CONVENTIONAL TAGGING OF BLUEFIN TUNAS IN THE TRAP FISHERY OF SARDINIA (W-MEDITERRANEAN): A CRITICAL REVIEW

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SUMMARY

In May-July 2013 the first conventional tagging of bluefin tuna by divers was conducted in the trap fishery of Sardinia (western Mediterranean). The Isola Piana and the Portoscuso trap, the last active traps in the Mediterranean Sea, were involved in the scientific programme. In order to adapt the fishing gear and the equipment for tagging, a few changes were needed at the earliest tagging design. Major changes regarded the use of modified speraguns, underwater action cameras, and the utilization of underwater laser pointers useful for size estimation of tunas. A comparative analysis was conducted to validate length estimations by direct method (photo referencing techniques) and indirect method (visual estimation of weight). A total of 208 bluefin tunas were tagged and released during four days of tagging. Finally, recommendations and technical advices have been proposed to improve the methodology for future tagging activities by traditional traps.

RÉSUMÉ

Entre mai et juillet 2013, le premier marquage conventionnel de thon rouge a été réalisé par des plongeurs dans la pêcherie de madrague de Sardaigne. Les madragues de Isola Piana et de Portoscuso, les dernières madragues actives en Méditerranée, ont pris part au programme scientifique. Afin d'adapter l'engin de pêche et l'équipement de marquage, quelques modifications ont été nécessaires lors de la toute première conception du marquage. Les principaux changements ont concerné l'emploi des fusils sous-marins et des caméras sous-marines modifiés, ainsi que l'utilisation des pointeurs laser sous-marins utiles pour estimer la taille des thonidés. Une analyse comparative a été réalisée pour valider les estimations de la longueur par la méthode directe (techniques de référencement des photos) et la méthode indirecte (estimation visuelle du poids). Un total de 208 thons rouges ont été marqués et remis à l'eau pendant quatre jours de marquage. Finalement, des recommandations et des avis techniques ont été formulés afin d'améliorer la méthodologie pour les futures activités de marquage des madragues traditionnelles.

RESUMEN

En mayo -julio de 2013, se llevó a cabo el primer marcado convencional de atún rojo realizado por submarinistas en la pesquería de almadrabas de Cerdeña (Mediterráneo occidental) Las almadrabas de Isola Plana y Protoscuso, las últimas almadrabas del Mediterráneo, participaron en el programa científico. Para adaptar el arte de pesca y el equipamiento para el marcado, se requirieron algunos cambios en la primera fase del diseño de marcado. Los cambios más importantes estaban relacionados con la utilización de arpones modificados, cámaras subacuáticas y la utilización de punteros láser útiles para la estimación de tallas de los túnidos. Se realizó un análisis comparativo para validar las estimaciones de talla mediante un método directo (técnicas de referencia fotográfica) y un método indirecto (estimación visual del peso). Se marcaron en total 208 atunes rojos, que se liberaron durante los cuatro días que duraron las actividades de marcado. Finalmente, se han propuesto recomendaciones y asesoramiento técnico para mejorar la metodología para futuras actividades de marcado en almadrabas tradicionales.

KEYWORDS

Bluefin tuna, Trap fishing, Tagging, Sardinia

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1. Introduction

Sardinia (western Mediterranean) is geographically included in the reproductive migration pathways of the Atlantic bluefin tuna. From late April until mid July tuna schools migrate along the western coastline in a southward direction, swimming closer to the bathymetric contour of 40 m and lower, where they have for centuries been intercepted by the local trap fishery (Addis *et al*. 2012). This fishery, the only remaining trap in the Mediterranean, together with Spanish, Moroccan and Portuguese traps, provides valuable scientific information about the status of the bluefin tuna population (ICCAT, 2012). This ancient method of fishing has today been included in some national and international scientific projects aimed to the monitoring of the biology and ecology bluefin tuna.

Within the Atlantic-wide research programme on bluefin tuna (ICCAT/GBYP – Phase 4), the first conventional tagging of bluefin tuna was conducted in May-July 2013 in this trap fishery. The project objectives were the estimation of the feasibility of tagging bluefin tunas in traps by divers and the develop a reliable estimate of sizes. The tagging programme effectively began on April 19, 2013 after the proposal was awarded by the ICCAT secretariat. Ad-hoc consortium composed by the Centro di Competenza sulla Biodiversità Marina (Com.Bio.Ma.), representing the leading scientific entity, the Carloforte Tonnare PIAM (Isola Piana trap), the Consociazione Tonnare Sardegna (Portoscuso trap) was established to accomplish the objectives of the project. This paper reports some results of the experimental trials conducted in two traditional traps where the original tagging design was adapted at the features of this fishing system.

