

**PACIFIC TUNA TAGGING PROGRAMME – PHASE 2:  
WESTERN AND CENTRAL PACIFIC**

**Prepared by the WCPFC Regional Tagging Project Steering  
Committee**



WCPFC Regional Tagging Project Steering Committee

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## Executive summary

This document proposes the creation of a Pacific Tuna Tagging Programme (PTTP) consisting of (i) the recently completed PNG Tuna Tagging Project (Phase 1); (ii) a new tagging project in the equatorial western and central Pacific Ocean (WCPO) that is the main subject of this proposal (Phase 2); and (iii) a series of sub-regional or national projects implemented under the umbrella of the PTTP by national fisheries agencies in sub-tropical or temperate waters, and by the Inter-American Tropical Tuna Commission (IATTC) in the eastern tropical Pacific. The goal of the PTTP is **to improve stock assessment and management of skipjack, yellowfin and bigeye tuna in the Pacific Ocean.**

The objectives of the Phase 2 project are (i) to obtain data that will contribute to, and reduce uncertainty in, WCPO tuna stock assessments; (ii) to obtain information on the rates of movement and mixing of tuna in the equatorial WCPO, between this region and other adjacent regions of the Pacific basin, and the impact of FADs on movement at all spatial scales; (iii) to obtain information on species-specific vertical habitat utilisation by tunas in the tropical WCPO, and the impacts of FADs on vertical behaviour; and (iv) to obtain information on local exploitation rates and productivity of tuna in various parts of the WCPO.

To achieve these objectives, the Phase 2 project will undertake conventional, archival and acoustic tagging of skipjack, yellowfin and bigeye tuna throughout the equatorial WCPO (10°N–10°S; 120°E–130°W). A chartered commercial pole-and-line vessel suitably modified for tagging will operate for 20 months primarily in the western part of this region (west of 180°). One or more chartered smaller vessels (possibly Pacific Island-based longliners) will undertake shorter cruises of 1–2 months in the central Pacific, targeting bigeye tuna by handling on drifting fish aggregation devices (FADs), oceanographic moorings and seamounts. The feasibility of an eastern Pacific-based baitboat pole-and-line fishing in the central Pacific will also be investigated.

The implementation of measures to maximise the return of recaptured tags will be crucial to the success of Phase 2 and of the PTTP in general. Wide publicity, attractive rewards, lotteries, in-country tag-recovery officers and tag-seeding experiments will be conducted to achieve (and verify) high rates of tag reporting. Tag releases and returns will be processed and stored in an established database. Tag-return data will be cross-checked against other data sources (logsheets, vessel monitoring systems) to verify reported data and estimate missing data. Established and new methods will be used to analyse the data.

The PTTP will be jointly managed by the Western and Central Pacific Fisheries Commission (WCPFC) and the IATTC through the PTTP Steering Committee. The Phase 2 project in the WCPO will be implemented by the Secretariat of the Pacific Community Oceanic Fisheries Programme (SPC-OFP). **A total budget for this Phase 2 project of USD 9.8 million** is proposed. Contributions of USD 2.4 million have already been identified, leaving **USD 7.4 million to be raised**. Subject to the results of the project, consideration should be given to maintaining a continuous tagging effort throughout the Pacific Ocean as a means of providing ongoing fishery-independent information for tuna stock assessments.

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# 1 Introduction

## 1.1 Background

The tuna fishery in the western and central Pacific Ocean (WCPO) produces approximately half of the world's tuna and is of high economic importance to Pacific Island Countries and Territories. Throughout the WCPO, total annual catches of target tuna species (skipjack, yellowfin, bigeye and albacore tuna) are now over two million metric tonnes (mt). The fishery comprises a variety of fishing activities, the most important of which are the industrial-scale purse seine, longline and pole-and-line fisheries. Large catches are also made by numerous small fishing vessels employing a variety of fishing methods in the Pacific Ocean waters of Philippines and Indonesia. While the overall fishery is distributed widely from about 40°N to 40°S, by far the majority of the catch occurs in equatorial waters between 10°N and 10°S, and west of 180° (Figure 1). In this region, catches are dominated by purse seiners (Figure 1), which catch mainly skipjack and yellowfin tuna, with a smaller catch of bigeye tuna (Figure 2). Purse seiners have two main operational modes – setting on free-swimming (or unassociated) schools of skipjack and medium-large yellowfin; and setting on schools associated with floating objects such as drifting logs and anchored or drifting fish aggregation devices (FADs). These associated sets tend to catch larger quantities of small yellowfin and bigeye tuna. Longliners target large bigeye and yellowfin tuna in this region and at higher latitudes.

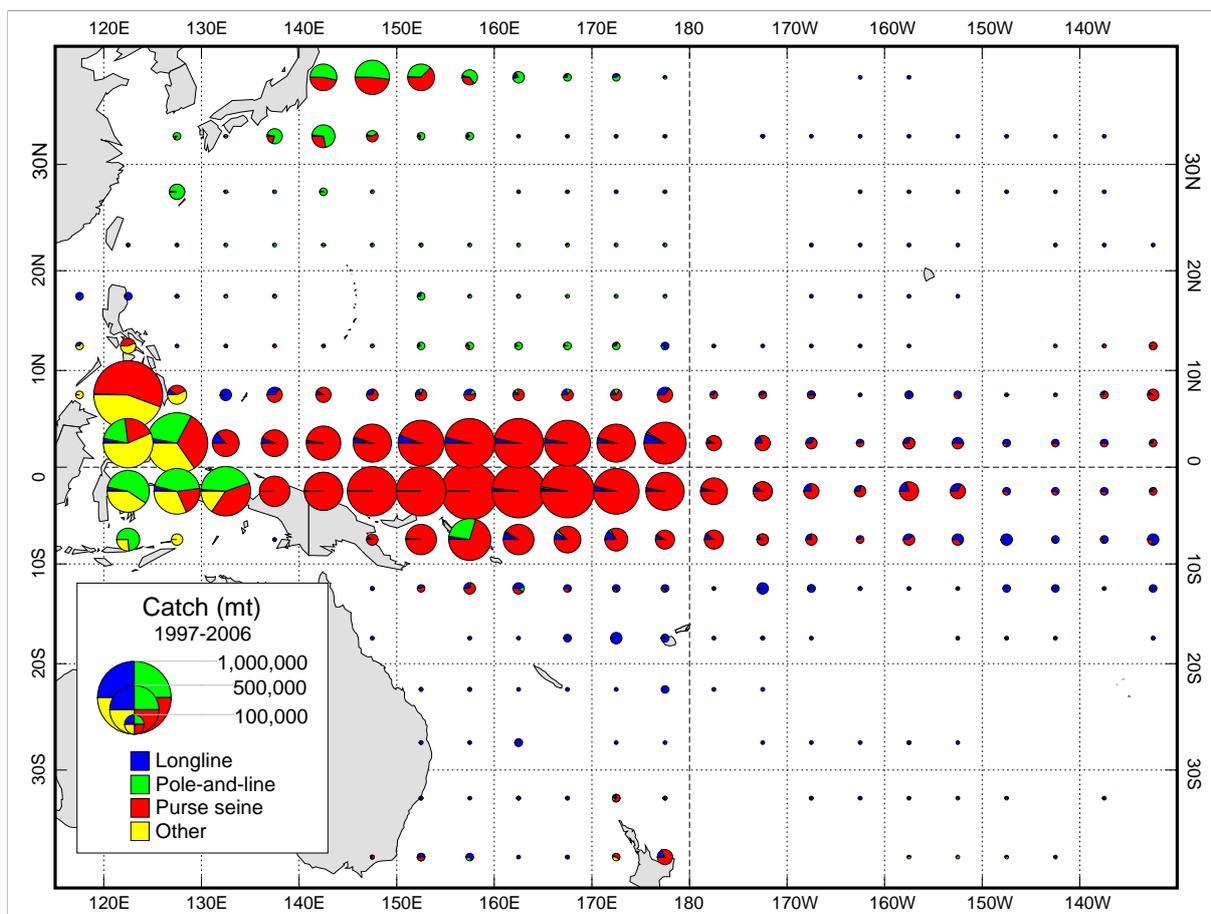
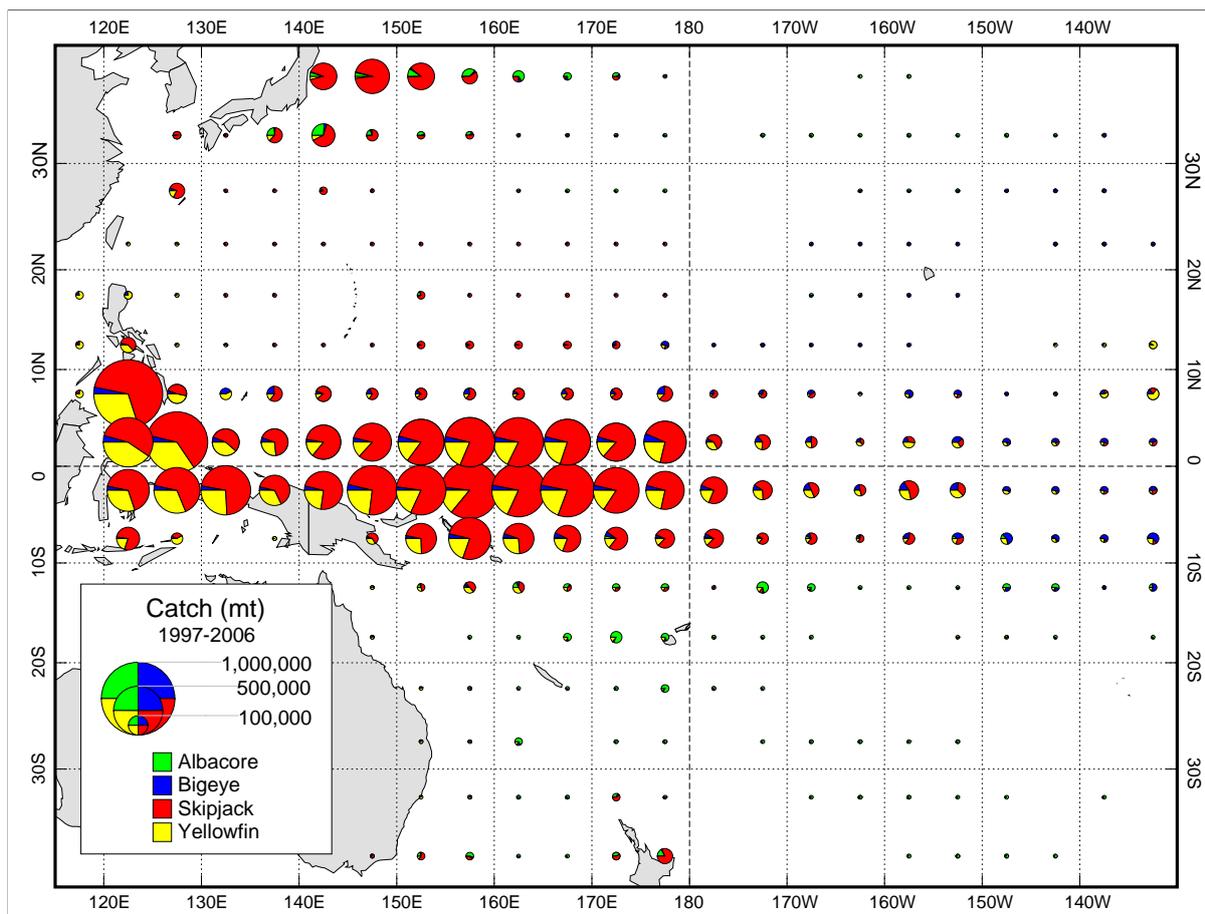


Figure 1. Total catch of tuna by gear in the WCPO, 1997–2006, in 10° cells.



**Figure 2. Total catch of tuna by species in the WCPO, 1997–2006, in 10° cells.**

The rapid increase in catches of target tunas in the equatorial WCPO over recent decades (Figure 3) has increased the need for effective management strategies to be designed to ensure sustainable exploitation and conservation of these important resources. Regular assessments of the status of skipjack, yellowfin and bigeye tuna stocks<sup>1</sup> are undertaken by the Secretariat of the Pacific Community’s Oceanic Fisheries Programme (SPC-OFP), on behalf of the Western and Central Pacific Fisheries Commission (WCPFC). While the current skipjack tuna harvest is considered sustainable, serious concerns regarding the status of yellowfin and bigeye tuna stocks, particularly in this equatorial region of the WCPO, are beginning to emerge.

The WCPFC Strategic Research Plan<sup>2</sup> outlines a strategy for obtaining the necessary scientific information to support management decision-making. It identifies four overall research and data collection priorities: (1) collection and validation of data from the fishery; (2) monitoring and assessment of the ecosystem; (3) monitoring and assessment of stocks; and (4) evaluation of management options. Fishery-independent information is critical for undertaking the latter two tasks with the necessary rigor. The Plan acknowledges the important role of tagging experiments as a method for collecting fishery-independent data for stock assessment and the evaluation of management options for highly migratory species:

<sup>1</sup> See the Scientific Committee meeting web pages, Stock Assessment Specialist Working Group section, on <http://www.wcpfc.int>

<sup>2</sup> [http://www.wcpfc.int/pdf/Research\\_Plan\\_2007\\_2011.pdf](http://www.wcpfc.int/pdf/Research_Plan_2007_2011.pdf)

*“Tagging is an important tool for biological and behavioural studies of fish and has special importance in the assessment of highly migratory fish stocks (HMS). Stock assessments for other types of fish (e. g. small pelagic and demersal species), benefit greatly from “fishery independent” survey data, which provide information on population size independent of data from the commercial fishery. Such survey data can potentially reduce the bias and uncertainty in the stock assessments. Unfortunately, routine scientific survey methods are not applicable to HMS because of the large geographical scales and resultant costs. Tagging studies on all scales are the closest approximation to fishery independent data currently available to support WCPFC management activities. Tagging studies provide information on rates and direction of movement, mortality, habitat utilisation, aggregation and vulnerability, all of which are directly used in the stock assessments.”*

Two successful large-scale tagging projects have been previously conducted by SPC in the WCPO. The Skipjack Survey and Assessment Programme (SSAP) was carried out in the late 1970s and early 1980s, and demonstrated for the first time the very large productivity and exploitation potential of skipjack tuna (Kearney 1983; Kleiber et al. 1987). The Regional Tuna Tagging Project (RTTP) was carried out in the early 1990s, providing an update of information on skipjack tuna as well as important new information on the dynamics of yellowfin and bigeye tuna (Kaltongga, 1998). Both projects produced a wealth of data that are still used in present-day assessments for these species<sup>3</sup>. Final recapture rates of the SSAP and RTTP (4% and 12.5% respectively) are a simple but telling indication of increasing exploitation rates over time. More recently, sub-regional tagging projects have been conducted in Hawaii (by the University of Hawaii) and in the EPO (by IATTC). Further details of these projects and the data generated are provided in Annex 1.

