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ELECTRONIC TAGGING OF ADULT BLUEFIN TUNAS (*THUNNUS THYNNUS*) IN THE EASTERN MEDITERRANEAN AND SARDINIAN SEA; IMPROVING THE PRECISION OF TUNA SIZE ESTIMATES

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SUMMARY

Two scientific tagging campaigns were carried out in the Eastern Mediterranean sea (Gulf of Antalya, purse seine) and in the Sardinian sea (trap of Carloforte), in the framework of the Tagging programme 2015 - ICCAT/GBYP 05. A total of 39 bluefin tunas were tagged with electronic tags to address several important biological and ecological topics regarding Atlantic Bluefin. To improve the quality of the method to estimate tuna size, different images of a fish died during the fishing activities were taken simulating different shooting distance from the fish and moving the spear gun to get different angles in order to "mime" the different possible approaches to the fish during tagging activity. Calculations were used for a better tuning of a method previously adopted for the size estimate.

RÉSUMÉ

Deux campagnes de marquage scientifique ont été réalisées dans la Méditerranée orientale (golfe d'Antalya, à la senne) et dans la mer de Sardaigne (madrague de Carloforte), dans le cadre du programme de marquage de 2015 - ICCAT/GBYP 05. Au total, 39 thons rouges ont été marqués avec des marques électroniques en vue de traiter plusieurs thèmes biologiques et écologiques importants concernant le thon rouge de l'Atlantique. Afin d'améliorer la qualité de la méthode d'estimation de la taille du thon, on a pris différentes images d'un poisson mort durant les activités de pêche, en simulant différentes distances de prise de vue du poisson et en déplaçant le fusil à harpon de façon à obtenir différents angles pour "mimer" les différentes façons possibles d'approcher les poissons pendant l'activité de marquage. Des calculs ont été utilisés pour obtenir un meilleur calibrage d'une méthode adoptée précédemment pour l'estimation de la taille.

RESUMEN

Se llevaron a cabo dos campañas científicas de marcado en el Mediterráneo oriental (golfo de Antalya, cerco) y en el mar de Cerdeña (almadraba de Carloforte), en el marco del programa de marcado de 2015 del ICCAT GBYP 05. Se marcaron en total 39 atunes rojos con marcas electrónicas para abordar diversos temas biológicos y ecológicos importantes relacionados con el atún rojo del Atlántico. Para mejorar la calidad del método para estimar la talla de los peces, se tomaron diferentes imágenes de un pez muerto durante las actividades pesqueras simulando diferentes distancias de grabado hasta el pez y moviendo el arpón para obtener diferentes ángulos con el fin de representar los diferentes posibles acercamientos al pez durante las actividades de marcado. Se utilizaron cálculos para ajustar mejor un método previamente adoptado para la estimación de tallas.

KEYWORDS

Bluefin tuna, Thunnus thynnus, *Eastern Mediterranean Sea, Sardinian Sea, electronic tagging, purse seine, trap*

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1. Introduction

One of topic points in a tagging campaign where no direct manipulation of the samples is foreseen is a correct estimate of the length of the tagged individuals. In the framework of a previous Iccat tagging campaign, carried out by Unimar in the South Tyrrhenian in 2013 with conventional (spaghetti-type) tags, a method aimed at assessing tuna length from images captured by a spear gun mounted camera was developed and tested. The method used rendered 3D tuna models (**Figure 1**), showing that good estimates could be obtained provided that the shooting distance was known and constant. The method was based on an Artificial Neural Network (ANN) and required only apparent length and height in pixels as input data, but it was trained to handle only specimens in the 130-200 cm length range and assuming a constant shooting distance.

During the 2015 Iccat tagging campaign, this method was improved and tuned to acquire a better precision.

2. Materials and methods

The activities were carried out in the Eastern Mediterranean Sea (Gulf of Antalya) in May - June 2015. According to the ToRs of the Call for Tenders GBYP 05/2015, 40 miniPATs were prepared to be applied on adult Bluefin tunas caught by a Turkish purse seiner. The tagging protocol followed what recommended by Iccat, and described by SCRS/2014/189.

