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Study on the methods to reduce the by-catch of juvenile Bigeye tuna

in purse seine FADs operations

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Abstract

   Three joint research cruises were done during the period from 2009 to 2012 with the intention of developing methods to mitigate by-catch of Bigeye in purse seine FADs operation. A fishery research vessel "Shoyo maru" of Japan Fishery Agency and a tuna seiner "Nippon maru" chartered by Fisheries Research Agency participated in the research cruises.

   Light stimuli were applied in attempts to move Bigeye schools and let them escape through the mesh or underneath the net. The movements of fish were observed with coded pingers, scanning sonars, a wide-band quantitative echo sounder, and an underwater camera. Introducing new micro coded pingers (Fusion Inc.) in 2011 resulted in longer survival or / and retention of tagged fish. Consequently large data sets of the movement of Bigeye and Skipjack around FADs with or without light stimuli were obtained.

1. Backgrounds and Objectives

  Purse-seine operation with FADs(Fish Aggregating Devices) are considered to affect the stock of Bigeye tuna negatively. It is necessary to develop effective methods to reduce the by-catch of juvenile Bigeye tuna by FADs operation.

  To achieve this goal, Fisheries Research Agency decided to send a research purse seiner "Nippon Maru" to the Pacific Ocean to do research in cooperation with Fisheries Agency's "Shoyo Maru".

The objectives of the joint survey are;

(1) To assess how the fish behavior is affected by light stimulus, 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.

2. Research Vessel (Fig.1,2,3)

(1) Fisheries Research Vessel of Fisheries Agency, "Shoyo Maru", Government of Japan

Her major dimensions are as follows.

- Gross tonnage: 2581 tons
- TL: 77.85m×B: 14.00m×D: 7.25m
- Main Engine: 2,265.5kW×2 sets
- Electric propulsion motor: 350 kW

(2) Tuna purse-seiner "Nippon Maru" was chartered by Fisheries Research Agency and employed for the survey.

Her major dimensions are as follows.

- Gross tonnage: 1817 tons
- TL: 75.97m×B: 13.40m×D: 7.50m
- Main Engine: 2647kW
- Auxiliary propulsion motor: 1103kW

3. Research Period

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

Maru left Shiogama port on 23rd June 2009. Started research work on 1st July and completed it on 8th August, and then arrived at Makurazaki port, Japan on 16th August.

(ii) Shoyo Maru left Nagasaki port on 28th October 2010. Started research work on 15th November and completed it on 8th December and arrived at Tokyo port on 28th December. Nippon Maru left Banyuwangi port on 3rd November 2010 and then called at Rabaul port to take a PNG observer aboard. The vessel started research work on 13th November and completed it on 9th December, and then arrived at Phuket port on 25th December.

(iii) Shoyo Maru left Tokyo port on 22nd December 2011. Started research work on 8th January 2012 and completed it on 9th February arrived at Tokyo port on 5th March 2012. Nippon Maru left Phuket   port on 28th December 2011. Started research work on 8th January 2012 and completed it on 9th February.

4. Area of the Research

(i) 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 site, but because FADs had not flowed to a sea area concerned, the research was not unavoidably done.

(ii)The research area was EEZ of the Federated States of Micronesia and Papua New Guinea .

(iii) The open sea region in the eastern Indian Ocean.

5. Materials and Methods

(1) Devices

Following devices were used for generating light stimulus.
- KNY-LED-F2 (intermittent LED light)
- Underwater light (continuous light) (Fig.4)

Following devices were used for observing fish behavior and purse-seine net.
-Echo sounder (Nippon Maru) FCV30 (38kHz)
-Echo sounder (Workboat of Nippon Maru) KFC5000 quantitative echo sounder (38kHz)
-Scanning sonars (Nippon Maru) FSV30 (24kHz), FSV84 (84kHz)
-Scanning sonars (Workboats of Nippon Maru) CSH-8L4 (68kHz)
-Searchlight sonar (Mizunagi of Shoyo Maru) CH-34 (162kHz)
-Wide-band quantitative echo sounder(Workboats of Nippon Maru): the dolphin mimetic broadband sonar (70~130kHz)
- Underwater camera: Hitachi zosen "Eyeball" (Workboats of Nippon maru)
- Underwater camera: Kowa "SEEKER-III-mini" (Boat of Shoyo maru)
- ID pinger tag: Vemco "V16P-1H-S16" (51kHz, 54kHz, 57kHz, 60kHz) (in 2009 & 2010)
        Vemco "V13P-1H-S16" (60kHz, 63kHz) (in 2010)
        FUSION "FPX-1060-30P250" (31.25kHz) (in 2010 & 2012)
        FUSION "FPX-1050-60P250" (62.5kHz) (in 2010)
        FUSION "FPX-1030-60P250" (62.5kHz) (in 2010 & 2012)
- Signal tracker of ID pinger tag: "SEA-TRACK-170" System (Shoyo maru)
-"FRX-4001 & FRTD-400" System (Shoyo maru) (in 2010)
-"FRX-4002 & FRTD-403A" System (Shoyo maru) (in 2012)

(2) FADs

(i) Most of the experiments or observations were carried out around FADs, which include so-called "artificial log" (Fig.5a) and natural drift woods. The FADs had been set by Fukuichi Maru No.83 prior to the survey. The additional drift woods were found during the survey by Nippon Maru.

