

LENGTH-WEIGHT RELATIONSHIPS APPLICABLE TO BLUEFIN TUNA JUVENILES (*THUNNUS THYNNUS*) CAUGHT FOR FARMING PURPOSES DURING THE PURSE SEINE FISHING SEASON IN THE ADRIATIC

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SUMMARY

Following recently recommended equation by Standing Committee on Research and Statistics (SCRS) to calculate bluefin tuna weights from lengths measured by stereoscopic cameras, a model for Adriatic ($RWT = 3.77278 \cdot 10^{-5} \cdot SFL^{2.86308}$) is determined on the basis of samples collected during purse seine fishing season in 2017. This length–weight relationship is compared with recently adopted ones by the International Commission for the Conservation of Atlantic Bluefin Tuna (ICCAT). The results of analysis indicates that the ICCAT equation recommended to be used in 2017 for the Mediterranean areas including bluefin tuna caught by traps in the Atlantic Ocean is not suitable for bluefin tuna juveniles caught during purse seine fishing season in the Adriatic. It is clear that the established model for the Adriatic region differs from the available models recommended by the relevant authorities suggesting the need to apply the regional approach with the adjustment of length–weight relationship to the size/age classes.

RÉSUMÉ

Suite à l'équation récemment recommandée par le Comité permanent pour la recherche et les statistiques (SCRS) pour calculer les poids du thon rouge à partir des longueurs mesurées par des caméras stéréoscopiques, un modèle pour l'Adriatique ($RWT = 3,77278 \cdot 10^{-5} \cdot SFL^{2.86308}$) est déterminé sur la base d'échantillons prélevés au cours de la saison de pêche à la senne en 2017. Cette relation longueur-poids est comparée à celles qui ont été récemment adoptées par la Commission internationale pour la Conservation des thonidés de l'Atlantique (ICCAT). Les résultats de l'analyse indiquent que l'équation de l'ICCAT dont on recommande l'utilisation en 2017 pour les régions méditerranéennes, y compris le thon rouge capturé par des madragues dans l'océan Atlantique, n'est pas adéquate pour les juvéniles de thon rouge capturés au cours de la saison de pêche à la senne dans la mer Adriatique. Il est clair que le modèle établi pour la région de l'Adriatique diffère des modèles disponibles recommandés par les autorités compétentes, ce qui suggère la nécessité d'appliquer l'approche régionale avec l'ajustement de la relation longueur-poids aux classes de taille/âge.

RESUMEN

Utilizando la ecuación recomendada recientemente por el Comité Permanente de Estadísticas e Investigación (SCRS) para calcular los pesos del atún rojo a partir de tallas medidas mediante cámaras estereoscópicas, se determinó un modelo para el Adriático ($RWT = 3.77278 \cdot 10^{-5} \cdot SFL^{2.86308}$) basándose en las muestras recogidas durante la temporada de pesca de cerco en 2017. Esta relación talla-peso se comparó con la que ha adoptado recientemente la Comisión Internacional para la Conservación del Atún Atlántico (ICCAT). Los resultados del análisis indican que la ecuación que ICCAT ha recomendado que se utilice en 2017 para las zonas del Mediterráneo, lo que incluye el atún rojo capturado por las almadrabas en el océano Atlántico, no es adecuada para los juveniles de atún rojo capturados durante la temporada de pesca con cerco en el Adriático. Está claro que el modelo establecido para la región del Adriático difiere de los modelos disponibles recomendados por las autoridades pertinentes, lo que sugiere la

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necesidad de aplicar el enfoque regional con el ajuste de la relación talla-peso a clases de talla/edad.

KEYWORDS

Bluefin tuna, Thunnus thynnus, stereocamera, Adriatic, length-weight relationships

Introduction

Farming is a main destination for the purse seine catches of the Eastern Atlantic Bluefin tuna (*Thunnus thynnus*) (BFT) juveniles in Croatia. In accordance to the ICCAT Recommendation 06-07, as of 2008 farms are reporting size from each harvest operation, and the same is covered also by the Regional Observer Program (ROP). Due to inaccuracy of estimation of caged quantities (mostly assessed by divers combined with mortality of limited number of fish) harvesting used to be the only moment when the fish were exactly numbered and weighted for the purpose of shipping to the Japanese market for years (Katavic *et al.*, 2016).

