Possibility of use of acoustic camera system for counting and measuring captured Southern Bluefin Tuna for the farming
養殖用ミナミマグロ計数・計測における音響カメラ利用の可能性

Miki Ogura[1], Toshihiro Watanabe[1] and Kazuhiro Hantani[2]
小倉未基[1]・渡部俊広[1]・半谷和祐[2]
1: Tuna Institute, Fisheries Research Agency　水産総合研究センターまぐろ研究所
2: TOYO Corporation　株式会社東陽テクニカ

要約
音響学的手法によりオーストラリアにおける養殖ミナミマグロをモニターする可能性検討の参考とするために、わが国における市販の音響カメラによる養殖クロマグロ観察結果を紹介した。研究用飼育施設、日本国内の養殖業者生け簀、メキシコの養殖業者の生け簀間移動を、音響カメラと一部光学ビデオカメラで観察した。音響カメラでは、海の透明度に関係なくクロマグロの遊泳状況の鮮明な画像が得られ、遅いフレームレートでも遊泳個体のコマ落ちは無かった。さらに本手法では明るさに影響されることも無い。さらに簡単な操作で、通過するクロマグロの計数・サイズ計測がかなりの精度で行うことができた。これらのクロマグロでの結果から、音響カメラは類縁種のミナミマグロの生簀間の移動時の計数・計測に適したシステムと考えられ、モニタリングに使用することを強く推薦したい。

Summary

This document presented the outline of our trials on observing rearing Pacific Bluefin Tuna by using the acoustic camera system, in order to provide a cue an opportunity of discussion on the application of the acoustic technique to monitoring the farming Southern Bluefin Tuna in Australia. Field trials using the DIDSON (a commercial product of the acoustic camera system) were carried out at the tuna rearing experimental station in Japan, a tuna farming industry in Japan, and that in Mexico. The clear images of farming tuna by the acoustic camera were obtained regardless of bad water transparency. The frame rate of the camera could follow the swimming speed of the fish. The system is not influenced by the light intensity. Counting the fish passing and measuring the size of them with rather good precision were performed automatically or semi-automatically on the software. Based on the observation of the Pacific Bluefin Tuna under farming operations by the DIDSON, the monitoring ability of acoustic camera system is appropriate, and we strongly recommend that the system be used for the monitoring of rearing Southern Bluefin Tuna.

1． Introduction

The number of fish removed from wild tuna stock with size or age is essential information to evaluate the stock status. One of the removal source from southern bluefin tuna (SBT) stock is catching young fish for farming by purse seine, as well as those by fisheries targeting adult fish. In order to estimate its amount with best accuracy, counting fish at the time the purse seiner just encircling fish school is needed. If there is any difficulty on doing this, it is important to inspect fish at any time during rearing as early as possible.

At any timing to observe, optical and visual based observation methods have been used so far. However observing underwater live fish by such way needs always enough light intensity and good transparency. Also these methods have disadvantages in terms of the time consumption for analyzing the image. In Japan, we are applying the acoustic camera system, which was originally introduced for the research of the Nomura's (giant) jelly fish that has made serious damage on coastal fishery, for feasibility study on the behavior of farming pacific bluefin tuna (PBT) in the floating net cage.

Actually this system become to be widely used for salmon counting in the fresh water in the north America after field experiments testing the ability of the system on counting fish and estimating fish size (Moursund et al., 2003, Holmes et al., 2006). There are some trials even in Australia (Baumgartner et al., 2006). It is easy to expect that this system will apply to counting and measuring SBT objectively in the net cage or during transferring from net to net.

In this paper, we present the field trials of this system on observing PBT and discuss the possibility of applying to the SBT farming monitoring.

2. Equipment

An acoustic camera used for observing PBT behavior is a commercial product known as the DIDSON (the dual-frequency identification sonar). This is a high frequency, multi-beam sonar with a unique acoustic lens system designed to focus the beam to create high resolution images. The DIDSON has two frequencies, 1.8 and 1.1 MHz (Table 1). The high frequency beam is divided into 96 - 0.3°×14° beams with range settings up to 12 m. The 1.1 MHz beam is divided into 48 - 0.6°×14° beams with range settings up to 40 m. Acoustic lens focuses from 1 m to the maximum range setting. Frame rates are up to 21 frames/s (variable depending on the range setting). A standard DIDSON transducer which weighs approximately 7kg in air and almost neutral buoyancy in water, and measures 171 mm x 307 mm x 206 mm. Further details on DIDSON sonar specifications can be found in Sound Metrics Corp. (2004) and their HP (http://soundmetrics.com/).