(ii)Most of the experiments or observations were carried out around four FADs. FAD No.1 was so-called "artificial log" and FAD No.2 was a drifting object (steel drum) (Fig.5b). FAD No.3 and 4 were artificial logs provided by Japanese commercial seiners Fukuichi Maru No.83 and Fuji Maru respectively.

(iii) Most of the experiments or observations were carried out around FADs, which include so-called "artificial log" had been set by Nippon Maru and the additional drift artificial device were found during the survey by Nippon Maru.

(3) Methods

Before investigation, we conducted the check experiment carefully on the influence which the echo signal of ID pinger has on the echo sounders and echo sonars of research vessels.

Sampling of fish were carried out using lure fishing by Shoyo Maru or trolling by workboats of Nippon Maru near each FADs. The fish caught were measured, tagged with ID pingers and released.

The movements of fish were tracked by following the echo signal of ID pingers using the transducers of Shoyo Maru in 2009 and 2010, further in 2011 tacking used the additional transducers of more vessels. Acoustic devices like Searchlight sonar of Mizunagi (Fig.6), echo-sounder and scanning sonars, wide-band quantitative echo sounder of workboats were also used for the observation.

Underwater cameras were used to observe the fish and mesh of the net. The cameras were suspended from the side of boat or workboats and video image were recorded.

For light experiments, LED light was suspended at depth (various from 10 to 85m) to generate light stimuli. Underwater continuous lights were employed at fixed depth of 10 and 12m by workboat of Nippon Maru. Then fish's reactions to the light stimulus were observed using ID pinger tags, along with acoustic and optical devices (Fig.7). These experiments were done around FADs or inside the purse-seine net.

Observations of mesh opening were done on occasions of operation by Nippon Maru. Mizunagi or boat, workboats of Nippon Maru came inside the net and observed the net and fish both acoustically and optically.

The body lengths of fish caught by the purse-seine net of Nippon Maru were measured for every species.

Observations of fish behaviour in three different conditions were made around each FADs; (i)without light stimuli, (ii)with light stimuli, (iii)with light stimuli during purse seine operation.

Most of the experiments were made around dawn as it is usually the time for FADs operations.

(i)Observation of fish without light stimuli

Fig.8 shows a typical formation of vessels for the experiments without light stimuli. Fish behavior around the FAD were observed with coded pinger system and acoustic devices such as scanning sonars and echo sounders. Signals from coded pingers were received with more than two receiver units attached to the boats. A work boat with a receiving unit is connected with the FAD.

Shoyo maru stayed near the FAD with a separation of 50 to 200 meters.

(ii)Observation of fish reactions to the light stimuli

Fig.8 shows a typical formation for the experiments of fish reactions to the light stimuli.

Two halogen underwater lights were deployed at fixed depth of 10 and 12m from a work boat connected to the FAD. A LED light was deployed about 5 to 80m deep from a board of Shoyo maru.

We applied following 3 patterns of lighting where one light period continued 15 to 30 minutes.

-only continuous halogen lights
-only a LED intermittent light
-combination of both continuous and intemittent light

Signals from coded pingers were received with more than two receiver units attached to the boats.

(iii) with light stimuli during purse seine operation

During PS operation, experiments of light stimuli were done.

Fig.9 shows the design skeleton of PS net used for the study. The length of cork line is 1794m and net depth is 185m. The painted area in the figure illustrates the section of largest mesh size(270mm). MDS depth sensors were used to measure the depth of the foot rope. "Buoy-line" style PS operation, which use only parachute anchor to set the net instead of skiff boat, was used for the operations for these research cruises.

Signals from coded pingers were received with the receiver units of Shoyo maru, a work boat and Nippon maru. Such multiple receiving stations make the receiving area wider. Moreover, having multiple receiving stations allows better estimation of the position of a given fish(pinger) with "cross bearing method".

Fig.10 shows the formation of vessels for periods from just before the operation until the net hauling. In this formation, intermittent light is radiated from starboard of Nippon maru. With this formation we expected that Bigeye, which has more compatibility to the intermittent light, concentrate under Nippon maru and consequently have better chance of escaping from the net.

After the end of operations Shoyo maru went circles around the FAD to catch signals from the fish that are still around the FAD so that we can confirm the escapement.

(4)Results

(i) Coded pingers

Due to introduction of smaller pingers in 2011, survival or retention of tagged fish increased dramatically, especially for small Bigeye of size under 40cm and Skipjacks. Full analysis of pinger data have not finished yet and the analysis and discussions in this paper are preliminary.

