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EXPLAINING THE DISCREPENCY BETWEEN STEREOCAMERA FOOTAGE AND MEASURED HARVEST LENGTH DATA OF FARMED ATLANTIC BLUEFIN TUNA (*THUNNUS THYNNUS*)

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SUMMARY

This paper presents three parameters which could help explain the observed discrepancy between the pre-harvest stereocamera (SC) determined straight fork lengths (SFL) and the manually measured SFL taken during the actual harvest of the same population of fish during the GBYP Growth in Croatia and Central Med Farms studies. The first parameter involves the calibration error associated with the use of the SC and dependent on the distance between the SC and the fish being measured. The second parameter relates to the differences in the relative position and shape of the upper jaw and lower jaw of live and dead BFT, with a significantly bigger difference being apparent in post-mortem BFT. The final parameter relates to the shrinkage in length which has been observed in a number of (non-BFT) fish. Collectively, these three parameters account for most of the discrepancies found in the Croatian and Central Med studies.

RESUMEN

Ce document présente trois paramètres qui pourraient contribuer à expliquer la divergence observée entre les longueurs droites à la fourche (SFL) déterminées par stéréo-caméra (SC) avant la mise à mort et les SFL mesurées manuellement lors de la mise à mort réelle de la même population de poissons au cours des études du GBYP sur la croissance dans les fermes de Croatie et de Méditerranée centrale. Le premier paramètre concerne l'erreur de calibration associée à l'utilisation de la SC et dépend de la distance entre la SC et le poisson mesuré. Le deuxième paramètre concerne les différences dans la position relative et la forme de la mâchoire supérieure et de la mâchoire inférieure des thons rouges vivants et morts, une différence significativement plus importante étant apparente chez les thons rouges post-mortem. Le dernier paramètre concerne la diminution de la longueur qui a été observée chez un certain nombre de poissons (autres que le thon rouge). Collectivement, ces trois paramètres expliquent la plupart des divergences constatées dans les études menées en Croatie et dans la Méditerranée centrale.

RESUMEN

En este trabajo se presentan tres parámetros que podrían ayudar a explicar la discrepancia observada entre las longitudes rectas a la horquilla (SFL) determinadas por la cámara estereoscópica (SC) antes del sacrificio y las SFL medidas manualmente durante el sacrificio real de la misma población de peces en los estudios de crecimiento en granjas de Croacia y del Mediterráneo central en el marco del programa de investigación GBYP. El primer parámetro se refiere al error de calibración asociado al uso de la SC y que depende de la distancia entre la SC y el pez medido. El segundo parámetro se refiere a las diferencias en la posición relativa y la forma de la mandíbula superior y la mandíbula inferior de los atunes rojos vivos y muertos, con una diferencia significativamente mayor evidente en los atunes rojos post mortem. El último parámetro se refiere a la contracción de la longitud que se ha observado en varios peces (no atunes rojos). En conjunto, estos tres parámetros explican la mayoría de las discrepancias encontradas en los estudios de Croacia y del Mediterráneo central.

KEYWORDS

Atlantic bluefin tuna; Thunnus thynnus*; stereocamera; straight fork length*

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1. Introduction

As part of the GBYP Phases 9 and 10 Biological Studies, the growth of Atlantic bluefin tuna (BFT) in cages, from caging to harvesting, was studied in a number of geographical areas (Croatia, Malta, Portugal, Spain and Türkiye). These studies involved the use of stereocamera (SC) footage analysis for the determination of the straight fork length (SFL) distribution of the population of caged BFT at caging, during the production phase and pre-harvesting; the studies involved the measurement of the individual SFL and round weight (RWT) of each of the harvested individuals in the study cages.

Modal progression analysis (MPA) was carried out with the SC and harvest data made available in these cage growth studies. The results of the MPA analysis, which provides mean modal lengths and not individual measures, were presented in SCRS/2021/145 (Alemany *et al.,* 2021), and it was found that modal sizes from the analysis of SFL distributions obtained through manual measurements at harvest were systematically (between 2 and 6cm) lower than those obtained from the SC footage analysis **(Table 1**, **Figure 1)**. These discrepancies were attributed to issues with the calibration of the SC, the actual measurements of SFL during harvesting and possible shrinkage of individuals after harvesting.

This paper presents three parameters which together may account for this discrepancy.

2. Materials and methods

2.1 Deducting calibration error from % SC – Harvest difference

Using the original SC analysis results, the average distance from the SC of the fish in each of the modal groups presented in **Table 1** was determined.

