音響カメラ(DIDSON)を用いて
トランスファー時に魚の体長を計測する手法の高度化

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Advance technique for measuring the length of fish during transfer by the acoustic camera (DIDSON) system

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1. 要旨

2 つの生簀間を移動する魚(平均全長: 83.1 cm)を音響カメラ(DIDSON)で観察することで，体長を計測した。音響カメラはトランスファーゲートに固定することで波浪による揺れが及ぼす悪影響を軽減した。記録されたデータは手動計測および新たに開発した自動計測プログラムにより解析した。音響カメラで計測された各トランスファーの平均全長と実際の平均全長の差は，手動計測では-3.0～0.3 cm (平均= -1.4 cm)，自動計測では-2.4～2.8 cm (平均= -0.4 cm)であった。音響カメラを適切に設置した上で，適切な計測プログラムを用いることで，自動計測で正確な計測ができた。2 台の音響カメラを同時に用いると，遊泳する魚の形状を立体的に把握することができ，より正確な全長および尾叉長の計測が可能であった。

1. Summary

Body length was measured by observing fishes (Mean total length: 83.1 cm) moving between two pontoons by acoustic camera (DISSON). Affection caused by shaking due to ocean waves was alleviated by securing the acoustic camera to transfer gate. The recorded data were analysed by manual measurement and newly developed automatic measurement program. Difference between mean total length of each transfer measured by acoustic camera and actual mean total length was 3.0 to 0.3 cm (Mean = -1.4 cm) in manual measurement, and -2.4 to 2.8 cm (Mean = -0.4 cm) in automatic measurement. Precise measurements could be made in automatic measurement by properly installing the acoustic camera and then using appropriate measurement programs. When two acoustic cameras were simultaneously used, it was possible to stereoscopically figure out shapes of swimming fishes and measure more precise total length and fork length.

2. はじめに

近年開発された音響カメラは，水中の照度や透明度に依存せずに超音波で対象物を観察できるため，河川を遡上する魚類の計数や体長計測，および海洋生物の行動や分布を調べるための手法として利用され始めている。マグロ類の養殖場においても，音響カメラを用いた魚体長の計測手法の適用が期待されている。しかし，生簀内の適切な機器の設置方法や観察方法は確立されていなかったので，正確に体長を計測することは困難であった。また，適切な自動計測プログラムもまだ開発されていなかったので，客観的かつ信頼性の高い値を自動計測で求めることも困難であった。そこで本実験では，音響カメラを生簀内に適切に取り付けて撮影し，手動計測手法および新たに開発した自動計測手法により正確な体長を求めることを目的とした。

2. Introduction

Recently developed acoustic camera can observe objectives with ultrasonic sound without depending on illuminance and transparency in water, therefore, begins to be used as approaches to count fishes running upstream in river and measure body length, and investigate behaviour and distribution of marine animals. In tuna farm, it is also expected to apply measurement technique for fish body length using acoustic camera. However, as appropriate equipment installing method in pontoon and observing method were not established, it was difficult to precisely measure body length. Further, as appropriate program was not also developed, it was difficult to derive objective and reliable values in automatic measurement. Therefore, this experiment aims to derive precise body length by properly installing acoustic camera in pontoon and taking images, further using manual measurement method and newly developed automatic measurement method.

3. 試料および方法

3.1. 音響カメラの概要

本実験で用いた音響カメラは，Sound Metric corp.の DIDSON (Dual-frequency IDentification SONar, Standard type, 大きさ: 20 cm×17 cm×30 cm)である(Fig. 1)。DIDSON は 1.1 MHz と 1.8 MHz の超音波を使い分けることができる。本実験では正確な体長計測が目的であるため，高精細な映像が得られる 1.8 MHz を使用した。1.8 MHz では幅 0.3° の超音波ビームを水平に 96 本並列に送波し，映像表示面(水平面)での視野角は 29° である。分解能は，DIDSON からの距離 5 m で約 3 cm である。映像表示面(水平面)に対し垂直方向の有効視野角は約 14° であり，この方向の分解能はない。

3. Materials and Methods

3.1. Overview of acoustic camera

The acoustic cameras used in this experiment are DIDSON (Dual-frequency IDentification SONar, Standard type, Size: 20 cm by 17 cm by 30 cm) (Fig. 1). The DIDSON can use ultrasonic sounds of 1.1 MHz and 1.8 MHz individually. This experiment was intended for precise body length measurement, therefore, used 1.8 MHz which can obtain high definition images. At 1.8 MHz, 96 ultrasonic sound beams of width 0.3 degree were horizontally transmitted in parallel, and the field of view on image display surface (horizontal surface) was 29 degree. The resolution was approximately 3 cm at a distance 5 m from the DIDSON. The effective view angle in a direction perpendicular to the image display surface (horizontal surface) was approximately 14 degree, and there’s no resolution in this direction.

3.2. 実験場所

実験は，独立行政法人水産総合研究センター五島栽培漁業センター(長崎県五島市)の海上施設でおこなった。実験には正方形の生簀(大きさ: 5 m×5 m)が 2 個連なった施設を用いた(Fig. 2)。 2 つの生簀は深度約 3 m の位置で 2 個の正方形のトランスファーゲート(大きさ: 1 m×1 m)により連結されている。

3.2. Experiment site

The experiment was conducted at the marine facility in Goto station, National Center for Stock Enhancement, Fisheries Research Agency (Goto-City in Nagasaki-Prefecture). The experiment used a facility in which two square pontoons (size: 5 m by 5 m) were connected (Fig. 2). The two pontoons were connected at a position of approximately 3 m deep by two square transfer gates (size: 1 m by 1 m).