(ii) Observation of fish without light stimuli

We conducted 3 sets of experiments with 2 FADs.

Fig.11 shows an example of the vertical movement of small Bigeye. Between four and five o'clock fish slowly swam up and down in the layer between 20 to 80m. At 5:28 fish started descending and at 5:31 started sudden and sharp ascending move up near to the surface. The time when the sharp rise were observed is about 25 to 30minutes before the sunrise. Then in 5:54 individuals started descending slowly to 60m.

Fig.12 shows an example of the vertical movement of skipjack. Between four and five o'clock fish slowly swam up and down in the layer between 40 to 80m and some fish periodically went up near to the surface. Then at 5:26 fish started descending and at 5:32 to 5:35 they started sudden and sharp ascending move from 80m to 10m. After

that they showed small scale up & down move and gradually descend down to 80m by 6:15.

(iii) Observation of fish reactions to the light stimuli

We conducted 6 sets of experiments with 6 FADs.

Fig.13 shows the vertical movement of Bigeyes which are the same individuals that are shown in Fig.11. Time period and depth that the lights were on were overlayed to the figure. Between four and five o'clock, during the halogen lights were on at 10 and 12m fish were at 10-60m that is 10-20m shallower than when no light was on. When the halogen lights went off at 5:09 all the fish started descending rapidly. These results suggested the effect of lights to the behavioral pattern of both Bigeye and Skipjack.

(iv) with light stimuli during purse seine operation

We conducted 7 sets of experiments during PS operations with 7 FADs.

Fig 14 shows the vertical movement of two groups of Bigeye. One group is the individuals that were successfully escaped(in cold colors) and the other is the ones that captured in the net(in warm colors). Fig 15 shows the magnification of Fig.11. Before and during the net setting, two groups showed no difference in swimming depth; both in 30 to 90m. Pinger signals were missing until 5:40. After that the two groups separated in depth , where fish caught were observed in layer shallower then 50m and two of the escaped fish were in 80m or deeper.

Fig.16 also shows the vertical movement of two groups of Bigeyes. One group is the individuals that were successfully escaped (in cold colors) and the other is the ones that captured in the net (in warm colors). Fig 17 shows the magnification of Fig.16. In this case swimming depth of two groups remain the same until the late stage of net hauling. A 43cm Bigeye successfully escaped from this set. It started the dive at 5:40 but stopped at 50m and then started ascending again. This could be caused by the presence of net because when there was no net the same individual started decreasing at 5:37 and reached 100m depth. And at 6:10 the same fish started descending again and reached 90m this time. We assume that at this second dive the fish could escape through the mesh opening.

Fig.18 shows the vertical movement of two Bigeyes that were considered to get entangled with the net (C-1 and C-13). The C-1 pinger was found entangled with the large mesh section of the net during hauling. The fish to which the pinger had been attached was not found. Consequently we assume that the entangled fish struggled and freed itself with the pinger left on the net. The vertical movement of the pinger C-1 stopped somewhere between 5:20 to 5:24 which is just around the time when the pursing ended. C13 pinger was not found on the net but it showed the same pattern in vertical change with C-1 so we could assume that this individual was also entangled with the net. Both C-1 and C-13 was with a middle-sized Bigeye (54cmFL for C-1 and 52cmFL for C-13).

(5) Discussions

A large data set was obtained through three years of survey. These data include rich information on the behavior of Bigeye and Skipjack both with and without light stimuli. The fish behavior data can be basic information for the study of FADs ecology. The data of the reactions of fish to light stimuli or PS operations need closer analysis in order to develop effective methods to mitigate Bigeye by-catch.

Fig.1 Shoyo Maru, boat of Shoyo Maru and workboats of Nippon Maru (in 2012)

Fig.2 Nippon Maru (in 2010)

Fig.3 Mizunagi of Shoyo Maru (in 2012)

Fig.4 Underwater light by workboat of Nippon Maru (in 2010)

Fig.5a FAD of the experiments or observations ("artificial log") (in 2009)

