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Regional study of South Pacific albacore population biology: Year 1 - biological sample collection

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Jessica Farley[1], Ashley Williams[2], Campbell Davies[1], and Simon Nicol[2]

[1] CSIRO Marine and Atmospheric Research, Hobart, Australia
[2] Oceanic Fisheries Programme, Secretariat of the Pacific Community, Nouméa, New Caledonia

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Jessica Farley[1]
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[1]CSIRO Marine and Atmospheric Research, Hobart, Australia
[2] Oceanic Fisheries Programme, Secretariat of the Pacific Community, Nouméa, New Caledonia

Executive summary

This paper describes the results of the first year of a regional study of South Pacific albacore population biology. The main objective of the study was to develop a biological sampling program for the southwest Pacific region to ensure that unbiased estimates of biological parameters (age, growth and reproduction) can be obtained. These parameters are required inputs for regional stock assessment models and Australia's Eastern Tuna and Billfish Fishery (ETBF) harvest strategy.

Existing biological data for albacore from the ETBF were analysed to estimate the minimum sample size required for reliable estimates of growth and maturity. Although this length-age data set was small (n=83), the results indicated that size-at-age data from 100 individuals (~7 fish per age class for ages 1+ to 14+ years) should provide acceptable levels of precision (i.e. coefficients of variation <0.2) for estimating growth parameters, provided the samples cover the same size and age ranges used in the analysis. Given this is the first study of this nature for albacore in the South Pacific and that the maximum age of albacore could be older than 14 years, we suggest that at least 200 size-at-age estimates are obtained by year/sex/region in the first instance, and that this estimate is updated as additional otoliths are read. Approximately 100 individuals were found to be sufficient to estimate the size at 50% maturity (by year/sex/region), although it is recommended that this analysis also be updated as more data becomes available.

A sampling programme was developed, based the results of the above analysis, with the aim of sampling 500 albacore from the ETBF, 160 from the New Zealand troll fishery and 240 from each of seven Pacific Island Countries and Territories (PICTs) each year for two years.

Biological sampling of albacore in the ETBF (otoliths, spines, gonads, & muscle tissue) for the current FRDC/WCPFC-funded project was initiated in November 2008 and 469 fish have been sampled so far. Sampling of the New Zealand troll fishery was initiated in 2008 (Jan-April '08 n=160 and Jan-Mar '09 n=67) and will be undertaken again in 2010. Biological sampling of the PICTs (otoliths and gonads), as part of the EU-funded SCIFISH project, was initiated in 2009 and 136 fish have been sampled to date. All biological material sampled will be sent to CSIRO Marine laboratories (Hobart) for archiving and laboratory processing.

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1. Introduction

Albacore tuna are found in waters between approximately 10-50°N and 5-45°S globally. Separate northern and southern stocks are assumed to exist in the Pacific Ocean based on their spatial distribution and different spawning times/locations. In the South Pacific, albacore have been targeted by longline fleets since the early 1950s, and recent catches have increased from 20,000-30,000 t per annum in the mid-1980s to 60,000-70,000 t per annum in the mid-2000s (Hoyle et al., 2008). The increase in catch has been largely due to an increase in the catch by small longline fisheries in Pacific Island Countries and Territories (PICTs). The catch of albacore in Australia's Eastern tuna and Billfish Fishery (ETBF) has also grown substantially from a few hundred tonnes prior to 2004 to 2,591 tonnes in 2006 and 1,916 tonnes in 2007. The species now represents a main target species for the ETBF fleet. These increased catches have raised concerns about whether these catch levels can be maintained long-term, the potential risk to the stock(s) and the potential reduction in the economic return from the fisheries.

In 2006, a regional age-based stock assessment for South Pacific albacore estimated the stock to be well above the level corresponding to the average maximum sustainable yield (MSY) and fishing mortality rates to be much lower than required to produce the MSY (Langley and Hampton, 2006). The stock assessment, however, used many biological parameters that were either uncertain or assumed (Hoyle, 2008). In 2006, a pilot project was undertaken in the ETBF to provide preliminary descriptions of a number of these biological parameters for albacore (Farley and Clear, 2008) for the ETBF, some of which were examined in the 2008 stock assessment and sensitivity analysis (Hoyle et al., 2008). The 2008 stock assessment was more pessimistic than the 2006 assessment (Anon, 2008) and the recent management strategy evaluation for albacore in the ETBF also suggested that the population is at low levels (Preece et al., 2009). It is recommended that substantially more biological samples are required to provide age-based estimates of population parameters to address the biological uncertainties in the current stock assessments for albacore in the South Pacific (Farley and Clear, 2008; Hoyle et al. 2008; Hoyle 2008).

