Vertical distribution pattern of CPUE for striped marlin in the north Pacific estimated by the with data of the time, depth and temperature recorders collected through a longline research cruise of Shoyo-maru in 2004 in the north east Pacific, preliminary results [1]

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Introduction

Vertical distribution patterns of billfishes, which are estimated with the data collected by tracking study, and pop-up and archival tag study, has been used for estimating effective fishing effort of Japanese longliners in studies of CPUE standardization using the habitat model (Hinton and Nakano, 1996; Yokawa and Takeuchi, 2000, 2001, 2002). In these studies, probability that a billfish taking bait in a vertical stratum is assumed to be proportional to total time it spends in their habitat. Though this hypothesis is essential for estimation of effective fishing effort, there have been no studies that verify the hypothesis so far (Goodyear et. Al., 2002). In the autumn of 2004, we conducted a longline research cruise targeting striped marlin in the northeast Pacific. During the cruise, more than 150 of the time, depth and temperature recorders (TDRs) are attached on the branch line in every operation to estimate hooking time, depth and temperature of fishes caught during operation, as well as vertical coverage of longline gear. This document reports the preliminary results of analysis of TDR data to estimate vertical distribution pattern of CPUE of striped marlin caught by longline gear, as the possible input for the biological and statistical habitat model.

Materials and Methods

a)Longline research cruise

In the period of September to November 2004, Japanese RV Shoyo-maru carried out longline research cruise targeting striped marlin in the northeast Pacific (Fig.1). Total of 30 longline operations were conducted. Research area of first cruise (1st – 16th operation) is the same are where Japanese distant-water longliners were conducted operations targeting striped marlin (left panel of Fig. 1). Operation area of second cruise (17th – 30th operation) is the one of bigeye tuna fishing ground of Japanese distant-water longliners (right panel of Fig. 1). In all operation, large sized Pacific mackerel is used as bait.

In the 1st – 7th and 17th – 30th operations, both shallow and deep settings were conducted in a single operation. Number of hooks between float (NHF) of shallow settings are

three. NHF of deep settings of 1st – 7th and 17th – 20th are seven, and 21st – 30th are eleven. NHF of deep settings modified during research cruise so that effort of deep settings can cover the depth well below the thermocline. Number of basket of the shallow setting of these 21 operations is three. Amount of effort of deep setting with NHF=7 is 420 hooks (60 baskets) per operation, and amount of effort of deep setting with NHF=11 is 440 hooks (40 baskets) per operation. Amount of effort of shallow settings is 450 hooks (150 baskets) per operation.
In the 8th – 16th operations, only shallow setting (NHF=4) is used, and amount of effort is 800 hooks (200 baskets) per operation.

Length of branch line is 40m in all operation. Length of float line is 10m for shallow setting, and 10 or 20 m for deep setting. Length of float line of deep setting is modified based on the depth of thermocline so that effort of deep settings can cover the depth well below the thermocline. Distance between branch line and distance between branch line and float line are set as 50m, except for the distance between branch and float lines of shallow setting which is set as 40m to make setting depth of hooks of shallow setting shallower.
In 1st-16th operation, circle hooks are used in addition to regular tuna hooks to compare the effectiveness of them to the regular tuna hooks. Because number of circle hooks and regular hooks used in a operation are same and they are evenly arranged, effect of circle hook is ignored in this analysis.

Data of 22nd operation is excluded from analysis because of serious trouble during gear retrieving, which has high possibilities to cause significant reduces of catch.

b) Vertical CPUE trend of striped marlin

About 190 TDRs were deployed in each operation. TDRs were attached at a point just above hook line (2m above hooks), and recorded depth and temperature of TDRs were approximated to the ones of the hook. TDRs are attached on at least one branch line for a basket of shallow settings (3 or 4 hooks per basket), and one or two branch lines for a basket of deep settings. Calibrations of TDR were conducted using CTD once in a cruise to correct recorded data of TDRs.

Number of branch line with TDR is altered in order by baskets so that under water movement of the hook without TDRs could be extrapolated by data of TDRs attached to branch lines close to it.

TDRs used in this study recorded depth and temperature by every 10 seconds during operation. These data are used to determine hooking time, depth and temperature of the hooked fishes as well as vertical distribution of hooks. Time of hooking of marlins is identified by unnatural change of recorded depth of hook.

In case that striped marlins hooked by a branch line without TDR, when the hooking time of striped marlin can be detected by data of TDR attached on branch lines near to the hooked one, hooked depth and temperature are estimated using data of TDR around hooked one by assuming that under water positions of hooks without TDRs is same as the ones with TDR. When hooking time of striped marlin cannot be detected or difficult to detect by data of TDRs attached on branch line near to the hooked one, such case is eliminated from analysis.

Surface temperature, temperature at the bottom of surface mixed layer, as depth of thermocline of hooking point of striped marlin is obtained by the data of TDR same as the ones used for estimation of hooking time. Surface temperature is assumed to be the same as the first record of temperature of TDR after it go down under water. Bottom of surface mixed layer and depth of thermocline are assumed to be same depth which is obtained as the largest inflection point of depth – temperature relationship calculated from data of TDR same as the ones used for estimation of hooking time.

To estimate vertical CPUE pattern of striped marlin, effect of each hook in catching striped marlin in a particular depth layer is assumed to have linear relationship with total time that hook stayed in that layer. Under this assumption, amount of effort is calculated as the sum of soaking time of all hooks by depth layers, and it was estimated for each operation. To do this, under water movements of hooks of branch line without TDR were assumed to be the same as the nearest one with TDR. Vertical layers are categorized by the depth (by 25m) and by the relative temperature to the surface (by one degree Celsius). CPUE of striped marlin in a particular depth layer is calculated as the quotient of catch number of striped marlins in the depth layer to the sum of soaking time of all hooks in the depth layer.

In all operation, gear setting started at around 8 AM and it takes two and half or three hours. Retrieving of gear started around 5:30 PM, and ship time adjusted in each operation so that sunset occurred in around 6:00 PM. Gear retrieving usually finished between 0:00 AM and 1:00 AM, but it varied by the condition of each operation.

Results

Total of 199 striped marlins are caught during 30 operations, and hooking time, depth and temperature could be estimated for 191 individuals. Length frequencies by sex of striped marlin caught and measured during the research cruise are shown in Fig. 2. Total of 161 striped marlins are measured. Other 38 striped marlins are released with pop-up tags, dropped off during bringing fish up to the deck, and part of their body bit off by other organisms. All tagged and released striped marlin are examined their body weights by naked eye observations and end those estimated body weights are converted into the eye-fork length by the relationship shown in Fig. 3. No striped marlins are caught moving hooks (hooks in gear setting or gear retrieving).