Following the ICCAT Recommendation 14-04, Contracting Parties (CPCs) started to submit the data on E-BFT size in accordance with the results of stereoscopic camera system (SCS) application at caging. Although SCS technology applied for counting and measuring the size of farmed fish covered 100% of caging operation (rearing cages), without a precise and appropriate length-weight (L-W) relationships, it was difficult to determine the actual biomass placed into the farming cage and thus prove compliance with the ICCAT quotas.

For the area of east Atlantic and Mediterranean ICCAT has recommended the Rey and Cort (Unpublished) L-W relationships for BFT with FL <101cm, and Arena (Unpublished) for BFT having a FL >100cm. Comparison of these equations with the various L-W equations from the literature shows a correspondence with fish size, place and time when the fish were caught, or if the fish were affected by the starvation and variety of environmental and biological factors (Ticina, 1994; Sinovic *et al.* 2004; Katavic *et al.*, 2002; La Mesa *et al.*, 2005). Abid *et al.* (2015) have connected the monthly L-W relationships with the condition factor (K) of the bluefin tuna caught in Moroccan waters. It was documented that the evolution of K throughout the year may significantly affect the accuracy of L-W relationship (Deguara *et al.* 2013; Cort and Vicente, 2017). It became clear that using the L-W relationships of BFT caught in different months of the year represents an important element as well and a new L-W equation was recommended by SCRS (Rodriguez-Marin *et al.*, 2016) for the purpose of caging in 2016, for May and June separately. However, the suitability of using these equations to calculate weights from lengths measured by SCS for each fishery were questioned, and the L-W matrix is suggested to be adjusted for particular region (Gordoa, 2017). Since the differences among various models that are translated into biomass of the purse seine catch may have a significant impact on the estimation of the real catch in the region (Gordoa, 2017), a room for uncertainty was created because of possible exceeding of the quota uptake by each CPC.

To ensure the necessary legal clarity between the ICCAT as a main management and controlling entity and CPCs conducting the caging operations a review was carried out by the various L-W algorithms provided by many scientist over the wide Mediterranean area where the purse seine fishery is practiced (Deguara *et al.*, 2017). Based on the analysis ICCAT (2017) recommended a new equation for the Mediterranean area including the BFT caught by traps in the Atlantic Ocean to be applied to calculate weights from BFT lengths measured by stereoscopic cameras in 2017. Regarding the fish caught in the Adriatic Sea, ICCAT (2017) has concluded that the algorithm used in 2016 could continue being used until the development of a specific algorithm for this purse seine fishery.

The aim of this study is to determine an alternative L-W relationship specifically applicable for the conversion of stereo camera obtained length data to weight of the BFT juveniles caught by purse seiners in May and June in the Adriatic for further farming.

Materials and Methods

Size frequency data were collected in 2017 from caging operations with SCS in June/July at 4 farms and 16 caging operations. Pursuant to ICCAT Recommendation 14-04, the SCS was deployed for length data covering minimum 20% sample of fish caged.

The relation between straight fish length (SFL) and round weight (RWT) was determined from 214 specimens taken from 9 individual catches made during purse seine fishing season. Fish were sampled the soonest possible after the purse seine operation was done, killed and individually measured for straight fork length (SFL) with measuring callipers (MC) and subsequently weighted. Fish SFL and RWT had been measured to the nearest cm and 0.1kg, respectively. Fish ranged from 73cm to 110cm and from 7.5kg to 29.1kg in weight. Condition factors (K) were estimated using equation:

$$K=100 \times W/L^3$$

where W is RWT in grams, and L is the SFL in cm (Ricker, 1979).

Length-weight relationships applicable to BFT juveniles during the purse seine fishing season in the Adriatic were calculated and compared with recent L-W equations applied for the area of Mediterranean.

Results and Discussion

Figure 1 shows BFT length frequency of the purse seine catches based on 12.774 specimens measured by stereoscopic camera that represents around 21% of the total 59.631 tuna caged in 2017. Frequency data indicated catches of primarily BFT juveniles from 66 to 110cm FL. Following a standardized age-length key for East Atlantic and Mediterranean, bluefin tuna based on otoliths reading (Rodriguez-Marin *et al.*, 2016) majority of the fish belong to juveniles, age 2 (from 66 to 85cm) and much less to age 3+ (from 80 to 110cm). These results are in line with findings of Katavic *et al.*, (2017) which showed a significant degree of size/age homogenization.

