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A photographic method of obtaining length measurements for Pacific Yellowfin Tuna

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Summary

This document is to compendiously introduce a photograph-based approach (Chang et al., 2009), to estimate verifiable length of large fish such as tuna and tuna-like species from photograph of the fish alongside a calibration board taken by a regular digital camera. The images (fish and calibration board) on the photograph are transformed to reduce errors of perspective distortions before conducting length estimation. It was demonstrated that if all the photographs are captured following the developed guidelines, the approach shows the potential of obtaining cheaply a large quantity of length estimates that deviate around 3% (up and down) on average from the actual measurements taken by observers. Additional examinations on application of the approach to photos of Pacific yellowfin tuna taken by scientific observers onboard of Taiwanese longline vessels were also provided.

Introduction

Length frequencies are essential data for fish stock assessments, particularly for longer-lived species. They are usually provided by commercial vessels, or by port sampling, observers, or sample-vessel programmes, but each of these has limitations. Collection by sample vessels might be the most balanced way provided that the data quality is verifiable.

The followings introduce a photograph-based length measurement approach was developed by Chang et al. (2009), for sample vessels to photograph fish images with a calibration board, using a regular digital camera for the purpose of obtaining length estimates that can be verified after the images are transformed, to reduce errors of perspective distortions. The approach has been analysed under ideal conditions, and a set of objective criteria for choosing acceptable photographs from observers has been developed. The criteria can serve as guidelines for photographing: if images are captured following these guidelines, the approach shows the potential of obtaining cheaply a large quantity of length estimates that deviate around 3% (up and down) on average from the actual measurements taken by observers.

This paper introduces the approach based on the work of Chang et al. (2009) and provides additional analyses with yellowfin photos taken by scientific observers onboard of Taiwanese longline vessels in the Pacific Ocean.

A. Photograph-based Length-measurement Approach (summarized from Chang et al. 2009)

The approach

Calibration board and correcting the perspective distortion of the images

By taking a photograph of the target object (the fish) together with a calibration object of known size, the length of the target object can be estimated from the proportional relationship between images of the target object and the calibration object. However, it is well known that when the image of the target object is shot from different horizontal directions and/or vertical angles, the geometric relationship between the target and calibration objects will be affected. To avoid the errors in length estimation, the digital images of both the target object and the calibration object need to be transformed to adjust for the distorted and varying geometric projection.

For this purpose, we designed a calibration board using small squares of known size as the calibration object (Figure 1). The board contains eight 12.5 cm solid-coloured squares (4 × 2). There are four colours on the board, which help to delineate boundaries. By choosing the four corner points of one of the arbitrarily selected squares from the calibration board (the reference square), we could then conduct an inverse perspective transformation to the images. Figure 1 shows the images before and after distortion correction.

(a) (b)

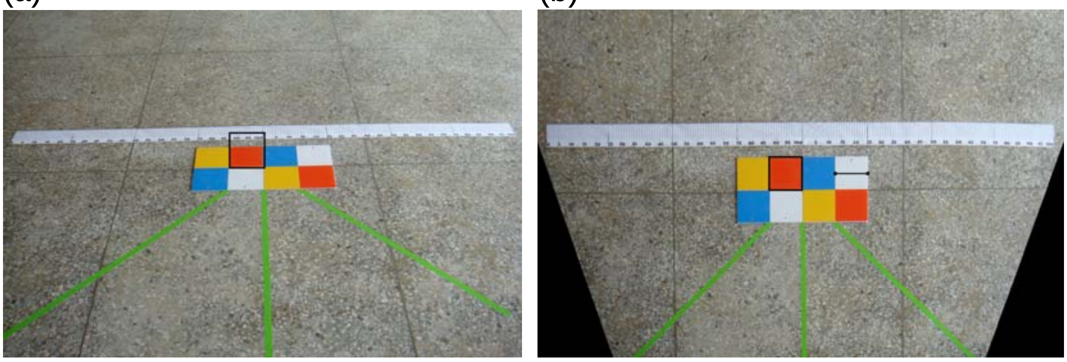

Figure 1. Sample photographs to show the effect of image distortion on the photograph-based length-measurement approach. The calibration board (with eight coloured square blocks) is in front of a ruler (200 cm long). (a) The original photograph taken at about 45° vertical shooting angle in which the image has been distorted; blocks are not in an exact square-shape. (b) A geometrically corrected photograph after by perspective correction. The dark line on the white block denotes the length of the reference square (L_{IR}) used to obtain the estimated length (L_E) from a proportional relationship.