CSIRO subsequently proposed a 3-year project on albacore population biology in collaboration with SPC who had obtained EC funding for albacore (SCIFISH project). At the 3rd session of the Western and Central Pacific Fisheries Commission Scientific Committee (WCPFC-SC) meeting, it was noted that the project had "strong assessment implications with wide-spread benefits to a number of fisheries active in the WCPO". In 2008, the WCPFC-SC recommended and the Commission approved funding towards the first phase of the project. The aims were to:

1. Develop a biological sampling program to provide unbiased estimates of biological parameters for albacore are obtained for the southwest Pacific region.

2. Collect biological samples (otoliths/spines, gonads & muscle tissue) from albacore caught in the southwest Pacific in cooperation with CSIRO, SPC and the New Zealand Ministry of Fisheries.

This paper describes the results of this first phase of the study.

2. Biological sampling program

2.1 Samples and data required

CSIRO and SPC albacore biology projects are primarily focussed on providing estimates of biological parameters that are central to implementation of harvest strategies for the ETBF, and improving the regional stock assessment for albacore in the South Pacific. The aims are to obtain:

- Age-based estimates of growth;
- Quantitative estimates of reproductive potential, via size/age-based estimates of specific reproductive parameters (maturity, spawning fraction, batch fecundity, and possibly total annual fecundity etc);
- Length-weight relationships;
- Sex ratio statistics;

To fulfil the objectives of the projects, the following biological material and data are required:

- Gonads (gender, maturity, batch fecundity, spawning frequency)
- Sagittal otoliths (direct age estimation)
- First dorsal fin spine (compare/verify age with otoliths)
- Fork length to the nearest cm
- Weight to the nearest 0.1 kg (whole and dressed for conversion factors)
- Capture date, location and time (if possible)
- Fishing method

2.2 Minimum sample size

When designing a biological study it is important to determine the sample size required to estimate the reproductive (maturity) and growth parameters with appropriate confidence intervals. Analyses were conducted on existing biological data for 83 albacore obtained from a 2007 pilot in the ETBF (Farley and Clear, 2008) to determine the minimum sample size required. The full analyses are provided in Appendix A of Farley and Dowling (2009) and are summarised below.

2.2.1. Growth

Von Bertalanffy growth curves were estimated and bootstrapping (200 replicates of four types of bootstrap) was used to explore the characteristics of parameter estimates (uncertainty, CV in particular) under different sampling levels. Although the existing length-age data set for albacore caught in the ETBF is small (n=83; size range 48-108 cm FL; age range 1+-14+ years), initial examination showed that these provided low CVs for growth parameters (CVs of 1.2% for L_∞, 6.9% for K and ~ 12.7% for t_0) (Table 1). CVs on the parameter estimates decreased when the sample size was increased to 150 and 200.

Table 1. CVs of von Bertalanffy growth parameters for 200 bootstraps for all, males and females. Note that *n*=10 were of unknown sex. The CVs for other sample sizes (150 and 200) was inferred.

CV (%)	L_∞	K	t_0
All (*n*=83)	1.19	6.9	12.70
By individual n=83	1.28	7.46	10.76
By age *n*=83	1.19	8.89	24.34
Males (*n*=45)	1.53	10.56	24.11
Females (*n*=28)	1.85	11.98	28.69
n=150	0.90	5.30	7.70
n=200	0.80	4.60	6.70

The effect of dropping out individual age classes was also examined. This confirmed the importance of the first age class (age 1) as CVs for growth parameters were the highest when this age class was dropped (CVs: 1.8% for L_∞, 13.2% for K and ~ 28.1% for t_0) (see Appendix A). The analysis also confirmed the importance of the third age class (age 3) which is the age at which growth is estimated to decelerate considerably.