Since the conclusion of the RTTP, catch and effort, particularly in the purse seine fishery, have continued to increase. The purse seine fishery has become more reliant on the large-scale deployment of drifting FADs, and in some areas, anchored FADs. FAD technology has developed rapidly, with some operators deploying satellite buoys with integrated echosounders on drifting FADs, which they are able to interrogate remotely to estimate the quantities of tuna aggregated. These developments have greatly increased the efficiency of purse seining, increasing catches of skipjack and incidentally increasing catches of small yellowfin and bigeye tuna also. However, the extent of efficiency increase is difficult to quantify as there is little information available on the dynamics of tuna attraction and residence on FADs. The scientific and management problems associated with FADs are common to large-scale tuna fisheries in all ocean basins.

The need for a new regional tuna tagging project in the WCPO, and in the Pacific Ocean generally, in the light of these developments in the fishery has long been recognised. Successive meetings of the Standing Committee on Tuna and Billfish, and more recently the first two meetings of the WCPFC Scientific Committee (SC), have recommended that a new large-scale tagging project on all three species (but with particular attention to yellowfin and bigeye tuna) be carried out to reduce uncertainty in the assessments. Similar recommendations have been made by the IATTC’s Working Group on Stock Assessment<sup>4</sup> in respect of the eastern Pacific Ocean (EPO). Such a project would involve the large-scale tagging of

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<sup>3</sup> Tagging data are used in two ways in WCPO tuna stock assessments: (i) as direct data inputs that influence the model estimates via a likelihood function component for the tagging data; and (ii) as the basis for framing structural assumptions in the model, e.g. relating to stock structure, natural mortality-at-age, etc.

<sup>4</sup> See <http://www.iattc.org/PDFFiles2/SAR-8-Meeting-report.pdf>

skipjack, yellowfin and bigeye tuna throughout the area of operation of the major fisheries for these species in the WCPO (Figure 1). The goal of the project would be to improve stock assessment and management of skipjack, yellowfin and bigeye tuna through the provision of information on a range of biological processes, including medium- to large-scale movement, fishing and natural mortality rates (and their variability with age or size), growth, habitat utilisation, and the impact of FADs on population dynamics, behaviour and vulnerability to fishing.

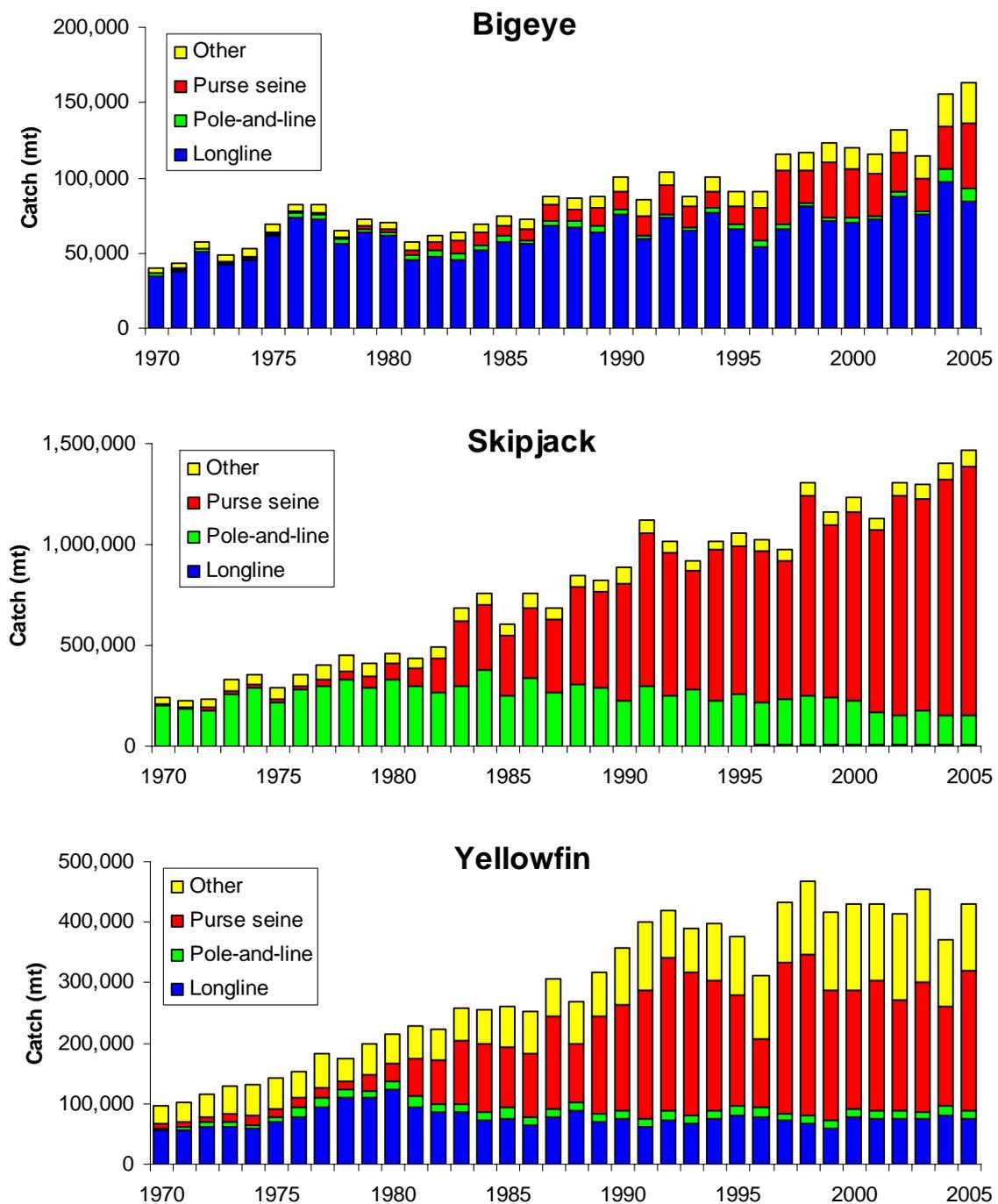


Figure 3. Catch (mt) of bigeye, skipjack and yellowfin in the WCPO, by gear type.

In order to better understand the dynamics of the WCPO tuna fishery, particularly the effects of large-scale FAD deployment on skipjack, yellowfin and bigeye tuna, the SPC, in partnership with the National Fisheries Authority (NFA) in Papua New Guinea (PNG) conducted a tagging project in PNG national waters from mid-2006 to mid-2007 (see Annex 1 for further details). The purpose of this project was to provide critical information on the impact of FADs on tuna population dynamics and vulnerability to purse seining, and to improve estimates of population parameters required for regional stock assessments.

## **1.2 A new “Pacific Tuna Tagging Programme”**

The vision that is articulated in this proposal is that of a Pacific Tuna Tagging Programme (PTTP). The PTTP would consist of a series of regional, sub-regional or national projects. The PNG project would constitute Phase 1 of the PTTP. The main body of funded activity presented in this proposal is for a regional project focused on the equatorial WCPO. This is referred to as Phase 2 of the PTTP. While not part of the funding package that is developed here, the proposal strongly encourages other national or sub-regional projects to affiliate with the PTTP. In order to meet certain Pacific-wide objectives, a closely-coordinated sub-regional project in the EPO is an essential component of the PTTP.

The WCPFC has strongly supported the Phase 2 project, and has established a Steering Committee to, *inter alia*, “develop a project proposal for the Phase 2 extension of the SPC/PNG tagging project to other areas of the WCPFC and develop a long-term plan for a tagging project in the Pacific Ocean”. The current proposal has been developed by the Steering Committee for use in attracting the necessary funding support for Phase 2 and to guide further planning and implementation. The proposal also creates an umbrella, the PTTP, under which collaborative Pacific-wide tagging can be coordinated and implemented to achieve common objectives. While the Phase 2 project, as framed in this proposal, is of fixed duration, many scientists believe that more continuous tagging activity, rather than short-term projects of decadal frequency, would provide a much better approach to providing fishery – independent data for tuna stock assessments. We believe that this approach merits serious consideration by both the WCPFC and the IATTC.

## 2 Goal and objectives

The goal of the Pacific Tuna Tagging Programme is **to improve stock assessment and management of skipjack, yellowfin and bigeye tuna in the Pacific Ocean.**

The specific objectives of Phase 2 are:

1. **To obtain data that will contribute to, and reduce uncertainty in, WCPO tuna stock assessments.** Conventional tagging data are an important component of tuna stock assessments, providing quasi-fishery-independent information on various biological and fishery processes, such as exploitation rates, natural mortality, movements and growth rates, and their spatial and temporal variability.
2. **To obtain information on the rates of movement and mixing of tuna in the equatorial WCPO, between this region and other adjacent regions of the Pacific basin, and the impact of FADs on movement at all spatial scales.** This information is important for understanding the relationship of tuna stocks in the tropical WCPO with those in the sub-tropical WCPO and the EPO. Movement rates are particularly important for assessing the potential for interaction between fisheries operating in different areas. The comparison of tagged fish movements from areas of high FAD density with tagged fish movements from the same areas in the early 1990s (before extensive FAD deployment) will provide important new information on the meso- to large-scale effects on tuna movement of high-density FAD arrays. This will allow various hypotheses regarding the impact of FADs on the movements of small tuna, e.g. the “ecological trap” hypothesis (Marsac et al 2000), to be tested. The movement data will also provide critical information on appropriate spatial structuring of stock assessment models.
3. **To obtain information on species-specific vertical habitat utilisation by tunas in the tropical WCPO, and the impacts of FADs on vertical behaviour.** Vertical habitat utilisation plays a large role in determining vulnerability to all major gear types operating in the fishery. This objective seeks to characterise the effect of FADs (anchored and drifting) and other possible impactors (e.g., seamounts) on tropical tuna vertical behaviour and habitat utilisation. This information will allow better estimation of abundance indices and standardised effort for the main fisheries and possibly contribute directly to the design of management measures for FAD fishing.
4. **To obtain information on local exploitation rates and productivity of tuna in various parts of the WCPO.** Knowledge of local exploitation rates, productivity and movements is important for understanding the impact of fishing at more local scales. In particular, it allows estimation of the extent to which current catch levels may reduce the standing stock of tuna and the catch-per-unit-effort of the fisheries, a phenomenon commonly known as “local depletion”.

Objectives, activities, outputs, outcomes and assumptions are summarised in a logical framework format in Table 1. Examples of specific management questions or issues that will be addressed by the project are given in Table 2.

**Table 1. Logical framework table – objectives, activities, outputs, outcomes and assumptions.**

<b>Goal: To improve stock assessment and management of skipjack, yellowfin and bigeye tuna in the Pacific Ocean</b>				
<b>Objectives</b>	<b>Activities</b>	<b>Outputs</b>	<b>Outcomes</b>	<b>Assumptions</b>
1. To obtain data that will contribute to, and reduce uncertainty in, WCPO tuna stock assessments	Conventional tuna tagging; tag recovery; tag seeding, data analysis & modeling	Conventional tag release and recapture data and estimates of tag-reporting rates provided for stock assessment models; estimates of growth rates and their regional variability	More accurate & precise estimates of stock status, recent fishing impacts; assessment of management alternatives based on improved scientific information	Suitable tagging vessel(s) can be chartered;  Fishing success is similar to previous large-scale tagging projects;  Industry & Governments cooperate in the return of tags;
2. To obtain information on the rates of movement and mixing of tuna in the equatorial WCPO, between this region and other adjacent regions of the Pacific basin, and the impact of FADs on movement at all spatial scales	Conventional tuna tagging; archival & acoustic tagging; tag recovery; data analysis & modeling	Estimates of movement rates and the impacts of FADs on movement	Appropriate, science-based assumptions relating to stock structure incorporated into stock assessment;	Regional/national observer programmes can be used to conduct tag seeding on purse seiners;  Archival & acoustic tags perform to specifications;
3. To obtain information on species-specific vertical habitat utilisation by tunas in the tropical WCPO, and the impacts of FADs on vertical behaviour	Archival & acoustic tagging of all three species associated with anchored & drifting FADs, and in other school types; tag recovery; data analysis & modeling	Species-specific depth distributions for FAD and non-FAD associated tunas; ambient temperature impacts on depth distribution; ontogenic changes in depth distribution	Improved purse seine and longline CPUE standardisation; science-based management plans for FADs; improved parameterisation of habitat preferences for use in stock assessment models	Regional and national tuna fisheries management authorities take appropriate actions on the basis of new information
4. To obtain information on local exploitation rates and productivity of tuna in various parts of the WCPO	Conventional tuna tagging; tag recovery; tag seeding; data analysis & modeling	Conventional tag release & recapture data, estimates of tag-reporting rates provided for fine-scale spatial models (such as SEAPODYM); estimates of local exploitation rates, levels of local depletion, fishery impacts	Improved science-based plans for management of tuna fisheries at the national level	

**Table 2. Examples of important management issues addressed by proposal.**

Management issue	Current scientific resources	The role of fishery-independent tagging data in resolving issue	Relevant WCPFC Convention text
1. What are current exploitation rates across the WCPO and what is the likelihood that they are sustainable?	The only source of independent data is from the early 1990's and consequently current estimates of exploitation rate assume that the relationship between this independent data and fisheries catch data remain unchanged. Preliminary information from Phase 1 (PNG EEZ) of this project indicates that this assumption is not justified.	Tagging data will be used to estimate exploitation rates for each species at the WCPO and within management zones. This information is critical for the Scientific Committee (SC) to determine whether current levels of fishing are likely to lead to significant population decline.	The collection of tagging data will be integral to the WCPFC achieving the following management measures and performance indicators.
2. Are there spatial differences in population dynamics (e.g. growth) that would warrant assessment and management being undertaken on a sub-regional basis?	Earlier tagging data did not detect differences in growth and consequently can provide only marginal input into identifying regional differences. Some age-growth data from fish otoliths exist but do not provide the precision to address this question.	Tagging data will be used to estimate regional age and growth functions jointly with existing and future age-growth data from fish otoliths. This information is critical for the SC to determine importance of regional differences and provide advice for region-specific management.	5. Conservation and Management measures that support long-term sustainability & optimum utilisation of highly migratory fish stocks in the Convention Area are adopted on the basis of the best scientific information available (Articles 5a,b,g,h, 12.1 and 12.2).
3. Has the extensive deployment of FADs since the 1990s altered age specific fishing and natural mortalities?	The earlier 1990's tagging data was collected when FAD deployment was minor in comparison to current deployment rates. No other WCPO fishery independent data exists to estimate these rates. Consequently current estimates of age specific fishing & natural mortality assume that the relationship between this independent data and fisheries catch data remain unchanged. The expansion of the purse seine fleets that target FADs and smaller sized individuals caught with this method since this data was collected indicates that this assumption is unlikely to be justified.	Tagging data will provide estimates of growth, age specific fishing and natural mortality for input into stock assessment models. When used jointly with the data from the 1990s and the catch data, the precision in stock assessment will be substantially improved in addition to the ability to include FAD effects. This will provide necessary information to the SC and regional authorities for developing FAD policies.	P.I. The information, advice and recommendations to the Commission by the SC in accordance with the research plan recommended to the Commission constitute the best scientific information available (Article 12.2a).
4. Are the current management zones defined for WCPO stock assessments valid given the expansion of FAD based fishing and environmental change?	Estimated movement between management zones in current stock assessments is independently informed only by the earlier tagging data which was collected prior to the rapid expansion in FAD deployment. Research from other oceans indicates that FADs alter localised behaviour. Unknown if increased FAD density has alter larger scale behaviour & no WCPO information available.	Data on movement patterns provided by a well-designed, WCPO wide tagging programme will provide a basis for determining the current stock structure of all species tagged. This information is critical for the SC to determine importance of regional differences and provide advice for region-specific management.	7. Impacts on target stocks, non-target species and species belonging to the same ecosystem or dependent upon or associated with target species managed effectively by the Commission (Article 5 a and d).
5. Has the extensive deployment of FADs created sink zones for tuna stocks?	Information is available that demonstrates altered behaviour around FADs in the EPO and Indian Ocean that potentially increases individual susceptibility. Unknown if this applies at a population/stock level. Some WCPO information will be available for PNG (Phase 1). However this data will require expansion to allow generality to be drawn over the WCPO regions.	Tagging data will provide the information necessary to determine the movement patterns and residency of fish at FADs and to examine the interactions between FADs. This will provide necessary information to the SC and regional authorities for developing FAD policies (e.g. value of time based closures).	P.I. The capability of the SC to assess the impacts of fishing, other human activities and environmental factors on target stocks, non-target species and species belonging to the same ecosystem or dependent upon or associated with target species (Article 5d).