Figure 4 shows the number of striped marlin by hooked time of the day. Two peaks observed in the hooking time of striped marlin, larger one is in 10-11 AM, and smaller one is 5-6 PM. Figure 5 is same histogram but time is relative time to the sunset. Among 191 striped marlins, 21 (11% of total) marlins are hooked after sunset.

Figure 5 shows the number of striped marlin by soak time of hooked branch line. Soak time of hooked branch line is calculated as the remainder of estimated hooked time and set time of hooked branch line which recorded in the operation report. Highest catch number observed in one-two hour after set of hooked line. Number of hooked striped marlin shows steady declining trend after that. No striped marlin hooking is observed in the period 0-1 hour after the set of branch line.

Figure 7 shows the relationship between size (cm, EFL) of hooked striped marlin, hooked depth (m) of striped marlin. No particular relationships are observed between two, but smaller sized fish (smaller than 130 cm) seemed only caught relatively shallower layers. Figure 8 shows relationship between hooked depth (m) of striped marlin and depth of thermocline (m) of hooking area. Roughly positive linear relationship is observed between two. Figure 9 shows the relationship between size of hooked striped marlin and hooked depth relative to thermocline (m, Δdepth). Δdepth=0 m means fish hooked at depth of thermocline. Only few fishes are hooked above thermocline, and majority of them are hooked in depth between Δdepth = 0 – 50m. No particular relationship is observed between size of fish and Δdepth.

Figure 10 shows relationship between size of striped marlin and hooked temperature (C°), and Fig. 11 shows relationship between size of striped marlin and hooked temperature relative to thermocline (C°, Δtemp). It seems that water temperature give

Deepest record of hooking is 186m (water temperature is 12 C°, and Δtemp = 11.6 C°) by fish of 148.5cm EFL, and the depth of thermocline is 60m. Shallowest record of hooking is 33m (water temperature is 29 C°, and Δtemp = 0.3 C°) by fish of 74cm EFL, and the depth of thermocline is 26m. Largest Δtemp recorded is 14.6 by fish of 176cm EFL, with hooked temperature is 15 C°, hooked depth is 100m, and depth of thermocline is 67m.

Results of basic analysis of catch time, temperature, and depth suggest that hooked depth smaller sized (>130cm EFL) striped marlin tend to restrict to shallower layers than large sized one, those small sized fishes are eliminated from the analysis of vertical CPUE pattern in this study. A former study in the Atlantic by (Yokawa and Saito, 2003) indicated that CPUE of marlin during night is significantly lower than day. Because the results shown in Figures 4-6 show similar tendencies also observed in the Pacific striped marlin, catch and effort data after sunset is also deleted from the analysis of vertical CPUE pattern. As a result of this data selection, records of hooking of total 139 striped marlins are used in the analysis.

Figure 12 shows vertical distribution of catch number of striped marlin, effort (hours x hooks) and CPUE (number/1000 hooks x 15 hours) of striped marlin by 25m depth layer. Largest number of catch (60%) is obtained in 50-75m where largest amount of effort (44%) allocated. Total of 84% of catch are obtained in 50-100m where 61% of effort are set. No striped marlin is caught in 0-25m. Some efforts, however, existed in layers deeper than 200m, no striped marlin catch is observed in those layers. Highest CPUE is obtained in 50-75m, and second highest one is 75-100m. Values of CPUEs of these two layers are more than double from one in 25-50m.

Shoyo-maru research cruises conducted in two areas which have different environmental characters, 1st cruise (operations 1 – 16) conducted in area of the past striped marlin fishing ground of Japanese longliners, and this area receiving strong influences of up-welling and characterized by the fast surface current and shallow thermocline. 2nd cruise (operations 17 - 30) conducted in the one of bigeye tuna fishing ground in the northeast Pacific, where velocity of current is relatively slow and depth of thermocline is deeper than the area of 1st cruise. As these different environmental characters might give some influences on the vertical CPUE pattern of striped marlin, analysis of data is also conducted for each area. For convenience, former area named area 1 and later area named area 2 in this study.

Figure 13 shows the vertical distribution of catch number, effort and CPUE by 25m depth layer, and by area. In area 1, 71% of total catch is obtained in 50-75m. In area 2, 38% of the total is obtained in 50-75m, and 42% is obtained in 75-100m. No striped marlin caught in layers deeper than 125m in area 1, while 4 fishes (3% of total) is caught in 125-200m in area 2. In area 1, 11 fishes (11%) caught in 25-50m, while only 1 fishes (2%) caught in area 2. In both areas, highest CPUE recorded in 75-100m, and lowest CPUE recorded in 25-50m (except for layers with no catch).

Because many former study about underwater movement of marlins indicated that vertical distribution probability of marlins is regulated by the vertical change of water temperature (e.g. Brill et. al., 1993), vertical CPUE is analyzed relative temperature to the surface (Δtemp, C°). Figure 14 shows the vertical distribution of catch number, effort and CPUE by the depth layer categorized by the relative temperature to the surface. Vertical layers are divided by every 2 C°, except for the surface where one independent layer of 0 - -1 C°. Largest number of catch is obtained Δ3-4 which is 24% of total. CPUE increased gradually from 0 to Δ5-6, and decreased thereafter except for Δ9-10 where highest value is recorded.

Figure 15 shows the vertical distribution of catch number, effort and CPUE by Δtemp depth layer, and by area. In area 1, largest number of catch obtained in Δ5-6, and highest CPUE obtained in Δ9-10. CPUE of Coolest layer Δ13-14 recorded 3rd highest value. In area 2, largest number of catch obtained in Δ3-4, and highest CPUE obtained in Δ3-4. CPUE of Coolest layer Δ11-12 recorded 3rd highest value. Figure 16 shows the two vertical CPUE pattern with the confidence interval.

Discussion

In the present study, two types of scales, distance to the surface and relative temperature to the thermocline (bottom of surface mixed layer), are used to analyze vertical CPUE of striped marlin. In ether case, vertical distribution pattern of CPUE of striped marlin is quite different from the vertical distribution probability pattern striped marlins obtained from data of pop-up tags which are attached on fishes caught during same longline operations (Saito et al, 2005). This indicates that the vertical pattern of the catch ability of the longline gear is not uniform, then, the vertical CPUE pattern of striped marlin estimated in this study is appropriate for an input parameter to the habitat model to estimate the effective fishing effort of Japanese longliner on striped marlin.

