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CONVENTIONAL TAGGING OF ADULT ATLANTIC BLUEFIN TUNAS (*THUNNUS THYNNUS*) BY PURSE-SEINERS IN THE MEDITERRANEAN – METHODOLOGICAL NOTES

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SUMMARY

A scientific tagging campaign was carried out in the Tyrrhenian Sea with the aim to address several important biological and ecological topics regarding Atlantic Bluefin tuna as well as to possibly provide fishery independent estimates of abundance and/or fishing mortality rates. This was the first attempt at this kind of activity in the Tyrrhenian Sea during spawners aggregation and the general approach was to define a tagging methodology for adult BFT by divers in the purse seine, obtaining reliable size estimates as well as keeping research-related mortality as low as possible.

RÉSUMÉ

Une campagne de marquage scientifique a été réalisée dans la mer Tyrrhénienne dans le but de répondre à plusieurs importantes questions en ce qui concerne la biologie et l'écologie du thon rouge de l'Atlantique et afin de tenter de fournir des estimations indépendantes des pêcheries de l'abondance et/ou des taux de mortalité par pêche. Il s'agissait de la première fois que ce genre d'activité était réalisée dans la mer Tyrrhénienne pendant les concentrations de reproducteurs et l'approche générale visait à définir une méthodologie de marquage des thons rouges adultes par des plongeurs dans la senne, afin d'obtenir des estimations fiables ainsi que de réduire au maximum la mortalité liée à la recherche.

RESUMEN

En el mar Tirreno se llevó a cabo una campaña científica de marcado con el objetivo de abordar varios temas importantes biológicos y ecológicos respecto al atún rojo del Atlántico, así como para posiblemente facilitar estimaciones de abundancia independientes de la pesquería y/o tasas de mortalidad por pesca. Este es el primer intento de este tipo de actividad en el Tirreno durante la concentración de los reproductores y el enfoque general era definir una metodología de marcado para el atún rojo adulto mediante buzos en el cerco, obteniendo estimaciones de talla fiables, así como manteniendo la mortalidad relacionada con la investigación al menor nivel posible.

KEYWORDS

Bluefin tuna, Thunnus thynnus*,*
Mediterranean, Tyrrhenian Sea, Tagging, Purse seine

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1. Background

The improvement of management advices and the reduction of uncertainty in bluefin tuna stock assessment depends on a better knowledge of key biological processes. As underlined by Iccat, almost all data currently used in stock assessment are obtained by fishery-dependent sampling, and need to be cross-checked with data coming from alternative sources, such as tagging studies, in order to be properly validated. The first need, therefore, is to set up a scientifically robust methodology facing an activity still rarely carried out in some environmental and operational conditions.

2. Introduction

This report refers to the activities carried out in the Tyrrhenian Sea according to the ToRs of the Call for Tenders GBYP 01/2013 "Conventional tagging of juvenile and/or adult bluefin tuna by purse-seiners in the Tyrrhenian Sea (ICCAT/GBYP Phase 4 – 2013)". A series of specific objectives of the tagging activity were set out by Iccat, and among them, "the estimation of the feasibility of tagging BFT in traps and purse-seiners by divers getting at the same time reliable size estimates." The paper refers particularly to the application and improvement of methods applied to the topic, as set up during the specific tagging campaign carried out in June 2013.

3. Materials and methods

Considering the high risks of fish mortality and the several field practical difficulties that this pilot tagging activity may present, preparatory activities with the experts participating to the project, the fishermen and the divers, were carried out to discuss about the practical possibility of adapting the methodology suggested by Iccat to operational conditions.

Tagging

As far as adults are concerned, great concern was expressed about the viability of the proposed methodology, mostly for the possible high rate of mortality. Concerns were focused on the possible reactions of adult specimens to the shot, the tendency of going deeper and deeper and therefore on the possibility of tagging many individuals in this way, besides the danger that the behaviour of some stressed entangled specimen could compromise the stretch of the net, causing a fast and potentially dangerous reduction of water for the fishes preventing them from schooling or inducing a frenzy reaction. Moreover, in case of any change of the sea state, the risk of having a Bluefin tuna school of adults restricted inside a purse seine in high sea could create unacceptable risks for both the net and the vessel and, as a consequence, the net should be opened and the fish should be released into the wild.

