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Study on the methods to reduce the bycatch of juvenile bigeye tuna by purse seine operation on FADs in the western and central Pacific Ocean

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Study on the methods to reduce the bycatch of juvenile bigeye tuna by purse seine operation on FADs in the western and central Pacific Ocean.

－Report of the joint research by Shoyo Maru, Nippon Maru and No.83 Fukuichi Maru in 2009－

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Abstract

Joint research by two research vessel (Shoyo Maru and Nippon Maru) and one commercial purse seine vessel (No. 83 Fukuichi Maru) was conducted in July 2009 at the western tropical Pacific Ocean to search the mitigation measure for the bycatch of juvenile bigeye tuna by purse seine operation on floating objects such as FADs. This research consists of two main objectives; to observe the escape of juvenile bigeye tuna from large mesh purse seine net and to observe the reaction of bigeye, yellowfin and skipjack to the stimulus of blinking flush light. These behaviors were observed using underwater camera, sonar, and acoustic transmitter (coded transmitter:ID pinger).

For the former part, we could not record the escape of a small tunas from large mesh, but escape of a silky shark and fish schools (maybe small skipjack) were observed during the operation of Nippon Maru. The school size of juvenile bigeye around FADs might be too small to observe their escape. For the latter part, some juvenile bigeye tuna exhibited various reactions to the light stimulus depending on the situation including experiment time, the distance between the light source and the animal. In most case, they showed rapid downward or upward movement just after stop of the light stimulus. Horizontally, the bigeye tuna exhibited flight reaction from the blinking light in many case with some exception, maybe depending on the experiment time.

Introduction

Purse-seine operation with FADs (Fish Aggregating Devices) has brought the increase in the catch of small sized individuals of bigeye and yellowfin tunas. With the rapid increase of FADs operation worldwide, there is growing concern about the impact of these operations on the stock status of these tuna species, especially in bigeye tuna (*Thunnus obesus*). For effective utilization of bigeye tuna resources, it is necessary to develop effective methods to reduce the bycatch of the small sized bigeye tuna caught in FADs operation.

To achieve this goal, Fisheries Agency planned to conduct joint research by Shoyo Maru (Fisheries Agency; 2851 GRT), "Nippon Maru (Fisheries Research Agency; 1817 GRT)" and commercial purse seine vessel "Fukuichi Maru No.83 (Fukuichi Gyogyo Co., Ltd.; 760 GRT)" in the western Pacific Ocean.

The objectives of this joint survey are;

(1) To assess how the fish behavior is affected by light stimulus, by which we consider a potential gear to lead fish to large mesh section of the net and let them escape through it.
(2) To get basic information about shape of mesh opening at each stage of hauling.
(3) To observe how the fish react to adjacent net.

Materials and Methods

(1) Research Period

Shoyo Maru left Tokyo port on the 2nd July 2009. Started research work on the 12th July and completed it on the 1st August and arrived at Tokyo port on the 10th August.

Nippon Maru left Shiogama port on the 23rd June 2009. Started research work on the 1st July and completed it on the 8th August, and then arrived at Makurazaki port, Japan on the 16th August.Day-by-day research record is shown in Table1.

(2) Area of the Research

The research area was EEZ of the Federated States of Micronesia and open sea. Although EEZ of Papua New Guinea was also planned to be included in the research area, the research was not conducted in the area because FADs had not flowed to the area concerned,

The vessel location trajectory at the noon is shown in Fig.1 and the area of experiments or observations is shown in Fig.2

(3) FADs

Most of the experiments or observations were carried out around FADs, which include so-called "artificial floater" and natural drift woods. The FADs had been built up and drifted by Fukuichi Maru No.83 prior to the survey. The additional drift woods found during the survey were checked for the size of fish school by Nippon Maru and some of them were used for the experiment.

(4) Observation of reaction of bigeye on the light stimulus and mesh shape under water

Fish behavior including reaction to the light stimulus was observed both acoustically and optically. Precedential to acoustic observation, the fish was released with coded transmitter around FADs. We tracked the echo signal from each fish by Shoyo Maru and observed the behavior in response to light stimulus. Searchlight sonar of Mizunagi, and echo-sounder and scanning sonar of workboats were used for the observation of fish school.Underwater cameras were suspended from the side of boat, workboats, and Mizunagi for the optical observation of fish behavior, and the video image were recorded.

For light experiments, Patriot Star (intermittent light emission device: Kawasaki Denki Inc.) was suspended at depth of 15 to 120m and intermittent flash light were emitted. Underwater lights were employed at fixed depth of 10 and 12m. These experiments were done around FADs or inside the purse-seine net (Fig.3).

Echo-sounders and scanning sonars of both Nippon Maru and its workboats were used for the observation. The data of KFC5000 and FCV30 were recorded for later analysis. Also, the sonar video images were recorded with HD recorder for later analysis.

