Monitor of the change of shortening ratio of longline gear during an operation using a newly developed buoy with a built-in GPS [1]

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Introduction

The vertical distribution pattern of the longline effort is one of the important input parameter of the habitat model, which estimates the effective fishing effort of fishes caught by longline gear, but only a quite rough way to estimate this pattern is available now. Mizuno et., al. (1997) suggested that there are two major factors which affects on the set depth of longline gear; one is sheer current and the other is shortening ratio.

The change of the set depth of the longline gear during the operation has been studied by many scientists since the 1960s and also some scientists investigated the effects of the sheer currents on the set depth of the gear. However, there has been no study about the effects of the shortening ratio on the set depth of the longline gear because no method has been available to attain direct measurement of the distance between the floats during operation.

Mizuno et., al. (1997) developed a floating buoy with a built-in a GPS (GPS buoy) to measure a distance between floats, but they could not obtained good results mainly because low performance of a GPS they used. We have developed new type of a GPS buoy and succeeded in a measurement of the distance between the floats in a longline research cruise conducted by Japanese RV Shoyo-maru in the autumn, 2004. This report describes basic results of the analysis of data we obtained by GPS buoy in the research cruise.

Materials & Methods

In the period between September and November, 2004, we conducted 30 longline operations in the northeast Pacific by Japanese R/V Shoyo-maru. The research area and position of longline operations are shown in Figure 1.

In the 1^{st} – 7^{th} and 17^{th} – 30^{th} operations, both shallow and deep sets were conducted in a single operation. Number of hooks between float (NHF) of shallow sets are three. NHF of deep sets of 1^{st} – 7^{th} and 17^{th} – 20^{th} are seven, and 21^{st} – 30^{th} are eleven. NHF of deep sets modified during research cruise so that effort of deep sets can cover the depth well below the thermocline. Number of the basket of the shallow sets of these 21 operations is three. Amount of effort of deep sets with NHF=7 is 420 hooks (60 baskets) per operation, and amount of effort of deep sets with NHF=11 is 440 hooks (40 baskets) per operation. Amount of effort of shallow sets is 450 hooks (150 baskets) per operation.

In the 8^{th} – 16^{th} operations, only shallow sets (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 sets, and 10 or 20m for deep sets. Length of float line of deep sets is modified based on the depth of thermocline so that effort of deep sets can cover the depth well below the thermocline. Distance between branch line and distance between branch line and float line are set at 50m, except for the distance between branches and float lines of shallow sets which are set at 40m to make setting depth of hooks of shallow sets 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. A polyethylene multifilament mainline (Dyneema, Toyobo Co., Ltd.), and monofilament nylon branch lines were used. Vertical current profile is recorded by ADCP in 10 minutes in gear setting.

In order to investigate the change of the shortening ratio, we attached a small floating buoy equipped a handy GPS (GARMIN, map60CS) inside of it (GPS buoy) to floats in both sides of selected baskets in each operation (Fig. 2). Time, temperature, and depth recorder (TDR, Murayama Electric Co., Ltd.) attached in the position close to hooks to monitor the movement of them (Fig. 2). Number of basket with GPS buoy in an operation is 2 – 8, and they are arranged at roughly equal intervals in a gear so that a shape and a movement of a gear during an operation can be monitored. GPS buoy and TDR collected data in every 10 second during operation.

Distance between GPS buoys was calculated using formula in the chronological scientific tables 2004. The shortening ratio is obtained as the quotient of a distant between the two GPS buoys from a length of main line between floats with GPS buoys.

Catenary depth was calculated by the modified Yoshihara's formula (1954) using the shortening ratio descried above:

$$D = h_a + h_b + l\left\{\sqrt{1+\cot^2\phi_0} - \sqrt{\left(1-\frac{k_b + k_a(j-1)+g}{l}\right)^2 + \cot^2\phi_0}\right\}$$

D : hook depth

h_a : length of branch line

h_b : length of float line

k_a : length between branch lines

k_b : length between branch line and float line

l : half length of mainline

j : number of subject branch line

g : length of error

φ_0 : angle of inclination of support of mainline

where g is the error term which is accounting for a variance in the timing of an attachment of branch line to the main line during gear setting.

Relationship between a shoaling ratio of hook, a shortening ratio and a sheer current was analyzed using multiple linear regression analysis to evaluate the effect of current. The sheer current is defined as the difference in the velocity of the current between the surface and the depth which ADCP recorded data. Surface current estimated by the drifting speed of a GPS buoy, and vertical profile of current at the shooting position of a GPS buoy is estimated from an average values of ADCP data in the period of before and after five minutes to the shooting time. A north-south, east-west, and vertical components of the calculated sheer current were input into the regression analysis independently.

