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A preliminarily analysis of variations in the fishing gear configurations and practices of Japanese longliners in the western and central Pacific Ocean since 2007

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Title

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Author

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Abstract

Time series of abundance index of tropical tuna species is an essential component for stock assessment of these species. Catch-per-unit-effort (CPUE) analysis of Japanese commercial longline vessels using logbook has been frequently used to estimate abundance index of large size tropical tunas. To consider CPUE as a stock abundance index, information about changes in catchability of the fishery over time is important. Variations of fishing gears and practices result in differences of catchability, which have altered the relationship between CPUE and abundance. Records of Japanese longline on-board observer programs were explored to gather information about variations of fishing gear and practices since 2007 in the western and central Pacific Ocean.

Introduction

Catchability is defined as the probability of catching an animal with a single unit of fishing effort (Paloheimo and Dickie 1964 referring in Ward 2007). Catch-per-unit-effort (CPUE) of commercial longline vessels have been used to estimate abundance index for stock assessments of tropical tuna species (bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*)) (e.g., Vincent et al. 2019). Large scale Japanese longline fishery have long time series of logbook data records since 1950s, and their fishing grounds cover wide range on the tropical tuna habitats, which is the reason why the CPUE of the fishery is appropriate for observing trend of the tropical tuna's abundance. The number of hooks is usually used as a unit of effort for the fishery. The catchability of hook could vary depending on their shape and size. The "long line gear" is composed of branch line, float line and main line, of which materials are known to change drastically in 1990s from traditional black rope to Nylon, this replacement will affect branch line visibility and thus longline catchability (Ward 2008). Other materials with different relative density for the lines have been introduced. In addition, float line and branch line are a line from float to the mainline, a line from main line to hook, respectively. The difference of gear density may affect hook depth and thus encounter rate between the hook and target species. The vertical habits varies by species (e.g., Hinton and Nakano 1996, Bigelow et al. 2002, Ward and Hindmarsh 2007, Schaefer & Fuller 2010, Schaefer et al. 2011). The longline hook depth is also controlled by conditioning shortening ratio, which is the ratio between ship speed and line shooter (thrower) speed (Boggs, 1992) when setting longline gear (Satoh et al. 2021). The shortening ratio is essential to estimate desired hook depth of the vessel. The vessel's intention of target species for each set is useful to characterize specific combination of gear configurations and practices by target species. Equipment used for the longline vessel, such as vessel size, vessel engine power, cruise speed, freezer capacity, communicators, weather and oceanographic information collecting system, navigation system (Satellite, GPS), fish finder, multi-directional sonar, doppler profiler, which are considered to affect efficiency to finding fish in the open ocean. Such information about fishing gear, practices and vessel are partially available thorough logbook data collecting system mandatory reported by vessel, but some of them are missing or their temporal resolution is not a set-basis.

The catchability may be positively changed according to improvement of fishing gears, practices and vessel properties to find, catch and store fish more effectively. Some of management measures for the stocks could negatively affect the catchability. If these changings are not reflected properly thorough CPUE standardization process, the estimated abundance index is biased. Despite its importance of changing catchability over time for the tropical tuna stock assessment, detailed analysis of catchability for Japanese longline vessel have not been conducted recently after Ward and Hindmarsh (2007) and Ward (2008), mainly because detailed information about gear configurations and practices from wide spatio temporal scale was not available. In the WCPFC area, on-board observer program for the longline fishery has been implemented after 2007, collecting information on fishing gears, practices and vessel properties including targeted species information for each set. The purpose of this report is summarizing such information using on-board longline observer data-base and understanding trends of fishing gears, practices and vessel properties.

Methods and materials

Japanese longline on-board observer program data are stored and updated continuously by the Highly Migratory Resources Division, Fisheries Resources Institute, National Research and Development Agency, Japan Fisheries Research and Education Agency (FRA). The database includes information on vessels (e.g., length, size, freezer capacity), vessel's equipment (e.g., communicators, navigation system (Satellite, GPS), fish finder), longline gears (e.g., hook size, hook type, branch line length, branch line materials), fishing practices (e.g., target species, date, time, position, bait), and biological information (e.g., species composition, size). Information about vessels and equipment is obtained on a cruise basis, while other information is obtained on a set basis. However, information on main line is only available for cruise basis. Based on the difference of the temporal resolution for each data field, different effort amount (number of sets or number of hooks) are used in this report. This report deals mainly with information related to fishing gears and practices. Analysis related to vessel, equipment and biological information will be conducted in the near future. In addition, information on target species in this paper was obtained through interviews with fishing masters or captains.

Results and discussion

The number of cruises, sets, and days of observation by year showed (**Table 1**) for those vessels that operated for even one day in the WCPFC conventional area (**Fig. 1**). The analysis was limited to the 2008–2019 period because the number of cruises after 2020 was quite small due to COVID-19 pandemic.

Vessel and equipment

A scatterplot matrix of vessel information (total length (m), tonnage (GRT), engine power (kw), fish well capacity (t), cruising speed (knot), maximum speed (knot), fuel capacity (kl), and freezer capacity (m^3)) was shown (**Fig. 2**). Smaller vessels (< 200 GRT) operated in vicinity of Japan, while larger vessels (>= 200 GRT) fished in waters far from Japan (**Fig. 1**).

Main line (ML)

Time series of material, length, and diameter of main line (ML) were shown (**Fig. 3**), as well as a scatterplot matrix of these items (**Fig. 4**). ML materials were mostly Nylon, with some Kevlar + traditional black rope, and Cremona was also used. Regarding the length of ML, some were quite long (> 200 km), but most being 50–150 km. The diameters of ML were predominantly around 3 mm, with most being 2–7 mm. Nylon lines showed large variation of the lengths and the diameters. Kevlar tended to be thicker and longer (**Fig. 4**).

Float line (FL)

Time series of material, length, and diameter of float lines (FL) were shown (**Fig. 5**), as well as a scatterplot matrix of these items (**Fig. 6**). The lengths of FLs were generally 20–40 m, but there was quite long FL (> 100 m). The longer FL were mainly used in the start point of Kuroshio Current area from Palau to southern Japan (the Kuroshio origin area; **Fig. 7A**). FL materials were Cremona, Nylon, Kevlar + black rope, and Tetoron. The material of Tetoron became popular recently. There were no clear geographical pattern by FL materials (**Fig. 7C**). FL diameters were mostly 2–3 mm and showed no trend. Nylon had no FL with large diameters (4 mm at the widest), but other materials have a wide range of diameters (**Fig. 6**). Longer FLs were rarely composed of Nylon and Tetoron. Cremona and Kevlar + black rope had a wide variety of line lengths. Thick diameter lines appeared to be more common in the northern part of Japan (around 40° N). The large variety of geographic FL length (**Fig. 7A**) indicates that it is an important factor when controlling the hook depth.

Branch line (BL)

Time series of material, length, and diameter of branch lines (BL) were shown (**Fig. 8**). BL were composed mainly of Nylon (relative density; 1.14, assuming a monofilament), Tetoron (1.38), and PVDF (Poly Vinylidene Di Fluoride; Seaguar; 1.78). The diameters were clearly different by the materials, with Nylon and PVDF being thinner (2 mm) and Tetoron was thicker (4 mm). The geographical distribution pattern by material was not clear (**Fig. 9C**). However the diameter and relative density of the materials can influence on the hook depth with interactions of marine environments, such as shear currents (Mizuno et al., 1997), meaning further investigation on the geographical pattern in detail is needed. BL length was around 30 m and showed low annual fluctuation (**Fig. 8B**), but there was clear geographic distribution pattern by BL length (**Fig. 9A**). Short BLs were more abundant around 40°N, while longer BL were more common in the tropical area.

Hooks between float (HBF)

The number of hooks between float (HBF) is expected to be greater if the vessel intends to set the hook deeper and is often considered an indicator of target species. Small HBF target (3 or 4) targeted sharks or swordfish. Annual fluctuations of HBF were small, with the median annual value being between 17 and 18, and these were generally considered to target tropical tuna species. Since the mid-1990s, there had been no significant fluctuation in HPB, which was usually observed not only in the WCPO area, but also other t-RFMO areas. There were substantial difference of geographical distribution pattern of HBF (**Fig. 10B**), small HBF (around 5) distributed around 40° N, and larger HBF distributed in the Kuroshio origin area.

Shortening ratio (SR)

The smaller shortening ratio (SR; vessel speed / line shooter speed) when setting longline gear, the more the main line hangs in the water and the deeper the hook would be set. The vessel speed and the line shooter speed were around 5 (ms^{-1}) and 6 (ms^{-1}), respectively, with a little annual variation (**Fig. 11A and B**). SR distributed around 0.8 without trend. Although geographical pattern of SR were not clear (**Fig. 12C**), it is necessary to analyze the ratio in conjunction with the ocean environment, such as currents. The shear currents strongly affect the hook depth after gear setting (Mizuno et al. 1997), thus the vessel may consider the current situation and then decide SR when setting.

Hooks

Four types of fishing hooks have been reported (tuna hook, j hook, circle hook, and others). Most of them were tuna hooks (**Fig. 13A**). The geographic distribution patter for hook type was unclear (**Fig. 13B**) due to the high coverage of the tuna hook. Although not shown here, the information on hook size were available, which may influence the fish size and target species.

Bait

Eight major bait types were observed (**Fig. 14B**). When bait type were mixed in a set, five bait types in maximum were used (**Fig. 14A**). Major bait types were saury, squids, sardines, mackerels and horse mackerels, but "Milkfish", "Dotted gizzard shad", and "Bluestripe herring" had also been used since 2015. There were geographical patterns by bait type (**Fig. 14C**), but availability of the bait types may differ at different times of the year and stock status for each bait species, thus such information related to bait species should be included in future analyses.