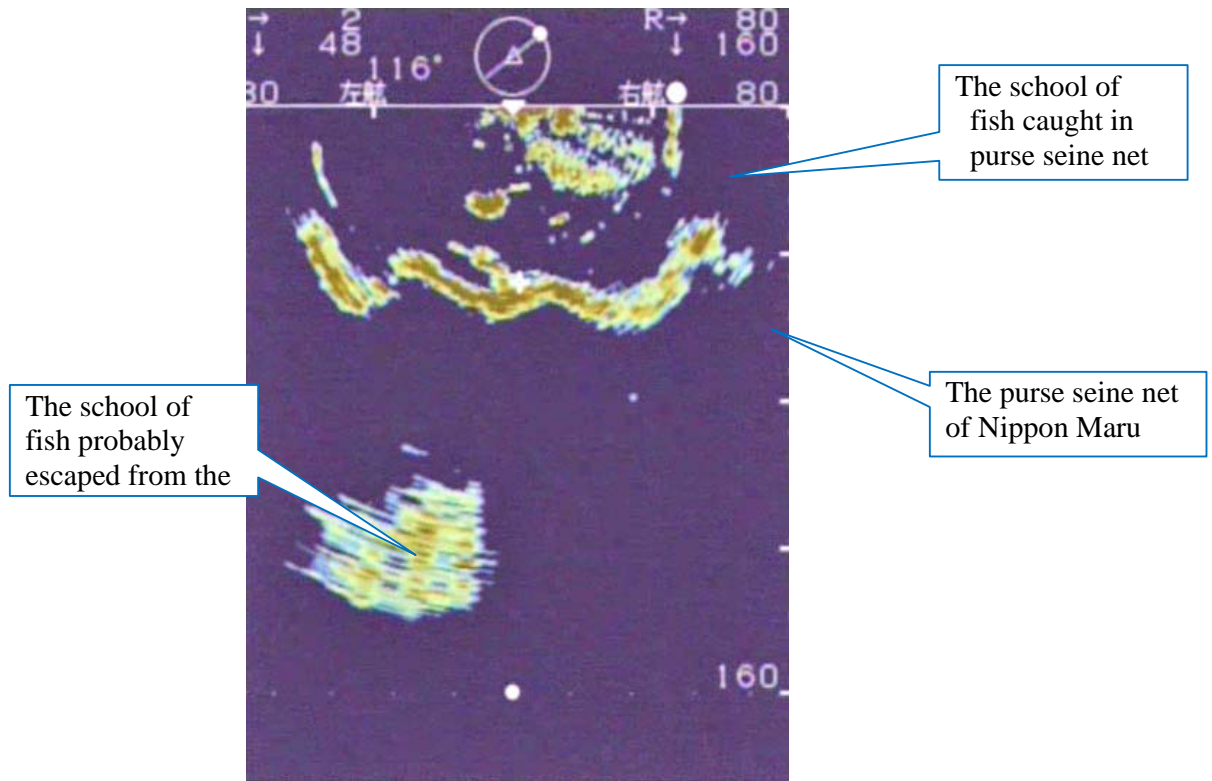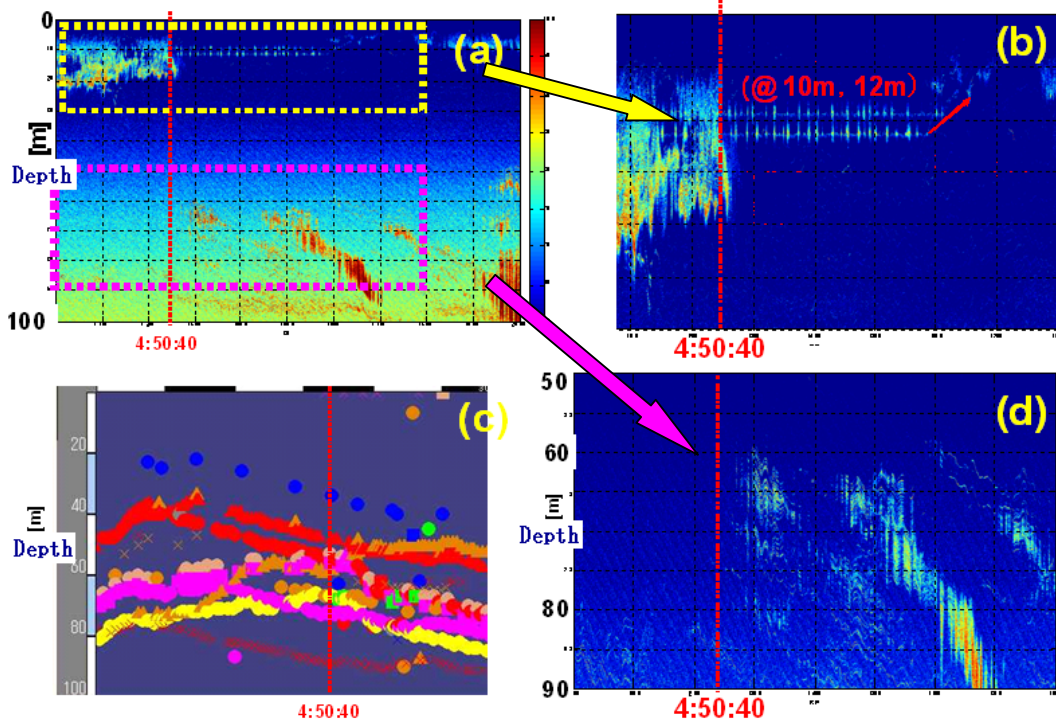Fig.5b FAD of the experiments or observations (drifting object "steel drum") (in 2010)

Fig.6 Picture of searchlight sonar of Mizunagi (in 2010)

Underwater light was put out at 4:50:40.