As the vertical profile of the current recorded by ADCP available only during the gear setting, an average and catenary depth of hook of first 10 minutes after settlement of the hook was used in the calculation of shoaling ration.

A shoaling ratio of a hook calculated as a quotient of an averaged depth divided by a catenary depth. A higher shoaling ratio means a deeper hook depth. Because change of shortening ratio by time affects on the set depth of hook, a shoaling ratio was calculated using corresponding value of shortening ratio in every ten second.

Result

Longline drift

Figure 3 and 4 show typical examples of the tracks of the longline gear recorded by GPS buoys. A track of longline gear is roughly classified into two types; one is a parallel track to the shooting course, and the other is a meandering track. The former type was observed in the half of all operations, and 10 of them were drifted in the direction of east and west. In the later type, GPS data indicated that an each basket with GPS buoys drifted by different speed during an operation.

The change of hook depth

The underwater movement and the shortening ratio of hooks in the basket with GPS buoys and the difference of the observed and theoretical depth by the catenary model are shown in Figure 5. The data by GPS buoys enable us to calculate the time dependent catenary depth, which is eliminate the effect by the timely change of distance between the floats, during the operation; we can monitor timely difference between the catenary and the observed depth of the hook during the operation. An observed difference shown in Fig. 5 would be a “true difference” caused by the sheer current.

A theoretical difference between the observed and the theoretical depth is small in hooks of the shallow sets (NHF=3, 4) and hooks in the shallower position of the deep sets, while that difference is large in case of hooks in a deep position of the deep sets. A depth of hooks in a deep position of a deep set tends to be more fluctuate than that of hooks in a shallow position.

Thought a change of shortening ratio during an operation influenced on the depth of the hook, a magnitude of influence is varied by the condition of sea. Fig. 5 shows the typical two observation; one is the case which a change of a shortening ratio has small impact on the change of hook depth (Fig. 5- G', A"), the other is that a change of a shortening ratio is almost control the change of hook depth (Fig. 5- A', D'). In case that the change of the shortening ratio has a minor impact on the hook depth, the change of hook depth would be controlled by the sheer current.

Generally, it seemed that the effect on the change of the shortening ratio was larger to the deep set than shallow set, and it also has larger impact on the hooks near the center position of the longline gear than those near the end position.

Effects of a position of a blanch line in a basket on a depth of its hook

Figure 6 shows relationship between the average depth (average from 1 hour after the shooting of the hook to 1 hour before the relieving of the hook) of the hook and its standard deviation for sets of NHF=3, 4, and 7.

No clear relationship is observed in the shallow hooks (all hooks in sets of NHF=3, 4 and 1st and 2nd hooks in sets of NHF=7), while positive relationship is observed in the deep hooks (3rd and 4th hooks in sets of NHF=7). An average depth of a shallowest hook was similar between 3 different types of sets.

Vertical profile of current

An analysis of relationship between a vertical profile of current and a depth of hook is conducted by selected data of which the longline gear drifted parallel to its set course, to make the analysis simple.

Figure 7 shows an example of a drift speed of a GPS buoy and recorded vertical profile of current by east-west, north-south, and vertical components, in 4th. The vertical profile in the 4th operation is characterized by a strong current in a western upper direction in 40-60m, which is replaced by a strong of southeastern current in 80m and deeper.

In the 4th operation, all hooks of the deep set stayed around 80m (Fig. 7 – A", theoretical depth of 4th hook is about 140m) and this would be caused by the change of direction of strong current at the depth around 80m. Depth of hooks of shallow set (Fig. 7 – A') did not affected so much by this strong sheer current as their theoretical depth are shallower than 80m.

Relationship between shoaling ratio and sheer current

Tentatively, relationship between shoaling ratio and sheer current was conducted using data of 1st and 3rd hooks in the set by NHF=7. Results of multiple linear regression analysis are shown in Table 1 and 2. Significant relationship is observed between shoaling ratio and value of intercept in both 1st and 3rd hooks, but relationships between shoaling ratio and value of 3 components of sheer current. Relatively higher R^2 values are obtained in 36m and 116m.

Discussion

Newly developed GPS buoy enable us to monitor the movement of the longline gear and the change of shortening ratio during the operation. Data obtained by GPS buoy will contributes to the study about the relationship between the marine environment and the hook depth.

Because the distance between the floats of the deep set is longer than that of the shallow set, the shortening ratio of the deep set is more fluctuate than that of the shallow set. And as the depth of the hooks of the deep set are deeper than the shallow set, the hooks of the deep set are susceptible to the effect of the sheer current. Those are the major reasons why the hooks of the deep set fluctuate more than the shallow set.