Geographic area

The area of the scientific tagging campaign was the Southern Tyrrhenian Sea. The importance of this area for the concentration of BFT spawners is well known (Arena, P. 1978, 1982,), and constant activity of purse seine fishing has developed starting from the early Seventies (Arena, 1990).

Vessel

The vessel used for the scientific tagging campaign in the Tyrrhenian Sea was selected among the purse seiners fleet actually operating in Italy (Error! Reference source not found.). The selection of the vessel was made taking into account both the technical features and the comfort/safety on board for the tagging team. The crew also included two professional divers for the achievement of the planned activities.

Tagging equipment

UNIMAR received from ICCAT the technical equipment which was selected and used according to the "best value for money" principle: conventional tags and applicators for spaghetti tags, small billfish tags, large billfish tags. 10 units of wooden handles for applicators + additional 10 small billfish applicators were also provided.

Spearguns

According to the decision of the preparatory meeting, four spearguns, a 120cm, a 100cm and a 95cm custom wooden made (Error! Reference source not found.) and a OMER Cayman 95cm “Arbaletes” were set up. All weapons were equipped with a single or coupled circular power band in Dynatex (Power band Ø 14 mm).

Three hand rods were prepared: two in aluminium 3 metre long and a stainless steel one, 2.5 metre long, all with a diameter of 2.5 cm, at the end of which was acquitted a threaded stainless steel dice, which can hold a series of short harmonic steel (17-4 PH) 30 cm long spear, 7 mm in diameter.

The tip of the spear gun shaft was appropriately modified for the insertion of the different models of applicators provided by ICCAT (Error! Reference source not found.): for the applicator models "Bill fish", it was decided to drill into the 6,25 mm Ø and 6,50 mm Ø harmonic steal (17-4 PH) spearheads a hole, in which the applicators were firmly glued. To prevent an excessive subcutaneous penetration of the applicator, each shaft was equipped with a semi-rigid rubber stopper, large 2 cm Ø and 3 cm long. In order to avoid the sliding of the stopper during shooting causing an excessive penetration of the tag, it was decided to lock it on the shaft, through a thickness obtained along the shaft.

The tags, arranged in series of 20, were sewn onto a tape that was applied to the leg of the operator through a velcro, ensuring an easy access to the tags during the shooting phases. All the tags were sterilized with a water resistant disinfectant spray, just before the deployment.

On the chance that tags might be manually applied, the set included a large floating cradle for cetaceans and a couple of inflatable mattresses.

Recording system

The videos of the tagging were recorded using a Gopro video camera installed on the side of the speargun using a specific mounting bracket (Error! Reference source not found.). The video camera was set up with the following parameters:

- PAL system 48 frame per second
- Field of View (FOV) Ultra-wide
- Screen Resolution/Aspect Ratio 1920x1440 4:3

Analysis of video images

The estimate of tuna size had to be determined from the analysis of images coming from the video-camera mounted on the spear guns, defining an algorithm that compares images of tunas with those of 3D tuna models as well as with those of a graduated pole, taken from a given distance. Field trials had to be carried out during the fishing campaign.

In order to analyse images we adapted a Machine Learning approach that has been already applied to dual camera systems (Mariani *et al.,* 2013). In our case the analysis was performed on single images captured right before firing a tagging spear. Such a procedure, which is based on an Artificial Neural Network (ANN), can be “trained” to assess actual tuna size on the basis of information about apparent tuna size retrieved from the images.

