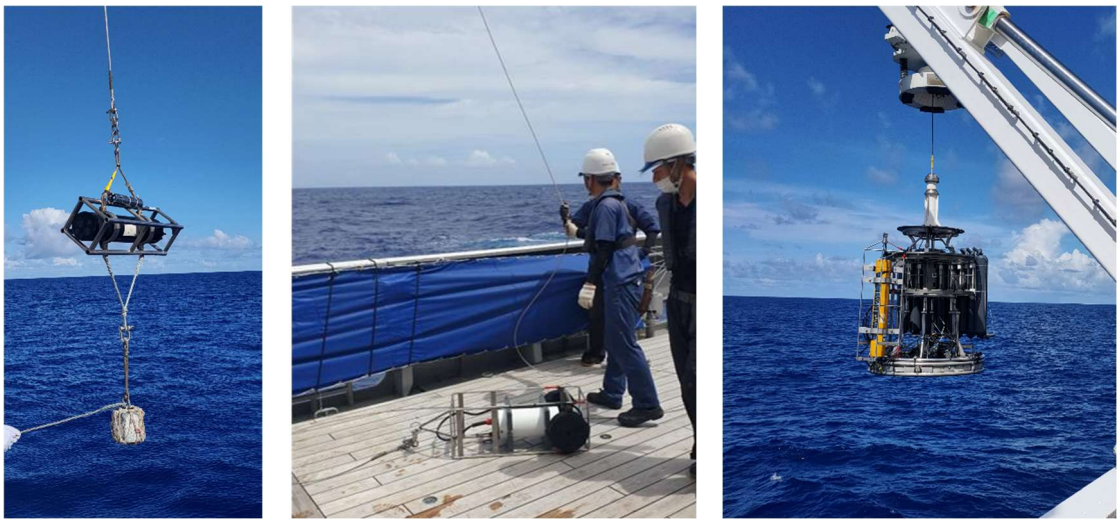


Figure 2 Profilers deployed in Kaiyo-Maru 2405 cruise. Left: Tractor Acoustic Profiling System (TAPS), center: Acoustic Zooplankton Fish Profiler (AZFP) and right: WideBand Autonomous Transceiver (WBAT).

Collection of Biological samples

A stratified collection was conducted using a twin-type North Pacific standard (NORPAC) net and a Vertical Multiple Plankton Sampler (VMPS) to sample the zooplankton that could be the food of tuna larvae. The zooplankton sampling by NORPAC net (mouth diameter, 0.45 m and mesh size, 0.1 mm) was conducted by vertical tow from 200 m depth to the surface. One of the collected samples was fixed in 5% formalin, the other was frozen. Sampling by the VMPS (mouth size, 0.5×0.5 m and mesh size, 0.1 mm) was conducted by vertical tow at four layers: 600–400, 400–200, 200–100 and 100–0 m. VMPS samples were frozen to conduct isotope analysis. The volume of water filtered by the NORPAC net and VMPS was estimated with a mechanical flowmeter installed at the mouth of the net respectively.

Two types of ring net (mouth diameter; 2.0 m, mesh size; 0.334 and 1.0 mm) were towed horizontally in the surface layer to investigate the distributions of tuna larvae. A bongo net (mouth diameter; 0.70 m, mesh size; 0.334 mm) was also towed obliquely at

the different layers (60–40, 40–20 and 20–0m).

Additionally, to investigate vertical distribution of tuna larvae and early juvenile, Matsuda-Oozeki-Hu Midwater Trawl (MOHT) with a mouth area of 5 m^2 and a square mesh of 1.95 mm bar length (1.59 mm square pores) (Oozeki et al., 2004) were conducted by oblique tow at three different depth layers. The depth of the three trawl operations by MOHT will be determined in relation to the warm pool. A scanmar is attached to the net mouth to monitor the depth in real time. SBT500 was attached to obtain depth and water temperature on the tow net layer. The volume of water filtered by the MOHT was estimated with a mechanical flowmeter installed at the mouth of the net.

Midwater trawl (NST-660-SR) with height ca. 45 m × width ca. 40 m net mouth size and 60 mm mesh size in cod end, the operations were conducted at predetermined seven depth layer, 190, 170, 150, 130, 110, 70 and 30 m to collect juvenile tropical tuna (skipjack, yellowfin and bigeye).

Preliminary results

Oceanographic condition

Three major surface currents were observed in the study area using ADCP (**Fig. 3**): the westward-flowing North Equatorial Current (NEC) and South Equatorial Current (SEC) in the north and south part of the transect, respectively, and the eastward-flowing North Equatorial Countercurrent (NECC) between NEC and SEC. In addition, there was the Equatorial Undercurrent (EUC), flowing eastward below SEC.

Along the Leg 1 east-west transect, temperature increased westward, and a warm pool—where the surface temperature is higher than 29 °C—was observed at 3 western stations while salinity was consistently high along the transect (**Fig. 4a, b**). Nitrate and chlorophyll-a conditions were generally similar along this transect, with low but not depleted nitrate levels and relatively high chlorophyll-a concentrations within the upper 100-m layer with maxima between 20 and 50-m depth (**Fig. 4c, d**).

As for the Leg 2 south-north transect, temperature is higher than 29℃ at the surface and generally decreased from south to north, but thermocline became shallower at Station 4–6 (**Fig. 5a**). On the other hand, variation in salinity was different; low-salinity water was observed in the central part of the transect and high-salinity water at both edges of the transect (**Fig. 5b**). Nitrate was depleted in the surface layer, although an elevation of nutricline was observed around Station 5, concurrent with the shallow thermocline (**Fig. 5c**). Obvious subsurface chlorophyll maxima were observed mostly below 100-m depth (**Fig. 5d**).