Figure 2. Sample photograph of a bigeye tuna together with a calibration board for length estimation, photographed by a Taiwanese observer in the Atlantic Ocean on 1 November 2005.

With these designs, the length measurements could be obtained from the following simple procedures: (1) photograph the fish alongside a calibration board by a digital camera (an example in Figure 2); (2) upload the fish photograph into the measurement software; (3) select one small square on the image as the reference square and click on the four corners using the mouse for image transformation; (4) click on the two boundaries of the reference square for measurement of size of the reference square image (L_{IR}); and (5) click on the tip of the snout and the fork of the tail for measurement of size of the fish image (L_{IF}) (in case of fork-length estimation). The software will then calculate and show the estimated length of the fish (L_E) by the equation of $L_E = (L_{IF}/ L_{IR})*12.5cm$.

The performance tests

Under ideal conditions

To examine the performance of this approach, images of known-size paper rulers placed alongside a calibration board were taken under compound matrix designs. Four major factors were considered in the evaluation: the position of the calibration board, the size of the object (the ruler), the horizontal shooting direction (H. direction) when photographing, and the vertical shooting angle (V. angle). Three photographs were taken for each test design, and for each, three replicate length measurements were conducted.

Important conclusions from these tests are:

(1) The precision of length estimations among replications of each photograph was high (generally s.d.< 1cm).

(2) Correcting for perspective distortion has signification effect on the accuracy of length estimation. The correction could result in an improvement of as much as 95%, and that **the photograph-based approach with distortion correction can provide length estimates with biases of <1% when the photograph is taken under the recommended guidelines in (3)**.

(3) A set of **guidelines for photographers taking fish images** to estimate length using this approach can be developed, which are as follows: (i) the calibration board should be placed in front of and parallel to the fish; (ii) the photographer should stand right in front of the fish and, to the extent possible, the H. direction

should be perpendicular to the fish; (iii) the V. angle should be over 45° to 90°; and (iv) the photographer should aim for good contrast in the photographs, ensuring that the click points are clear and visible.

(4) The approach tends to underestimate length, and the deviation (between estimated length and actual length) tends to increase with size (Figure 3). However, after distortion correction, the variance became small (1 cm difference for a 200-cm estimate, ε = 0.5%) and the slope of the regression on corrected length estimates against actual lengths was very close to 1.

Practical application to photographs of bigeye tuna
To assess the utility of this approach to bigeye tuna, 300 photographs of bigeye tuna were selected based on the screening criteria (the guidelines) derived from the performance evaluation above. These photographs were taken by scientific observers onboard of Taiwanese longliners in 2005. Actual size of the fish was also measured by the observers (observed length) while photographing.

A regression of the estimated length from this approach against the observed length was shown in Figure 4. The slope of the regression was very close to 1, indicating almost no variance of the estimated length from the observed length. The estimation error in this application was generally small and <2% on average (average 1.88%, s.d. 1.09%).

Figure 5 shows the frequency distributions of estimated lengths together with observed lengths, and application of a Kolmogorov–Smirnov two-sample test detected no significant differences between the two distributions, demonstrating that **the photograph-based estimation approach did not significantly change the length frequency pattern of bigeye tuna from the observer dataset**.

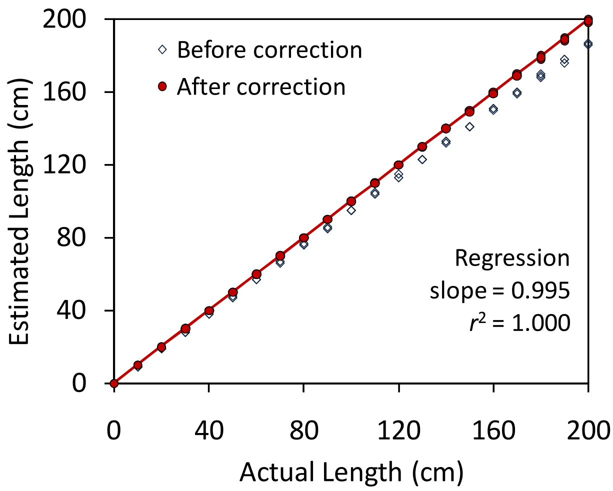

Figure 3. Estimated length plotted against actual length for a ruler before and after distortion correction, with regression output information for length estimates after correction against actual lengths.