The calibration error (Deguara *et al.,* 2014) was calculated for the average distance from the SC using the following equation:

$$E_{cal} = 0.1191D + 0.6134$$

where the calibration error, E_{cal}, is the percentage difference between the SC estimate and the length of the fish and D is the distance (m) from the SC.

The calibration errors for each modal group were used to determine a new % SC - Harvest difference. An overall % difference was then calculated, weighted by the number of fish in each modal group, for the Croatian and Central Med populations.

2.2 Live vs post-mortem changes in jaw shape and position

There appears to be differences in the relative position and shape of the upper and lower jaws of BFT of live fish and dead BFT, although some overlap is also apparent (**Figure 2**). In order to determine if this was an important difference or not, and assuming that the lower jaw position or shape does not change as does the upper jaw, screenshots of a 100 fish from stereocamera footage of live BFT were manually analysed using ImageJ 1.54g as follows:

1) Based on the SFL measurement positions required by the GBYP (**Figure 3**), the line between the tail and the farthest position of the upper jaw was measured. (red line, **Figure 4**).
2) From the same point on the tail, the line between the tail and the farthest position of the lower jaw was measured (yellow line, **Figure 4**).
3) Since the actual length of the fish was unknown, the % difference between lower jaw and upper jaw was determined as:

$$\text{\% Difference between lower jaw and upper jaw} = \frac{\text{ImageJ lower jaw length} - \text{upper jaw length}}{\text{ImageJ lower jaw length}} * 100$$

In the case of dead fish, suitable photos available on the internet were analysed using ImageJ in the same way to similarly determine the % differences between the upper and lower jaws.

In both cases, the images of the fish used for analysis were selected based on overall relative position (straight and at right angles to the observer) and suitability to be measured.

In the case of the dead fish, it was not possible to assess actual length of the fish nor the actual duration of time post-mortem that the photo was taken.

2.3 Post-mortem length shrinkage

Not a lot of research has been reported in the literature involving studies relating to the change in total or fork length of whole unprocessed fish within the few hours post-mortem before the onset of rigor mortis. The data that is available pertains to fish of relatively small (compared to BFT) size. Since, In the case of BFT harvesting in farms, SFL measurements typically take place within the first hour of harvesting, the data available was used to provide an estimate of the % shrinkage/h within the first few hours post-mortem.

3. Results and discussion

Deducting the calibration error reduces the overall % difference between the SC measurement and the actual harvest measurements (**Table 1**) for the Croatian and Central Med fish. This reduction still leaves 1.64% and 1.25% differences in the Croatian and Central Med measurements respectively so is not sufficient to account for all of the discrepancies observed. It should be noted that the SC footage of the BFT were taken 10 and 17 days (on average) respectively before the fish were harvested, during which time the fish would have been expected to grow further; hence there would have been a larger difference between the SC and the harvest SFL measurements had the fish been harvested immediately after the SC footage was taken.

The distribution of % differences between upper and lower jaws of live fish and dead fish are presented in **Figure 5**. Statistical analysis (Mann-Whitney U test) of the data indicated a significant difference between the two data sets ($p < 0.000$). Within the photos of dead BFT analysed, a number were available from harvesting operations on traps and farms ($n = 20$). There were also a number of photos with fish which can be designated as 'small' (BFT typically caught by recreational fishing with the photo of fish on the deck or being held by the recreational fisher)($n = 16$). T-tests between % differences upper to lower jaw of non-farm/trap and farm/trap dead fish did not find a significant difference ($p = 0.252$), but % differences of the upper to lower jaw of all dead BFT less the 'small' BFT was significantly different to that of the 'small' fish ($p = 0.014$). There were also significant differences when comparing dead 'small' fish to farm/trap dead fish and either group to the live BFT results. **Table 2** summarises the averages and standard deviations of the various groups of fish as well as significant differences between the different groups of fish analysed.

If the average values of the percentage differences between upper and lower jaws are accepted as being representative of the differences in measurements taken with the SC on live fish and manually with all dead fish (1.59 - 0.56% = 1.03%) the overall discrepancy for the Croatian and Central Med fish drop to 0.61 and 0.22% respectively. If the % differences for the 'small' dead and trap/farm dead BFT are accepted, the overall discrepancy for the Croatian and Central Med fish now drop to 0.23 and 0.38% respectively.

Typically, fish from cages will be processed/taken on board a processing boat and thereby measured within a short period of time. In the case of changes in length, it is not possible from the literature to know what actually happens with BFT. From the data presented in **Table 3**, with smaller fish and with % shrinkages considered as soon as possible post-mortem, the overall average % shrinkage is 0.217%/h (if the data for summer whiting is not included, the average drops to 0.188%/h).