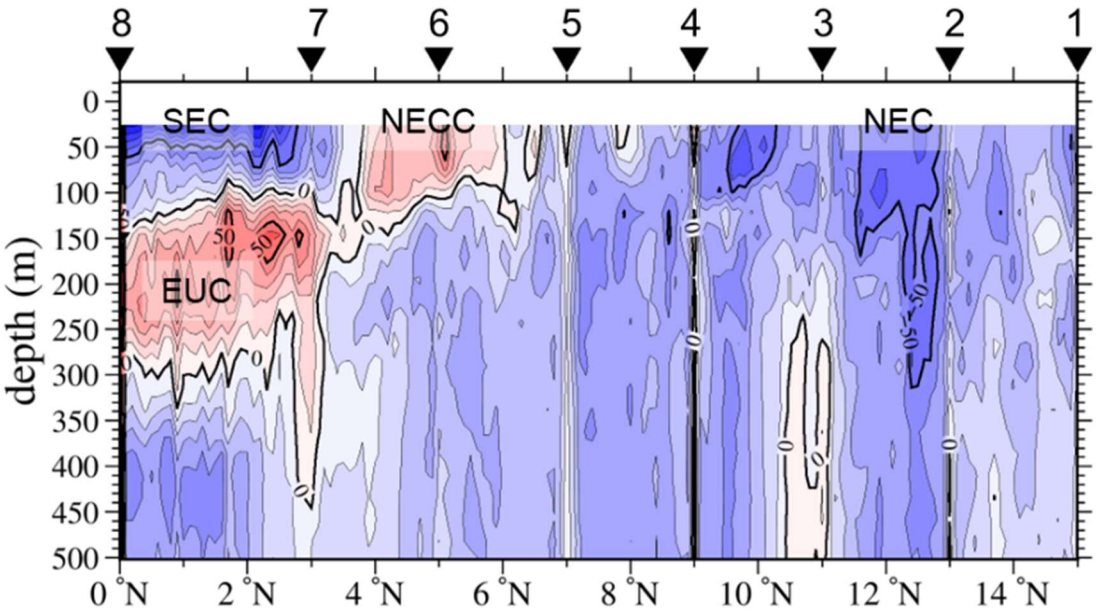
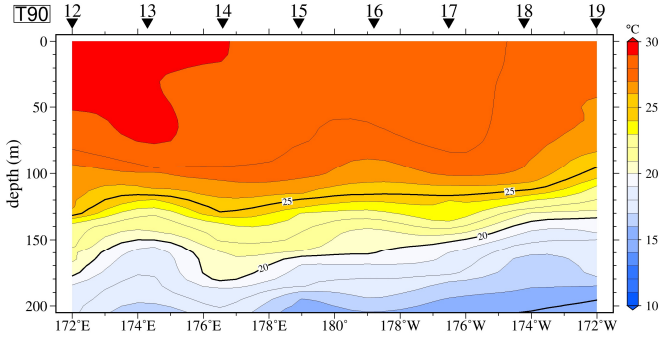
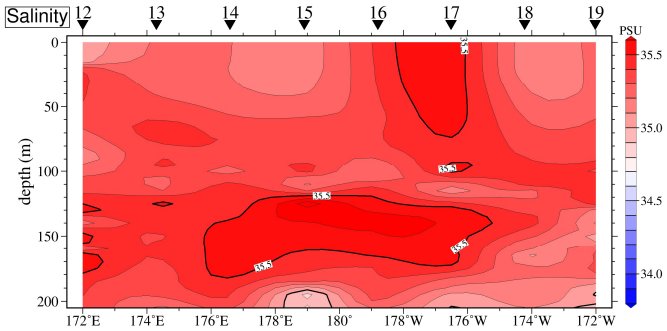


Figure 3 Current velocity (cm/s) along the Leg 2 south-north transect measured by ADCP. Blue and red show westward and eastward flows, respectively. Abbreviations represent major currents in the study area. SEC: South Equatorial Current, NEC: North Equatorial Current, NECC: North Equatorial Countercurrent, EUC: Equatorial Undercurrent

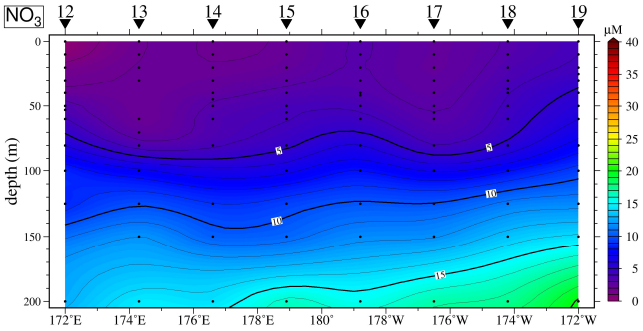
(a) Temperature (°C)



(b) Salinity



(c) Nitrate (μM)



(d) Chlorophyll-a (μg / L)

