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Information available for developing a stock assessment for New Zealand albacore *(Thunnus alalunga)*

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7. Executive summary

Albacore in the south Pacific Ocean most likely comprise a discrete stock and are widely distributed from Australia to 100°W, and from the equator to 49°S. Total annual catches from the stock are around 60 000 t taken by longline fisheries from Japan, Taiwan, Korea, and the domestic fisheries of south Pacific nations, and by surface troll fisheries in the New Zealand (NZ) EEZ and in the sub-tropical convergence zone. Regional stock assessments of south Pacific albacore are reviewed by the Scientific Committee of the Western and Central Pacific Fisheries Commission (WCPFC). Objective 4 of this project reviews available information on albacore from NZ of utility to the regional assessment, and proposes a framework for a NZ assessment.

Historical biological data for longline-caught albacore from the Ministry of Fisheries Observer Programme includes annual length frequencies, a length-weight relationship, annual catch sex ratios, stomach contents, and life status of albacore at the time of capture. Albacore are generally landed whole, and therefore data is unavailable for gonad condition, age at sexual maturity or spawning distribution. Historical biological data for troll-caught albacore from a port sampling programme includes annual length frequencies, a length-weight relationship, sex ratio in 1999, and an otolith sample. The time series of observations from the longline fishery is from 1987 to 2004, and for the troll fishery from 1997 to 2004.

Albacore in longline catches range in length from around 42 to 115 cm, and in troll catches from around 40 cm to around 95 cm. The length distribution in troll catches is multi-modal with distinct modes corresponding to the 1, 2, and 3 year age classes, and a mean length of around 63.0 cm which is substantially smaller than that for longline catches.

The temporal distribution of observer samples on average is reasonably consistent with tuna longline fishing effort within particular fisheries management areas (FMAs) making up the NZ EEZ. The coverage of the Japanese charter fishery that operates predominantly in FMAs 5 and 7 is disproportionately high; consequently the spatial distribution of observer samples is not representative of the fishery. However, within each of the FMAs, or within discrete regions of the fishery, the spatial distribution appears representative. For these data to be of utility for the regional stock assessment, it is recommended it be temporally and spatially stratified for calculating a weight mean annual length frequency distribution.

The review of the troll port sampling data confirms it is spatially and temporally representative of the fishery, with a large sample size yielding estimates of acceptable precision.

Approximately 12% of the annual regional albacore catch is taken by the troll and longline fisheries in NZ waters, with around 5 300 t caught annually (average from 1995 to 2004). A summary of NZ albacore catch since 1972, and as reported from Licensed Fish Receiver Returns (LFRRs) since 1989 is presented. Regional catches for albacore are summarised annually by the Ocean Fisheries Programme (OFP) at the Secretariat for the Pacific Community (SPC) for the WCPFC.

Albacore catch in weight reported on LFRRs is the most reliable record of total removals by the NZ fisheries. Catch length compositions estimated from observer and port samples are of utility for estimating annual mean weight of albacore in longline and troll catches, respectively. The total numbers caught in each fishery is the input required for the regional assessment model, and this may be calculated using the reported catch in weight and the estimated mean weights from the length frequencies.

The nominal and standardised catch per unit effort (CPUE) indices for the period 1992-93 to 2003-04 are available for the longline fishery operating in the north and eastern areas (northern part of FMA 9 and FMAs 1, and 2), and the troll fishery operating mostly on the west coast (FMAs 7, 8, and 9). The indices were standardised with respect to fishing operation and remote sensed environmental variables. Detailed fishing operation location information was linked to high resolution sea surface temperature (SST) data which is combined with physical oceanographic models to represent meso- and synoptic-scale variation in ocean climatology. The temporal and spatial specifications of the CPUE indices for both fisheries are consistent with the structural assumptions of the regional assessment model.

The longline CPUE index shows a relatively flat trend from 1994 to 1998, followed by a dramatic decrease in catch rates to 2000, with a relatively flat trend from 2000 to 2004. It is likely the factors contributing to the decline are a stock-wide change in availability, and altered fishing practices for the targetting of other species. A similar decline is evident in the Taiwanese longline fishery operating in the same spatial stratum, and a decline in stock biomass is predicted by the regional assessment model over that period.

Two clear peaks are evident in the troll CPUE time series – one in 1995 and another in 1999-2000. These peaks can be related to dominant modes in the time series of port sampling length frequencies that infers strong cohorts entering the fishery. The estimated relationship between troll standardised CPUE and SST was weak, whereas a clear relationship with respect to thermocline depth has been reported for albacore surface fisheries elsewhere. Estimating a relationship for the NZ troll fishery was limited by the coarse spatial resolution of the catch and effort data. To increase the utility of troll CPUE for the regional assessment by standardising with respect to a thermocline covariate, it will be necessary to improve the spatial resolution at which troll catch and effort data is recorded.

From a review of the current stock assessment presented to the Scientific Committee of the WCPFC in August 2005, the main sources of uncertainty in the assessment were identified. A MULTIFAN-CL population model is used that assumes a single discrete stock for the south Pacific region. Although model scenarios were considered having four spatial strata, a base case model was selected that assumed a single homogeneous stratum. The two main sources of uncertainty identified in the regional albacore stock assessment were seasonal movement processes, and a conflict between important data to which the model was fitted.

It is suggested that a weakness in the assessment approach that ignores movement processes relates to the fundamental assumption implicit in a single stratum model, i.e. homogeneity in the age and length composition throughout the population. Failure of this assumption may underlie a number of the problems identified in fitting the model to observations, and that may indicate process error in the model caused by the lack of seasonal and age-specific movement of albacore. Combined with temporal-spatial patterns in CPUE, seasonality in length frequency between strata provides an indirect observation of age-specific seasonal migrations from which movement may be inferred. Length frequency data in the southern strata reveals seasonal differences in size composition of the population available to the fishery. Relative to the northern strata, there is only a moderate amount of data available since the mid-1990s in the southern strata. The NZ CPUE and length frequency data is regarded to be of high potential utility for estimating movement parameters.

Diagnostics from the regional assessment model revealed a conflict between the observed trend in catch rates of the Taiwanese longline fishery and the length frequency data from the longline fisheries. The large initial decline in catch rates is in contrast to the trend of increased size of fish in longline catches. The model estimates of decadal trends in recruitment appear to reconcile this conflict, however, this suggests uncertainty in the recruitment parameters, and, hence, model biomass. Length frequency data from the NZ troll fishery has been identified as information from which year class strengths may be inferred, and are therefore of high utility to the regional assessment.

A framework for a NZ assessment of the albacore stock supporting domestic fisheries must recognise the regional characteristics of this stock, and, therefore, it is recommended the regional stock assessment be used as the basis for a NZ assessment framework. Disaggregated fisheries definitions were applied in the regional assessment to the level of domestic fisheries, and given the flexibility for spatial stratification, its specifications are suitable for developing a framework for assessing stock status relevant for fisheries operating in the NZ EEZ. Main features of the framework include:

- contributing biological and fisheries data to the regional assessment;
- participating in developing the inputs, specifying the model, and in reviewing the results at the Scientific Committee meeting of WCPFC;

- estimate the proportion of annual stock production available to NZ fisheries and determine sustainable catch levels in the NZ EEZ; and,
- assess the relative impact of the NZ fisheries on the regional stock.