From the available information, it is not known whether much larger fish than those presented in Table 3 exhibit the same degree of shrinkage. Subtracting one hour's worth of shrinkage to the corrected % discrepancy value brings the SC – harvested size difference down to 0.01 and 0.16% respectively for the Croatian and Central Med fish.

4. Conclusions

Collectively, the various parameters presented here, whilst based on various assumptions, provide an explanation for the differences which have been observed in the MPA analysis between the SC SFL measurements and the subsequent harvest measurements.

The results of the analysis described above can be improved by expanding the sample size for each of the groups identified and, wherever possible, extracting more information on size (SFL) and time post-mortem. A lot is still unknown about what causes the differences in relative position and shape in the upper jaw of the BFT and about the % shrinkage of fish of the size of BFT, and these are parameters which may also be studied further, especially within the typical time frame between harvesting of farmed BFT and subsequent SFL measurement.

If the lower jaw is indeed a more ‘stable’ sampling point for the determination of BFT length, it might be beneficial to consider the lower jaw as the standard measurement point rather than the upper jaw.

Acknowledgments

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Table 1. Summary of MPA SC – Harvest differences and correction of calibration rod error.

Croatia	*SC SFL (cm)*	*Harvest (H) SFL (cm)*	*SC-H diff (cm)*	*% Diff*	*Av. Distance from SC (m)*	*Calibration Rod error (%)*	*New % diff*	*Weighted average % diff*
Age 2	137.81	134.32	3.49	2.60	3.74	1.06	1.54	**1.64**
Age 3	154.31	148.98	5.33	3.58	3.98	1.09	2.49	
Age 4	163.92	160.48	3.44	2.14	3.83	1.07	1.07	
Central Med	*SC SFL (cm)*	*Harvest (H) SFL (cm)*	*SC-H diff (cm)*	*% Diff*	*Av. Distance from SC (m)*	*Calibration Rod error (%)*	*New % diff*	*Weighted average % diff*
Gp1	147.74	145.48	2.26	1.55	5.92	1.32	0.23	
Gp2	156.84	155.56	1.28	0.82	5.01	1.21	-0.39	
Gp3	168.97	163.47	5.5	3.36	5.33	1.25	2.12	
Gp4	178.87	172.31	6.56	3.81	5.73	1.30	2.51	
Gp5	189.46	184.72	4.74	2.57	5.52	1.27	1.30	**1.25**
Gp6	200.65	195.87	4.78	2.44	5.45	1.26	1.18	
Gp7	209.78	204.41	5.37	2.63	5.87	1.31	1.31	
Gp8	220.09	213.70	6.39	2.99	5.73	1.30	1.69	
Gp9	230.02	224.01	6.01	2.68	5.78	1.30	1.38	
Gp10	238.02	234.31	3.71	1.8	5.83	1.31	0.28	

Table 2. Summary of % differences between upper and lower jaws of the different groups of BFT analysed with ImageJ and statistical analysis between selected groups.

Group of BFT	*Number*	*Av. % Diff*	*SD*
Live BFT	100	0.56	0.42
All dead BFT	100	1.59	0.70
'Small' dead BFT	16	1.97	0.57
Farm/Trap dead BFT	20	1.43	0.58
All Dead less 'Small' dead BFT	84	1.51	0.69
All Dead less Farm/Trap dead BFT	80	1.63	0.72
All dead BFT less 'Small' less Farm/Trap dead BFT	64	1.54	0.73
Live BFT vs All dead BFT		**4.441e-16**	
Live BFT vs dead Farm/Trap BFT		**3.584e-8**	
Live BFT vs 'Small' dead BFT		**1.137e-9**	
Dead Farm/Trap vs All other dead BFT		0.252	
Dead Farm/Trap vs All other dead less 'small' dead BFT		0.530	
'Small' dead BFT vs all other dead BFT		**0.014**	
'Small' dead BFT vs dead Farm/Trap BFT		**0.008**	

Table 3. Summary of data pertaining to whole fish shrinkage following death.