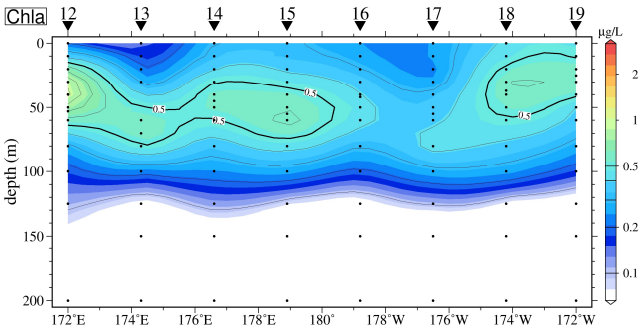
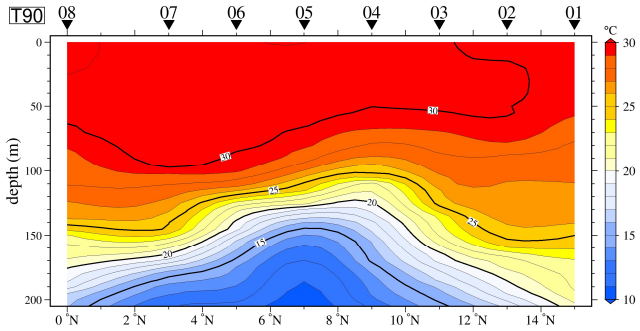
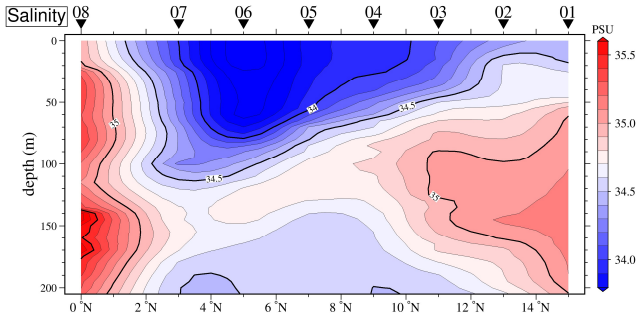


Figure 4 (a) Temperature, (b) salinity, (c) nitrate, and (d) chlorophyll-a concentration at 0–200 m depth along the Leg 1 east-west transect.

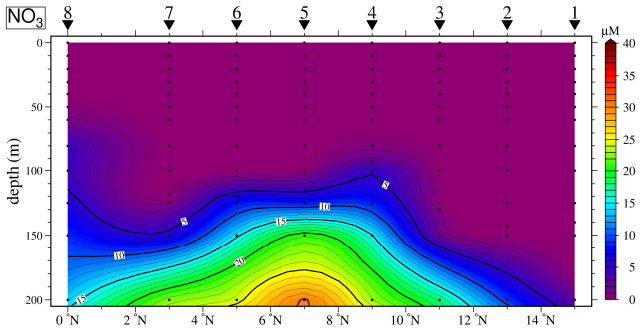
(a) Temperature (°C)



(b) Salinity



(c) Nitrate (µM)



(d) Chlorophyll-a (µg / L)

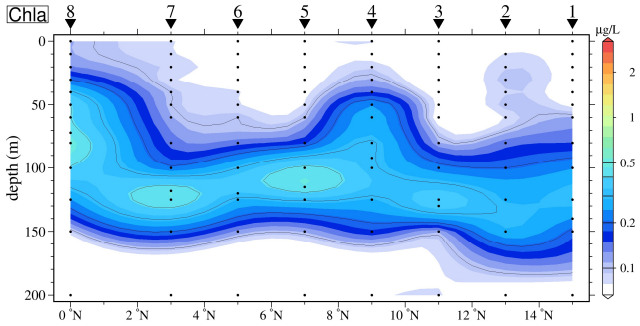


Figure 5 (a) Temperature, (b) salinity, (c) nitrate, and (d) chlorophyll-a concentration at 0–200 m depth along the Leg 2 south-north transect.

Hull-mounted echosounders

The EK80 data were acquired at 4 frequencies 38, 70, 120 and 200 kHz, at ranges down to 1000, 700, 300 and 200 m, respectively. Acoustic data were emitted every 7 seconds, alternately with ADCP data. The acoustic density integrated over the water column is plotted in **Figure 6** at 38 and 70 kHz. The 38 kHz is integrated over [8-1000] m and 70 kHz over [8-425] m. This representation highlights the spatial variability of acoustic density across the entire survey area. At 38 kHz, areas at the equator (latitude <2°N) and north of 25°N present high acoustic densities (NASC>8000 m².nmi-2). This contrasts with the area located between 2°N and 25°N, which has a much lower acoustic density. Similar patterns are found at 70 kHz, even though the region north of 25°N is not as distinct as at 38 kHz.

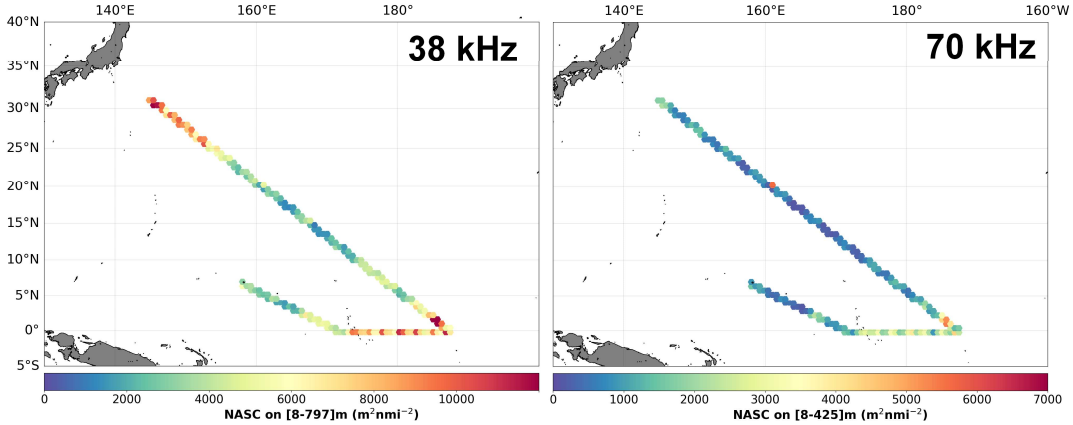


Figure 6 Nautical Acoustics Scattering Coefficient (NASC, in m².nmi^{-2}) summed over the water column (8-1000m) during KY2405-Leg 1 at left) 38 kHz and right) 70 kHz.