DIDSON's high resolution images provide almost video quality images in dark and turbid water where optical systems are ineffective. Simultaneously, DIDSON's software has many feature for assisting the operation and data analysis; Auto-Counting, Auto-Sizing, Direction-of-Passage, Motion Detection, etc. (Sound Metrics Corp. 2006).

Several kinds of near video quality DIDSON image examples are available at the products HP (http://soundmetrics.com/FM/FM.html).

3. Field trials on PBT observation

3-1. at the facility of the Fisheries Research Agency (FRA)

We conducted an experiment of observing rearing PBT at the Amami field station, National center for stock enhancement, FRA, located at the northern Ryukyu Archipelago, on 19 September 2007 (Figure 1). Observations by the DIDSON were carried out at part of partitioned inlet, 40m diameter net cage and 10m diameter net cage. It was almost fine but cloudy during experiments. The transparency and turbidity of experiment sites were shown in Table 2.

3-1-1. In the partitioned inlet with 8 years old PBT (2.5 m, 300 kg, guesstimated)

DIDSON was fitted at the bottom of the plastics pipes which was mounted on the wood deck over the inlet, camera shooting free swimming PBT with approximately 20 degree of downward angle (Figures 2 and 3 (left)). Sample image at this site was shown in Figure 5. Half of the fish body, side facing to the camera, came out well in the image. Opposite site did not appear.

3-1-2. 40m net cage with 3 years old PBT (1.5 m, 100 kg, guesstimated)

DIDSON was fitted at the bottom of the plastics pipes which was mounted on the frame of the net cage and was submerged about 1 m under the surface with approximately 20 degree of downward angle (Figures 2 and 3 (right)). Sample image at this site was shown in Figure 6. There were noisy images of small fishes near the camera and babbles produced by the bait thrown in.

3-1-3. 10m net cage with 1 year old PBT

DIDSON's settings were same as those of 40m net cage experiment. Also we tried the DIDSON with a frame sinking in the net cage bottom hung by two ropes and observed the fish school from bottom to the surface (Figure 4). Observing in the small size net cage, opposite side cage net was also shown with the shadows of fish in front of the net (figure 7). PBT of 1 year old swam in school of 3 m thickness, from 1 m to 4 m depth (figure 8).

3-2. at the industry facility in Japan

The underwater technology Research center, Institute of Industrial Science, University of Tokyo and TOYO Corporation jointly conducted the observation of rearing PBT of Japanese farming industry. The net cage was 10m × 20m rectangle and containing several hundreds of fish. The DIDSON was fitted at the bottom of the pole which was hung from another pipe put horizontally on the corner of the cage and submerged about 1 m under the surface (figure 9). Size of fish was supposed to be 1.2m ～1.5m. It was cloudy and occasionally sunshine. Transparency was about 10m.

Only the underwater acoustic images of fish (belonging to the University of Tokyo, all right reserved) were available (figure 10). Reporting the scenery on the water and the underwater structure are prohibited by the request of the farming industry (figure 10). Under this degree of density of fish, most of fish were recognized as an individual fish.

3-3. at the industry facility in Mexico

TOYO Corporation carried out the experiment of observing the rearing PBT being transferred from net cage to net cage by using The DIDSON in Mexican water. One net cage was 40m diameter and keeping about 4,000 fish. Size of fish was supposed to be around 1m, 15kg. It was fine day and transparency there was bad (4 or 5 m). The DIDSON was fitted at the bottom of the pole which was attached the frame of the net cage. The DIDSON transducer was aimed horizontally at the gate of transfer joint between net cages. The transfer gate was about 2.5m X 2.5m and attached with the optical video camera and the background canvas wall (figure 11).