The procedure requires that some assumptions are met to obtain accurate size estimates based on such a simplified set-up. In fact, we assumed that;

1. all tuna fishes are exactly identical in shape, while their size may vary;
2. the firing distance of tagging spears is constant and equal to the distance from which the graduated pole images used for calibration were shot;
3. tagging spears are always aimed at the centre of mass of the target tuna fish.

As the apparent shape of tuna fish that is about to be tagged may vary in each image, we used the apparent length and the maximum apparent width as predictive variables for actual length. Obviously, the apparent length varies depending on fish aspect, whereas the maximum apparent width is more strictly related to the actual size.

While the role these predictive variables may play is clear, the way they are related to the actual length of tuna fish may be captured by several types of models. The advantage of a Machine Learning approach and in particular of an Artificial Neural Network (ANN) is that the model structure is not to be specified in advance. In fact, an ANN learns from the examples that are passed to it and when fully "trained" it is able to behave according to what it learned. For instance, it might learn to assess tuna fish size on the basis of only two predictive variables.

In order to provide examples that an ANN may learn, not only the values of predictive variables must be known, but also the value of the target variable. In the tuna fish case, the target variable was the actual length. As the length of tuna fish specimens in the available images was obviously unknown, we had to use other images to train the ANN.

The only way to associate known lengths to images from which apparent size could be measured relied upon the generation of a 3D tuna fish models (Error! Reference source not found.), which were shaped using the available images as templates. This satisfied assumption 1, while assumption 2 was met by using the image of a pole of known length (2.5 m), captured from a distance that we assumed was equal to the usual distance from which tagging spears were fired (Error! Reference source not found.**6**).

The reference pole image was then used to scale 3D tuna fish models (Error! Reference source not found.**7**), setting the virtual lenses to the same focal length as the underwater camera mounted on the speargun (equivalent to 12 mm for a 35 mm film). 3D models were scaled to 7 different known lengths, namely equivalent to 135, 150, 155, 160, 165, 175 and 200 cm FL, and rotated in order to change their orientation and aspect several times in small increments. The outcome of this procedure was a set of 356 images, in which each one of the seven above-mentioned lengths of the 3D tuna fish model was the basis for about 50 different images.

While 267 of the available images were randomly assigned to ANN training, the remaining 89 were used as validation set. The ANN we trained was a multilayer perceptron with a 2-11-1 architecture and sigmoid activation functions both in the hidden and in the output layer. The training procedure was stopped as soon as the validation error began to increase and repeated several times up to 10^7 epochs. The best ANN was then selected according to its Mean Square Error (MSE).

4. Results

Activities started on 12th of June 2013, right after the closure of the BFT fishing season. The search of the schools of adult BFT to be tagged, was carried out according to the experience of the fishermen and their best knowledge on the major spots in the Tyrrhenian sea.

According to the information gained by the fishermen and their recent experience of BFT catch, the research for adult BFT focused in the Southern Tyrrhenian (Error! Reference source not found.**8**). Differently from the usual habits of the fishing campaigns, the screening of the spots was carried out without any support from other fishing vessels of the same fleet which is normally a key factor for the success of the fishing campaign.

The total amount of NM covered over the 14 days of activity was about 1455 NM and the average cruise speed of the vessel was approximately 9.5 knots, with an average of 12 hours/day spotting covering approximately 10.000 square miles.

Besides the many sightings of juveniles, over the campaign, two different schools of adult BFT were found and one of these was successfully caught by the purse seine on the 13th of June.

Catch and tagging operations

Considering the sighting on the 13th, the round weight range of individuals was 30-200 kg and the estimation of the total weight of the school was about 50 tons. Because of the bad sea conditions and the strong current it was decided to leave tunas in a very large portion of the purse seine (about 300 metres in circumference, corresponding to 100 metres in diameter and about 50 metres deep) with the purpose to minimize the risk of inducing any frantic behaviour of the fish school, avoiding as much as possible to increase the mortality rate for accidental entanglement.