To illustrate the vertical structure of micronekton and zooplankton organisms, the acoustic profiles averaged over time (10 pings ≅ 70 seconds) and depth (3 m) for each frequency are indicated in **Figure 7**. Micronekton and zooplankton organisms form dense layers of a thickness of about 200 m, known as scattering layers. These layers' vertical movements reveal the diel migration of organisms between the mesopelagic (deeper than 200m depth) and epipelagic zones (shallower than 200m depth), with the organisms diving into the mesopelagic zone at sunrise and rising to the epipelagic zone at sunset. The exact depth of the scattering layers varies across the survey.

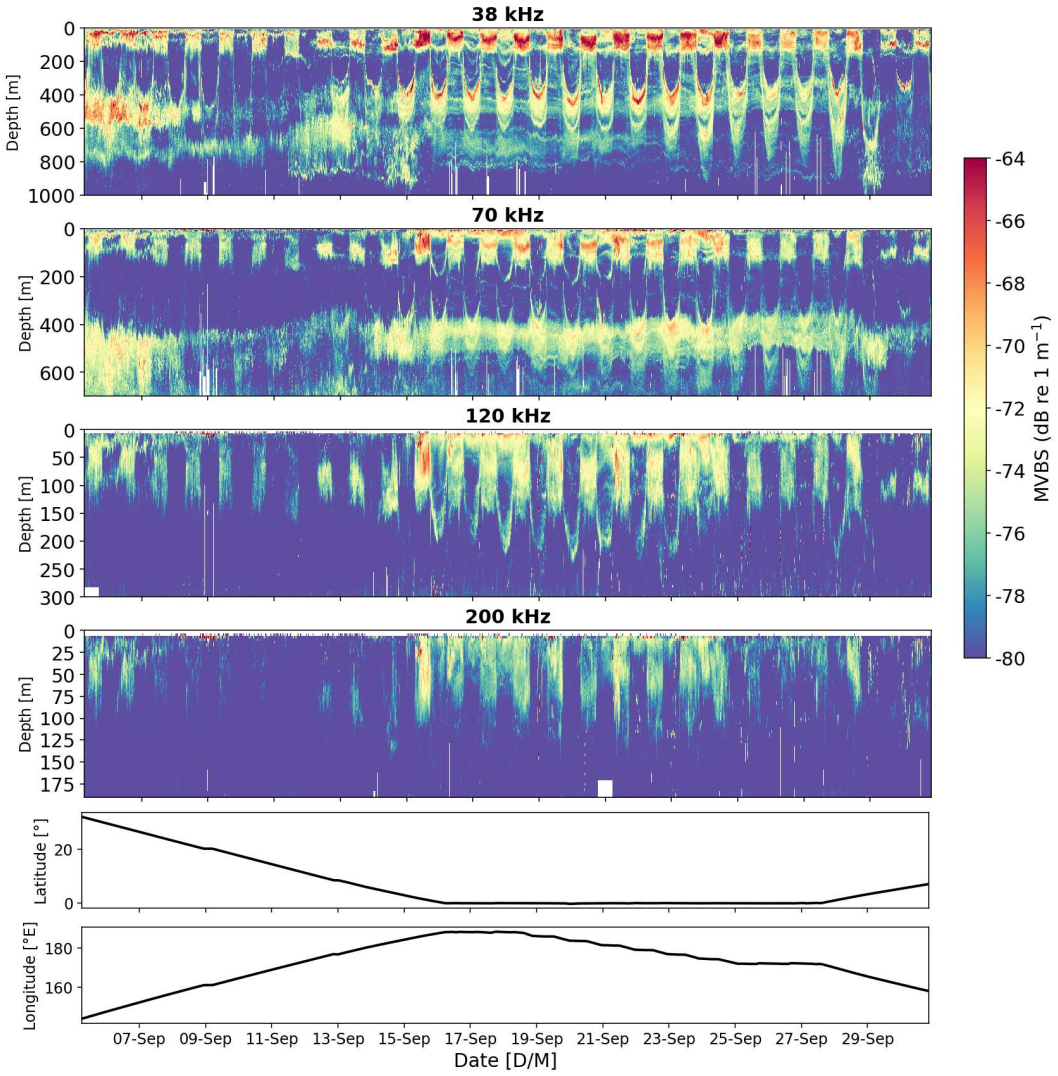


Figure 7 Echo-integration of KY2405-Leg 1 with a resolution of 3 m vertically and 10 pings (~70 seconds) horizontally, at four frequencies (38, 70, 120 and 200 kHz) as a function of time. The acoustic density per volume unit is indicated in MVBS (Mean Volume Backscattering Strength in dB *re* 1 m^{-1}). The latitude and longitude along acoustic data are indicated in the two last bottom graphs.