Higher CVs for growth parameters (Table 1) were obtained when analysing the data by sex, which indicated that sample sizes as low as 28 or 45 are not adequate for estimating growth curves by sex. Given that there appears to be significant sex-specific differences in growth (and/or mortality?) rate and L_∞ (male 104.5; female 98.4), it was recommended that sufficient samples be collected to estimate separate growth curves by sex.

Overall, the results suggest that 100 individuals should give acceptable CVs for growth parameters for each sex, provided the samples cover the size/age ranges as in the pilot sample. It was recommended that:

- A minimum of one hundred albacore be aged for both males and females, and that there is good coverage of ages 1 to 5 and old fish. If area specific growth curves are the aim, then >100 individuals applies to each area and gender.

- Otoliths for ageing are stratified by length class, and that it may be necessary to sample additional large individuals to provide sufficient samples sizes.

The above analyses were based on age estimates ranging from 1+ to 14+ years (48-108 cm). A minimum of 100 age estimates suggests that ~7 fish per age class are required to calculate a growth curve. This estimate is consistent with a simulation study by Kritzer et al. (2001) which recommended a general rule of 7-10 fish per age class. Given that the maximum age of albacore could be older than 14 years (since albacore larger than 108 cm have been landed) we suggest that at least 200 age estimates are obtained by strata. The analysis should then be updated to re-assess the distribution of sizes at age and avoid reading more otoliths than necessary.

Several factors need to be taken into account in attempting to obtain unbiased estimates of growth parameters for each sex/year/area strata. For example, Farley and Clear (2008) showed that ~70% of albacore caught by longliners in the Coral Sea are male, and that ~15% of the otoliths sectioned for ageing were unreadable due to poor otolith clarity. In addition, it is likely that there will be fewer fish sampled from certain size/age classes (i.e. the very small

and very large in each region – especially if random sampling is undertaken), and that some otoliths may be broken or found to be unsuitable for sectioning. Therefore, substantially more otoliths need to be collected to obtain 200 size at age estimates with a good spread across age classes. We suggest that at least 40 otoliths are sampled per month from eastern Australia, 20 per month from the PICT's, and 40 per month from New Zealand, so that there are sufficient otoliths to select from for ageing.

2.2.2. Maturity

Bayesian bootstrapping was undertaken to explore the CV of the predicted size at 50% maturity (L_{50}) estimate based on a logistic regression fitted to the maturity data (from histology) to determine the minimum sample size required (see Appendix A). The existing data set for maturity estimates for the ETBF is small (n=61). However, the CV from the L_{50} estimate is 1.7% and the direct CV of L_{50} is 1.5%. Again, these CVs are very low suggesting that a sample size of ~100 individuals would be acceptable. However, these analyses were done on samples from a limited time/area strata and it is recommended that they are updated as more data becomes available.

It is important to note that robust estimates of maturity depends on both immature and mature individuals being sampled in an unbiased way. Thus, estimating the maturity schedule is difficult for any species where the mature fish migrate to discrete areas to spawn, or where there is any bias towards mature or immature fish in the sampling program. Although the migratory patterns of albacore are poorly understood, they are thought to be one of only four tuna species that are truly migratory and undertake seasonal migrations to specific feeding and spawning areas (Schaefer, 2001). Spawning is thought to occur predominantly between 10-25ºS in the western and central regions of the Pacific Ocean during summer, and juveniles quickly move south of 30°S. It has been suggested that juveniles and sub-adults do not return to the sub tropics and tropics until they mature (Jones, 1991; Murray, 1994; Chen et al., 2005).

To obtain an accurate maturity schedule for albacore, it is important that sampling sites and times are selected to sample across the size range that includes immature to fully mature females at the time of year when it is possible to distinguish between the two reproductive states. There are three main factors to consider:

1. **Size range**: Farley and Clear (2008) indicated that L_{50} could be around 82 cm in the ETBF, although this estimate could be biased because the sampling was targeted at the spawning latitudes in the northern ETBF where immature fish are potentially underrepresented. Thus it is recommended that sampling should include fish at least in the size range of 70-100+ cm FL, and ideally smaller.

