

## MOVEMENTS OF BLUEFIN TUNA (*THUNNUS THYNNUS* L.) TAGGED IN THE MEDITERRANEAN SEA WITH POP-UP SATELLITE TAGS

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### SUMMARY

*Although there have been several studies of the migratory movements of Atlantic bluefin tuna (*Thunnus thynnus*, L.) between the Western and Eastern Atlantic, the two-stock hypothesis remains untested and exchange rates are still unidentified. TUNASAT, an EU-funded research programme involving Italy, Spain, Greece and the UK, which was carried out during the three-year period 1998-2000 in the Mediterranean Sea and the Strait of Gibraltar, and a subsequent tagging program funded by the Italian Ministry of Agriculture and Forestry Policies, which was carried out during 2003 in the Eastern Mediterranean, aimed to better understand this problem. Both bluefin tuna tagging programs were executed using pop-up satellite tags. Results from both tagging programs indicated that adults < 100 kg remain in Mediterranean after spawning and feed in areas of high primary productivity, as indicated by SeaWiFS satellite data for chlorophyll-a concentration. After spawning large bluefin 150-230 kg migrate into the eastern North Atlantic, either south towards the Cape Verde Islands or north to Iceland and the Norwegian Sea. Some large bluefin move to and fro between the Alboran Sea and Atlantic, feeding on both sides of the Strait of Gibraltar. No evidence of transatlantic movement was observed.*

### RÉSUMÉ

*Bien que plusieurs études aient été consacrées aux déplacements migratoires du thon rouge de l'Atlantique (*Thunnus thynnus*, L.) entre l'Atlantique Ouest et Est, l'hypothèse de deux stocks demeure non vérifiée et les taux d'échange n'ont pas encore été identifiés. TUNASAT, programme de recherche financé par l'UE auquel participent l'Italie, l'Espagne, la Grèce et le Royaume-Uni, a été mené pendant la période triennale 1998-2000 en mer Méditerranée et dans le Déroit de Gibraltar, et un programme de marquage ultérieur, financé par le Ministère italien des Politiques Agricoles et Forestières, qui a été réalisé en 2003 dans l'Est de la Méditerranée, visaient à mieux appréhender ce problème. Les deux programmes de marquage du thon rouge ont été exécutés avec des marques pop-up reliées par satellite. Les résultats des deux programmes de marquage ont indiqué que les adultes < 100 kg demeurent en Méditerranée après le frai et s'alimentent dans des zones de forte productivité primaire, comme l'indiquaient les données par satellite SeaWiFS pour la concentration en chlorophylle-a. Après le frai, les gros thons rouges de 150-230 kg migrent vers l'Atlantique Nord-Est, soit en direction du Sud vers les îles du Cap-Vert, soit en direction du Nord vers l'Islande et la mer de Norvège. Certains gros thons rouges font le va-et-vient entre la mer d'Alboran et l'océan Atlantique, s'alimentant des deux côtés du Déroit de Gibraltar. Aucune preuve de déplacement transatlantique n'a été observée.*

### RESUMEN

*Aunque se han realizado numerosos estudios sobre los movimientos migratorios del atún rojo del Atlántico (*Thunnus thynnus*, L.), entre el Atlántico oriental y occidental, la hipótesis de los*

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dos stocks sigue sin haber sido comprobada y aún no se han identificado las tasas de intercambio. TUNASAT, un programa de investigación financiado por la UE, en el que participan Italia, España, Grecia y el Reino Unido, que se desarrolló durante un periodo de tres años, 1998-2000, en el Mediterráneo y el Estrecho de Gibraltar, y un programa de marcado posterior financiado por el Ministerio de Agricultura y Políticas Forestales de Italia, que se desarrolló durante 2003 en el Mediterráneo oriental, tenían como objetivo adquirir un mayor conocimiento de este problema. Ambos programas de marcado de atún rojo se llevaron a cabo con marcas "pop up" vía satélite. Los resultados de estos programas indicaron que los adultos <100 kg permanecen en el Mediterráneo tras reproducirse y que se alimentan en zonas de alta productividad primaria, tal y como indican los datos vía satélite de SeaWiFS sobre concentración de clorofila-a. Tras reproducirse, los atunes rojos grandes de 150-230 kg migran hacia el Atlántico nororiental, ya sea en dirección Sur hacia las Islas de Cabo Verde o en dirección Norte hacia Islandia y el mar de Noruega. Algunos atunes rojos grandes se desplazan de un lado a otro entre el mar de Alborán y el Atlántico, alimentándose en ambos lados del Estrecho de Gibraltar. No se observaron evidencias de movimientos trasatlánticos.

