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Lessons learned from implementing three, large-scale tuna tagging programmes in the western and central Pacific Ocean

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ABSTRACT

In the western and Central Pacific Ocean mark-recapture experiments have been an integral part of monitoring tuna stocks since the late 1970s. The data from tagging campaigns have been included in stock assessments since the 1980s and in integrated analyses since the late 1990s. Ensuring that tagging experiments are implemented in a manner that satisfies the incorporation of the data in stock assessment is important to maximize the return on investment. We review three large scale tuna experiments implemented in the western and central Pacific Ocean to synthesize the lessons learned so that future tagging programmes can save considerable time and money, and maximize the quantity and quality of the data needed to obtain more accurate and precise assessments of stock status. We highlight particular knowledge gaps that require further attention, and suggest some approaches, both technological and methodological, from which future studies could benefit in order to improve our understanding of tuna biology.

1. Importance of tunas to Pacific Ocean pelagic ecosystems, fisheries and economies

Oceanic fisheries of the tropical Pacific Ocean are dominated by four tuna species: skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*), bigeye (*Thunnus obesus*) and albacore (*Thunnus alalunga*). These species represent over 90% of the Pacific catch taken by industrial fishing fleets, and 70% of the estimated global tuna catch, or just over 4 million metric tonnes (mt) in 2010 (FAO, 2013). The remainder of the catch mostly comprises Pacific bluefin tuna (*Thunnus orientalis*), billfishes (marlin and swordfish) and oceanic sharks (Sibert et al., 2006). The four tuna species are distributed throughout the tropical and temperate waters of the Pacific Ocean, and the tropical purse-seine and pole-and-line fisheries (referred to collectively as the "surface" fishery), which target skipjack, yellowfin and bigeye tunas, dominate the total catch and tend to be concentrated in the far western and eastern regions of the Pacific (Harley et al., 2013). Skipjack dominates the total catch of tunas, and almost all skipjack catches are taken by surface fisheries (especially the purse-seine fishery) together with young yellowfin tuna. The subsurface longline fishery targets mature bigeye and yellowfin tunas in equatorial waters. According to the Western and Central Pacific Fisheries Commission and the Inter-American Tropical Tuna Commission, the fisheries for these tuna resources are approaching the maximum sustainable yield and, in some cases (e.g. bigeye), appear to have exceeded this level (ISSF, 2013). The fishing of these apex predators has led to hypotheses proposing changes in ecosystem structure (Pauly et al., 1998; Myers and Worm, 2003; Worm et al., 2006) and species distribution (Worm and Tittensor, 2011). The supporting evidence for these hypotheses is limited (Hampton et al., 2005; Maunder et al., 2006; Sibert et al., 2006) although increasing (Polovina et al., 2009; Polovina and Woodworth-Jefcoats, 2013). In the western and central Pacific Ocean (WCPO), tunas represent the greatest shared natural resource of Pacific Island countries (PICs). Tuna fishing is estimated to contribute US$260 million to PICs combined gross domestic product, and provide over 12,000 jobs to Pacific Islanders (Gillett, 2009). For most PICs, the licence fees obtained from distant water fishing nations to harvest tunas from their exclusive economic zones represent between 10% and 42% of all government revenues (Gillett, 2009).

2. Tuna tagging and its role in the management of Pacific Ocean tuna stocks

Tagging studies are commonly used in fisheries research (Pine et al., 2003) to improve estimation of animal population size, mortality, movement (spatial stock structure) and growth. The general objective of these studies is to establish an "experimental"

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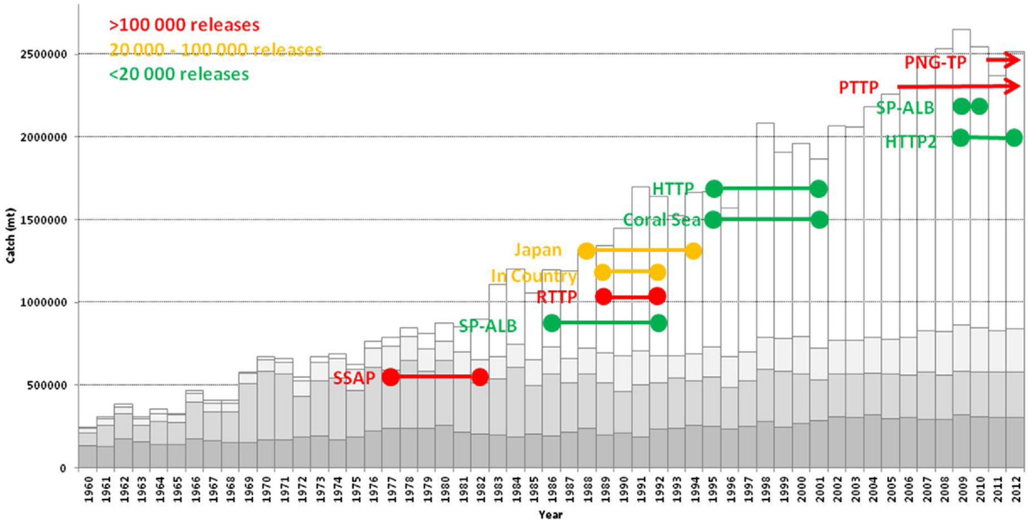