After a first dive in which it was observed the quiet behaviour of the school, estimated on an average of 600 adult specimens, we started the tagging trials using a minimally invasive approach, through slow and silent free-diving descent (Error! Reference source not found.**9**), armed with the spear guns properly studied and developed.

Beyond all expectations, the school of fish turned to be more than just “collaborative”, small groups, driven on by curiosity, continued to approach to operators who, through silent glide dive, could easily direct the shot on the back of the tuna, which, in turn, reacted almost with indifference to the penetration of the tags. The ductility of the setting, allowed to quickly modulate the ballistics of the guns during the trial and the optimal compound was achieved by coupling a single circular power band, regardless of the length of the spear gun used. Gluing the applicator tip to the spear-shaft, enabled us to significantly speed up the replacement of the applicators, whenever was recorded the bending or breaking of the applicator’s needle.

This problem occurred mainly with the applicators "Bill fish small" whose thin needle turned to be too weak for the application of the tags using the spear gun.

The strategy planned by the team shortly before the start was guided by the primary need of a very conservative and “precautionary” approach in order to avoid any possible risk of frenzying reactions and eventual massive mortalities.

The shoots were placed at depths ranging from 6 to 15 metres from the surface. The setting of the spear gun chosen for the operations turned out to be optimal, allowing to place accurate shot at a distance between 1 and 2 meters, estimated from the tip of the applicator to the back of the fish. The slimness and the frusto-conical shape of the rubber annexe stopper, turned to be fundamental for a correct ballistics of the compound, ensuring a fair compromise between a good hydrodynamics and the relative accuracy of the shot, with a good stopping power during the phase of penetration of the applicator into the flesh of the marked fish.

The cameras mounted on rifles due to their small size, did not affect in any way the efficiency of the spear gun.
Unfortunately, after about six hours of tagging, a sudden further increase of bad sea conditions, particularly of the current, did not facilitate the action of the tender and whenever the purse seine lost its optimum circularity, the school began to swim frantically, causing the fatal entanglement of some specimens. It was very difficult to keep the net opened and, it was decided to release all the catches, including the tagged individuals, to avoid possible massive mortality; fortunately in this way losses were very limited (5 samples out of the 600 estimated samples of the school).

Despite of the difficult environmental conditions, it was possible to successfully tag and record 70 bluefin tuna with conventional tags:

- 7 small billfish
- 63 large billfish

Underwater videos of the tagging have been recorded. Every single tag has been associated with a single video of the tagging.

A series of underwater images of a graduated pole 2.5 metre long have been taken, at different measured distances of 1 – 1.5 – 2 m, to be applied in the set up of the model for size measurement.

Size evaluation

The ANN we trained allowed to explain as much as 83% of the variance of tuna fish length in the validation set, while MSE was 70.09. Errors in length estimates ranged from -19.97 cm to +17.59 cm, but 90% of them fell in the [-12.37 cm, +14.43 cm] interval and 50% of them in the [-4.93 cm, +5.76 cm] interval.

After further linear corrections, errors in the length estimates from the corrected model ranged from -18.66 cm to +20.22 cm (i.e. in a slightly wider range relative to the uncorrected estimates), but as much as 88% of the errors fell within the [-10 cm, +10 cm] interval, and about 50% of the errors fell within the [-5 cm, +5 cm] interval (**.**). While the linear correction improved the model performance in the central quantiles, the MSE grew about 10% larger (78.21) because of the outliers (**.**).

After this set-up phase, the routine measurements consisted in choosing a photogram per each specimen, measuring apparent length and width in terms of number of pixels, and passing those values to the ANN that model, whose output was the estimate of the actual linear length of the specimen.