Each tagging activity was recorded with underwater cameras (**Figure 2**), with the purposes of estimating the size of each individually tagged fish. Biological samples were collected as well during the tagging activities according to the ICCAT protocol. As a result of this activity, 30 tags were deployed.

Because 10 miniPat weren't used in Turkish campaign, according to ICCAT GBYP Steering committee, tagging programme was modified to tag supplementary 10 bluefin tunas with the last 9 tags (one was broken and it was not possible to use it) in the Sardinian Sea ("tonnara" of Carloforte), in accordance with COM.BIO.MA., the group in charge of the other tagging activities.

In addition of the images taken for each sample, images of two dead tunas (whose length was obviously known) have been acquired in Turkey and in Sardinia, in order to validate the method (**Figure 3**). However, this two tunas were both over the range of the previous series of samples (one bigger, the other smaller), therefore the ANN was not able to extrapolate beyond the range of known values used for its development. Moreover, images of the two dead tunas were also shot from too close (respect to the first series of samples of the 2013 campaign), and this contributed to make length estimates even less accurate.

The only viable solution to extend the capabilities of the length assessment method was to recalibrate it from scratch. This has been done by re-training the ANN using a wider range of images and a wider range of tuna lengths than in the original implementation.

As only 13 new images were available (11+2), apparent size measurements from them were used more than once in the training and validation set to roughly match the frequency of other tuna sizes. In order to avoid using too often exactly the same images, some noise was added to the measurements (in pixels) obtained from the original pictures. Moreover, as in new images the shooting distance was shorter (1.5 m) than in older ones (2 m), shooting distance in cm has been added as a third input variable to train the new ANN.

Combining old data and data from the new images, a training data set (N=280) and a validation data set (N=70) were obtained. Due to the limited number of available images, some input/ouput pattern have been replicated more than once, although not exactly. As previously stated, in order to avoid equal patterns, jittering (=addition of small random values) was used. This procedure makes the ANN fit an envelope rather than a set of points, thus improving its generalization ability.

Images in which the FL to H ratio was too extreme were not included in the training and validation sets. Only FL/H values in [2,5.5] range were considered, thus excluding images in which the specimen's aspect was unlikely to correspond to those more frequently observed during tagging operations.

While a simple multiple linear regression was able to provide reasonably good length estimates (validation set Mean Square Error, MSE=233.4), it did not match the accuracy of the old 2-11-1 ANN-based method.

Therefore, a new ANN was trained, using a 3-3-1 structure. A smaller number of hidden units, in addition to jittering and early stopping, helped preventing overfitting as much as possible.

The resulting ANN was implemented in a very handy software tool that requires an ASCII input data file with FL, H, shooting distance triplets, returning another ASCII data file in which the estimated lengths are stored.

3. Results

The new 3-3-1 ANN was perfectly able to adapt itself to both shooting distances (1.5 and 2 m). As for different lengths, the new ANN fitted extreme values better than intermediate ones, because a smaller number of different images was available in those cases.

The MSE of the new ANN was 61.1 for the training set and 85.4 for the validation set (the latter set is shown in **Figure 4**).

While the old 2-11-1 ANN showed a slightly better MSE with its own validation set (78.21), it was less effective than the new 3-3-1 ANN with the new validation set, even in case only tunas in its original range were taken into account (MSE: 118.7).

The distribution of the errors in length estimates did not change very much relative to the old data set, but the new ANN performed slightly better with the newest data (Figure 5), thus obtaining an overall improvement in accuracy. However, although the range of tuna lengths in the old data set was narrower, both ANNs were less effective with them than with the newest data. The most likely reason for this difference is probably that the newest data have been obtained from a smaller set of very homogenous images.