Being a component of the regional assessment, the reliability of a NZ stock assessment will depend on uncertainties in the regional population model estimates. For example, estimation of movement, catchability, and selectivity of the NZ fisheries would be critical to the NZ assessment framework as these parameters underpin estimates of temporal-spatial availability of albacore productivity to the NZ fishery. Therefore, improving the quality and quantity of observations input to the regional model that may address these uncertainties will benefit the NZ assessment directly. It is recommended that troll catch and effort data be reported to a finer spatial resolution to allow standardising a CPUE index relative to local environmental variables, in particular thermocline depth. Also, length frequency estimates from the NZ longline and troll fisheries should be temporally and spatially stratified to calculate weighted mean annual distributions that are representative of each fishery.

8. Objectives

OVERALL OBJECTIVE:

To further develop the stock assessment for the South Pacific albacore (*Thunnus alalunga*) stock.

SPECIFIC OBJECTIVE 4:

> To describe approaches to the development of a stock assessment, including estimating biomass and sustainable yields for albacore in the New Zealand EEZ.

The original intention of this specific objective was to construct a framework for selecting and specifying an assessment model and determining the desired outputs that made use of data available, both within NZ, and from the south-west Pacific region. The framework aimed to take account of a regional approach to assessing albacore rather than attempting a localised population assessment within NZ waters. Consequently, an examination of the current albacore stock assessment model in the context of the objectives of the framework was to be completed before describing the approaches to evaluating assessment models for albacore in NZ.

Following a review of the project's scope, the proposed approach for objective 4 was in excess of what was feasible. Consequently, objective 4 of SWO2003/01 was reduced in its scope, and a suggested re-wording of the specific objective that is consistent with the tasks retained in the objective is as follows:

> To collate and review available information on albacore from NZ for developing a stock assessment model and outline an assessment framework.

9. Methods

See attached report.

10. Results

See attached report.

11. Discussion and Conclusions

See attached report.

12. Publications

Nil.

13. Data Storage

Tuna longline observer data are stored on the Empress *l_line* database, maintained by NIWA.

Tuna longline catch and effort data is stored in the Ministry of Fisheries *TLCER* database.

1. Introduction

The biology of south Pacific albacore, and the fisheries it supports were comprehensively reviewed by Murray (1994). Albacore in the south Pacific Ocean most likely comprise a discrete stock. Adult albacore are distributed throughout south Pacific to 49° S, 15° to 25° S in summer, and 30° to 40° S in winter, and from Australia to 100° W. The NZ EEZ extends over only part of this distribution. Aspects of albacore biology that may be significant from a New Zealand (NZ) stock assessment perspective includes the distribution of juveniles that is between 30° to 45° S, and in the surface waters (upper 100-120 m), having temperatures of 16 - 18° C. The juveniles are between 45 to 85 cm, with individuals <45 cm rarely being caught, but are reported off NZ north of 39° S, and in the sub-tropical convergence zone (STCZ). Movement of juveniles into sub-tropical and deeper waters occurs in autumn.

Albacore appear to have very specific temperature preference ranges for the larval, juvenile and adult stages (Murray 1994). Larvae generally occur in depths < 60 m, with sea surface temperatures (SST) of around 24°C, and a thermocline at 250 m. Juveniles are commonly associated with coastal upwelling fronts, SST >15°C, usually close to the STCZ, with high abundances occurring in waters with SST from 16.1°C to 18.3°C; with thermoclines < 95 m, and most abundant at thermoclines < 50 m (Murray 1994). Adults occur mostly in depths of 100 to 380 m, with SST from 9°C to 20°C; and are often associated with water mass boundaries (having salinity, temperature gradients). This indicates specific habitat preferences for the respective life stages.

Since 1952 annual catches of albacore over the south Pacific Ocean have been from 1954-57 ~ 9000 t; 1958-1961 ~ 20 000 t; 1962- 67 ~ 35 000 t; 1968-present 20 000 to 37 000 t (mean 29 700 t). A large component of this catch was taken by the Japanese, Taiwanese, and Korean longline fisheries, with the surface fisheries including trolling, and a short period of drift netting in the mid- to late-1980's.

The longline fishery operates year round having an annual pattern with the fishery shifting southwards to sub-tropical waters for the period January to April, and then shifting northwards to tropical waters for the period July to October. Most effort is west of longitude 120° W. There is little effort around the Tasman Sea and NZ waters, with most occurring on the high seas.

Foreign longliners have operated in NZ waters since before the 1980's. Since the early 1990's a domestic longline fishery has developed. The mean annual catch has been 5 308 t over the past 10 years. Albacore catch in the longline fishery is largely a bycatch of the fishery targeting southern bluefin tuna in FMAs 5 and 7, and bigeye in FMAs 1 and 2. NZ longline effort is variable but averages 200-250 million hooks per year (Murray 1994).

The high seas troll fishery includes vessels from USA, Canada, NZ, French Polynesia and Fiji. Since the late 1960's the NZ surface troll fishery has operated approximately 40-80 miles off the west coast, during the summer season (Murray 1994). Currently the fishery is comprised of up to 200 vessels and can land 2000-4000 t annually. The east coast fishery on the STCZ has expanded since 1986 from 89 t to 4 000 t in 1988-89. This fishery operates from 39° to 41° S on the high seas. Troll fisheries are restricted to the summer season (Dec. – Apr.), and SST of 16-21°C.

South Pacific albacore were most recently assessed by the Scientific Committee of the Western and Central Pacific Fisheries Commission (WCPFC) in 2005 using a model developed by the Oceanic Fisheries Programme (OFP) of the Secretariat of the Pacific Community (SPC). The assessment model (MULTIFAN-CL) is an extension from MULTIFAN that estimates proportions at age as free independent parameters. MULTIFAN-CL fully integrates the estimation of growth, recruitment, catchability, selectivity, natural mortality and other parameters to estimate the catch-at-age within length frequency samples (Fournier et al. 1998). It has complex spatial and temporal stratification with four spatial strata, and 23 separate fisheries defined by method, nation, and spatial stratum, including distant water longline, domestic longline, troll (NZ), troll (STCZ), and drift net.

In 2000 the model was updated to include data from tagging programmes (Hampton and Fournier, 2000). An OFP tagging programme was carried out in summer 1990-91 and 1991-92; and NZ tagging in 1990-91 from a pole-line vessel. Most tags were released by observers on NZ and US troll vessels in NZ and STCZ areas. Tag releases were stratified in the model by region, quarter and size class. The total release sample was 9619, and the total number of recaptures was 135. In 2003 the model was adjusted such that the tag-recapture likelihood assumed a negative binomial distribution with fishery-specific variances; tag-recapture reporting rates were constrained, and a weak spawner-recruit relationship (2 yr lag) was included, with a beta prior distribution for steepness having a mode at 0.9, σ = 0.04 (Labelle & Hampton, 2003). In 2005, the structural assumptions of the model were reappraised and more detailed definitions of the fisheries were applied (Langley & Hampton 2005).

Objective 4 was to describe approaches to developing a stock assessment for albacore. This could be expressed in other words as an examination of a range of alternative population models within assessment and management contexts. This objective was subsequently revised by restricting its scope. Under objectives 1, 2 and 3 of this project, all available biological and catch-effort data for albacore in NZ was collated and summarised. This report reviews the utility of the information for input to a regional stock assessment model for south Pacific Ocean albacore as specified under the revised wording of objective 4:

> **To collate and review available information on albacore from NZ for developing a stock assessment model and outline an assessment framework.**

This project was funded by the Ministry of Fisheries research project TUN2002/03 Objective 4.