Only the underwater acoustic and optical images were available, same as Japanese farming industry. Optical video images could not show the fish clearly under this bad transparency condition (figure 12). Although the DIDSON was set relatively away from the transfer gate, it could show multiple fishes (Figure 14) as well as an individual fish which led a school of fish to passing through the transfer gate (figure 13). Even at slow frame rate, such as 4 frames per second, fish moving through the field of vision were all taken in the each continuous frame. This experiment site was located in the open bay and the DIDSON was shacked and swayed with the net cage frame moving by the waves and swells, so the images was influenced by these to tend to be unsteady.

4. Counting and measuring trials

We used the manual measure function of the DIDSON software to measure the size of nine fish passing in the field of vision of the DIDSON in the partitioned inlet with 8 year old PBT (see section 3-1-1). Because there was no way to identify individual fishes, it may be repetitious measure. The mean estimated size was 273 cm (ranged from 238 cm to 306 cm), and it was reasonable one for 8 years old rearing PBT estimated size.

At the observation of the tuna transferred between nets in Mexican water (see section 3-2), Auto-Counting and Auto-Sizing function were applied. These function showed real time counting number and the size of fish targeted at that time on the screen (Figure 15 is a screen shot example). The number of fish estimated was about 3800. This number was slightly less than around 4000, which had been estimated visually by divers at the time of transferring from the purse seine net to the net cage for transportation two days before the DIDSON observation. During the DIDSON observation, some masses of PBT, which could not be identified individually, were passing, and it might have caused underestimate of the counting. The size distribution of PBT by the DIDSON was also estimated and presented to the Mexican tuna farming industry. The Mexican tuna farming industry rated the estimated size distribution highly. Any concrete data could not be presented here, because the farming industry did not like to disclose any information on their fishes, density, size, etc.

5. Conclusions and recommendation for SBT monitoring

The clear images of farming PBT were obtained by the DIDSON. The acoustic camera, the DIDSON, observations were something akin to an scene of lighting the dark by the searchlight with strong directivity, 14° vertically and 29° horizontally. The characteristic of the acoustic camera system makes us free from the turbidity consideration. The frame rate of the camera could follow the swimming speed of the fish in the net cage. Counting the fish passing and measuring the size of them with good precision could be easily carried out automatically or semi-automatically by the software. Many kinds of additional functions for image analysis are easily conducted. The acoustic camera system is superior to the optical based method in system requirement on light and turbidity condition, operating range, and image analysis. Although the stereo video camera system also provides measuring function, it needs strict calibration on setting cameras. Based on the observation and measurement of PBT under farming condition by the DIDSON, it is easily expected that the DIDSON will be efficient in observing and measuring the SBT also.

Although fish size measure is influenced by the resolution which depends on the operating range theoretically, the laboratory tank experiment using live fish showed the DIDSON's measurement software had only 2 cm accuracy at range up to 6 m (Weiland et al. 2003). Unsteady image (or camera shake) observed at the open ocean site is expected to affect the measuring difficulty, but it will be solved by the digital image stabilization technique etc.

There are some proper subjects to the PBT observation that should be solved for applying this system. In Mexican water experiment, too large density of fish once came in the field of vision, multiple fish distorted the image of a fish and /or fish school. Bubbles from the divers hurrying tunas from one net cage to another became noise for the acoustic camera.

In the case of the SBT, which do not pass the transfer gate with too much individuals together and are not hurried by divers making bubbles, the above-mentioned subjects are not problematic. Therefore, it is clear that the ability of the acoustic camera system for monitoring farming SBT is sufficient, and we strongly recommend that the system should be used for the monitoring of rearing SBT.

References

Baumgartner, L. J., N. Reynoldson, L. Cameron, and J. Stanger. 2006. Assessment of a dual-frequency identification sonar (DIDSON) for application in fish migration studies. Fisheries Final Report Series No. 84. NSW Department of Primary Industries, Cronulla NSW Australia. 33pp.

Holmes, J. A., G. M. W. Cronkite, H. J. Enzenhofer, and T. J. Mukkigan. 2006. Accuracy and precision of fish-count data from a "dual-frequency identification sonar" (DIDSON) imaging system. ICES Journal of Marine Science, 63: 543-553.

