PRELIMINARY EXPERIENCES IN APLYING THE STEREOSCOPIC SYSTEM IN BLUEFIN TUNA SIZE ESTIMATES

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SUMMARY

A stereoscopic camera AQ100 was used in 16 transferring events during which fish were stocked into 9 cages located at three bluefin tuna farms in the Croatia. Aiming to test the accuracy of the fish length obtained by stereoscopic camera, 112 fish were randomly sampled from the cages, measured for fork length (FL in cm) and total weight (WT in kg), then placed into the sea for subsequent measurement. The tuna filmed with stereoscopic camera and on board measured with caliper ranged from 73.5 to 97.0 cm in FL with an average of 78.75 ± 3.6 cm, and 8.0 to 17.6 kg in total weight with an average of 9.57 ± 1.5 kg. Length-weight relationships were compared among measured and estimated ones. Different levels of errors were considered to get insight into the accuracy of estimates of FL and WT. Obtained differences between estimates and direct measurements as well as calculated errors in length-weight relationships are encouraging in making a reliable, non invasive measurement of length frequency distribution of the wild bluefin tuna catch.

RÉSUMÉ

Une caméra stéréoscopique AQ100 a été utilisée dans 16 opérations de transfert au cours desquels les poissons ont été stockés dans neuf cages situées dans trois fermes de thon rouge en Croatie. Dans le but de tester la précision de la longueur des poissons obtenue par caméra stéréoscopique, 112 poissons ont été aléatoirement échantillonnés dans les cages, leur longueur à la fourche (FL en cm) a été mesurée ainsi que leur poids total (WT en kg), puis ils ont été remis dans la mer pour être mesurés ultérieurement. Les thons filmés à la caméra stéréoscopique et mesurés à bord au moyen d'un pied à coulisse oscillaient entre 73,5 et 97,0 cm (FL) avec une moyenne de 78,75 ± 3,6 cm, et entre 8,0 et 17,6 kg (poids total) avec une moyenne de 9,57 ± 1,5 kg. Les relations longueur-poids ont été comparées entre les poissons qui avaient été mesurés et ceux ayant fait l'objet d'une estimation. Différents niveaux d'erreurs ont été pris en compte pour appréhender l'exactitude des estimations de FL et WT. Les différences obtenues entre les estimations et les mesures directes ainsi que les erreurs de calcul des relations longueur-poids sont encourageantes pour mesurer de façon fiable et non invasive la distribution des fréquences de taille des thons rouges capturés à l'état sauvage.

RESUMEN

Se utilizó una cámara estereoscópica AQ100 en 16 operaciones de transferencia en las que los peces se introdujeron en nueve jaulas situadas en tres granjas de atún rojo en Croacia. Con el fin de comprobar la precisión de las tallas de los peces obtenidas mediante la cámara estereoscópica, se muestrearon aleatoriamente 112 ejemplares extraídos de las jaulas, se realizaron mediciones de longitud a la horquilla (FL, en cm) y del peso total (WT, en kg), y posteriormente se introdujeron en el mar para posteriores mediciones. La talla de los atunes filmados con la cámara estereoscópica y medidos a bordo con calibrador osciló entre 73,5 y 97,0 cm de FL con un promedio 78,75 ± 3,6 cm, y su talla entre 8,0 y 17,6 kg, con un promedio de 9,57 ± 1,5 kg. Se compararon las relaciones talla-peso medidas y estimadas. Se consideraron diferentes niveles de error para obtener una perspectiva de la precisión de las estimaciones de FL y WT. Las diferencias constatadas entre las estimaciones y las mediciones directas, así como los errores calculados en las relaciones talla-peso resultan alentadoras para la realización de mediciones fiables no invasivas de distribuciones de frecuencias de tallas de atún rojo silvestre.

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KEYWORDS

Tuna fisheries; Adriatic Sea, imaging techniques, size composition

1. Introduction

Fattening and farming activities in the Croatia has started in 1996. The amount of farmed bluefin tuna (BFT) obtained from purse seine catches were continuously increased. In 1999 and 2000, respectively, 30% and 37% of the purse seine catches were caged (Miyake et al., 2003), while in the recent years majority of BFT purse seine catch were destined for caging operations.