#### KEYWORDS

*Bluefin tuna, Migrations, Tagging, Pop-up tags, Pop-up archival tags, Mediterranean Sea*

## 1. Introduction

Although there have been several studies of the migratory movements of Atlantic bluefin tuna (*Thunnus thynnus*, L.) between the Western and Eastern Atlantic, the two-stock hypothesis remains untested and exchange rates are still unidentified (ICCAT, 1994, 2002).

TUNASAT, an EU-funded research programme involving Italy, Spain, Greece and the UK, which was carried out during the three-year period 1998-2000 in the Mediterranean Sea and the Strait of Gibraltar, and a subsequent tagging program funded by the Italian Ministry of Agriculture and Forestry Policies, which was carried out during 2003 in the Eastern Mediterranean, aimed to better understand this problem (De Metrio *et al.* 1999, 2001, 2002). Both bluefin tuna tagging programs were executed using pop-up satellite tags.

Specifically, the projects set out to identify and describe movements of this species both within the Mediterranean and between the Mediterranean and the Atlantic Ocean in relation to spawning and nursery areas, and to improve our understanding of the relations between fish behaviour and environmental characteristics.

Tagging in 2000 was carried out in conjunction with the Tuna Research and Conservation Centre, as part of the U.S. Coordinated TAG Programme; tagging in 2003 was conducted in co-operation with the University of New Hampshire (USA).

## 2. Material and methods

As regards the first tagging program (TUNASAT A), a total of 84 bluefin tuna (42-230 kg) were tagged in traditional traps (Sardinia, Spain) or pens (Spain), using an underwater gun or harpoon; during sport fishing (Corsica waters), using a T-shaped stick or hand-stick on deck; and during hand-line fishing for bluefin tuna (Aegean Sea), using a hand-stick on deck.

Pop-up satellite tags were: 61 single-point tags (PTT-100, Microwave Telemetry) and 23 archival tags (PAT, Wildlife Computers), programmed to pop-up from 5 to 300 days after the date of deployment.

A series of charts of chlorophyll-a concentration were plotted for the Tyrrhenian Sea close to Corsica and Sardinia (central Mediterranean) and the eastern Atlantic to the south of the Strait of Gibraltar, the two areas in which most of the tags surfaced. Data were extracted from the SeaWiFS database (Parrish, 1996; IOCCG, 1999). During the second program (TUNASAT B), a total of 43 bluefin tuna (31-155 kg) were tagged using a hand-stick on deck. The fish were taken from schools of bluefin captured by Turkish purse seiners in the Levantine Sea, or from pens located along the Turkish coast, in the Aegean and Levantine Seas, or on the north-eastern coast of Cyprus.

Pop-up archival satellite tags were: 20 PTT-100 (Microwave Telemetry) and 23 PAT tags (Wildlife Computers), programmed to pop-up from 34 to 300 days after the date of deployment.

### 3. Results

In the framework of TUNASAT A, allowing for 6 tags recovered from recaptured fish, Argos detection rates were 21% (12/57) for PTT-100 tags and 62% (13/21) for PAT tags. Comparable detection rates obtained by US scientists in the western Atlantic were 56-93%. Among 25 detected tags, 23 transmitted valid data. Most of the tagged bluefin tuna were located in the Mediterranean Sea (70%), 13 of them with size of 42-100 kg and 3 with size of 150-170 kg. The rest of the tagged specimens (30%) were located in the eastern Atlantic Ocean and these tuna weighed between 150 and 230 kg.

Concerning TUNASAT B, Argos detection rates were 75% (15/20) for PTT-100 tags and 91% (21/23) for PAT tags, with a total detection rate of about 84% (36/43). No messages were received by ARGOS from 7 tags (5 PTT-100 and 2 PAT tags) on the programmed dates. Several tags transmitted valid messages but with a certain percentage of missing or corrupted data. Most of the tagged bluefin tuna were located in the Eastern Mediterranean (94%), showing a tendency to remain in probable feeding areas. Only two fish moved towards the central Mediterranean: one surfaced southeast of Malta, the other in the Bocche di Bonifacio, between Corsica and Sardinia.

The positions of the pop-up satellite tags deployed in the Mediterranean Sea in the framework of the TUNASAT A and TUNASAT B tagging programs are shown in **Figure 1**.