2. Material and methods

Three technical meetings have been arranged to introduce and discuss on the tagging protocol, methodologies and equipment to use for tagging. An explicative guidebook has been distributed to the trap managers and to the chiefs of fishermen (Rais) to explain the purposes.

2.1 The trap fishery of Sardinia

Tagging activities were conducted at the Capo Altano or Portoscuso trap (39°14′ N; 08°22′ E), and the Isola Piana trap (39°11′ N; 08°18′ E) (**Figure 1**). The third trap active in southern Sardinia, that is the Porto Paglia, has not been used for tagging purposes because considering recent data this location has low productivity of tuna, probably due to lower environmental suitability for tuna migration (in shore position).

The Portoscuso trap (ICCAT number ATEU2ITA00009) is the oldest trap in Sardinia dated back to XVII century. It is deployed in Capo Altano at a depth of 38 m. Its main features are: five chambers, a tail 1500m long and the strong hydrodynamism of coastal waters. The Portoscuso trap is managed by the Compagnia Tonnare Sardegna.

The Isola Piana trap (ICCAT number ATEU2ITA00003) is deployed in the northern part of the island of San Pietro in the location known as Tacche bianche. It is the second oldest trap of Sardinia and nowadays the most productive one, it has a tail 1050 m long, five chambers settled at 42m depth. The trap of Isola Piana is manged by the Carloforte Tonnare PIAM srl which joint the Compagnia Tonnare Sardegna. Both traps have a crew composed by 25 fishermen.

2.2 Fishing season 2013

In late April 2013 the three traps were entirely operative and the first observation of entrapped bluefin tuna occurred on early May. It must be pointed out that starting from 2011 the fishing practice in Sardinian traps changed from the traditional system of capture tunas by "mattanzas" on-site, to the capture and caged of bluefin tuna alive in transporting cages for a tuna farm in Malta. Two cages are positioned adjoined to the death chamber (camera della morte) in each trap system. A specific waterway allows the transfer of tunas from the death chamber to the cage. Here, counting and videotapes of specimens are acquired for commercial purposes (biomass estimation) and to control the achievement of the quota.

In 2013 the quota assigned to the trap fishery by the Italian Ministry for Agriculture Policy and Forestry was 165 tons. During the fishing season the trap companies acquired 56.99 tons reaching a total quota of 221.99 tons. The full quota was completed on June 14 when a small mattanza of 5 tons occurred in the Portoscuso trap. Starting from this date the tagging operation began with experimental trials into the trap chambers.

2.3 Tagging protocol changes

Earliest tagging requirements consider the following points: a) tagging adult bluefin tuna from several hundred fish, possibly close to 1.000, depending on the remaining tunas kept in the traps; b) tag by divers directly underwater using a pole with tag applicators for spaghetti tags, small billfish tags and large billfish tags (FT1-94; FIM-96; BFIM-96); c) furnish proofs of tagging by a second diver equipped with an underwater stereoscopic camera and finally; d) estimate the length of each individual tagged by laser system.
In order to accomplish such requirements but adapting the protocol to the technical features of the trap array, few changes were needed in the equipment and the methods of entrapping tunas inside the chambers.

2.3.1 Trap description

The trap array in Sardinia (**Figure 2**) consists of nylon nets arranged in a tail and five chambers (from east to west): the "Grande" (120 m x 45 m), the "Bordonaro" (50 m x 45 m), the "Bastardo" (45 m x 40 m), the "Camera di ponente" (45 m x 40 m) and the "Camera della morte" (the "death chamber") (45 m x 30 m). Only the death chamber has a vertical moving net 'floor' (corpus) used to pull up bluefin tuna during the "mattanza". Once entrapped in the first chamber (the "Grande), tunas swim naturally from east to west chambers crossing the doors (a system of vertical nets with a large mesh size). Bluefin tuna unlikely swim in the reverse path, therefore specimens tend to concentrate into western chambers. Considering such features, the trap represents an optimal system for tagging large numbers of bluefin tuna by conventional tags in confined waters, but can be also useful for implanting electronic tags (De Metrio *et al*., 2003; Quílez-Badia *et al*., 2013), temperature logger (Addis at el., 2009) and direct visual estimation of abundances (Addis *et al*. 2013).