## 3 Tag release design

### 3.1 Tag types

Three general tag types will be used to address project objectives: conventional dart tags, and implanted archival and acoustic tags. Large quantities of conventional tags will be needed to provide meaningful levels of data to estimate horizontal movement, fishing mortality, natural mortality and growth rates (objectives 1, 2 and 4). Tags, which may be of different sizes according to the sizes of tuna being tagged, are implanted in the dorsal musculature using stainless steel applicators. The tags<sup>5</sup> bear a legend including a unique serial number, project identification and contact details.

Depth- and temperature-sensing archival tags<sup>6</sup>, implanted in the body cavity, will be used with all three tuna species to define vertical habitat utilisation by region and changes in behaviour and vulnerability caused by association with FADs, floating objects and seamounts (objective 3). Light-based geolocation archival tags will also be used and can provide estimates of daily positions, usually with an accuracy of two degrees of latitude and one degree of longitude or better in equatorial waters (Schaefer and Fuller 2002). Such information will contribute to the understanding of meso- to large-scale mixing rates and regional fidelity (objective 2). Archival tag data may also be analysed concurrently with conventional tag and other data in spatially-structured models to estimate mortality rates and other population processes (objectives 1 and 4).

Light-based geolocation by archival tags is not sufficiently accurate to determine with certainty if a tuna is associated with a FAD or not. Tagging using depth-sensing acoustic tags in conjunction with FAD or seamount equipped receivers<sup>7</sup> of limited range (receivers record both the presence of a tagged tuna and its depth distribution whilst in range of the receiver) can provide finer-scale positions and depth-distribution data when the tagged tuna is known to be associated with a FAD. Such tagging in association with anchored FADs has been successfully trialed in Hawaii (Dagorn et al. 2006) and during the Phase 1 PNG project. During Phase 2, acoustic tagging of tuna associated with drifting FADs will be incorporated into the tag-release strategy through the double tagging of tuna with an archival and an acoustic tag. Drifting FADs will be deployed from and their position remotely monitored by the tagging vessel. Double tagging will allow known periods of FAD association to be identified in the archival tag depth and geolocation data should the tag be recaptured and returned. Sonic tagging will contribute to objective 3. In combination, the archival and sonic tagging will also provide useful information on short-term spatial mixing of tagged fish (objective 2); such information will assist in determining appropriate spatial and temporal scales for the conventional tagging analyses, and in particular the framing of structural assumptions regarding short-term post-release mixing.

External pop-up satellite-transmitting archival (PAT) tags are useful to monitor large-scale movements of fish where the likelihood of recapture is low as is usually the case for

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<sup>5</sup> See <http://www.hallprint.com/1327/1354.html>

<sup>6</sup> See <http://www.lotek.com/ltd.htm>, <http://www.wildlifecomputers.com/Products.aspx?ID=34>

<sup>7</sup> See <http://www.vemco.com/>

large billfish and some shark species. Due to their high individual cost and the generally high recapture rates anticipated for archival tags, we do not plan to utilise PAT tags to any great extent in this project. However, we will consider requests from researchers who wish to supply such tags for deployment on an opportunistic basis (see also section 3.10).

### **3.2 Target species**

Skipjack, yellowfin and bigeye tuna will be the species targeted during the Phase 2 project. Because of their different spatial distribution to the tropical tunas, albacore will not be a target species of Phase 2<sup>8</sup>. The three species of tropical tunas will be accorded approximately equal priority; however, operationally it is known on the basis of previous experience that special arrangements will be required to tag bigeye tuna in significant numbers throughout the area of interest.

### **3.3 Fishing methods and constraints**

Pole-and-line fishing is the method of choice for large-scale tagging programmes because of the ability to supply large quantities of tuna in good condition for tagging. In the western tropical Pacific, Japanese-style live bait pole-and-line vessels are a proven tagging platform, and remain the only viable option capable of tagging several hundred tuna per day in good condition. A medium-sized pole-and-line vessel is thus proposed as the primary tag release platform for Phase 2. The SSAP used two pole-and-line vessels of 200–250 GRT, which were of sufficient range and autonomy to operate throughout the WCPO. The RTTP chartered a 173 GRT pole-and-line vessel of similar design, and operated from the Philippines to Kiribati. This vessel was generally adequate to meet project objectives, but was somewhat restricted from operating in some of the more remote areas.

The proposed Phase 2 project will require a Japanese-style pole-and-line vessel of around 200 GRT capable of extended movements throughout the proposed study area. It will be necessary that the vessel have adequate fuel, provisions and accommodations suitable for extended voyages. The limiting factor for operational range with such a vessel would be bait tank and drinking water capacity, both of which will need to be carefully stipulated in the charter tender. A reverse osmosis desalinator should be required and at least eight efficient bait tanks of around 100 m<sup>3</sup> total capacity.

While pole-and-line fishing is clearly the only option for large-scale tuna tagging in the WCPO, there are a number of limitations that need to be considered in the design of the tag-release programme. First, pole-and-line fishing generally requires access to good supplies of live bait. The hardest of western tropical Pacific baitfish species, notably stolephorid anchovies, can survive up to only one week in bait tanks when carefully handled. This is in contrast to the more robust engraulid anchovies used as tuna baitfish in other areas such as the EPO and off Japan. Therefore, the range of pole-and-line fishing in the western tropical Pacific is effectively restricted to areas that are within three or four days steaming from viable bait grounds. Secondly, pole-and-line fishing is relatively inefficient in capturing bigeye, compared to skipjack and yellowfin. While some quanti-

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<sup>8</sup> Tagging of South Pacific albacore is however scheduled as part of SPC-OFP's new European Commission EDF9-funded project, SCIFISH, which will commence in 2008.

ties of small bigeye can normally be captured and tagged using pole-and-line, the maximum proportion that can reasonably be expected in a large-scale tag release programme is about 5–10% of the total. Occasionally, larger numbers can be caught, but it is unpredictable<sup>9</sup>. Thirdly, while pole-and-line fishing captures skipjack of approximately the same size distribution as taken by the dominant fishing method (purse seine), only smaller juvenile yellowfin and bigeye (<70 cm) are generally vulnerable to pole-and-line. By contrast, purse seine captures both species not only of this smaller size, but also in considerable numbers at larger size. Longline captures both species almost exclusively >80 cm. These restrictions relating to pole-and-line fishing all require careful consideration in the design of pole-and-line-based tagging operations.

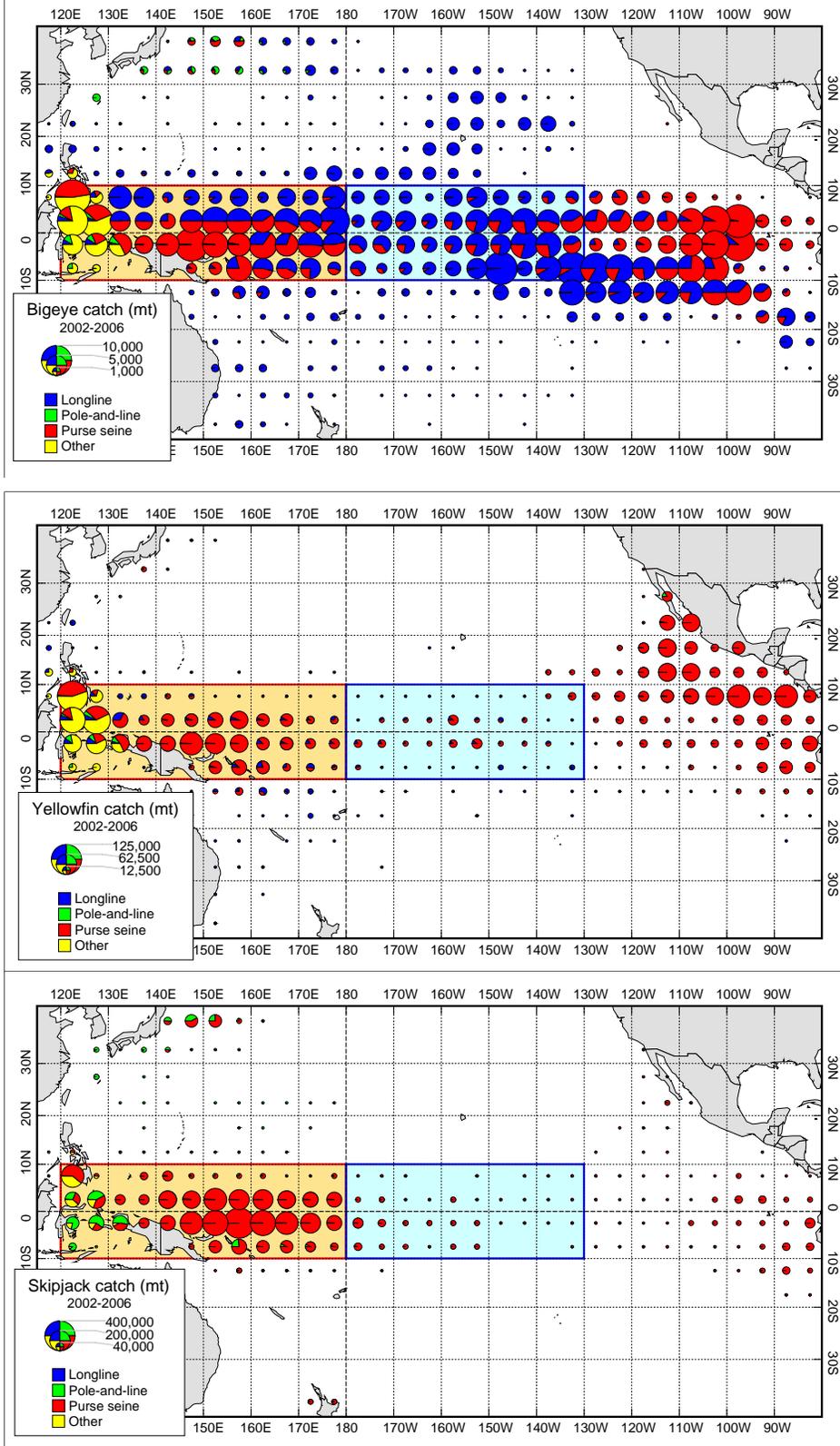
### **3.4 Areas of operation and fishing strategies**

The area of interest to the Phase 2 project is determined primarily by the distribution of WCPO stocks and the distribution of catches. Catches are highly concentrated in the equatorial zone (10°N–10°S) across the Pacific (Figure 4). In the WCPO, 85% of the total skipjack catch, 82% of the yellowfin catch and 53% of the bigeye catch is taken in the equatorial zone to the west of 180°. While tagging tropical tunas in sub-tropical and temperate areas in order to gain information, particularly on seasonal movements, from throughout the ranges of the stocks is important (and is addressed in the overall PTTP tag-release strategy – see below), it is of lower priority than tagging in the equatorial zone where the fishery is concentrated. It is therefore intended that the principal tagging vessel operate exclusively in the equatorial zone.

As noted earlier, the requirement that viable bait grounds are accessible constrains the area of pole-and-line-based tagging operations. Comprehensive baitfish survey data collected during the SSAP and similar data collected during the RTTP were examined to estimate the geographic area of effective operation of a pole-and-line tagging vessel within the overall area of interest. The analysis incorporated information on historical tuna baitfish CPUE, the number of productive bait grounds per sub-region, species composition/hardiness, seasonality and accessibility to a research vessel. The mapped operational areas show that wide coverage of the area west of 180° is possible, but the area to the east and the high-seas pocket between Solomon Islands-PNG and Nauru-Kiribati-Tuvalu pose considerable difficulties (Figure 5). Tagging in these areas would involve trading off fishing and tagging time for steaming time from bait grounds. The possibility of purchasing milkfish (*Chanos chanos*), a hardy bait species, from an aquaculture facility in Tarawa, Kiribati (as was done during the RTTP), might allow the latter high-seas pocket to be more efficiently accessed; this is an option that should be investigated.

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<sup>9</sup> An exception is the seasonal aggregations of bigeye tuna that occur in the northwestern Coral Sea.



**Figure 4. Distributions of bigeye, skipjack and yellowfin tuna catch superimposed on the proposed western (core) and central Pacific (secondary) tagging areas.**

Taking account of the above, we propose the following tag-release strategy for the PTTT:

1. The main pole-and-line tagging vessel will focus its operations in a core area (orange area in Figure 4) comprising the equatorial zone (10°N–10°S) extending from Indonesia and Philippines to approximately 180°. This area covers a large proportion (>80%) of the WCPO skipjack and yellowfin catch, >50% of the bigeye catch and has suitable bait grounds that would allow wide-coverage pole-and-line operations. Note that Indonesia and Philippines are specifically included in this operational area due to the importance of the small-tuna catches in these countries.
2. A secondary operational area to the east (to approximately 130°W – light blue area in Figure 4) will also be fished. This area is of interest mainly in respect of targeting bigeye tuna, as it straddles the WCPFC and IATTC regions, abuts a major longline fishing ground for bigeye and approaches the area of the EPO where purse seiners target skipjack and often capture large quantities of bigeye in FAD sets. It is envisaged that tagging in this area would be a collaborative exercise with the IATTC. Because of the difficulty in reliably catching live bait, tagging would be conducted by one or more vessels primarily handline and rod & reel fishing with dead bait and weighted jigs on drifting FADs, Tropical Atmosphere Ocean (TAO) moorings and seamounts. Pacific Island-based longline vessels 20–30 m length may be suitable platforms for this type of tagging. Bigeye tuna would be targeted and skipjack and yellowfin tagged opportunistically. It may also be possible for an EPO-based baitboat to carry live anchovetta (*Centengraulis mysticetus*), a very hardy anchovy that can survive in excess of three months in bait tanks, into the easternmost parts of this area for pole-and-line fishing. These methods have proven effective for tagging bigeye tuna in the EPO, but are untested in the central Pacific. We therefore envisage that one or more pilot expeditions would be undertaken early in the project to test the feasibility of this approach.
3. Sub-regional tagging projects outside of the core area described above and undertaken by other agencies would be encouraged. Such projects would ideally be undertaken during the same time period as the equatorial tag-release operation, use the same types of tags bearing the same legend, use the same fish handling and tagging methods and be fully integrated into the overall tag recovery mechanisms of the regional project. Also, and most importantly, the data resulting from these sub-regional projects should be fully integrated with data from the regional project to enable comprehensive analysis and reporting under appropriate collaborative agreements. The costs of such sub-regional projects are not funded in this proposal (although costs of tag rewards could likely be met from the Phase 2 project), but would be contributed in-kind by the agencies undertaking the projects. While there are no firm commitments to such projects at this stage, the following is a list of sub-regional projects that would make valuable contributions to the overall PTTT:
  - (i) **Japan** – The National Research Institute of Far Seas Fisheries has in the past conducted tagging operations in the temperate and sub-tropical North Pacific utilising prefectural high-school training pole-and-line vessels. A dedicated Japanese tag-release programme in this region, synchronised and coordinated with the Phase 2 project, would allow an extension of the spatial coverage of tag releases of all three species to be achieved. Japanese commercial pole-and-line

vessels, carrying engraulid anchovies in temperature-controlled bait tanks, routinely operate over extended periods in tropical waters as far east as the Line Islands of Kiribati (~150°W). The charter of such a vessel for tagging could potentially enhance coverage of the PTTP in the central equatorial Pacific.