Caging practices of live BFT (*Thunnus thynnus*) captured by purse seine caused problems and uncertainties in collecting purse seine catch-at-size data. The catch quotas for caging are monitored by counting all fish transferred from purse seine to tow cages, and again at the farm from tow cages to grow-out cages. Recording and counts of the BFT transferred are made by means of an underwater video camera operated by divers. To calculate the biomass a limited number of specimens per cage from incidental mortalities were measured in lengths and weights. The total number of BFT during transfer is multiplied by the average weight to derive a total biomass per cage. The small size of the sample in comparison to the thousands of caged fish could not be reliable in estimation of biomass and size frequency distribution of the catch nor in the scientific stock assessment. Due to the significant increase in length and weight during farming period, catch-at-size data is difficult to back calculate at the time of harvesting.

To solve this problem, ICCAT encouraged all contracting parties to undertake a pilot project aiming to better estimate biomass of bluefin tuna at the point of caging by means of stereoscopical systems (Rec. 10-04). Since 2010 the Croatia has been experimenting in application of underwater stereoscopic system that can be used in estimating the size composition of BFT caged. This paper brings preliminary results of the accuracy of camera system estimates by using two different models provided by ICCAT.

2. Material and methods

Collected video recordings were eventually analyzed using software package delivered with camera. Aiming to test accuracy of fish length obtained by stereoscopic camera live fish were randomly sampled using spare-gun. Additionally some incidental mortality collected during transfer operations were also used. Thus, 112 specimens in the total were measured for fork length (FL in cm) and total weight (WT in kg). All fish were recorded by means of stereoscopic camera as to determine individual fish lengths eventually to calculate fish weights by applying length-weight relationships adopted by the ICCAT/SCRS for bluefin tuna having a FL<100cm (Rey and Cort, unpublished) and from Arena (unpublished) for bluefin tuna with a FL >100cm. To calculate round total weight (RWT) from fork length (FL) being obtained by stereoscopic camera, the following equations were used:

(1) $RWT = 2,95x10x^{-52,8990}(FL)$ *(Rey & Cort, unpublished)*

(2) $RWT = 1,9607x10x^{-53.0092}$ *(FL) (Arena, unpublished)*

Length-weight relationships were compared among measured and estimated ones. The non-parametric Mann–Whitney U test was applied for statistical comparisons of measured weights by calliper and estimated ones. Four levels of errors were considered as to summarize the accuracy of estimates of FL and RWT for each specimen. These four measures were calculated using the adequate mathematical approximations as follow:

Error	$E = S-M$
Relative error (%)	$RE = (S-M) / M * 100 = E / M * 100$
Absolute error	$AE = absolute \lvert S-M \rvert = \lvert E \rvert$
Relative absolute error (%)	$RAE = absolute \lvert S-M \rvert / M = \lvert E \rvert / M = \lvert RE \rvert,$

where estimated bluefin tuna either length or weight were marked as *S*, and measured value were marked as *M*.

An error might be a positive or negative, depending whether the observed length or weight is overestimated or underestimated. A mean of *E* close to zero may implies either estimates are accurate, or that cancellation of under and overestimations has occurred. The *RE* and *RAE* expressed as a percentage indicate the consistency of estimates across the full range of true dimensions (Harvey *et al.*, 2001, 2003). The *AE* avoids cancellation when a mean is taken, but does not give indications of the direction of estimation errors.

3. Results and discussions

The tuna filmed with stereoscopic camera and on board measured with calliper ranged from 73.5 to 97.0 cm in FL with an average of 78.75 ± 3.6 cm, and 8.0 to 17.6 kg in total weight with an average of 9.57 ± 1.5 kg. Estimated FL obtained by stereoscopic system gave a mean error of 1.45 cm with a mean relative error and relative error of 1.86 % **(Table 1)**. Plot of the differences between estimated and measured values suggest that estimates in FL were slightly higher than measured ones of the same fish **(Figure 1)**. When the sign (plus or minus) of the differences between camera and calliper measurements of FL is ignored, a mean *AE* of 2.24 cm and a mean *RAE* of 2.84 % were noticed in favour of the camera measurements.