3.3. 体長計測用音響カメラの設置

トランスファーゲートと音響カメラの相対的な位置が波浪やうねりの影響で変化して，トランスファーゲートが観察範囲内から外れたり，画像が揺れ動いたりすることを防ぐために，魚の体長計測に用いた音響カメラ(DIDSON_A, Horizontal)は鉄製ポール(長さ:4.3 m, 直径:28 mm)を用いてトランスファーゲートに直接取り付けた(Fig. 3)。DIDSON_A はトランスファーゲートと同深度に固定し，観察面を水平方向にして，トランスファーゲートを通過する魚を側方から観察した(Fig. 2)。DIDSON_A の取り付けに要した時間は，ダイバー1 名と海上からの補助者 2 名の作業で約 10 分間であった。取り外しには同じく 3 名で約 5 分間を要した。音響カメラは水中ケーブルによりボート上のラップトップ PC および DC12 V バッテリ(AC100V インバータを経由)に接続し，映像データを PC 内蔵の HDD に記録した。

3.3. Installation of acoustic camera for measurement of body length

The acoustic camera (DIDSON_A, Horizontal) used for measurement of fish body length was directly installed to the transfer gate using an iron pole (length: 4.3 m, diameter: 28 mm) in order to prevent the transfer gate from deviating out of the observing range or prevent image from shaking due to change in relative position of the transfer gate and acoustic camera by influence of waves or swells (Fig. 3). The DIDSON_A was fixed at the same depth as that of the transfer gate, and the observing surface was directed in horizontal direction, then fishes passing through the transfer gate were observed from the side (Fig. 2). Time required to install the DIDSON_A was approximately ten minutes by an operation of one diver and two assistants on the sea. The removal took approximately five minutes by the same three parsons. The acoustic camera connected to a laptop PC and DC12 V battery on a boat through an underwater cable (via AC100V inverter), and the image data were recorded in a PC built-in HDD.

3.4. 遊泳姿勢と尾部形状の観察

観察面を水平方向にした音響カメラでは，魚が鉛直方向に傾いて遊泳する場合に体長を過小に計測する懸念がある。また，魚体映像は水平面で見た形状の映像として記録されるため，側面から見た尾部の形状を視認できない。そこで，観察の一部では DIDSON_A と同時にもう一台の音響カメラ(DIDSON_B, Vertical)を使用することで，魚の遊泳姿勢と尾部形状の観察を試みた。DIDSON_B は，鉄製ポール(長さ: 2.5 m, 直径:28 mm)を用いて生簀の外枠に取り付けた(Fig. 2)。DIDSON_B はトランスファーゲートとほぼ同深度に固定し，観察面を鉛直方向にして，トランスファーゲートを通過する魚を正面から観察した(Fig. 2)。

3.4. Observation of swimming posture and tail shape

There is a concern that an acoustic camera of which observing surface is directed in horizontal direction measures body length to be excessively small when fish inclines in vertical direction and swims. In addition, image of fish body is recorded as an image of shape viewed on horizontal surface, therefore, tail shape cannot be visually recognized. Thus, in a part of the observation, observation of swimming posture and tail shape of fish was attempted by simultaneously using the DIDSON_A and the other one acoustic camera (DIDSON_B, Vertical). The DIDSON_B was installed to the outer frame of the pontoon using an iron pole (length: 2.5 m, diameter: 28 mm) (Fig. 2). The DIDSON_B was fixed at the nearly same depth as that of the transfer gate, and the observing surface was directed in vertical direction, then fishes passing through the transfer gate were observed from the front (Fig. 2).

3.5. 供試魚

あらかじめ体長を直接計測した全 18 尾のブリ *Seriola quinqueradiata* (全長: 75.0～90.0 cm, 尾叉長: 69.0～84.0 cm)を，繰り返し一方の生簀から他方の生簀まで移動させて，その間にトランスファーゲートを通過する魚を音響カメラで観察した。18 尾中 9 尾の尾部にはそれぞれ色分けをした ID タグ(幅: 3 cm，長さ: 約 50 cm)を装着して，生簀内に設置した水中ビデオカメラ(Sony, HC3)を用いて音響カメラと同時に観察することにより，個体識別をした。ID タグは，音響カメラの映像で尾鰭と容易に区別できるように，尾鰭との間隔が約 50 cm ほど空くようにして細い糸で結んだ(Fig. 4)。

3.5. Sample fish

Total 18 Yellowtail, *Seriola quinqueradiata*, (Total length: 75.0 to 90.0 cm, Folk length: 69.0 to 84.0 cm) whose body lengths were directly measured in advance were repeatedly moved from one pontoon to the other pontoon, and fishes passing through the transfer gate were observed with the acoustic camera during this period. Respectively colour coded ID tags (width: 3 cm, length: approximately 50 cm) were attached on tails of 9 fishes among the 18 fishes, and the individuals were observed by using an underwater camera (Sony, HC3) installed in the pontoon and simultaneously observing with the acoustic camera. The ID tags were connected with thin strings with a space between caudal fin and the ID tag of approximately 50 cm kept so that the ID tags can be easily distinguished from caudal fin with image of the acoustic camera (Fig. 4).

3.6. 実験日時

実験は 2008 年 7 月 1 日から 7 月 2 日におこなった。観測時間を Table 1 に示す。計 4 回のトランスファーを完遂した。その他に，ID タグを識別することで個体毎の体長を計測するためだけの観測を数回実施した。一部の観測では DIDSON_A と DIDSON_B の 2 台を同時に使用した。

3.6. Date and time of experiment

The experiment was conducted from July 1 to July 2, 2008. The observed time is shown in Table 1. Total four transfers were completed. Further, some observations only for measurement of body length per individual were made through identifying the ID tags. In some of the observations, two of the DIDSON_A and DIDSON_B were simultaneously used.

Table 1. Transfer numbers and observed time by the DIDSON measurements.

Transfer number	Date	Transfer Gate Open	Transfer Gate Close	DIDSON_A (Horizontal)	DIDSON_B (Vertical)
T1	7/1	13:49:45	13:51:15	○	-
T2	7/2	10:56:00	11:01:35	○	-
T3	7/2	13:11:48	13:17:10	○	○
T4	7/2	14:17:30	14:22:40	○	○

3.7. 体長の計測方法

全観測終了後に，手動および自動計測手法を用いて個体毎に体長を計測した。

3.7. How to measure body length

After all observations were completed, body lengths per individual were measured using manual and automated measurement methods.

