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Fifty years of dart tag recoveries for tropical tuna: A global comparison of results for the western Pacific, eastern Pacific, Atlantic, and Indian Oceans

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A B S T R A C T

Over the last 50 years, numerous dart tagging programs have been conducted on tropical tunas worldwide. Through these programs more than 1.4 million tunas have been tagged across the Pacific, Atlantic, and, most recently, Indian Oceans with the majority of individuals tagged being skipjack (*Katsuwonus pelamis*, 858,000 individuals) and yellowfin tuna (*Thunnus albacares*, 360,000 individuals). The subsequent recovery of 173,574 tagged tunas (skipjack: 94,835, yellowfin: 49,079, and bigeye, *Thunnus obesus*: 29,660) presents a significant opportunity to obtain a wide range of scientific results. In this paper, we used recovery data from a variety of programs to compare the growth rates from the period between tagging and recovery of three tropical tuna species from four oceanic regions. We also analyzed the maximum time durations between tagging and recovery events as an indication of each species' longevity, as well as apparent movement patterns and distances traveled by the tuna. Collectively, these comparisons revealed major similarities between tropical tuna species of the basic biological parameters studied. In some instances, our analysis also revealed that the same species show major differences between areas. In addition, this paper also examines the current interest in conducting large-scale, simultaneous tagging of the three tropical tuna species and highlights the importance of improving the quality of recovery data. In particular, there need is paramount to increase the percentage of recoveries that have been fully validated in terms of the fishing zone, recovery date, length and sex of the tagged tunas. Our assessment suggests that large-scale, multi-species tagging programs should become a routine scientific obligation for all tuna regional fisheries organizations, as they are necessary in providing the basic parameters of all stock assessment models.

1. Introduction

Although the tagging of tropical tunas began in the early 20th century (Alverson and Chatwin, 1964), the majority of tagging has occurred since the early fifties. The outputs of the various tagging programs are commonly used by scientists and tuna regional fisheries organizations (RFOs) at their relevant geographical scales to improve understanding of tropical tuna stocks. However, despite the widespread regional use of recovered tag data, no global comparisons have been made. In this paper, we compared the main results from tropical tuna tagging programs worldwide in the current context of increasing global fishing pressures on tropical tuna stocks. This comparison was based on the analysis of tagging and recovery data gathered across three ocean basins and sourced from the four tuna tagging programs. The geographical areas and the relevant commissions which run the tagging programs were:

- the eastern Pacific Ocean (EPO) run by the Inter-American Tropical Tuna Commission (IATTC),
- the western Pacific Ocean (WPO) run by the Secretariat of the Pacific Community (SPC). This international organization has 26 member countries, mainly island countries, and works across the WPO on a wide range of fields, including fisheries. The tagging program run by this regional multidisciplinary commission has been very active in developing tuna statistics, running investigations, and tagging since the early 1970s, well before the creation of the Western and Central Pacific Fisheries Commission (WCPFC) established in 2004.

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- the Atlantic Ocean run by the International Commission for the Conservation of Atlantic Tuna (ICCAT), and
- the Indian Ocean run by the Indian Ocean Tuna Commission (IOTC).

We have limited the focus of this study to dart tag information collected for the three tropical tuna species (skipjack, *Katsuwonus pelamis*, yellowfin, *Thunnus albacares*, and bigeye, *Thunnus obesus*). Dart tags are still used in large numbers by the major tuna tagging programs and they remain an essential tool as they return unique data which are indispensable for tuna stock assessments. Furthermore, since the majority of electronic tagging results are widely scattered and their sources are often kept confidential, incorporating such results would be extremely difficult and/or impossible. Our comparison focused on a review of the apparent movements of tropical tunas and their growth, basic biological parameters that can be estimated from tag recovery data. Due to the lack of detailed fisheries data, this study did not attempt to use the statistical models that are often used in the analysis of recovery data (Kleiber et al., 1987; Sibert and Fournier, 1994; Adam et al., 2003). In addition, key metrics developed by each of the tagging programs, such as reporting rates, shedding rates, and mortality due to tagging, are briefly compared and discussed. Finally, we examined the current scientific interest in dart tagging programs and optimal conditions of future tagging programs conducted on tropical tuna.