5. Remarks and conclusions

Fishing activities and tagging

The application of a never-before-tried method, in such an extreme operational context as the one found on the field, has implied a discrete organizational effort, especially when, in order not to leave anything to chance, various series of tagging tools have been designed and customized. Among these, all those providing for the hand setting of the tag were discarded, such as poles or manual applicators, which for their use, would have entailed a considerable water restrictions for the fish swim, with potentially fatal consequences. The trials were also successful to answer all the concerns about the tunas behaviour in the purse seine and after the tag application. The bluefin tuna school in the purse seine was quite calm, keeping the typical round swim at about 10-15 m depth. Divers preferred to shoot without any scuba equipment, believing that free movements and reduced noise could be the best choice for a successful tagging, avoiding so any source of additional stress to the fish. The operations permitted to test several methods of tagging using different spear guns and tags. In particular the best tag applicator in relation to the shooting power and the best assembly of the cameras on the guns. From the technical point of view, therefore, both equipment as it was modified, and tagging strategy, turned to be suitable for the purpose of the project.

During the tagging campaign we experienced several approaches and methodologies that are now a good basis to provide recommendations for any future trial.

a) "small" tags applicators pins were not strong enough and turned out to brake easily. We therefore used the "Large" ones which never broke and, at the same time, caused no apparent harm to tunas;
b) we started using a speargun armed with two power bands. This approach turned to be over dimensioned, it is therefore enough to use a single power band. Other kinds of even simpler settings could be tried and tested. Arbaletes shot avoid any water turbulence that could adversely affect the quality of the first most important video frame of the tagging;
c) taking into account the quantity of juveniles BFT which have been sighted during the campaign, the possibility to use the same equipment to tag juveniles, could be considered. Nevertheless it should be considered very carefully that the reactions of small specimens to the approach of divers and shooting could be different respect to a large individuals;
d) the higher risk of entanglement for BFT in the seine is connected with the effects on the net of strong currents, which are very difficult to fight with tenders. Working in an open sea situation, the environmental conditions remain the more unpredictable factor for the success of the operations.

From the technical point of view, as said before, a good setting of equipment and tagging operations was achieved. Modifications and improvements can be eventually applied quite easily.

The strategy of fishing campaign is the focus point to be modified for the success of operations. Working with no reference point, i.e. information from other fishing boats operating at the same time in the same area, means to have no possibilities to search for tunas other than continuing to turn around in the areas traditionally known, as we did. Nevertheless in this situation uncertainty is too high and, as a matter of fact, only one day was devoted to the activities of fishing and tagging in 14 days of campaign, with a huge waste of time and money.

According to the experience gained in this trial, the use of an aircraft, flying for a few hours in the same area of the boat seems to be crucial to reduce drastically the spotting time. Once the school location is transmitted by the aircraft, the vessel can reach that point, saving time and reducing fuel and navigation costs. To avoid any possible problem, the campaign would start after the end of the official fishing campaign, and the aircraft would be duly identified by ICCAT.

Size evaluation

The ANN based approach for assessing tuna fish length from images captured during tagging seems a very promising solution. While ANNs are usually more effective than other computational methods in solving regressive problems, other tools can be tested in the future, and more data (i.e. more 3D model images) can be used. Further tests will allow to check whether these changes may really improve the accuracy of length estimates, but in the meantime good results can be already obtained from two simple measures derived from images captured by a speargun mounted camera, thus adding significant value to tuna fish tagging with almost no additional effort.

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Figure 1. The purse seine “Vergine del Rosario”.

Figure 2. Spearguns used during the trial (wooden and carbon fiber).

Figure 3. Tags and hand rods.

Figure 4. Video camera with mounting bracket.

