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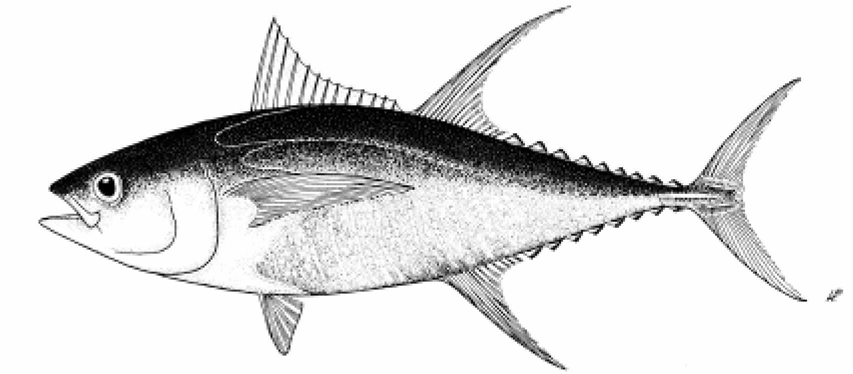
Behavioural study of small bigeye and yellowfin tunas aggregated with floating object using ultrasonic coded transmitter



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Summary

Swimming behavior of bigeye, yellowfin and skipjack tunas associated with floating object was observed using coded transmitters in the equatorial area of central Pacific in 2001 (July) and 2003 (October to November). Tracking were conducted on nine floating objects and 160 fishes attached with ID pinger (coded telemetry) were released and monitored. In the two cases of tracking, several bigeye and yellowfin tuna individuals stayed rela-tively long period around the floating object and their diurnal swimming behavior was observed. It seems that swimming depth of bigeye and yellowfin tunas was related with the depth of thermocline; both species mainly stayed in or just under the mixed layer similarly, where water temperature was more than 20℃ in 2001 and 24℃ in 2003, although several individuals especially bigeye tuna dived into or under the thermocline (maximum around 300m). Difference of swimming depth by fish size was partly observed but the difference was not clear because of insufficient coverage of fish size. Little data of skipjack tuna were obtained because it left the floating object shortly after released.

1. Introduction

Equatorial area of central and western Pacific Ocean is main fishing ground for Japanese distant water purse seine fishery targeting tropical tunas (mainly skipjack and yellowfin tuna). In the central and western Pacific, like other oceans, purse seine operation on FADs (fish aggregating devices) has come to be common since the end of the 1990s. Small yellowfin and bigeye tunas, as well as skipjack tuna, are usually caught in the operations around floating objects including FADs. It is concerned that the large amount of catch of small individuals may have bad influence on stock utilization of both species. In addition, these small tunas, especially bigeye tuna, are less valu-able in the market, so purse seine fishermen usually don't target them. Therefore, it is desirable to find out a way to prevent or reduce catching them.

It is supposed that, in the fish school consisting of skipjack, yellowfin and bigeye tunas, skipjack tuna is dis-tributed in the shallowest layer, bigeye tuna in the deepest layer, and yellowfin tuna in the middle of them. If this hypothesis is true, it might be possible to catch each of these species selectively and reduce or prevent the catch of small bigeye and yellowfin tunas by adjusting the depth of the net of purse seine. However, behavior of tunas ag-gregated around floating object has so

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far scarcely been known.

In recent years ID pinger (coded transmitter), that is, ultrasonic telemetry system which enables to identify more than one individuals at the same time, has been developed. By using this system, accurate swimming depth and rough horizontal position of more than one individual can be monitored simultaneously. Japanese research vessel Shoyo-maru is equipped with this biotelemetry system which enables to monitor maximum 56 individuals by ID pingers (Matsumoto et. al., 2002).

We conducted study of monitoring fish school behavior aggregated with floating objects (mainly FAD) in 2001 and 2003 by using Shoyo-maru in cooperate with purse seine vessel in the equatorial area of central Pacific.

2. Method

Two research cruises by Japanese research vessel Shoyo-maru were conducted in the equatorial area of central Pacific. First study was conducted from 10 to 23 July, 2001 in the north latitude (5-8 N, 177 E -179 W). Sec-ond study was conducted from October 25 to November 14, 2003 in the south latitude (3-7 S, 164-178 E). Summary of the each pinger tracking is shown in Table 1, position of this study in Fig. 1 and summary of each pinger tracking for each cruise is shown in Fig. 2.

Floating objects released or found by Japanese distant water purse seine vessel No. 18 Taijin-maru (chartered by JAMARC (Japan Marine Fisheries Resources Research Center, at present Marine Fisheries Research and De-velopment Department of Fisheries Research Agency)) were used for this study. FADs which were made of bam-boo and net were mainly used for this study, although natural log or shipwreck found in the ocean was also used. Examples of floating objects are shown in Fig. 2.

ID pinger (Vemco coded transmitter, V16P-1H, 62mm in length, 16mm in diameter, 9g in water and V16P-3H, 74mm in length, 16mm in diameter, 14g in water, 51 to 60 KHz for both) was used in this study. The pinger transmits its ID code and depth data. Signals from ID pinger were received and analyzed by biotelemetry systems (Vemco Track170 and Track 28) equipped in Shoyo-maru, which enables to monitor real time depth and horizon-tal bearing and distance of maximum 56 pingers, although horizontal bearing and distance are not so accurate. The pinger we used transmitted data irregularly at 20 to 69 seconds interval but data can’t be received when signals from more than one pinger were given at the same time. Therefore, the biotelemetry system received and recorded data from a certain pinger approximately once in one minute. Using ID pingers and biotelemetry systems shown above, effective signals from the pingers could correctly reach about 1000m distance to the vessel.