- (ii) **Hawaii/central North Pacific** – The Hawaiian domestic pole-and-line fishery includes one vessel of modern steel construction that could be a useful tagging platform to operate in the vicinity of Hawaii and south to the Line Islands (Kiribati) area of the central Pacific. Tagging operations were not conducted in this area during the SSAP or RTTP due to the distance from viable bait grounds. However, the area can be highly productive for tropical tuna, particularly during *El Niño* conditions, and is also an important longline fishing area targeting bigeye. A sub-regional project utilising a Hawaii-based vessel carrying live milkfish to support tagging would extend the spatial coverage of tag releases in the central north and equatorial Pacific areas. Offshore handline vessels with proven autonomy and range could also be used to support archival tagging on drifting FADs and moored weather buoys.
- (iii) **Coral Sea** – Large aggregations of medium to large-sized bigeye and yellowfin that are highly vulnerable to simple hook and line gear form in the Coral Sea off eastern Australia during October to December. The RTTP exploited these aggregations, enabling significant numbers of bigeye and yellowfin tuna in size classes normally not available to pole-and-line gear (80–125 cm) to be tagged (Hampton and Gunn 1998). The aggregations were successfully chummed and fished with locally purchased frozen pilchards and mackerel from tagging stations located below the normal poling stations close to water level. This suggests that these aggregations could be efficiently tagged using chartered Australian longline or handline vessels of around 20–30 meters length. The specialised capture and tagging techniques developed during the RTTP could be applied to increase tag releases of bigeye and yellowfin from these larger size classes.
- (iv) **Philippines** – The extensive handline fishery that targets larger yellowfin and bigeye in the Moro Gulf and Celebes Sea could be utilised to deploy conventional and archival tags in medium and large-sized tuna that are difficult to access by other means. Government personnel familiar with tagging studies are available through experience gained during the RTTP and the collaborative Philippines Tuna Research Project that existed during the early 1990s. This option is attractive due to the importance of this region to overall fishing mortality of yellowfin and bigeye and the relatively low cost of operation.
- (v) **Indonesia** – Indonesia has the largest domestic pole-and-line fishery within the proposed study area, consisting of small vessels targeting skipjack on anchored FADs. The RTTP conducted successful tagging cruises throughout eastern Indonesia. The area has productive bait grounds as well as commercial live bait suppliers for the domestic fishery. The Indonesian Government has conducted domestic tuna tagging projects and is currently collaborating with CSIRO (Australia) in tuna tagging with domestic vessels in the eastern Indian Ocean. A locally-based pole-and-line charter in eastern Indonesia could considerably augment and coordinate with the activities of the regional tagging vessel.

- (vi) **Eastern Pacific Ocean** – The EPO has a large purse seine fishery, a part of which targets skipjack and bigeye tuna associated with drifting FADs in equatorial waters. In recent years, the IATTC conducted a series of successful tagging cruises utilising a chartered EPO-based baitboat tagging considerable numbers of bigeye, skipjack and yellowfin tunas with both conventional and archival tags. Additional tagging cruises in this region contemporaneous with WCPO tagging activities would allow a Pacific-wide scope to the PTPP to be achieved.

A graphical summary of the overall potential operational area of the PTPP is shown in Figure 6.

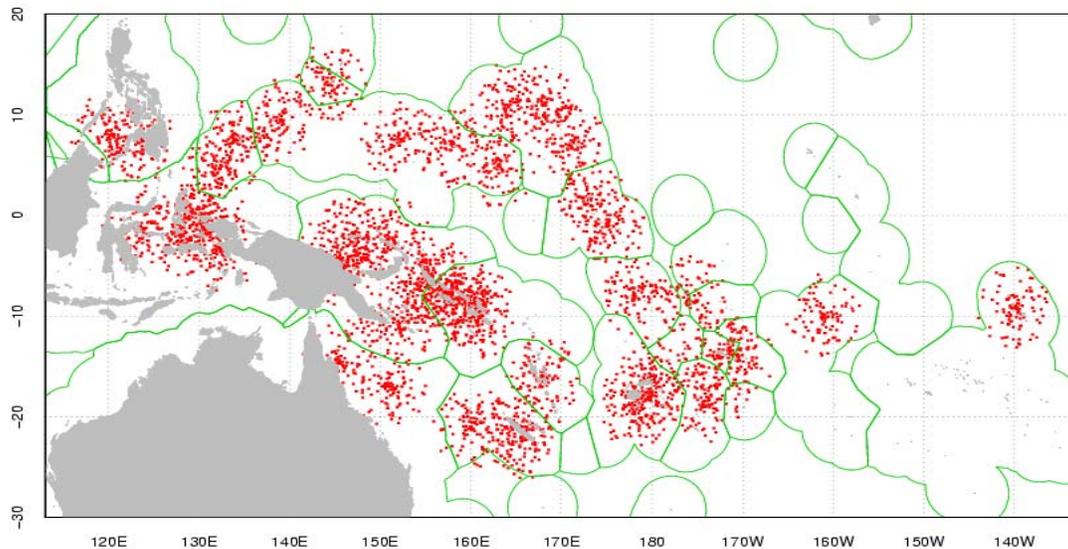
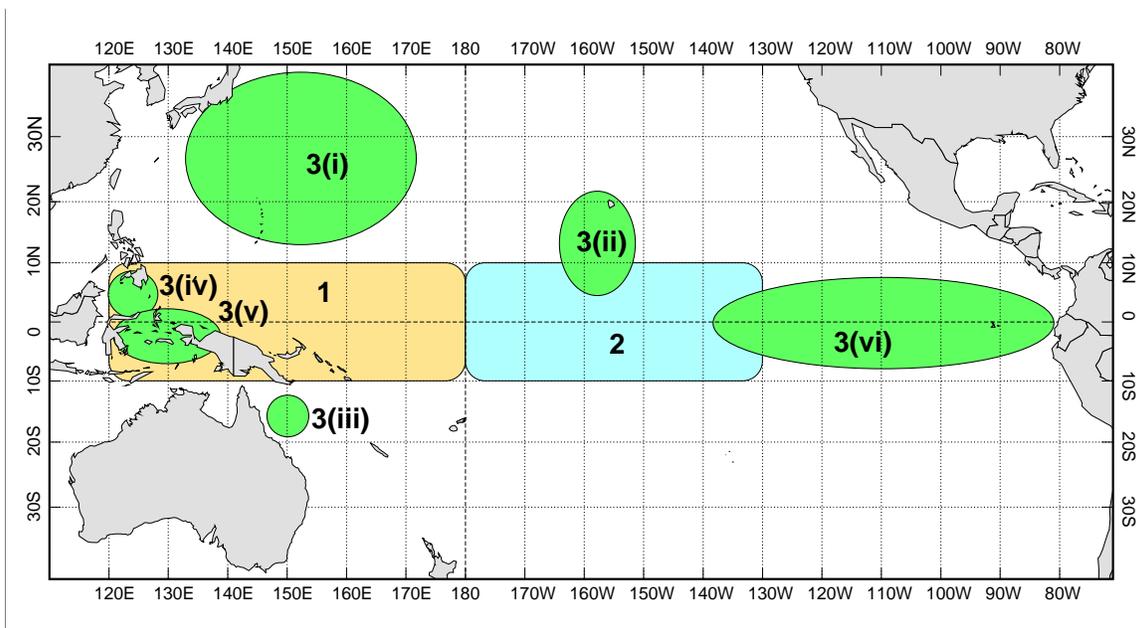


Figure 5. Potential range of pole-and-line tagging operations from known bait grounds.

### 3.5 Timing

The total duration of field activities in the equatorial WCPO foreseen in this proposal is two years, broken into two ten-month charter periods for the principal chartered pole-and-line vessel. Various follow-up activities related to tag recovery, analysis and reporting would be expected to continue for at least a further three years following the completion of fieldwork. A detailed calendar of activities is provided in Table 3.

The exact timing of tag-release activities depends on the availability of funding and the charter of suitable vessels. It is expected that significant funding provided by the European Commission via a new project to be implemented by SPC will be available in early 2008. On this basis, it is possible that field activities could commence as early as mid-2008, following the completion of staff recruitment, tendering and other administrative/logistical arrangements. However, there is some flexibility to this arrangement, particularly in relation to synchronising tag releases in the equatorial WCPO with other sub-regional tag-release activities.



**Figure 6. Potential operational area of the Pacific Tuna Tagging Programme. Orange: core operations of the main pole-and-line tagging vessel; light blue: secondary operational area (targeting bigeye) utilising handline operations with deep jigging techniques and dead bait; green: potential sub-regional tagging projects. Areas are numbered as referred to in the text.**

**Table 3. Approximate calendar of activities and milestones. Each X denotes one year quarter.**

Activity/milestone	2008	2009	2010	2011	2012
Staff recruitment	XX	XX			
Design study	XXXX				
Equipment purchase	XX				
Charter arrangements finalised	XX				
Tag recovery arrangements in place	XXXX	XXXX	XXXX	XXXX	XXXX
In-house data processing arrangements in place	XXXX	XXXX	XXXX	XXXX	XXXX
Tagging in core equatorial area	XX	XXXX	XX		
Cruises in secondary equatorial area	X	X X	X		
Tag returns received and processed	XX	XXXX	XXXX	XXXX	XXXX
Tagging data incorporated into annual assessments		X	X	X	X
Data analysis and modeling		XXXX	XXXX	XXXX	XXXX
Interim reports (SC)	X	X	X	X	X
Scientific publications				XXXX	XXXX
Final project report					X

### **3.6 Conventional tag releases**

In designing a tag-release programme, it is of course necessary for budgeting and planning purposes to have a target total number of fish to tag. However, from an experimental design point of view, it is more the number of tag returns and their distribution across various strata that determine the statistical properties of the estimates derived from the data. All other things being equal, more tags would need to be released in a lightly-exploited fishery to achieve the same results in terms of statistical precision of parameter estimates than in a heavily-exploited fishery. The number of tags returned is also determined by the reporting rates of the various fisheries recapturing the tags. Consideration in the experimental design and programme budgeting must therefore be given to both maximising tag-report rates and estimating the achieved rates of reporting for the major fisheries recapturing the tags (see section 4).

The numbers of tag releases and recoveries required to achieve certain levels of precision in parameter estimates is sometimes determined by simulation studies, in which assumptions are made concerning the values of the population parameters to be estimated and the statistical properties of the estimators (e.g., Bills and Sibert 1997). Such studies cannot provide concrete quantitative guidance on experimental design but may give general guidance on the achievability of the objectives subject to various design parameters and the analytical methods that are planned to be used. Such a study has not yet been carried out, but is planned during the first part of year 1 (see section 5.3). In the meantime, provisional tag release targets and general stratification guidelines have been established based on the objectives of the project, previous experience, logistical constraints and expected tag-return rates.

#### **3.6.1 Target conventional tag releases by species**

As noted earlier, the project objectives target three species – skipjack, yellowfin and bigeye tuna – with approximately equal priority. While skipjack is not a species of current management concern, it is beneficial to accord equal priority to tagging skipjack with all tag types for the following reasons:

- Skipjack is the dominant species in the WCPO purse seine catch, and understanding its dynamics is vital to understanding the behaviour of the fishery;
- Lower tag-return rates of skipjack compared to yellowfin and bigeye are expected (on the basis of preliminary Phase 1 results); therefore larger release numbers are required to achieve the same number of returns;
- The skipjack stock assessment is more reliant on tagging data than the yellowfin and bigeye assessments; and
- Changes in skipjack distribution and abundance may well be sensitive indicators of ecosystem state (Sibert et al. 2006).

In any case, it is known from previous experience that skipjack will dominate the species composition of tuna caught by pole-and-line in most if not all areas. Typical species composition in commercial pole-and-line catches is ~95% skipjack, ~5% yellowfin and <1% bigeye. This was also the approximate species composition of the ~150,000 tuna released during the SSAP, when no particular attempt was made to favour any particular

species. However, during the RTTP, specific attempts were made to increase the proportions of yellowfin and bigeye tagged, mainly through limiting fishing/tagging on pure skipjack schools and concentrating on floating object and seamount associations when available. This resulted in a species composition of tag releases of ~67% skipjack, 27% yellowfin and ~6% bigeye. While this strategy probably reduced the total amount of tuna that could have been tagged (although the total number tagged was similar to the SSAP), it increased the numbers of yellowfin and bigeye tagged while still enabling sufficient numbers of tagged skipjack to be achieved.

Given the increases in exploitation rates that have occurred since the early 1990s, it is likely that somewhat fewer tuna than released in the RTTP would need to be conventionally tagged to generate a similar number of total recaptures (~18,000). Our provisional target for conventional tag releases in Phase 2 is 100,000 tuna, which we would expect to generate on the order of 20,000 tag returns (and possibly more depending on the success of tag recovery efforts). The approximate species composition targeted is skipjack ~60%, yellowfin ~30% and bigeye ~10%. This ideal species mix is certainly achievable with respect to skipjack and yellowfin (as demonstrated in the Phase 1 PNG tagging), but is a challenging target in respect of bigeye. There are several operational strategies that can be employed to maximise the numbers of bigeye and yellowfin tagged:

- Priority will be given to tagging schools associated with floating objects (FADs, logs, etc), which tend to result in larger percentages of bigeye tuna in particular;
- The proportion of bigeye and yellowfin in purse seine associated sets tends to increase markedly east of 180° (Figure 7). Special efforts will therefore be made to operate in the eastern part of the core equatorial area, and in the central Pacific area using FADs deployed by the tagging vessel(s);
- Tagging schools with a high percentage of skipjack will be subject to an appropriate per-school limit, so as to conserve live bait and minimise time spent in situations unlikely to yield significant numbers of tagged bigeye or yellowfin; and
- The recent Indian Ocean Regional Tuna Tagging Project (RTTP-IO) has had considerable success in tagging tuna, a large proportion of which is bigeye and yellowfin, which become associated with the tagging vessel itself. The RTTP-IO has used this method to greatly increase the numbers of tagged bigeye in particular. An additional advantage is that live bait may not be required to effectively fish such aggregations. This methodology will be trialed during Phase 2 both from the principal pole-and-line tagging vessel, and the handline operations.