An observed difference between the vertical probability pattern and the vertical CPUE would partly affected by the unbalanced distributions of longline efforts (Fig. 12). The longline hooks stayed quite few amount of time in the depth layer of 0-25m where striped marlin stays majority of their time, usually, longline hooks are just “passing through” this layer. Research with other fishing gear such as vertical longline, which allocated efforts more equally, would be useful for estimating “unbiased” vertical feeding probability of striped marlin. Former similar study by Boggs (1991) also reported that highest CPUE of striped marlin observed in depth layer of 40 – 120m.

In compare to the vertical CPUE pattern by the distance to the surface, a layer by layer variation of the one by Δtemp is large and irregular. If the accessibilities of striped marlin to the longline gear were mainly regulated by a particular factor, a vertical distribution pattern of CPUE analyzed by that factor would show a pattern which can be explained some probability distributions. Though many former studies (e.g., Brill and Lutcavage, 2001; Holland et., al. 1990) indicated that the vertical distribution probability of marlin regulated by relative temperature to the surface, result of this study suggests that vertical CPUE pattern would seemed to rather be regulated by distance from the surface where striped marlin usually stay than by relative temperature to the surface. There maybe another factor, such as distance to the thermocline, which can explain vertical distribution pattern of CPUE of striped marlin. Further study is necessary to obtain better estimation of effective fishing effort of marlins.

The vertical CPUE pattern by the distance to the surface shows two different patterns between 1st-16th operation and 17th -30th operation. The pattern of 1st-16th operation, high CPUE observed in 50-125m and no striped marlin catch observed in layer deeper than 125. In 17th-30th operation, a peak of the mode of CPUE is not so notable as the one of 1st-16th operation but some striped marlins were caught in layers of 125-200m. This difference would be caused by difference of environmental condition of operational area. An area of 1st-16th operation characterized by a shallow surface mixed layer and cold water mass below the mixed layer (Fig.

17). An area of 17^{th}-30^{th} operation has more moderate condition (Fig. 17). This cold water mass would become a barrier for striped marlin. The result of pop-up tag study (Saito, 2005) supports this. Striped marlin released in an area 17^{th}-30^{th} dive deeper than that in an area of 1^{st}-16^{th} operation

In this study, no striped marlin is caught by the moving hook. This results is different from the results by Boggs (1992), which reported that many striped marlin caught by sinking and raising hooks. One of the major reasons of this is large size of Shoyo-maru (2500 tons). Noises caused by Shoyo-maru, and strong current caused by the screw of the ship would bring off striped marlin around the ship.

The catch number of striped marlin by the time of the day shows that there are two modes in catch number, one is in the morning and the other is in the afternoon (one – two hors before sunset). Coastal sports fishing tournaments on billfishes recorded similar observation. In those tournaments, peak of hooking reported one in the morning, and also one in the afternoon, and many sports fishermen believes this phenomenon is caused by the movement of current in the fishing ground (JGFA, personal comm..).

Average catch number of striped marlin by hour in the daytime (before sunset) is more than 5 times higher than that in the night time (after sunset). Average catch number in the night time is influenced by gear retrieving which starts within one hour before the sunset; it seems the catch ratio in the night time is lower than that in the daytime.

Catch number and soaking time of the hooked gear seemed to have negative relationships. Such relationship would be affected by the starting time of operation; it would be interesting to research this issue to make precise evaluations of efficiency of longline gear.

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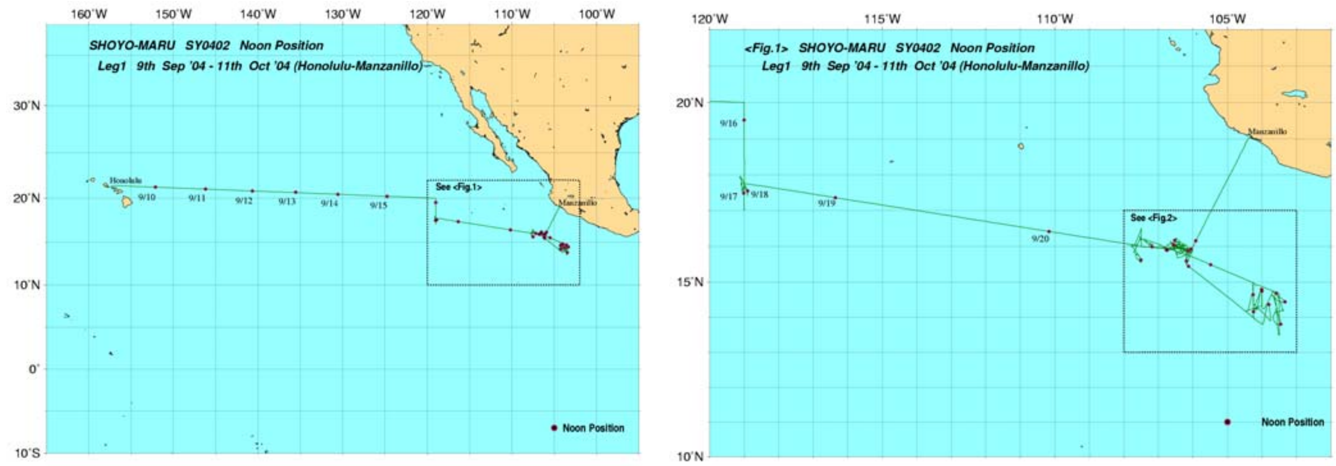

Fig. 1. Research areas (shown as square box) and operation points (shown as red circle) of first and second research cruise of Shoyo-maru in the autumn of 2004. Left panel shows the ones of first cruise and right panel shows the ones of second cruise.

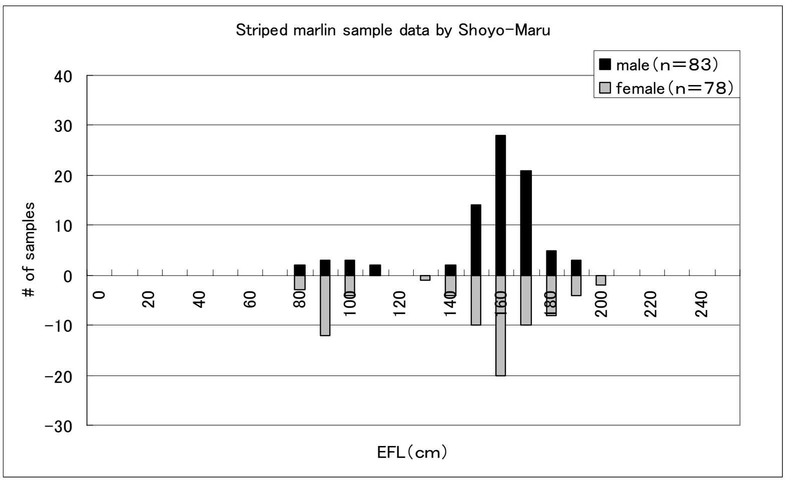

Fig. 2. Length frequency by sex of striped marlin caught and measured during Shoyo-maru research cruise in the autumn of 2004.