In the total 180 observations of GPS buoys collected during the research cruise, 80 percents of them was the case that the shortening ratio affected on the change of the hook. This fact strongly indicates that it is necessary to investigate the factor that affect on the shortening ratio during the operation to estimate actual depth of longline gear.

No relationship between the shoaling rate and the strength of current sheer was found in this study. The main reason of it would be luck of information about vertical profile during operation. In this study, ADCP only collected underwater current information during the gear setting. We should develop a new device or a method to obtain it to investigate an effect of a sheer current on the longline hook.

References

Mizuno K, Okazaki, M, Nakano, H. & Okamura, H. (1997) 'Estimation of underwater shape of tuna longline by using micro-BT's', ***Bulletin of The National Research Institute of Far Seas Fisheries*** (in Japanese, with English abstract), Vol. 34, pp. 1-24.

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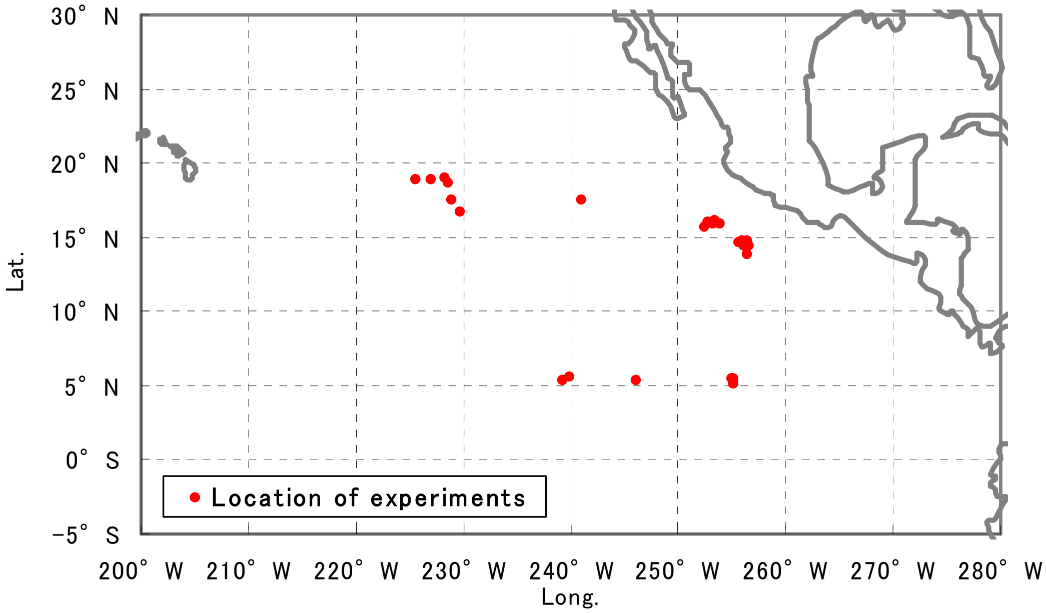

Figure 1. Research area and position of longline operation.