Figure 2 shows the relationship between fish straight length and round weight from 214 specimens measured. The values of parameters a and b of the allometric power function were the following;

$$RWT = 3.77278 \times 10^{-5} \times SFL^{2.86308} \quad (\text{Figure 2}) \text{ with a correlation coefficient } R^2=0.9676$$

Condition factor of BFT caught in Adriatic Sea during purse seine fishing season estimated from length and weight data showed that average K value of wild BFT juveniles in May/June was 2.1 (± 0.14 SD). The mean K-value of harvested BFT juveniles for the purpose of tagging in the similar fishing season was much lower (1.49) that can be explained by prolonged starvation during transport and acclimatization (Katavic and Grubisic, cited in Deguara *et al.*, 2017).

New Adriatic curve vary significantly from that recommended by ICCAT to be applied for the entire Mediterranean including bluefin tuna caught by traps in the Atlantic Ocean in 2017 (Deguara *et al.*, 2017), and much less from the equation recommended by the ICCAT based on Rodriguez-Marin *et al.*, (2016) algorithm for the purpose of caging bluefin tuna in 2016 (**Figure 3**).

It is clear that the equation that is recommended to be applied in 2017 (Deguara *et al.*, 2017) is not suitable for the bluefin tuna juveniles in the Adriatic at the time when they are caught for farming purposes (May/June). While no single model fits all fisheries and stocks types, it is suggested to adjust the L-W algorithm for particular region and the time when the fish are caught for farming purposes (Cort *et al.*, 2015; Gordo, 2017). Moreover our findings point to the need for L-W matrix adjustment to size/age classes that may differ significantly.

The importance of the differences between new Adriatic equation (present study) and equation provided by Deguara *et al.*, (2017) becomes critical in compliance with the size and weight of juvenile fish (>8 kg and/or >75 cm) to be placed into cages for farming purposes (**Figure 4**). The weight for a 75cm fish predicted by current ICCAT equation is 9% underestimated (8.8kg versus 8.1kg) (**Table 1**).

Conclusion

Targeted research activity aimed to determine the L-W relationships of BFT juveniles in the Adriatic Sea caught by purse seine fleet for further farming when compared to other relations used in Mediterranean clearly proved the regionally based specificity of stock types and fisheries applied. New Adriatic equation for BFT juveniles caught in May and June in the Adriatic for caging purposes differ significantly from that recommended by ICCAT to be applied in 2017, and much less from the equation recommended by the ICCAT for the purpose of caging bluefin tuna in 2016 (Rodriguez-Marin *et al.*, 2016). The minimum size as defined per provisions of the ICCAT framework (8kg and/or 75cm) does not precisely reflect L-W relationship determined nor natural size distribution of targeted bluefin tuna in the Adriatic for the purpose of further farming.