2. Methods

In collating information of potential utility for input to a NZ albacore stock assessment, five key activities were carried out:

- collate the results of three specific objectives in this project;
- identifying other information of potential utility;
- review past and current south Pacific albacore stock assessments;
- design a framework for a NZ albacore stock assessments; and,
- identify information having utility for a stock assessment.

Under specific objectives 1 and 2 of this project all historical and biological data for albacore in NZ were sourced, collated and summarised (Griggs 2005a). Historical biological data were identified and collected from all available sources and summarized (Objective 1). Length frequency data and other biological observations (e.g. weight, sex ratio, stomach contents) collected under the Ministry of Fisheries Observer and port sampling programmes up to December 2004, were summarised and analysed (Objective 2). The temporal and spatial distribution of observer samples was compared relative to the tuna longline fishery to indicate how representative the samples are. That information of immediate utility for a stock assessment was presented in this report.

Specific objective 3 of this project, required albacore catch and effort data from the tuna longline and troll fisheries to be collated and groomed for deriving standardised catch-per-unit-effort indices for each fishery (Unwin et al. 2005). Catch and effort data for these fisheries over the period from 1 January 1993 to 30 September 2004 were extracted from separate databases. The data from the longline fishery were taken from the Tuna Longline Catch Effort Return (TLCER) statistical forms provided by each fisher to MFish, and stored in the centralised database *tuna* administered by NIWA. This data was checked for errors according to established guidelines (Wei 2004). Data from the troll fishery were taken from the Catch Effort Landing Return (CELR) statistical forms provided by each fisher to MFish. The nominal and standardised indices calculated by Unwin et al. (2005) for these fisheries that are of immediate utility for a regional assessment are presented.

A review was undertaken of previous research on albacore in NZ, which was outside the scope of this project, to identify information of potential utility for stock assessment.

Past regional stock assessments of south Pacific albacore presented to the Standing Committee of Tuna and Billfish, and the current stock assessment presented to the Scientific Committee of the Western and Central Pacific Fisheries Commission were reviewed. Main sources of uncertainty in the assessment and the information of utility for addressing this uncertainty were identified.

Based upon the stock assessment review, a framework for undertaking a NZ albacore stock assessment was designed. This took account of the regional approach to assessing albacore that are distributed over the south Pacific. Steps required for further developing this framework are listed.

Given the uncertainties identified in the current albacore assessment and the requirements for a NZ assessment, the information collated in this report is discussed in terms of it utility for an assessment. This discussion highlights the information that may address the main areas of uncertainty and make recommendations for future research.

3. Results

3.1 Biological data

3.1.1 Longline fishery

The Ministry of Fisheries observer programme is the only source of biological information for albacore caught by the NZ longline fishery, and is available from 1987 to 2004. A full description of the observations recorded on board vessels with summaries of the data is provided by Griggs (2005a) and is not replicated here. Where possible, albacore length, weight, sex, and the life status when landed is recorded, and, sometimes, biological samples are collected. The total number of hooks and the location of each observed set is also recorded.

The biological data summarised by Griggs (2005a) is listed in Table 1. In summarising the data with respect to area, the convention used by Griggs (2005a) is generally consistent with the spatial distribution of the NZ tuna longline fleets. The North region was made up of FMAs 1, 2, 8, 9, and 10, and the South region of FMAs 5 and 7. The domestic fleet operates mainly in the North region, and the foreign charter fleet operates mainly in the South region, with only limited effort in the south-eastern area (FMAs 3 and 6). Length frequencies have been estimated annually (sexes combined), and over all years with respect to area and sex. Individual processed weights and whole weights were recorded, sex-specific measurements were recorded for a subset of this sample (n = 1 188 males, n = 1 124 females). Annual catch sex ratios were calculated, with area-specific estimates over all years. Stomach contents have been identified and the proportions over the major prey types (viz. fish, squid, crustaceans, and salps), calculated over all years. Albacore are generally landed whole, and therefore data on gonad condition, age at sexual maturity or spawning distribution is unavailable. Life status of albacore at the time of capture has been summarised for the period 1992 to 2004, with 61% being alive, on average.

The observer coverage of the longline fishery was monitored in respect of the total number of hooks set (Griggs 2005a). For the Japanese foreign and charter fleet there was generally 100% coverage, whereas that for the NZ domestic fleet was lower, at 4.2% in the past 10 years. The temporal and spatial distribution of observed sets reflects the disproportionately high coverage of the Japanese charter fleet, such that most sets coincide with the southern bluefin tuna operations undertaken by these vessels during April to July. The spatial distribution of albacore catches show most occurs in the northern areas, viz. FMA's 1, 2, and 10 (82%), whereas observed sets occurred mainly in southern areas, FMAs 5 and 7 (61.4%), (Figure 2). With respect to each FMA, the temporal coverage appears on average to be adequate, with the monthly collection of observer samples coinciding reasonably well with the monthly effort (number of sets) in the fishery (Figure 3). Where there were discrepancies, e.g. FMAs 4 and 6, there was little effort on average directed in these areas. A substantial proportion of fishery effort is expended in FMA 1, and observer samples tend to be collected earlier in the year relative to the fishery.

Griggs (2005a) discussed how representative the observer data was in terms of its spatial and temporal coverage of the fishery. The spatial coverage was examined in terms of the three discrete regions where tuna longline operations occur: west coast of South Island, East Cape, and Northern area (east Northland and Three Kings Islands). As can be expected the coverage was adequate for the southern area where the charter fleet generally operates. Coverage of the domestic fishery within the East Cape area appears adequate, and although low in the past, coverage of the Northern areas has improved in recent years.

In summary, the temporal distribution of observer samples on average is reasonably consistent with tuna longline fishing effort within particular FMAs. The disproportionately high coverage of the Japanese charter fishery that operates predominantly in FMAs 5 and 7 means the observer samples have a spatial distribution that is not representative of the fishery. However, within each of the FMAs, or within discrete regions of the fishery, the spatial distribution appears representative.

Catch length composition

Griggs (2005a) presents the annual and summarised length frequency distributions of albacore in longline catches, having a range of between 42 and 115 cm. Annual variation in length compositions is apparent mostly in the smaller length intervals (52 to 70 cm) where in some years a clear mode exists. This has little impact on the mean length that displays only a slight general decline from 1987 to 2004 (Table 2, taken from Griggs 2005a).

Differences in growth rates with respect to sex have not been found in south Pacific albacore (Labelle et al. 1993), and no sex structure has been included in the stock assessment model (Langley & Hampton 2005). Only a slightly higher proportion of males are evident in longline catches, with the mean percentage for 1987 to 2004 being 54% males. These two factors are consistent with the close similarity between the length distributions for males and females in longline catches (Griggs 2005a).

Clear differences were evident between the length distributions from the North and South regions. A broad mode at 75 cm dominates the length distribution from the North region, while a bimodal distribution is evident from the South region with the smaller mode at 75 cm and the larger mode at 100 cm. This is inconsistent with the general pattern of latitudinal differences in albacore length composition where smaller fish are more abundant in the southern latitudes (Langley & Hampton 2005). However, the target species and season differ between the fisheries operating in the North and South regions, and the difference in fishing practice is likely to influence the catch length composition of albacore.

The total length composition of albacore in longline catches from 1987 to 2004 is presented in Figure 4 (taken from Griggs 2005a).

Length-weight relationship

Estimates of the relationship between albacore length and weight are provided by Griggs (2005a), and are presented in Table 3 for samples from the longline fisheries. Individual fish were weighed to the nearest 1 kg by observers.