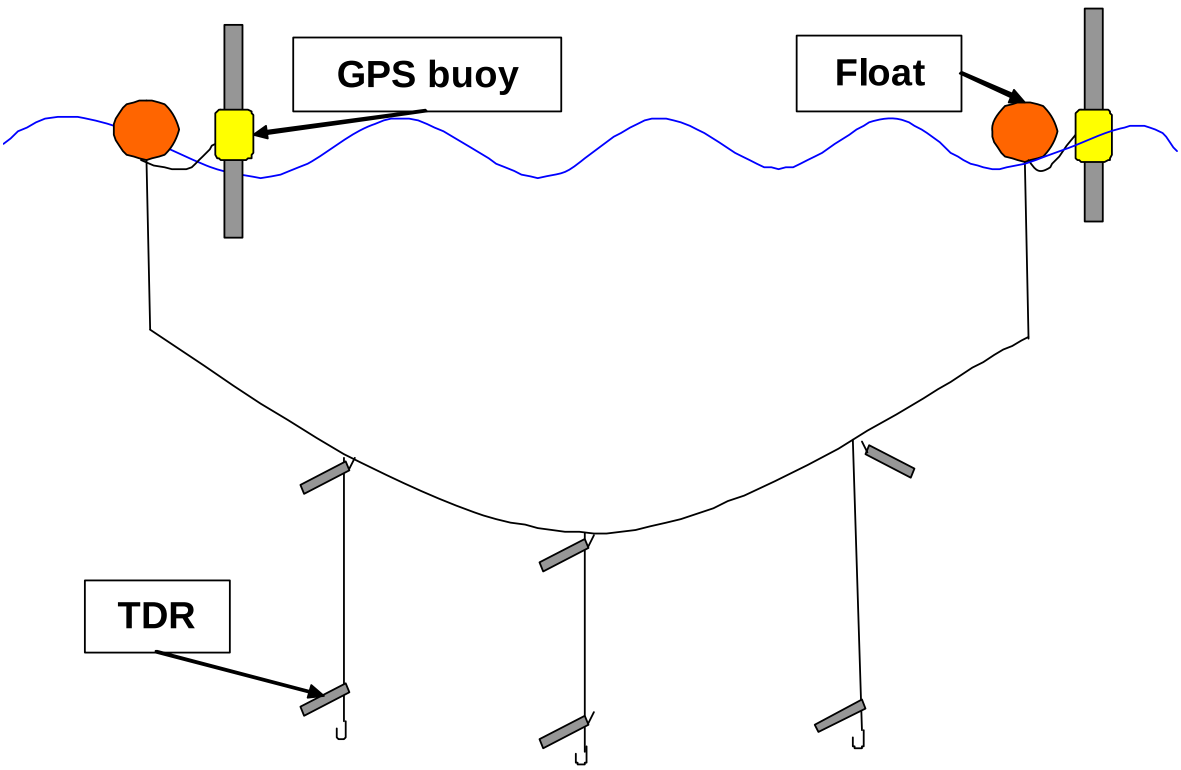

Figure 2. A schematic depiction of GPS buoy and TDR.