4. Conclusions

Collecting 13 images of two dead specimens (11+2 images) allowed to extend the operational range of a software tool based on an ANN and aimed at assessing tuna length from images collected during tagging. The updated software tool was more accurate than the previous version over the whole range of tuna lengths used for its calibration

While the new ANN outperforms the old ANN, most of the improvement is due to better performance with new data in the validation set, which were obtained from images of specimens whose FL/H ratio is more homogenous and significantly smaller than in older images (**Figure 6**).

As for future work, more data are definitely needed. While the new ANN scales very nicely its estimates, it was trained on only two shooting distances and a very limited set of tuna sizes and therefore it cannot be perfect. An example of the kind of errors that can be induced by the lack of complete data is shown in **Figure 7,** where the curve showing the expected length as a function of shooting distance is presented. While the length vs. distance curve is good enough, it should not be S-shaped. Therefore, more data and more work are needed in order to fully optimize the ANN based size estimates.

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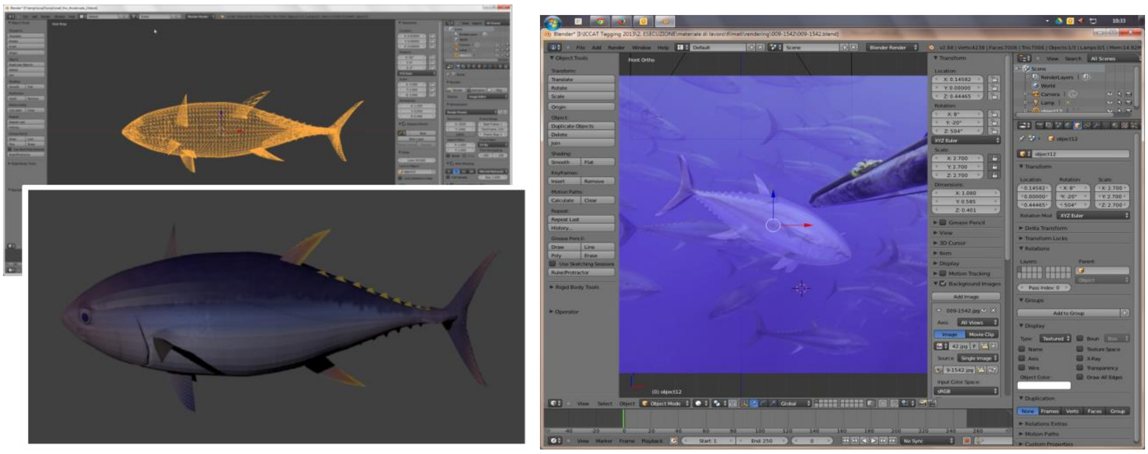

Figure 1. 3D tuna fish model generation - 3D model of the fish overlapped to a real image.

Figure 2. Tagging operations.

	Eastern Mediterranean Sea		
FL (cm)	242		
RWT (kg)	247		
	Reference angle		
Reference distance (cm)	45°	90°	135°
100	X	X	X
200	X	X	X
300	X	X	X

Figure 3. Images of the fish were taken simulating different shooting distances.