3.1.2 Troll fishery

Griggs (2005a) presents summaries of the biological data collected from port sampling of the albacore troll fishery over the period 1997 to 2004. The data is shown to be representative of the fishery in terms of its spatial and temporal distribution. A sample size of between 3 400 and 7 600 length frequencies, and between 300 and 700 individual weights, is collected annually. Troll caught albacore are generally juvenile, and sex ratio was determined in 1999 from a histological examination of gonad samples (n = 320). A sample of 122 otoliths was collected on behalf of the Ocean Fisheries Programme (OFP) of the Secretariat of the Pacific Community (SPC) in recent years for ageing juvenile fish (< 50 cm).

Catch length composition

Albacore in troll catches range in length from around 40 cm to around 95 cm, with a mean length of around 63.0 cm, which is substantially smaller than the length composition in longline catches (Figure 4, taken from Griggs 2005a). Annual length distributions are multi-modal with modes around 51 cm, 62 cm, and 72 cm (Figure 5, taken from Griggs 2005a). Given the growth estimates for albacore (Labelle et al. 1993) and summer spawning (Langley & Hampton 2005), these modes most likely correspond to 1, 2 and 3 year old albacore, with most fish in troll catches being 2 year olds. This is consistent with similar surface fisheries for albacore in other areas, e.g. sub-tropical Atlantic ocean (Goñi & Arrizabalaga, 2005).

Mean weight

The albacore stock assessment model expresses the total removals from the population in terms of numbers of fish caught in each fishery. This information is immediately available for the NZ longline fishery from the Ministry of Fisheries tuna longline catch effort return (TLCER) forms completed by fishers for each fishing event. Catch and effort information from the troll fishery is reported on the Ministry of Fisheries catch effort landing return (CELR) forms, and is summarised on a daily basis with the estimated albacore catch recorded in terms of numbers caught and greenweight. There has been poor reporting in some years that limits the reliability of these estimates Therefore, it is necessary to convert this catch weight as reported to licensed fish receivers (LFRs) into total catch in numbers, and this is achieved using the port sample estimates of troll catch length frequency to derive the mean weight of fish landed (Langley & Hampton 2005).

Length-weight relationship

Estimates of the relationship between albacore length and weight are provided by Griggs (2005a), and are presented in Table 3 for samples from the troll fishery. Individual fish were weighed to the nearest 0.1 kg in port samples.

3.1.3 Movement

Information available for describing the movement of albacore in, and around, NZ waters is extremely limited, and has been summarised by Griggs (2005a). As part of a cooperative gamefish tagging programme, 39 albacore have been tagged and released since 1996–97, with 1 reported recapture (Holdsworth & Saul, 2005). On a regional spatial scale the net displacement from the point of release was limited (140 nm), and the period at liberty was short (50 days).

An albacore tagging programme was implemented in the summers of 1990-1992 in the sub-tropical south Pacific by the OFP with most releases made by observers on board NZ and US troll vessels fishing in NZ waters and in the STCZ (Langley & Hampton 2005). A total of 9691 fish were tagged and released, being mostly juveniles, and 138 recaptures were reported mostly from the Taiwanese tuna longline fishery operating in subtropical waters north of the STCZ. This information generally indicated northward movement of tagged fish from the point of release, and has been used in the current albacore stock assessment model.

3.2 Fisheries data

3.2.1 Longline fishery

Catch and effort data

Specific objective three of this project was to calculate standardised catch-per-unit-effort (CPUE) indices for longline-caught albacore and contrast its performance relative to nominal CPUE. The catch-effort data used for this objective is summarised by Unwin et al. (2005). A total of 58 420 catch-effort records were extracted from the TLCER database *tuna* for the period 1992–93 to 2003–04. This period was defined because it corresponds with that for which remote sensed environmental data was available. Following error checking procedures for ensuring data quality, and excluding records for areas outside of the study area, 47 954 records remained for the albacore CPUE analysis. About 12% of all the longline operations occurred in the south-western areas of New Zealand (FMAs 5 and 7, see Figure 1), and nearly 100% of these operations were targeting southern bluefin tuna predominantly in the second quarter. Operations in the north and eastern areas (northern part of FMA 9 and FMAs 1, and 2, see Figure 1) accounted for 99% of albacore landed (Unwin et al. 2005). Therefore, only data from these areas were included in the CPUE analysis.

The longline fishery operating in the north and eastern areas primarily targets bigeye tuna and accounts for on average 87% of longline operations nationally. The number of longline sets, number of hooks set, albacore catch frequency, and nominal CPUE (number of albacore caught per 1000 hooks) from 1993 to 2004 is presented in Table 4 (taken from Unwin et al. 2005). The average nominal catch rate over this period was 27.14 albacore per 1000 hooks.

Nominal and standardised annual CPUE

The nominal and standardised annual CPUE indices from 1993 to 2004 are presented in Figure 6 (taken from Unwin et al. 2005). There is a relatively flat trend from 1994 to 1998, followed by a dramatic decrease in catch rates to 2000, with a relatively flat trend from 2000 to 2004. No substantial differences were evident between the nominal and standardised annual indices, and, with the exception of 2003, the general pattern through time was similar. A large difference was found between the average nominal and standardised quarterly indices for the second and third quarters. The effect of this was that standardisation of the quarterly CPUE indices somewhat dampened the between-season variation indicated by the nominal series.

The standardised CPUE model explained 45.5% of the null deviance and the categorical variables: year, quarter, nationality, experience, and target species, were significant in explaining catch rate variability (Unwin et al. 2005). Of the continuous variables sea surface temperature (SST) had the strongest effect, with highest catch rates in the range 18 to 19° C. SST features associated with ocean fronts were of lesser significance. Catch rates were highest for day lengths corresponding to the winter and summer periods, with a weaker negative relationship with respect to night fraction. Fishing location exerted a strong influence and the highest catch rates occurred off east Cape. Weaker effects were detected for depth and the intensity of fishing activity in the vicinity of the fishing operation.

3.2.2 Troll fishery

Catch and effort data

Included in specific objective three of this project, was the calculation of standardised CPUE indices for troll-caught albacore and contrast its performance relative to nominal CPUE. Troll catch-effort data used for this objective is summarised by Unwin et al. (2005). Catch and effort information from the troll fishery, as reported on the Ministry of Fisheries CELR forms, was collated from 1993 to 2004 and comprised 107 763 records. The troll fishery operates mostly on the west coast of NZ in FMAs 7, 8, and 9. Environmental data was unavailable for part of this area, and records associated with operations with this area (48.7% of total number of records) were necessarily excluded from the CPUE analysis. In addition to the removal of records to maintain quality assurance, the total number of records used in the analysis was reduced to 49 622 (Table 5, taken from Unwin et al. 2005). The nominal catch rate (albacore per hook-day) from 1993 to 2004 was 14.26 on average.

Nominal and standardised annual CPUE

Unwin et al. (2005) defined the unit of troll CPUE as catch/(hooks × duration/24). This was selected because from exploratory data analyses wide ranges were found in both the operation duration, and the number of hooks used by vessels. Standardised CPUE indices for the troll fishery were estimated using a quasi Poisson general additive model (GAM), and for comparison a negative binomial generalised linear model (GLM) was also fitted (Unwin et al. 2005). Although mostly consistent, there are differences between the nominal and standardised year-quarter CPUE indices, being most pronounced in the negative binomial model (Figure 7, taken from Unwin et al. 2005). Two clear peaks are evident in the time series – one in 1995 and another in 1999-2000. Despite these features, no consistent trend in CPUE is apparent over the period estimated.