Consequently, the EK80 data is useful for characterising ecosystems, particularly at 38 kHz, which has the deepest range. Day and night data are separated and averaged over 2°x 2° cells, and then concatenated vertically. Applying a hierarchical classification algorithm to the averaged acoustic profiles identifies different acoustic regions (**Fig. 8**). The first clusterincludes the equatorial areaand the region north of 25°N, both of which are characterized by a strong acoustic density and associated with the equatorial

upwelling. The other two clusters divide the intermediate subtropical area (low acoustic density) into two distinct regions. When considering four clusters, the equatorial upwelling is separated from the northern region. Hull-mounted acoustics help to improve our understanding of the large scale patterns of the pelagic ecosystems and the links between biology and biogeochemical components.

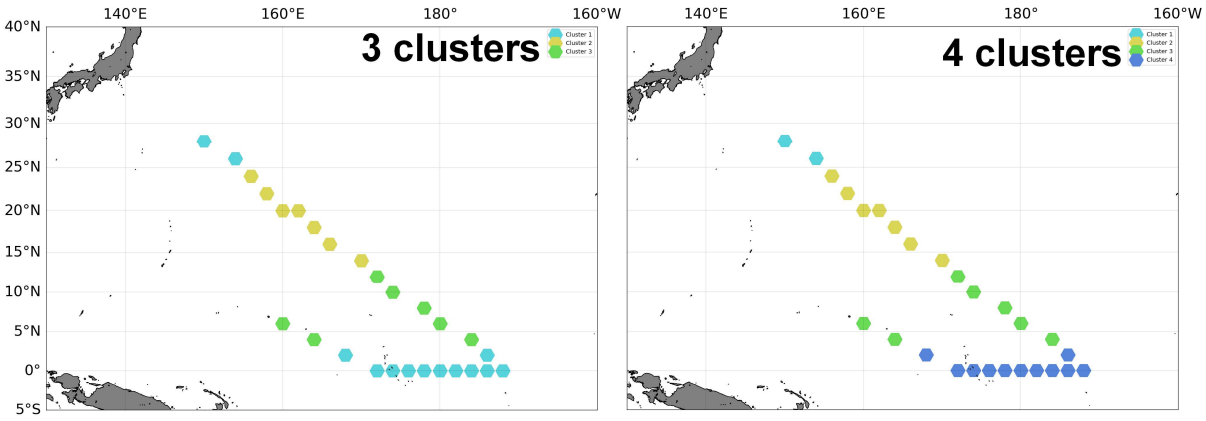


Figure 8 Hierarchical clustering of MVBS profiles at **38 kHz** averaged in 2°x2° cells. Results when choosing three and four clusters.

Acoustic profilers

Unlike other deployed echosounders, the WBAT acquires data in broadband mode. Instead of recording acoustic intensity for a given frequency, it records it over a continuous frequency range; a feature that can leverage organism identification. The intensity over frequency, or spectrum, depends on the size, the composition (flesh, fat, bone, gas), the shape and the orientation of organisms. Prior to spectrum analysis, organisms were first detected from data, then tracked to keep their average spectrum over successive detections. It is reasonable to assume that organisms with similar spectra are morphologically similar. To group the organisms into homogeneous groups, the spectra were clustered using the K-Means algorithm. Among output clusters, some patterns resemble theoretical modeled responses. Clusters 3, 6 and 7 (see **Fig. 9**) contain curves named “resonant” which correspond to air bubbles or organisms bearing gas inclusions such as swimbladdered fishes or siphonophores. Except in this particular case, the exact content of other clusters remain unknown. The only admissible assumption is that, within a given cluster, organisms look alike. So the clusters’ proportions were analysed according to depth and a vertical structure seems to appear, with a dominance of certain clusters at certain depth (see **Fig. 10**). This suggests a vertical stratification of organisms, coincident with diel migration patterns of mesopelagic micronekton.

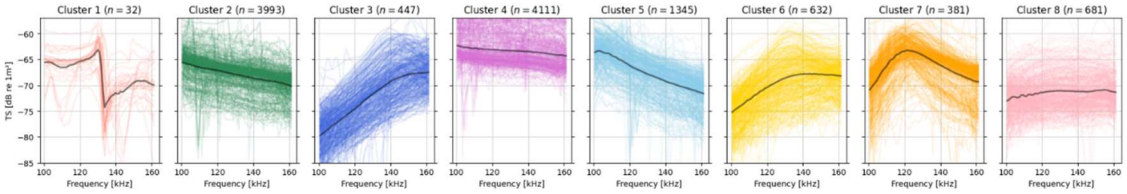


Figure 9. Clustered spectra. The curves are spectra: the acoustic intensity, expressed in TS [dB re 1 m²] over the frequency band 100-140 kHz recorded by the WBAT. All spectra, independently of their depth or station, were classified using the K-Means algorithm to identify distinct patterns. The optimal number of clusters (k=8) was determined by the elbow algorithm.