Fig. 1. The duration of tuna tagging programmes undertaken in the western and central Pacific Ocean using conventional tagging as the primary technique since 1978. SSAP = Skipjack Survey and Assessment Programme; SP-ALB = South Pacific Albacore; RTTP = Regional Tuna Tagging Project; In Country = tagging programmes undertaken by member countries of the Secretariat of the Pacific Community; Japan = Japanese Tuna Tagging Project; HTTP = Hawaiian Tuna Tagging Project; Coral Sea = electronic tagging of bigeye in the Coral Sea; HTTP2 = electronic tagging of yellowfin and bigeye in Hawaii; PTTP = Pacific Tuna Tagging Programme; PNG-TP = PNG Tuna Tagging Project. Ghosted on the background are the annual catches (metric tonnes) by gear (shading from darkest grey to white arelongline, pole-and-line, other and purse-seine, respectively).

sub-population of individuals tagged with numbered tags that can then be monitored and modelled over time through recaptures by the fishery. Mortality rates and population size can then be estimated on the assumptions that: (i) tagged individuals are subject to the same processes and behave in the same way as untagged individuals; (ii) the probability of subsequent capture of a tagged individual (in the particular spatial area and time period under consideration) is the same as that for an untagged individual; and (iii) tag losses due to tag shedding, tagging-induced mortality, and non-reporting of recaptured tagged fish are negligible or can be separately estimated (Hampton, 1997, 2000). Experimental designs and/or analytical corrections are applied to enable these assumptions to be met. For example, it is desirable to release tags widely over the area under consideration in order to meet assumption (ii) above. Size-structured (or age-structured as a proxy for size) modelling approaches (e.g. Hampton, 2000) can be used to address non-compliance with assumption (ii) if the size distribution of tagged fish differs from that of the catch of the fishery. When the above assumptions are met, tagging data have the potential to provide highly relevant information for stock assessment, either by way of stand-alone analyses (Brownie et al., 1985) or, preferably, through integration with other data directly in the stock assessment model (Hampton and Fournier, 2001).

Tagging data have been included in WCPO stock assessments for skipjack tuna since 1987 (Kleiber et al., 1987), and since 1992 for yellowfin tuna (Hampton, 1992), and since 1996 for South Pacific albacore (Bertignac et al., 1996) and bigeye tuna (Hampton et al., 1998). Since 2001, tagging data have been included routinely in WCPO tuna stock assessments using the integrated assessment model MULTIFAN-CL (Hampton and Fournier, 2001). While catch and size data are collected annually in the WCPO, tagging has been episodic (Fig. 1). The first large-scale tagging programme implemented by the Secretariat of the Pacific Community (SPC) was the Skipjack Survey and Assessment Programme (SSAP), which was carried out between 1977 and 1981 (Kearney, 1983; Kleiber et al., 1987). The main purpose of this tagging effort was to better understand the migrations and stock structure of skipjack tunas to determine the degree to which fisheries in different areas exploit the same stock and interact with each other. During this period, the annual surface catch, mostly taken by pole-and-line vessels, was approximately 500,000 mt, with the longline fishery taking 200,000 mt (mostly yellowfin tuna). Between 1989 and 1992 a second large-scale tagging programme, the Regional Tuna Tagging Project (RTTP) was implemented by SPC (Kaltongga, 1998). It was initiated in response to the continued expansion of the skipjack and yellowfin fisheries in the WCPO during the 1980s, primarily through the rapid growth of the purse-seine fishery (Fig. 1), and aimed to provide data for the assessment of skipjack, yellowfin and bigeye stocks. The WCPO tuna fishery has continued to expand since the RTTP, with annual catches now approximately 2,500,000 mt (Fig. 1). In 2006 SPC began its third large-scale tagging project, the Pacific Tuna Tagging Project (PTTP), to update the data used in the assessments of skipjack, yellowfin and bigeye stocks. PTTP tagging is scheduled for completion in 2013, and expects to tag over 400,000 tunas. A number of additional smaller tagging programmes were implemented in the WCPO between the RTTP and PTTP (Fig. 1). These programmes have typically tagged fewer than 20,000 tunas and have had restricted geographical coverage. Overall, nearly 800,000 tunas have been tagged in the WCPO, with the three large-scale tagging projects conducted by SPC contributing about 83% of this total. Each of the large-scale projects has tagged tunas throughout the equatorial WCPO, and recoveries have correspondingly been reported from across the equatorial WCPO (Fig. 2).

3. Objectives of this review

The collective experience from three large-scale tuna tagging projects in the WCPO over 40 years provides "a reference" for such research activity. We synthesize this information to identify and document the lessons learned, so that future tagging programmes can save considerable time and money and maximize the quantity and quality of the data they obtain. This will help to support more accurate and precise assessments of stock status. We also highlight particular knowledge gaps that require further attention, and suggest some approaches, both technological and methodological, by which future studies may improve our understanding of tuna biology.