Harvey et al. (2003) reported for southern bluefin tuna (SBT) even less expressed errors associated with stereo system estimates of FL (mean E = 1.72 mm, ± S.D. = 8.13 mm with mean RE = 0.16 %, ± S.D. = 0.76 %). Malta's report stated that stereo-camera software provide acceptable estimates for FL of bluefin tuna adults with mean *E*= 3 cm and mean *RE* = 1.5 % (Anonymous, 2012).

Conversion of lengths measured by stereoscopic system to weights by means of models integrated into camera software has produced an average total weights of 9.84 ± 1.64 kg (Rey and Cort, unpublished) and 10.61 ± 1.95 kg (Arena, unpublished) respectively. The non-parametric Mann–Whitney U test showed significant difference between measured weights and estimated ones of both models ($p = 0.038$ and $p < 0.001$ respectively). Estimated total weights gave a mean *E* of 1.04 kg with mean *RE* of 10.90% for Arena (unpublished) equation. When the sign of differences between camera and direct measurements is ignored, a mean *AE* of 0.68 kg and a mean *RAE* of 7.13 % for Rey & Cort (unpublished) equation were obtained. When applying Arena (unpublished) equation, the value of mean *AE* was 1.13 kg with the mean *RAE* of 7.13 %.

Comparisons of the length-weight relationships of BFT measured by calliper and estimated one by camera software using Rey and Cort (unpublished) and Arena (unpublished) equations are presented in **Figure 2.** Arena (unpublished) model produces a trend line that significantly standouts of the observed one, while Rey and Cort (unpublished) trend line is aligned with observed one in length range of 75 to 85 cm. Information dealing with observed and estimated total weight comparison are rather limited. L-W equation for East Atlantic BFT being produced by Tzoumas *et al.* (2009) specifically during the months of May and June is suggested by Ramfos *et al*., 2012. Other authors demonstrated that L-W relationship can be affected not only by the catch period but also by the number of parameters including the gears being used in related geographical areas (Santos *et al.*, 2004; Deguara *et al*., 2012). Updating of the currently ICCAT adopted Atlantic bluefin tuna length-weight model is also suggested by Malta's report (Anonymous, 2012). No doubt, the size of the fish, particularly when related to the maturation period should be taken into account when new L-W relationships for East Atlantic bluefin tuna stock assessment.

4. Final remarks

The results of stereoscopic camera systems in estimating the value of both lengths and weights compared to the measured ones are encouraging and could provide an estimate of catch composition of much greater precision than former counting based on incidental mortalities. Application of such a technology could be beneficial for both fishers and farmers as it reduce the time to estimate stock composition without handling live fish. Such a system if used by the skilled operators and under the optimal working conditions might be helpful in collecting numerous, precise and accurate length data at the point of stocking into the cages without scarifying fish. However, the system is unlikely to be capable of counting and measuring length of all fish in a transfer. Part of the recorded fish might be unmeasured because of overlapping when their head or the tail was not visible in the available images. Some of the recordings were of poor image quality due to the water transparency. Portion of the fish may not be measured because of quick swimming in dense school, and/or inadequate positioning of the camera system that also may prevent accurate measuring for length of bluefin tuna stocked .

References

Anon. 2012. Malta's report on a pilot study carried out in 2011 to estimate the number and weight of bluefin tuna at the point of capture and caging by stereoscopic camera. Collect Vol. Sci. Pap. ICCAT 68(1): 291-301.

Arena, P. (Unpublished). In: Length –weight relationships adopted by the SCRS for major species. http://iccat.int/Documents/SCRS/Manual/Appendices/Apendix%204%20III%Length-weight. pdf

Deguara, S., Gatt, M., Caruana, S. and Agius, C. 2012. Changes in length-weight relationships of Atlantic bluefin tuna, Thunnus thynnus, caught by Maltese longliners during the years 20082011. Collect. Vol. Sci. Pap. ICCAT, 68(1):223-229

Harvey, E.S., Fletcher, D. and Shortis, M. 2001. A comparison of the precision and accuracy of estimates of reef-fish lengths made by divers and a stereo–video system. Fish. Bull. 99: 63–71.