### **3.6.2 Spatial distribution**

As is always the case with tuna tagging projects, the spatial distribution of releases that is achieved will depend to a large extent on the prevailing fishing conditions at the time. However, the overall tag-release strategy will be to distribute tag releases of the three species as widely as possible throughout the equatorial WCPO, hopefully supplemented by tag releases in other areas by cooperating sub-regional projects. As noted above, some preference will be given to areas in which larger numbers of bigeye and yellowfin can be released, should such areas be located.

Widely distributing tag releases enhances the mixing of the overall tagged population with the general population. This is an important design consideration, as it maximises the numbers of returns that can be used in tag-attribution and similar models<sup>10</sup>. A wide distribution of tag releases is also required to meet objectives 2 and 4, which have a clear spatial context. One operational method that can be employed to promote mixing of tagged fish is to remove the drifting FAD or other floating object from the water after tagging has been completed on that aggregation. Sudden removal of the FAD and departure of the vessel leaves the tagged fish in an unassociated state, which may encourage short-term movement/mixing and reduce the likelihood of short-term recapture by the purse seine fishery. Instances where this procedure is used would of course need to be carefully recorded and distinguished in analyses aimed at estimating the impact of FADs on processes such as horizontal and vertical movements.

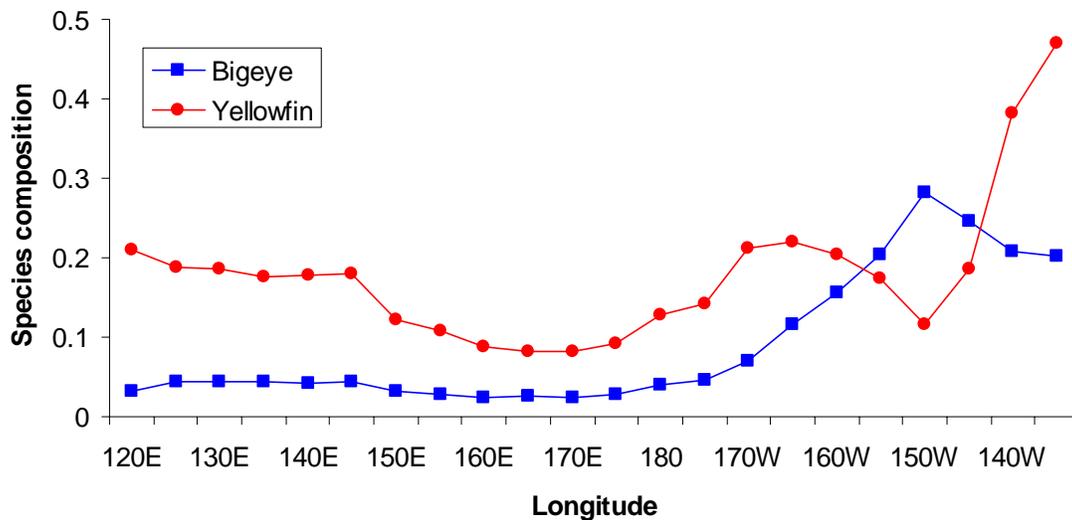


Figure 7. Purse seine associated-set bigeye and yellowfin species composition by five-degree longitudinal bins (western boundary denoted) in the equatorial zone 10°N–10°S, 2000-2006.

### 3.6.3 Size distribution

From previous tagging projects, we have a good idea of the size range of tuna that will be available to pole-and-line gear. Generally, the tagged fish, particularly bigeye and yellowfin, are from the smaller part of the size range caught by purse seine (Figure 8), and smaller than the smallest sizes caught by longline. In the western extremity of the WCPO (Philippines and Indonesia), even smaller sizes are commonly captured. This discrepancy

<sup>10</sup> Short-term recaptures frequently need to be removed from the analysis (or their effect diminished by additional parameterisation) as the initial probability of capture may differ considerably from that of the untagged population. Differential capture probabilities may occur because of either non-random spatial distributions of tags or fishing effort. The extent to which an allowance for mixing is required depends on the spatial structure of the model being used – weaker assumptions are required for models having a finer spatial structure as mixing will occur faster over a smaller area provided that movement rates are non-zero.

is not necessarily a fatal flaw in the experimental design<sup>11</sup>. The main implication is analytical – it is essential that any assumption that the tagged fish are representative of commercial catches be avoided in the population dynamics models used to analyse the data. The solution is to use a model that has size- or age-structure (or both) and growth explicitly in the model. When this is done, the model can in essence “correct” for the smaller size-at-release of the tagged fish compared to the size distribution of the commercial catches. That said, it remains desirable for the tagged sample to encompass as many larger fish as possible. This is because the numbers of fish tagged at small size decline with time due to mortality, thus reducing the size of the tagged sample with respect to the larger part of the population. Strategies for tagging larger-sized fish, particularly bigeye and yellowfin, include:

- Tagging at night by jigging on FADs at depths characteristic of larger bigeye and yellowfin;
- Aggregating bigeye and yellowfin to drifting FADs monitored by the tagging vessel; and
- Tagging in areas known to produce larger bigeye and yellowfin, e.g. the north-western Coral Sea in October – December.

Capturing fish for tagging by purse seine and longline would in principle provide access to larger-sized fish. However, the experience in the WCPO when these methods have been trialed has been generally negative – the condition of the fish has often deteriorated during the capture process raising concerns about post-tagging survival, and the numbers that can be tagged by these methods per fishing operation is quite limited.

### **3.6.4 School type**

The WCPO purse seine fishery targets tuna in unassociated schools and tuna associated with drifting or anchored FADs and naturally-occurring floating objects. In the EPO, an additional operational type is yellowfin associated with dolphins. It will be important that conventional tag releases be stratified across these school types as much as possible, although, as noted above, higher priority will be given to tagging on FADs and other floating objects due to the greater likelihood of capturing bigeye from these associations.

## **3.7 Archival tag releases**

For archival tag releases, a more even distribution of releases among the three species can be envisaged, because of the much smaller numbers of tags involved and the resulting ability to be selective regarding the individuals to be tagged. The total number of archival tags to be deployed will depend on the available budget, but we have nominated 600 as an achievable target, divided equally across the three species<sup>12</sup>. It is likely that this num-

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<sup>11</sup> It would be more problematic if the fishery caught smaller fish than was encompassed by the tagged sample. In such a case, the tagging data could not provide size-related information on the smaller fish.

<sup>12</sup> Non-geolocating archival tags are considerably smaller and less expensive than geolocating tags, and may be considered for deployment on a proportion of skipjack and smaller yellowfin and bigeye. This would allow a larger amount of vertical movement and temperature data to be collected at the cost of a small reduction in the number of tag returns with geolocation estimates.

ber of releases will result in approximately 40–60 returns per species, hopefully distributed over a wide range of times at liberty. These numbers, while small, would nevertheless provide much data on vertical habitat utilisation, horizontal movements and the impacts of FAD association on these processes. As with the conventional tag releases, efforts will be made to distribute archival tag releases over areas, sizes and school types. Different models of tags will be used as appropriate for each species and size category. Archival tags will be deployed from both the main pole-and-line tagging vessel and during the central Pacific handline tagging operations.

### **3.8 Acoustic tag releases**

As noted earlier, acoustic tagging offers the opportunity of providing additional depth distribution and geolocation data for tagged fish when they are known to be associated with FADs. This can greatly assist interpretation of subsequently recovered archival tag data through the characterisation of “on FAD” and “off FAD” behaviour, and provide multi-species depth information for fish in the same aggregation. Acoustic tagging and FAD monitor deployment will be undertaken from the main pole-and-line tagging vessel and the handline tagging operations in the central Pacific in conjunction with archival tagging. It is planned to double-tag 150 fish (50 per species), captured in association with monitored drifting FADs, with acoustic and archival tags. The positions of the drifting FADs themselves will be monitored remotely from the tagging vessel. The exact design of these experiments will be more fully developed at a later date.

### **3.9 Tag shedding and double tagging**

Double tagging using conventional tags is often undertaken to estimate the rate of tag shedding. Double tagging was undertaken in the RTTP, and the rates of tag loss estimated to be approximately 11% (6–18%) after two years at liberty (Hampton 1997). Approximately 6 of the 11% loss rate was estimated to occur immediately on release. Systematic double tagging using conventional tags is not planned for Phase 2. However, all archival-tagged tuna will also be conventionally tagged; therefore this will provide a check on conventional tag shedding since the probability of the internally-implanted archival tag being shed is very low. While differences in tag-shedding rates among individual taggers was not found to be significant in the RTTP data (Hampton 1997), there was considerable variation in the tagger-specific point estimates. Therefore, a high priority will be given to training new tagging staff, restricting tagging to a minimal number of trained individuals and conducting periodic on-board quality control checks. A statistical analysis based on school-specific tag-return rates will also be developed to compare the performance of different taggers.

### **3.10 Innovative tagging technologies**

While we are not providing budget support for this item, it is intended, to the extent possible, to provide opportunities for researchers to utilise the field programme to undertake research involving innovative tagging technologies (e.g. genetic tagging, PAT tagging of large pelagics) and perhaps other research. Such opportunities will be provided subject to space and accommodation limitations of the vessel(s) and on the condition that it does not compromise or disrupt the key tagging activities.

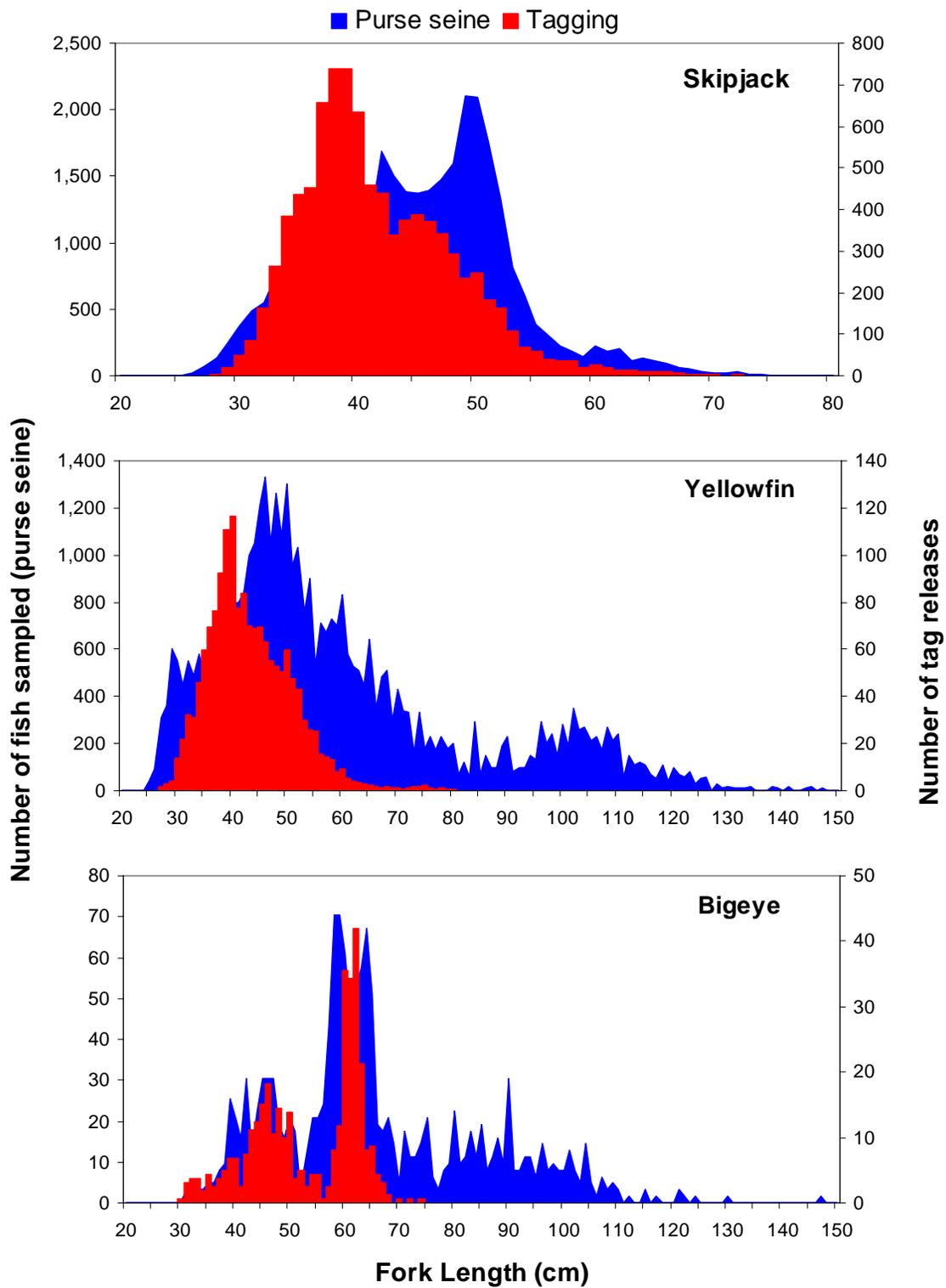


Figure 8. Size composition of tuna releases by species during the PNG Phase 1 tagging in 2006-2007 (red) compared to size composition of purse seine catches during the same period (blue).

## 4 Tag Recoveries

Conventional and archival tagging projects rely on recaptures by the fishery to provide information. Attention to tag recovery procedures should be a high priority for any large-scale tagging programme. Industry cooperation throughout the range of the fishery and across all gear types is essential in this regard. A number of steps will be taken to ensure high reporting of recaptured tags and the full cooperation of industry and artisanal fishers throughout the very large region where tagged fish might be recovered, i.e. where fish are landed or processed. In most cases, these arrangements have already been initiated to support Phase 1.

### 4.1 *In-country tag-recovery arrangements*

Recovery procedures will be established in major tuna landing ports throughout the region and elsewhere, e.g. Thailand, utilising, for the most part, established catch monitoring programmes. Industry briefing, publicity, tag-reward payment and data collection will be focused through individuals identified in each location. A preliminary product-flow analysis (Table 4) provides important information regarding the allocation of tag-recovery effort. For the WCPO tuna fishery, Thailand emerges as a particularly important product destination and a likely major tag-recovery location. As part of the PNG Phase 1 tagging, tag-recovery arrangements have been established in Thailand, Philippines, Indonesia, Korea, Japan and in Pacific-Island unloading/transshipment locations. Arrangements will be put in place to obtain accurate length and weight measurements of recaptured tuna through the provision of calipers and possibly weighing scales.

### 4.2 *Publicity*

A publicity campaign will be mounted throughout the region to publicise the project. Publicity will occur via tagging posters in various languages (e.g., Figure 9) distributed to landing ports and processing facilities, announcements in local news media and personal contact of project staff with the fishing industry and local communities. A website will also be established for the purpose of disseminating publicity and information about the project, and also as a means of collecting tag-recovery data (e.g., see <http://www.spc.int/tagging>).

### 4.3 *Tag rewards*

Rewards will be paid to tag finders for the return of tags. For conventional tags, a reward of USD 10 per tag return will be paid. For archival tags, a reward of USD 250<sup>13</sup> for each tag return will be paid. For acoustic transmitting tags, a reward of USD 50 for each tag return will be paid. These differential rewards reflect the value of the hardware and/or of the data accompanying the tag. Assuming that there is complete reporting of the higher value tags, any significant differences in return rates between conventional and electronic tags might be attributable to non-reporting (of conventional tags). This information will be important for subsequent modeling of the tag-return data.