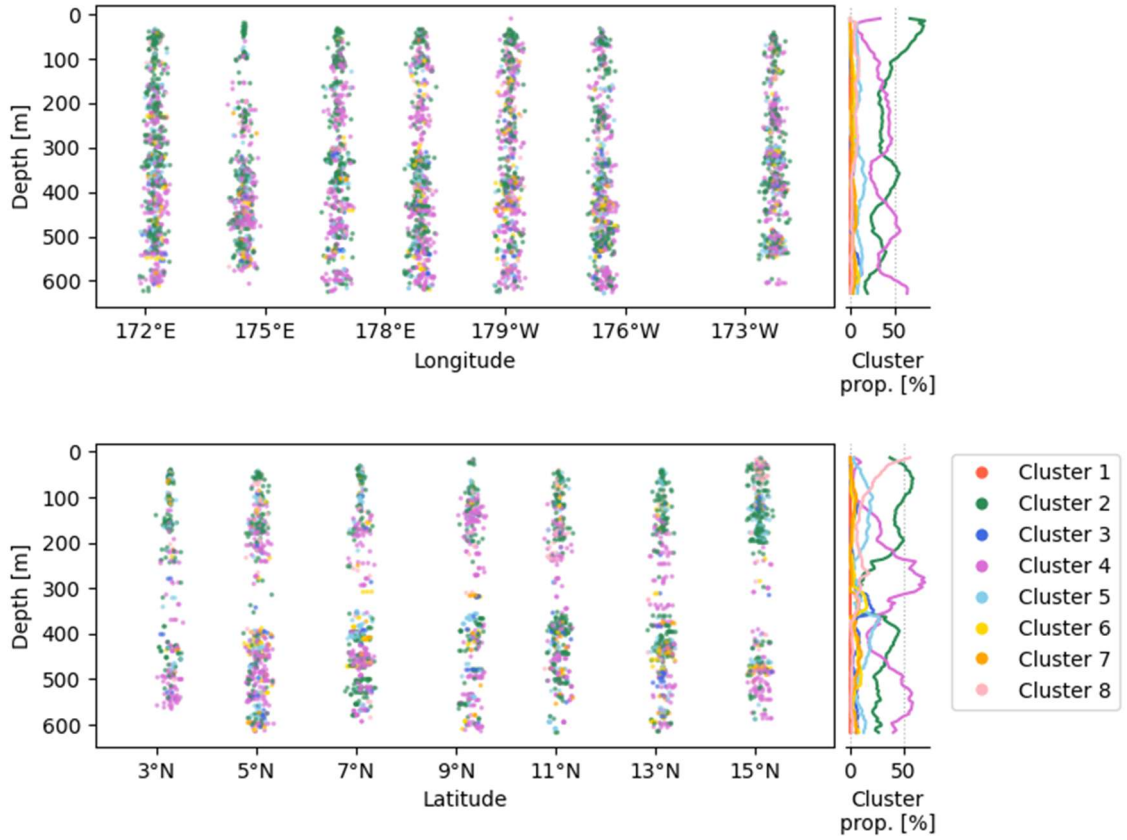


Figure 10 Vertical distribution of clusters. Each point is an organism and its color corresponds to the cluster it belongs to. Beam thickness is not on scale. Top: stations on Leg 1, along latitude 0°N. Bottom: stations on Leg 2, along longitude 150°E. Side panels give the relative proportions of clusters along depth, all stations combined. The cluster 2 is dominant at the surface and around 350-400m on both legs. The cluster 4 is dominant at ~500m on both legs and at ~300m solely on Leg 2. Cluster 8 is relatively important on the surface for the Leg 2.

Larval distribution by ring nets, bongo net and MOHT

A total of 77 larval net surveys were conducted during research period using ring nets (32 tows), bongo net (27) and MOHT (18). As a preliminary result of onboard sorting, the numbers of tuna larvae collected with ring nets with mesh sizes of 0.3 and 1.0 mm were 61 yellowfin, 452 skipjack (**Fig. 11**) and 23 unidentified tuna larvae. Most of the larvae were collected at the southern station on Leg 2, and, they were collected at the western station in Leg 1, but the number of individuals was clearly smaller in Leg 1 (**Fig. 12**). A big patch of skipjack larvae was observed in station 7 on Leg 2.

The numbers of tuna larvae collected with bongo nets were 25 yellowfin tuna, 87 skipjack tuna, and 1 unidentified tuna larvae. The number of yellowfin tuna larvae was high in the shallowest layer of 20–0 m and tended to decrease as the water depth increased. On the other hand, skipjack tuna larvae were found in a wide range of water depths, but the highest number was found at 40–20 m (**Fig. 13**). The preliminary results of vertical distribution of tuna larvae on this research cruise were similar to those reported off the Hawaiian Islands (Boehlert and Mundy, 1994), the Indian Ocean (Tim et al., 1990), and the Gulf of Mexico (Llopiz et al., 2010).

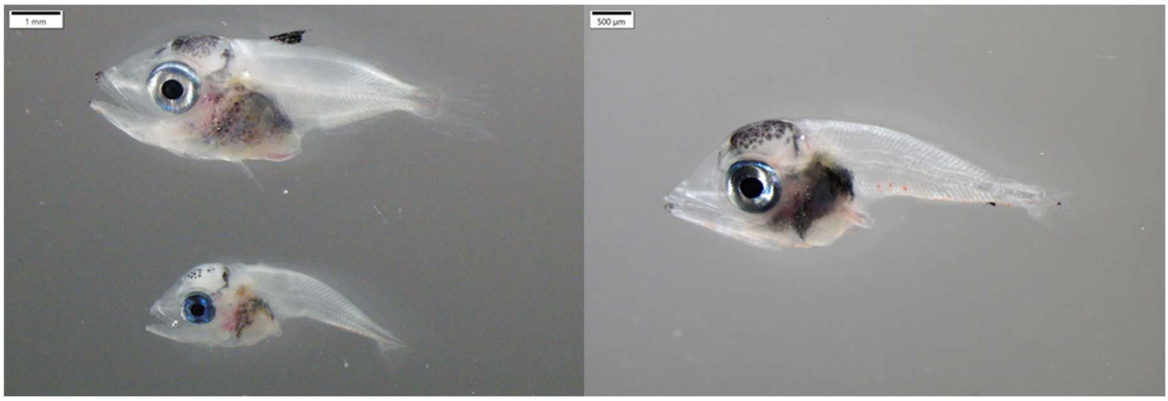


Figure 11 Yellowfin tuna *Thunnus albacares* larvae collected by ring net with 1.0 mm mesh from St.14 (7.1 mm FL, 4.5 mm FL, left top, left bottom), skipjack tuna *Katsuwonus pelamis* larvae collected by ring net with 0.334 mm mesh (5.1 mm FL, right)