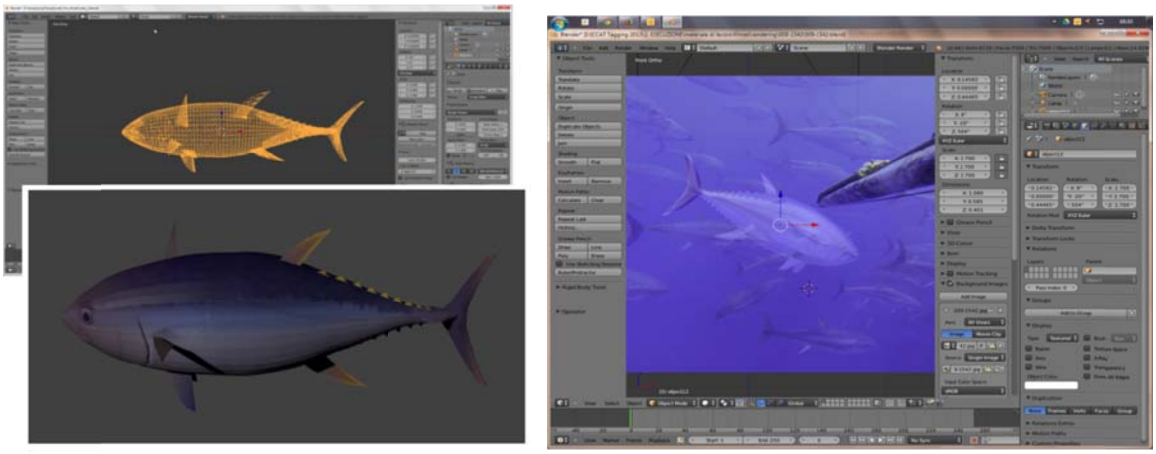

Figure 5. 3D tuna fish model generation - 3D model of the fish overlapped to a real image.

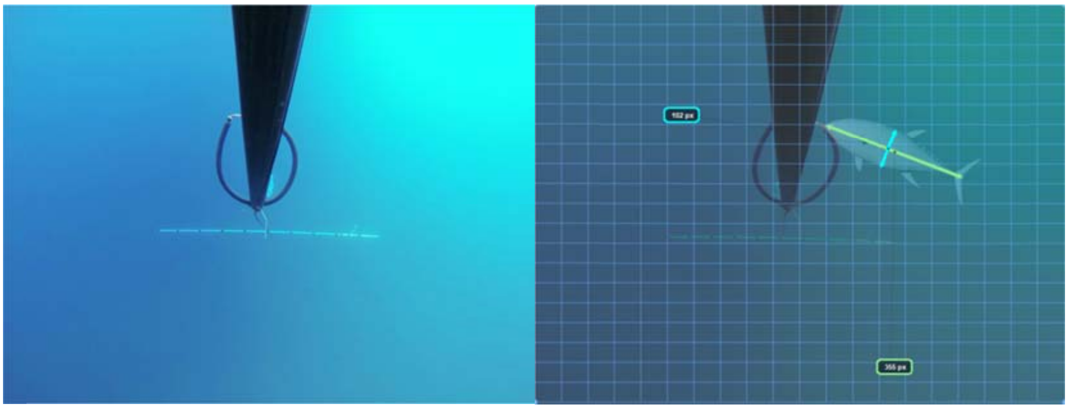

Figure 6. Image of a virtual fish near the graduated pole.

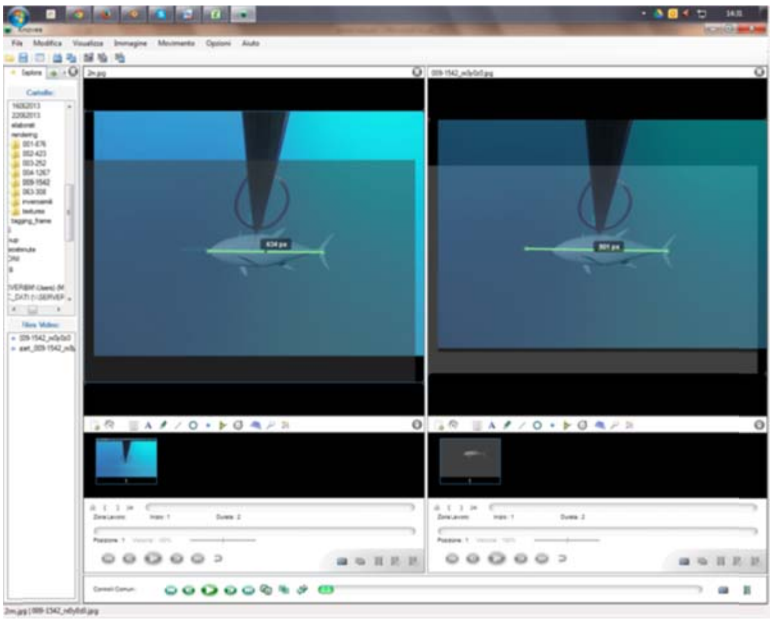

Figure 7. Scale 3D tuna fish models.