Moursund, R. A., Carlson, T. J., and Peters, R. D. 2003. A fisheries application of a dual-frequency, identification sonar, acoustic camera. ICES Journal of Marine Science, 60: 678-683.

Sound Metrics Corporation. 2004. Dual-frequency Identification Sonar. DIDSON Operation Manual. V4.47.15. Sound Metrics, Seattle, WA. 44 pp.

Sound Metrics Corporation. 2006. Additional Software Features. Sound Metrics, Seattle, WA. 2 pp.

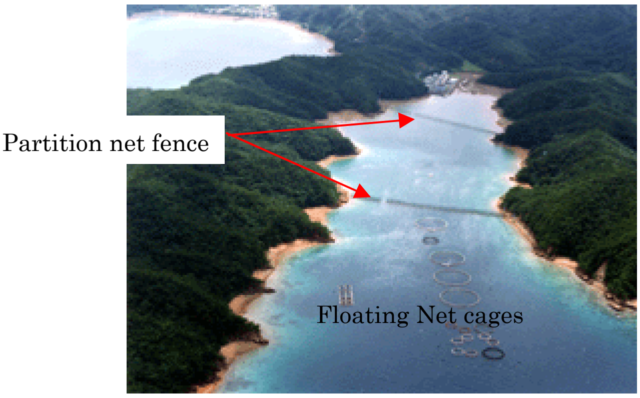
Weiland, M.A. and T. J. Carlson. 2003. Technologies for evaluating fish passage through turbines. PNNL-14437, Pacific Northwest National Laboratory, Richland, WA

Table 1. Technical specifications of the DIDSON.

High-frequency mode	
Operating frequency	1.8MHz
Beam width (two-way)	0.3° horizontal by 14° vertical
Number of beams	96
Low-frequency mode	
Operating frequency	1.1MHz
Beam width (two-way)	0.6° horizontal by 14° vertical
No. of beams	48
Both modes	
Field-of-view	29°
Power consumption	30W typical
Weight in air	7.0 kg
Weight in water	minus 0.61 kg
Dimensions	171mm X 307mm X 206mm

Table 2. The transparency and turbidity of experiment sites at the Amami field station.

Site	transparency	turbidity at 0m	turbidity at 10m
Partitioned inlet	11m	1.6	0.5
40 m net cage	15m	0.8	0.3
10 m net cage	15m	NA	NA



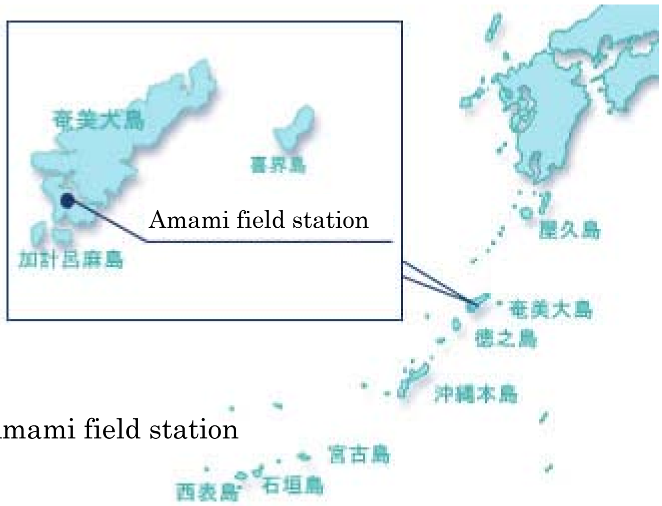


Figure 1. Location and raring facilities of Amami field station

Figure 2. Attaching the DIDSON to the plastics pipe (left), control computer and battery unit onboard support boat (right).