Target species

In this report, information on target species was obtained by interviews with fishing master and/or captains. The interview results were classified into 11 species (**Fig. 15A**). The results were further aggregated into five main target species types (bigeye tuna, yellowfin tuna, tropical tuna (bigeye and yellowfin tunas), albacore, and others) to present geographical pattern (**Fig. 15B**) and scatter plots matrix in the next section (**Fig 16**). The target species for each set was assigned to one of the five target species types. The geographical distribution pattern of each target species were clear with overlapp, with bigeye showing a distribution near the Japanese coast and offshore between 30 and 40° N, the Kuroshio origin area, and the border area with the eastern Pacific Ocean (**Fig. 15B**). Yellowfin tunas targeted area showed only a small number of cases, and no clear pattern was found. Tropical tunas area covered almost the entire study area. Albacore targeted sets distributed between 15 and 35° N. Although not shown here, these geographical distribution by the targeted species were reasonable, presenting good consistency with logbook species composition. The results of catch of each set will be analyzed further using biological information of the observer data-base.

Relationship between target species and gear configuration

Matrix scatter plots of target species and gear configurations (HBF, BL, FL, SR) were shown (**Fig. 16**). Although there was no clear difference among gear configurations when the target species were albacore and bigeye tuna, there were significant differences in fishing grounds: 15 to 35° N for albacore and 30 to 40° N for bigeye tuna. In addition, sets targeting bigeye distributed in both the Kuroshio origin area and the 30° to 40° N area, but the configuration of fishing gears were quite different. The depths at which the target species distributed may vary by areas (fishing grounds), so it is necessary to understand the relationship between the target species and the fishing gear configurations in conjunction with these oceanographic conditions by fishing ground.

Summary

Information about fishing gear and practices was summarized, which was collected by longline on-board observers in WCPFC conventional area. The information on target species by interviews is useful when considering the relationship between gear configurations and target species. The target species information facilitates our understanding for the situations that target species vary by area even with the same gear configurations, and that the gear configurations changed by area even with the same target species. In the Kuroshio origin area, long line operations were conducted by vessels with long FL (>100 m) and large HPBs by smaller size vessels. There is no other area where such combination of gear configurations and vessel size in the WCPFC conventional area. Therefore, it would be difficult to estimate the effects of these elements when comparing with other areas. To quantify the effects of the gear configurations, it might be useful analyzing by area (fishing ground). The vessel equipment and biological information will be included for further analysis, and then quantify trend of catchability of longline gear, practice, vessel information to help CPUE standardization process. For future work, making maps for estimated hook depth using information on length of BL, length of FL, shortening ratio and oceanographic conditions (e.g., shear current, mixed layer depth, vertical profile of sea temperature) by targeting species will facilitate our understanding catchability of the longline fishery.

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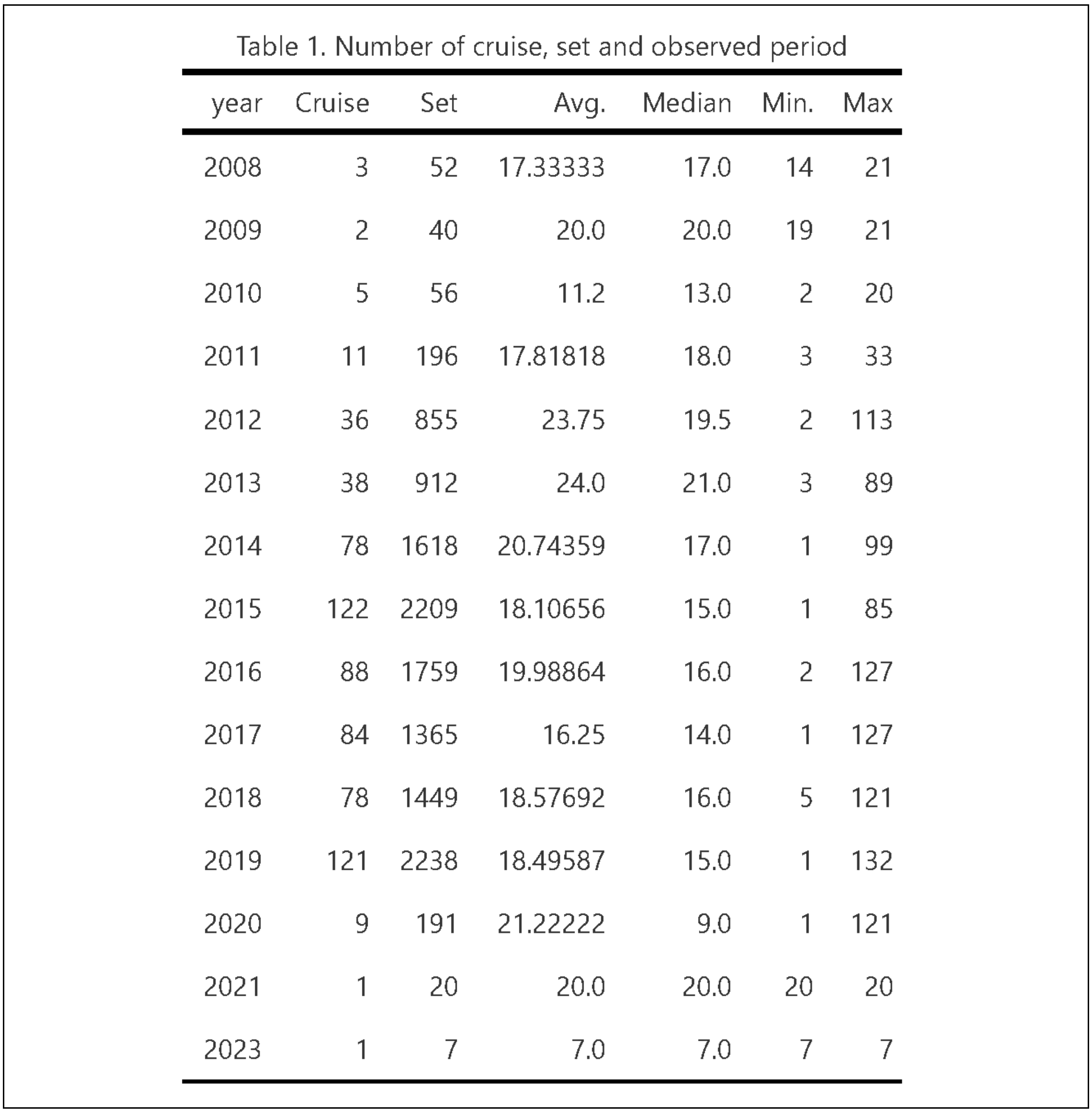


Table 1. Number of cruise, set and observed period

year	Cruise	Set	Avg.	Median	Min.	Max
2008	3	52	17.33333	17.0	14	21
2009	2	40	20.0	20.0	19	21
2010	5	56	11.2	13.0	2	20
2011	11	196	17.81818	18.0	3	33
2012	36	855	23.75	19.5	2	113
2013	38	912	24.0	21.0	3	89
2014	78	1618	20.74359	17.0	1	99
2015	122	2209	18.10656	15.0	1	85
2016	88	1759	19.98864	16.0	2	127
2017	84	1365	16.25	14.0	1	127
2018	78	1449	18.57692	16.0	5	121
2019	121	2238	18.49587	15.0	1	132
2020	9	191	21.22222	9.0	1	121
2021	1	20	20.0	20.0	20	20
2023	1	7	7.0	7.0	7	7

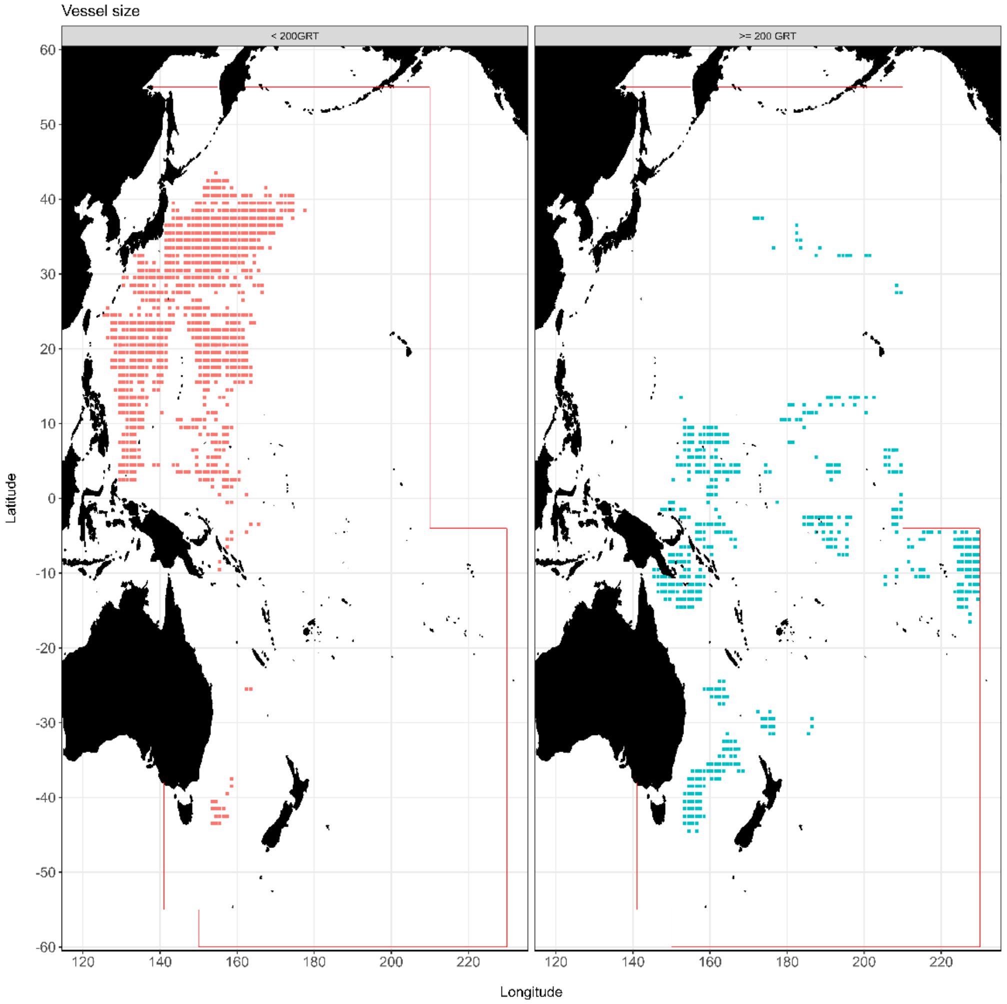


Fig. 1. Maps of study area by vessel size (left panel; < 200 GRT, right panel; >= 200 GRT)