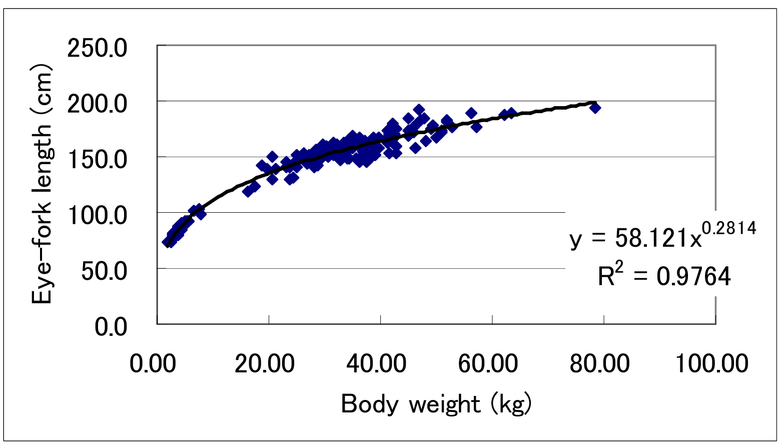

Fig. 3 Sex combined relation ship between eye-fork length (cm) and body weight of striped marlin caught by Shoyo-maru in the autumn of 2004 (n=161).

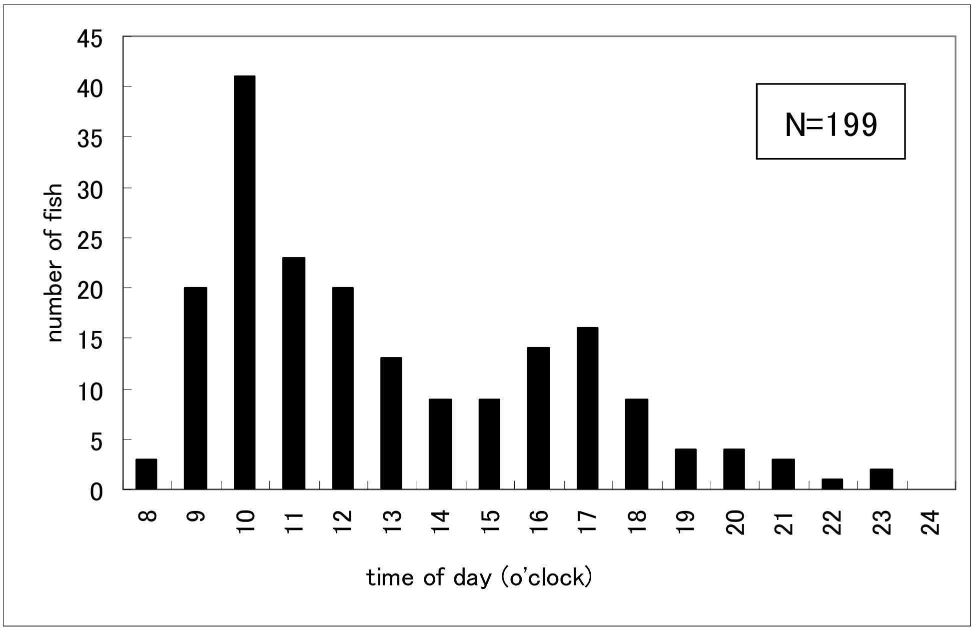

Fig. 4. Number of striped marlin by hooked time (o'clock) of the day (ship time). In all operation, ship time is adjusted so that sunset occurs around 6 PM.

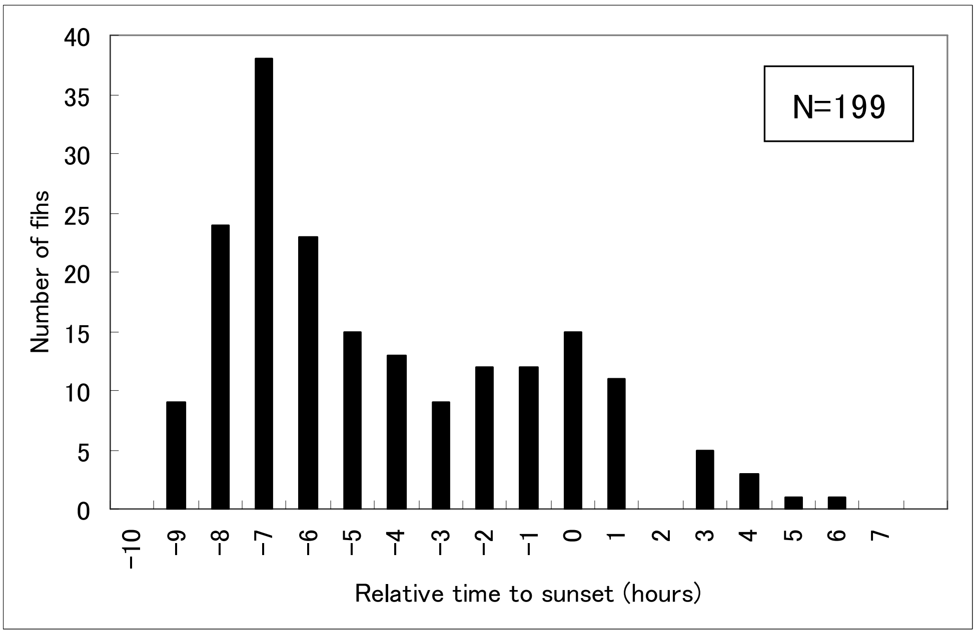

Fig. 5. Number of striped marlin by hooked time (hour) relative to the moment of sunset.