2.3.2 Handle-pole rejection

According to the expertise of the trap chiefs (Rais) and the scientific staff, the handle-pole tagging would be only suitable into the death chamber lifting tunas near the surface. Theoretically the net-floor (corpus) should go up at ~2 meters from the sea surface minimizing the volume of the death chamber and making available tunas to be hold for measurements and be tagged by a 2.5-3 meters handle-pole. Nevertheless, such procedure has been considered highly hazardous with a high risk of mortality caused by entangling and hypoxia of tunas (this will cause an intentional "mattanza"). In order to avoid such risks, the use of tagging by pole was rejected by the operational team.

2.3.3 Speargun tagging adoption

Tagging by spearguns removes previous difficulties because: 1) tagging occurs without handle tunas which remain free-swimming in a vital water depth and 2) tags can be shot from a reasonable distance (to be tested with specific trials).

Nevertheless the use of speargun requires : a) a remote system for the estimation of length b) a system for capturing tagging action, i.e. an action digital camera and c) the adaptation of the tag applicators to the speargun shafts.

Moreover, in order to facilitate tagging by divers, tunas should be entrapped in a small water volume. Considering the technical features of the five trap chambers, we excluded a-priori tagging operation in the chambers "Grande" and "Bordonaro" because tunas are generally too scattered. The options for tagging operations were:

- the "Bastardo" and the "Camera" (without the net-floor);
- the "Camera della morte" (equipped by net-floor)

Experimental tagging were carried out in both of the two groups of chambers. Here, tests of spearguns by SCUBA divers and free diving divers, were carried out.

2.4 Length estimation

2.4.1 Laser inter-distance validation

Underwater red laser pointers (650nm) were assembled on each speargun for the purpose of length estimation. The inter-distance of the coupled lasers was established in 9.0 cm. Inter-distance may be adjusted on each speargun by a system of calibration screw. Possible variability of the inter-distance among coupled lasers (i.e. red beams) was tested for each speargun at 1m, 3 m and 5 m (likely distances of shots/tagging). One-way ANOVA was applied to test differences in measurements among laser pointers. No-significant differences resulted in the test.

2.4.2 Direct length estimation (EFR)

Digital images were obtained by frames of the video recordings by the GoPro camera. Fork length (FL) was estimated by photo referencing techniques (EFR) using TpsDig2.14 for digital image analysis (Rohlf, F. J., 2009: TpsDig. Version 2.14). The inter-distance of laser beams was fixed in 9.0 cm, representing the primary scale reference on the tuna body. Image analysis was conducted independently by 2 readers, and the mean of the two measurements was calculated.
When laser beams were not detectable during image analysis, we used as scale reference the yellow spaghetti tag (7,5 cm in length) detectable in the frames of each tagged tuna.

2.4.3 Action camera

We used the GoPro Hero3, which is a waterproof camera to 197' (60m), capable of capturing ultra-wide videos and 12MP photos at a rate of 30 photos per second (Full HD). Optics are Ultra sharp $f/2.8$ 6-element aspherical glass lens and Ultra wide angle / reduced distortion. The camera was fixed and aligned on each speargun with a specific bracket.

2.4.4 Indirect length estimation (EWL)

In cases of failure in the photo referencing analysis, we used the weight estimation conducted by diver during each tagging action. It must be pointed out that professional divers of the traps are skilled in such operation since they use this practice for biomass estimation for commercial purposes, mainly during transfer of bluefin tuna from the death chamber to the transport cage (Addis *et al*., 2013).
Successively, the straight fork length (cm) was calculated using the Length/Weight relationship calculated for bluefin tuna captured in Sardinian traps in the period 1994-2007 (May-June; n=2800)

$$W = FL^{2.8171} * 0.000044300$$

2.4.5 Comparison of length estimation methods

Direct length estimation (EFR) and indirect estimation (EWL) were plotted as scatter diagram and regression line. The accuracy of the linear regression between measurements was tested at 95% of confidence interval by Passing and Bablok regression. Cumulative sum linearity test was performed to investigate possible significant deviation from linearity (p=0.05).

3. Results

Experimental tagging inside the trap chambers “Bastardo” and “Camera” resulted in low effectiveness in term of number of individuals tagged (n=9 for Isola Piana; n=28 Portoscuso). Inside these chambers, tunas are too scattered to be approached by divers for tagging by speargun.

The use of the “death chamber” has been appropriate for tagging by speargun (n=173 for Isola Piana). The net-floor kept at 5-7 meters leaves tuna flocks free-swimming and excluding any distress and risk of entangling. No mortality occurred during tagging operations. Finally, tagging by free diving is definitely more effective than SCUBA because air bubble seems to disturb tunas which kept away from divers.