Observations of mesh shape under water were done during purse seine operations by Nippon Maru, Fukuichi Maru No.83 or No.85. Workboats of Nippon Maru or Mizunagi and small transport boat (both of them are equipment of Shoyo Maru) (Fig.4) came inside the net and observed the net and fish both acoustically and optically. ,

(5) List of devices used in this research

Following devices were used for generating light stimulus

- "Patriot-Star" Model YC-200B-SS (intermittent light)
- Underwater light (continuous light)

Following devices were used for observing fish behavior and purse-seine net

- Echo sounder (Nippon Maru) FCV30
- Echo sounder (Workboat: Nippon Maru) KFC5000 quantitative echo sounder
- Scanning sonars (Nippon Maru) FSV30, FSV84
- Scanning sonars (Workboats: Nippon Maru)CSH-8L4
- Searchlight sonar (Mizunagi: Shoyo maru)CH-34
- Underwater camera: Q.I. "Twin" (Mizunagi: Shoyo maru)
- Underwater camera: Hitachi zosen "Eyeball" (Workboats: Nippon maru)
- Underwater camera: Kowa "SEEKER-III-mini" (Boat: Shoyo maru)
- Coded transmitter: (VEMCO Division AMIRIX Systems Inc.) "V16P-1H-S16" (90 pieces: 51kHz, 54kHz, 57kHz, 61kHz)
- Biotelemetry system: (VEMCO Division AMIRIX Systems Inc.) "SEA-TRACK-170" System (Shoyo maru)

Results and Discussion

Note: The analysis of the data is still on the way and the results described here should be considered as provisional.

(1)Observation of fish behavior with coded transmitter (conducted by Shoyo Maru and Nippon Maru)

Throughout the research, 12 skipjack, 18 yellowfin and 54 bigeye tuna were released with coded transmitter in the total of 9 FADs. All skipjack scattered from the vessel within a day, although sporadic return around the vessel was observed. For yellowfin and bigeye tunas, the residence time was longer than that of skipjack; however, most individual disappeared before the experiment.

We could observe the response of one bigeye tuna of 57.5 cm (fork length) to blinking light stimulus in the experiment on 19th July. Each light stimulus experiment consisted of emission for 5 minutes and extinction for 10 minutes to the extent possible. The sunrise time on 19th July was 4:17.

In the experiment conducted around FAD from 3:00 to 3:40, the bigeye tuna steeply dived downward just after stop of light stimulus and then moved upward, followed by downward movement again (Fig.5). The light was emitted 20m just above the fish. Horizontally, the bigeye swam away from the light source after start of emission of blinking light (Fig.6a).

In the experiment conducted around FAD from 3:40 to 4:10, the bigeye tuna exhibited the steep upward and downward movement just after stop of light stimulus. The light was emitted 30m just above the fish (Fig.5). Horizontally, the fish once closed to the light source after emission of the light and then receded from the source after stop of emission (Fig.6b).

In the experiment after sunrise, experiments were conducted during the purse seine operation by Nippon Maru by stopping the hauling of net. At this time, the bigeye tuna was encompassed by the net. Preceding the light emission at 5:20, the bigeye had already begun to move upward at the rate of 17m per minute from the depth of 80m. It was suggested that this behavior reflected the rapid elevation behavior observed ordinarily just before the sunrise, which was known as "spike dive" for juvenile southern bluefin tuna (Willis et al., 2009), rather than the behavior which was caused by the light stimulus (Fig.7). After this experiment, the rapid vertical movement was not observed, while horizontal avoidance from the stimulus was observed in the some case (Fig.6c,d).

These results suggest the possibility that the blinking light stimulus influence the vertical behavior of bigeye tuna and this effect may change depending on the time and distance between the animal and light source. Horizontally, this individual showed avoidance behavior in varying degree, however, further collection of behavioral data is necessary to discuss the effect of blinking light stimulus on the behavior of bigeye tuna.

(2) Fish reactions to light stimulus observed by eco sounder (conducted solely by Nippon Maru)

In most cases, on the start of intermittent light, school echo on the sonar tended to aggregate and form dense school. And when intermittent light stopped the school tended to become loose.

By echo sounder observation, at the start of intermittent light, school echo disappeared or descended in many cases (Fig. 8). On the contrary, in some other cases, school at deep layer ascended rapidly on the start of intermittent light. With continuous light, some school ascended rapidly on the start of light and form dense school in shallow layer. Then, when the light stopped the school descended.

The magnitude of fish reaction to light stimulus were different by time of the day, or brightness of the environment (Fig. 9). Before or around dawn, when it's still dark, the schools were tend to swim away from the light stimulus. Still, even when there's no artificial light, tuna sometimes show sharp ascending movement at dawn. So we need to confirm if the observed movements were really induced by light stimulus.

(3)Mesh shape under water and shape of purse seine gear

As far as we observed with underwater camera, larger mesh of the net maintained its square shape, during hauling. The shape of the net gear was occasionally skewed by the force of current.