3.2.3 Catch history

A summary of NZ albacore catch (t) as reported from Licensed Fish Receiver Returns (LFRRs) is presented in Table 6 (taken, and updated, from Sullivan et al. 2005). Regional catches for albacore are summarised annually by the Ocean Fisheries Programme (OFP) at the Secretariat for the Pacific Community (SPC) for the Western and Central Pacific Fisheries Commission (WCPFC). The region defined as the south Pacific Ocean (SPO) for which catches are summarised (Figure 7) was assumed for the regional albacore stock assessment (Langley & Hampton 2005). Approximately 12% of the annual regional albacore catch is taken by the troll and longline fisheries in NZ waters, with around 5 300 t caught annually (average from 1995 to 2004).

Method-specific catches of albacore in NZ waters from 1991 to 2000 are reported by Murray et al. (2004); for 2001 and 2002 by Griggs & Richardson (2005); and, for 2003 and 2004 by Kendrick et al. (2005). A time series of the method-specific catches from 1960 to 2004 by the NZ troll and longline fleets is presented in the tuna fishery yearbook 2004 (OFP 2005), and was that used in the SPO albacore regional stock assessment in 2005 (Langley & Hampton 2005).

Annual catches of the NZ domestic longline fleet increased rapidly from catches of around 300 t in 1993 to over 2 000 t in the 1998–99 fishing year, with an average of 2 000 t per year since 2000. The longline catch of albacore in 2004 was 1 360 t. Annual catches of the NZ domestic troll fleet increased from less than 1 000 t per year before 1980 to around 2 000 t per year in the 1980's, and 3 500 t per year in the 1990's. The troll catch for the 2002–03 and 2003–04 fishing years was 4 305 t and 4 113 t respectively (Kendrick et al. 2005).

A catch history of the total annual number of albacore caught in NZ waters from 1952 to 2003 has been collated for input to the regional stock assessment model for the south Pacific region (Langley & Hampton 2005). The troll fishery defined in the model (Troll 3) applies to a spatial stratum that includes most of the NZ EEZ as well as south-east Australian waters. For the NZ longline fishery, total numbers of albacore landed is reported on TCELR forms by fishers, however, while catch in numbers is reported on CELR forms by troll fishers this may be an unreliable measure of total catch. As mentioned above, albacore catch length compositions estimated from port samples of the troll fishery were used to calculate annual mean weight, and, hence, total numbers caught from troll catches. Mean weights from both the NZ and United States fisheries operating in the spatial stratum were available since the mid-1980s (Langley & Hampton 2005). For years prior to that date, a mean was assumed that was calculated from samples taken in the first several years (mid-1980s) and applied in all years for which catches were recorded since 1952.

3.3 Environmental data

A wide range of oceanographic variables was collated for deriving standardised indices of albacore CPUE in the NZ tuna longline and troll fisheries. These were remotely sensed from NZ waters (Uddstrom & Oien 1999). Sea surface temperature variables included indicators of frontal strength, ocean climatology and anomalies, and temporal-spatial oceanographic conditions as described using empirical orthogonal functions (Uddstrom et al. in review). A similar range of these variables was also collated for sea surface chlorophyll. The spatial resolution was to within 1 km and calculated using five-day temporal composites. These oceanographic variables have been linked to individual longline fishing operations on a relevant spatial scale (a square with a side equal to half the longline length). This level of resolution was possible because the location of each fishing operation is reported by longline fishers on the TLCER forms. However, troll fishers report the location of their operations on CELR forms with respect to fishing statistical areas (approximately 1° latitude boundaries). This significantly reduces the spatial resolution of the oceanographic variables relating to the troll fishery.

3.4 Regional albacore stock assessments

A MULTIFAN-CL model was developed and used for the first regional stock assessment of albacore in 1998 (Fournier et al. 1998). The population was spatially stratified into 3 latitudinal zones, with 11 separate fisheries having either quarterly or monthly time steps. A range of hypotheses was tested including spatial structure, age-dependent movement and natural mortality, seasonal variability in catchability, and density dependent growth. This model was extended for an updated assessment in 2000, with additional catch, effort, CPUE, length frequency, and tagging data (Hampton & Fournier 2000). More detailed stratification of the fisheries was applied with respect to nation, method, and spatial stratum, creating 14 separate fisheries. The age structure was extended from 11 to 14 age classes. Separate troll fisheries for the NZ EEZ and SCTZ waters were maintained, however the NZ longline fishery not defined separately, and the Japanese joint-venture fishery in NZ waters was amalgamated with the Japanese fishery. The updated model produced a good fit to the tag-recapture observations of mortality rates, yet produced significantly higher estimates of natural mortality (0.4) compared to the previous assessment (0.2). Estimates of selectivity at length for the NZ and STCZ troll fisheries were polymodal, which is counter-intuitive. The statistical assumption relating to the fit to the tag-recapture data was modified in the assessment undertaken in 2003 (Labelle & Hampton 2003), such that a negative binomial distribution was assumed for the maximum likelihood function, with fishery-specific variances. Tag-recapture reporting rates were constrained to a maximum of 0.2, with the rates for longline fisheries assumed equal. Estimates of natural mortality were 0.3 for juveniles, and 0.5 for large adults, which were considerably higher than previous assessments. A research recommendation from this assessment was for an index of absolute abundance to scale model biomass estimates and as a means for addressing uncertainty in effective fishing effort.

South Pacific albacore were most recently assessed at the first meeting of the Scientific Committee of the WCPFC in August 2005 (Langley & Hampton 2005). An overview of the main features of this assessment, and particularly those relating to the data from the NZ fisheries, follows.

A single discrete stock was assumed for the south Pacific region (Figure 7). Albacore spawn in tropical and sub-tropical waters in the summer with seasonal migrations inferred from monthly trends in catch rates between latitudinal zones. It is understood that albacore migrate south in early summer, north in winter. Albacore grow to 45-50 cm in the first year, with annual growth of 10 cm per year up to an age of 4 years. The assumed age at maturity is 5 years.

The south Pacific region has been stratified spatially to account for consistencies in the seasonal and temporal trends in catch rates in particular areas, and the spatial distribution of the main domestic longline fisheries. Four strata have been specified, delineated by 30 ° S latitude, and 180 ° E longitude. Temporal processes have been disaggregated into quarterly time steps that accommodate the observed strong seasonal trend in the distribution of the longline fishing operations, with high fishing pressure in the northern latitudes during the winter and in the southern parts during the summer.

Fisheries have been defined such that each is a relatively homogeneous unit having unique characteristics for selectivity and catchability that are typically time invariant. The model includes 23 fisheries; 19 longline, 2 driftnet, and 2 troll fisheries. The NZ domestic fisheries are discrete, viz. longline (fishery 16), troll within the NZ EEZ (fishery 20, in stratum 3), and troll outside the NZ EEZ, in the sub-tropical convergence zone, STCZ (fishery 21, in stratum 4). Catch and effort data for each fishery was derived from logbook data, with catch expressed in terms of numbers of fish.

The model was fitted to length frequency data collected from port samples and observers on board vessels, and to data from a tag-recapture experiment implemented in summers of 1990-1992 by the OFP. Most fish were tagged and released by observers on board NZ and US troll vessels in NZ waters and in the STCZ. The 9 691 releases were mostly juveniles, from which 138 were recaptured, mostly from the Taiwanese LL fishery operating in the two southern strata. The model is also fitted to the total catch from each fishery, and this is assumed to be unbiased and relatively precise (sd = 0.07).