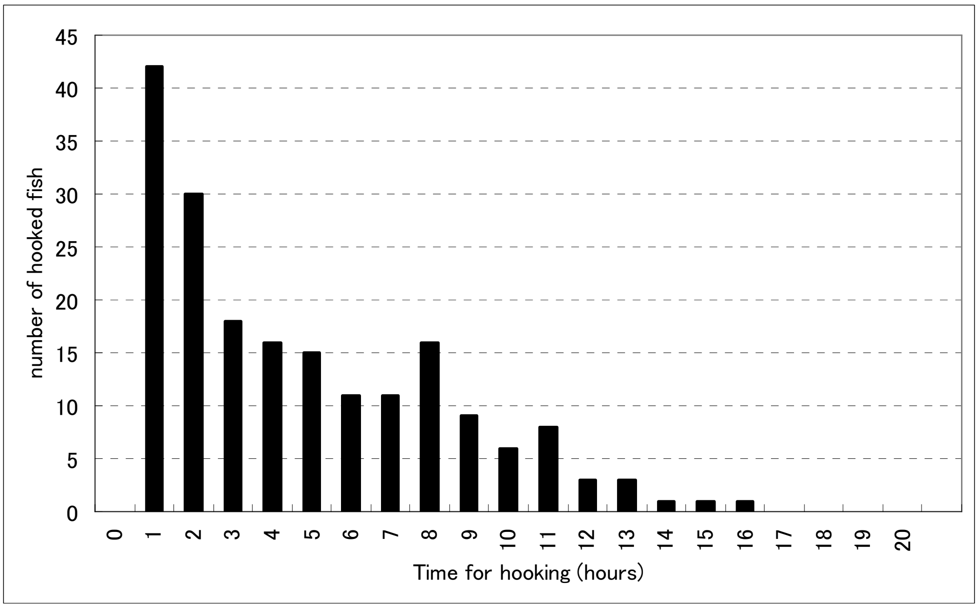

Fig. 6. Number of striped marlin by soak time (hour) of hooked branch line.

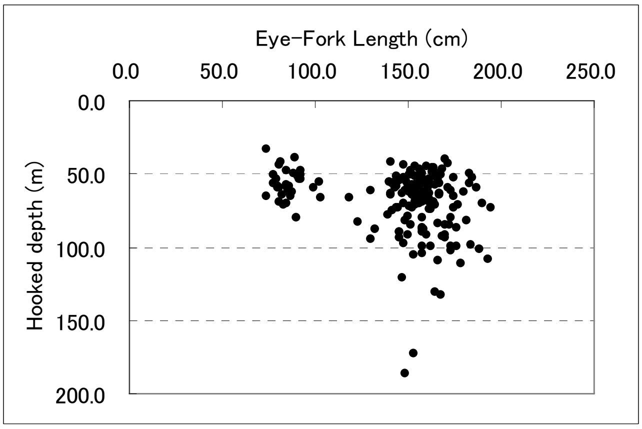

Fig. 7. Relationship between eye-fork length (cm) of striped marlin and hooked depth (m) of it.

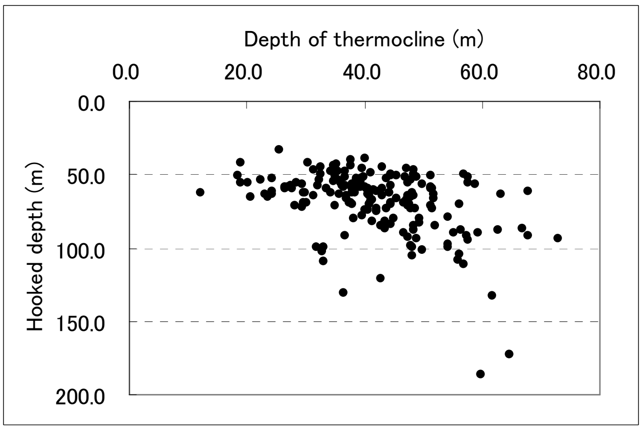

Fig. 8. Relationship between hooked depth (m) of striped marlin and depth of thermocline (m) of hooking area.

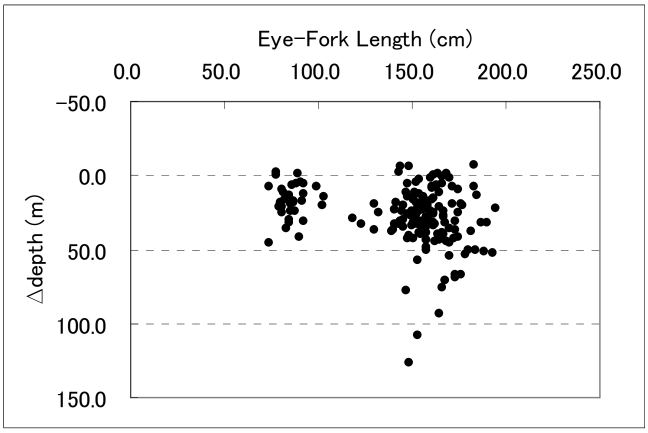

Fig. 9. Relationship between eye-fork length (cm) of striped marlin and hooked depth relative to thermocline (m, Δdepth).

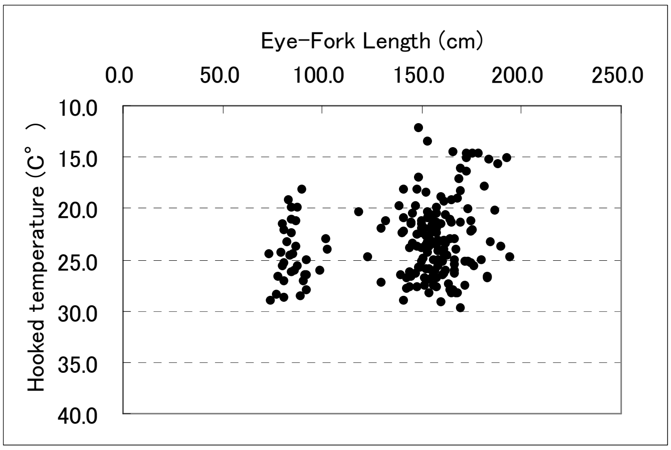

Fig. 10. Relationship between eye-fork length (cm) of striped marlin and hooked temperature (C°).

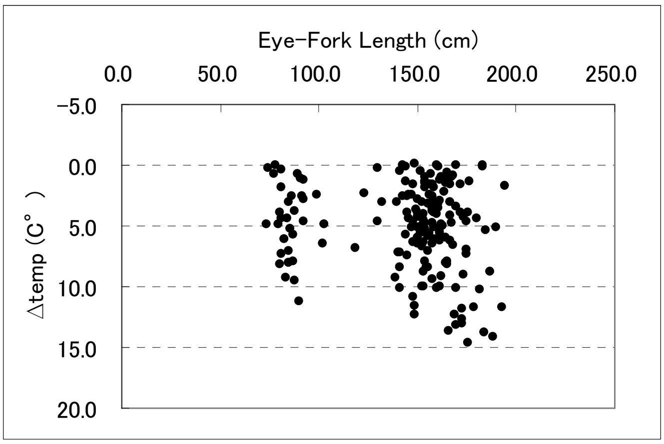

Fig. 11. Relationship between eye-fork length (cm) of striped marlin and hooked temperature relative to thermocline (C°, Δtemp).