The fish to be monitored with ID pinger were caught by purse seine operation by No. 18 Taijin-maru or angling (jigging) by Shoyo-maru. When there was no sufficient number of individuals or many fish left the floating object during tracking, additional catch and release was conducted by jigging. Pinger was attached between first and second dorsal fins using one or two plastic bands. Fork length of the fish was measured and released. Shoyo-maru normally stayed about 250 to 600 m away from the floating object during tracking.

Table 1 shows summary of each pinger tracking. A total of nine times of tracking (three times in 2001 cruise and six times in 2003 cruise) was conducted and a total of 160 individuals (52 bigeye tuna, 83 yellowfin tuna and 25 skipjack tuna) were released with ID pinger.

3. Results and discussions

Of nine tracking, only two were regarded as successful tracking (No.3 in 2001 and No.6 in 2003 of Table 1). In other tracking, only a few individuals could be monitored, or most or all fish swam away from the floating object shortly after released. In this paper we will detail the results of two successful tracking.

3.1 2001 cruise No.3 tracking

This tracking was started at around 6 57’N, 175 52’W on 15th July and finished at 7 18’N, 176 42’W on 23rd July, although it was suspended from 20th to 22nd July (about 54 hours) to meet and conduct another re-search with No.18 Taijin-maru. Species composition of the school based on purse seine catch by estimation of fishermen’s eyes was 16t skipjack and 4t yellowfin tuna. At first, 10 bigeye, 11 yellowfin and 11 skipjack were released from the catch of purse seine operation by No. 18 Taijin-maru. During this tracking, 7 bigeye, 13 yellow-fin and 2 skipjack were caught by jigging and released additionally. Fig. 3 shows appearance of signals from each pinger. Most fish caught by purse seine left the FAD shortly after released, that is, 27 of 29 individuals left the FAD within four hours. Some of the fish caught by jigging stayed longer time around the FAD. As for bigeye tuna, of seven fish caught by jigging, two stayed around the FAD for more than 7 days and other two for more than 2 days. As for yellowfin tuna, similarly, of 13 individuals, 5 individuals could be monitored for more than 3 days. On the other hand, as for skipjack tuna, both purse seine and jigging catch went away from the FAD within two hours.

Fig. 4 shows time series swimming depth of bigeye and yellowfin tunas. Both bigeye and yellowfin tunas dis-tributed mostly in the layer shallower than 100m, where water temperature was usually higher than 24℃, although some of them dived to deeper than 150m during the daytime of July 23. Daily pattern of vertical movement was scarcely observed for both species except for the data of July 23.

Fig. 5 shows frequency distribution of swimming depth for each individual which more than 1000 data were recorded. As for bigeye tuna, all the fish monitored were small (smaller than 52cm), but #3 (47.2cm) and #15 (51.5cm), which were larger than the other individuals (34.1 to 36.5 cm), were distributed in the deeper layer compared with smaller fish. In the case of yellowfin, swimming depth in day time tends to be deeper than that in night although the trend is not so clear.

3.2 2003 cruise No.6 tracking

This tracking was started at 3 35'S, 177 08'E on 6th November 2003, and finished at 3 53'S, 176 51'E on 14th November. Species composition of the school based on purse seine catch by estimation of fishermen's eyes was 20t skipjack and 5t yellowfin tuna. All the fish monitored were caught by jigging. The tracking began with three yellowfin tuna caught and released in the evening (about 17:00) of November 6, 2003. As the number of fish was not sufficient, additional catch and release was made during tracking almost every day (around dawn and dusk) by jigging. A total of ten yellowfin and six bigeye tunas were caught and released including the first three yellowfin tuna, although no skipjack was caught and released. The tracking was continued until November 14, although it was suspended from 10 to 12 November (about 51 hours) to meet and conduct another research with No.18 Taijin-maru. Some of the fish stayed for more than 2 days around the FAD（BET #1, #3, YFT #2, #3, #5）; one bigeye and two yellowfin tunas stayed almost all the period of tracking (Fig. 6).

Fig. 7 shows time series swimming depth of bigeye and yellowfin tunas. Both bigeye and yellowfin tunas dis-tributed mostly in the layer shallower than 150m, where water temperature was usually higher than 28℃. During daytime many of the fish stayed at the layer deeper than 100m, which was on average deeper than the depth in the night. Also, some of bigeye tuna dived to around 300m depth during daytime, which was not observed as for yel-lowfin tuna.

Fig. 8 shows frequency distribution of swimming depth for each individual. Bigeye tuna showed comparatively clear mode of depth around 150m in the daytime, and that of yellowfin tuna was around 110 to 130m, which was somewhat shallower than that of bigeye tuna. Also, all the bigeye dived to deeper than 200m, which was rare for yellowfin tuna. For both species, most individuals showed shallower swimming depth during night than that of daytime when a clear mode was observed around 70 to 80m depth and for some individuals around 10m as well. No clear difference by fish size was seen as for bigeye tuna. On the other hand, during daytime, as for yellowfin tuna, large fish (ID #7 and #10, around 100cm), although the number of depth data was not so many, were distributed in the deeper layer than smaller fish.

3.2 Summary and discussions

Based on the studies during two cruises, small difference was observed for swimming depth between bigeye and yellowfin tunas, that is, swimming depth of bigeye tuna was usually a little deeper than that of yellowfin tuna, although the range of depth overlapped to some extent. In this study swimming depth of both bigeye and yellow-fin tunas was mostly shallower than 150m. Both species showed change in swimming depth between day and night, that is, swimming depth during daytime was on average deeper than that of night, although the difference was not necessary clear.