2. **Sampling area**: The size frequency of albacore caught in the ETBF by latitude suggests that albacore caught in the south are smaller than those in the north. Thus, to sample the above size range (70-100 cm), sampling must include the latitudinal bands from at least 15-35ºS across the pacific, rather than simply concentrating on the northern latitudes where albacore landings are highest.

3. **Sampling time**: Farley and Clear (2008) found that there is a relatively long temporal window for sampling albacore (January to July at least) which will allow for a clear distinction between mature and immature females. For the months following the spawning season (April –July), maturity is based on the presence of delta stage atresia in ovaries. These months will be particularly important for sampling.

2.3 Sampling strategy

To undertake a complete study on age, growth and reproduction, ideally the sampling should include the entire distribution of the species on a regular basis (monthly) over a year. To determine if there is variation in parameters such as growth and maturity over time, it is necessary to repeat the sampling over a second year at least and ideally three or more. However, a sampling program must also be cost effective and logistically feasible as complete time and space sampling is costly and requires extensive field work.

In the South Pacific, albacore is caught over a large area predominantly by longline fisheries west of 110ºE (Figure 1). The most cost effective way to obtain biological samples is from these fisheries via port sampling or regional observer programs in Australia (ETBF) and the Pacific Island country and territory (PICT) fisheries on a monthly-basis. Port sampling of the seasonal troll fishery in New Zealand and recreational fishery in south eastern Australia is also feasible.

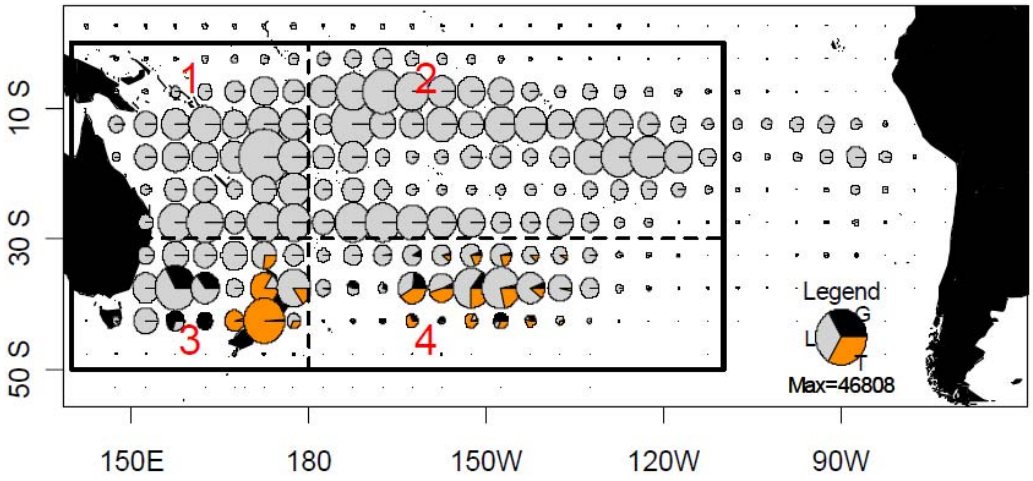

Figure 1. Total catch from 1960 to 2003 by 5 degree squares of latitude and longitude by fishing gear: longline (L), driftnet (G), and troll (T). The area of the pie chart is proportional to the total catch. The boundary of the stock assessment area is delineated by the grey lines. (Map reproduced from Langley, 2006).

2.3.1. Australia

CSIRO is coordinating collection of biological samples from albacore caught in the ETBF and the local recreational fishery in south eastern Australia. The ETBF is particularly well positioned to obtain hard parts from albacore as the fishery covers almost the entire latitudinal (and thus size) range of the species. In addition, the recreational fishery in southern Australia predominantly catches juveniles ranging in size from 45-75 cm FL. Thus sampling along the length of Australia's east coast will allow for the full size/age range of the species to be sampled, which is not possible in many other fisheries. Port sampling is the most efficient method for the collection of biological material for albacore caught in the ETBF as the fish are landed whole and cannot be sampled at sea and there is a formal port sampling program in place.

Sampling method: Observers, contractors and CSIRO staff in ports.