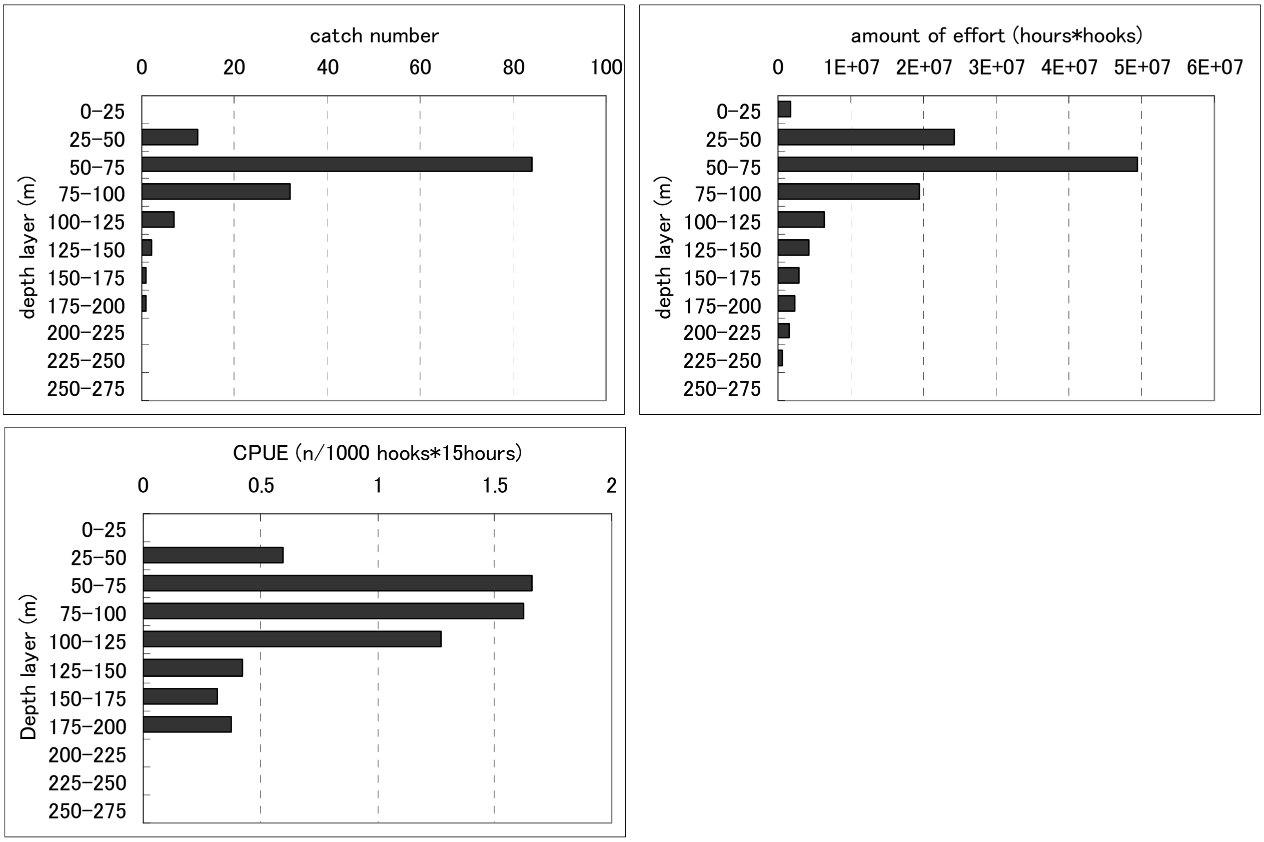

Fig. 12. Vertical distribution of catch number, effort (hours x hooks) and CPUE (number/1000 hooks x 15 hours) of striped marlin by 25m depth layer. Data of all operations (except for 22th operation) are used.

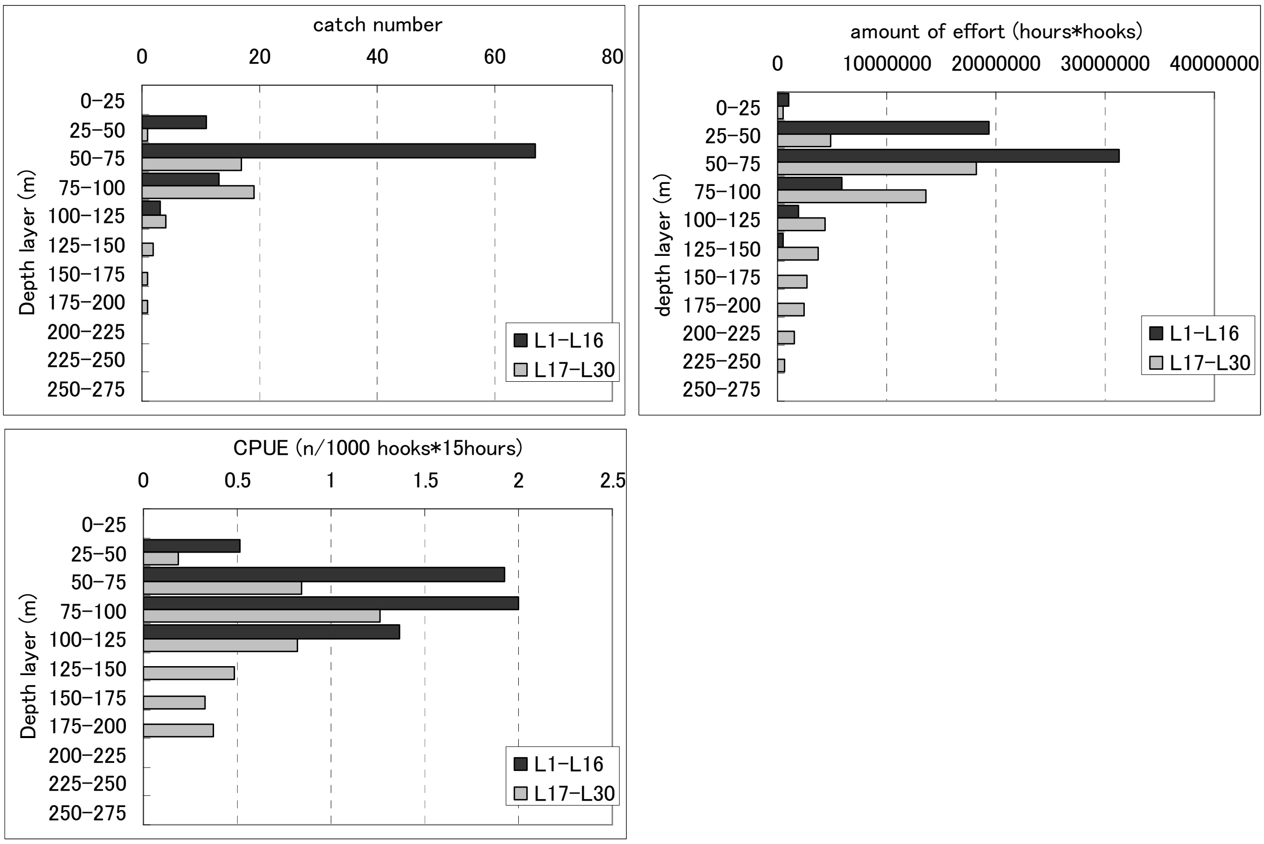

Fig. 13. Vertical distribution of catch number, effort (hours x hooks) and CPUE (number/1000 hooks x 15 hours) of striped marlin by 25m depth layer. Black bars show results in area 1 (1st – 16th operations), and gray bars shows results in area 2 (17th – 30th operations).