Swimming depth of the fish monitored during 2001 cruise was on average shallower than that of 2003 cruise. That is probably because of the difference of water temperature profile as shown in Fig. 4 and Fig. 7. In the study of 2001, thermocline was observed between around 100m and 150m depth which water temperature declined from 24℃ to 13℃. Both bigeye and yellowfin tunas were mostly distributed in the layer around or shallower than the upper limit of the thermocline (0 to 120m depth, 20 or 24 to 28.5℃). On the other hand, in the study of 2003, thermocline was observed between about 150m and 250m depth which water temperature declined from 28℃ to 13℃. Also, water temperature in the mixed layer (about 30℃) was higher than that of 2001 research area (about 28.5℃). Similar to the case of 2001 study, both species were distributed in the layer around or shallower than the upper limit of the thermocline (0 to 170m depth, 24 to 30℃). Taking these results into account, swimming depth of both species differed depending on the area, but water temperature in the swimming layer was comparatively similar. Therefore, it seems that swimming depth was related with water temperature profile.

Difference of swimming depth between day and night, which was observed for the results of 2003 cruise, was scarcely observed for the results of 2001 cruise. That also may be because of lower temperature at the same depth in the area of 2001 cruise than that of 2003 cruise.

During the study of both 2001 and 2003 cruises, most of the fish released from the purse seine catch swam away from the floating object shortly after released. Two possible causes are supposed. One is that, by the purse seine operation, most of the fish school aggregated may be caught and not many fish remained around floating object. Therefore, the fish caught and released with ID pinger may not be able to meet school and therefore will leave the floating object. At least, the original fish school should have been broken to some extent by purse seine operation. The other is that, it takes about two hours from gear setting to release by purse seine, so it may be that the fish have much stress. Anyway, it is considered that purse seine catch are not suitable for pinger tracking.

4. Future outlook of this study

Based on the studies of two research cruises, behavior of tunas aggregated with floating object has become clearer to some degrees. However, the number of individuals is not sufficient and fish size is biased. In addition, little data of skipjack tuna could be obtained so far.

We are planning to conduct another research cruise from June to September 2005 in the central Pacific. In this cruise, , we plan to ask Taijin-maru to release several FADs in advance, and catch and release by jigging and also by trolling, targeting skipjack tuna as well because the fish caught by purse seine proved to be not suitable for pinger tracking. Also, it is important to collect data from different season, area and fish schools with different species composition.

Acknowledgements

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Table 1 **Summary of each pinger tracking of tunas.**

2001 cruise

No.	**Date and time of release**	**Type of floating object**	**Method of capturing fish**	**Position of initial release**	**Amount of catch by purse seine vessel No.18 Taijin-maru (based on the estimation of fishermen on board)***	**Number of individuals released***	**Duration of tracking (hr)**
1	2001/7/10 6:52-7:32	FAD	Purse seine and jigging	07-23.4N 177-42.2E	20 t (detail is unknown)	BET 5, YFT 11, SKJ 11 Total 27	25.5
2	2001/7/13 5:40-6:17	FAD	Purse seine and jigging	05-32.5N 179-04.4W	Several tons (detail is unknown)	BET 1, YFT 1 Total 2	1.0
3	2001/7/15 6:18-6:47 Additional 2001/7/15 10:30-7/20 5:05	FAD	Purse seine and jigging	06-57.1N 175-52.1W	Total 20t SKJ 16t, YFT 4t	BET 10, YFT 10, SKJ 9 Subtotal 29 Additional BET 7, YFT 13, SKJ 2 Subtotal 22 Total 51	127.5 Additional 24.0 Total 151.5

*BET: bigeye tuna, YFT: yellowfin tuna, SKJ: skipjack tuna.

Table 1 Summary of each pinger tracking of tunas. (continued)

2003 cruise

No.	**Date and time of release**	**Type of floati ng object**	**Method of capturin g fish**	**Position of initial release**	**Date of operation and amount of catch by purse seine vessel No.18 Taijin-maru (amount is based on the estimation of fishermen on board)** *	**Number of individuals released***	**Duration of tracking (hr)**
1	2003/10/25 5:35-5:53	Natur al log	Jigging	04-09.4S 164-17.2E	2003/10/24 Total 15t YFT 9t, BET 6t	YFT 2 Total 2	2.0
2	2003/10/29 5:40-8:38	FAD	Jigging	06-52.0S 168-09.5E	Unknown	BET 1, YFT 2, SKJ 1 Total 4	18
3	2003/11/1 17:13	FAD	Jigging	04-23.4S 174-07.8E	2003/10/31 Total 15t SKJ 3t, YFT 12t	YFT 1 Total 1	0.15
4	2003/11/2 6:03-6:43 Additional 2003/11/3 4:43-5:20	Shipw reck	Purse seine and jigging	04-25.2S 174-25.3E	2003/11/1 Total 70t SKJ 42t, YFT 20t, BET 8t	BET 10, YFT 15, SKJ 2 Total 27 Additional YFT 2 Total 29	12 Additional 1.5 Total 13.5
5	2003/11/4 6:35-7:21	FAD	Purse seine	03-27.0S 176-59.9E	2003/11/4 Total 15t SKJ 6t, YFT 9t	BET 12, YFT 16 Total 28	56.5
6	2003/11/6 16:27-17:04 Additional 2003/11/7 4:24-11/13 5:45 (six times, by jigging)	FAD	Jigging	03-35.4S 177-08.3E	2003/11/15 Total 25t SKJ 20t, YFT 5t	YFT 3 Additional BET 6, YFT 7 Total 13 Total 16	92 Additional 32.5 Total 124.5

*BET: bigeye tuna, YFT: yellowfin tuna, SKJ: skipjack tuna.