A total of 208 bluefin tuna were tagged and released in four operational days (two days of tagging in the death chamber and two in the Camera/Bastardo). Tagging rate (fish tagged on fish entrapped) inside the death chamber was 40/110±25 (36%) on June 20 and 133/220±20 (60%) on July 2. Additional tagging of 39 specimens has failed because of technical problems with the steel applicators.

Size of individuals tagged is reported in **Figure 3** (size range 90-270cm – modal class 120cm). A total of 164 high resolution pictures were suitable for the photo referencing techniques. 123 individuals were sized by laser pointers methodology, while the remaining (41) using the yellow spaghetti tag as scale reference. It must be pointed out that laser beams were not detectable on digital images because of air bubble interferences, water turbidity and light overexposure. Last 85 individuals were sized by indirect length estimation.

The effectiveness of length estimation by direct and indirect methods is illustrated **Figure 4** and **Table 1**. The test of linearity showed no significant deviation from linearity (P=0.48). Since the test was not rejected, both methods have no significant difference and then the indirect estimation method can replace with the direct length estimation in the cases of failure in the photo referencing analysis.

4. Conclusion and recommendations

The first conventional tagging by speargun in the trap fishery of Sardinia has been a satisfactory experience. Progressive experimental trials have provided a significant advance of the methodology. During the last day of trials about 60% of the entrapped tunas (n=220) were tagged and released. The methodology for a reliable length estimation, after a difficult start, was developed in a satisfactory manner as confirmed by regression analysis.

In order to ameliorate the effectiveness of tagging by traps and spearguns, we suggest the following recommendations to be taken:

- applicator for the single barb spaghetti FT is not appropriate for speargun tagging: the applicator truncate the tag when penetrate into the tuna body;
- steel tip of the applicator for the double barb (FIM) breaks easily during shots: to improve the quality of stainless steel of the tip can avoid such problem;
- large Billfish applicator and tag (BFIM) have been ideal for tagging by spearguns;
- double tagging has been difficult when dissimilar tags were associated (i.e. FT + FIM and FIM + BFIM): the double tagging is feasible when two BFIM are associated in the harpoon;
- red laser (650nm) has proven partially effective for length estimation because sun-light overexposure and back light may interfere red laser beams; experiments with other wavelength laser may sole this issue;
- GoPro Hero3 has been proper for recordings the sequence of tagging, the video and photo quality (resolution) is functional for length estimation: the new GoPro 3D system could ameliorate the quality of video recordings and assimilating the system to the stereoscopic cameras.

Finally, we believe that the encouraging results and the critical aspects raised, have allowed to define significant basis for future tagging activities by traditional traps.

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Table 1. Passing and Bablok regression analysis between direct length estimation (EFR) and indirect estimation (EWL) of bluefin tuna tagged in the trap fishery of Sardinia.

Intercept A	-26.9
95% CI	-43.26 to -13.66
Slope B	1.18
95% CI	1.09 to 1.30
Test for linearity	No significant deviation from linearity (P=0.48)

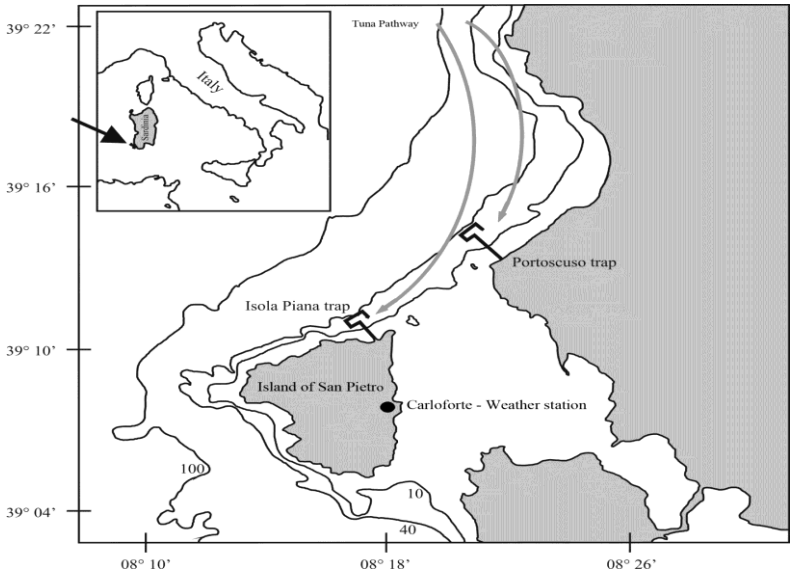

Figure 1. Location of the trap fishery of Sardinia (western Mediterranean) where tagging activities were conducted in 2013.