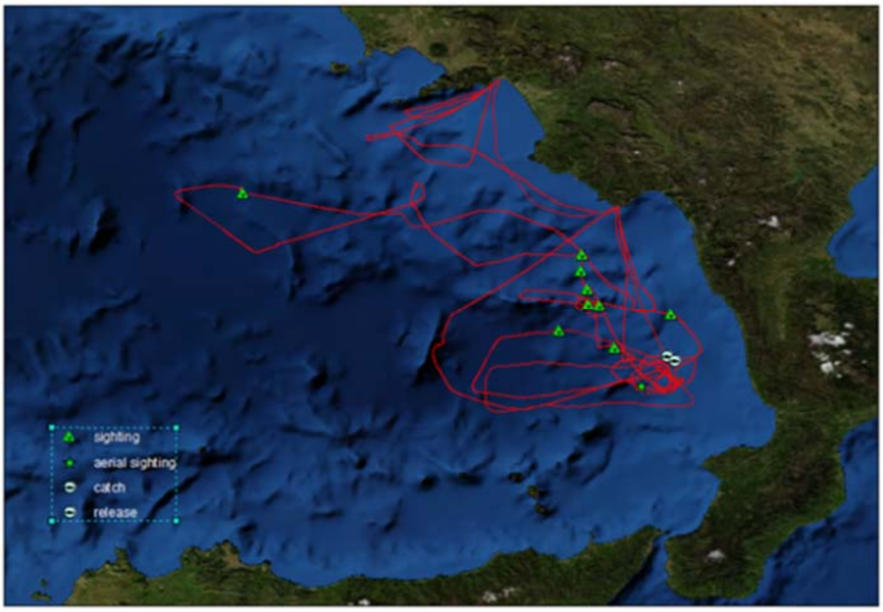

Figure 8. Vessel track and sightings.