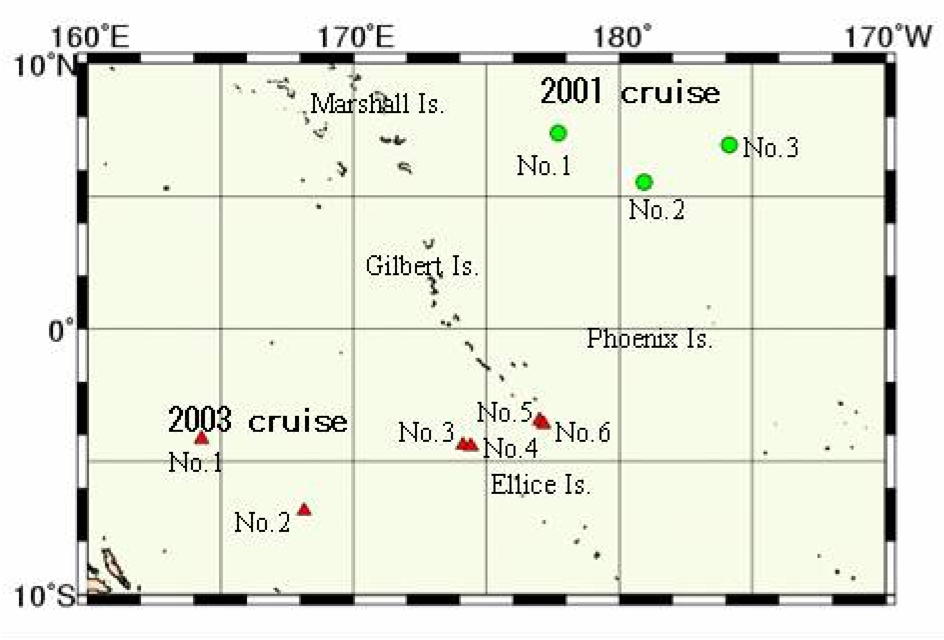

Fig. 1 Position of start of pinger tracking. Circle: 2001 cruise, triangle: 2003 cruise. The numbers in the map show the sequential number of pinger tracking written in Table 1.

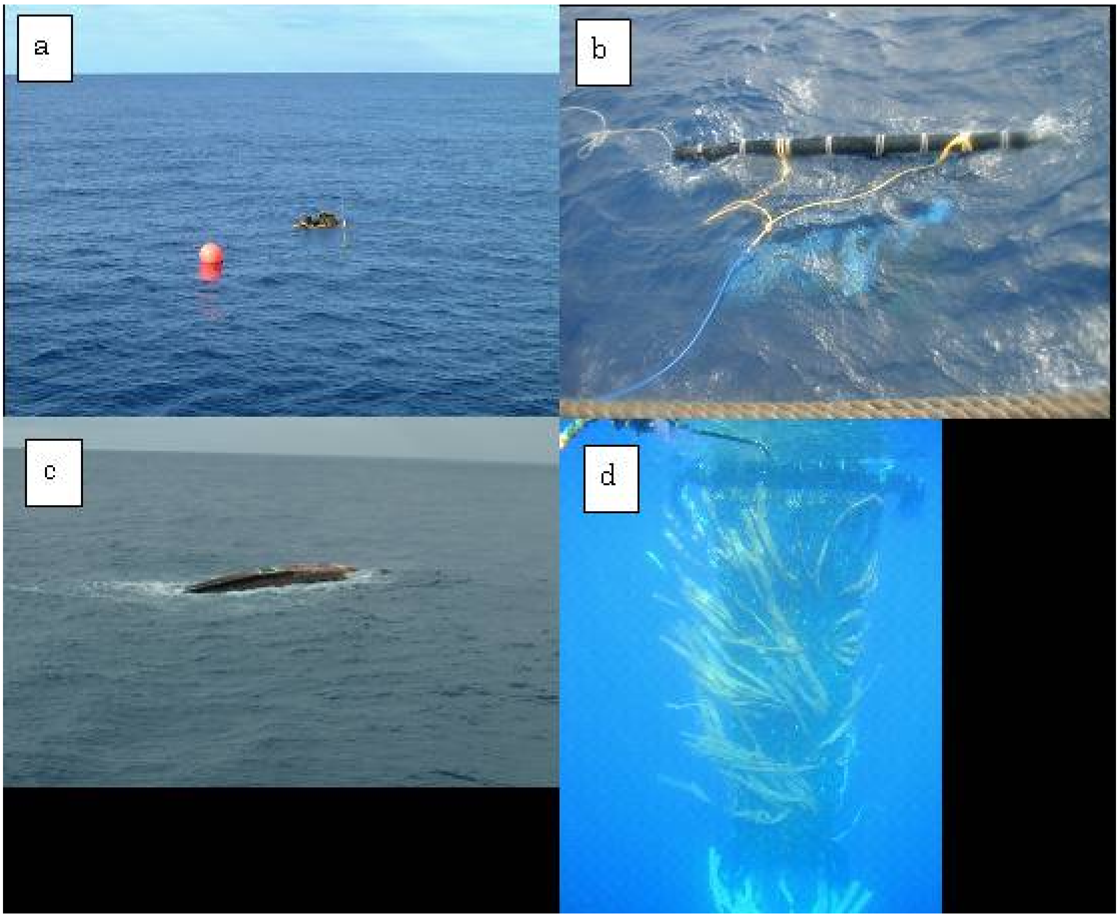

Fig. 2 Examles of floating objects around which this study was conducted. A: natural log, b: FAD, c: shipwreck, d: FAD (in the sea).