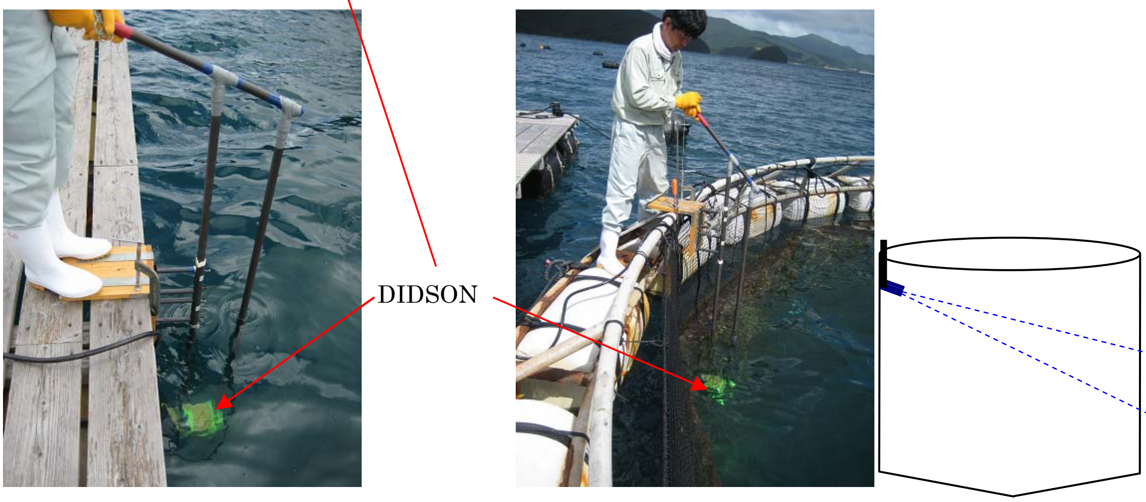


Figure 3. DIDSON setting for observation by using plastics pipes at partitioned inlet (left) and at floating net cage (middle). Schematic diagram of DIDSON arrangement was also shown (right).

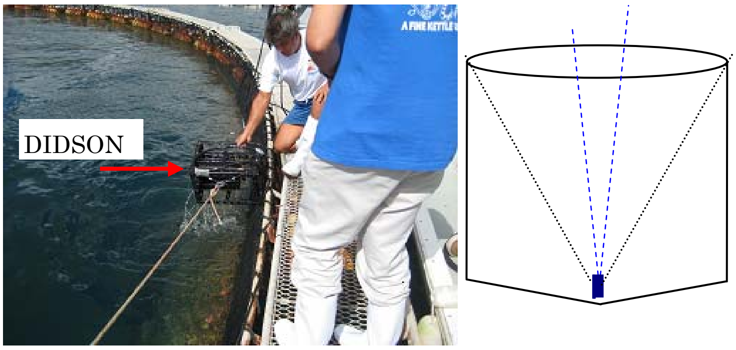
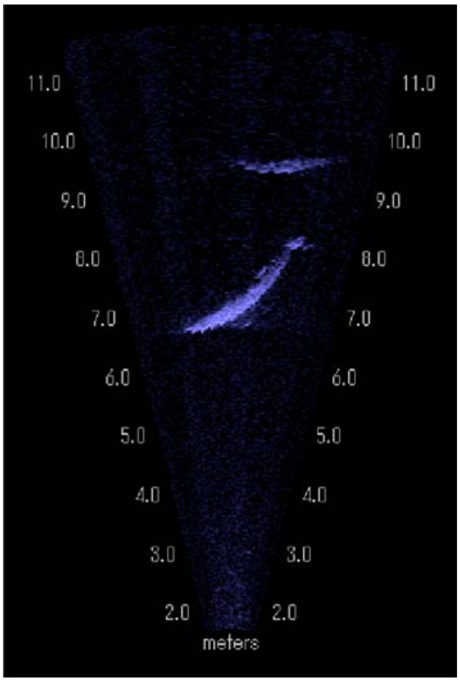


Figure 4. (left) DIDSON setting for observation by using two ropes and just start to sink. Schematic diagram of DIDSON arrangement was shown (right).