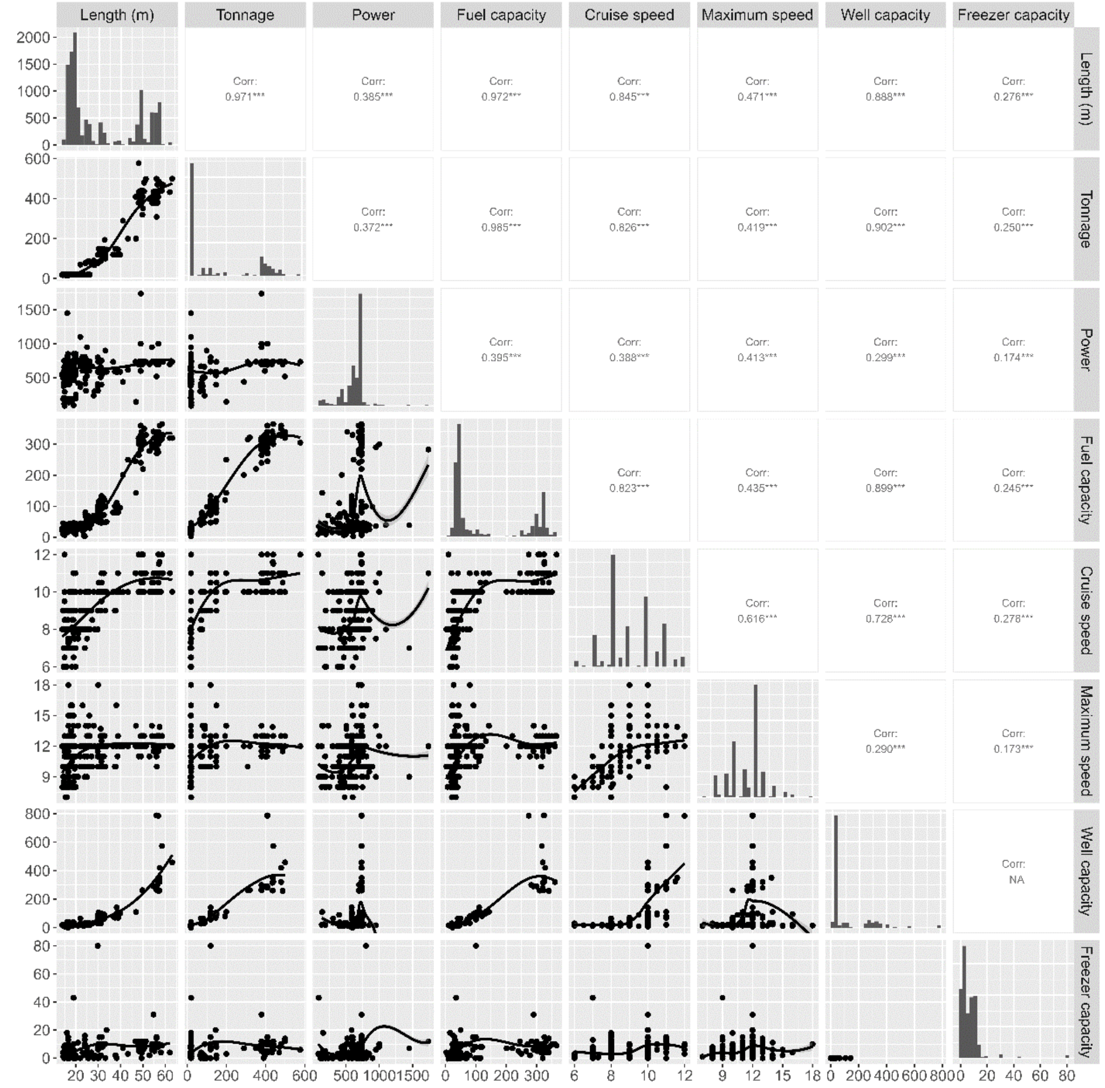
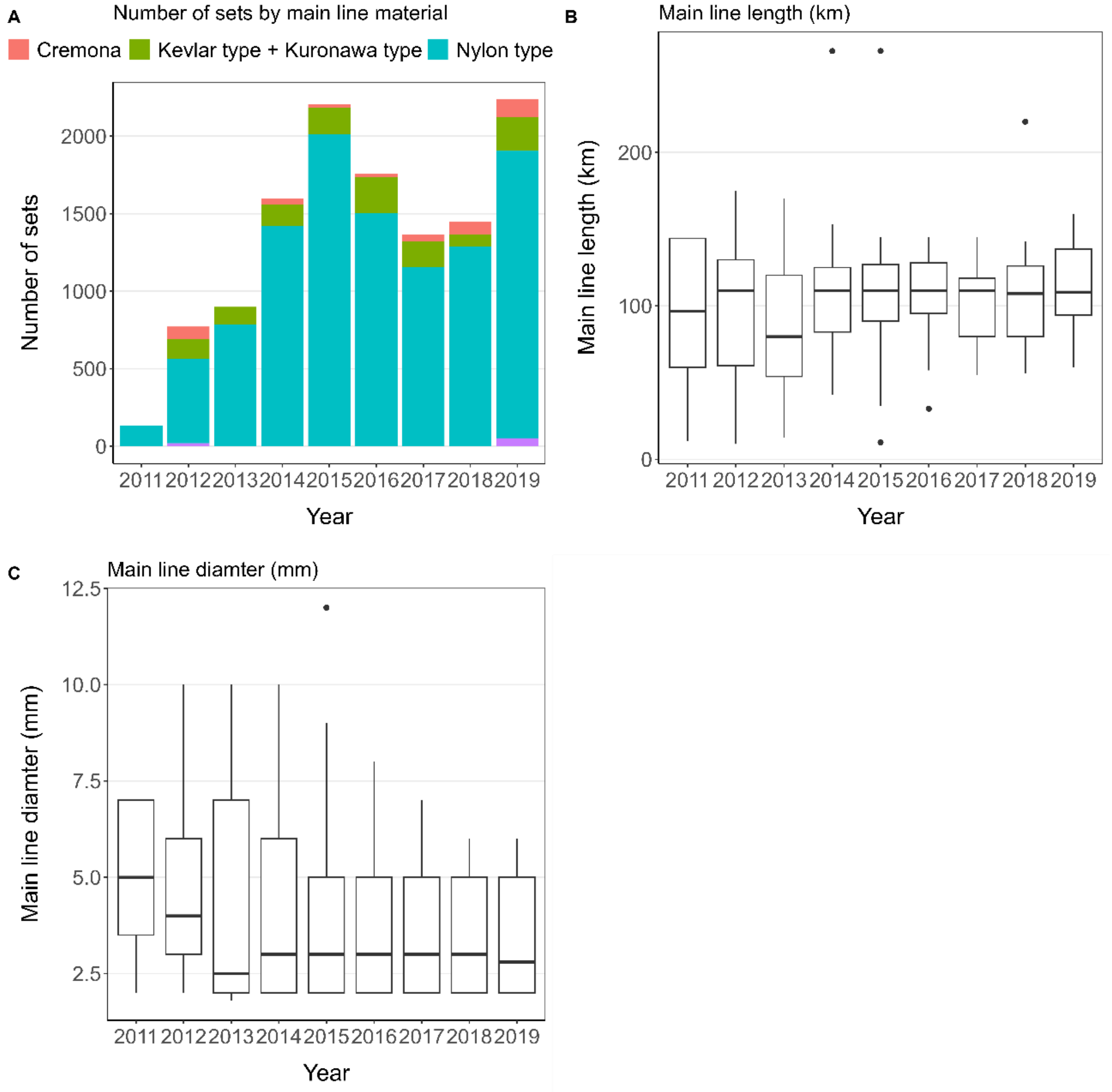


Fig. 2. Scatter plot matrix among longline vessel information.


A Number of sets by main line material

B Main line length (km)

C Main line diamter (mm)

Fig. 3. Time series of main line characteristics. A; number of sets by main line material. B; main line length (km), C; main line diameter (mm)