(4) Fish movement near the net

We could not confirm that small tuna ran away from the large mesh of net, but could observe a silky shark (*Carcharhinus falciformis*) and fish schools (may be small skipjack) escaped from large mesh during the operation by Nippon Maru (Fig.10). According to the observation by underwater camera fish schools tended to swim along the side of the net or above the bottom of the net when they swam near the net. It seems that fish recognize the net and does not try to escape through the opening even though it is large enough.

Reference

Willis, J., Phillips, J., Muheim, R., Diego-Rasilla, F. J., and Hobday, A. J. (2009). Spike dives of juvenile southern bluefin tuna (*Thunnus maccoyii*): a navigational role? Behav Ecol Sociobiol 64(1) 57-68.

Table and Figure

Table1: Day-by-day research record of Shoyo Maru and Nippon Maru

Date		Shoyo Maru	Nippon Maru
6/23	Tue		Left Shiogama port
6/24	Wed		Sailing for Pohnpei
6/25	Thu		Sailing for Pohnpei
6/26	Fri		Sailing for Pohnpei
6/27	Sat		Sailing for Pohnpei
6/28	Sun		Sailing for Pohnpei
6/29	Mon		Arrived at Pohnpei, Left Pohnpei for research area
6/30	Tue		Sailing for Research area
7/1	Wed		Commenced Research, Checked machinery, Surveyed a FAD
7/2	Thu	Left Tokyo port	Searching, Surveyed 4 FADs
7/3	Fri	Test of research devices	Searching, Surveyed 2 FADs
7/4	Sat	Test of research devices	Searching, Surveyed a FAD
7/5	Sun	Sailing for Research area	Searching, Surveyed 2 FADs
7/6	Mon	Sailing for Research area	Searching, Surveyed 3 FADs
7/7	Tue	Sailing for Research area	Carried out Intermittent light experiments
7/8	Wed	Sailing for Research area	Carried out Intermittent light experiments
7/9	Thu	Sailing for Research area	Carried out Intermittent light experiments
7/10	Fri	Sailing for Research area	Carried out Intermittent light experiments, Surveyed a FAD
7/11	Sat	Sailing for Research area	Carried out observations on FAD school without artificial stimulus
7/12	Sun	Test of ID tag	Carried out observations on FAD school under light stimulus
7/13	Mon	Met & Carried out acoustic interference test joint two R/V	
7/14	Tue	Sampled fish to attach ID tag	Carried out underwater light experiments, Met & Co-operated with Fukuichi Maru No.83
7/15	Wed	Sampled fish to attach ID tag	Carried out underwater light experiments
7/16	Thu	Sampled fish to attach ID tag	Carried out underwater light experiments
7/17	Fri	Met & Carried out biotelemetry experiments joint two R/V	
7/18	Sat	Carried out biotelemetry experiments joint two R/V	
7/19	Sun	Carried out biotelemetry experiments joint two R/V Shoyo Maru , Operation #1	
7/20	Mon	Sampled fish to attach ID tag joint two R/V	
7/21	Tue	Sampled fish to attach ID tag joint two R/V, Nippon Maru surveyed 3 FADs	
7/22	Wed	Sampled fish to attach ID tag, Met Fukuichi Maru No.83	
7/23	Thu	Observed fish movement and net opening inside the net of Fukuichi Maru No.83 joint two R/V	
7/24	Fri	Observed fish movement and net opening inside the net of Fukuichi Maru No.83 joint two R/V	
7/25	Sat	Observed fish movement and net opening inside the net of Fukuichi Maru No.83 joint two R/V	
7/26	Sun	Observed fish movement and net opening inside the net of Fukuichi Maru No.83 joint two R/V	
7/27	Mon	Canceled operation, Surveyed a FAD joint two R/V	
7/28	Tue	Sampled fish to attach pinger, Surveyed 2 FADs	
7/29	Wed	Carried out light experiment joint two R/V, Operation #2	
7/30	Thu	Sampled fish to attach ID tag joint two R/V	
7/31	Fri	Carried out light experiment joint two R/V, Operation #3	
8/1	Sat	Sampled fish eyes for optical analysis, Carried out Calibration of scannning sonar joint two R/V	
8/2	Sun	Sailing for Tokyo	Searching, Surveyed a FAD
8/3	Mon	Sailing for Tokyo	Searching, Surveyed 2 FADs
8/4	Tue	Sailing for Tokyo	Carried out light experiments
8/5	Wed	Sailing for Tokyo	Observed fish movement and net opening inside the net of Fukuichi Maru No.85
8/6	Thu	Sailing for Tokyo	Searching, Surveyed 3 FADs
8/7	Fri	Sailing for Tokyo	Observed fish movement and net opening inside the net of Fukuichi Maru No.85
8/8	Sat	Sailing for Tokyo	Carried out light experiments, Complete all research work
8/9	Sun	Sailing for Tokyo	Sailing for Pohnpei
8/10	Mon	Arrived at Tokyo	Arrived at Pohnpei, Left Pohnpei for Makurazaki
8/11	Tue		Sailing for Makurazaki
8/12	Wed		Sailing for Makurazaki
8/13	Thu		Sailing for Makurazaki
8/14	Fri		Sailing for Makurazaki
8/15	Sat		Sailing for Makurazaki
8/16	Sun		Arrived at Makurazaki