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References

- Abid, N., Benchoucha, S., Arraf, S. El, Fanichi, C. El., Baibbat, S.A. 2015. Updated length weight relationship of bluefin tuna (*Thunnus thynnus*) caught in Moroccan waters. Collect. Vol. Sci. Pap. ICCAT, 71(2):1036-1040.
- Cort, J.L., Vicente, D.E., Dos Santos, M.N., Di Natale, A., Abid, N., de la Serna J.M. 2015. On the variability of the length-weight relationship for Atlantic bluefin tuna, *Thunnus thynnus* (L). Rev. Fish. Sci. & Aquacult. 23(1):23-38.
- Cort, J.L., E. Vicente, 2016. Analysis of the length-weight relationships for the Atlantic Bluefin, *Thunnus thynnus* (L.) tuna. Rev. Fish. Sci. & Aquacult. 24(2): 126-135.
- Deguara, S., Cort, J.L., Galaz, T., Vicente, D.E., Perez, E.J.B. 2013. Use of Fulton's condition factor to filter out outliers from Atlantic bluefin tuna (*Thunnus thynnus* L.) length-weight relationships. Collect. Vol. Sci. Pap. ICCAT, 69(2): 671-683.
- Deguara, S., Gordo, A., Cort, J.L., Zarrad, R., Abid, N., Lino, P.G., Karakuluk, S., Katavic, I., Grubisic, L., Gatt, M., Ortiz, M., Palma, C., Cid, J.J.N., Lombardo, F. 2017. Determination of a length-weight equation applicable to Atlantic bluefin tuna (*Thunnus thynnus*) during the purse seine fishing season in the Mediterranean. Collect. Vol. Sci. Pap. ICCAT, 73(7): 2324-2332.
- Gordo, A. 2017. Possible consequences of the use of Atlantic bluefin tuna population biometrics in the algorithms of stereo cameras. Collect. Vol. Sci. Pap. ICCAT, 73(6): 2013-2019.
- ICCAT. 2017. Report for biennial period, 2016-17 PART I (2017), Vol. 1: 1-611.
- Katavic, I. Ticina, V., Franicevic, V. 2002. A preliminary study of the growth rate of bluefin tuna from Adriatic when reared in the floating cages. Collect. Vol. Sci. Pap. ICCAT, 54(2):472-476.
- Katavic I., Segvic-Bubic, T., Grubisic, L., Talijancic, I. 2016. Reliability of bluefin tuna size estimates using a stereoscopic camera system. Collect. Vol. Sci. Pap. ICCAT, 72(7): 1848-1861.
- Katavic, I., Grubisic, L., Ticina, V., Segvic-Bubic, T., Males, J., Talijancic, I. Zuzul, I. 2017. Catch structure of purse seine bluefin tuna fishing in the Adriatic Sea: the first age frequency distribution estimate based on a spine age-length key.
- La Mesa M., Sinopoli, M., Andalaro, F. 2005. Age and growth rate of juvenile bluefin tuna, *Thunnus thynnus* from the Mediterranean Sea (Sicily, Italy). Sci. Mar. 69(2):241-249.
- Ricker, W.E. 1979. Growth rates and models. In: Hoar, W.S., Randall, D.J., Bret, J.R. (Eds.), Fish Physiology. Academic Press, New York, pp.677-743.
- Rodriguez-Marin E., Quelle, P., Ruiz, M., Luque, P.L. 2016. Standardized age-length key for east Atlantic and Mediterranean bluefin tuna based on otoliths reading. Collect. Vol. Sci. Pap. ICCAT, 72(6): 1365-1375.
- Sinovic, G., Franicevic, M., Zorica, B., Cikes-Kec, V. 2004. Length-weight and length-length relationships for 10 pelagic fish species from Adriatic Sea (Croatia). J. Appl. Ichthyol., 20:156-158.
- Ticina, V. 1994. Morphological characteristics, feeding and fishing on the bluefin tuna (*Thunnus thynnus*) in the Adriatic Sea (In Croatian). M.Sc. Thesis, University of Zagreb, 84pp.

Table 1. Round weight (RWT) predictions for given length (SFL) by various length-weight relationships. The weight for a 75cm fish predicted by ICCAT 2016 equation (Rodriguez-Marin *et al.*, 2016); current ICCAT 2017 (Deguara *et al.*, 2017), and ADRIATIC NEW equation generated from current study is indicated.

SFL (cm)	ICCAT 2016 (R-M <i>et al.</i> , 2016)	ICCAT 2017 (D <i>et al.</i> , 2017)	ADRIATIC NEW (present study)
66	6,18	5,60	6,11
67	6,45	5,85	6,38
68	6,74	6,11	6,66
69	7,02	6,37	6,94
70	7,32	6,64	7,23
71	7,63	6,92	7,53
72	7,94	7,21	7,84
73	8,26	7,51	8,16
74	8,59	7,81	8,48
75	8,93	8,12	8,81
76	9,28	8,44	9,15
77	9,64	8,77	9,50
78	10,00	9,10	9,86
79	10,38	9,44	10,23
80	10,76	9,80	10,60
81	11,15	10,16	10,99
82	11,55	10,53	11,38
83	11,97	10,90	11,78
84	12,39	11,29	12,19
85	12,82	11,68	12,61
86	13,26	12,09	13,04
87	13,70	12,50	13,48
88	14,16	12,92	13,93
89	14,63	13,36	14,39
90	15,11	13,80	14,85
91	15,60	14,25	15,33
92	16,10	14,71	15,82
93	16,61	15,18	16,32
94	17,13	15,66	16,82
95	17,66	16,15	17,34
96	18,20	16,65	17,87
97	18,75	17,15	18,41
98	19,32	17,67	18,95
99	19,89	18,20	19,51
100	20,48	18,74	20,08