Fish sampled	*Size range (mm)*	*Number of fish sampled*	*Hours post mortem used in calculation*	*Average % shrinkage/h*	*Reference*
Black bream (*Acanthopagrus butcheri*)	246-353 (TL)	70	6	0.217	Morison *et al* (2003)
Summer whiting (*Sillago ciliata*)	134-329 (FL)	13	2	0.389	Morison *et al* (2003)
Pink snapper (*Pagrus auratus*)	179-262 (FL)	100	4	0.227	Morison (2004)
Largemouth bass	216-568 (TL)	130	3-6 (4.5h used in calculation)	0.168	Dunn *et al* (2022)
Catfish spp.	190-875 (TL)	105	3-6 (4.5h used in calculation)	0.178	Dunn *et al* (2022)
Black crappie	95-360 (TL)	208	3-6 (4.5h used in calculation)	0.156	Dunn *et al* (2022)
Sunfish spp.	136-295 (TL)	118	3-6 (4.5h used in calculation)	0.184	Dunn *et al* (2022)

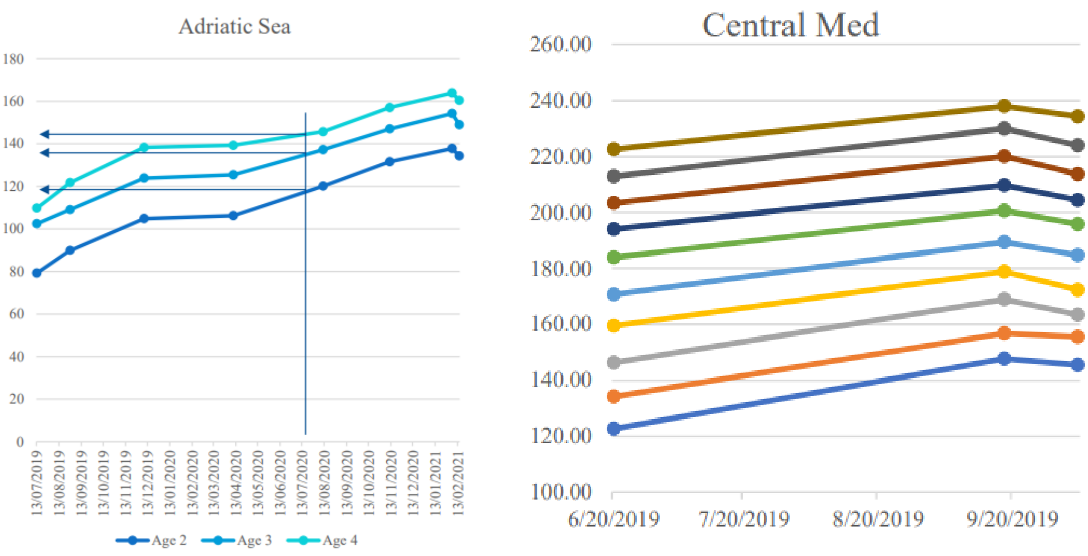

Figure 1. Modal SFL progressions of BFT in Adriatic Sea fand Central Mediterranean farms showing relative dip in SFL between final SC footage analysis and actual harvest measurements (Alemany *et al*., 2021).

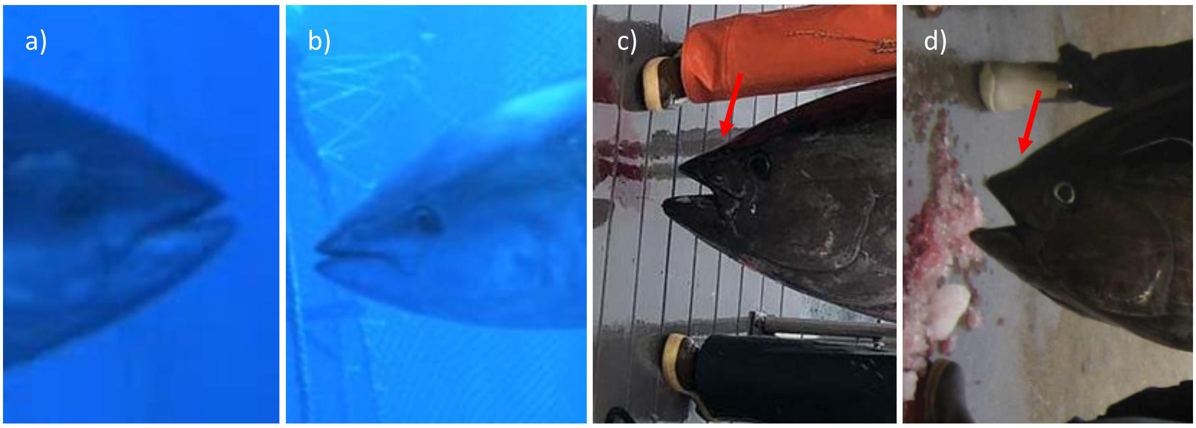

Figure 2. Differences in relative lower jaw to upper jaw positions in live (a and b) and dead BFT (c (https://www.thefisherman.com/article/noaa-closes-giant-bluefin-fishery-for-northeast-anglers/) and d (https://www.tunahunter.com/bluefin-tuna-charters/)). Red arrow indicates a shape difference which could account for differences seen in relative lengths of upper and lower jaw between live and dead fish.