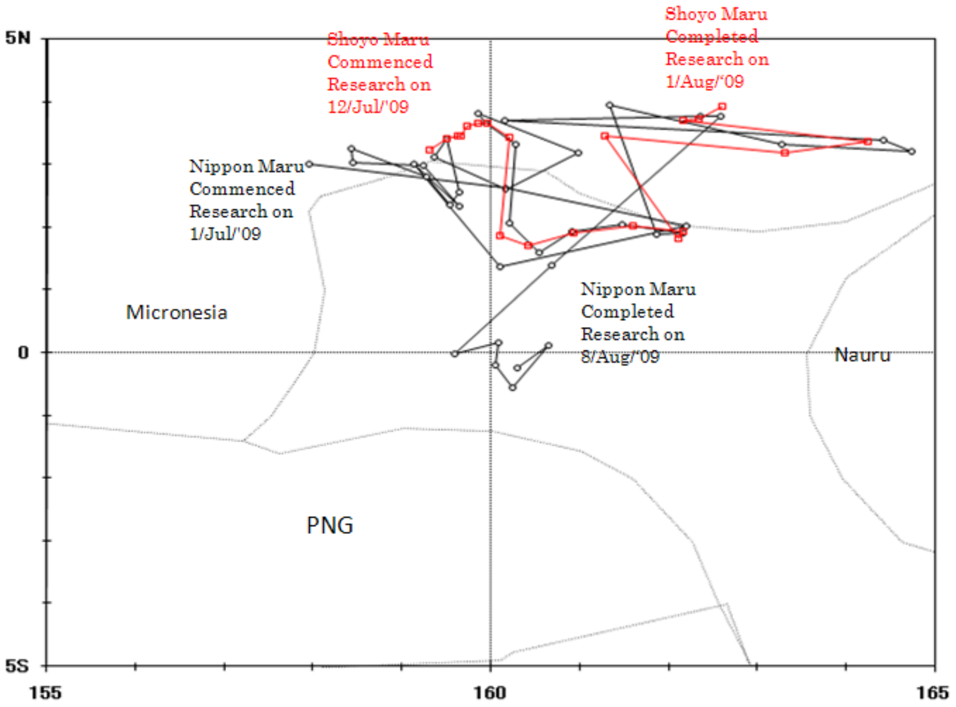
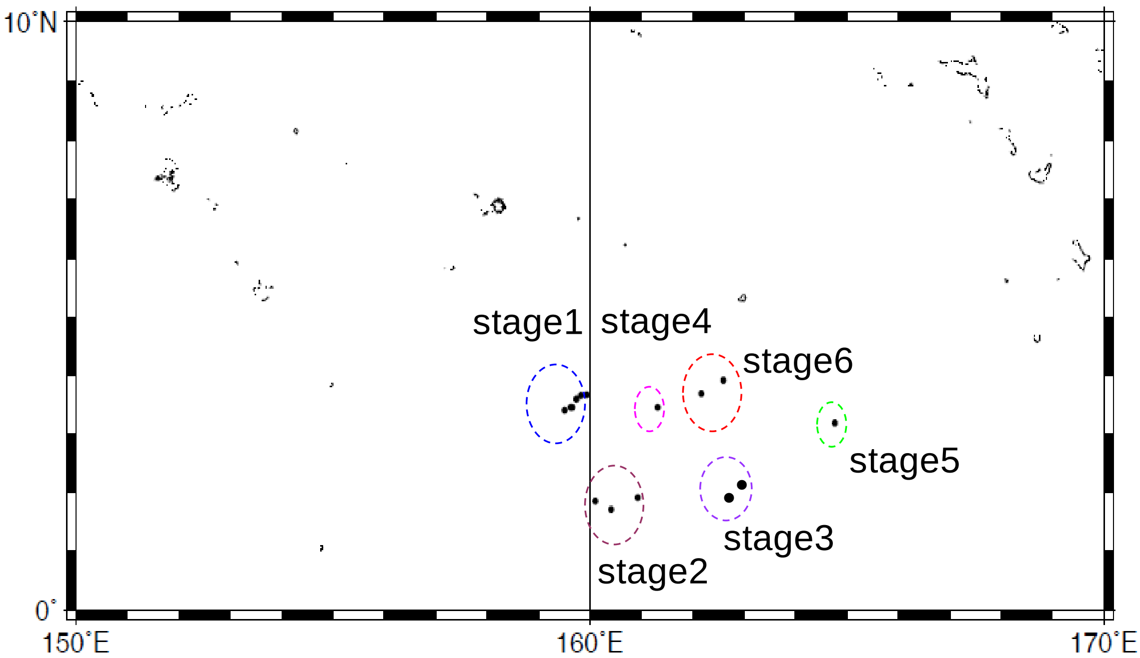