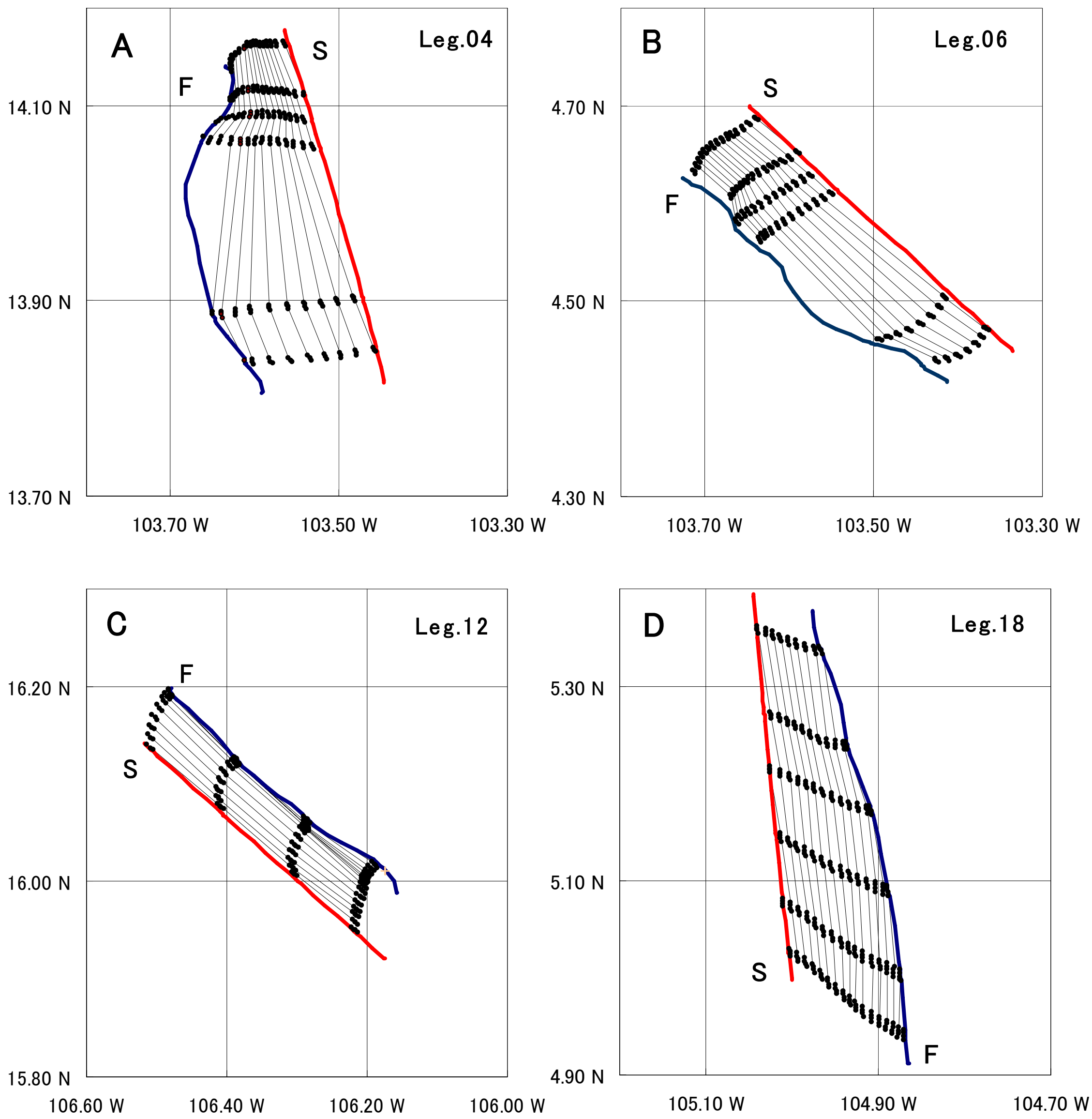

Figure 3. The typical example of the parallel track of the longline gear monitored by GPS buoys.

A; Leg. 04, B; Leg. 06, C; Leg. 12, D; Leg. 18

S; Start point of shooting, F; Finish point of retrieving

Shooting course（red thick line）, retrieving course (blue thick line), hourly location of GPS buoy (Black little circle) and hourly shape of longline(thin line) .

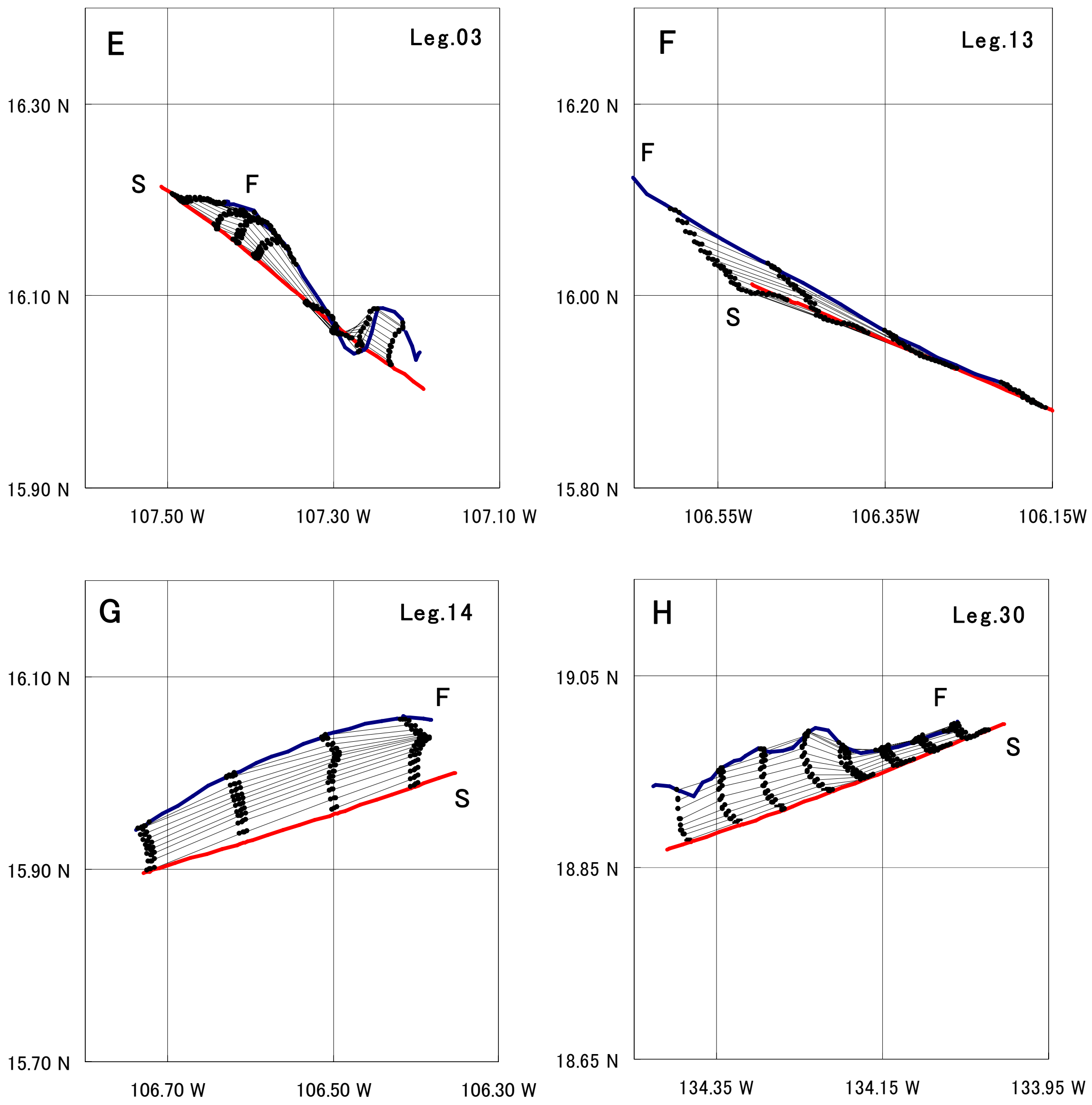

Figure 4. The typical example of the meandering track of the longline gear monitored by GPS buoys.