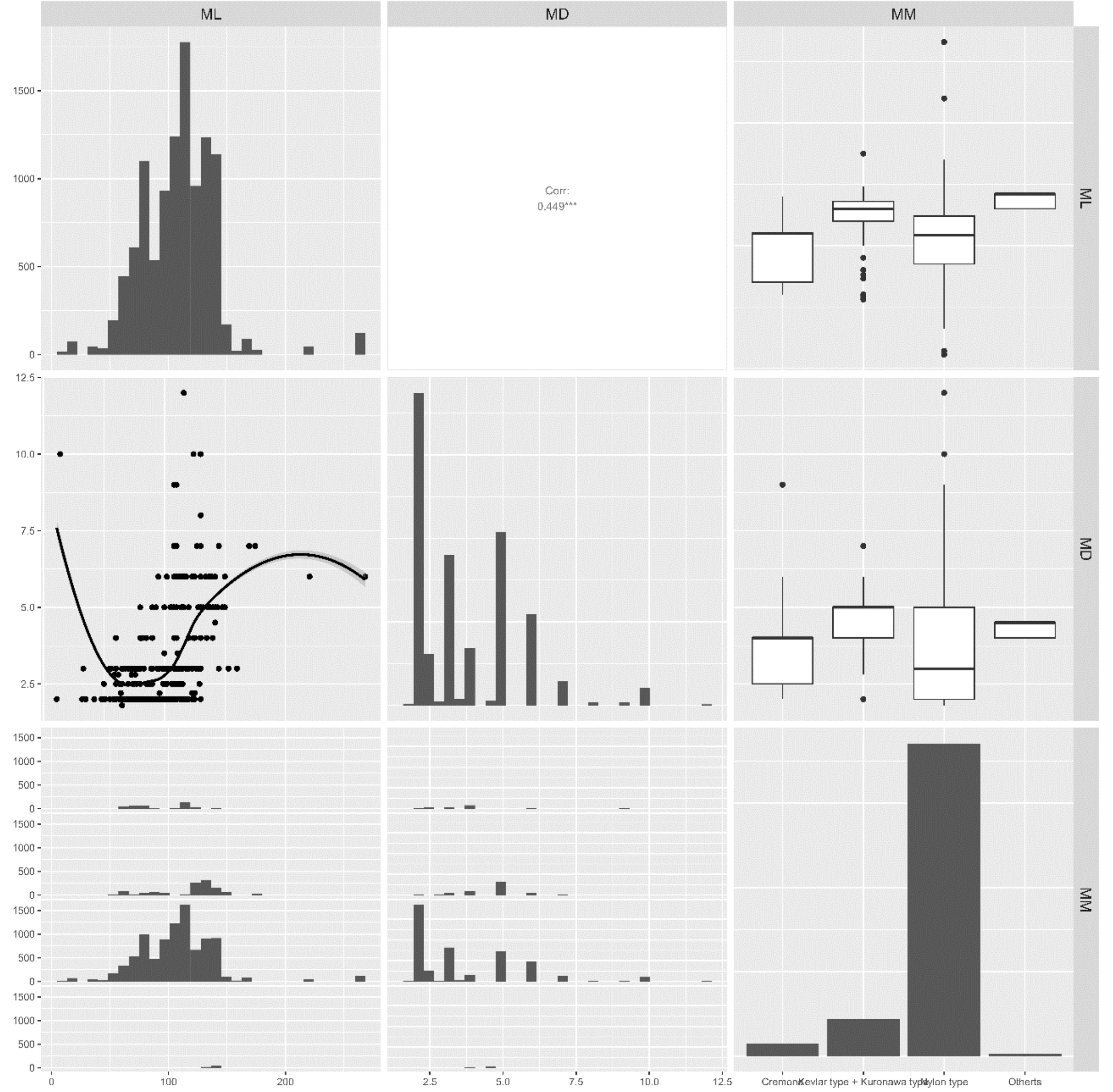


Fig. 4. Scatter plot matrix among longline main line information. ML; main line length (km), MD: main line diameter (mm), MM; main line materials (Cremona, Kevlar type + Kuronawa type, Nylon type and Others). Kuronawa is traditional black rope.

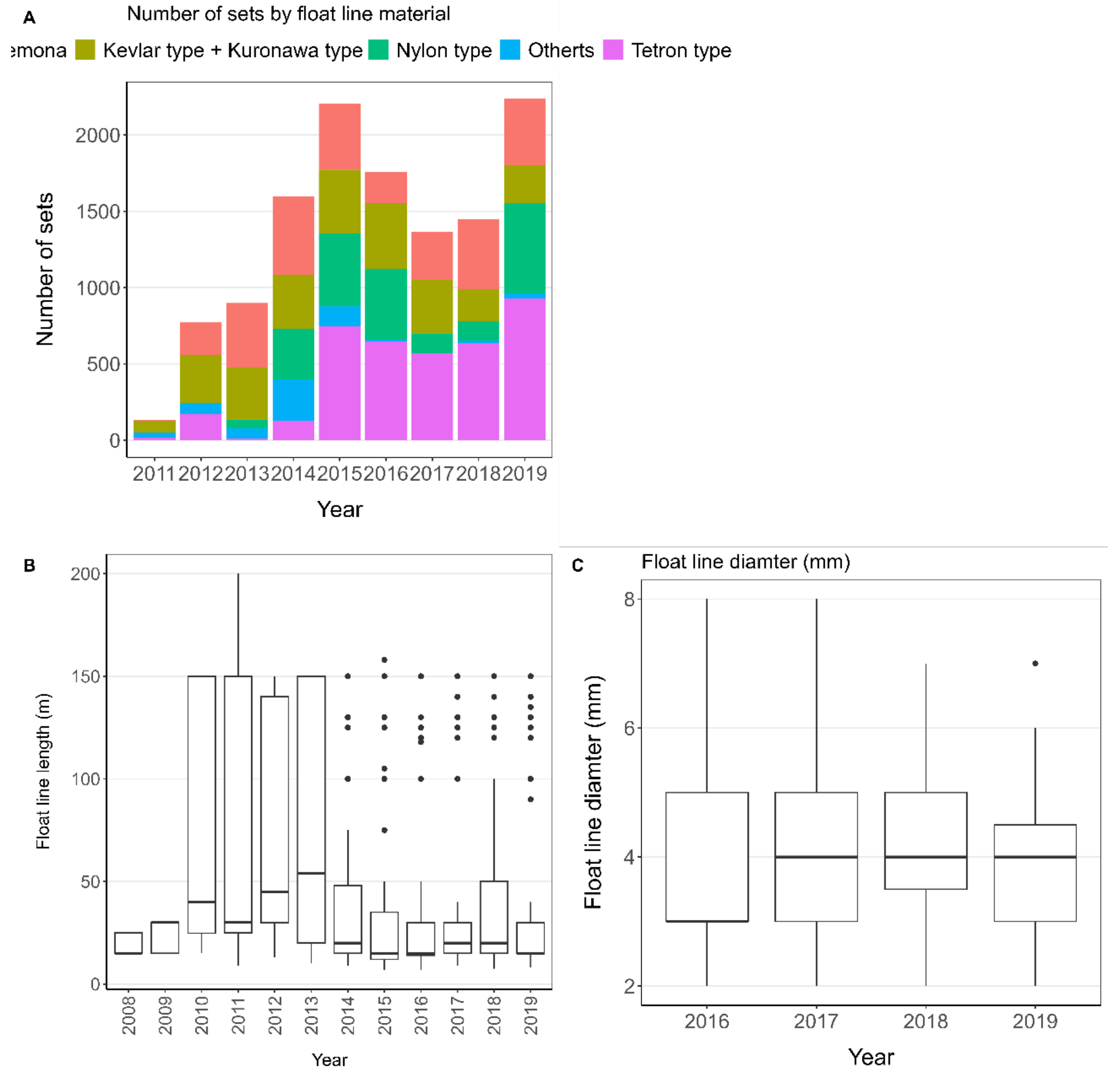


Fig. 5. Time series of float line characteristics. A; Number of sets by float line material. B; float line length (m), C; float line diameter (mm).

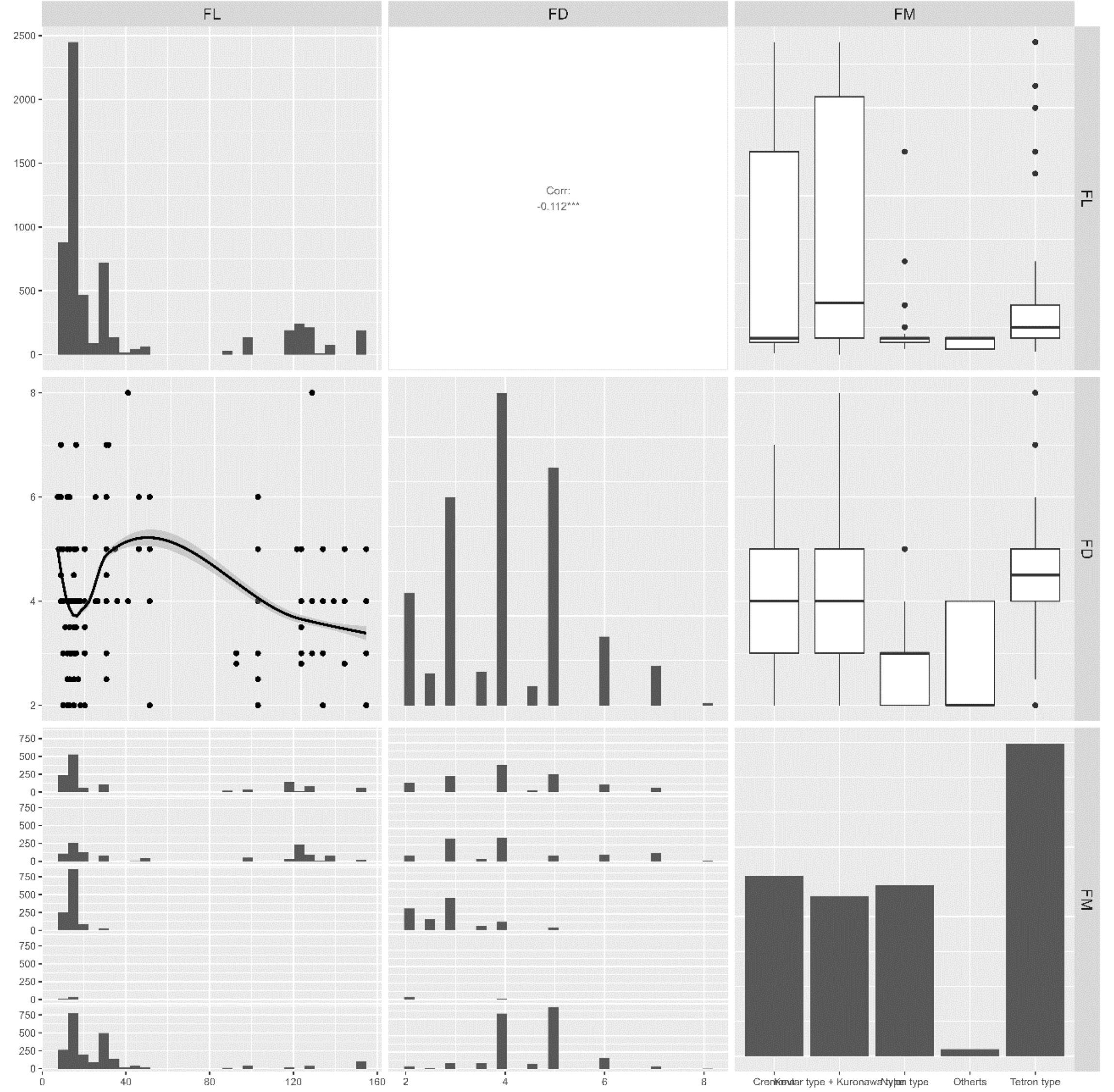


Fig. 6. Scatter plot matrix among longline float line information. FL; float line length (m), FD: float line diameter (mm), FM; float line materials (Cremona, Kevlar type + Kuronawa type, Nylon type, Others and Tetron type). Kuronawa is traditional black rope.