Fig.7 The example which carried out information integration of broadband sonar and the ID pinger.
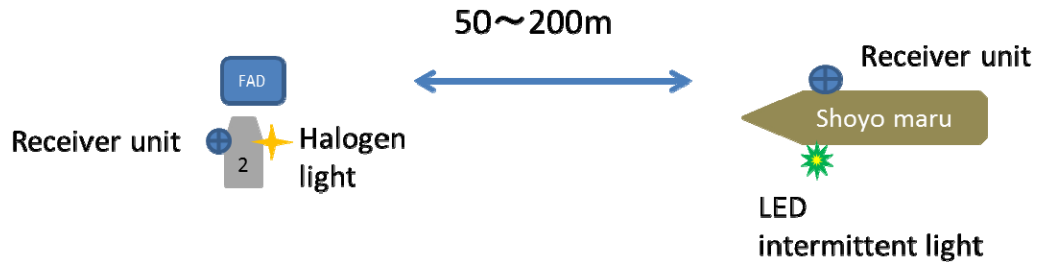
Fig.8 Formation of vessels for the observations with / without lights
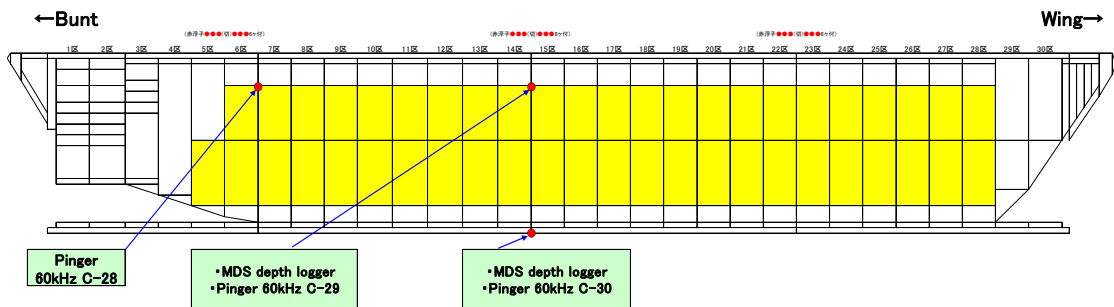
Fig.9 Design skeleton of purse seine net (The parts painted in yellow are the sections of largest mesh size(270mm))