E; Leg.03, F; Leg.13, G; Leg.14, H; Leg.30

S; Start point of shooting, F; Finish point of retrieving

Shooting course（red thick line）, retrieving course (blue thick line), hourly location of GPS buoy (Black little circle) and hourly shape of longline (thin line) .

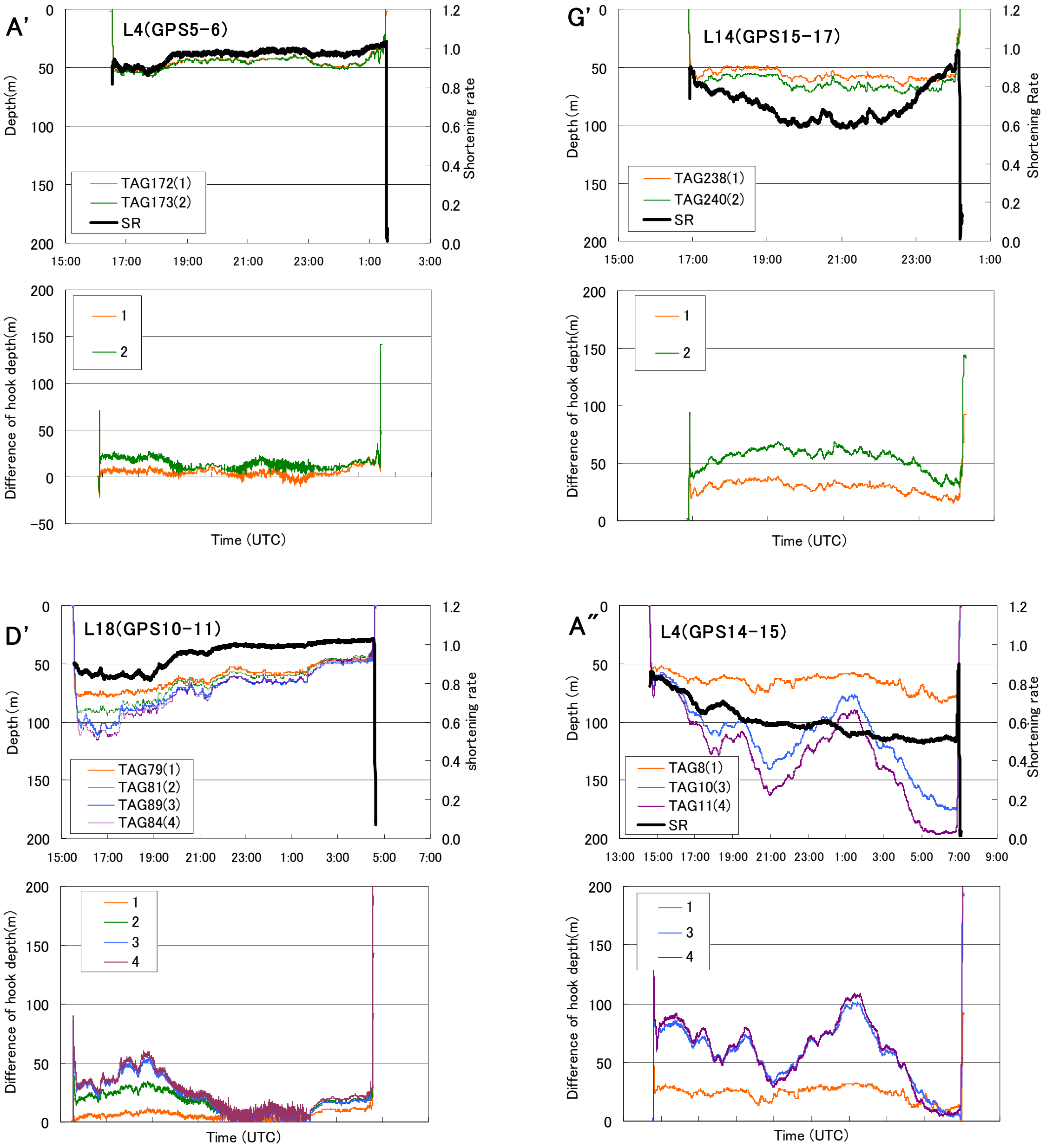

Figure 5. The underwater movement and the shortening ratio of hooks in a basket with GPS buoy.