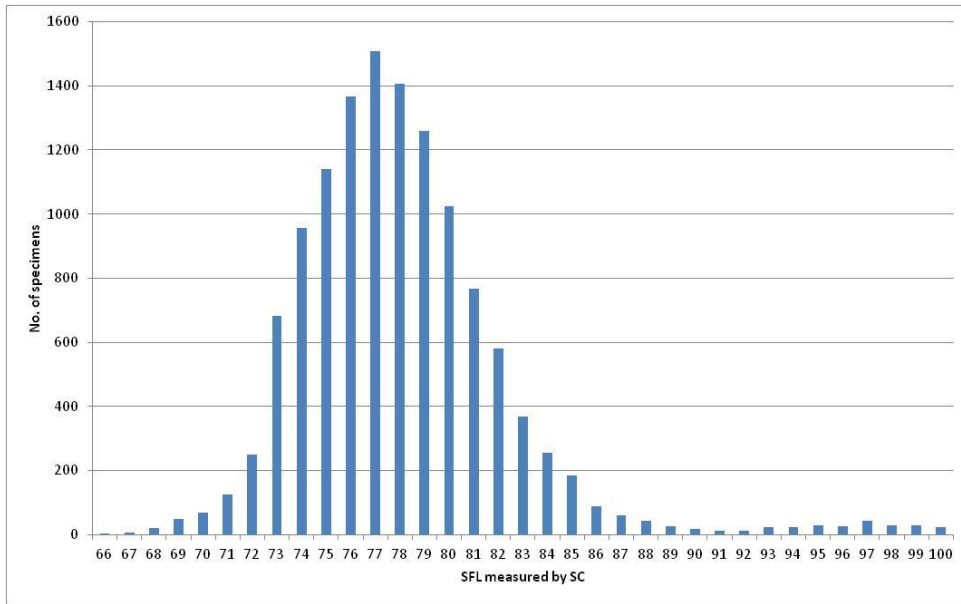


Figure 1. Bluefin tuna length frequency of the purse seine catch in the Central Adriatic (Croatia) during May and June 2017 based on 12.774 SC- measured specimens.

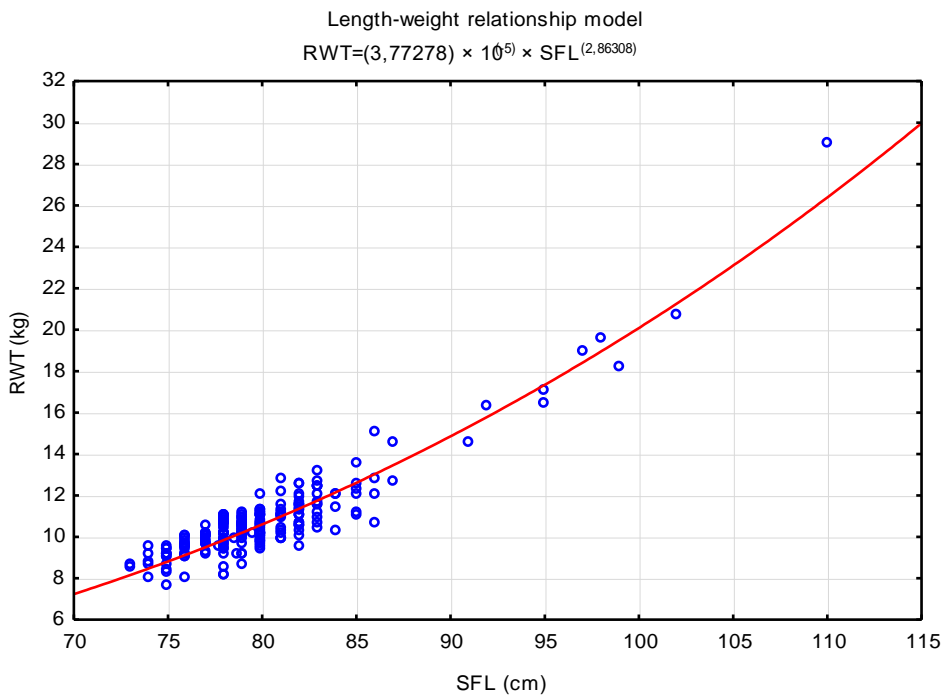


Figure 2. Fork length (SFL in cm) versus round weight (RWT in kg) for Adriatic purse seine caught bluefin tuna in months of May and June 2017.