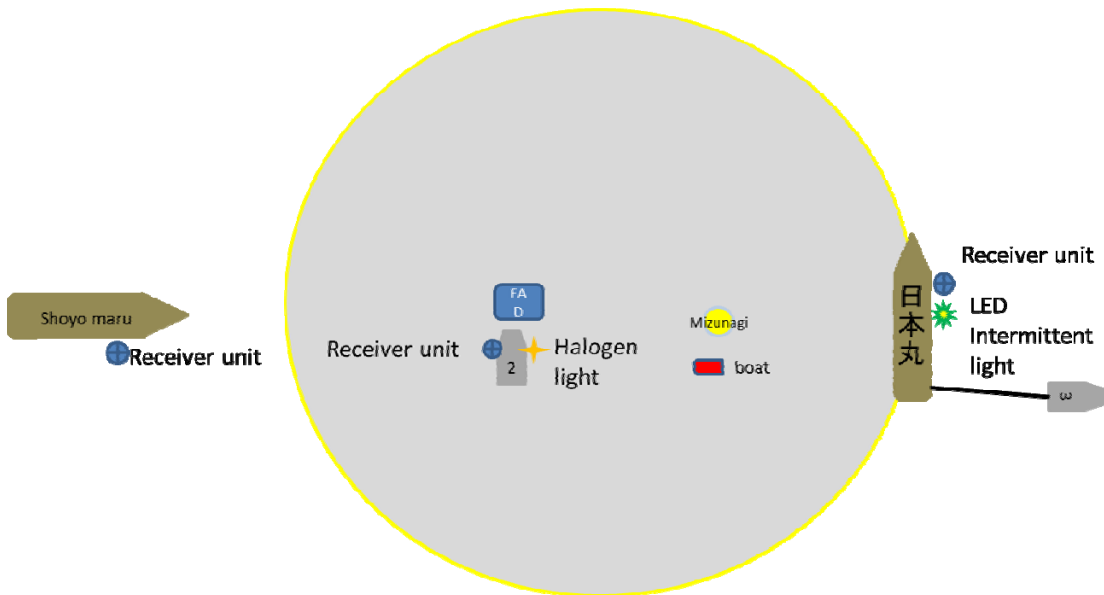
Fig.10 Formation of vessels for experiments during PS operations
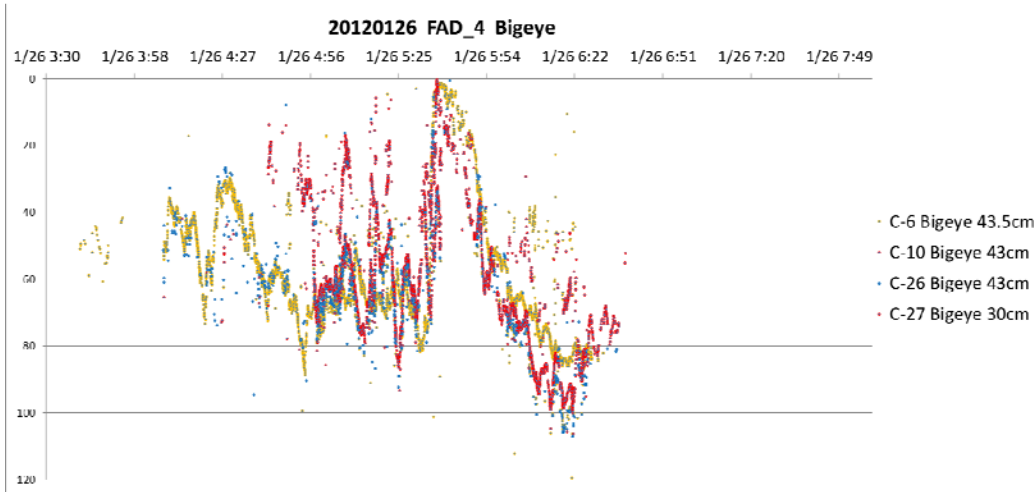
Fig.11 An example of the vertical movements of small Bigeyes
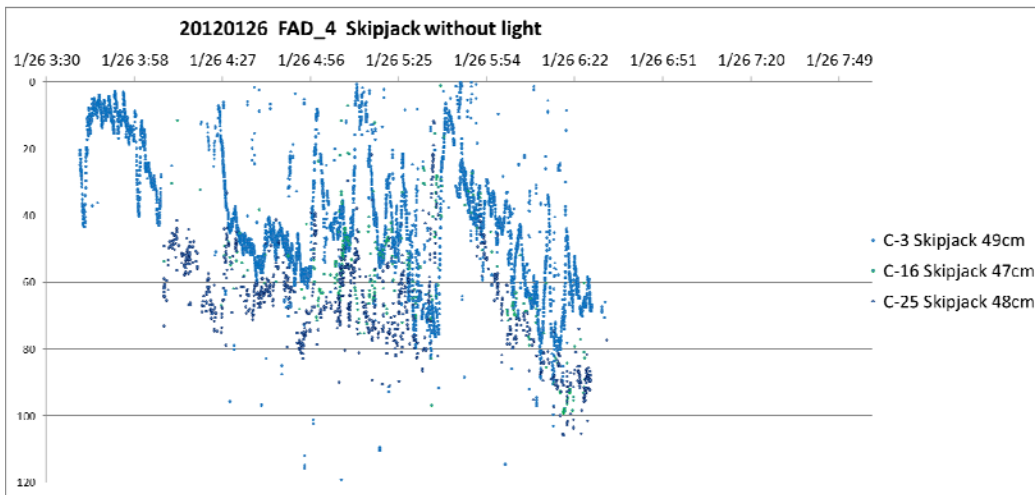
Fig.12 An example of the vertical movements of Skipjacks