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<sup>13</sup> Differential rewards for geolocating and non-geolocating archival tags would likely be used.

Regular (annual or biannual) lotteries with attractive cash prizes will also be held in key locations throughout the region.

#### **4.4 Tag-reporting rates**

The above procedures are all designed to maximise the reporting rate of recaptured tags. However, in any large-scale tagging programme such as this, the reporting rate will never be 100%. Therefore, the reporting rates for the different components of the fishery must not only be maximised through attractive rewards, publicity, etc, but must also be estimated if unbiased estimates of parameters such as fishing mortality are to be obtained. Several approaches to the estimation of reporting rates, reviewed below, are available.

##### **4.4.1 Tag-seeding experiments**

Tag-seeding experiments involve the surreptitious tagging of dead fish on board fishing vessels prior to the commencement of tag detection processes. The return rates of seeded tags are, subject to various conditions, indicative of the reporting rates of similar tags from the regular tagging programme. One of the key requirements of this approach is that seeded tags can be planted in the catch without the knowledge of the crew or others involved in tag detection. Previous work suggests that this will be feasible on purse seiners, which handle large quantities of fish, but not on longliners and other types of operation in which fish are individually handled.

In this project, we expect the majority of tag returns to originate from purse seiners<sup>14</sup>; therefore, high priority will be given to conducting tag seeding throughout the course of the project in order to estimate tag-reporting rates. We plan for tag seeding to be undertaken by regional and national observers on purse seine vessels operating throughout the WCPO. These experiments will be designed to provide statistically reliable information on tag reporting for the purse seine component of the fishery throughout the duration of the tagging programme. The analysis of seeded-tag-return rates will be stratified by processing location, which is known to be a major source of variation in reporting rates, and by time. Similar experiments were undertaken during the RTTP (Hampton 1997), providing important information on tag reporting (an overall reporting rate of 0.59 was estimated). Tag seeding has already commenced in support of the PNG project.

##### **4.4.2 High-reward approach**

The high-reward approach (Pollock et al. 2001), involves a sample of tags having such a high monetary reward that they can be assumed to have a reporting rate of 100%. The ratio of normal to high-reward tag-return rates by a particular fishery is then an estimate of the reporting rate of normal tags. Archival tags, with a reward of USD 250, might be suitable as a high-reward tag. For example, in the PNG Phase 1 project to date, the conventional tag-return rate for yellowfin released in 2006 is 19.7% (1,537 returns); the corresponding return rate of archival tags is 32.6% (15 returns). These return rates imply

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<sup>14</sup> If considerable numbers of larger bigeye can be tagged, recapture rates of bigeye by longline may also be high.

a reporting rate of conventional tags of 60%<sup>15</sup>, if the assumptions of the approach are satisfied. The high-reward approach may therefore provide information on tag reporting rate, particularly in the purse seine fishery where most returns are expected to occur. It is unlikely, however, to provide sufficient numbers of returns in the longline or other fisheries to estimate reporting rates.

#### **4.4.3 Observer approach**

In this approach, a known proportion of the catch is monitored by observers, and it is assumed that 100% of tagged fish in the monitored catch are reported. The concept is therefore similar to the high-reward approach. The main requirement is that a statistically meaningful proportion of the total catch is monitored, generating a sufficient number of tag returns. This approach may be suitable for longline if observer coverage was sufficiently high. Currently, observer coverage is <1% and mainly occurs on longliners targeting South Pacific albacore. Observer coverage of the purse seine fleet is higher (~7% overall); however the bulk handling of fish on board purse seiners means that the opportunity for individual fish inspection by observers is very limited. Port sampling programmes could provide for individual fish inspection, but the proportion of the total catch sampled (<1%) is too small. One possible application of the approach for longliners is using the extensive Japanese prefectural high school training vessel programme as an “observed” fleet. Seemingly good cooperation has occurred with tag returns from this fleet operating in the North Pacific (Itano, pers. comm.). With more concrete knowledge of the policy on tag reporting of these training vessels, it may be possible to assign a high, if not 100% reporting rate to their activities.

#### **4.4.4 Model-based approach**

The model-based approach involves using the tagging data directly in the stock assessment model, with parameters for the reporting rates of the various component fisheries. Population parameters (movement, mortality, growth, etc) of the untagged population are assumed to be shared by the tagged population (see Hampton and Fournier 2003 for details). This is the approach we have taken in using historical tagging data in tuna assessments conducted with MULTIFAN-CL. Information on reporting rates (means and variances) derived from any of the above methods can be provided to the model in the form of Bayesian prior means and variances. If there is no information on tag-reporting rate for a particular component fishery, a uniform prior is specified. Reporting rates are then estimated as model parameters, conditioned on the prior specifications. The tagging data have a negative binomial likelihood function for which overdispersion parameters are estimated. The advantage of this approach is that uncertainty in the reporting rates is propagated through the model and reflected in the variances of the various population parameters or stock status indicators of interest.

While this is a suitable analytical approach for dealing with heterogeneous tag reporting rates, the fact remains that tag returns in a fishery for which there is no independent information on tag reporting rate will not provide much if any information on mortality

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<sup>15</sup> This computation is provided as an example only, and should not be construed as an actual estimate of tag-reporting rate for the PNG project.

rates. Of course, if zero tag returns are reported, there is also no information. It is therefore important that cooperation is gained from those fleets for which obtaining independent information on tag reporting is difficult. Longline fleets, which are the only fleets that can potentially provide information on older age classes of bigeye tuna, fall into this category. In previous regional projects, the numbers of tag recaptures reported by longline fleets operating in the Pacific have been much lower than expected. Because of the careful individual handling received by longline-caught fish, it is unlikely that any tags would escape detection by longline crews. It is therefore suspected that some longline fleets either have had a deliberate policy of non-reporting of tag recaptures, or that for some reason longline crews have been unaware of the tagging programmes and did not know what to do with recaptured tags. It will be important that the longline industry be made aware of the tagging programme, its importance in stock assessment and management, and given information on how to report recaptured tags. Systematic visits by project staff or local fisheries officers to vessels while in port may assist in raising awareness of the project and improving the tag-reporting rate. However, the support of member Governments of WCPFC and IATTC will also be required to convince longline industries to cooperate with the tagging programme.

**Table 4. Disposal of purse seine catch by fleet, 2005. Shaded cells are the most uncertain, and all estimates are approximations based on available information, which is often sensitive and therefore incomplete.**

Fleet	Total Catch	Delivery location									Total
		Thailand	American Samoa	Japan	Philippines	Korea	NZ	PNG	Indonesia	Chinese Taipei	
China	48,660	17,600	30,000								47,600
FSM	27,505	45,200									
Japan	260,818	104,000		156,000							260,000
Kiribati	7,105			7,100							7,100
Korea	209,808	52,400	65,000			90,000					207,400
Marshall Is.	56,164	27,300									
Nether. Antilles		4,600									
NZ	16,438	8,300					8,400				16,700
PNG	220,079	120,000			20,000			60,000	2,000		202,000
Philippines	34,000	60,000			34,000						
Solomon Is.	16,100	15,000									
Chinese Taipei	195,039	144,000	30,000							20,000	194,000
USA	74,287	5,900	68,000								73,900
Vanuatu	73,232	73,000									73,000
<b>Total</b>	<b>1,239,235</b>	<b>677,300</b>	<b>193,000</b>	<b>163,100</b>	<b>54,000</b>	<b>90,000</b>	<b>8,400</b>	<b>60,000</b>	<b>2,000</b>	<b>20,000</b>	<b>1,081,700</b>

# TUNA TAGGING IN THE WESTERN AND CENTRAL PACIFIC

**HELP US TO BETTER UNDERSTAND AND MANAGE OUR TUNA RESOURCES!  
RETURN THE TAGS AND GET A REWARD; ANNUAL LOTTERY FOR TAG FINDERS**





**\$10 US**

**FOR A DART TAG**

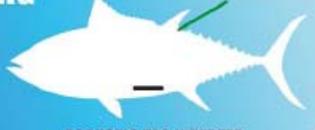



FORK LENGTH ( cm )



**\$50 US**

**FOR AN ACOUSTIC TAG**



ACOUSTIC TAG INSERTED



**\$250 US**

**FOR AN ARCHIVAL TAG**



ARCHIVAL TAG INSERTED, ANTENNA IS VISIBLE

**REWARD**

The SECRETARIAT OF THE PACIFIC COMMUNITY is conducting research into BIGEYE, SKIPJACK and YELLOWFIN TUNA movements and behaviour using different type of tags. Tagging tuna will provide better information on fishery exploitation rates and population sizes in the Western and Central Pacific. These data will allow the improvement of regional stock assessment for the 3 species. Every tagged tuna will have a yellow, green or orange DART TAG on its back, near the second dorsal fin. Each tag has a number (written twice) and the words "SPC NOUMEA-REWARD - [www.spc.int/tagging](http://www.spc.int/tagging)" on it.

**YELLOW** tagged tuna have no other tags, or occasionally have a second yellow tag on the other side of its back. Every tag gets a reward.

**GREEN** tagged tuna also have an acoustic tag hidden INSIDE their body cavity. Acoustic tags are used to study the movement of tuna around FADs, payaos and other floating objects.

**ORANGE** tagged tuna also have an archival tag placed INSIDE their body cavity. These tuna also have a pencil-length clear antenna trailing from their body cavity. Archival tags are small computers that record depth, inside and outside temperature, position and time. Please be careful when cutting the archival tag out and **please avoid pulling** the antenna when removing the tag from the fish. Wash the tag and keep it in a dry place until you return it.

Please record the fork length of the fish (from the upper-jaw to the fork in the tail), and the date and position of the recapture. Return the tag and information (with your name and address) to either :

JOHN HAMPTON  
Oceanic Fisheries Programme (OFF)  
Secretariat of the Pacific Community (SPC)  
B.P. D 5, 98848 Nouméa Cedex, New Caledonia  
Telephone : (Int) +687 262000 Fax : (Int) +687 263818  
[www.spc.int/tagging](http://www.spc.int/tagging)  
Email : [Oceanfish@spc.int](mailto:Oceanfish@spc.int)

or your local government fisheries office ...



Figure 9. A4-sized tagging poster developed for Phase 1. This poster is available in 13 languages.

## **5 Data processing and analysis**

### **5.1 Processing of tag-release and recapture data**

SPC has developed customised database software (using Microsoft Access) for field-based processing of conventional and archival tag-release data, entry of tag-recapture information and the production of a variety of summary reports. This software, enhanced as necessary, will be used in Phase 2. SPC will be happy to provide the software to other agencies for use in sub-regional projects. Customised database software for the storage of archival and acoustic tagging data is under development.

SPC has also experimented with web-based submission of tag-recapture data. This has proved to be quite useful, and further development of this approach is envisaged.

Tag-return data will be routinely cross-checked against other data sources (logsheets, vessel monitoring systems) to verify reported data and estimate missing data.

### **5.2 Data analysis**

Several types of data analyses are envisaged to meet the objectives of the project. Many of these are based on existing models, in particular the MULTIFAN-CL model used routinely in WCPFC stock assessments (Hampton and Fournier 2003), fine-scale spatial models for the analysis of conventional tagging data (Kleiber and Hampton 1994; Sibert et al. 1999; Sibert and Hampton 2003), and new methods that parameterise population dynamics as functions of environmental and biological/physiological relationships (Lehodey et al. 2003; Senina et al. in prep.). It will be instructive to apply these models to both the large conventional tagging data set that is expected to result from both the Phase 1 and Phase 2 projects, and to similar data from previous projects that pre-date the large-scale deployment of anchored and drifting FADs.

Analytical methods for the analysis of archival tag data are relatively new, and are likely to evolve further during the course of this project. Nielsen and Sibert (2007) have developed a new method of light-based geolocation that appears to be superior to the methods supplied by archival tag manufacturers. Other methods have been developed that utilise sea-surface temperatures collected by the archival tags to help determine latitude (Nielsen et al. 2006). Currently, there are initiatives to estimate movement parameters from joint conventional-archival tag data, and to characterise associative behaviour from depth-temperature records. All of these methods will be of benefit to the project in analysing and interpreting the large amount of data that will be generated.

### **5.3 Design study**

A design study will be undertaken to determine the achievability of the conventional-tagging-related objectives subject to certain design parameters and analytical approaches. The objective of the study will be to provide guidance on the number and distribution of tag releases/returns required to achieve the project objectives. The approach will involve simulating tag returns given specified design parameters and simulation model assumptions, and subjecting those simulated data to a selection of the key analytical approaches described above. The study will be undertaken during year 1 and its results will be used in the planning of tagging operations in years 2 and 3.

**Table 5. Examples of the types of analyses that are envisaged in support of the project objectives.**

Objective	Description of analysis	References
<p>1. To obtain data that will contribute to, and reduce uncertainty in, regional tuna stock assessments</p>	<p>Direct incorporation of conventional tag release and recaptures data into regional stock assessment models based on MULTIFAN-CL</p> <p>Estimate tag-reporting rates for component fisheries using tag-seeding data and other means</p> <p>Estimates of growth rates based on length-increment data from different regions of the WCPO</p>	<p>Hampton and Fournier (2001)  <a href="http://www.multifan-cl.org">http://www.multifan-cl.org</a></p> <p>Hampton (1997)</p> <p>e.g., Francis (1988)</p>
<p>2. To obtain information on the rates of movement and mixing of tuna in the equatorial WCPO, between this region and other adjacent regions of the Pacific basin, and the impact of FADs on movement at all spatial scales</p>	<p>Estimates of movement rates and FAD impacts from conventional tagging data using TAGEST and SEAPODYM models, including comparisons between RTTP and current data</p> <p>Estimates of geolocation for archival tags using modern light-based geolocation algorithms, and derivation of spatial habitat utilisation</p> <p>Estimates of fine-scale horizontal movements and FAD residence times</p>	<p>Sibert et al. (1999)</p> <p>Sibert and Hampton (2003)</p> <p>Kleiber and Hampton (1994)</p> <p>Nielsen et al. (2006)</p> <p>Nielsen and Sibert (2007)</p> <p>Schaefer and Fuller (2002)</p> <p>Schaefer et al. (2007)</p> <p>Dagorn et al. (2006)</p>
<p>3. To obtain information on species-specific vertical habitat utilisation by tunas in the tropical WCPO, and the impacts of FADs on vertical behaviour</p>	<p>Derivation of time-at-depth &amp; time-at-temperature distributions, appropriately stratified by time of day, season, sub-region</p>	<p>Gunn et al. (2004)</p> <p>Schaefer and Fuller (2005)</p> <p>Schaefer et al. (2007)</p>
<p>4. To obtain information on local exploitation rates of tuna in various parts of the WCPO</p>	<p>Estimation of local stock and fishery dynamics using SEAPODYM models parameterised by fitting to catch, effort, size frequency and tagging data</p>	<p>Lehodey et al. (2003)</p> <p>Senina et al. (in prep.)</p>

## **6 Institutional arrangements**

The PTTP will be jointly managed by the WCPFC and the IATTC through the PTTP Steering Committee. The proposed Phase 2 project will be planned and implemented under the auspices of the WCPFC, and in particular its Scientific Committee. The Steering Committee will continue to consult on various planning and implementation issues, and will report the progress of the project and of the wider PTTP to the Scientific Committee of the WCPFC and the Working Group on Stock Assessment of the IATTC at their annual sessions during the course of the project.