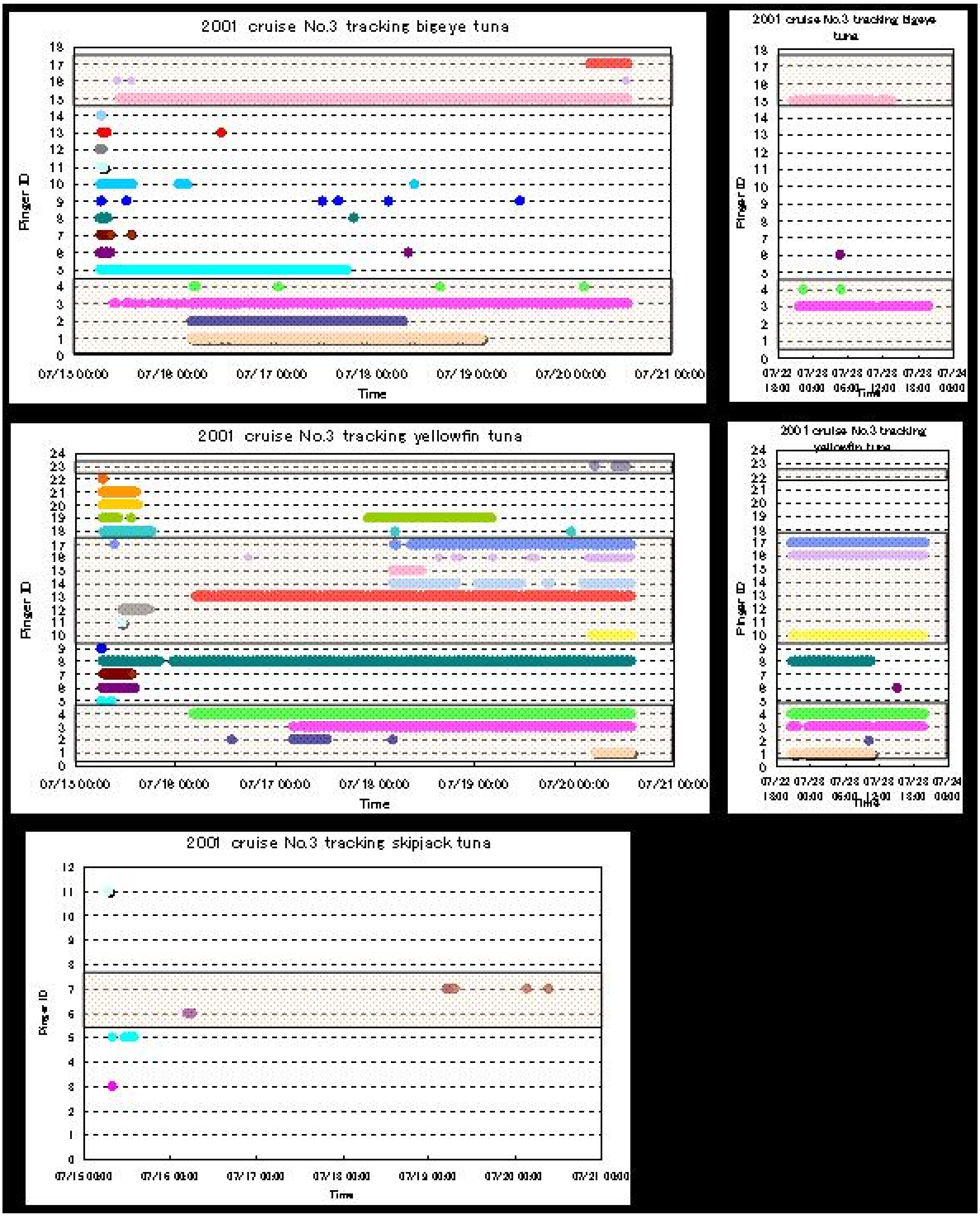

Fig. 3 Time series status of receiving signals from ID pingers (2001 cruise). Shaded zone show the fish caught by jigging (others by purse seine).