3.7.1. 手動計測

手動計測には，DIDSON 専用のデータ処理ソフトウェア(DIDSON Control and Display ver. 5.14)に搭載されている”Mark Fish”ツールを用いた。DIDSON_A で撮影された魚は，水平面上を遊泳する映像としてモニタ上に投影される。この映像をマウスカーソルでトレースすることで魚の全長が計測される(Fig. 5)。魚体が横方向に湾曲していても全長を計測できるため，魚体が直線状に伸びきったフレームを選択して計測する必要はない。ただし，魚体が水平ではなく鉛直方向に傾いていた場合には，実際よりも全長が過小に表示される可能性がある。この誤差を小さくするために，同一個体がモニタ上に表示されている間は可能な限り多くの計測を繰り返し，最も大きく計測された値をその個体の全長として適用した。計測は 2 名の独立した観測者(Technician A, Technician B)がおこない，計測に要した時間はトランスファー1 回あたり約 8 時間であった。

3.7.1. Manual measurement

“Mark Fish” tool installed in the data processing software (DIDSON Control and Display ver. 5.14) only for DIDSON was used for manual measurement. Fishes recorded by the DIDSON_A are projected on a monitor as images swimming on a horizontal surface. Total length of fish is measured by tracing these images with mouse cursor (Fig. 5). Total length can be measured even if fish body is laterally bent, therefore, it is unnecessary to measure by selecting a frame in which fish body is linearly stretched out. However, it is possible that body length is displayed to be excessively smaller than the real body length if fish body is inclined in vertical direction, not in horizontal direction. In order to decrease this error, as many measurements as possible were repeated while the same individual is displayed on the monitor, and the largest measured value was applied as a total length of the individual. Two independent observers (Technician A, Technician B) made measurements, and time required for measurement was approximately 8 hours per one transfer.

3.7.2. 自動計測

DIDSON Control and Display ver. 5.14 には魚体長の自動計測プログラムが搭載されている。しかし，生簀間を移動する魚の体長を計測するための専用プログラムではないため，波浪やうねりの影響で音響カメラやトランスファーゲートや網地などが動揺するとノイズが増えて誤検出が多くなり，正確な計測が困難となる。そこで，生簀間を移動する魚の体長計測に特化した自動計測プログラムを新たに開発した(Fig. 6)。このプログラムは，任意に設定した閾値や対象魚の移動方向，形状をもとに魚体映像を検出して，自動的に体長を計測する。対象魚以外の物体が動揺しても映像から除去することができ，映像中の細かいノイズの除去能力も優れている。この自動計測プログラムを用いて，手動計測と同様に DIDSON_A で撮影された魚の全長を計測した。解析に要した時間は，トランスファー1 回あたり約 1 時間 であった(通常の Windows PC を使用)。

3.7.2. Automated measurement

An automatic measurement program for fish body length is installed in DIDSON Control and Display ver. 5.14. But it is not a dedicated program to measure body length of fish moving between the pontoons, therefore, noise increases and erroneous detection increases when acoustic camera, transfer gate and net shake by influence of waves or swells, then accurate measurement becomes difficult. Thus, we have newly developed an automatic measurement program especially for measuring body length of fish moving between the pontoons (Fig. 6). This program detects image of fish body based on arbitrarily set threshold, moving direction and shape of objective fish, and automatically measures body length. This program can remove any object other than objective fish which shakes from images, and is excellent in removing fine noise in images. Similarly to the manual measurement, total length of fish recorded by the DIDSON_A was measured using this automatic measurement program. Time required for analysis was approximately one hour per one transfer (using general Windows PC).

3.7.3. 遊泳姿勢による全長補正および尾叉長の計測

DIDSON_A では水平面上の映像が表示されるため，尾部の側面形状を視認できない。したがって，計測した体長は尾叉長(Fork length)ではなく全長(Total length)となる。一方，DIDSON_B では，通過する魚を側面から見た形状として表示できる。そこで，一部の観測では，DIDSON_B の映像上で魚の遊泳姿勢(鉛直方向の傾き)を個体毎に計測して，同時に DIDSON_A で観察された個体の全長補正を試みた(Fig. 7)。また，DIDSON_B では尾部の形状も視認できることから(Fig. 7)，DIDSON_B で求められた見かけ上の全長と尾叉長の比率を，遊泳姿勢をもとに補正された全長に乗じることで，個体毎の尾叉長の計測を試みた。

3.7.3. Correction of total length by swimming posture and measurement of fork length

The DIDSON_A displays images on horizontal surface, therefore, cannot visually recognize side shape of caudal portion. Accordingly, the measured body length is total length not fork length. On the other hand, the DIDSON_B can display passing fish as a shape viewed from the side. Thus, in some observations, swimming angle (inclination in vertical direction) of fishes were measured individually on image of the DIDSON_B, and at the same time, total length of the individuals observed by the DIDSON_A were attempt to be corrected (Fig. 7). And, since the DIDSON_B can also visually recognize tail shape (Fig. 7), fork length of fishes were attempted to be measured individually by multiplying total length corrected based on swimming angle by ratio of apparent total length and fork length obtained by the DIDSON_B.

4. 結果

4.1. トランスファー毎の全長組成

Table 2 および Fig. 8 に各トランスファーで計測された魚の全長を示す。ここで示した音響カメラで計測した全長は，トランスファーゲートを順方向に通過 (元の生簀から音響カメラを設置した生簀へ移動) した個体の全長のみである。順方向と逆方向の通過を何度も繰り返した個体もあったことから，複数の個体を重複した計測した場合も含まれる。

各トランスファーにおいて手動計測手法で計測された全長の平均値の，実際の全長の平均値からの差は，Technician A で，-2.1～0.3 cm (平均= -0.6 cm, S.D. = 1.0 cm), Technician B で，-3.0～-1.7 cm (平均= -2.1 cm, S.D. = 0.6 cm)であった。自動計測手法で計測された全長の平均値の，実際の全長の平均値からの差は，-2.4～2.8 cm (平均= -0.4 cm, S.D. = 2.3 cm)であった。手動計測と自動計測の結果に大差はなかった。

4. Results

4.1. Composition of total length per transfer

Table 2 and Fig. 8 show total length of fish measured in each transfer. Total length measured by the acoustic camera shown here are only total length of individual which passed through the transfer gate in forward direction (moving from a pontoon to the other pontoon in which the acoustic camera was installed). There were some fishes which passed in forward and reverse directions, and then some individuals were repeatedly measured.
Difference between mean total length measured by manual measurement in each transfer and mean value of the actual total length was -2.1 to 0.3 cm (Mean = -0.6 cm, S.D. = 1.0 cm) by Technician A, and -3.0 to -1.7 cm (Mean = -2.1 cm, S.D. = 0.6 cm) by Technician B. Difference between mean value of total length measured by automated measurement and mean value of actual total length was -2.4 to 2.8 cm (Mean = -0.4 cm, S.D. = 2.3 cm). There was not much difference between the results of manual measurement and automated measurement.