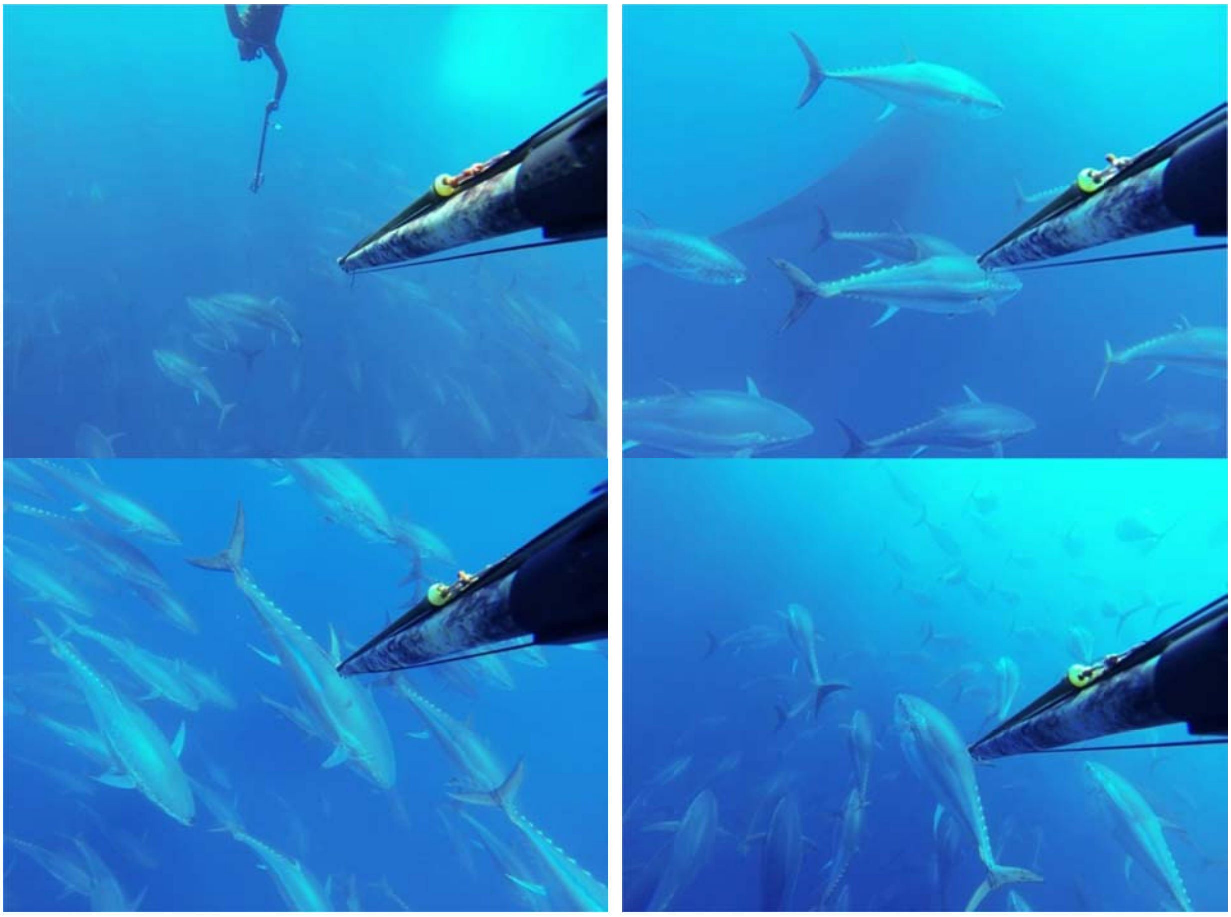

Figure 9. Vessel track and sightings.

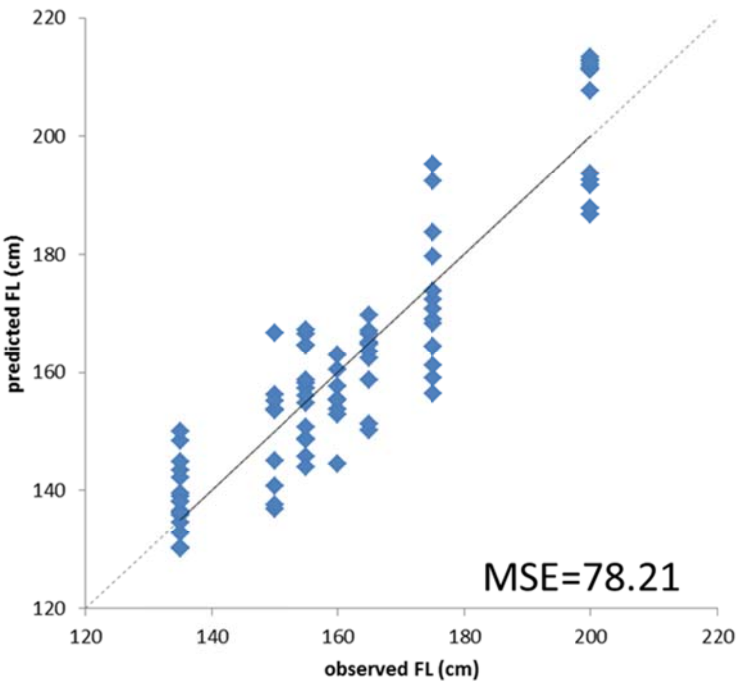

Figure 10. Observed vs. predicted FL values and Mean Square Error estimate after the linear correction.