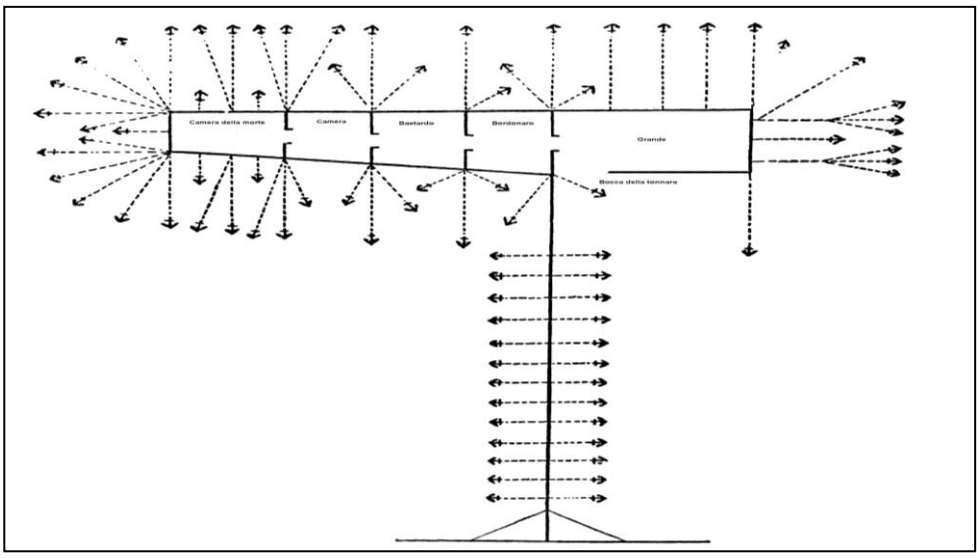

Figure 2. Scheme of the trap system used in Sardinia (five chambers).

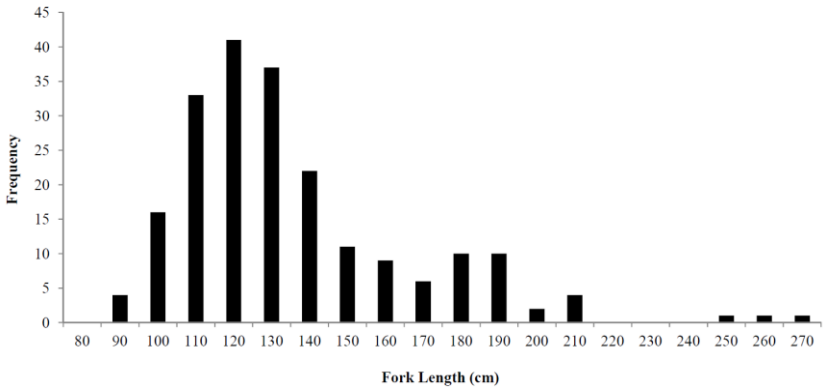

Figure 3. Size distribution of bluefin tuna tagged by speargun in the trap fishery of Sardinia.

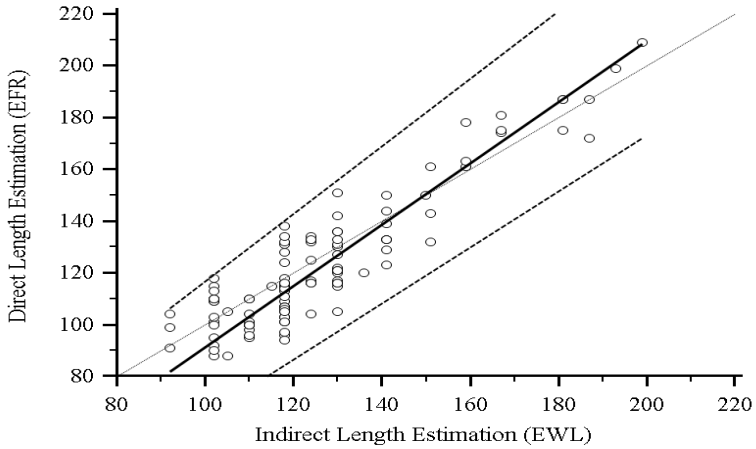

Figure 4. Regression analysis between direct length estimation (EFR) and indirect estimation (EWL) (n=112).