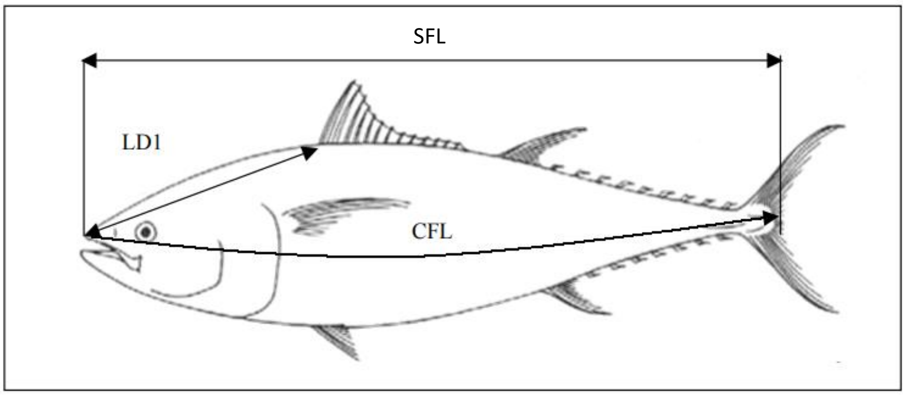

Figure 3. Types of measurements of Atlantic bluefin tuna: straight fork length (SFL), first dorsal length (LD1), curved fork length (CFL).

Figure 4. Upper and lower jaw length measurement positions taken with ImageJ.

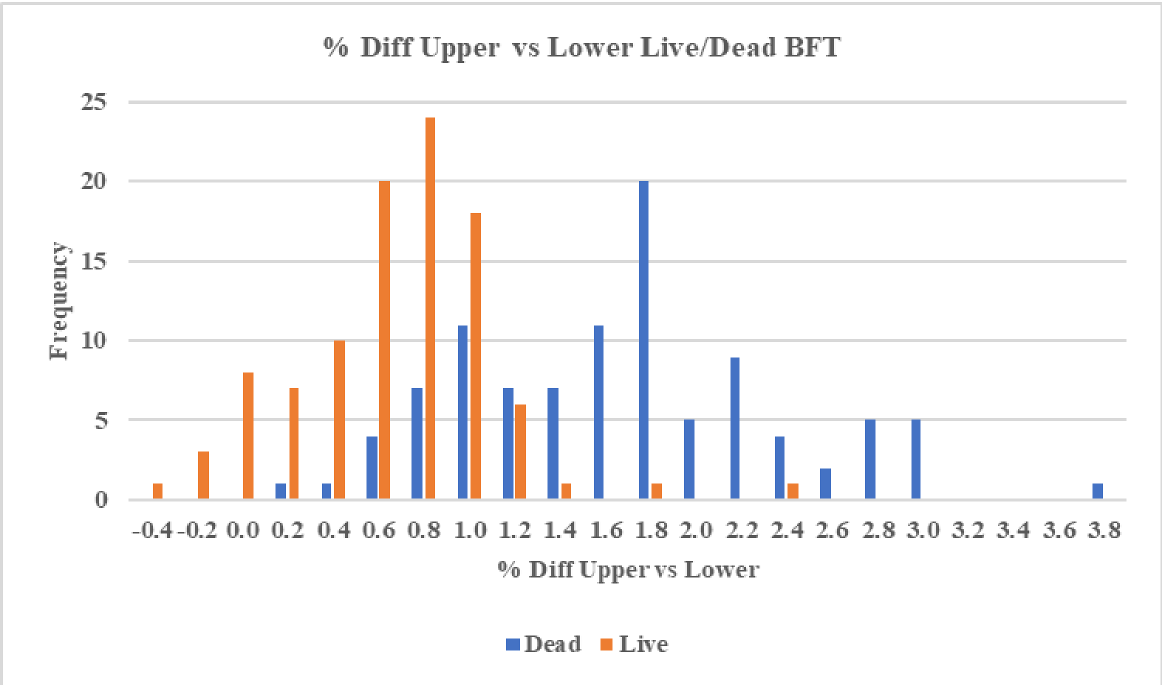

Figure 5. % Upper and lower jaw length differences of sampled screenshots and photos of live and dead BFT based on analysis with ImageJ.