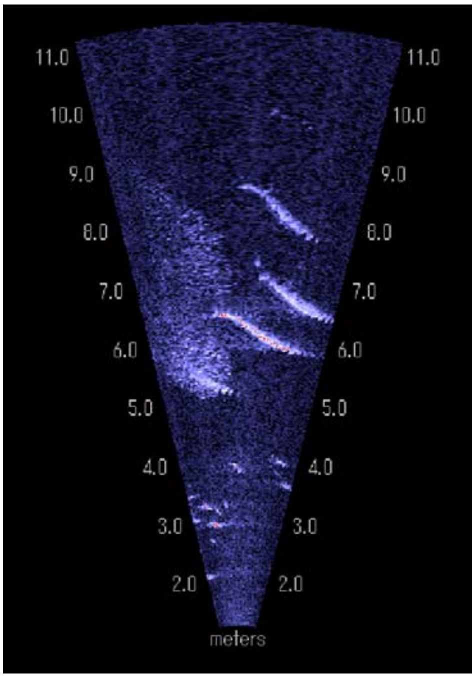
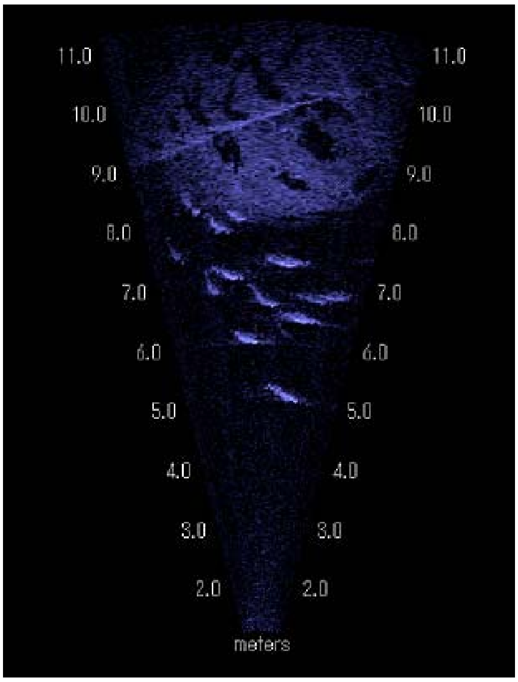


Figure 5. (left) PBT swimming across front of the camera setting at the partitioned inlet. Numerous beside indicate the distance from the camera to the object.

Figure 6. (right) PBT in 40m diameter net cage were seen at from 6 m to 9 m and there were smaller fish at around 3m distance.　Babbles with baits thrown in were observed the left side of the image around 6m distance.



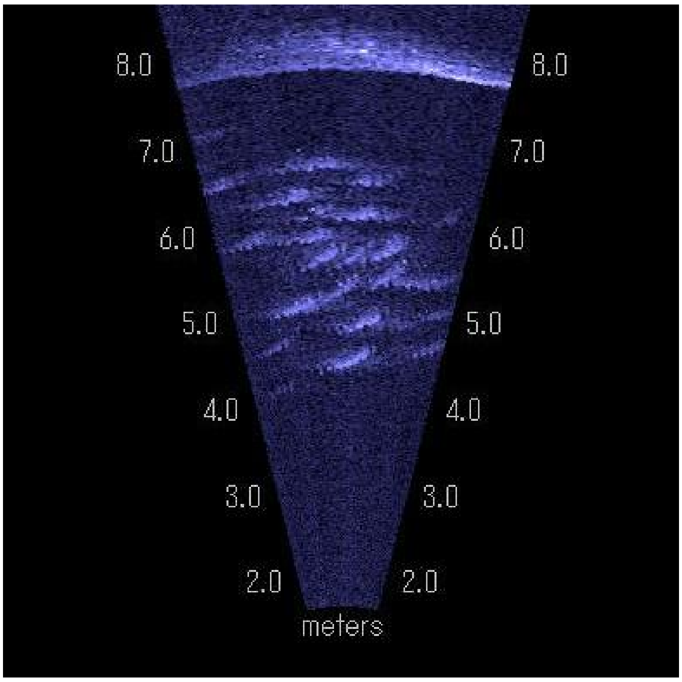
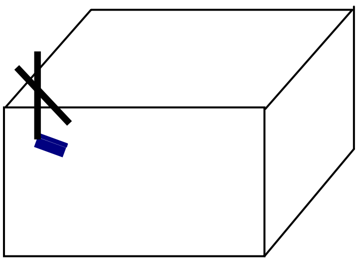


Figure 7. (left) PBT images and opposite side cage net with shadows of PBT seen foreground, in the 10m diameter net cage. PBT were seen at 5m – 8m, opposite net and shadows were from 8m to 11m.