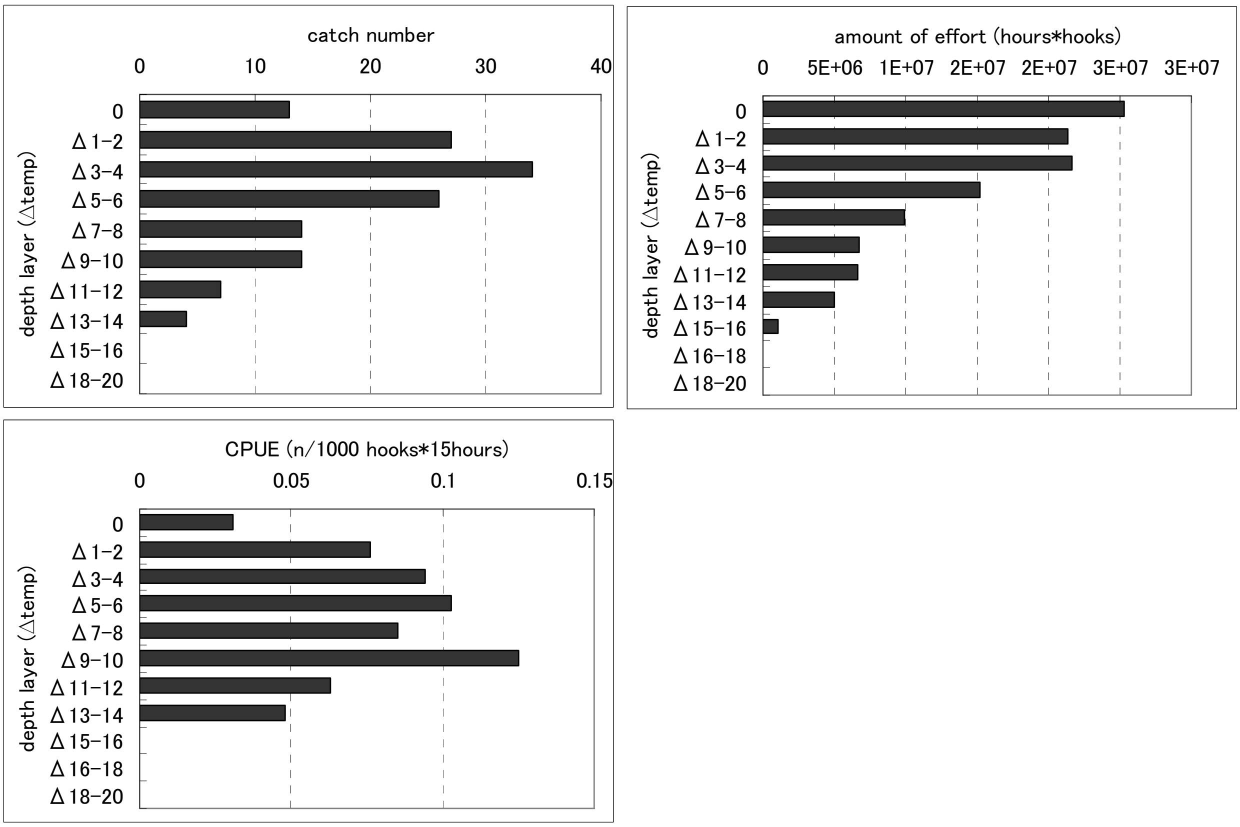

Fig. 14. Vertical distribution of catch number, effort (hours x hooks) and CPUE (number/1000 hooks x 15 hours) of striped marlin by depth layer (Δtemp, C°). Data of all operations (except for 22th operation) are used.