A major source of uncertainty in the assessment was the estimation of movement within the south Pacific region, i.e. between the four spatial strata. To address this four model scenarios were considered:

- four strata, fixed movement parameters, seasonal catchability coefficients;
- four strata, movement parameters estimated, no seasonal catchability coefficients;
- four strata, movement parameters estimated, seasonal catchability coefficients;
- single stratum, seasonal catchability coefficients

The differences specified between these scenarios aimed to highlight the functional relationship between movement parameters and seasonality in fishing method catchability coefficients, as both these processes may explain the observed seasonal variation in catch rates. For the scenario where movement was ignored, one homogenous population within the south Pacific region was assumed, however, the spatial stratification of the fisheries was retained, and seasonality in catchability coefficients was estimated.

Movement estimates for the multi-strata scenarios indicated large coefficients of northward migration in 4th quarter, with less in the first quarter, and small coefficients of southward migration in the 2nd quarter. These results were inconsistent with the understanding of seasonal population distribution (southward in summer, northward in winter).
The scenario with estimation of both movement and seasonal catchability produced excessively large increases in total biomass. These scenarios demonstrated a compensatory relationship between movement and catchability coefficients, suggesting uncertainty in the movement estimates. Whereas previous assessments were based on models with the estimation of age-specific movement coefficients, it was resolved to use the single region model with estimated seasonal catchabilities as a base case model for the updated assessment.

Diagnostics of the model fit indicated large catch residuals for the longline fisheries in the southern strata, and this was evident for the domestic NZ longline fishery operating within the NZ EEZ, and in the troll fishery for some years. The fit to NZ longline length frequency was poor for the modes observed at 70-80 cm. Although the fit to length frequency observations from the NZ troll fishery (within the NZ EEZ) was reasonable with respect to the median length of the main 3 length modes, it was poor in describing the strength of the main length mode centred on 65 cm. However, the fit to the distribution for the troll fishery in the adjacent southern stratum (operating in the STCZ) was reasonably good and consistent with the dominant length mode around 72 cm. Large negative effort deviations were estimated for the NZ troll fishery, where for around 11 quarters the deviations were less than -2. This was attributed to variability in population availability to the fishery induced by changes in oceanographic conditions, e.g. during an El Niño period.

The seasonal catchability estimates were consistent with the accepted patterns in albacore movement, such that catchability was high in the northern strata during 2nd and 3rd quarters, low in the 1st and 4th quarter, with a reversal for the southern strata. An increasing trend in catchability was estimated for the NZ troll fishery operating in the NZ EEZ from 1995 to 2003, however, a decline was estimated for the troll fishery operating in the adjacent southern stratum, i.e. the STCZ.

A contrast was evident between the estimated selectivity patterns for the longline fisheries operating in the southern and northern strata. Relatively high selectivity for younger fish was estimated for the southern fisheries, whereas low selection of juvenile fish was estimated for the northern fisheries such that 50% selectivity occurs at age 8 years.

Long term decadal trends in recruitment were estimated, being low from the initial population in 1952, high during the 1960's and early 1970's, and then stable at high levels during the 1980's and early 1990's, followed by a return to low recruitments to 2004. This pattern was interpreted as a consequence of model recruitments being estimated that reconcile the conflicting temporal patterns in longline length compositions and CPUE for the Taiwanese longline fishery. Model diagnostics indicated clear inconsistencies in the observed trends in these two data types, where the large initial decline in catch rate appears to conflict with the trend of increased size of fish in longline catches. The pattern in model recruitment indices reconciles this conflict somewhat and this was identified as a major source of uncertainty in the assessment because the recruitment time series strongly determines the estimates of stock size. A recommendation was made for future assessments to re-examine and re-analyse these two main input data sets (Langley & Hampton 2005).

4. Discussion

The available data collected from the NZ albacore fishery collated under objectives 1, 2, and 3 of this project, and from other research projects, is discussed in terms of its utility for developing a population model for assessing the NZ albacore stock in the following review.

4.1 Biological data

4.1.1 Length frequency

The time series of length and weight frequencies collected from the observer programme on-board longline vessels and from port sampling troll landings is substantive information of high utility for the south Pacific albacore stock assessment. A fundamental design requirement is that this information is of acceptable quality, and is representative of the fishery.

The review of both data sets confirms they are of high quality given the collections are by trained scientific staff, recorded to a high standard, and stored on a well administered database (Griggs 2005a).

The temporal distribution of observer samples, on average, is reasonably consistent with tuna longline fishing effort within particular FMAs. Observer coverage of the NZ foreign charter fleet that targets southern bluefin tuna predominantly in FMAs 5 and 7 during the second quarter is disproportionately high relative to the fishery operating in other areas. Therefore, observer samples have a spatial distribution that is not representative of the NZ fishery. However, within each of the FMAs, or within discrete regions of the fishery, the spatial distribution appears representative. For the information to be of utility for a stock assessment, i.e. representative of the catches throughout NZ waters, observer data must be temporally and spatially stratified. For a length frequency estimate of the NZ longline fishery it is recommended that the stratum estimates be combined to derive a mean length composition, weighted by the estimated total catch (in numbers) from each fishery stratum.

The review of the troll port sampling data confirms it is spatially and temporally representative, with a large sample size yielding estimates of acceptable precision, with a mean weighted coefficient of variation around 0.2, (Griggs 2004, 2005b). Troll-caught albacore are substantially smaller than in longline catches, with a mean length of around 63 cm compared to around 83 cm for longline. The multi-modal distribution has a dominant mode (at 62 cm) that corresponds to the 2 year old age class, and this is consistent with other albacore surface fisheries having high selectivity for juvenile albacore, e.g. east Atlantic (Goñi & Arrizabalaga 2005). This information is of high utility because it provides an observation of individual cohort strengths before fish recruit to the larger longline fishery operating in the northern range of the south Pacific Ocean albacore stock, and having higher selectivity for adult albacore. It is also fundamental information for calculating the mean weight of albacore in troll catches that is required for converting annual catch in weight to annual numbers caught for input to the regional stock assessment model.

4.1.2 Length-weight

Samples of individual fish weight are of high utility for calculating population model quantities of fish mass using a relationship between individual fish length and weight. Observer samples of individual weight were measured to a tenth of the resolution achieved in port samples; to within 1 kg compared to 0.1 kg, respectively. Consequently, there is higher variability around the observer estimate of the length-weight relationship compared to the port sample estimate ($r^2 = 0.91$ and 0.94 respectively). However, the relationships are essentially identical (Table 3).

As with catch length frequencies, account must be taken of temporal, spatial or sex-specific factors affecting the relationship between length and weight. No marked difference was evident in the relationships estimated for the northern and southern areas or with respect to males and females (Griggs 2005a). The estimated length-weight relationship is therefore of immediate utility for stock assessment model that is not sex-structured, and has a spatial stratification that encompasses most of the NZ EEZ within a single stratum.