Figure 8. (right) look up image from the bottom of the cage. PBT swam at the layers between 4 m and 7 m from the bottom. The surface was at about 8 m.



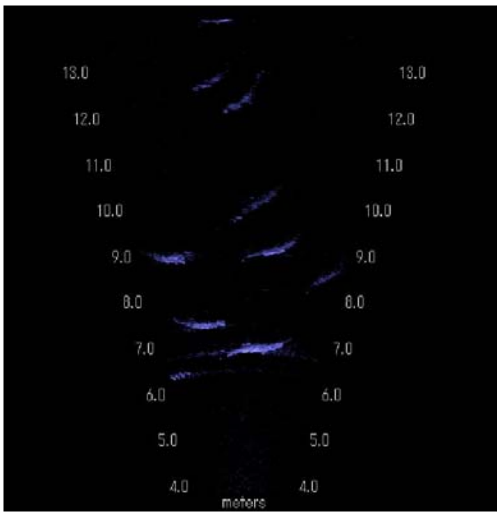
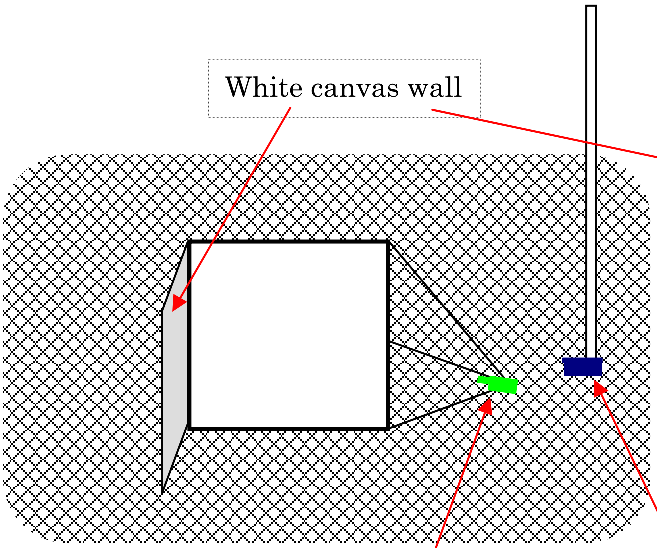


Figure 9. Schematic diagram of the DIDSON setting at the PBT farming industry's rectangle net cage.

Figure 10. PBT images in the 10m X 20m rectangle net cage.



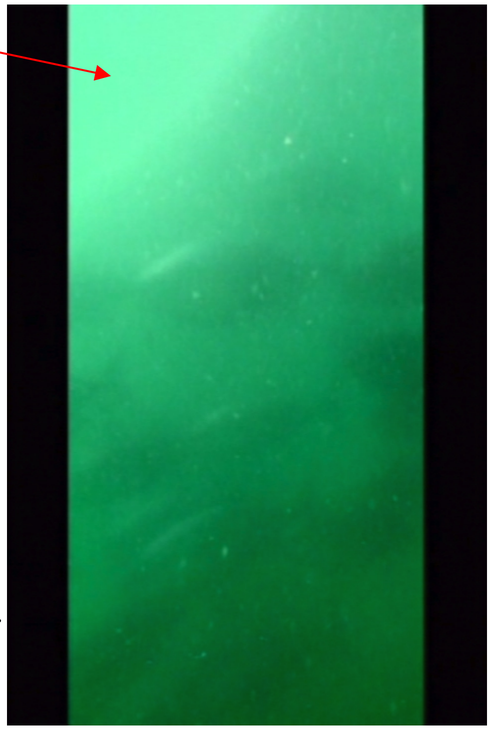


Figure 11. (left) Schematic diagram of equipment arrangement for observation of PBT in Mexican water farming site. Beside the 2.5m X 2.5m (approximately) transfer gate, optical video camera (green icon) was set forward the DIDSON (Blue icon). White canvas wall were set at the other side of cameras for the background of optical video camera.

Figure 12. (right) An image of the optical video camera with many PBT forward moving.