A'; 3blanches (Leg. 4, GPS5-6), G'; 4branches (Leg. 14, GPS15-16)

D'; 7blanches (Leg. 18, GPS10-11), A"; 7blanches (Leg. 4, GPS14-15)

Upper panel ; Hook depth （thin line） and shortening ratio (black thick line).

Lower panel; Difference between the observed and theoretical depth.

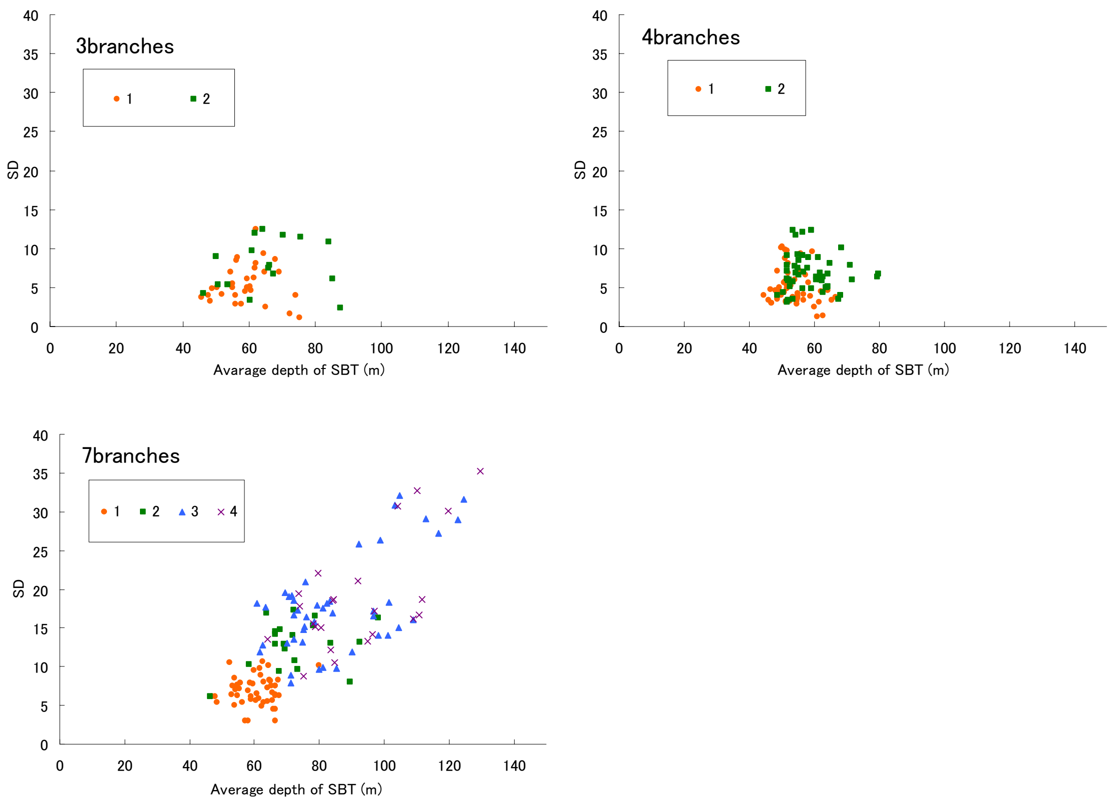

Figure 6. Average depth of the hook and its standard deviation for sets of NHF=3, 4, and 7.

