Aquaculture 434 (2014) 184–187

Contents lists available at ScienceDirect

Aquaculture

journal homepage: www.elsevier.com/locate/aqua-online

Short communication

Measurement of swimming pattern and body length of cultured Chinese sturgeon by use of imaging sonar

Hui Zhang [a], Qiwei Wei [a,*], Myounghee Kang [b,**]

[a] Key Laboratory of Freshwater Biodiversity Conservation, Ministry of Agriculture of China, Yangtze River Fisheries Research Institute, Chinese Academy of Fishery Sciences, No. 8, 1st Wudayuan Road, Donghu Hi-tech Development Zone, Wuhan, Hubei Province, 430223, PR China

[b] Department of Maritime Police and Production System/The Institute of Marine Industry, Gyeongsang National University, Cheondaegukchi-Gil 38, Tongyeong-si, Gyeongsangnam-do 650-160, South Korea

ARTICLE INFO

Article history:
Received 14 January 2014
Received in revised form 13 June 2014
Accepted 15 August 2014
Available online 23 August 2014

Keywords:
Acoustic camera
Farmed fish
Fish sizing
Swimming pattern
Acipenser sinensis

ABSTRACT

Measurement of fish length and assessment of behavior are important to fish farming, but it can be a practical challenge. In this study, an acoustic camera (Dual-frequency Identification Sonar, DIDSON) was used to observe the swimming pattern of 10 cultured Chinese sturgeon (*Acipenser sinensis*) in a net cage, and to estimate their length. In total, 2743 targets were identified from DIDSON data collected over 12 h. Target tracking indicated that most fish swam close to the net in a circular motion, at mean speed of 0.7 ± 0.3 m s^{-1}. The length (95.2 ± 25.0 cm) of the targets measured through the DIDSON was 35.6% shorter than the total length from manual measurements (147.9 ± 9.3 cm), although the maximum lengths found by both methods were similar. Swimming pattern had a considerable influence on the accuracy of target length estimation. Accordingly, it was essential to select the targets based on swimming behavior to achieve more accurate length estimates. This study proposes that the acoustic camera is a valuable tool for investigating the behavior of the cultured fish and for estimating their length. However, designs for system installation and the net cage should be enhanced.

1. Introduction

Assessing fish behavior and measuring their body length are both important parameters to fish farming. The Chinese sturgeons are reared in net cages. A sub-adult individual is approximately 1.5 m in length, and the length must be measured either by capture or by a diver. Therefore, the measuring process is time consuming, labor intensive and costly. For some hypersensitive fish species, direct handling may cause injury or death. Optical video cameras may be used but are ineffective in dark or turbid water, where the sturgeons usually live.

Recently developed multibeam imaging sonar, the so-called 'acoustic camera', as it is a Dual-frequency Identification Sonar (DIDSON), can capture dynamic and precise images in almost zero-visibility conditions. It was widely used in a variety of studies, including fish counting and sizing (Burwen et al., 2010; Han et al., 2009), behavior and abundance (Becker et al., 2011; Becker et al., 2013; Rakowitz et al., 2012), spatio-temporal distribution (Han and Uye, 2009; Makabe et al., 2012), and species discrimination (Langkau et al., 2012; Mueller et al., 2010). However, the use of DIDSON for behavioral observation and length measurement of cultured fish are still poorly investigated.

The Chinese sturgeon (*Acipenser sinensis*) is an anadromous fish species and its main distribution is on the continental shelf of the west Pacific Ocean and in the Yangtze River system (Wei et al., 1997). In 1989, the species was listed as a first-level protected animal in China, and, in 2009, was included as a critically endangered species on the International Union for Conservation of Nature (IUCN) Red List. In China, only a few of the sub-adult *A. sinensis* (approximately 250 individuals) are kept in artificial environments (fish cages, concrete tanks and ponds), as well as under intensive care (water quality control, optimal feeding and nutrition, disease control and prevention). In order to supplement the wild population a culture system for the species is necessary, and it should be both effective and having high standard for animal welfare, as every individual fish is important. The objective of this study is to investigate the feasibility of DIDSON for observing behavior, especially the swimming pattern, of sub-adult *A. sinensis*, and for estimating their length in a net cage, thus reducing the need for handling.

* Correspondence to: Q.W. Wei, No. 8, 1st Wudayuan Road, Donghu Hi-tech Development Zone, Wuhan, Hubei Province 430223, PR China. Tel./fax: +86 2781780118.
** Correspondence to: M. Kang, Cheondaegukchi-Gil 38, Tongyeong-si, Gyeongsangnam-do 650-160, South Korea. Tel.: +82 10 3583 3984 (cell), +82 55 772 9187 (office); fax: +82 55 772 9189.
E-mail addresses: weiqw@yfi.ac.cn (Q. Wei), mk@gnu.ac.kr (M. Kang).