Spatial coverage: The ETBF domestic longline fishery along Australia's east coast and recreational fisheries in southern Australia. The main sampling ports will be Cairns, Mooloolaba, Brisbane, Coffs Harbour, Portland, Ulladulla and Hobart. Other ports will be sampled if fish become available.

Temporal coverage: Sample on a monthly basis for 2 years. Started in November 2008.

Biological samples: Sagittal otoliths, gonads, dorsal spine and muscle tissue (gonads stored frozen or fixed in formalin). Samplers of the longline fishery will record fork length, dressed/whole weight, landing date and vessel name. Capture details, fishing method and set information can be obtained from AFMA logbook records. Samplers of the recreational fishery will record fork length, weight if possible, catch date and and location.

Sample size: Target of 40-50 fish per month from the landed catch. The expected total number of fish sampled could be 1200 (50 fish x 12 months x 2 years). A mixture of random and stratified sampling will be undertaken depending on the size of fish landed and logistics. Where possible, very small and very large fish will be selected so the maximum sample size of these rarer sized fish is obtained.

Fish size: It is anticipated that the full size range of albacore will be sampled. The recreational fisheries will be dominated by juveniles, while the longline fishery will comprise sub-adults and adults depending on the latitude caught.

Sample processing: All biological samples will be processed at CSIRO (Australia).

2.3.2. Pacific Island Countries and Territories (PICTs)

SPC is coordinating the collection of biological samples from albacore across the PICTs as part of their EU-funded SCIFISH project. Seven longline fisheries will be sampled from New Caledonia in the west to French Polynesia in the east. The latitudinal range of the fisheries is approximately 10-25ºS and it is expected that adults (>80 cm) will dominate the samples from this source.

Sampling method: Observers on PICT domestic tuna longline fleets.

Spatial coverage: PICT nations of New Caledonia, Vanuatu, Fiji, Tonga, Samoa, Cook Island and French Polynesia.

Temporal coverage: Aim to sample on a monthly basis from each country for 2 years.

Biological samples: Sagittal otoliths and gonads (stored frozen). Fixing gonads in formalin is not possible at sea on commercial vessels. Observers will also record fork length, location and date/time of capture, fishing method and set information.

Sample size: Target of at least 20 fish per trip (month) across a broad size range of fish. The expected total number of fish sampled might be 3360 (20 fish x 7 countries x 24 months).

Fish size: The majority will be >80 cm FL (adults).

Sample processing: All biological samples will be frozen and sent to CSIRO (Australia) for laboratory processing.

2.3.3. New Zealand

The New Zealand Ministry of Fisheries (MFish) and the National Institute of Water and Atmospheric Research (NIWI) are coordinating the collection of biological samples from troll caught albacore in New Zealand waters. In addition, SPC are sampling albacore caught during tagging operations within the New Zealand EEZ (Williams et al., 2009). It is anticipated that juveniles will dominate the troll caught fish, while juveniles and adults will be sampled during the tagging operations.

Sampling method: NZ MFish observer program in ports and SPC staff during tagging operations.

Spatial coverage: New Zealand's west coast domestic troll fishery and east coast troll/longline via SPC's tagging program.

Temporal coverage: Sample the troll fishery on a monthly basis during the 4 month season (Jan-Apr) for 2 years (2008 and 2010). Additional samples collected by SPC in summer 2009 via trolling and autumn 2010 via longlining.

Biological samples: Sagittal otoliths, gonads, dorsal spine and muscle tissue (stored frozen). Observers will also record fork length, location and time of capture, fishing method and set information.

Sample size: Target of 40 fish per month randomly selected from the landed troll catch. The expected total number of fish sampled is 320 (40 fish x 4 months x 2 years). A total of 70 samples collected by SPC in 2009 and a target of 100 fish in 2010.

Fish size: Predominantly juveniles ranging in size from 45-70 cm. Some adults sampled by SPC via longlining.

Sample processing: The 2008 material has already been frozen and sent to CSIRO (Australia) for processing. The 2010 material will also be sent to CSIRO.