Table 2. Mean (±S.D.), minimum and maximum Total length measurements per transfer. Manual measurements (Technician A, Technician B) and Automated measurements.

Transfer number	**Actual total length**				**Manual measurements** Technisian A				Technisian B				**Automated measurements**			
	Mean (cm)	±S.D. (cm)	Min. (cm)	Max. (cm)	Mean (cm)	±S.D. (cm)	Min. (cm)	Max. (cm)	Mean (cm)	±S.D. (cm)	Min. (cm)	Max. (cm)	Mean (cm)	±S.D. (cm)	Min. (cm)	Max. (cm)
T1	83.1	4.0	75.0	90.0	85.1	6.6	72.6	95.5	85.2	4.8	77.5	94.8	85.5	5.3	78.9	94.4
T2	83.1	4.0	75.0	90.0	82.8	5.5	70.0	93.5	84.8	4.8	69.5	92.4	84.7	4.3	74.9	92.0
T3	83.1	4.0	75.0	90.0	83.1	5.5	72.6	94.0	84.7	4.4	74.1	93.0	83.3	4.6	74.0	90.9
T4	83.1	4.0	75.0	90.0	83.6	6.3	58.2	98.6	86.1	4.4	75.6	95.3	80.3	4.7	72.3	89.7

4.2. 個体毎の全長の比較

水中ビデオカメラの映像で個体識別ができ，同時に音響カメラの手動計測および自動計測で魚に ID タグが付いていることが確認できた個体について，計測された全長と実際の全長を比較した (Table 3, Fig. 9)。音響カメラで計測された各個体の全長の，実際の全長からの差は，Technician A で，-7.8～-0.2 cm (平均= -5.2 cm, S.D. = 3.4 cm), Technician B で，-7.8～3.2 cm (平均= -1.8 cm, S.D. = 3.7 cm)，自動計測で，-0.9～5.9 cm (平均= -1.3 cm, S.D. = 4.0 cm)であった。手動計測と自動計測の結果に大差はなかった。

4.2. Comparison of total length per individual

For individuals which could be identified by image from underwater video camera and on which attaching the ID tag on fish could be simultaneously confirmed by manual measurement and automated measurement of the acoustic camera, the measured total length was compared with the actual total length (Table 3, Fig. 9). Difference between total length of each individual measured by the acoustic camera and the actual total length was -7.8 to -0.2 cm (Mean = -5.2 cm, S.D. = 3.4 cm) by Technician A, and -7.8 to 3.2 cm (Mean = -1.8 cm, S.D. = 3.7 cm) by Technician B, and in automated measurement, -0.9 to 5.9 cm (Mean = -1.3 cm, S.D. = 4.0 cm). There was not much difference between the results of manual measurement and automated measurement.

Table 3. Measured total length in the same individuals. Actual total length, Manual measurements, Automated measurements.

Transfer number	Individual number	Actual total length (cm)	Manual measurements Technisian A (cm)	Technisian B (cm)	Automated measurements (cm)
T3	ID4	88.0	93.0	-	88.6
T3	ID3	82.0	83.8	-	87.5
T6	ID8	85.2	92.1	86.0	87.9
T6	ID3	82.0	91.9	-	88.2
T6	ID3	82.0	-	84.3	88.0
T6	ID5	90.0	-	87.5	87.9
T7	ID7	80.0	80.2	83.3	84.3
T7	ID8	85.2	93.0	93.0	86.1
T11	ID3	82.0	-	82.8	79.8
T11	ID9	87.0	-	83.8	81.1
T11	ID8	85.2	89.9	90.4	83.6

4.3. 遊泳姿勢により補正された全長および計算で求められた尾叉長

DIDSON_A と DIDSON_B で同時に観察ができ，水中ビデオカメラで個体識別ができた魚を 1 個体ずつ選び，遊泳姿勢により補正された全長および計算で求められた尾叉長と，実際の体長を比較した。補正された全長の，実際の全長からの差は，-3.1〜2.3 cm (平均= -0.4 cm, S.D.= 1.5 cm)であった。計算で求められた尾叉長の，実際の尾叉長からの差は，-2.7〜2.9 cm (平均= -0.1 cm, S.D.= 1.7 cm)であり，計算で求められた尾叉長と実際の尾叉長に大差はなかった(Fig. 10)。

4.3. Total length corrected by swimming angle and fork length derived by calculation

Fishes which could be simultaneously observed by the DIDSON_A and DIDSON_B and could be identified by the underwater video camera were selected individually, and total length corrected by swimming angle and fork length derived by calculation were compared with the actual body length. Difference between the corrected total length and the actual total length was -3.1 to 2.3 cm (Mean = -0.4 cm, S.D. = 1.5 cm). Difference between the fork length derived by calculation and the actual fork length was -2.7 to 2.9 cm (Mean = -0.1 cm, S.D. = 1.7 cm). There was not much difference between the fork length derived by calculation and the actual fork length (Fig. 10).