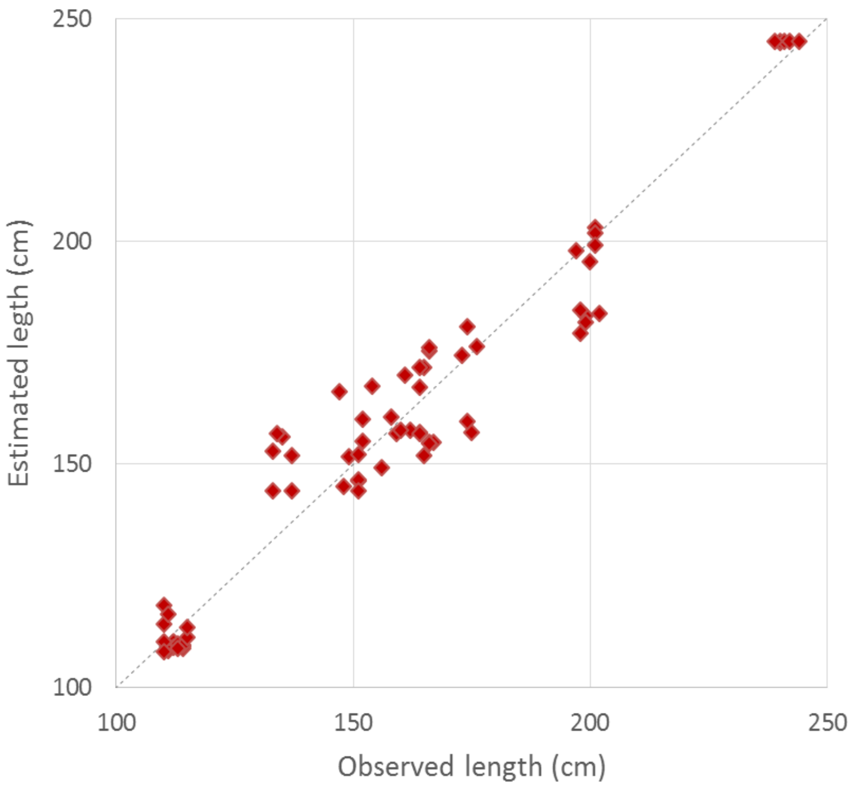

Figure 4. Observed vs. estimate values in the new ANN validation set. Training set MSE 61.1, validation 85.4.

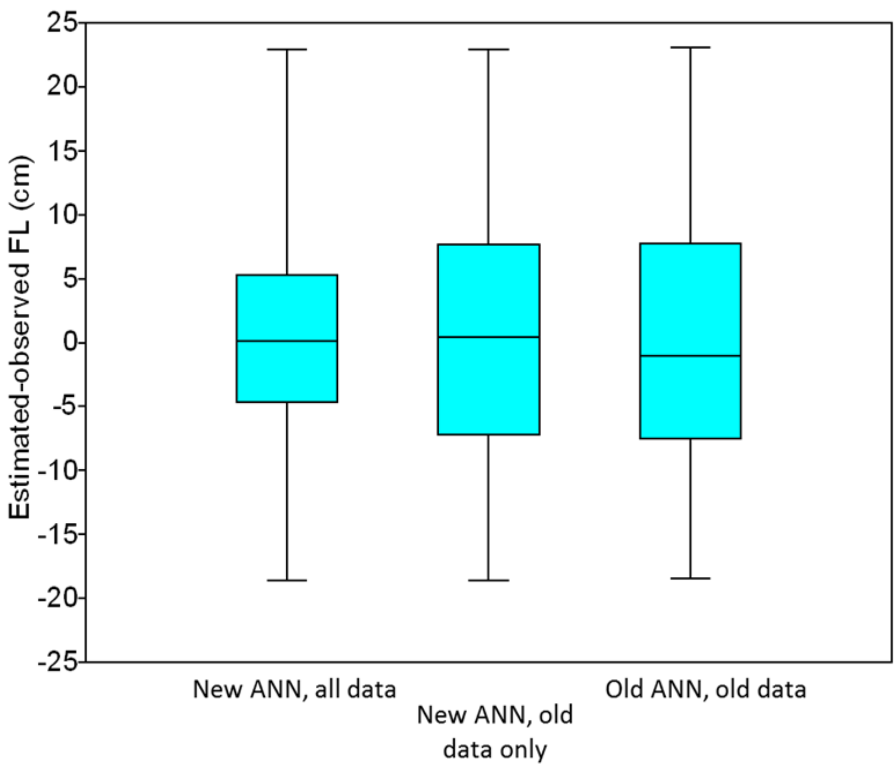

Figure 5. Error distribution: new vs. old ANN.