3. Sample collection to date

3.1 Australia

Gonads, sagittal otoliths, and fin spines were sampled from albacore landed at ports in the four eastern Australian states bordering the ETBF (Queensland, New South Wales, Victoria and Tasmania). A total of 469 fish were sampled (Table 2). For each fish sampled, the fork length (FL) was measured to the nearest cm and weight to the nearest g where possible (whole and or dressed). For commercially caught fish, the vessel name was recorded so that the fishing location and other data can be obtained from AFMA logbooks at a later stage. Full catch details were obtained for recreational caught fish. Muscle tissue samples were also collected for each fish for potential future genetic or stable isotope work aimed at stock structure and trophodynamics. It is anticipated that sampling will continue at these ports, and possibly others ports, over the next 12-18 months.

Table 2. Number of biological samples obtained from albacore caught in the ETBF by month.

Month	Fork Length	Weight (whole)	Weight (dressed)	Gonad	Otolith	Fin spine	Muscle
Aug 08	2	-	-	2	2	2	2
Nov 08	29	29	-	29	28	29	28
Jan 09	33	33	-	32	33	33	26
Feb 09	57	57	-	56	57	57	57
Mar 09	87	86	28	86	85	87	87
Apr 09	21	21	1	21	21	21	21
May 09	36	35	-	35	35	36	35
Jun 09	122	115	-	115	101	122	120
July 09*	82	82	-	82	82	82	82
Total	*469*	*458*	*29*	*458*	*444*	*469*	*458*

* sampling up to 22/7/09

3.2 Pacific Island Countries and Territories (PICTs)

SPC scientists have trained observers from a number of PICTs in methods for collecting biological samples during SPC observer training workshops. Additional PICT observers will be trained during future workshops in Vanuatu (July 09) and Fiji (September 09).

Gonads and sagittal otoliths have been sampled by observers from a total of 136 albacore landed by New Caledonian longline fisheries between March and June 2009 (Table 23). For each fish sampled, the FL was measured to the nearest cm. Information on the location, time of capture and method of fishing was recorded by the observer in the SPC observer logbooks. Sampling has commenced in French Polynesia and will commence very soon in other PICTs. Sampling will continue in all 7 PICTs over the next 12-18 months.

Table 3. Total number of measurements (length, weight) and samples (gonads, otoliths, dorsal fin spines, muscle tissue) obtained from albacore caught off New Caledonia by sampling month.

Month	Fork Length	Gonad	Otolith
Mar 09	48	49	48
Apr 09	6	4	6
May 09	19	19	19
Jun 09	63	62	63
Total	*136*	*134*	*136*

3.3 New Zealand

Gonads, sagittal otoliths, fin spines were sampled from troll caught albacore landed at Greymouth, New Zealand between Jan-Apr 2008. A total of 140 fish were sampled (Table 4). For each fish sampled, the FL was measured to the nearest cm and weight to the nearest g. Catch location was recorded and vessel id number. Muscle tissue samples were also collected for each fish. Similar sampling will be conducted in the 2010 summer fishing season.

Biological samples were also collected from albacore across a wide length range from 47 cm FL to 90 cm FL during the SPC albacore tagging cruise in Jan-Mar 2009. Samples of otoliths, gonads and stomachs were collected from a total of 67 albacore, while muscle and liver tissue

were collected from 61 of these fish (Table 5). The fat content of 147 albacore was recorded using a fatmeter.

Table 4. Number of biological samples obtained from albacore off New Zealand by month in 2008.

Month	Fork Length	Weight (whole)	Gonad	Otolith	Fin spine	Muscle
Jan 08	40	40	40	38	40	40
Feb 08	40	40	40	40	40	40
Mar 08	40	40	40	40	40	40
Apr 08	40	40	40	40	40	40
Total	*160*	*160*	*160*	*158*	*160*	*160*

Table 5. Number of biological samples and fatmeter readings taken from albacore during the SPC albacore tagging cruise in New Zealand waters between Jan-Mar 2009

Month	Fork Length	Gonad	Otolith	Stomach	Muscle	Liver	Fatmeter
Jan 09	34	34	34	34	28	28	
Feb 09	24	24	24	24	24	24	124
Mar 09	9	9	9	9	9	9	23
Total	*67*	*67*	*67*	*67*	*69*	*61*	*147*

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