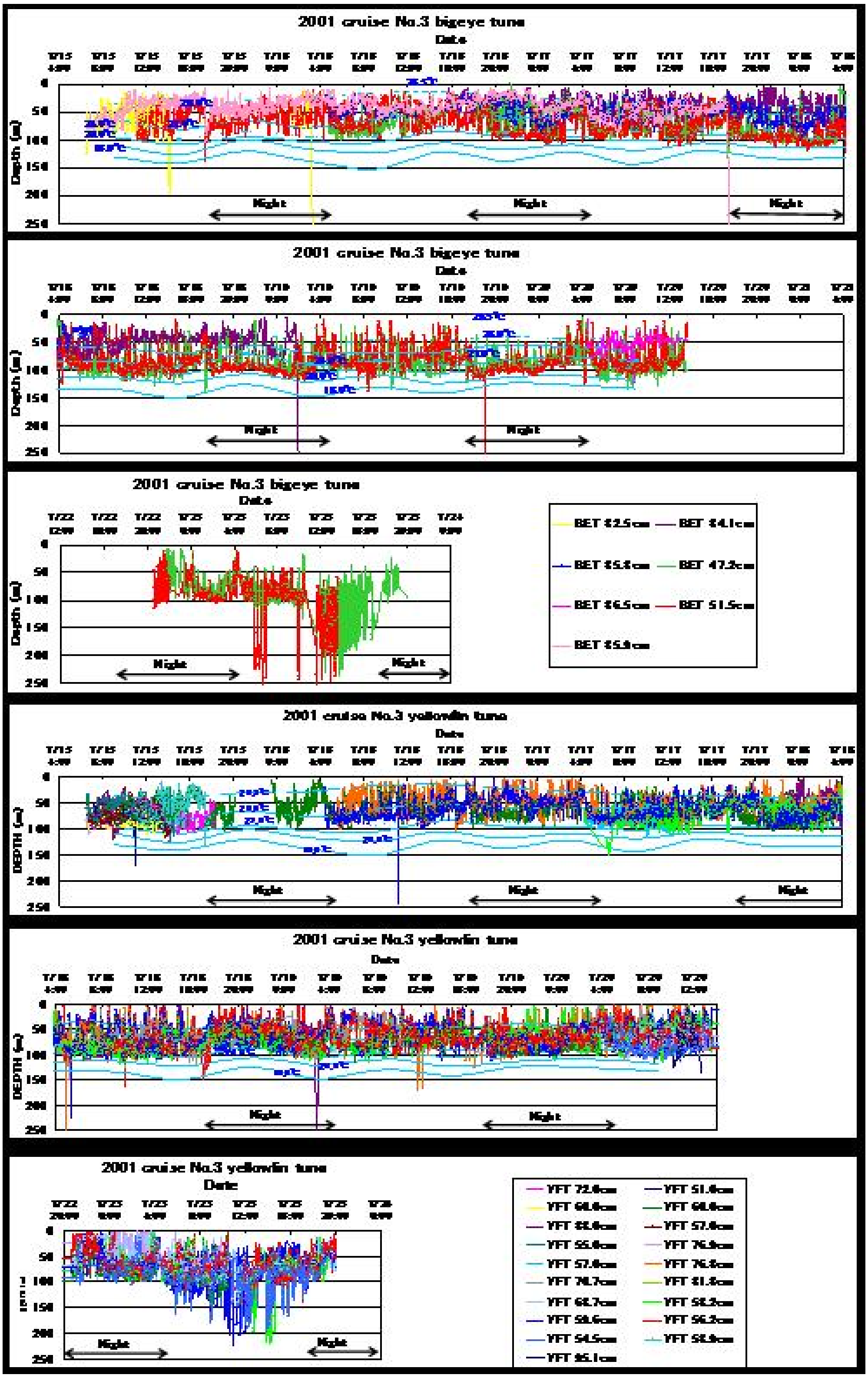

Fig. 4. Time series swimming depth of bigeye (upper) and yellowfin (lower) tunas measured by ID pingers (2001 cruise No.3 tracking). The legends show fork length of the fish.

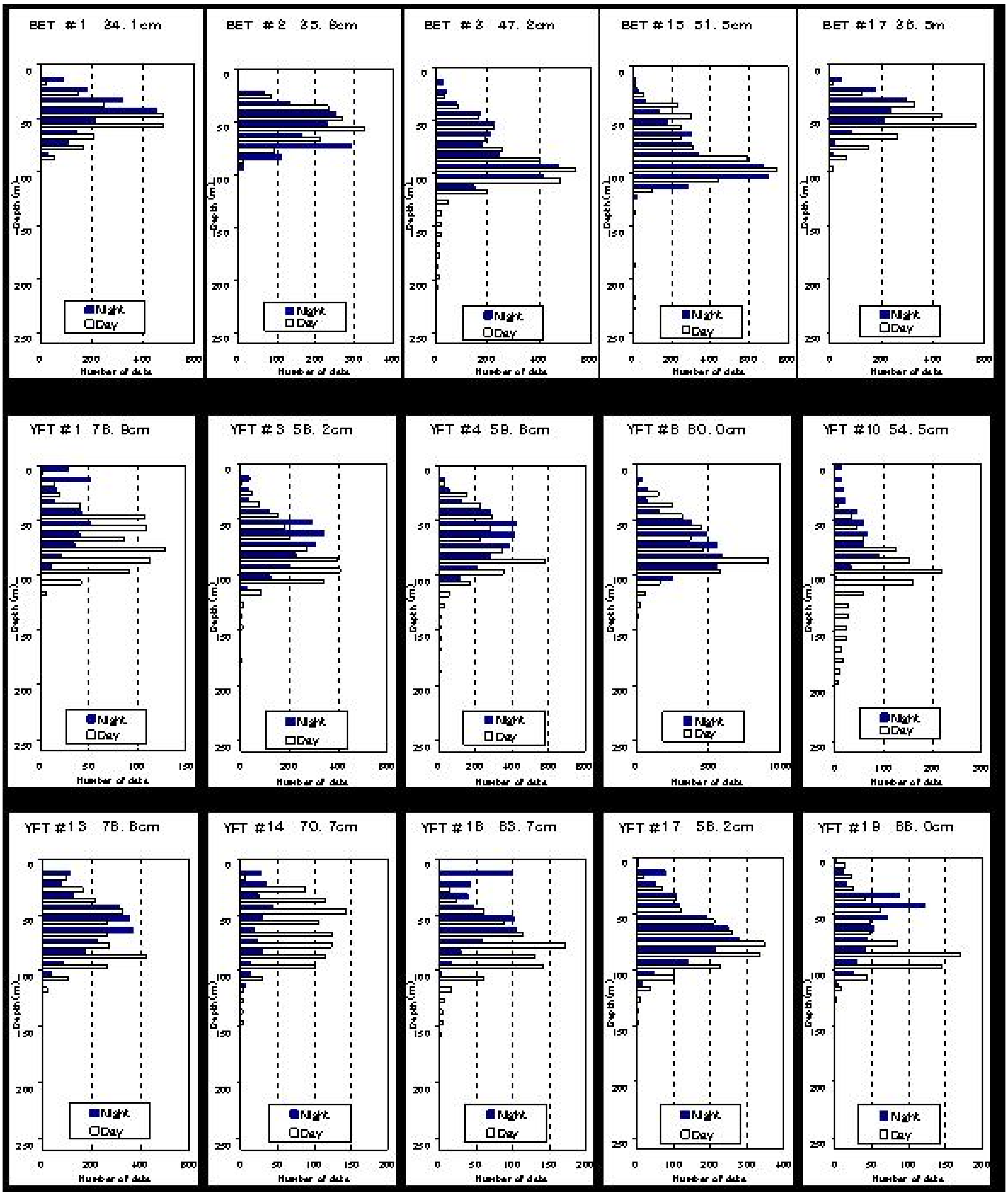

Fig. 5. Frequency distribution of swimming depth of day and night for each individual of 2001 cruise No.3 tracking (limited to the individuals which more than 1000 data were recorded). Title in the graph shows species (YFT: yellowfin tuna, BET: bigeye tuna), pinger ID and fork length of the fish.