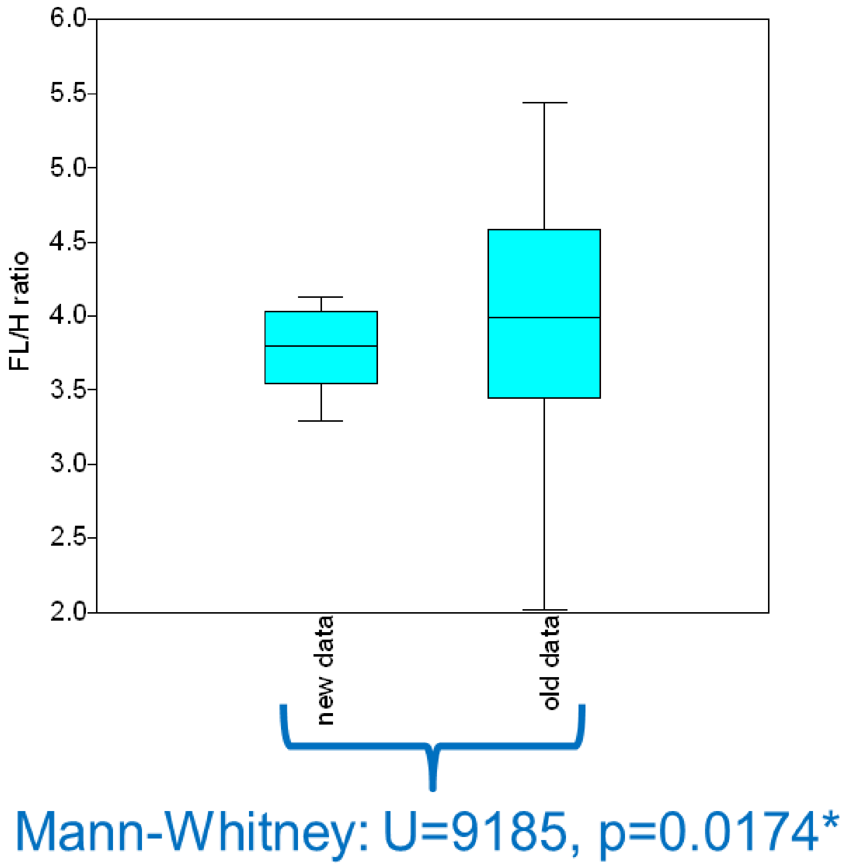

Figure 6. FL/H ratio is significantly smaller in data obtained from the newest images.

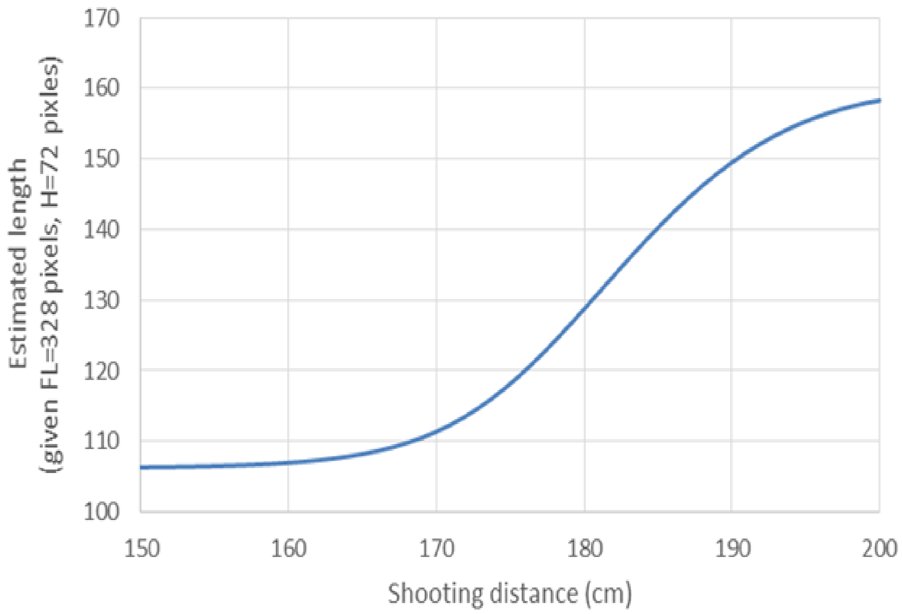

Figure 7. Estimated length of a specimen (FL=328 pixels, H=72 pixels) as a function of shooting distance.