Harvey, E.S., Cappo, M., Shortis, M., Robson, S., Buchanan, J. and Speare, P. 2003. The accuracy and precision of underwater measurements of length and maximum body depth of southern bluefin tuna (*Thunnus maccoyii*) with a stereo–video camera system. Fish. Res. 63: 315-326.

Miyake, P.M., De la Serena, J.M., Di Natale, A., Farrugia, A., Katavic, I., Miyabe, N. and Ticina, V., 2001. General review of bluefin tuna farming in the Mediterranean Area. Collect Vol. Sci. Pap. 55: 114 -124.

Ramfos, A., Tzoumas, A., Alaveras, P. and Katselis, G. 2012. Pilot study of a dual camera system for the determination of size of Atlantic bluefin tuna (*Thunnus thynnus*, L. 1758) during caging. Collect Vol. Sci. Pap. ICCAT 68(1): 230-235.

Rey, J.C. and Cort, J. L. (Unpublished). In: Length-weight relationships adopted by the SCRS for major species. http://iccat.int/Documents/SCRS/Manual/Appendices/Apendix%204%20III%Lengthweight.pdf

Ricker, W.E. 1975. Compulation and interpretation of biological statistic of fish populations. Fish. Res. Board. Can. Bull. 191: 1-382.

Santos dos, M. N., Garcia, A., Lino, P.G. and Hirofumi, M. 2004. Length-weight relationships and weight conversion factors for bluefin tuna (*Thunnus thynnus thynnus*) from Algarve:prior to and after fattening. Collect. Vol. Sci. Pap. ICCAT, 56 (3): 1089-1095

Tzoumas, A., Ramfos, A., De Metrio, G., Corriero, A., Spinos, E., Vavassis, C., and Katselis, G. 2009. Weight growth of Atlantic bluefin tuna (*Thunnus thynnus*, L. 1758) as a result of a 6-7 months fattening process in central Mediterranean. Collect Vol. Sci. Pap. ICCAT 65(3): 787-800.

Table 1. Errors associated with stereoscopic video estimates of the forklength (FL) and total weight (WT) produced by the L-W relationships Eastern Atlantic bluefin tuna provided by ICCAT manual and implemented in software packet of stereoscopic camera AQ100.

	Error	Absolute error	Relative error (%)	Relative absolute error (%)
LF				
Mean (cm)	1.45	2.24	1.86	2.84
S.D.	2.35	1.61	2.97	2.04
S.E.	0.22	0.15	0.28	0.19
Sample size	112	112	112	112
RWT – Rey&Cort				
Mean (kg)	0.27	0.68	3.15	7.13
S.D.	0.91	0.67	9.11	6.46
S.E.	0.09	0.06	0.86	0.19
Sample size	112	112	112	112
RWT – Arena				
Mean (kg)	1.04	1.13	10.90	11.85
S.D.	0.96	0.85	9.76	8.58
S.E.	0.09	0.08	0.92	0.81
Sample size	112	112	112	112