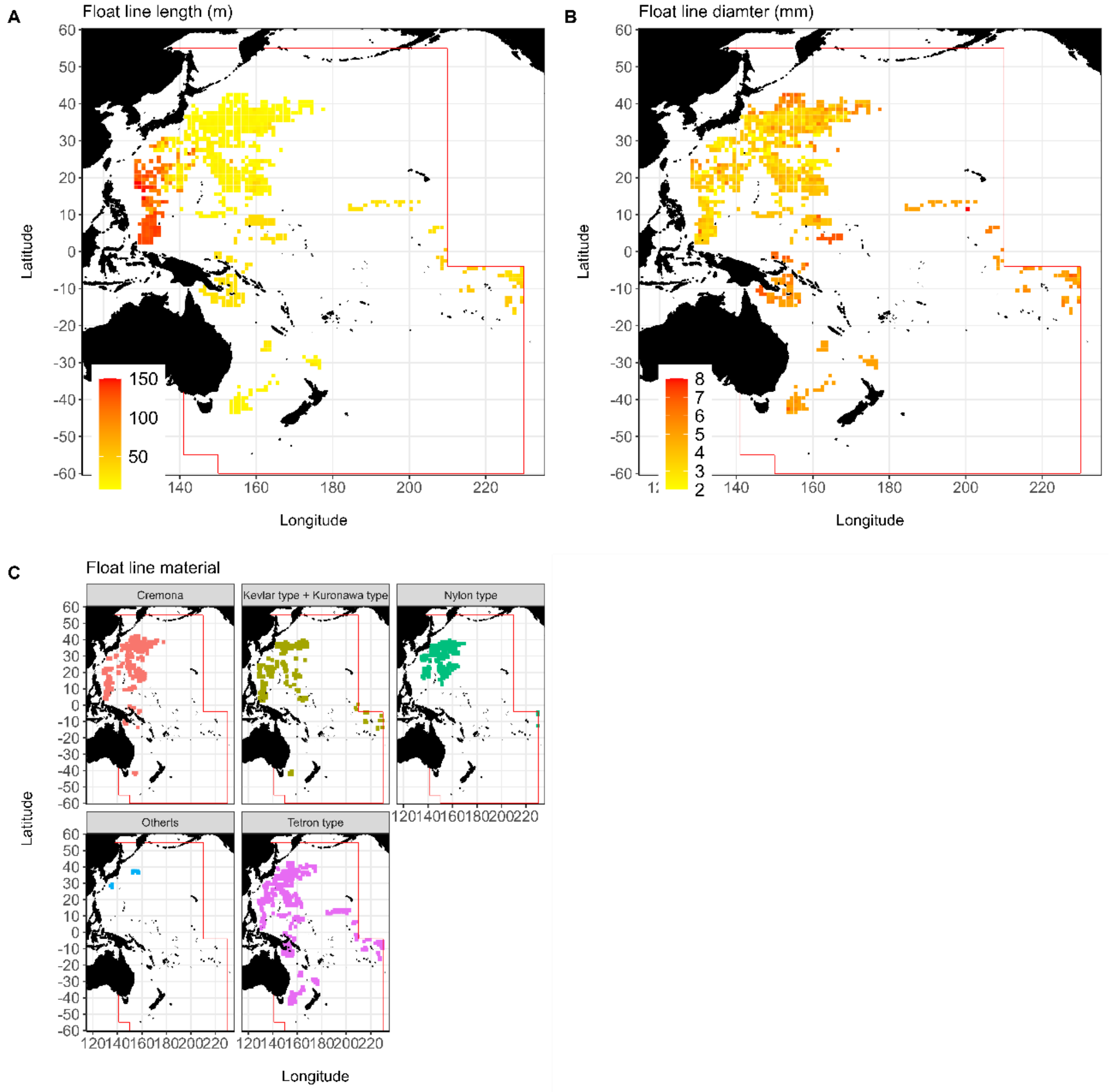


Fig. 7. Maps of float line characteristics. A; float line length (m), B; float line diameter (mm), C; float line materials (Cremona, Kevlar type + Kuronawa type, Nylon type, Others and Tetron type).

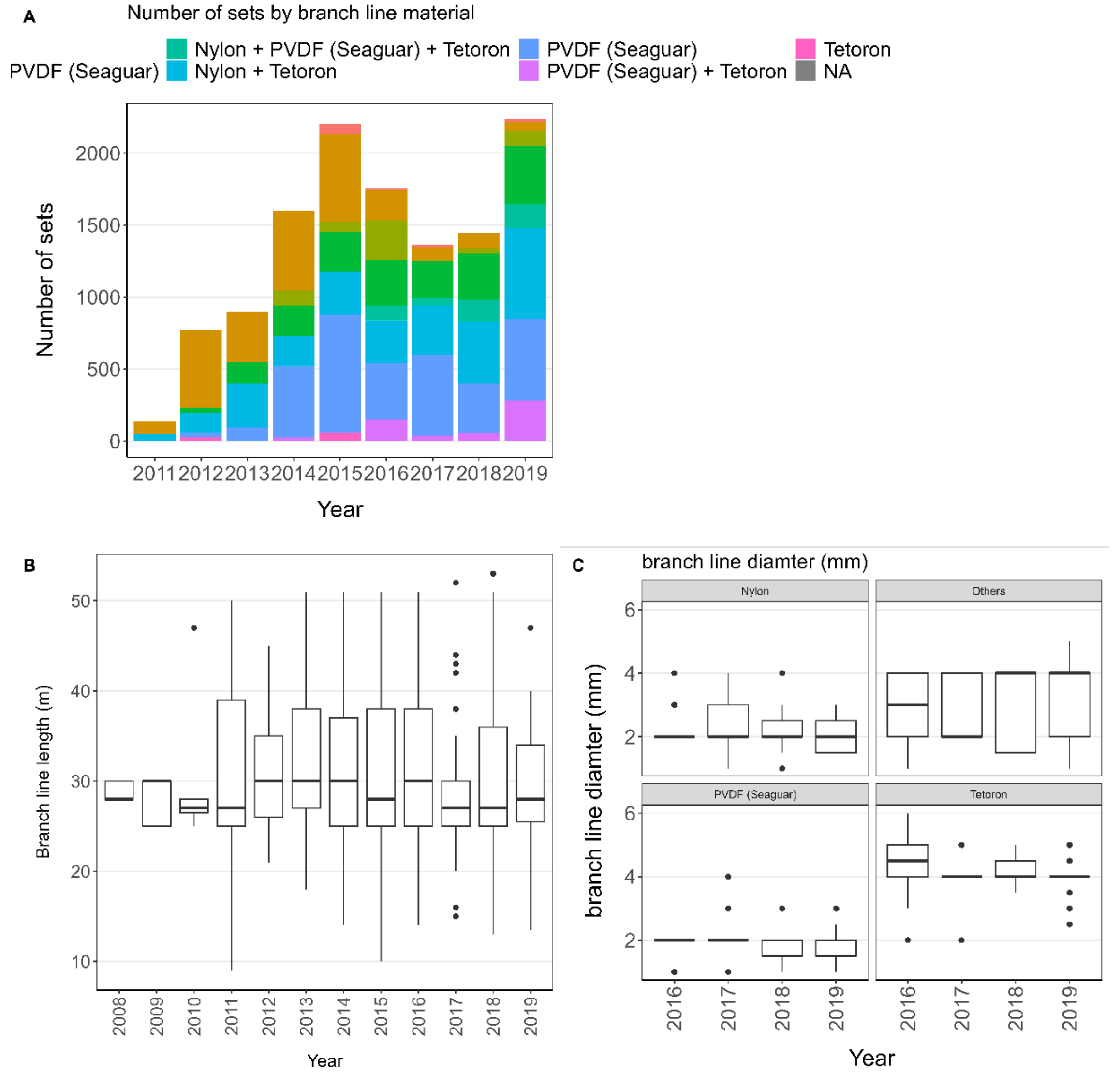


Fig. 8. Time series of blanch line characteristics. A; Number of sets by branch line materials. B; branch line length (m), C; branch line diameter (mm).