A minor difference was detected between the relationship estimated in NZ and that used in the regional stock assessment (SPC relationship, Langley & Hampton 2005), which produces a notable discrepancy for lengths above 95 cm (Table 3). Fish in this length range are predicted to be heavier on average using the SPC relationship applied in the stock assessment. Possible reasons for this are that length-weight observations used to derive the SPC relationship were most likely collected from port samples from the northern range of the stock and would include individuals in high condition. Albacore from NZ port samples are generally in a low condition (pers comm. Malcolm Francis, NIWA, Wellington). Also, there is higher variability in the relationship derived from observer samples from NZ longline catches because of the low resolution of weight measurements. It is recommended that these factors be considered more closely given that the former indicates potential differences in the length-weight relationship within the south Pacific region, which may impact on the assessment.

4.1.3 Other information

Estimates of age and growth, and specifically mean length-at-age, are fundamental for developing an age-structured population model. Via a relationship between length and weight, length-at-age is used for calculating mass quantities, such as absolute biomass, catch weights, and yields. As well as an estimate of natural mortality, a yield-per-recruit analysis requires this information. No estimates of growth for NZ albacore are currently available, however otolith samples have been provided to the OFP at SPC in recent years. Published growth estimates are currently input to the regional assessment model to specify prior distributions for the estimation of von Bertalanffy parameters within the model fitting procedure (Langley & Hampton 2005).

No substantive information on gonad condition is available for NZ albacore. A sample was collected from troll catches in 1999 to determine sex and derive sex ratios, and sex is determined for a small proportion of observer samples from longline catches (Griggs 2005a). No samples for gonad staging or to determine maturity at age have been collected to date. An age at maturity of 5 years is assumed for the regional stock assessment model, and it is accepted that spawning occurs in the northern range of stock distribution, i.e. tropical and sub-tropical waters, during summer (Langley & Hampton 2005). A high proportion of albacore in NZ troll catches are less than 5 years, thus providing an opportunity to estimate a maturity ogive for albacore. The troll fishery operates in the southern range of the stock distribution, and the incidence of individuals in high gonad condition is likely to be low. Also, fish are landed whole, and an incision is required to discern gonad status that may incur a cost. However, sampling this fishery warrants consideration in designing a study to deriving a maturity ogive for albacore.

There is no substantive tagging information for albacore within the NZ EEZ of utility for a stock assessment. Movement and stock structure is a primary source of uncertainty in the regional stock assessment to the extent that a base case model was selected that excluded migration coefficients, and rather estimated seasonality in fishery-specific catchabilities. Despite fitting to the results from the SPC tagging study, migration estimates from alternative model scenarios conflict with the accepted temporal-spatial pattern of albacore movement (Langley & Hampton 2005). Auxiliary information was presented regarding steeply declining albacore catch rates in some rapidly expanding domestic longline fisheries. This qualified the assessment results somewhat (Langley & Hampton 2005) and highlights the significance of uncertainty in understanding albacore movement.

4.2 CPUE

4.2.1 Longline

No absolute indices of south Pacific albacore abundance are available, and therefore, a time series indices of relative abundance, such as catch and effort information, are an important input to an assessment model. An absolute abundance index tends to reduce model uncertainty in estimates of population size (Davies & McKenzie, 2001), and an index was identified as a priority research need for albacore (Labelle & Hampton 2003). However, an informative time series of indices accurately reflecting relative change in population abundance is valuable in reducing uncertainty in model productivity estimates. Accuracy of the index is difficult to determine because the actual population biomass is usually not known. The contrast between nominal and standardised CPUE indices for albacore in the NZ tuna fisheries may assist with this uncertainty by indicating the factors affecting albacore catch rates besides stock abundance.

The standardised longline CPUE model explained nearly 50% of catch rate variability, thus improving the utility of CPUE information for the albacore stock assessment. The MULTIFAN-CL model applies standardised effort in calculating predicted catches, therefore, it is important that covariates are accounted for that influence effective fishing effort, and, hence, the relationship between catch rate and population abundance. For NZ longline-caught albacore, SST was the continuous variable having the strongest influence on longline catch rates of albacore with a defined optimum temperature range from 18° to 19° C. SST features associated with ocean frontal systems were less important. The effects of environmental factors that vary between seasons are accounted for the standardised indices that exhibit lower seasonal variation compared to the nominal indices. This has implications for the process between CPUE and population abundance specified in the model. Where estimated catchability coefficients are assumed to respond to seasonal variation in availability, as in the MULTIFAN-CL model, the standardised effort indices have accounted for season-specific environmental effects on albacore availability. Thus, standardising the CPUE will reduce error in the assumed process, and improve its utility for the assessment.

A Pacific-wide approach to assessing albacore that takes account of habitat preferences indicates temporal patterns in the spatial distribution of recruited biomass in response to the southern oscillation index, SOI (Lehodey 2004). This provides a process-based description that is consistent with the findings of a standardised CPUE analyses for south Pacific albacore (Langley 2003), although the relationship between CPUE and SOI was rather weak. The environmental variables explained little of the CPUE variability, however, the variables were expressed at low spatial resolution (5 degree squares), and localised effects occurring on a smaller spatial scale are likely to be masked. It was suggested the annual trend in CPUE was related to YCS variability responding SOI events. These results and those of Unwin et al. (2005) for NZ albacore confirm the need to take account of environmental variables when deriving indices of albacore abundance, however, this was not done for the most recent north Pacific assessment (Stocker 2005). Due consideration must be taken of the processes assumed in the population model between vulnerable biomass and indices of abundance, and also the structural assumptions made for temporal and spatial disaggregation, when considering the utility of fishery-specific standardised CPUE. In the case of the NZ longline CPUE presented in this report, the index is consistent with the structural assumptions of the model and is of immediate utility to the assessment.

A dominant feature in the longline albacore CPUE time series is the dramatic decline from 1998 to 2000. Concurrent to this decline there was a large increase in swordfish catch from 1600 fish in 1997 to over 12 000 in 2001 (Davies et al. 2005). The reciprocal relationship between these two features most likely reflects a shift in fishing practice in the longline fleet towards targetting for swordfish since the mid-1990s (Murray & Griggs in prep.). This is likely to have altered the catchability of the longline fishery for albacore through a physical change in the configuration of the fishing gear. Despite this operational factor, the general decline in since the mid-1990s is consistent with the trend observed in Taiwanese longline CPUE in the southern parts of the south Pacific region (Langley 2003), and with the substantial decline in biomass since the late 1990s predicted by the regional assessment model (Langley & Hampton 2005). Langley (2003) attributes the CPUE decline to that following a peak in catch rates that occurred in 1995, as a consequence of a 7-year cycle in albacore catch rates evident since 1978, and is a result of YCS variation in response to SOI cycles. This explanation describes a process that would potentially affect catch rates of albacore throughout the south Pacific region, and hence, the NZ longline fishery. It is therefore possible the factors contributing to the dramatic decline observed in the NZ fishery include stock-wide changes in availability, and a change in fishing practices.

4.2.2 Troll

The estimated relationship between troll standardised CPUE and SST was weak (Unwin et al. 2005), but this was attributed to the limitations imposed by the spatial resolution of the catch and effort data. Environmental data was necessarily summarised to correspond to the large spatial scale of the catch and effort data, and this will have masked any localised environmental effects. In a surface fishery having similar selectivity, age and length composition to the NZ troll fishery, oceanographic features on a relatively small spatial scale were strongly related to catch rates (Goñi & Arrizabalaga 2005). Ocean agitation that determines the depth of the seasonal thermocline was linked to the vertical availability of albacore to surface gears, such that high agitation increases thermocline depth, making age 2 year albacore less available at the surface. An observation reflecting this mechanism has been reported for albacore in the south Pacific troll fishery (Murray and Bailey 1986). To increase the utility of troll CPUE for an albacore assessment by taking account of this covariate, it will be necessary to improve the spatial resolution at which troll catch and effort data is recorded.