5. おわりに

一般に自動計測手法は手動計測手法よりも計測精度が低いものの，計測に労力を要さないうえに，測定者によるバイアスがかからないという利点がある。本実験により，音響カメラを適切に設置して，適切な計測プログラムを用いることで，自動計測手法の計測精度が手動計測の精度にかなり近づくことがわかった。ただし，本実験で用いた自動計測プログラムは，まだ開発途上であるので，一部に手動作業を要する。現在，計測に要する時間の短縮を目的として完全な自動化や，より正確な計測を可能とするためのプログラムの改良が進められている。

また，2 台の音響カメラを同時に用いた 3D 計測により，さらに正確な体長計測が可能であることも示された。現在，3D 計測は手動計測のみにより可能であるが，自動計測プログラムの開発も進められていることから，今後の利用が期待される(Fig.11)。

本実験のように，音響カメラをトランスファーゲートに直接取り付けることが可能であれば，安定した映像を得ることができる。なお，本実験で用いた DIDSON は鉛直方向の視野角は約 14°であったので，高さ 1 m のトランスファーゲートが観察範囲に入るためには約 4 m の距離が必要であった。ただし，DIDSON の視野角を 2 倍に広げる広角レンズが 2008 年に新たに発売されたため(www.soundmetrics.com)，今後は DIDSON からトランスファーゲートまでの距離を半分に縮めることも可能である。

5. Conclusion

In general, automated measurement has lower accuracy than manual measurement, however, does not require labor for measurement, and further has an advantage that there is no bias by measurer. This experiment showed that measurement accuracy of automated measurement is brought closer to accuracy of manual measurement by properly installing acoustic camera and using proper measurement program. However, since the automated measurement program used in this experiment is still in the process of development, it partly requires manual operation. At present, the program is being improved in order to allow complete automation and more accurate measurement for the purpose of reduction in time required for measurement.

It has been shown that more accurate body length measurement is allowed by 3D measurement simultaneously using two acoustic cameras. 3D measurement is presently allowed by manual measurement only, however, automatic measurement program is also being developed, and then it is expected to be used in the future (Fig. 11).

If it is possible to directly install acoustic camera to transfer gate as shown in this experiment, stable images can be obtained. Meanwhile, the DIDSON used in this experiment had field of view of approximately 14 degree in vertical direction, therefore, a distance of approximately 4 m was required in order that the transfer gate of 1 m high was within the observing range. However, a wide-angle lens which broadens the field of view for the DIDSON to two times was newly sold in 2008 (www. soundmetrics. com), therefore, it will be also possible to reduce the distance from the DIDSON to the transfer gate by half.

Figures

Fig. 1. Acoustic camera "DIDSON"

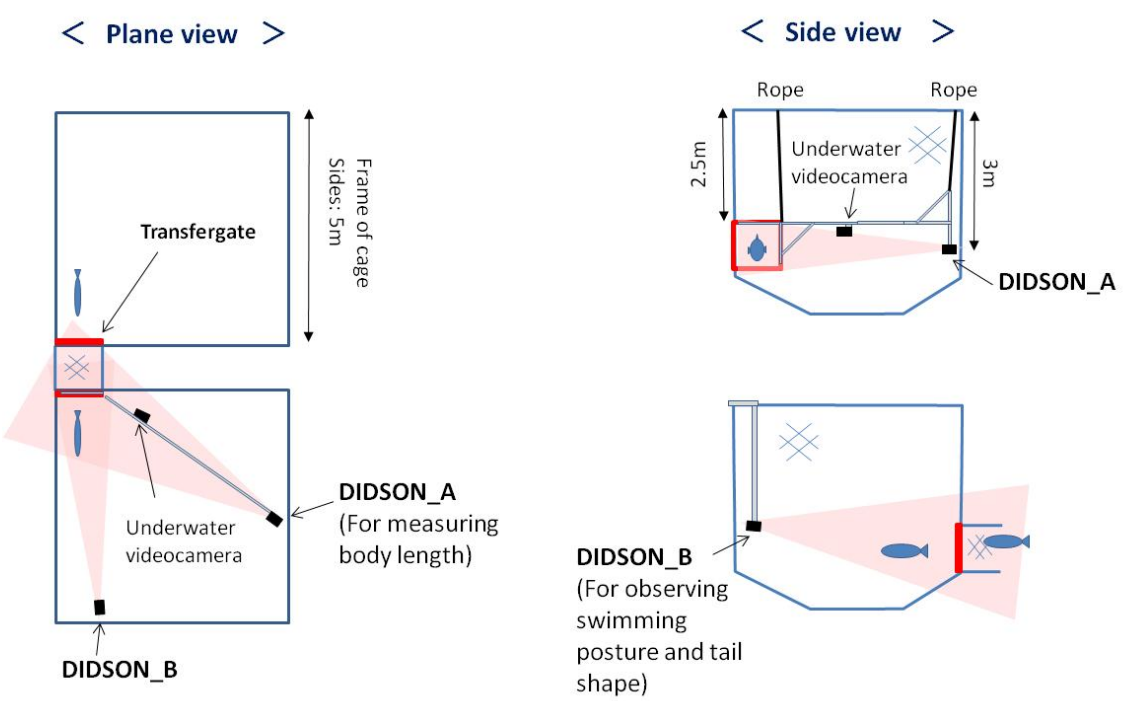

Fig. 2. Fixture of the DIDSON system in the pontoon. Left: Plane view, Right: Side view.

Fig. 3. DIDSON_A and mounting pole.