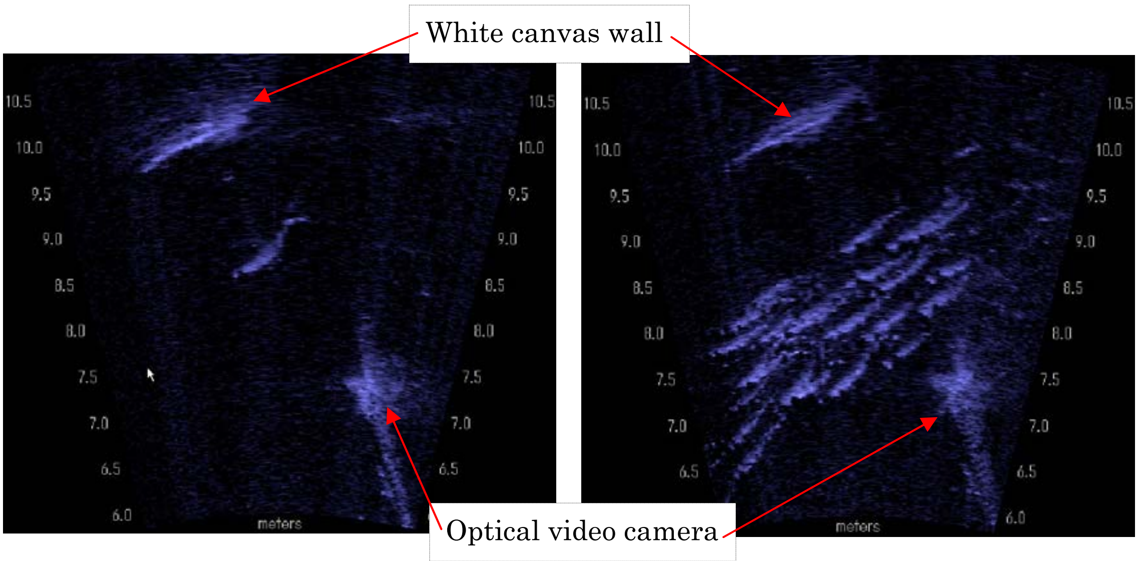


Figure 13. The DIDSON took one PBT passing the transfer gate, white canvas wall and the optical video camera set in front of the DIDSON.

Figure 14. PBT school were passing.

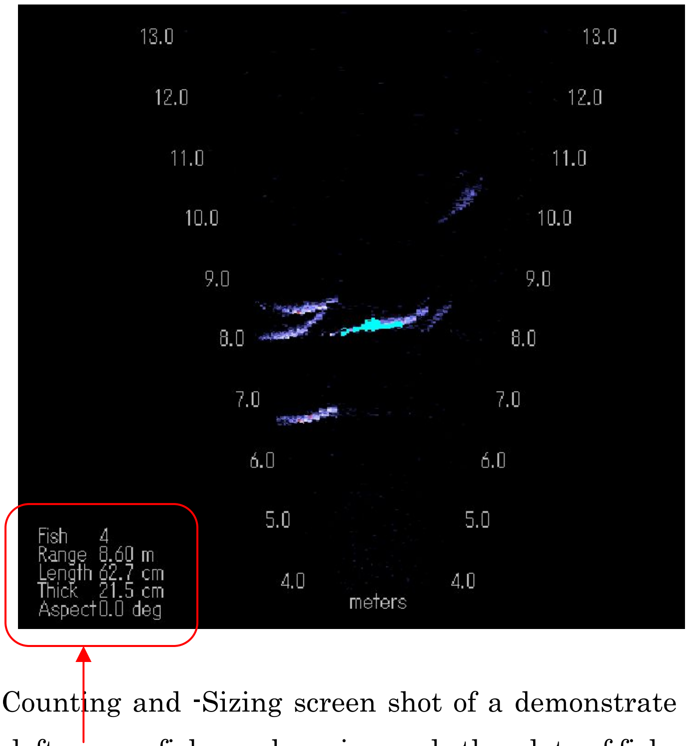


Figure 15. Auto-Counting and -Sizing screen shot of a demonstrate example. At the lower left corner, fish number, size, and other data of fish passing the field of vision.