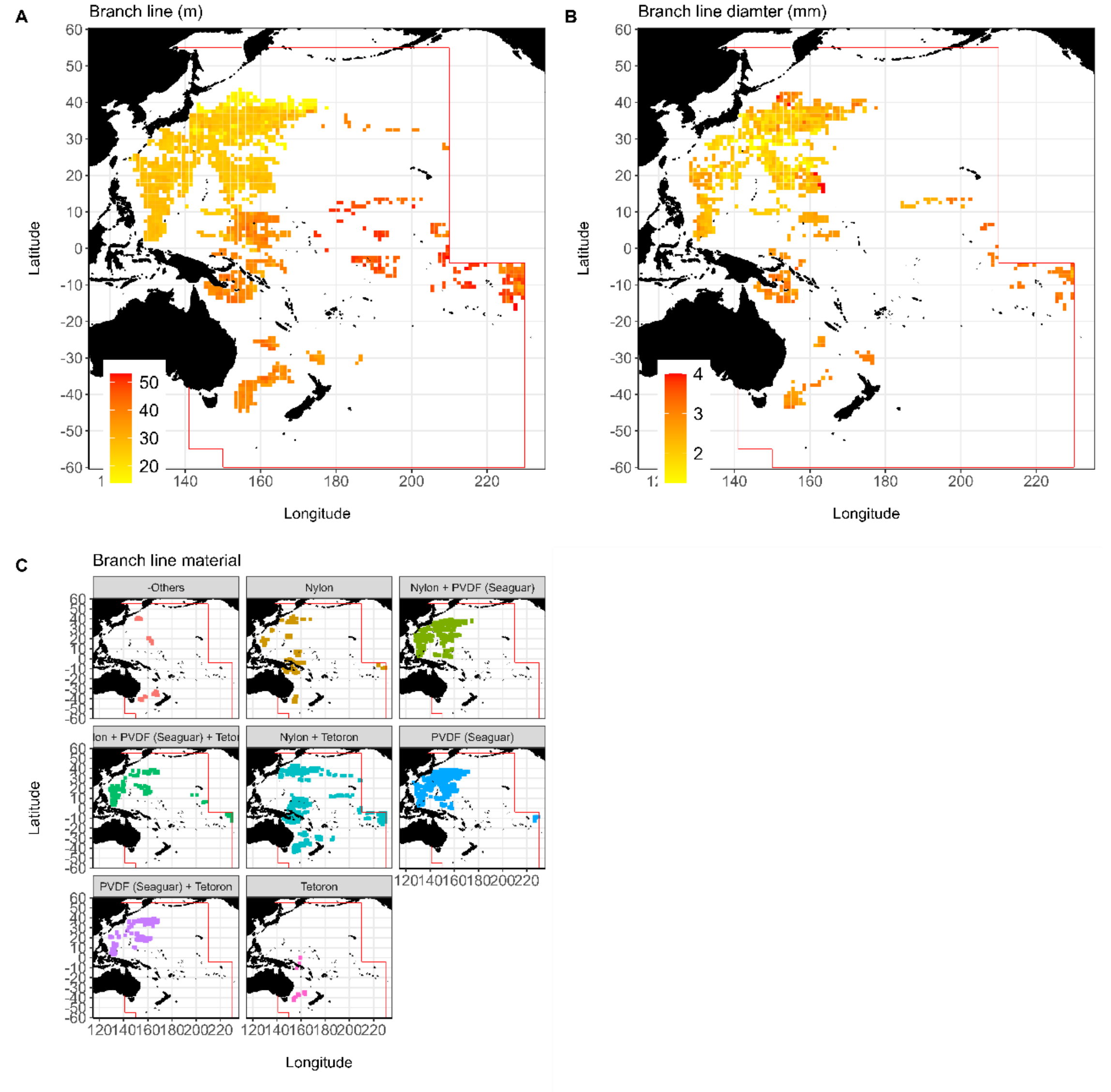


Fig. 9. Maps of branch line characteristics. A; branch line length (m), B; branch line diameter (mm), C; branch line materials.

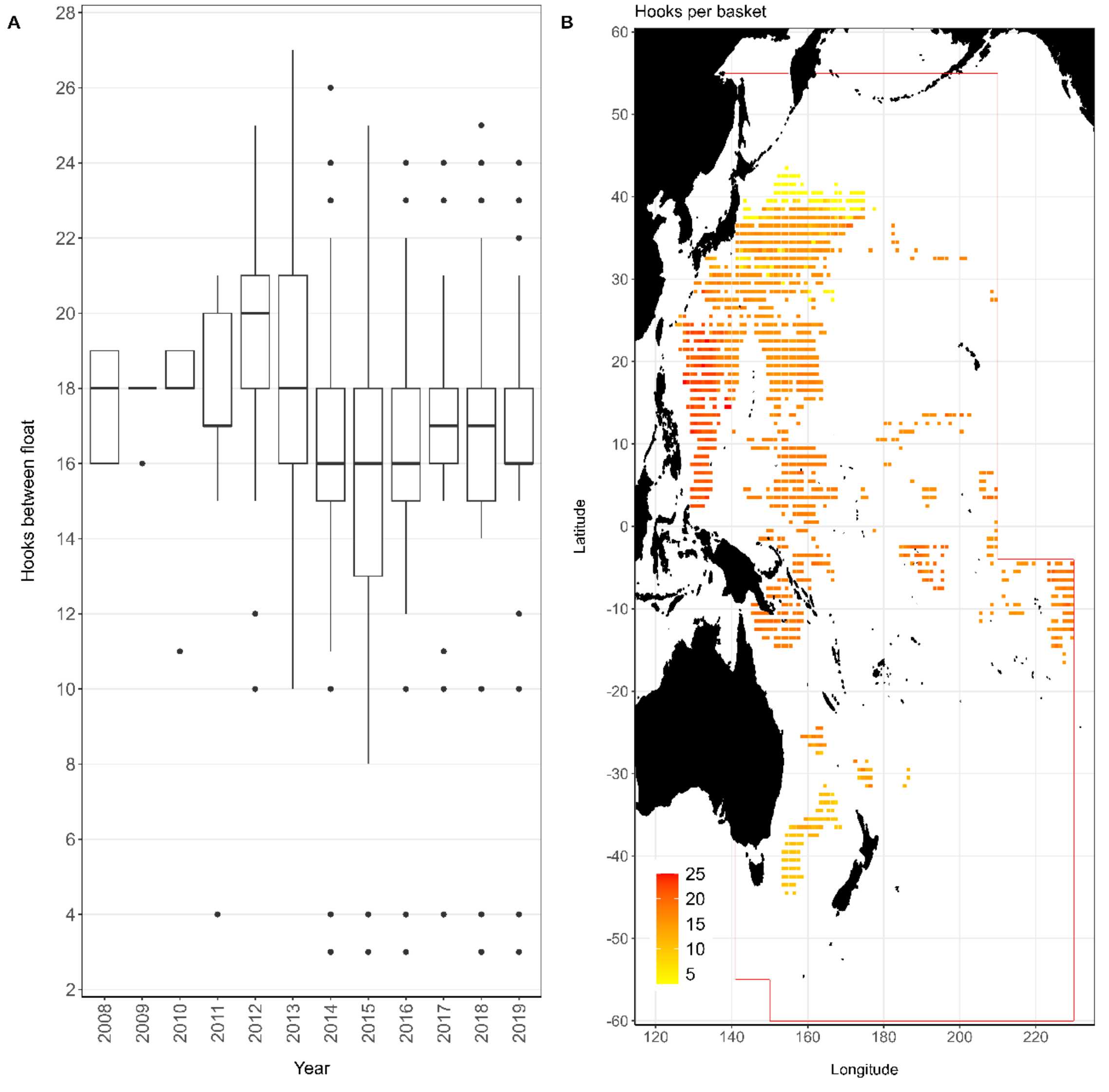


Fig. 10. Time series (A) and maps (B) of hooks per basket (HPB).

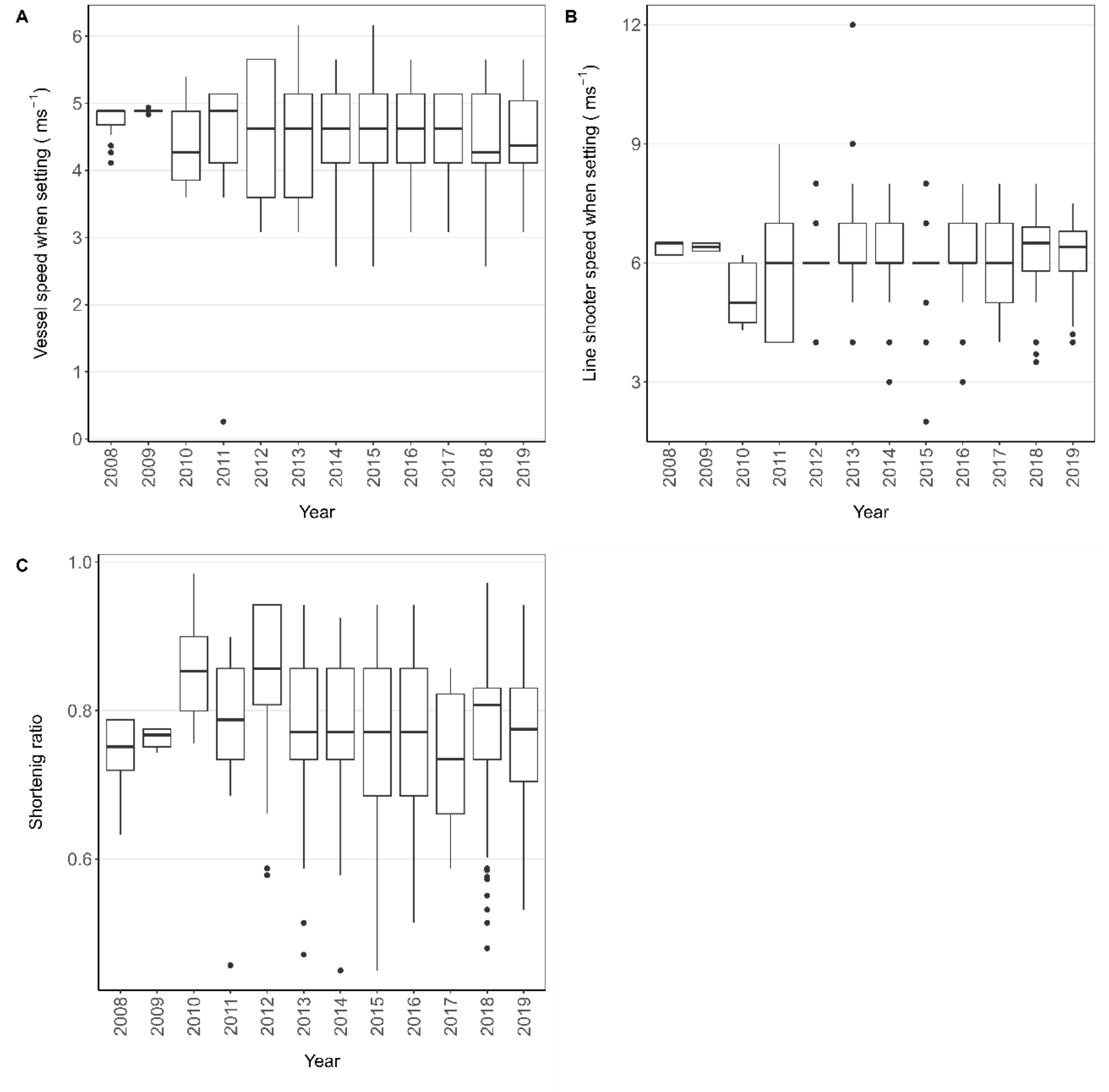


Fig. 11. Time series of vessel speed (A, ms^{-1}), line shooter speed (B, ms^{-1}) when longline gear setting and (C) shortening ratio.