Fig.1 Noon position trajectory (□—:Shoyo Maru ○—:Nippon Maru)



Stage1:7/12-19, Stage2:7/20-22,
Stage3:7/23-25,
Stage4:7/26-27, Stage5:7/28-29,
Stage6:7/30-8/1

Fig.2 Area of the experiments or observations

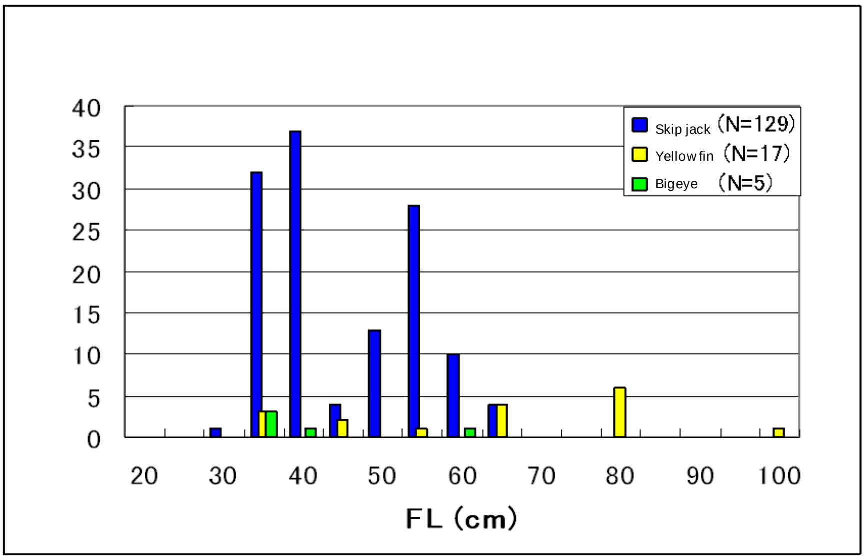


Fig.3 Frequency of fork length each fish in FAD1

(2009/7/19 by operation#1 of Nippon Maru)

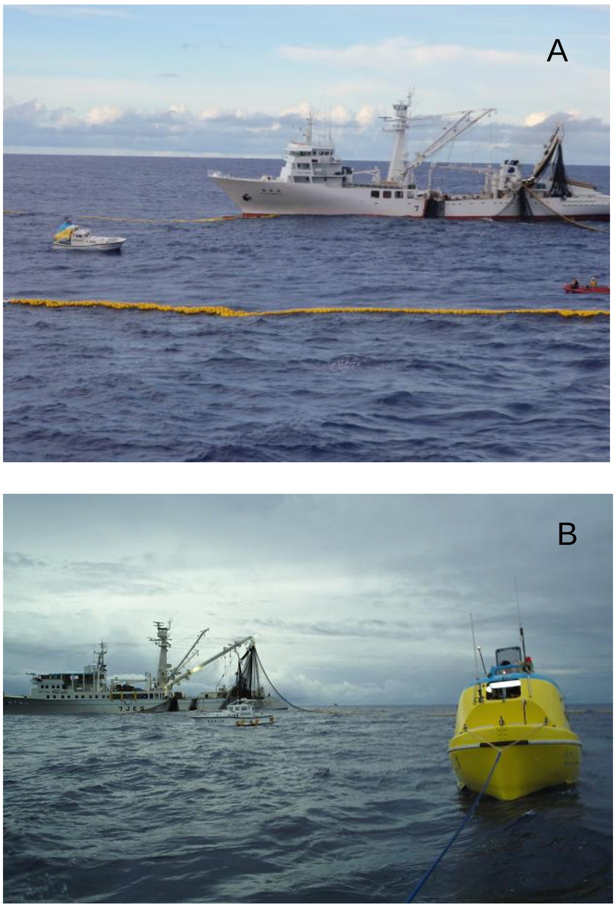


Fig.4 Research scenery

A: Joint research with Nippon Maru

B: Joint operation experiments with Fukuichi Maru No.83 (left) and Mizunagi (right: research boat of Shoyo Maru)