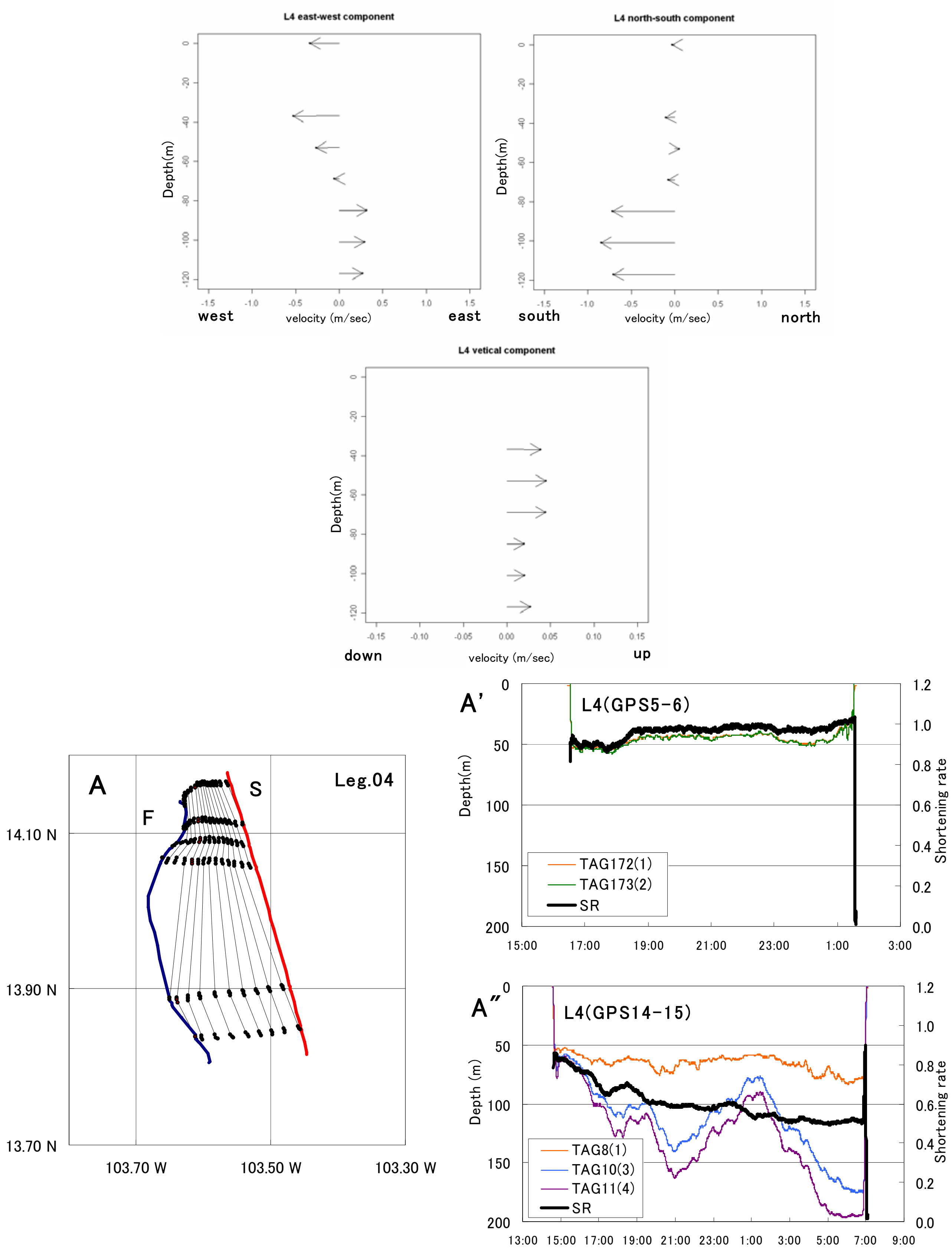

Figure7. Vertical profiles of east-west, north-south and vertical components of current recorded by ADCP in 4th operation (Upper three panels), the track of GPS buoys in 4th operation (lower left panel), and the underwater movement of hooks recorded by TDR and the shortening ratio of the shallow set of 4th operation (lower right, A') as well as the deep set (lower right, A").

Table 1. Result of multiple liner regression analysis. 1st hook of operation by 7 hooks per basket.

Depth(m)	Vx	Vy	Vz	Intercept	Adjusted R-squared
36	0.259 **	0.250 ***	-0.373	0.798 ***	0.523
52	0.148	0.083	-2.441 ***	0.845 ***	0.342
68	-0.508 ***	-0.584 **	-0.680	0.861 ***	0.377
84	-0.213 *	0.053	-0.222	0.867 ***	0.339
100	-0.155 *	0.099	0.009	0.853 ***	0.317
116	-0.133	0.200 ***	0.969 *	0.792 ***	0.438

*** ; P < 0.0001 , ** ; P < 0.001 , * ; P < 0.01 , . ; P< 0.05

Table 2. Result of multiple liner regression analysis. 3rd hook of operation by 7 hooks per basket.

Depth(m)	Vx	Vy	Vz	Intercept	Adjusted R-squared
36	0.504 **	0.497 ***	0.638	0.701 ***	0.523
52	0.383	0.148	-4.036 ***	0.776 ***	0.205
68	-0.819 **	-1.504 ***	-1.120	0.805 ***	0.276
84	-0.300	0.039	-0.667	0.819 ***	0.084
100	-0.303 .	0.063	0.097	0.792 ***	0.141
116	-0.145	0.472 ***	1.945 *	0.636 ***	0.541

*** ; P < 0.0001 , ** ; P < 0.001 , * ; P < 0.01 , . ; P< 0.05