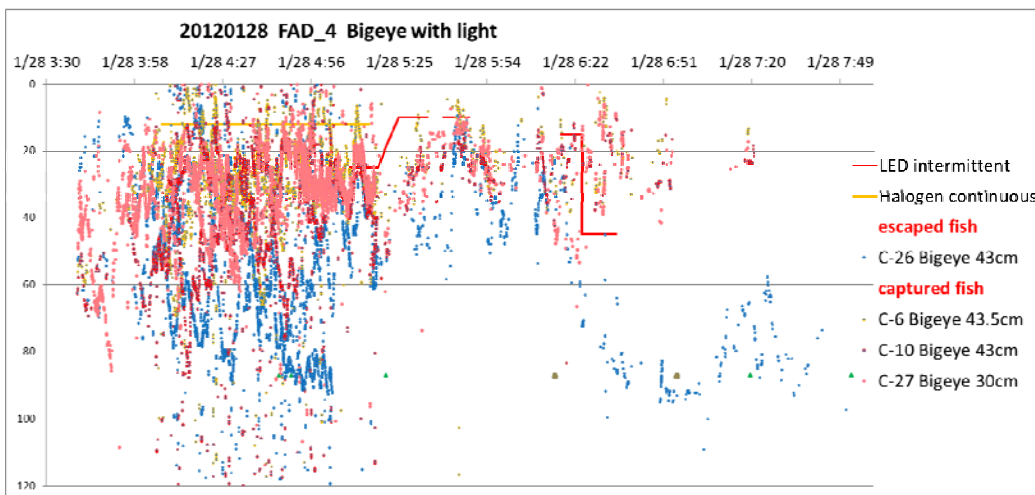
Fig.13 An example of fish's vertical reaction to light stimuli
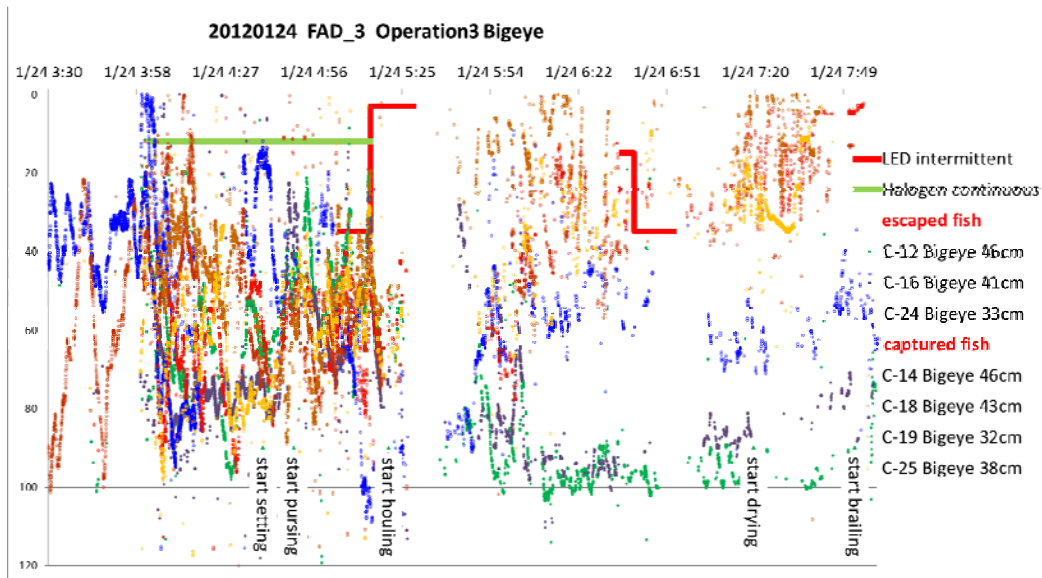
Fig.14 An example of the vertical movements of two groups of Bigeye; escaped (in cold colors) and captured (in warm colors)
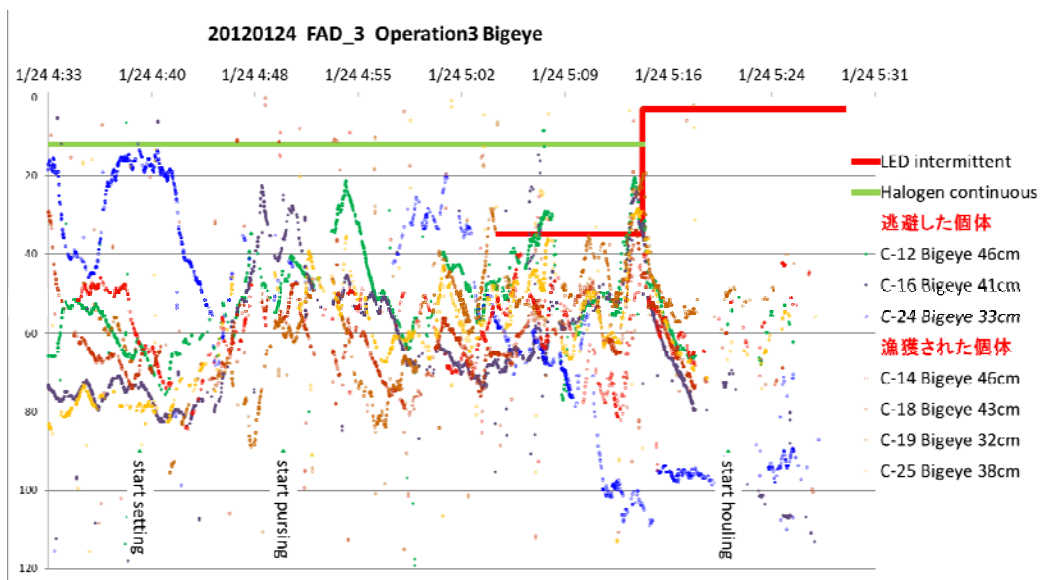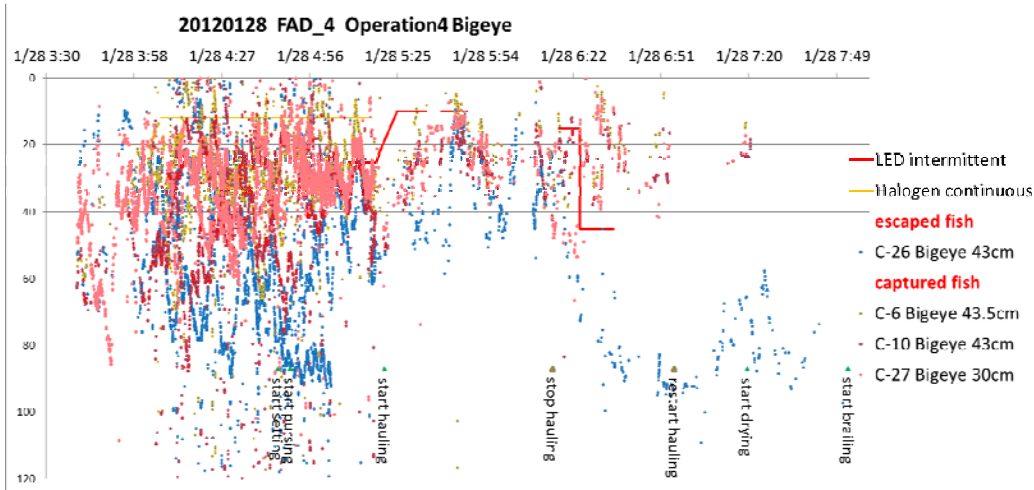