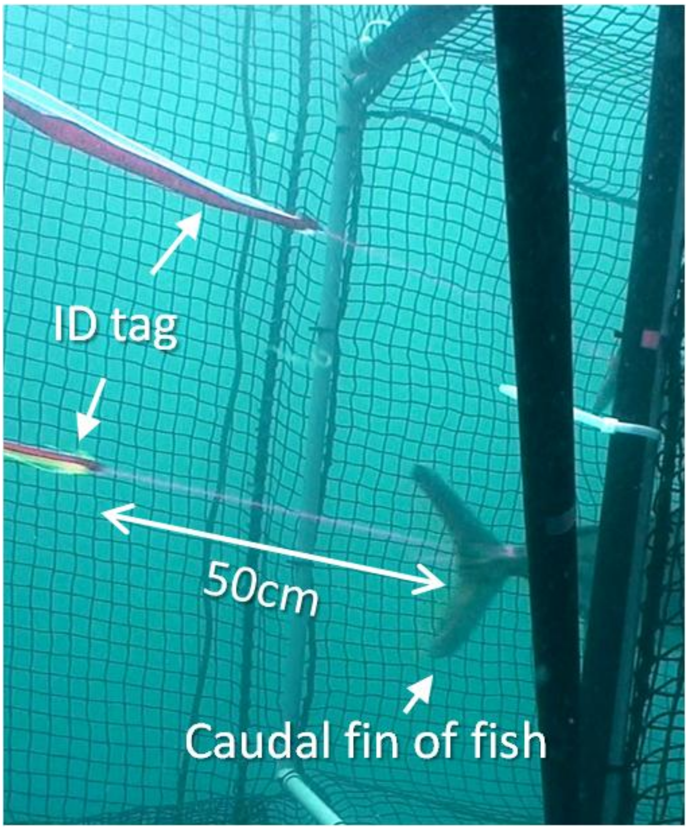

Fig. 4. ID tag attached on caudal fin of the fish.

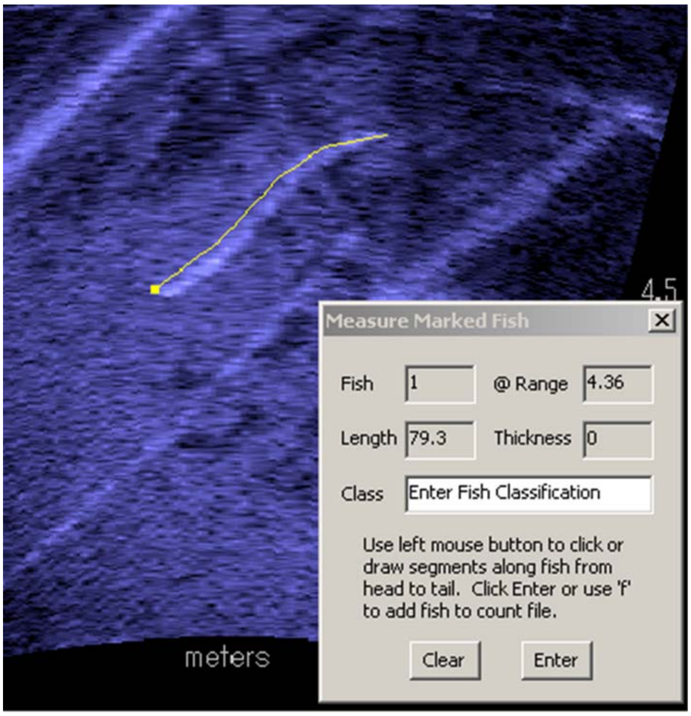

Fig. 5. Manual measurement of a YELLOWTAIL from sonar footage using DIDSON Control and Display (DIDSON_A, Horizontal).

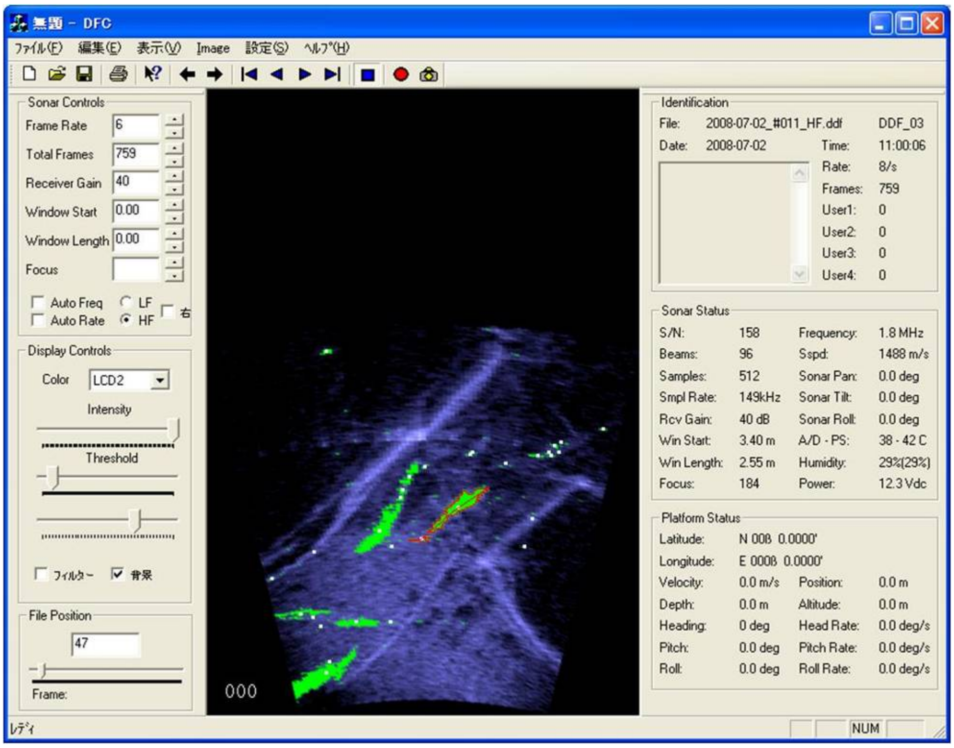

Fig. 6. Image of the automatic YELLOWTAIL measurements process by new automatic analysis program (DIDSON_A, Horizontal).