2. Materials and methods

Firstly, we created a dataset of basic fisheries metrics (total yearly catch, catch at size by gear, and catch by gear and by species ($5^\circ \times 5^\circ$)), which we obtained from the online databases of the various tuna commissions (ICCAT, IATTC, IOTC), and from the SPC. This dataset was used indirectly in the interpretation of the tag recovery information.

The second most important dataset we created combined tagging and recovery information: the yearly number of tags released by species for each ocean region and the detailed records of all recovered tunas for each area. The date and position of tagging and recovery events were noted where they were known. We obtained this data for each region from the following sources (and for the following time periods):

- Atlantic Ocean: ICCAT online database (1970–2010),
- Indian Ocean: IOTC online database (1990–2010; as available in Sep 2012),
- EPO: IATTC records that have been made available for this study with strict confidentiality rules (1960–2010), and the
- WPO: SPC records have been made available for this study with strict confidentiality rules (1970–2006). Since 2007, a large number of tagged tuna have been released by SPC but these records are still in the process of being analyzed and were not available for this analysis.

Although these records all contain very similar components (e.g., tagging and recovery dates, tuna sizes, and geographical positions), their format and individual details tend to be quite different between each dataset. Consequently, in compiling the global dataset, our first step was to standardize the data from each of the four data sources. It is also important to note that although this global dart tag dataset incorporates the majority of available data obtained for tropical tunas worldwide, it does not include data from some national and sub-regional tagging programs. These include programs conducted by Japan, the United States (near Hawaii), Australia and other countries, but this component of missing tagging data can be assumed to account for a very small percentage compared to the data available.

The tag recovery data are key to undertaking this comparative analysis. The recovery data corresponds with tags that have been returned by fishermen and reported to their relevant sources (noting that an unknown proportion of recovered tags are not reported). The tag recovery files contain information on both tagging and recovery. For each tuna tagged, it specifies species, size, geographical position (in degrees and minutes), and tagging date with quality codes. For each tuna recovered, it specifies when available species, size, position (in degrees and minutes), and recovery date. Frequently, some of this information is missing and/or noted with a degree of uncertainty. SPC and IOTC sometimes estimate and identify this uncertainty, but ICCAT and IATTC records provide much less information. An a posteriori quality control completed on these datasets showed that the recovery information often contained a significant percentage of errors (i.e., wrong size, recovery date, or fishing location). We compared the proportion of recoveries defined as 'well documented' (in terms of recovery date, position, species and size) between regions, as this is a very important parameter for evaluating the success of tagging programs. Visible errors were sometimes corrected on a case by case basis. Otherwise we selected recoveries with good date and position data (for movement studies) and recoveries with good date and size measurement data (for growth studies). Finally, recoveries with suspiciously high or low growth rates estimated in each ocean were eliminated, keeping data with growth rates between the 0.01 and 0.99 quantiles. These values were assumed to be due to sampling errors, e.g., measurement errors or errors in the calculation of tag duration at sea. We assumed this elimination would not introduce a bias into the comparative analysis of growth rates.

The apparent growth rates between tagging and recovery were estimated by simply calculating the average monthly growth rate during the period between tagging and recovery and assigning this growth rate to the mean size of this period. An uncertainty of the average growth at size was estimated, assuming a normal distribution of these values. This method has already been used by various scientists, including Schaefer et al. (1961) and Fonteneau and Gascuel (2008), and enabled us to do simple, but relatively realistic comparisons of the apparent growth rates at size at recovery for several species in different oceans. We note, however, that complex statistical models, such as that proposed by Laslett et al. (2002), should be used on a case by case basis to analyze the growth of tagged fishes.

To determine tuna movements between tagging and recovery, we calculated the distances that were traveled by the tuna from the linear distance between the position at tagging and the position at recovery. We calculated the distance between points of release and recapture to examine movement patterns of tagged tunas. The average linear displacement per month at liberty (the distance from release to recapture divided by the time at liberty) across the tagged fish by species was used as a conservative measure of the range of movement.

3. Results

3.1. Trends in catch in global tropical tuna fisheries

Stable or declining catches have been observed in tropical tuna fisheries during recent years in most oceans, mainly due to the fact that most stocks are at levels of full exploitation (Fig. 1). During recent years (2001–2010), surface fisheries (mainly purse seiners fleets) caught large quantities of skipjack, as well as a wide range of sizes of yellowfin and bigeye, most frequently from inter-tropical areas (Fig. 2). In contrast, during a similar time period (1997–2006)