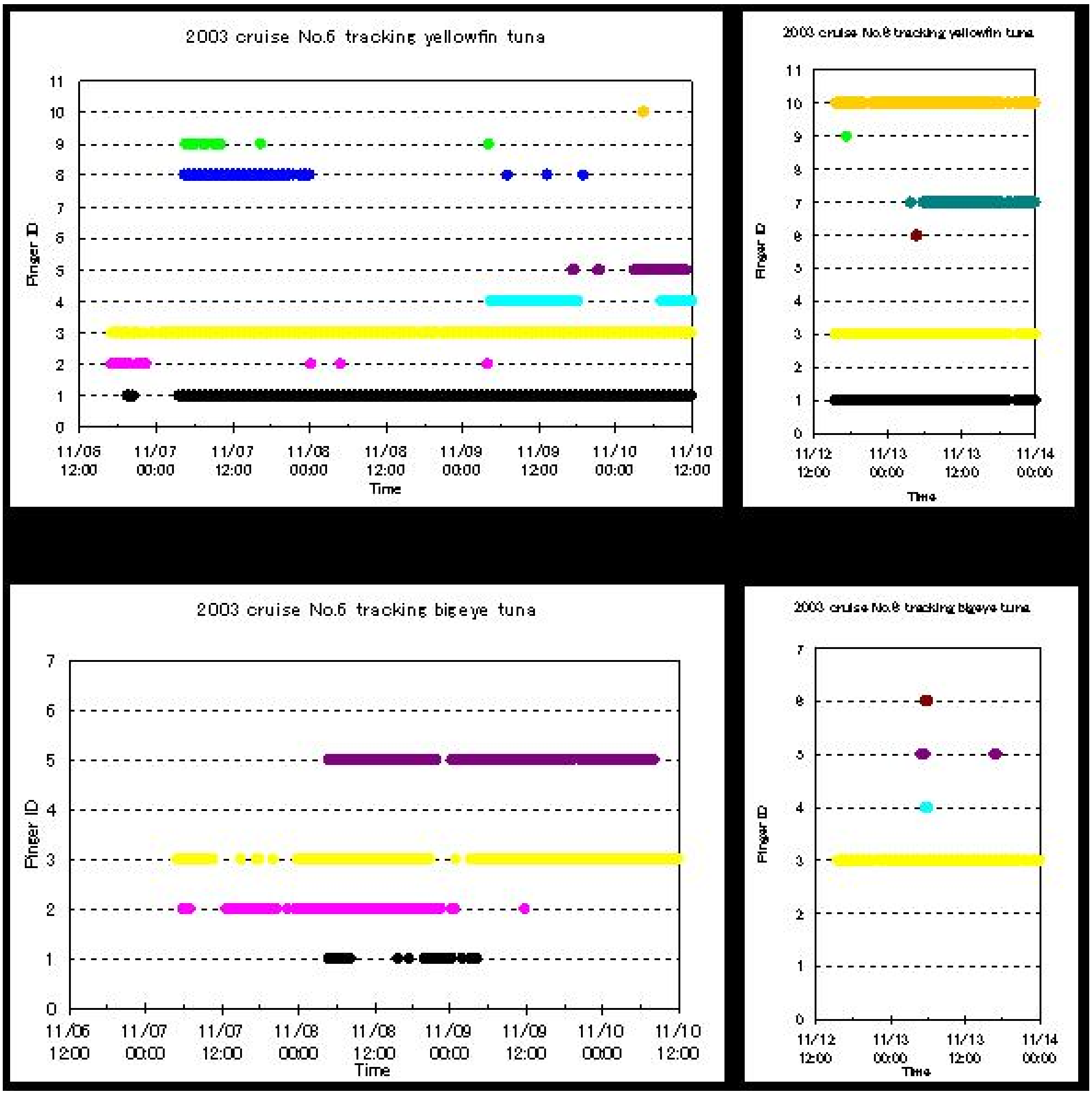

Fig. 6 Time series status of receiving signals from ID pingers (2003 cruise No.6 tracking).