Day-to-day management and implementation of the Phase 2 project will be vested in the SPC-OFP. SPC-OFP staff and contractors have considerable experience in the implementation of large-scale tagging projects, and have recently completed the successful Phase 1 project in PNG.

The SPC-OFP will cooperate with other national and regional agencies that are undertaking sub-regional tagging projects. In particular, it is envisaged that the IATTC would participate in this project through the conduct of a tagging cruise into the central Pacific region. This tagging cruise is included in the project budget, in view of its importance to the overall project objectives, particularly those having a Pacific-wide context.

Collaborative arrangements will need to be put in place for any sub-regional projects that wish to join the PTTP. Such arrangements will need to cover coordination of tag-release effort, standardisation of methods, tag rewards and tag-return data processing, data management and sharing, and collaborative analysis of data.

## 7 Budget

The following budget (thousand USD) is proposed for the activities described above. Considerable in-kind support by SPC, IATTC and other agencies in respect of both Phase 2 and sub-regional projects is not included below. Also, the costs of Phase 1 (~USD 1.7 million) are not included although the results of that project will contribute to the PTPP.

Item	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total	Remarks
Tagging vessel operations	1,005	1,969	985	0	0	3,959	Charter costs for principal tagging vessel, handline vessels, EPO baitboat, vessel modifications, bait purchase, vessel communications, crew incentives
Staff costs	640	640	640	288	288	2,496	SPC contracts for project manager, cruise leaders, field technicians, tag recovery officer, data quality officer, data analyst/modeler
Travel	78	138	78	18	9	321	Travel for field work, tag recovery and project management
Equipment	658	490	0	0	0	1,148	Conventional, archival and acoustic tags and related equipment, drifting FADs, FAD monitors, acoustic tag monitors, computer hardware and software, communications equipment, GPS unit, fishing and sampling equipment
Tag recovery	57	87	79	79	50	352	Tag rewards, lotteries, publicity, contract tag recovery agents, fish measuring equipment
Miscellaneous Costs	43	43	37	37	35	195	Shipping, office supplies and equipment, internet charges, printing, administrative support, bank charges
<b>Sub-total project costs</b>	<b>2,481</b>	<b>3,367</b>	<b>1,819</b>	<b>423</b>	<b>382</b>	<b>8,472</b>	
<b>Confirmed contributions</b>	<b>955</b>	<b>914</b>	<b>484</b>	<b>84</b>	<b>0</b>	<b>2,437</b>	SPC EC-funded SCIFISH project, SPC-FFA GEF-funded POFM project, PNG National Fisheries Authority
<b>Additional project costs required</b>	<b>1,526</b>	<b>2,453</b>	<b>1,335</b>	<b>339</b>	<b>382</b>	<b>6,035</b>	
<b>Organisational overhead</b>	<b>229</b>	<b>368</b>	<b>200</b>	<b>51</b>	<b>57</b>	<b>905</b>	SPC charges a 15% overhead on new funding provided by non-members; 7% for contributions by SPC members.
<b>Contingency</b>	<b>124</b>	<b>168</b>	<b>91</b>	<b>21</b>	<b>19</b>	<b>423</b>	A contingency fund at 5% of direct project costs is established to cover unforeseen costs, exchange rate losses, etc.
<b>TOTAL PROJECT BUDGET</b>	<b>2,834</b>	<b>3,903</b>	<b>2,110</b>	<b>495</b>	<b>458</b>	<b>9,800</b>	
<b>TOTAL NEW FUNDING SOUGHT</b>	<b>1,879</b>	<b>2,989</b>	<b>1,626</b>	<b>411</b>	<b>458</b>	<b>7,363</b>	

## 8 References

- Bills, P.J. and Sibert, J.R. 1997. Design of tag-recapture experiments for estimating yellowfin tuna stock dynamics, mortality, and fishery interactions. SOEST Publication 97-05, JIMAR Contribution 97-313, 80 pp.
- Dagorn L, Holland K.N., Itano D.G. 2006. Behavior of yellowfin (*Thunnus albacares*) and bigeye (*T. obesus*) tuna in a network of fish aggregating devices (FADs). *Mar. Biol.* doi: 10.1007/s00227-006-0511-1.
- Francis, R.I.C.C. 1988. Maximum likelihood estimation of growth and growth variability from tagging data. *NZ J. Mar. Freshw. Res.* 22: 42–51.
- Gunn, J., Hampton, J., Evans, K., Clear, N., Patterson, T., Langley, A., Bigelow, K., Leroy, B., Williams, P., Miyabe, N., Bestley, S., Hartmann, K., and Sibert, J. 2004. Migration and habitat preferences of bigeye tuna, *Thunnus obesus*, on the east coast of Australia – a project using archival and conventional tags to determine key uncertainties in the species stock structure, movement dynamics and CPUE trends. CSIRO Marine Research, FRDC Project No. 1999/109.
- Hampton, J. 1997. Estimates of tag-reporting and tag-shedding rates in a large-scale tuna tagging experiment in the western tropical Pacific Ocean. *Fish. Bull. U.S.* 95:68-79.
- Hampton, J., and Fournier, D.A. 2001. A spatially disaggregated, length-based, age-structured population model of yellowfin tuna (*Thunnus albacares*) in the western and central Pacific Ocean. *Marine and Freshwater Research* 52: 937–963.
- Hampton, J., and J. Gunn. 1998. Exploitation and movements of yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*T. obesus*) tagged in the north-western Coral Sea. *Mar. Freshw. Res.* 49:475-489.
- Kaltongga, B. 1998. Regional Tuna Tagging Project: data summary. Tech. Rep. No. 35, Oceanic Fisheries Programme, Secretariat of the Pacific Community, Noumea, New Caledonia.
- Kearney, R.E. 1983. Assessment of skipjack and baitfish resources in the central and western tropical Pacific Ocean: a summary of the Skipjack Survey and Assessment Programme. South Pacific Commission, Noumea, New Caledonia.
- Kleiber, P., Argue, A.W., and Kearney, R.E. 1987. Assessment of Pacific skipjack tuna (*Katsuwonus pelamis*) resources by estimating standing stock and components of population turnover from tagging data. *Can. J. Fish. Aquat. Sci.* 44: 1122–1134.
- Kleiber, P., and J. Hampton. 1994. Modeling effects of FADs and islands on movement of skipjack tuna (*Katsuwonus pelamis*): estimating parameters from tagging data. *Can. J. Fish. Aquat. Sci.* 51:2642–2653.
- Lehodey P., Chai F., and Hampton J. 2003. Modeling climate-related variability of tuna populations from a coupled ocean-biogeochemical-populations dynamics model. *Fish. Oceanogr.* 12(4): 483–494.

- Marsac, F., Fonteneau, A., and Ménard, F. 2000. Drifting FADs used in tuna fisheries: an ecological trap? *In* LeGall, J.-Y., Cayré, P., and Taquet, M. (Eds), *Pêche thonière et dispositifs de concentration des poissons*. Ed. IFREMER, Actes Colloq. 28: 537–552.
- Nielsen, A., Bigelow, K. A., Musyl, M. K., and Sibert, J. R. 2006. Improving light-based geolocation by including sea surface temperature. *Fish. Oceanogr.*, 15: 314–325.
- Nielsen A, and Sibert, J. R. 2007. State space model for light based tracking of marine animals. *Can. J. Fish. Aquat. Sci.* In press.
- Pollock, K.H., Hoenig, J.M., Hearn, W.S., and Calingaert, B. 2001. Tag reporting rate estimation: 1. An evaluation of the high-reward tagging method. *North Am. J. Fish. Manage.* 21: 521–532.
- Schaefer, K.M., and Fuller, D.W. 2002. Movements, behavior, and habitat selection of bigeye tuna (*Thunnus obesus*) in the eastern equatorial Pacific, ascertained through archival tags. *Fish. Bull.* 100: 765–788.
- Schaefer, K.M., and Fuller, D.W. 2005. Behavior of bigeye (*Thunnus obesus*) and skipjack (*Katsuwonus pelamis*) tunas within aggregations associated with floating objects in the equatorial eastern Pacific. *Mar. Biol.* 146: 781–792.
- Schaefer, K.M., Fuller, D.W., and Block, B.A. 2007. Movements, behavior, and habitat utilization of yellowfin tuna (*Thunnus albacares*) in the northeastern Pacific Ocean, ascertained through archival tag data. *Mar. Biol.* doi: 10.1007/s00227-007-0689-x
- Senina, I, Sibert, J., and Lehodey, P. In prep. Adjoint-based parameter estimation for basin-scale ecosystem-linked population models of large pelagic predators: application to skipjack tuna.
- Sibert, J.R., J. Hampton, D.A. Fournier and P.J. Bills. 1999. An advection-diffusion-reaction model for the estimation of fish movement parameters from tagging data, with application to skipjack tuna (*Katsuwonus pelamis*). *Can. J. Fish. Aquat. Sci.* 56: 925–938.
- Sibert, J.R., and Hampton, J. 2003. Mobility of tropical tuna and the implications for fisheries management. *Mar. Pol.* 27: 87–95.
- Sibert, J., Hampton, J., Kleiber, P., and Maunder, M. 2006. Biomass, size and trophic status of top predators in the Pacific Ocean. *Science* 314: 1773–1776. doi: 10.1126/science.1135347.

## **Annex 1 Review of Previous Tagging Programmes**

The WCPO tuna fishery stretches across more than 20% of earth's circumference and produces over half of the world's internationally marketed tuna. Figure 1 (main text) shows the recent catch distribution of the major species in the WCPO. Tagging programmes in the WCPO have contributed perhaps more than elsewhere to understanding the dynamics of the major global tuna fishery in this area, and to routinely anchor assessments of skipjack, yellowfin and bigeye stocks.

### **Skipjack Survey and Assessment Programme (SPC)**

The Skipjack Survey and Assessment Programme (SSAP) was carried out from 1977-1981, with main aim of investigating skipjack dynamics throughout the extensive SPC area (see Figure A1). At this time the surface catch, mostly taken by pole-and-line vessels, was around the 400,000 mt level, with a longline fishery taking an additional 200,000 mt of mostly yellowfin tuna.

More specifically, the project was to provide (SPC, 1975):

1. a better understanding of the migrations and stock structure of skipjack, thus determining the degree to which fisheries in different areas exploit the same stock and hence interact with each other;
2. valuable information on skipjack and baitfish as the basis for further development of these resources within the region; and
3. better knowledge of population parameters (growth, mortality etc) of each skipjack stock, this enabling better assessment of each stock and the effect of fishing on them.

The project aimed to tag and release 100,000 skipjack tuna over three years throughout the region to meet these objectives. Using two different chartered pole-and-line vessels supplied by Japan and with operational costs funded by various donors (total US\$ 3.8 million), 150,000 tunas (95% skipjack tuna) were ultimately tagged and released over wide area east of 140<sup>0</sup>E (Figure A1), with an overall recapture rate of around 4.5% ultimately recorded. Baitfish surveys and other biological research activities were also carried out.

Subsequent attrition analyses demonstrated for the first time the very large biomass of skipjack available in the region, and highlighted the potential for considerable increases in the tuna catch, especially of skipjack, at the prevailing low exploitation rates, then estimated at around 4%. These results were in large measure responsible for generating the increased interest in the WCPO tuna stocks by international fleets.

The SSAP work was regarded at the time as ground-breaking, generating new information on skipjack, including movement, mortality and spatial interaction data, and demonstrating the value of large-scale tagging for assessments of highly mobile resources. Indeed, much of the information is still used as an important reference point at that level of exploitation and SSAP tagging data is integrated into current skipjack stock assessments. However, little information was gathered on other tuna species of interest viz. yellowfin, bigeye and albacore tuna.

## Regional Tuna Tagging Project (SPC)

Through the 1980s, the purse seine fishery expanded rapidly in the equatorial waters of the WCPO, with the total purse seine catch exceeding one million tonnes in 1991. The longline fishery, on the other hand, declined to some extent, with a shift to targetting more valuable and less abundant bigeye tuna.

A second large scale tagging experiment, the Regional Tuna Tagging Project (RTTP) was launched in 1989, with the aim of updating the skipjack assessments, but with greater emphasis on yellowfin and if possible, bigeye assessments. Its specific objectives were:

1. to estimate interactions between tuna fisheries in areas where several different fisheries operate concurrently;
2. to further use the description of tuna movements to predict interactions for projected fishery developments;
3. to provide estimates for yellowfin tuna population parameters for selected areas of currently intense fisheries;
4. to provide updated estimates of skipjack tuna population parameters where fishing has increased since 1980;
5. to provide assessments of the potential for further expansion of tuna fishing in the region.

To achieve these objectives, it was planned to release at least 20,000 fish in each of two years, with emphasis on releases of yellowfin tuna.

A similar approach to the SSAP was adopted, with a Japanese-built pole-and-line vessel chartered from Tuvalu, and supported by funding from the 6<sup>th</sup> European Development Fund (€3.5 million). The use of the primary vessel was augmented by local pole-and-line vessels in Solomon Islands, Kiribati and Fiji, and as an extension to the project, troll/pole vessels for albacore tagging in the southern part of the WCPO. The main focus remained on tropical tunas, with tagging activity concentrated on the main fishing area for the international fleet (10°N–10°S, 140°E–180° – Figure A1), with extensions for the first time to Philippines, Indonesia and northeastern Australia. Separate in-country projects were carried out in Kiribati, Solomon Islands, Fiji and Philippines.

A total of 98,401 skipjack, 40,075 yellowfin and 8,074 bigeye were tagged, with good success in targeting juvenile yellowfin and juvenile/medium-sized bigeye. Approximately 18,500 recaptures (12.6%) were received, with extensive publicity to cover all possible sources of recoveries; sources of tag loss (slippage, non-reporting) were comprehensively estimated for the first time in these experiments.

Data generated by this highly successful tagging work were applied to tag-based assessments for skipjack and yellowfin tuna. Both species showed moderate levels of exploitation at that time (around 20%), with information on age-specific natural mortality (M), mobility, and spatial structure analysed. Valuable data on the poorly-understood bigeye tuna were obtained for the first time in the region from the experiments. These outcomes were concurrent with the development and evolution of a powerful length-based age-structured model (MULTIFAN-CL) to enable the incorporation of available tagging data routinely into stock assessment analysis.

The separate albacore tagging work in temperate waters was less successful, given the greater difficulty of tagging large numbers of this non-schooling species in good condition. However sufficient data were gathered from all sources to generate preliminary estimates of some basic stock parameters.

Other than the deployment of small numbers of electronic (archival and pop-up satellite) tags, which are now providing much new information at the individual level useful for better understanding habitat utilisation, vulnerability and interpreting catch/effort data, there has been little tagging in the WCPO since 1992.

### **PNG Tuna Tagging Project – Phase 1 (SPC and PNG NFA)**

In response to repeated calls for a new large-scale tuna tagging experiment to be carried out in the WCPO, noting the continuing increase in catch and fishing mortality and the need to reduce uncertainty in existing assessments, the first phase of a third regional project was launched in Papua New Guinea in 2006, utilising a chartered pole-and-line vessel from Solomon Islands. The PNG EEZ has produced close to 400,000 mt of catch in each of the years 2003, 2004 and 2005, with much of this taken in association with FADs.