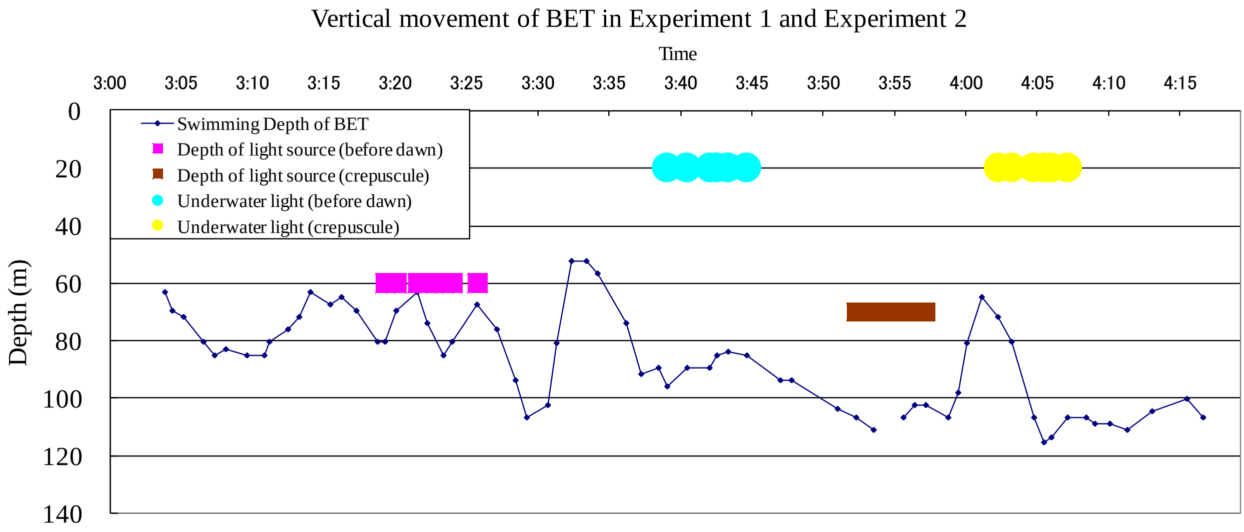


Fig.5 The vertical movement of bigeye tuna in response to light stimulus in experiment1 and experiment 2.

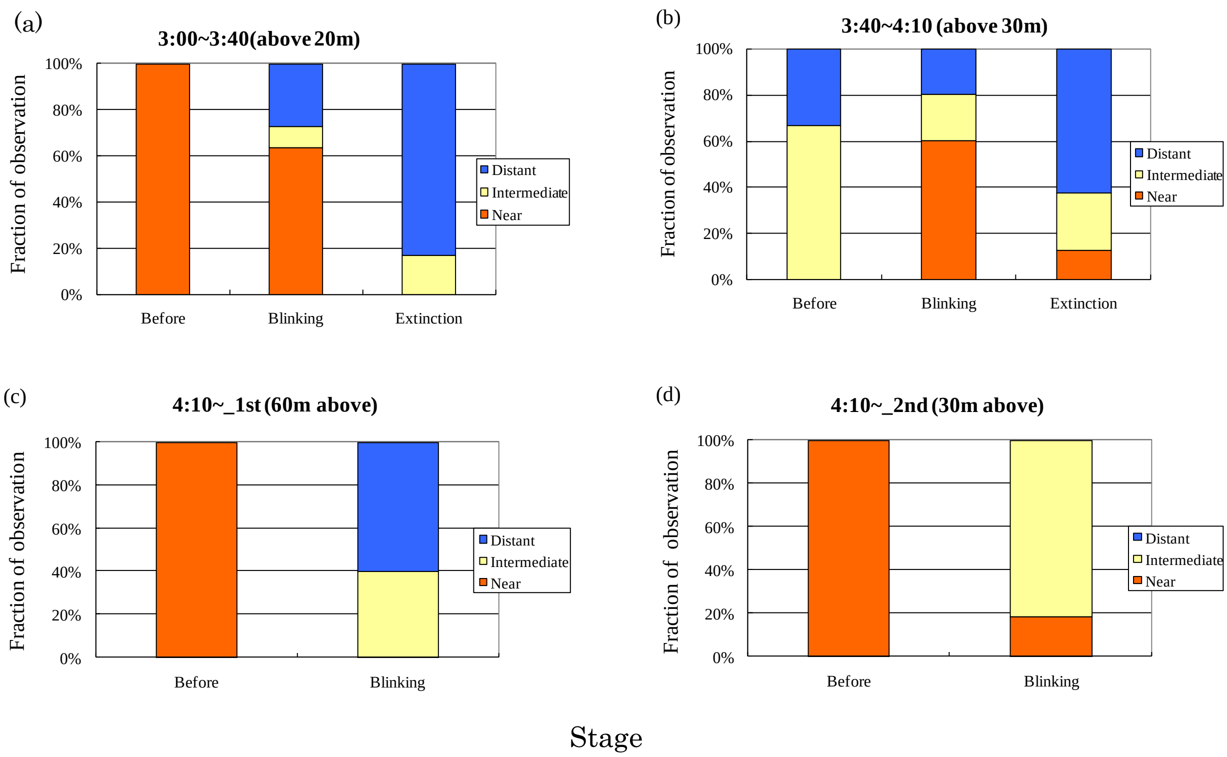


Fig.6 The horizontal movement of bigeye tuna in response to light stimulus for each experimental time (a~d). The count data obtained in the five minutes observation for each stage (“Before”, ”Blinking”, ”Extinction”) was used for the calculation of the frequency of each category of distance between light source and bigeye (“Distant”, ”Intermediate”, ”Near”).