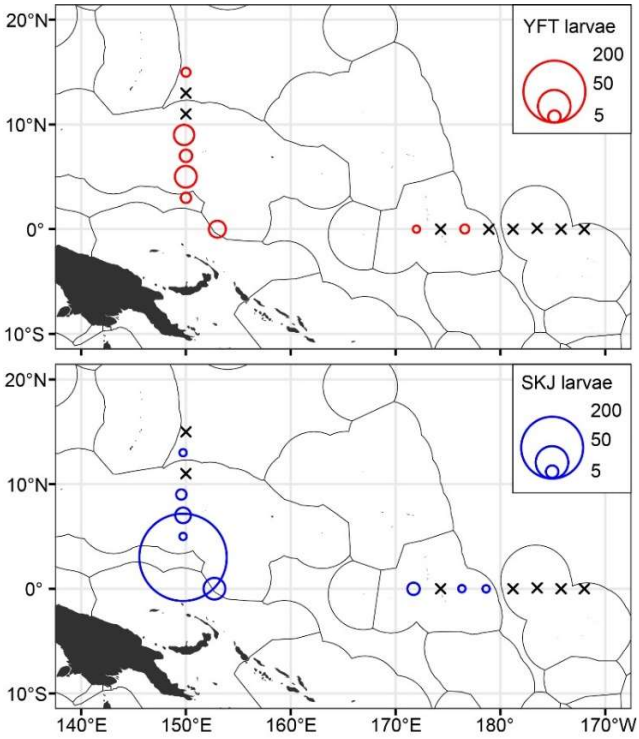


Figure 12 Horizontal distribution of yellowfin tuna (YFT, top) and skipjack tuna (SKJ, bottom) larvae, combining the results of onboard sorting using ring nets with mesh sizes of 0.334 mm and 1.0 mm.

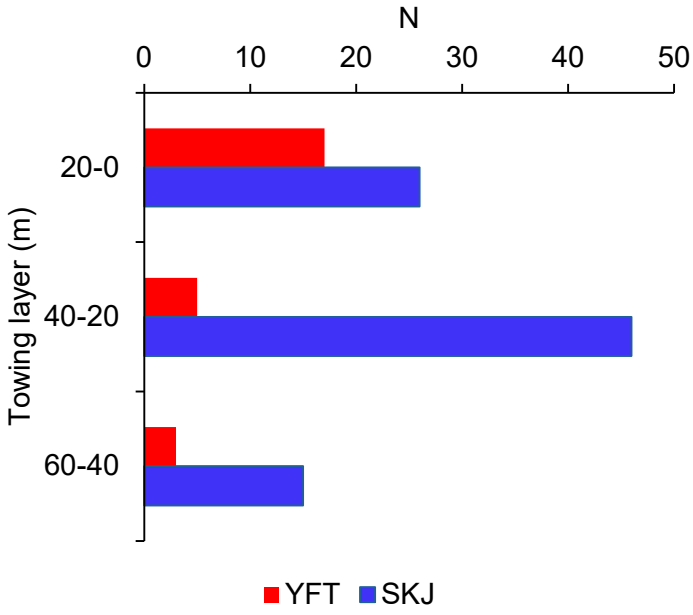


Figure 13 Vertical distribution of yellowfin tuna (YFT) and skipjack tuna (SKJ) larvae collected by stratified sampling with a bongo net as a result of onboard sorting.

As a result of 17 tows by MOHT survey, 3 yellowfin, 7 skipjack and 18 unidentified tuna larvae were collected at different depths. Currently, secondary sorting for ring net, bongo net and MOHT are being carried out on land, and species identification by DNA analysis of larvae is being carried out in parallel.

Juvenile distribution by stratified mid-water trawls surveys

A further 196 juvenile tuna were collected using a mid-water trawl at different depths. In Leg 1, 14 tows were trawled at two long stations, and 53 skipjack, 2 *Thunnus* spp. and 1 unidentified tuna-like juveniles (including those collected in the trial station) were collected. In Leg 2, 21 tows were trawled at three long stations, and 108 skipjack and 25 *Thunnus* spp. and 7 unidentified tuna-like juveniles were collected. The average and range standard length (SL) of skipjack juveniles was 44 (12–173) mm (**Fig. 14c**), and that of *Thunnus* juveniles was 45 (18–141) mm (**Fig. 14a, b**). In Leg 1, skipjack juveniles tended to appear in water depths deeper than 100 m, but in Leg 2, they were more likely to appear in water depths shallower than 100 m. Few *Thunnus* juvenile were collected in Leg 1 but appeared in a wide range of water depths in Leg 2. Because it is difficult to identify juvenile tuna to species by morphology, we are currently working on identifying them by DNA analysis. Preliminary results show that the juvenile tuna collected on this research cruise include at least three species: bigeye tuna (**Fig. 14a, b**), yellowfin tuna, and albacore tuna.