Fig.15 Magnification of Fig.14

Fig.16 An example of the vertical movements of two groups of bigeye; escaped (in cold colors) and captured (in warm colors)
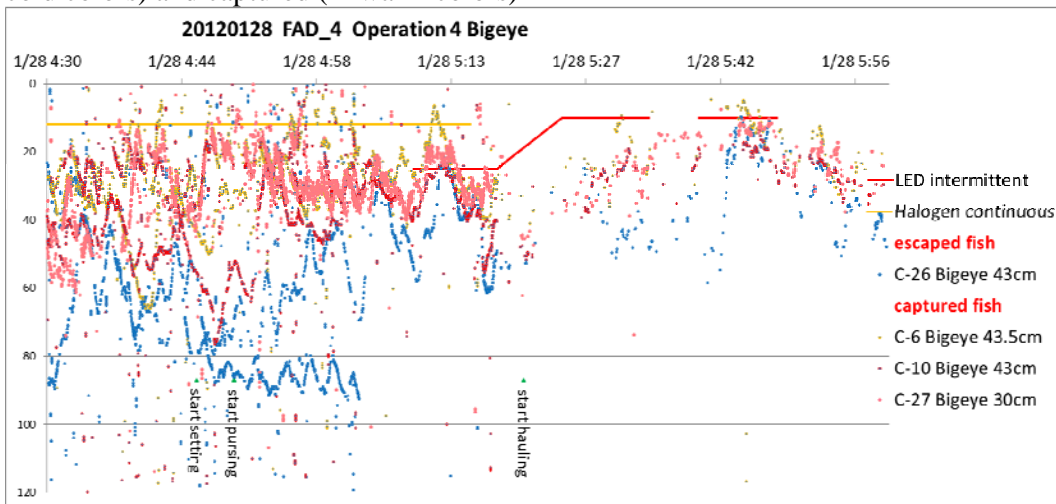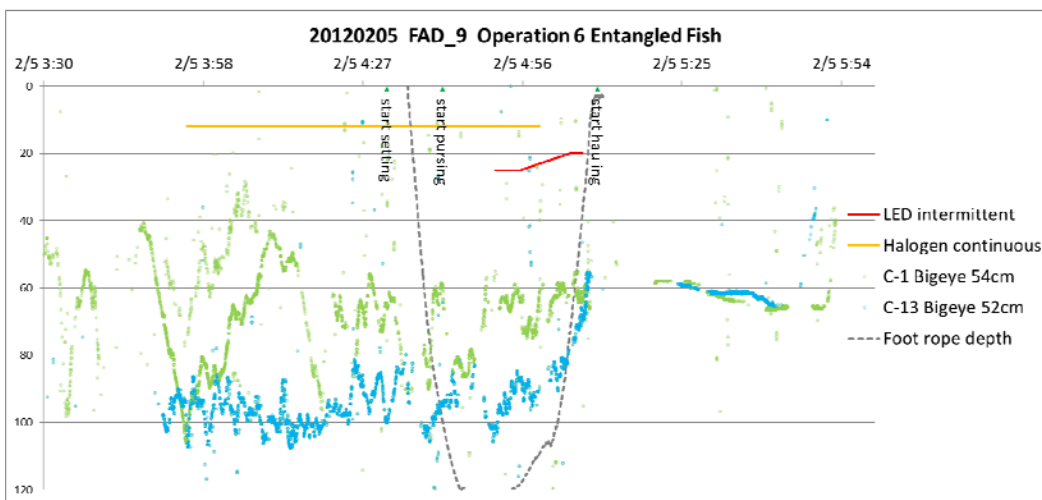

Fig.17 Magnification of Fig.16

Fig.18 Vertical movements of two bigeyes that are considered to be entangled with the nets during an operation