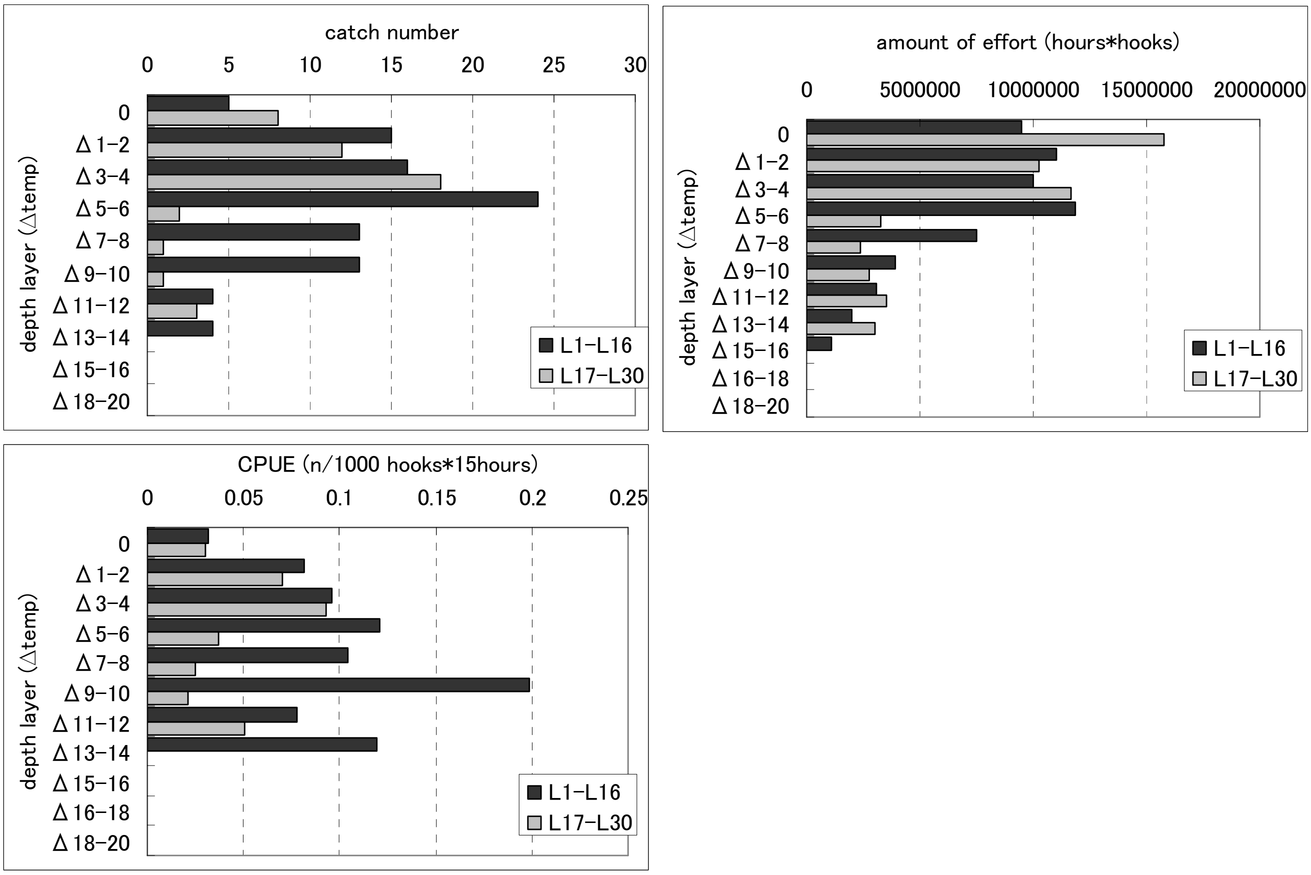

Fig. 15. Vertical distribution of catch number, effort (hours x hooks) and CPUE (number/1000 hooks x 15 hours) of striped marlin by depth layer. (Δtemp, C°) Black bars show results in area 1 (1st – 16th operations), and gray bars shows results in area 2 (17th – 30th operations).

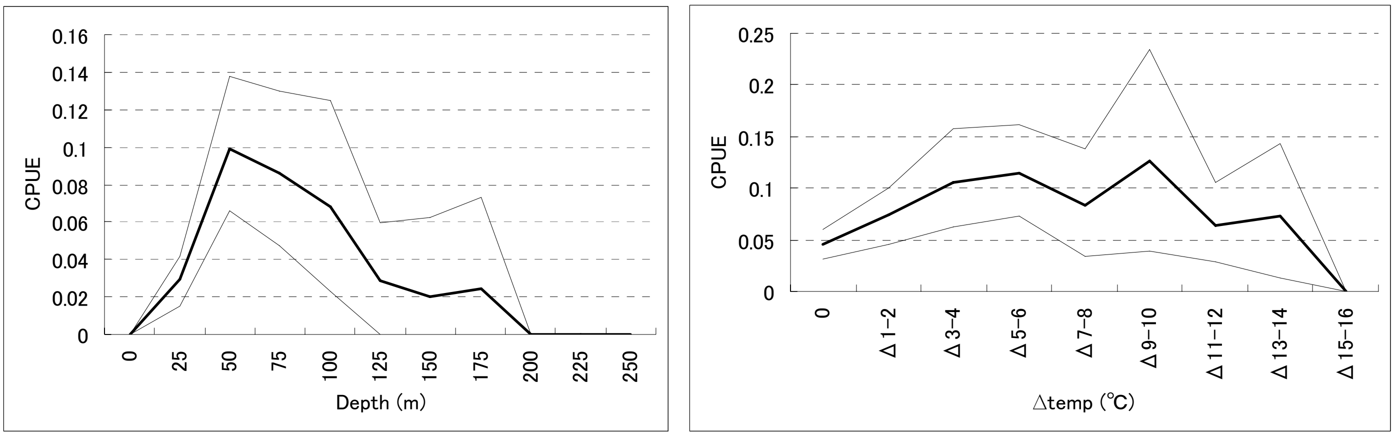

Fig. 16. Vertical pattern of CPUE (number/1000 hooks x 15 hours) of striped marlin and its confidence interval. CPUE by depth layer (m) is shown in left graph and one by Δtemp(C°) shown in right graph. All data were used. The confidence interval calculated by the boot-strap method.

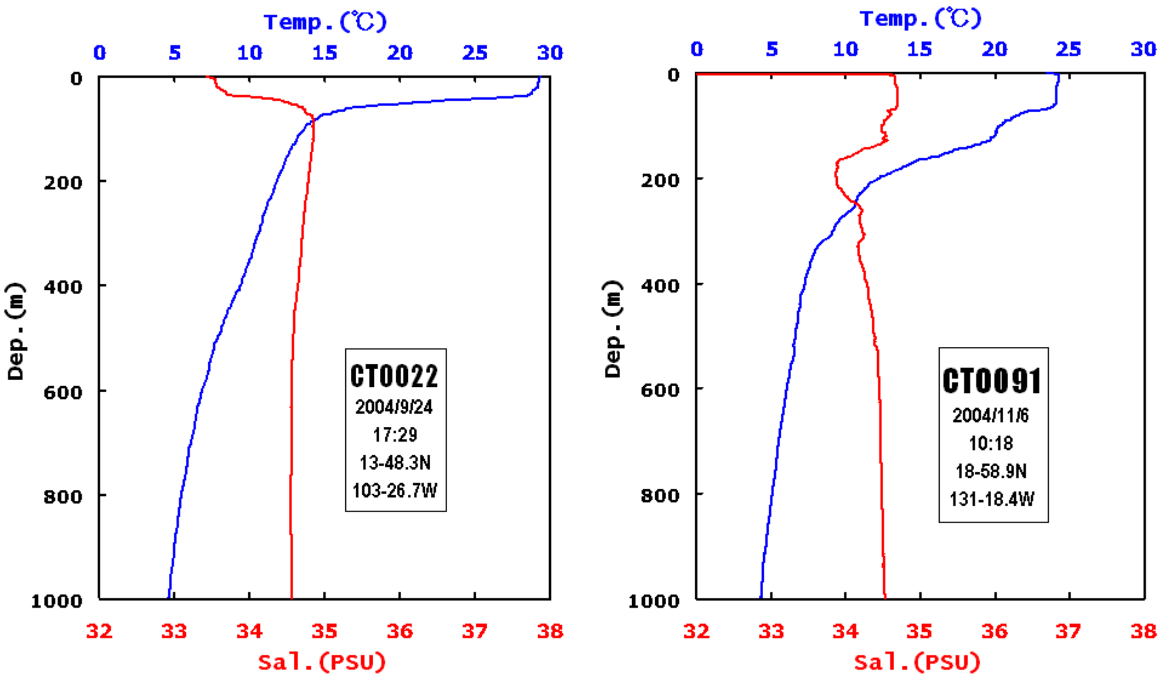

Fig. 17. Example of vertical profile of temperature and salinity in 1st-16th operations (left) and 17th-30th operation (right).