http://dx.doi.org/10.1016/j.aquaculture.2014.08.024
0044-8486/

2. Materials and methods

2.1. Data collection

The experiment was conducted in a net cage at an *A. sinensis* farm in the Three Gorges Reservoir, Yichang City, China. Ten specimens of *A. sinensis*, hatched in 2005, were randomly selected and moved into an empty net cage of 5 m length, 5 m width, and 5 m depth. The total length is the length of the fish measured from the tip of the snout to the tip of the longer lobe of the caudal fin, and the standard length excludes the length of the caudal fin. The DIDSON 300 LR (identification frequency: 1.2 MHz, detection frequency 0.7 MHz; Sound Metrics Corp., Bellevue, WA, USA) was suspended from a buoy in a corner of the net cage (Fig. 1). The device emits 96 beams, and each beam was 0.3° in horizontal by 14° in vertical, giving a total field of view of 29° wide and 14° high. The head of the DIDSON was positioned at approximately 40 cm depth and angled downward at 10° from the water surface to acquire data in the longest detection range. Thus, fish were viewed from the side. The survey was conducted in the high-frequency mode (1.2 MHz) from 08:00 pm on June 9, 2011 to 08:00 am June 10, 2011. After data collection, the fish were individually caught by dipnet for measuring and weighing.

2.2. Data processing

A DIDSON data analysis procedure using Echoview version 5.3 (Myriax Software Pty. Ltd., Hobart, TAS, Australia) was used (Boswell et al., 2008; Kang, 2011; Myriax, 2013). Background noise, such as that produced by the net, was removed and the image of a target (i.e. an individual fish) was smoothed without significantly affecting its shape. Multibeam targets were detected by clustering above-threshold samples, and the multibeam target echograms were converted to single target echograms, collapsing the multibeam ping into a single ping. Targets were tracked with respect to time and position, and properties, such as vertical direction and target length, were sampled and used in subsequent analysis. Target length was defined as the maximum distance between any two samples of the target. Swimming direction was estimated relative to the location of the DIDSON head and the entrance direction of a target into the beam. Vertical direction was the angle between the beam axis and a line drawn from the first to the final target in a detected track. Zero degrees was a direction parallel to a plane perpendicular to the beam axis, $-90°$ was a direction away from the DIDSON head, and 90° was towards the head. Tortuosity was calculated as the sum of the distances between adjacent targets in a detected track, divided by the straight line distance between the first and final targets in the track, measured in three dimensional spaces (Johnson and Moursund, 2000). A fish traveling in a straight line will have an index of tortuosity equal to 1. Fish traveling more circuitous paths will have index values greater than 1. Spearman correlation analysis package in SPSS version 19 (IBM Corp., New York, USA) was used to assess the correlation between target length and vertical direction, and between target length and tortuosity.

3. Results

3.1. Swimming patterns

A total of 2743 targets were identified from the DIDSON data and most targets swam close to the net in circular motion. The average distance between targets and the transducer was 3.4 ± 2.5 m. After excluding 167 targets, which swam either away or toward the transducer, 1598 (58.3%) moved in clockwise direction, while 978 (35.7%) moved in anticlockwise direction. The 12 hour survey period was divided into six sub-periods to characterize the swimming behavior over the course of the night (Fig. 2). The average swimming speed was constant at approximately 0.7 m s^{-1} (0.54 ± 0.23 body length, which is also the standard length, $second^{-1}$, BL s^{-1}); however, at 04:00–08:00, the range was narrower and mean speed was lower (One-way ANOVA, $F(1, 2741) = 17.469$, $p < 0.001$). The minimum and maximum speeds were 0.1 and 2.1 m s^{-1} (0.12 and 1.73 BL s^{-1}), respectively.

3.2. Target length estimation based on swimming pattern

The average total length of the 2743 targets was 95.2 ± 25.0 cm. The highest frequency, in terms of target length, was in the range of 100–120 m (Fig. 3A). However, the average total length and the average standard length measured manually was 147.9 ± 9.3 and 121.7 ± 6.9 cm respectively. The minimum and maximum total lengths were 135.0 and 168.0 cm, and their standard lengths were 113.0 and 137.0 cm. The average target length, measured by the DIDSON, was 35.6% shorter than the averaged total length from manual measurements. Average BW was 17.1 ± 3.4 kg.

The relationship between target length and its vertical direction was calculated (Fig. 3B). There were 1297 targets longer than 100 cm, with the targets ranging from $-30°$ to 30° making up 76.8% (996 targets of mean length 118.1 ± 11.0 cm). The vertical direction ranging from $-30°$ to 30° was shown in 58.9% of the targets, which had mean length of 103.0 ± 23.2 cm. The range of $-90°$ to $-30°$ contained 18.6% (88.4 ± 22.5 cm) and 30°–90° contained 22.5% (80.7 ± 23.5 cm) of the targets. This indicates that target length can be estimated more accurately for a target with a small vertical direction. Target length and vertical direction were found to be negatively correlated ($n = 2743$, $R^2 = -0.145$, $P < 0.001$).

At lower tortuosity the target length was close to the manual measured length, whereas at higher tortuosity the target length resulted in lower values in measurement, which leads to underestimation (Fig. 3C). Of the targets which are longer than 100 cm (117.5 ± 11.2 cm), 87.5% of them fell within the tortuosity range of 1 to 3. Of all

Fig. 1. Deployment and data sampling of DIDSON in the net cage. (A) sketch of deployment, (B) on-site view, and (C) DIDSON data display including three arrows indicate three targets of *Acipenser sinensis*; dotted line shows the net cage.