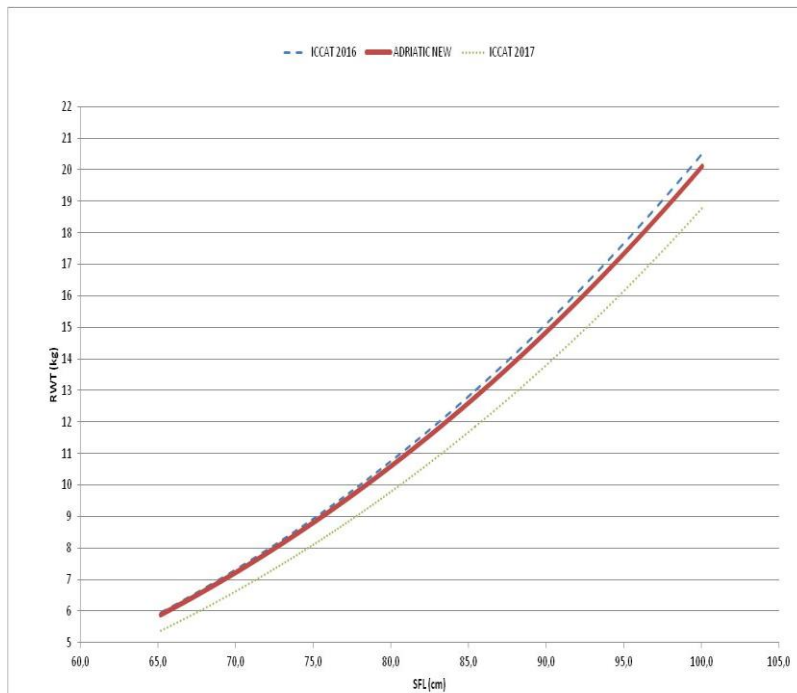


Figure 3. Length-weight relationships for the ICCAT June 2016 equations (Rodriguez-Marin *et al.*, 2016), current ICCAT 2017 equation (Deguara *et al.*, 2017) and Adriatic New equation (present study).

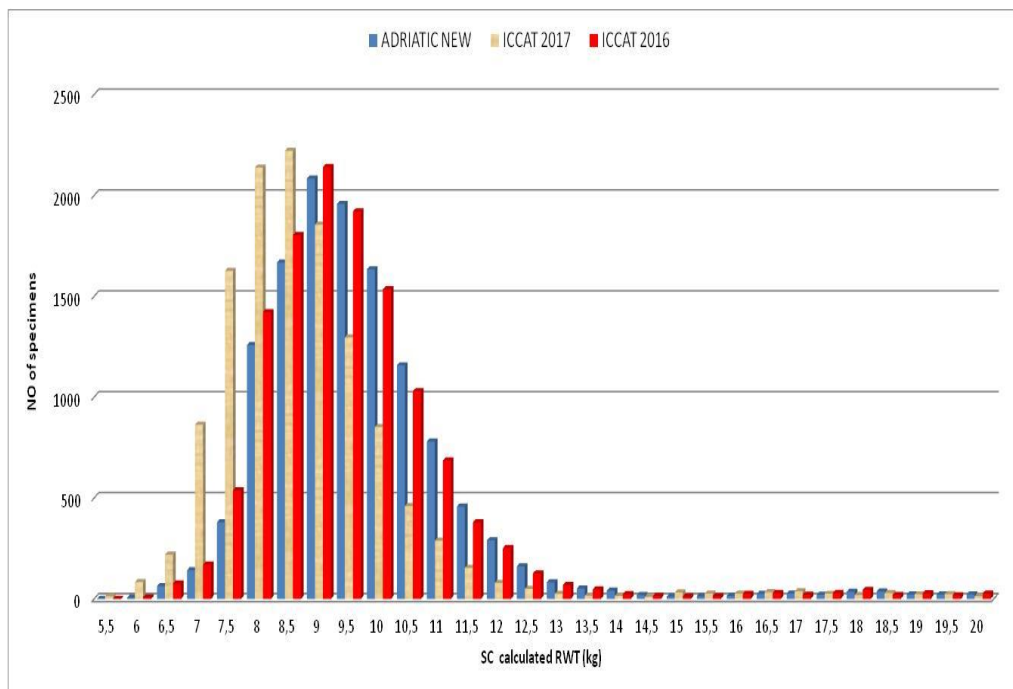


Figure 4. Calculated weight from stereoscopic camera system fork length data for bluefin tuna juveniles caged in 2017 in Croatian farms using three different equations that were recommended by ICCAT/SCRS over the last two years: ICCAT 2016 (Rodriguez-Marin *et al.*, 2016); ICCAT 2017 (Deaguara *et al.*, 2017), and ADRIATIC NEW equation (present study).