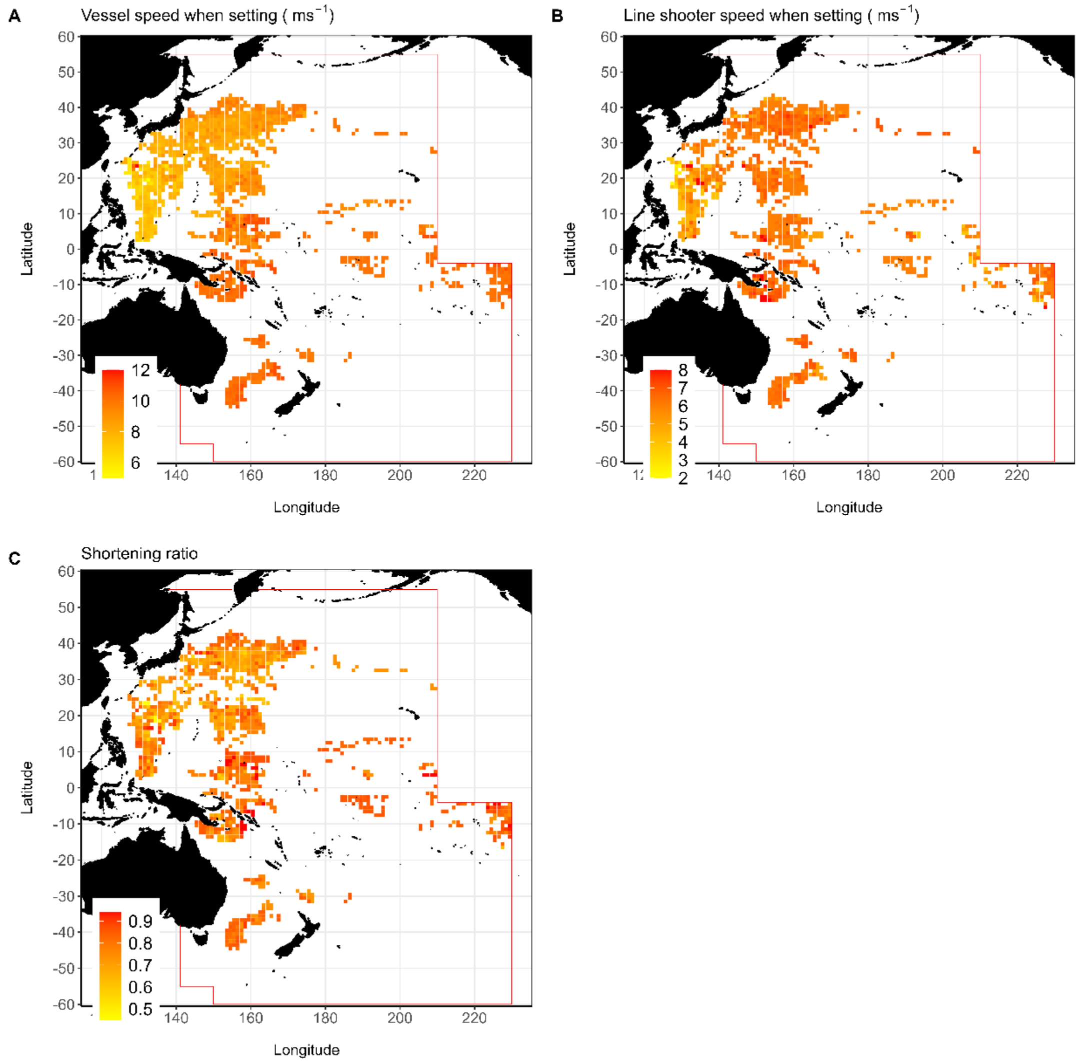


Fig. 12. Maps of vessel speed (A, ms^{-1}), line shooter speed (B, ms^{-1}) when longline gear setting and (C) shortening ratio.

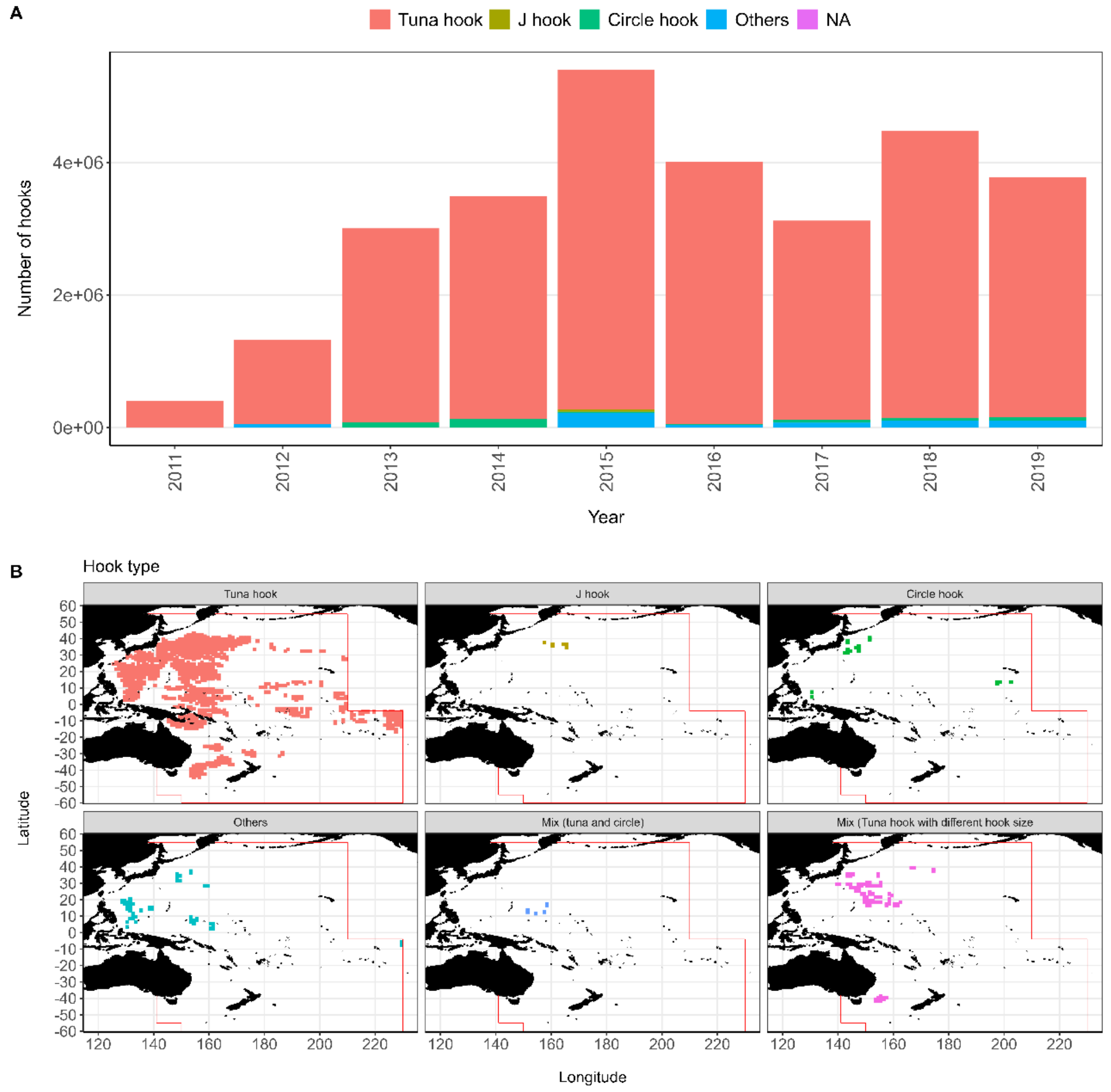


Fig. 13. Time series of number of hooks by hook type (A) and maps of hook types (B).