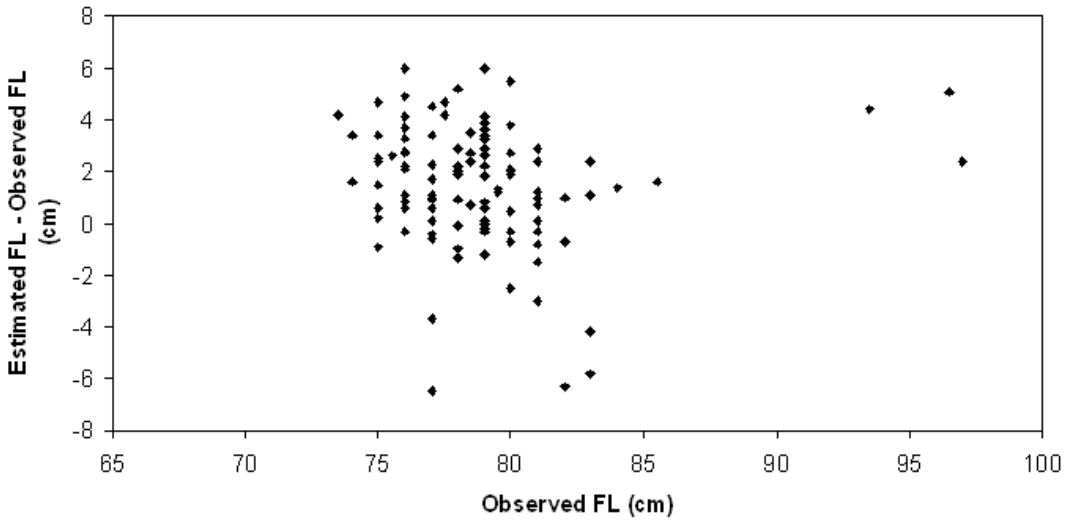

Figure 1. Relationship of the difference between the FL estimated by stereo camera and the FL measured by calliper plotted against the observed FL measured by calliper.

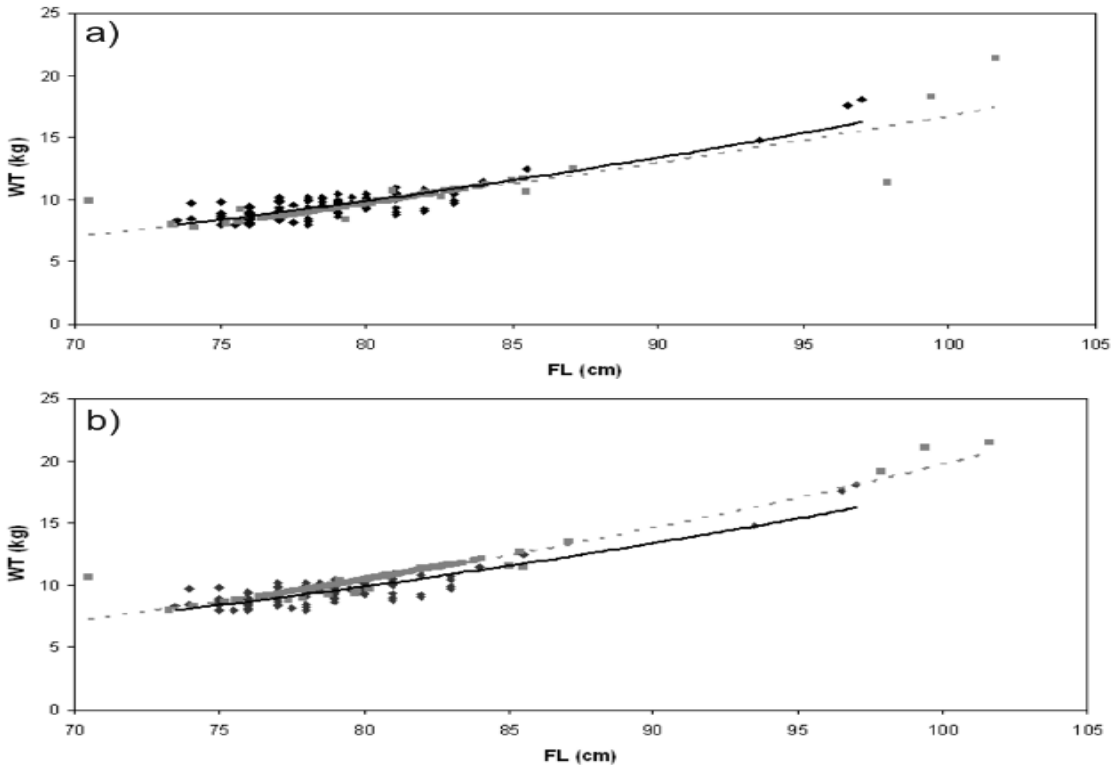

Figure 2. Comparison of the length-weight relationships of BFT measured by caliper and ones estimated by stereo camera software using L-W relationships provided by ICCAT: (a) Rey & Cort and Arena equations respectively. Black spot and black solid line indicate observed measurement; grey spot and dash line, estimated measurement.