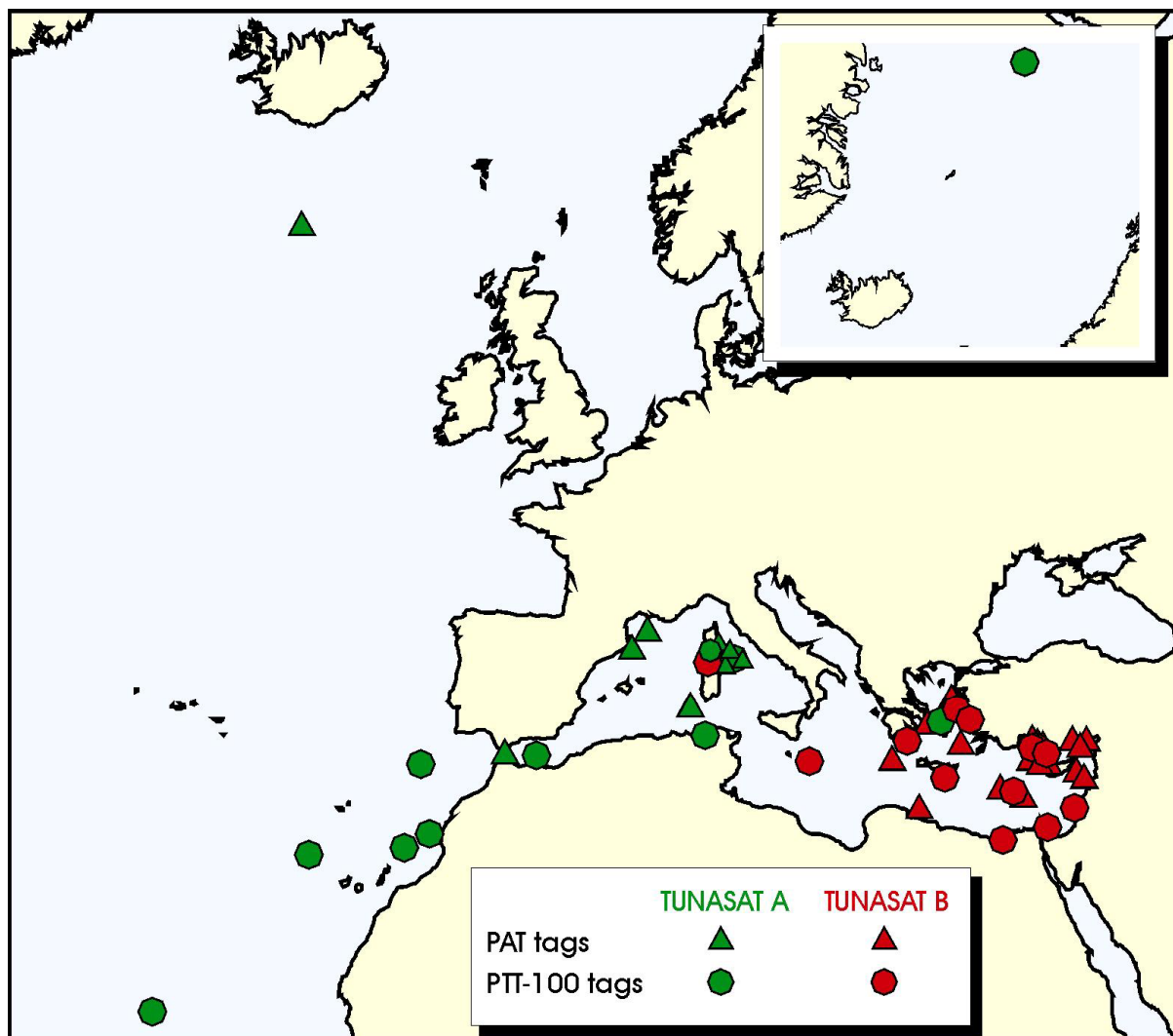
### 4. Conclusions

Because of the low detection rates experienced during the original project, a series of tag detection tests were carried out in several European sites and in the USA. Results clearly indicated that there is a problem with tag detection in the Mediterranean, especially with PTT-100 tags, which are less powerful than PAT tags. This problem almost certainly prevented us detecting tags that otherwise surfaced successfully on the programmed date. Our ability to detect and locate tags was certainly much less in the Mediterranean than it was in the eastern Atlantic and probably also much lower in the eastern Atlantic than it was in the western Atlantic.

Results from both tagging programs indicated that adults < 100 kg remain in Mediterranean after spawning and feed in areas of high primary productivity, as indicated by SeaWiFS satellite data for chlorophyll-a concentration. After spawning large bluefin 150-230 kg migrate into the eastern North Atlantic, either south towards the Cape Verde Islands or north to Iceland and the Norwegian Sea. Some large bluefin move to and fro between the Alboran Sea and Atlantic, feeding on both sides of the Strait of Gibraltar. No evidence of transatlantic movement was observed, despite a progressive increase in the probability of tag detection across the Atlantic from east to west.

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**Figure 1.** Pop-up locations of the satellite tags deployed in the Mediterranean Sea in the framework of the TUNASAT A and TUNASAT B tagging programs carried out during 1998-2000 and on 2003.