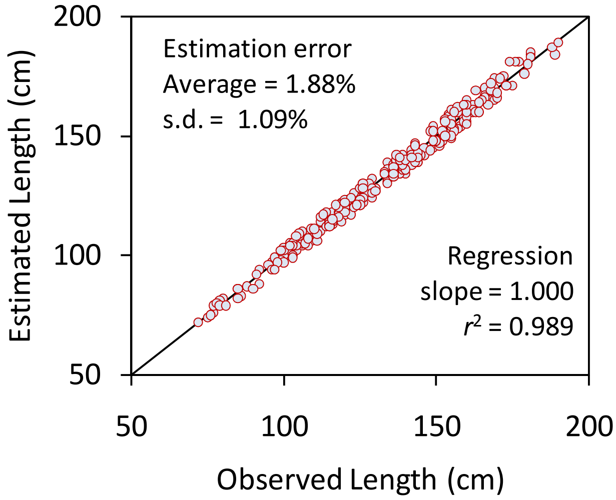

Figure 4. Estimated length plotted against observed length of bigeye tuna measured by observers on longline vessels in 2005, showing the average and the s.d. of the estimation error and the regression results. The diagonal line represents the connection of points when estimated length equals actual length.

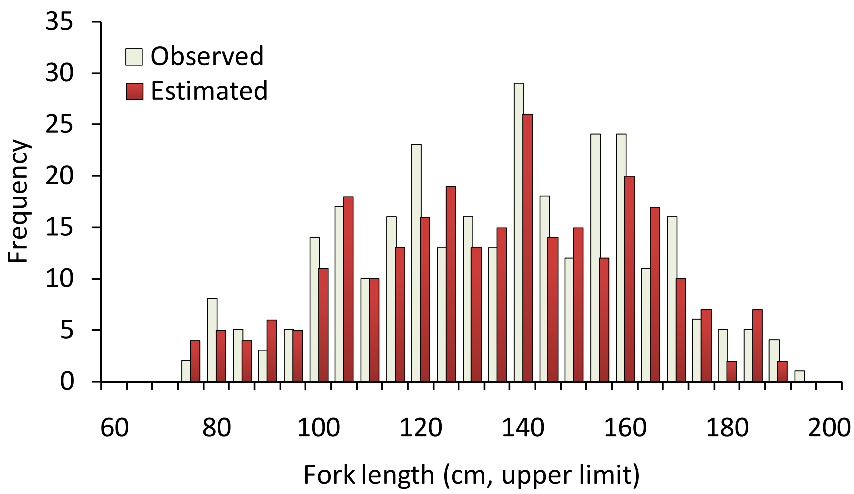

Figure 5. Distributions of the estimated lengths from fish photographs taken by Taiwanese longline-fishery observers, and the measured lengths of bigeye tuna from the three oceans where Taiwanese longliners operate, recorded by observers when photographing the fish in 2005.

Benefits of the approach

A major advantage of the photograph-based approach designed here is that it allows commercial longline vessels to collect fish images at sea using a regular digital camera, obtaining verifiable length estimates later on shore. (The approach can be applied to other types of fishing vessels provided that a suitable sampling protocol is implemented to deal with bias.) Additional benefits include the following:

(1) The procedure does not need pencil and paper; it therefore avoids the possibility of transcribing/keypunching errors. The length is visible and it can be re-estimated at any time, if necessary, for the purpose of verification. This is

entirely feasible. A test on photographs with clear fish images indicated that one estimate takes only ~30 s.

(2) This approach can provide more than just a single length measurement from one fish photograph. Many forms of length can be estimated from the same image, including standard length and fork length. Most RFMOs have required VMS to be installed on longline vessels in their territory. The photographs taken have the date printed on it, and if the vessel has installed a VMS, this photograph-based approach could provide length estimates with accurate spatio-temporal information through acquiring GPS position from the VMS.

(3) The fish image can also provide species identification information when such concerns are raised, particularly if the catch represents a major change in the perceived home range of the species. (This may be especially useful for bycatch species such as seabirds.)

(4) Compared with other photograph-based approaches, only an ordinary camera is required. The storage memory is also large enough in these inexpensive cameras to satisfy the requirement of large sample size. With two 4GB memory cards, the camera could provide ~5 400 fish photographs from a sampling trip. The cost of this approach is inexpensive and well within the budgetary constraints of most fishing nations.