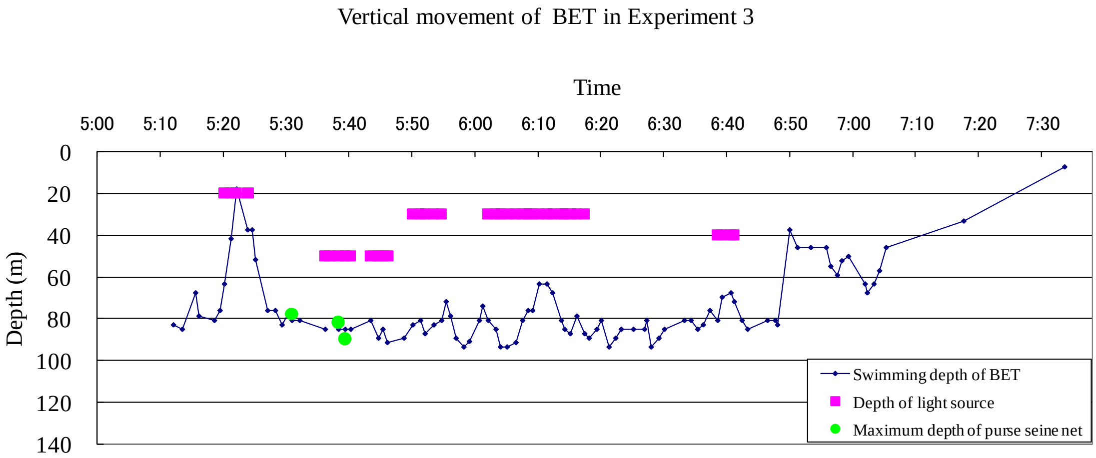


Fig.7 The vertical movement of bigeye tuna in response to light stimulus in Experiment 3.

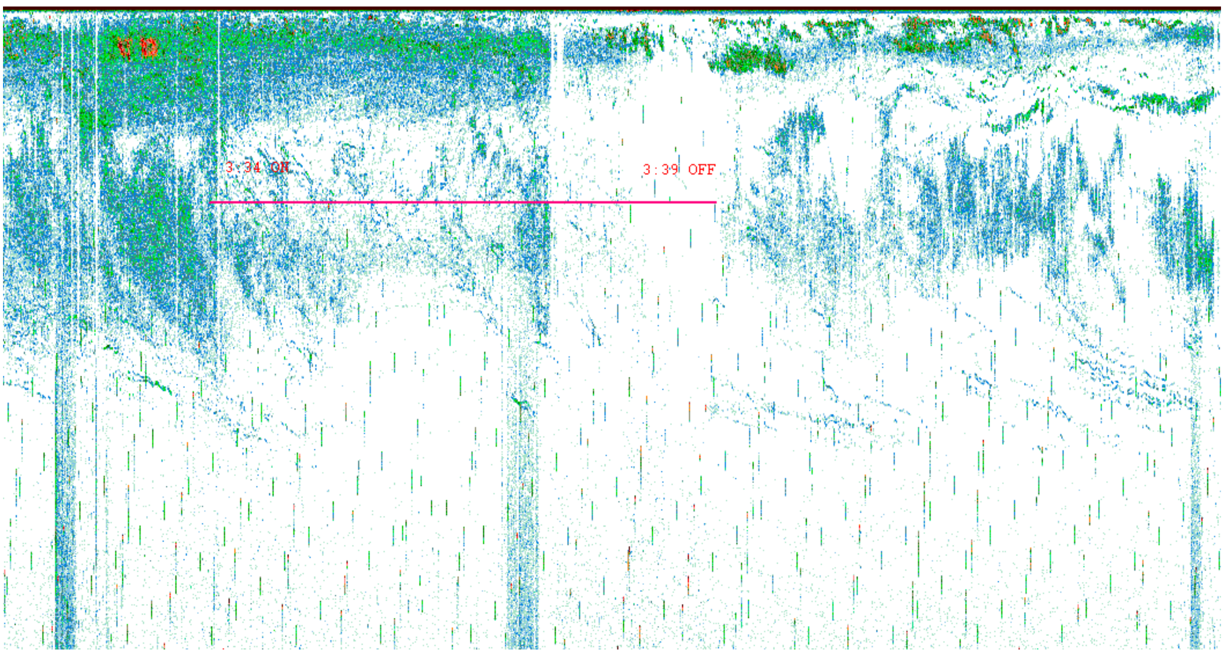


Fig. 8 An example of fish school reaction to the intermittent light. Horizontal and vertical directions denote the time and depth, respectively. The background image shows the echogram for the depth of 0m to 200m. The red line shows the depth and time of the light stimulus.