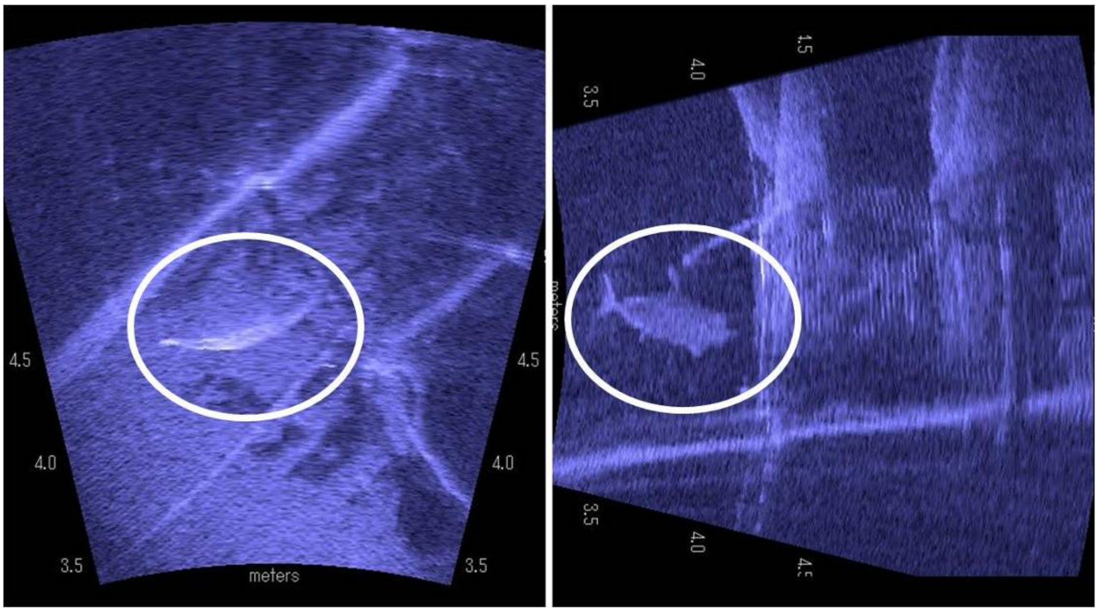

Fig. 7. Image of the same individual fish recorded by DIDSON_A (horizontal) and DIDSON_B (vertical) at the same time.

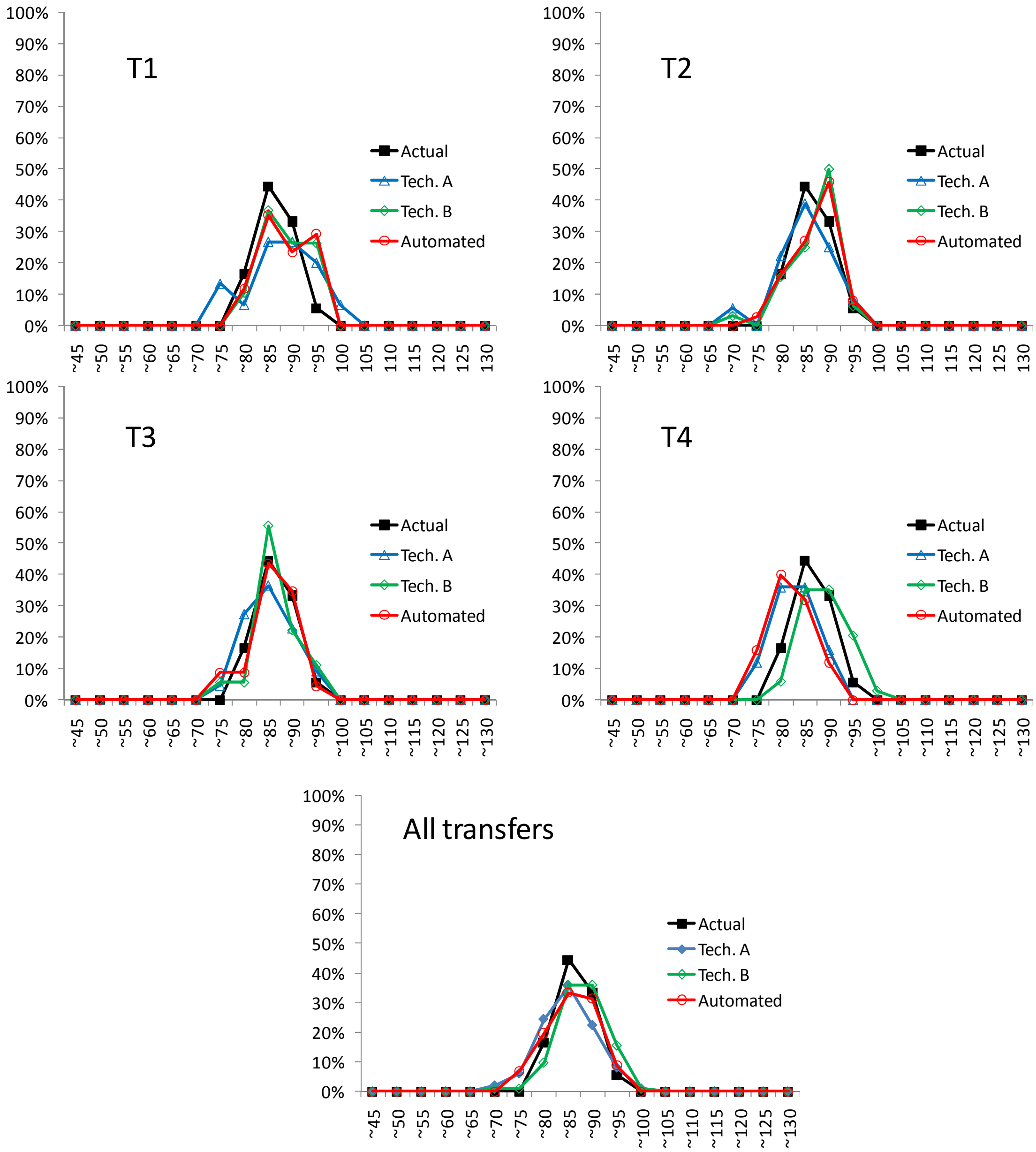

Fig. 8. Total length frequency histograms of fishes measured by manual measurements (Technician A and B) and automated measurements. X-axis: Total length (cm, 5 cm length classes), Y-axis: frequency (by percentage).