B. Analysis on photos of Pacific yellowfin tuna taken by observers

A total of 458 photos of yellowfin tuna taken by scientific observers onboard of Taiwanese longline vessels during 2007-08, were obtained from the Fisheries Agency. The observers have measured the length (observed length) of the fish beside of taking photos. A new estimator was asked to estimate the length (estimated length) by the photograph-based approach. These lengths were then compared with the observed lengths and the estimation errors were analyzed.

Before formal estimation, the estimator was trained for an hour with sample photos that were taken following the above guidelines. It was found an important key process to make the estimation accurate – the transformation of skewed reference square. If the skewed square is transformed correctly, then usually the estimation errors are small. Therefore, in the course of formal estimation, when the skewed reference square does not look like ‘square’ after transformation, then the estimator is asked to give up the estimation process and start over a new process, until she felt comfortable about the square.

Table 1 shows the results of the estimation. The photos were firstly screened and 40 of photos were removed because the fish images in the photos are incomplete. The rest were estimated by the photograph-based approach. Bearing in mind of the above key point that the transformed square should look like a square, 345 photos were estimated with estimation errors less than 3% (mean=1.7%, s.d.=1.0%).

For the rest 73 photos, the estimation errors were higher than 3% (mean=6.1%, s.d.=6.3%). A second estimation was made for each of the photos, and 47 of them can be improved – the estimation errors reduced to 1.9% in average (s.d.=1.1%). The estimator explained that the new estimator is getting better experiences about the clicking process and could make better estimations.

There were 26 could not obtain improvements in the second estimation. We examined the photos and found that (1) 9 of them the fish image on the photos were too dim or vague on the two click-points and so could not be properly recognized; (2) 7 of them the calibration board images were too dim or vague due to flash light and so the click-points could not be recognized; (3) 10 of them could not find reasons for the high estimation errors. However we noted that, among the 10 estimations, there are two adjacent fish length estimations that if we swapped the recorded ‘observed lengths’ then both of the estimation errors reduced to 1%. We therefore considered that the high estimation errors for these photos were coming from coding errors in the process of hand writing or digitizing, which has also been noted in Chang et al. (2009). These emphasized the importance of photographing the fish following the developed guidelines and the values of this approach to reduce the bias from paper and pen process.

Figure 6 shows the frequency histogram of the estimated length and observed length of the 345 photos that with estimation errors less than 3%. There was no significant difference noted between the two datasets.

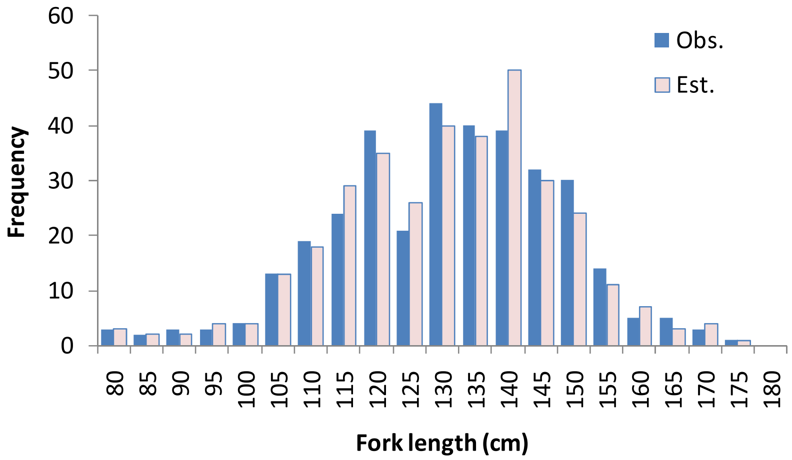

Figure 6. The frequency histogram of the estimated length (fork length) and observed length for Pacific yellowfin tuna.

Table 1. Summary statistics of the length estimation errors on photos of Pacific yellowfin tuna taken by Taiwanese observers in 2007-08.

	N			Mean	s.d.
Fish image incomplete	40				
Est. error ≦ 3%	345			1.7%	1.0%
Est. error > 3%	73			6.1%	6.3%
Improved in 2nd estimation		47		1.9%	1.1%
Not improved		26		6.1%	6.3%
Fish image vague			9	12.8%	12.1%
Calibration bd. vague			7	6.4%	4.4%
Others			10	7.4%	8.3%
Sum	458				

Reference

Chang, S. K., T. T. Lin, G. H. Lin, X. Y. Chang and C. L. Hsieh. 2009. How to collect verifiable length data on tuna from photographs: an approach for sample vessels. *ICES Journal of Marine Science,* 66: 907-915.