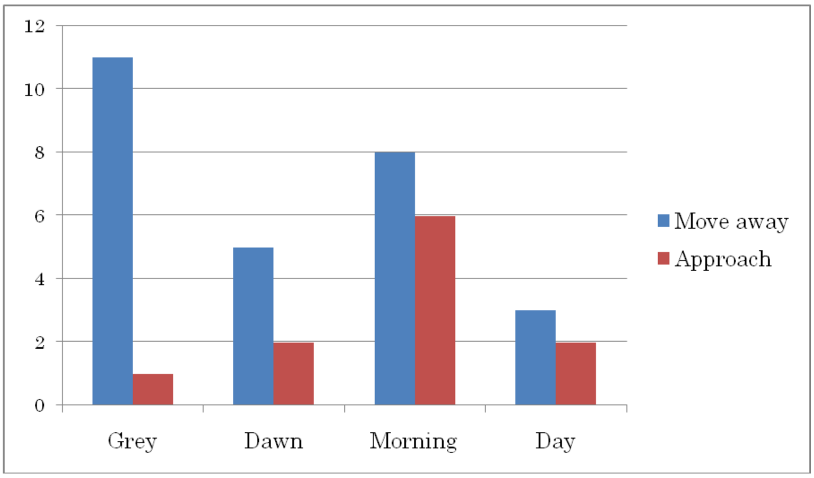


Fig. 9 Observed number of fish school vertical move reaction (Move away or Approach) to the intermittent light by time of the day. X and Y axis denote experiment time and number of frequency, respectively.

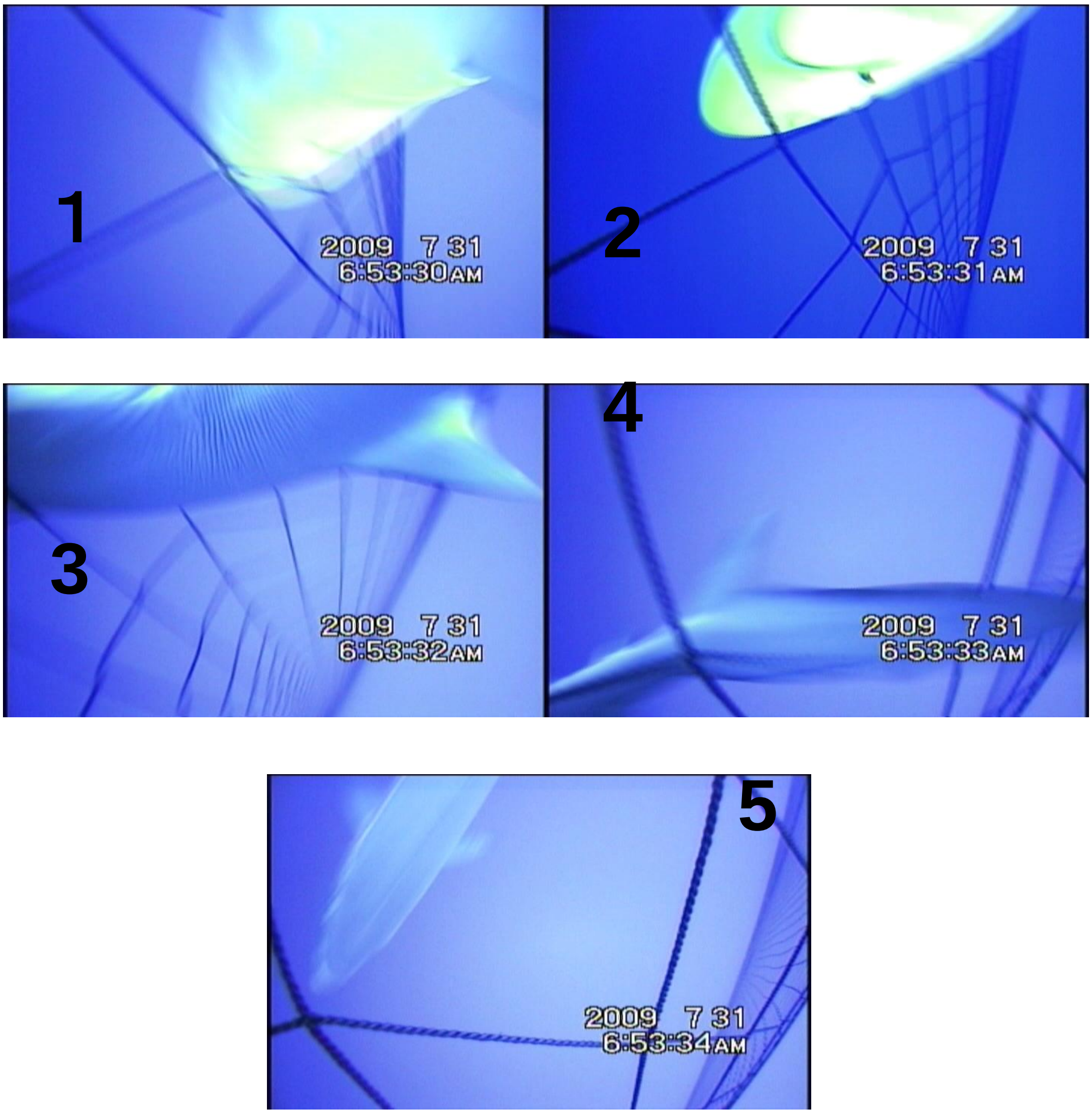


Fig.10 A silky shark (*Carcharhinus falciformis*) was escaped from large mesh.