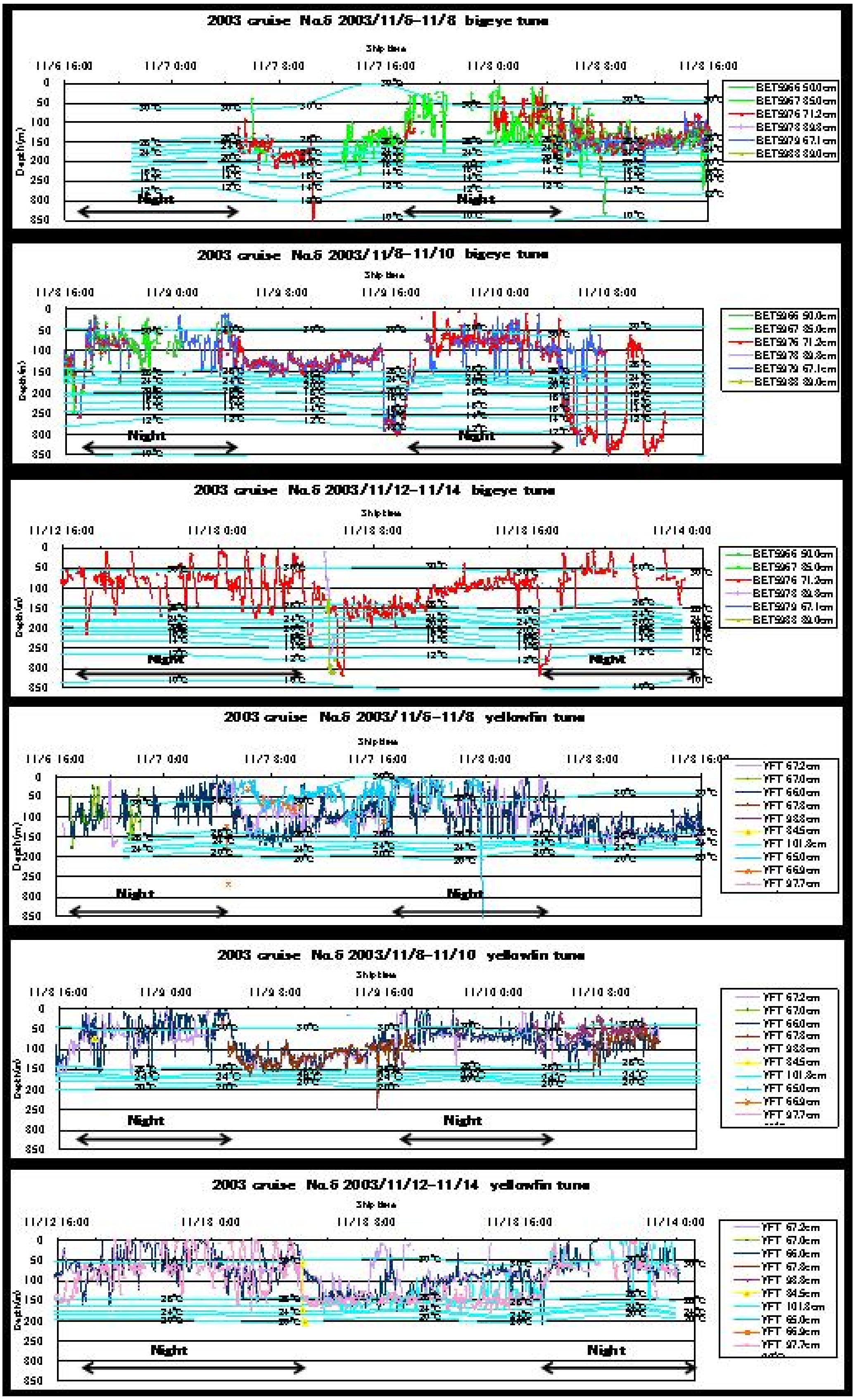

Fig. 7. Time series swimming depth of bigeye and yellowfin tunas measured by ID pingers (2003 cruise No.6 tracking). The legends show fork length of the fish.

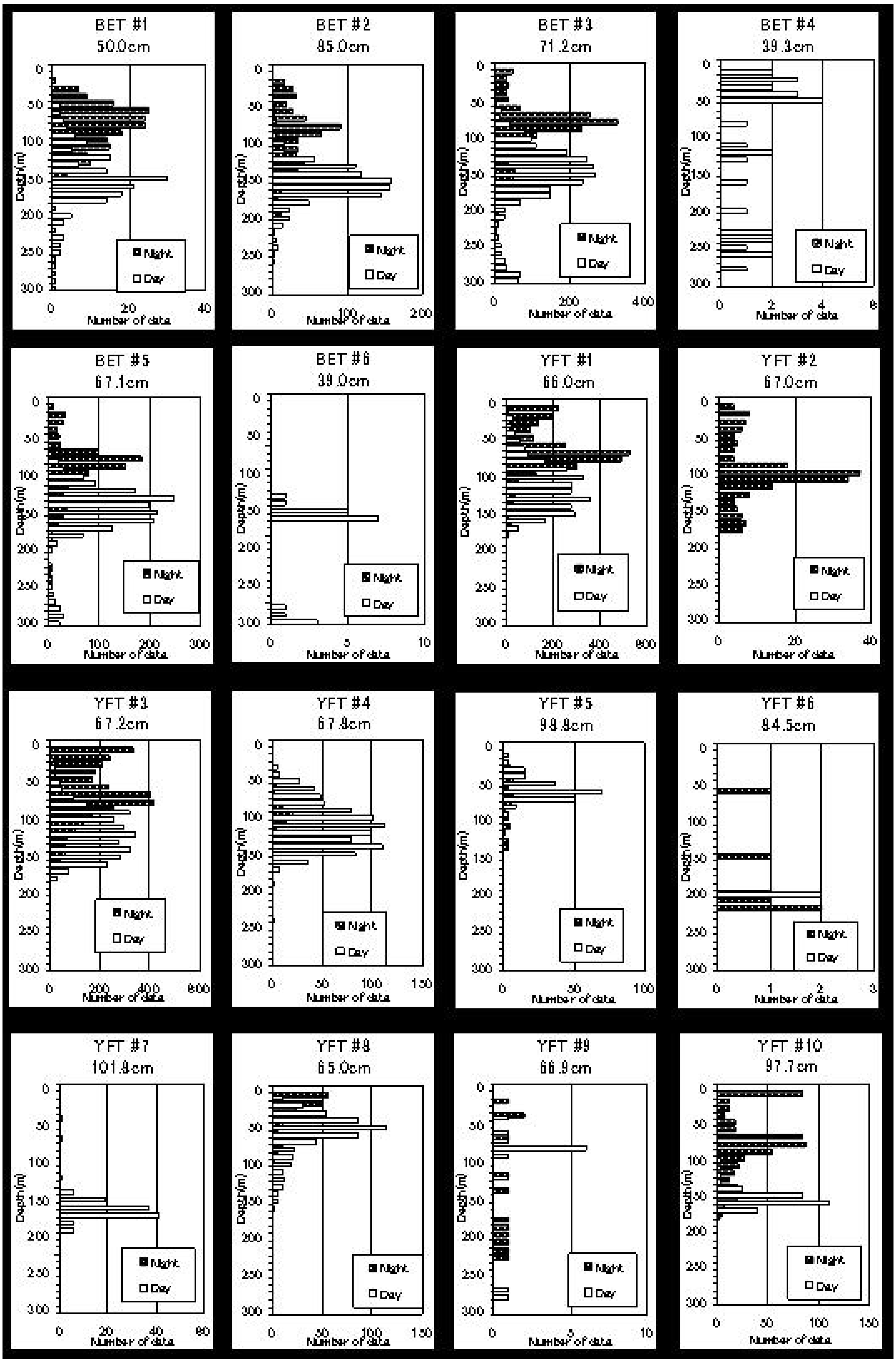

Fig. 8 Frequency distribution of swimming depth of day and night for each individuals of 2003 cruise No.6 tracking. Title in the graph shows species (YFT: yellowfin tuna, BET: bigeye tuna), pinger ID and fork length of the fish.