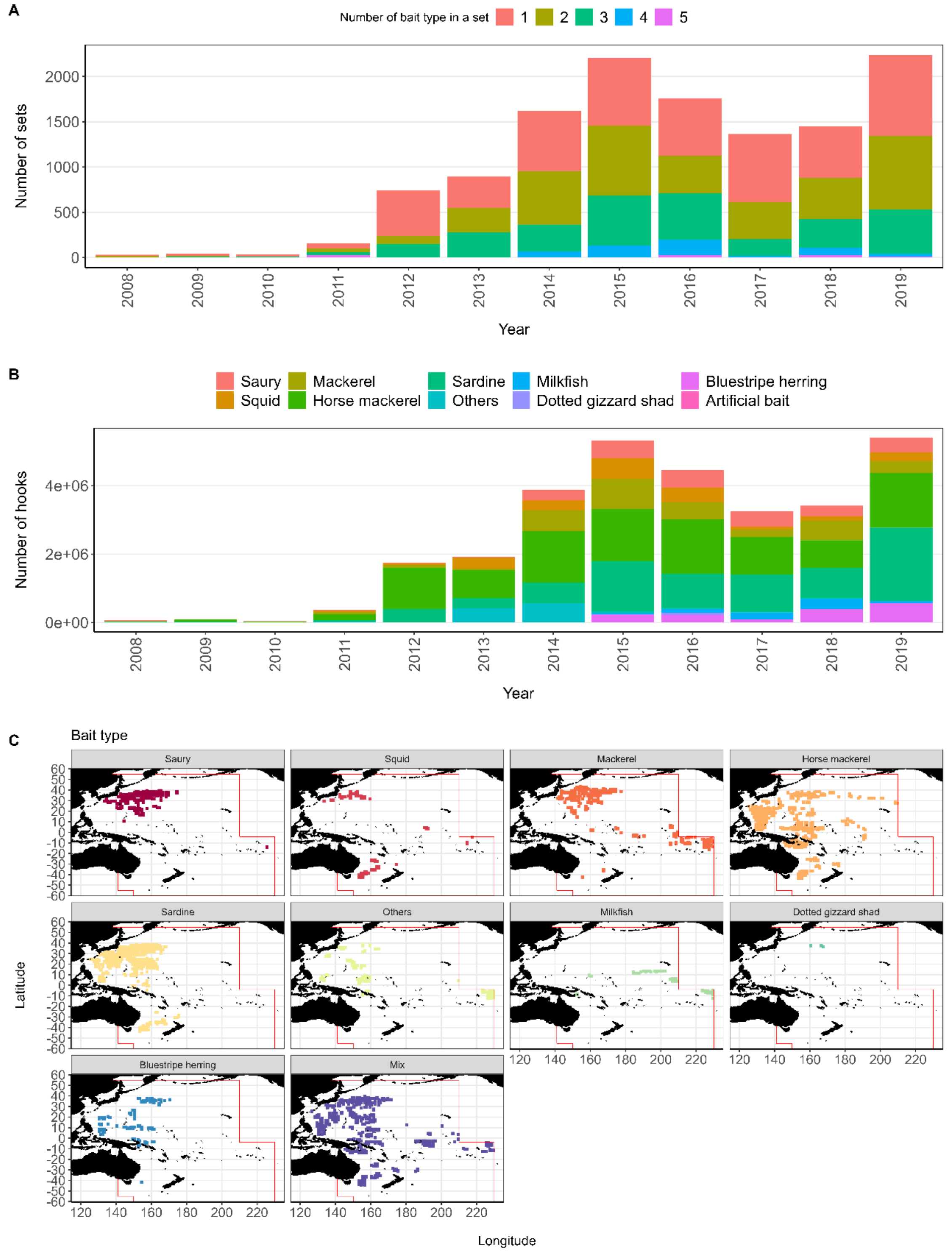


Fig. 14. Time series of number of bait type in a set (A) and number of hooks by bait type (B). Maps of bait type (C).

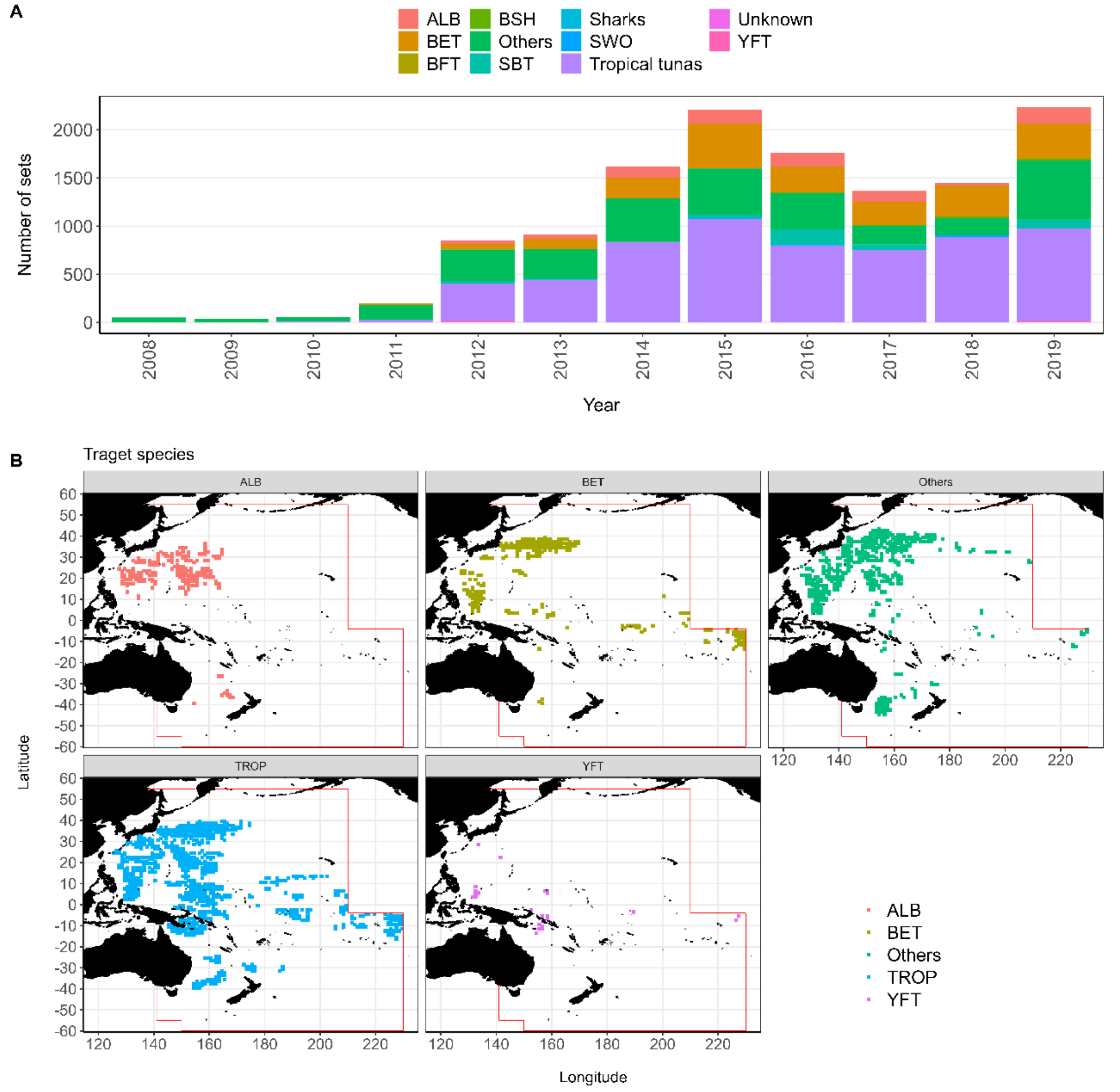


Fig. 15. Time series of number of sets by target species (A). Maps of target species (B). The number of target species is summarized into 5 in panel B from 11 in panel A.

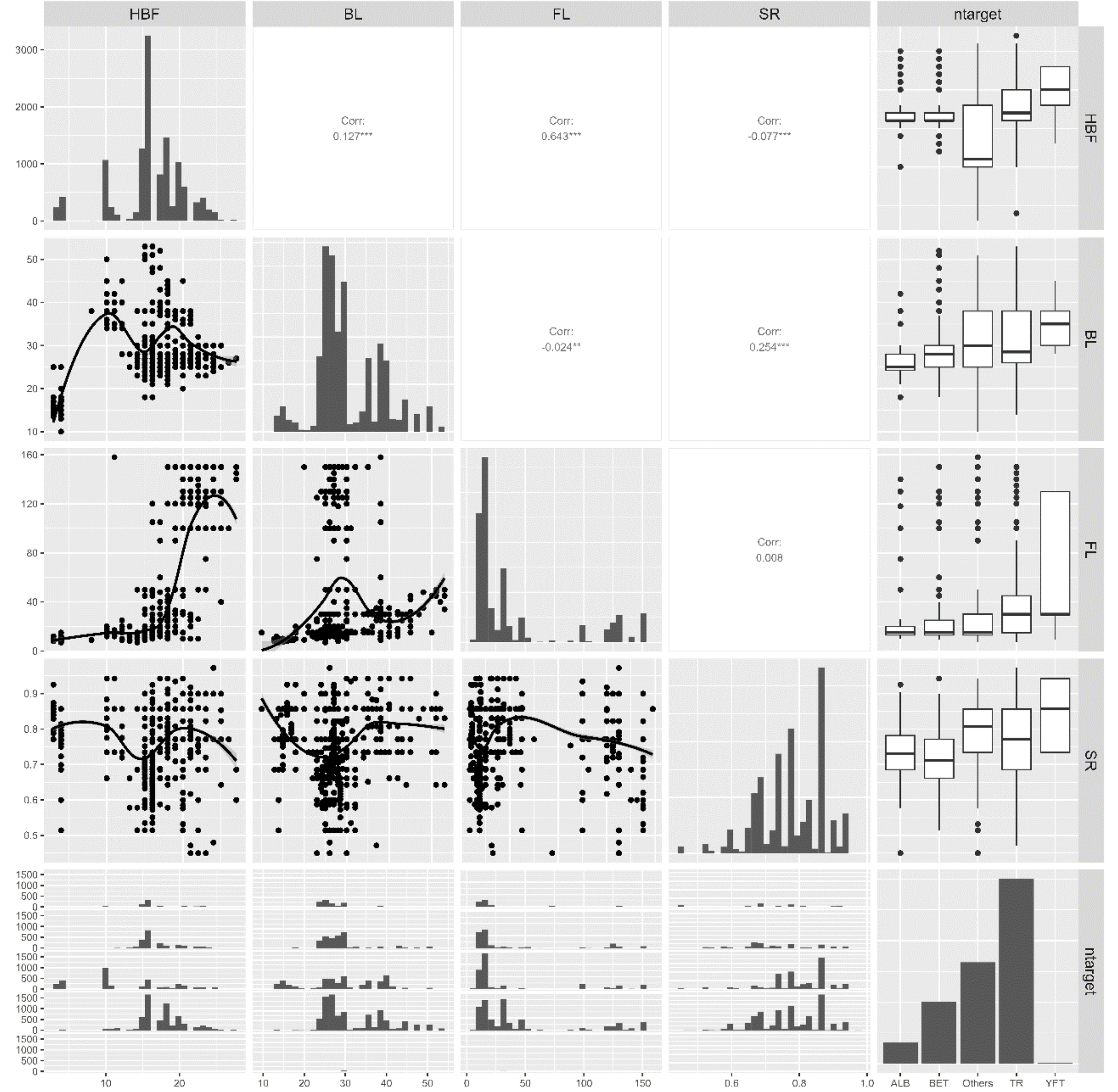


Fig. 16. Scatter plot matrix among longline gear configurations. HBF; hooks per basket. BL; branch line length (m), FL; float line length (m), SR; shortening ratio, ntarget: target species in figure 15.