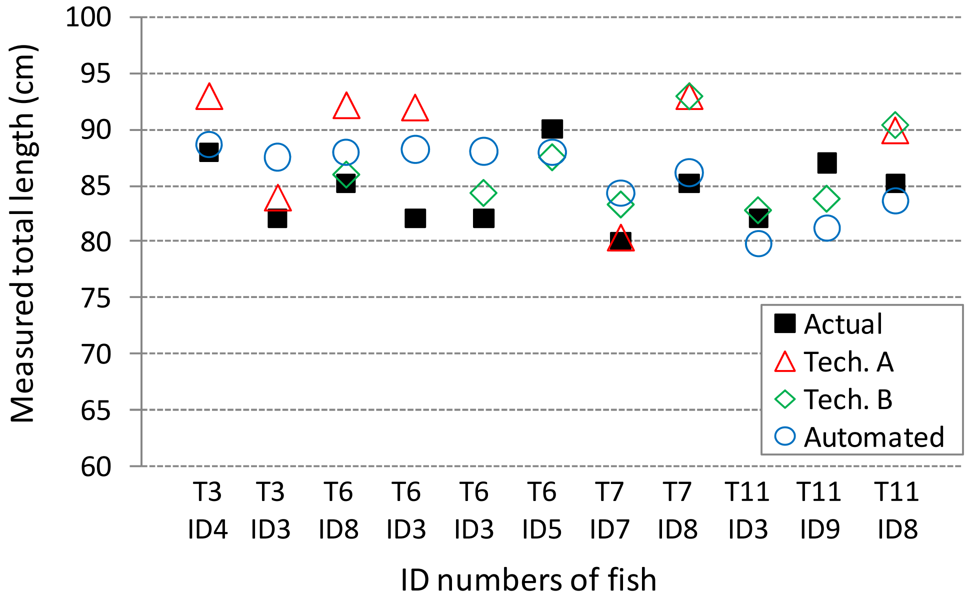

Fig. 9. Measured total length in the same individuals. Actual total length, Manual measurements, Automated measurements.

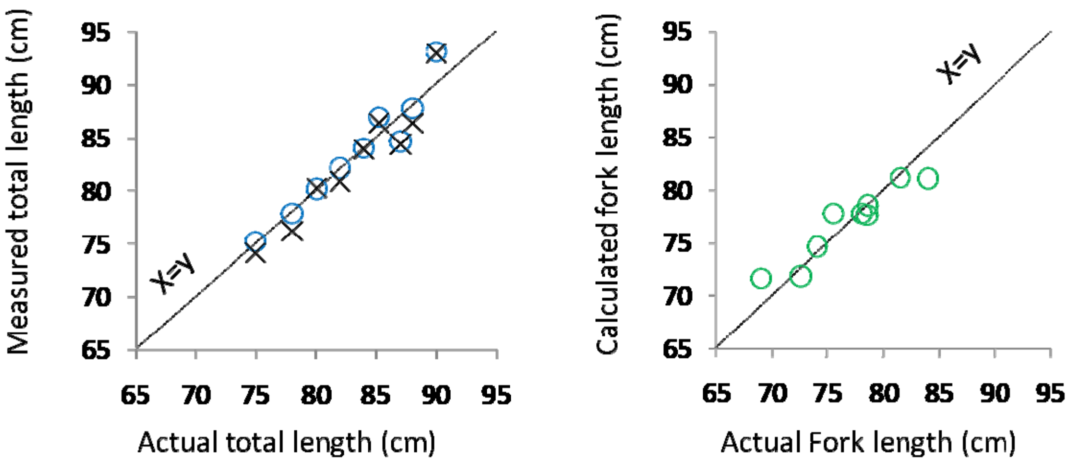

Fig.10. Left graph: Correlation between the actual total length and the total length of before corrected (black crosses), after corrected (blue circles). Right graph: Correlation between the actual fork length and the calculated fork length (green circles).

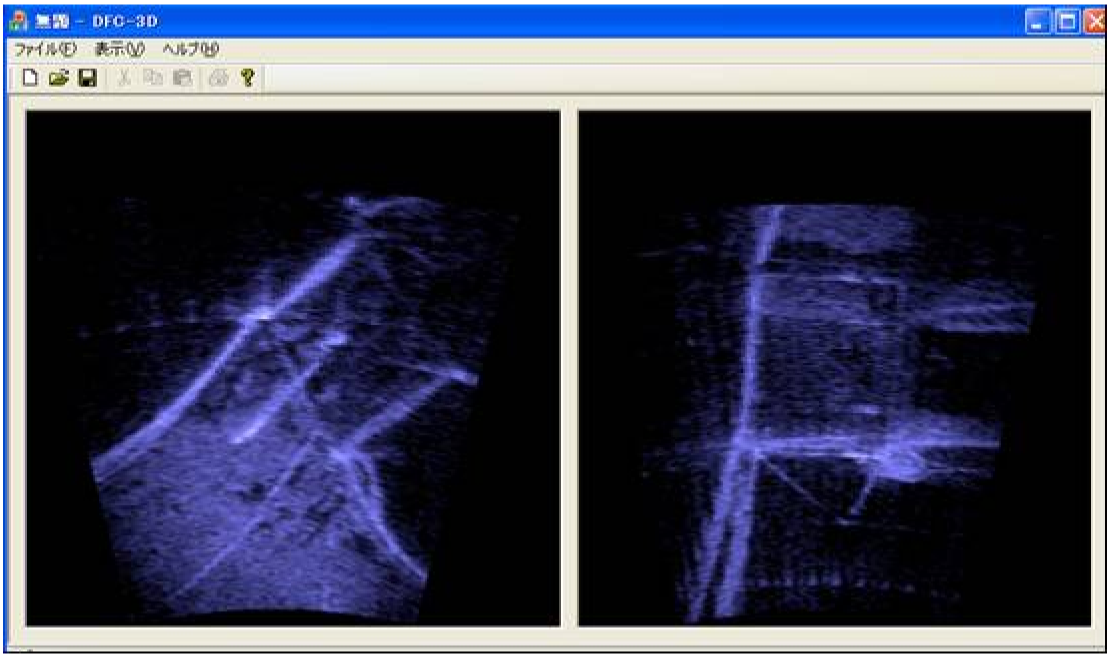

Fig.11. The image of new 3D analysis program which is under development. Two movie files are observed simultaneously, and composed 3D animation automatically.