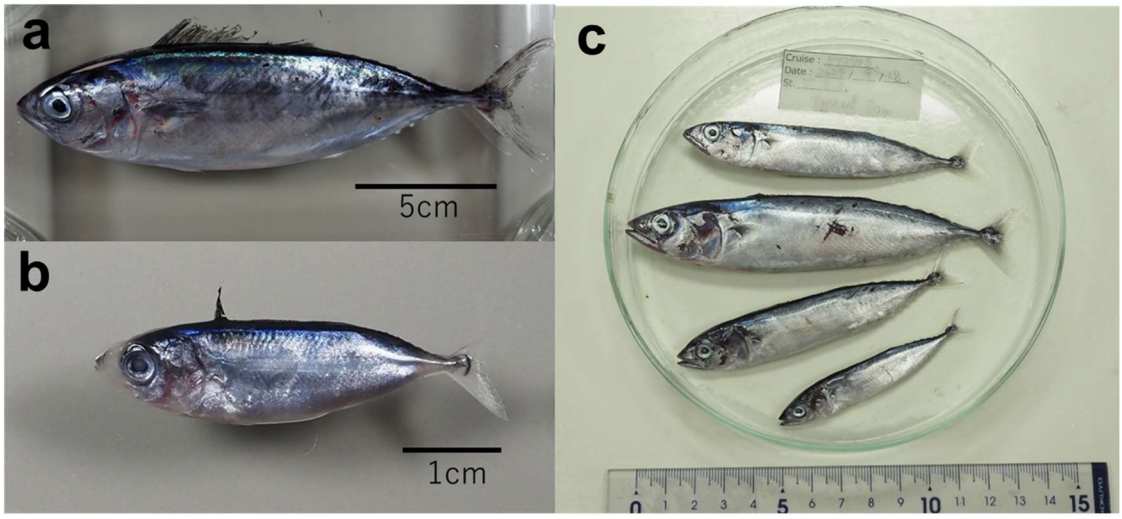


Figure 14 Juveniles of bigeye tuna *Thunnus obesus* (**a**, 14.1 cm SL; **b**, 3.6 cm SL) and skipjack tuna *Katsuwonus pelamis* (**c,** 67.6–126.3 cm SL) collected by mid-water trawl.

Other biological samples

Both surveys of the NORPAC net and the VMPS were conducted with 16 tows at all stations during this cruise. These zooplankton samples will be used to analyse the feeding environment of tuna larvae, as well as the relationship between oceanographic conditions and horizontal and the vertical distribution of zooplankton.

A large amount of biological samples except for tuna fishes were obtained by the mid-water trawl surveys (**Table 2**), for example, fish, squid, gelatinous, crustacean etc. (**Fig. 15**). The biomass varied depending on the location and water depth (**Table 2**). The biological samples obtained are currently being identified, and in the future, it is planned to clarify the biological community structure that characterizes this area.

Table 2 Wet weight (g) of biological samples each station and depth collected by mid-water trawl surveys

Depth	St.19	St.12	St.08	St.05	St.01
30 m	4,100	5,390	14,350	1,050	20
70 m	59,600	8,800	9,700	5,650	220
110 m	19,412	26,500	20,450	9,650	1,550
130 m	38,825	47,300	49,950	17,150	2,250
150 m	15,700	28,200	35,400	49,750	3,650
170 m	12,945	27,650	28,500	13,350	3,400
190 m	5,785	35,850	23,100	13,450	4,850

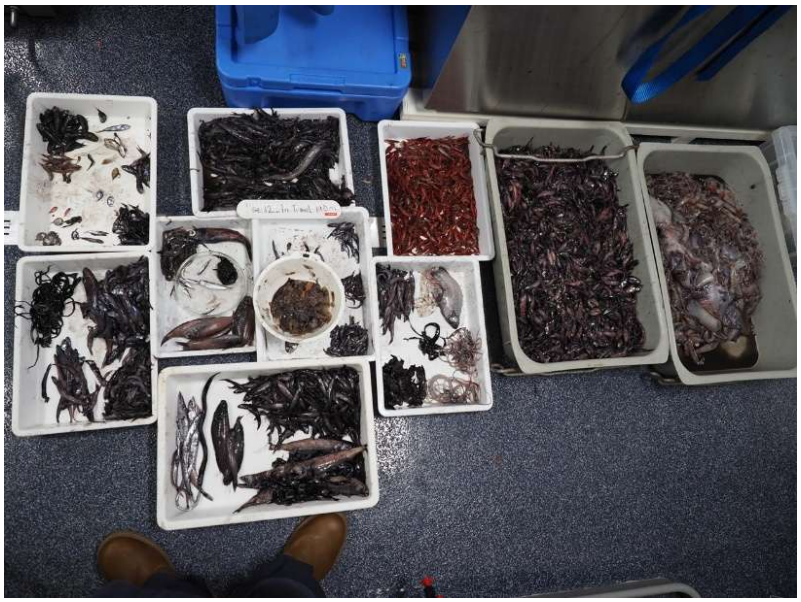


Figure 15 All biological sample collected by the mid-water trawl of 190m layer at St.12.

Future perspective

During this research cruise, we collected numerous biological samples, oceanographic data and acoustic data from the central and western Pacific Ocean. The samples and data collected in 2024 are currently being analyzed by various researchers. This information will help to clarify the dynamics and functions of the early life stages of larval tuna in marine ecosystems as well as the recruitment process in this area. We also plan to conduct a similar survey in 2025, at the same time of the year and in the same area as in 2024.

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