The objectives of the Phase 1 PNG Project were:

1. **To obtain information on the large-scale movement of tuna in, and from, the PNG EEZ.** This information is important for understanding the relationship of PNG stocks with those of adjacent areas. Movement rates are particularly important for assessing the potential for interaction between fisheries operating in different areas. The comparison of tagged fish movements from the Bismarck Sea that will result from this project with tagged fish movements from the same area in the early 1990s (before extensive anchored FAD deployment) will provide important new information on the meso- to large-scale effects on tuna movement of large anchored FAD arrays.
2. **To obtain information on current exploitation rates of tuna in the PNG EEZ.** Information on local exploitation rates is important for understanding the impact of fishing at the EEZ scale. In particular, it allows estimation of the extent to which current catch levels may reduce the standing stock of tuna and the catch-per-unit-effort of the fisheries, a phenomenon commonly known as “local depletion”.
3. **To obtain information on the dynamics of tuna associations with FADs, in particular species-specific information on residence times, vertical and horizontal movements and FAD interactions.** This information is required for a better understanding of the effects of FADs on tuna stocks and their vulnerability to fishing, and for the design of appropriate management measures.
4. **To obtain data that will contribute to regional tuna stock assessments.** Conventional tagging data are an important component of tuna stock assessments, providing quasi-fishery-independent information on exploitation rates, natural mortality, movements and other parameters.
5. **To obtain information on the trophic status of free-swimming schools of tuna, and tunas associated with FADs, other floating objects and seamounts.** This in-

formation is required for the general understanding of the ecosystem impacts of FADs compared to other types of tuna aggregations.

6. **To characterise the variability and extent of catches of by-catch species from purse seine catches in PNG.** NFA runs an observer programme with high coverage rates, which offers the opportunity to document by-catch levels and their variability in purse seine sets on anchored FADs and other set types.

During two three-month charter periods, from August to November 2006 and February to May 2007 respectively, the project has seen almost 62,000 tunas tagged and released over a wide area of PNG waters (Figure A1), comprising 40,338 skipjack (65.4%), 20,649 yellowfin (33.4%) and 691 bigeye (1.1%). This was more than twice the nominal release target for yellowfin and skipjack tuna, but with fewer bigeye tuna than the nominal target of 3,000 releases. In line with project objectives, 284 archival tags and 222 sonic tags were deployed. As June 30<sup>th</sup> 2007, close to 4,700 recaptures had been received (7.6%), mostly with good recapture data, and it appears at this stage that the Phase 1 project will be well placed to achieve most if not all of its primary objectives. Preliminary analysis of the data is expected to commence in early 2008.

### **Hawaii Tuna Tagging Project (University of Hawaii)**

The PFRP funded a tuna tagging project to investigate movement patterns of yellowfin and bigeye tuna to address local interaction issues and examine exploitation rates, particularly at FADs and seamounts. The objectives of the Hawaii Tuna Tagging Project were to examine:

1. movements of bigeye and yellowfin within the Hawaii EEZ and between major fishing grounds;
2. interactions:
  - a. direct gear interaction – concurrent interaction between competing fisheries in the same time/area strata for the same sized fish, including surface and sub-surface gear types;
  - b. sequential or progressive interactions – interactions which occur as fish grow and recruit to different fisheries;
  - c. spatially segregated interaction – interactions where fish move between fishing grounds and enter new fisheries remote in time and space;
3. exploitation rates and differential vulnerability (local fishing mortality) of tuna around seamounts and Fish Aggregation Devices (FADs); and
4. aggregation effects – retention rates of bigeye and yellowfin tuna around seamounts, FADs and local fishing grounds.

The project was established to address these specific issues of local interest and was preceded by a specific design study (Bills and Sibert 1997). Tag releases, primarily of tuna captured by handline fishing on FADs and seamounts, took place from 1995 – 2000, eventually releasing 15,397 conventionally tagged tuna consisting of 7,959 bigeye (52%) and 7,440 yellowfin (48%), very close to the proposed 1:1 ratio for the project. Tag releases for bigeye and yellowfin ranged from 29–133 cm fork length (FL) and 26–143

cm FL respectively, though most releases were close to mean values (bigeye 59.8 cm, yellowfin 58.4 cm). Recapture rates for both species were very similar with an overall recapture rate of 10.3% (Itano and Holland 2000)<sup>16</sup>.

Recapture data was analysed in a number of ways and resulted in peer reviewed publications on interaction and tuna movement rates (Holland et al. 1999, Sibert et al. 2000). Adam et al. (2003) examined HTPP data to produce size specific estimates of transfer rates between fishing grounds, natural mortality, fishing mortality and residence time at a productive seamount fishing area.

From an operational standpoint, the project was significant in that it was able to achieve over 15,000 tag releases with some release cohorts of over 500 fish per trip using relatively small troll and handline vessels. One Hawaiian pole-and-line vessel was also used to capture and tag smaller yellowfin and bigeye tuna from FADs. A range of handline fisheries exist in Hawaii and these methods and techniques were fully utilised to target bigeye tuna which are normally difficult to capture for tagging studies. The professional handline vessels or modern pole-and-line boat could be promising tagging platforms if sub-regional tagging projects were to be initiated.

### **EPO Tuna Tagging (IATTC)**

The Inter-American Tropical Tuna Commission (IATTC) began a bigeye tuna tagging project in the equatorial eastern Pacific Ocean (EPO) in 2000. The justifications for this project were: 1) Development and rapid expansion of the purse-seine fishery on drifting fish-aggregating devices (FADs) in the EPO in 1994 resulting in a substantial increase in catches of bigeye from about 5 thousand to over 50 thousand tons by 1996, 2) Declining trend in Japanese longline bigeye catch in the EPO from about 100 to less than 50 thousand tons by 1996, 3) Concern that the longline fishery for bigeye is being indirectly affected by the purse-seine fishery on FADs, 4) Lack of scientific information on bigeye population structure, movements, mortality, and growth in the EPO, and 5) The necessity to quantify these and other life history information for inclusion in annual stock assessments for bigeye in the EPO.

The objectives of this tagging project were to: 1) Utilize a live-bait pole-and-line vessel to target bigeye in a series of large-scale tag and release experiments in the EPO, 2) Tag and release with conventional plastic dart tags large numbers of smaller bigeye (<100 cm), 3) Implant archival tags in bigeye, over as great of size range as possible, and release them, 4) Conduct acoustic telemetry studies concurrently on bigeye and skipjack tunas associated with FADs, 5) Estimate age-specific movements, mortality, and growth rates from tagging data for bigeye in the EPO, 6) Estimate age-specific horizontal and vertical habitat utilization distributions from the archival tag data, and 7) Evaluate the degree of interaction between the purse-seine and the longline fisheries.

The IATTC conducted six bigeye tuna tagging cruises in the EPO during March to May of 2000, and 2002 through 2006, utilizing a chartered live-bait pole-and-line tuna fishing vessel. Bigeye tuna associated with drifting FADs and Tropical Atmosphere-Ocean

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<sup>16</sup> Total release numbers and recapture rates were slightly higher as a low rate of tagging continued after this analysis was conducted.

(TAO) moorings were captured, tagged, and released in the equatorial EPO between 5°S and 5°N and between 94° and 99°W. 84.3% of all releases were from fish captured in association with TAO moorings along the 95°W meridian between 2°S and 2° N. Fish were captured for tagging using lift poles (one- and two-pole outfits), handline gear, and rods and reels during the day and night.

**Table A1. The total numbers of conventional plastic dart tags released and returned for bigeye, skipjack, and yellowfin tuna during this project (current through July 30, 2007).**

Year	Bigeye Tuna			Skipjack Tuna			Yellowfin Tuna		
	Released	Returned	Percent Returned	Released	Returned	Percent Returned	Released	Returned	Percent Returned
2000	101	22	21.8	1235	262	21.2	73	8	11.0
2002	1418	581	41.0	249	30	12.0	186	29	15.6
2003	8605	4032	46.9	138	22	15.9	863	244	28.3
2004	7089	2800	39.5	878	152	17.3	306	39	12.7
2005	1929	805	41.7	333	32	9.6	265	38	14.3
2006	32	9	28.1	592	65	11.0	541	47	8.7
<b>Total</b>	19174	8249	43.0	3425	563	16.4	2234	405	18.1

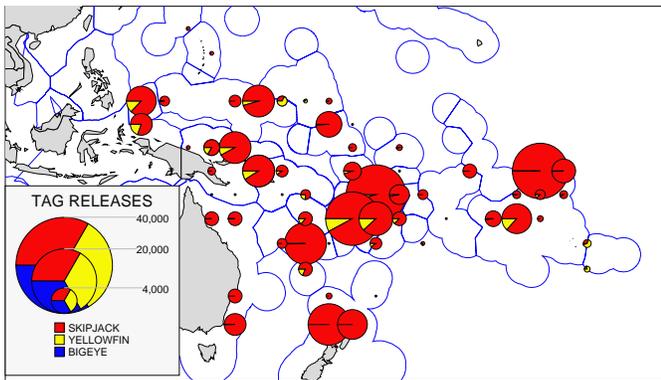
**Table A2. The total numbers of archival tags released and returned for bigeye, skipjack, and yellowfin tuna during this project (current through July 30, 2007).**

Year	Bigeye Tuna			Skipjack Tuna			Yellowfin Tuna		
	Released	Returned	Percent Returned	Released	Returned	Percent Returned	Released	Returned	Percent Returned
2000	96	35	36.5	NA	NA	NA	NA	NA	NA
2002	26	8	30.8	41	1	2.4	NA	NA	NA
2003	90	54	60.0	10	0	0.0	8	3	37.5
2004	58	32	55.2	33	6	18.2	NA	NA	NA
2005	53	33	62.3	48	0	0.0	NA	NA	NA
2006	NA	NA	NA	2	0	0.0	45	5	11.1
<b>Total</b>	323	162	50.2	134	7	5.2	53	8	15.1

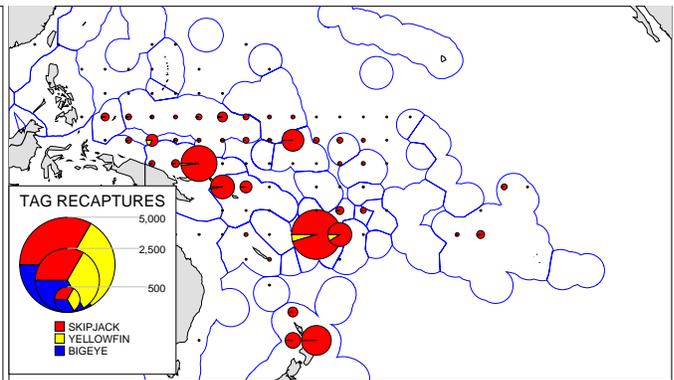
Results to date from tagging data analyses, regarding horizontal movements and population structure, indicate: 1) Conventional and archival tag recapture rates are quite high, indicative of the high affinity of bigeye to FADs and exploitation rate, 2) Conventional tag recapture data indicate limited dispersion from release locations, 3) Movement paths, derived from archival tag data, for bigeye at liberty in excess of one year show restricted movements and site fidelity, 4) Horizontal utilization distributions, derived from archival tag data, for bigeye are geographically confined, likely a result of affinity to areas of high prey availability, and 5) These results indicate regional fidelity for bigeye tagged and released in the equatorial EPO.

Several of the field objectives of this tagging project were accomplished and other objectives based on various data analyses are in progress. There have been several studies, based on data derived from this tagging project, published thus far and there are several in progress. Some of the results to date have been incorporated into the annual stock assessments for bigeye in the EPO, and others are expected to be utilized in that capacity in the near future.

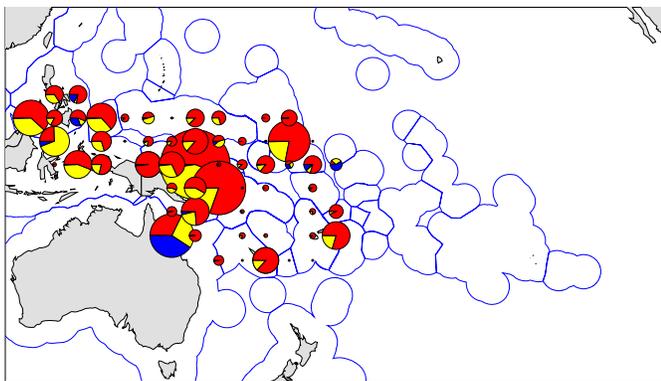
### SSAP Releases



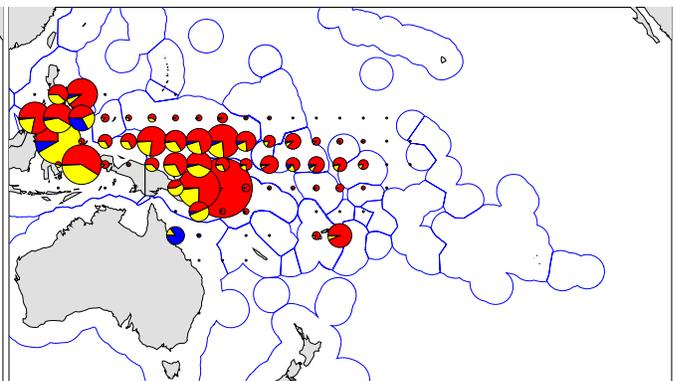
### SSAP Recaptures



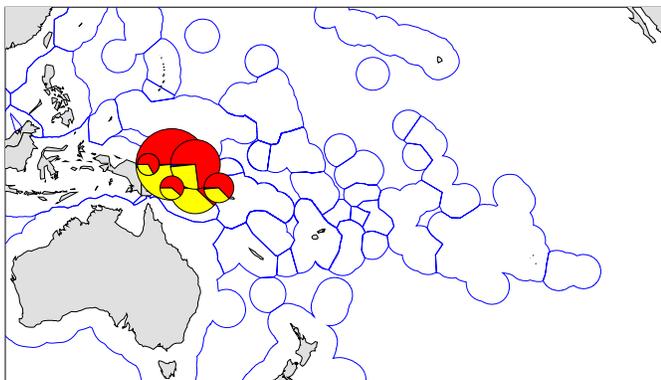
### RTTP Releases



### RTTP Recaptures



### Phase 1 (PNG) Releases



### Phase 1 (PNG) Recaptures (at 6 July 2007)

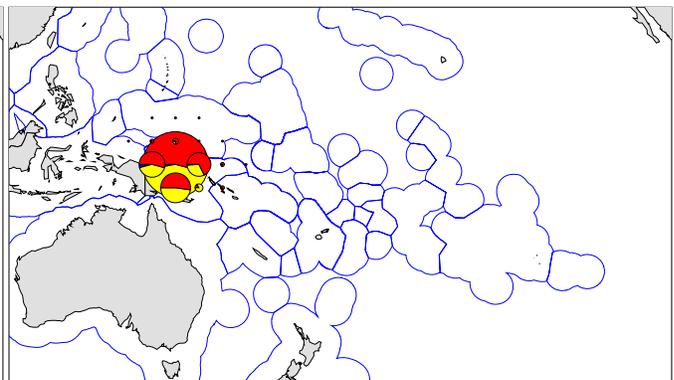


Figure A1. Distribution of tag releases and recaptures by species for previous SPC tagging programmes.