An examination of the multi-modal troll annual length frequency distributions reveals the progression of distinct modes associated with strong year classes. In 1999 a mode is evident in the length intervals 46-55 cm, and dominates the catch length distribution in the following year (Figure 5). It remains evident in 2001, and then in 2002 as a large component of the broad mode in the large length classes, indicating this to be a strong cohort. A similar pattern is visible in 1997 where a broad mode spans the large length classes indicating a strong cohort that entered the fishery before the time series commenced in 1997. This modal pattern appears to correspond to peaks in the standardised troll CPUE indices. The apparently strong year class that entered the fishery in 1999-2000 and subsequently formed the basis of catches in 2000-01 is likely to have contributed to the peaks in CPUE in 1999 and 2000. The modal pattern in 1997 and high mean length may reflect the presence of a large cohort that dominated the fishery in 1995 and is likely to have caused the peak in CPUE in 1995. Although qualitative, this pattern points to the potential utility of the troll CPUE for the albacore stock assessment in respect of its consistency with inferred relative year class strengths.

4.3 NZ albacore assessment framework

4.3.1 Basis for a NZ assessment framework

A framework for a NZ assessment of the albacore stock supporting domestic fisheries must recognise the regional characteristics of this stock. Features of this include:

- seasonal variability in the catch rates between large latitudinal zones that indicate seasonal north-south movement of the population (Langley 2003); and,
- a latitudinal gradient in the length composition of catches (Langley & Hampton 2005) that most likely reflects age-specific diffusion of fish to the tropical and sub-tropical waters (Murray 1994).

These indicate temporal and spatial dynamics of a large population that has a wide distribution, of which the NZ waters are a component. The NZ fisheries are, therefore, subject to the variability in the availability and size composition of the population within the NZ EEZ. An observation from the NZ longline fishery that supports this regional perspective is the significant quarterly indices in longline catch rates (Unwin et al. 2005) that most likely reflect the seasonal movement of albacore between latitudinal zones.

The regional stock assessment must therefore be used as the basis for a NZ assessment framework, and ideally the model structure must facilitate quantifying the population dynamics specific to the NZ EEZ, and yield calculations relevant to the characteristics of NZ fisheries. The most recent south Pacific albacore assessment reappraises the assumptions of the underlying stock structure used in previous assessments (Langley & Hampton 2005). This included more detailed definitions of fisheries, with disaggregation to the level of domestic fisheries. The model may therefore be used to investigate management issues relative to specific fisheries operating at a spatial scale approximating the EEZs of participating nations.

The spatial disaggregation of the model is relatively coarse with the NZ EEZ being a part of a relatively large stratum (denoted as region 3 by Langley & Hampton 2005), which also includes the south Tasman Sea and the waters of southeast Australia. Productivity and movement estimates for this stratum will affect predicted yields for fisheries operating within it, which are currently the Japanese and Korean longline, Australian longline, NZ longline and NZ troll fisheries. Landings from the NZ fisheries make up, on average, a high proportion of the annual total removals from this stratum. Therefore, the spatial stratification and fisheries definitions applied in the current stock assessment are well suited for developing a framework for assessing stock status relevant for fisheries operating in the NZ EEZ.

4.3.2 Proposed framework

The framework proposed for a NZ albacore stock assessment involves using the regional assessment model to determine that component of the annual production that is available to the NZ fisheries; i.e. within the spatial stratum encompassing the NZ EEZ. This would implicitly account for long term trends in abundance, seasonality in availability in the spatial stratum, and the selectivity characteristics of the NZ fisheries. Thus, the sustainable yield available to the NZ fisheries will depend upon both the absolute abundance of the regional population, and factors affecting availability including migration patterns between latitudinal zones, year class strength variability, and environmental variables. Model estimates for these quantities and processes may be used to predict sustainable removals by the NZ fisheries.

The main points making up a NZ assessment framework are:

1. Contribute biological and fisheries data for NZ albacore in a timely manner for updating the regional assessments.
2. Participate in specifying the priors required for estimating model parameters relating to NZ fisheries, e.g. catchability, and selectivity, by supplying independent information of utility for these priors. Provide relevant information for making statistical assumptions needed in fitting to observations from NZ, e.g. specifying effective sample sizes.
3. Participate in reviewing model results and assessing diagnostics of fits to NZ data, and participate in meetings of the Scientific Committee of the WCPFC that reviews the regional assessment.
4. Make recommendations for ways to improve the regional assessment.
5. Use the regional assessment to estimate the proportion of stock production available to NZ fisheries, (given movement, catchability, and selectivity parameters).
6. Make projections under alternative management scenarios (catch levels) for NZ fisheries to identify those that are sustainable while making assumptions for regional catch levels, i.e. the larger fisheries such as the longline fisheries operating in the northern parts of the SPO stock distribution. Use the regional assessment model to make predictions of the total annual surplus production available to the NZ fisheries.
7. Assess the relative impact of the NZ fisheries on the regional stock.

Two approaches are suggested for determining the sustainability of catches from the NZ fisheries under points 5 and 6 above. Firstly, a deterministic equilibrium yield is calculated from the regional model estimate of the mode of the posterior distribution (MPD). This yield would be apportioned to the particular fisheries operating in the spatial strata, allowing the NZ component of equilibrium annual production to be determined. The NZ yield would be calculated for regional population sizes associated with generally accepted biological reference points, such as the biomass that supports maximum sustainable yield (B_{MSY}) or 20% of the maximum unfished biomass ($0.2B_0$). Secondly, predicted yield is calculated from projections of the regional model assuming stochastic recruitments and parameter error distributions. Levels of NZ catch that maintain a sustainable stock size at preferrable levels may be predicted to within an acceptable degree of risk.

An additional component of this framework might include the development of an alternative regional stock assessment estimator, e.g. a stock production model, or an age-structured model using CASAL (Bull et al. 2005). The different structural and statistical assumptions made under alternative estimation approaches may provide insight into the main sources of uncertainty in the regional assessment.

4.3.3 Information of utility for the assessment

Information that facilitates the estimation of important parameters or that underpins fundamental assumptions is of high utility in developing a population model because it addresses the main uncertainties in the model estimation. The information available on albacore from NZ has been reviewed in this report, and is considered in terms of the uncertainties in the current regional stock assessment for albacore.

Two main sources of uncertainty in the regional albacore stock assessment were identified by Langley & Hampton (2005): seasonal movement processes, and conflict between important data to which the model was fitted. Being a component of the regional assessment, the reliability of a NZ stock assessment will depend on uncertainties in the regional population model estimates. For example, movement estimation would be critical to a NZ assessment framework as it underpins temporal-spatial availability of albacore productivity to the NZ fishery. Therefore, improving the quality and quantity of observations input to the regional model that may address these uncertainties will benefit the NZ assessment directly.

Movement uncertainty

Seasonal movement estimates derived from spatially disaggregated model options were considered highly uncertain because of an apparent compensatory relationship between movement parameters and seasonal catchability coefficients (Langley & Hampton 2005). Seasonal catchability coefficients were estimated that describe temporal and spatial variability in the availability of albacore, and hence catch rates, to the fisheries in each spatial stratum. The trade-off in this approach that ignores movement processes relates to the fundamental assumption implicit in a single stratum model, i.e. homogeneity in the age and length composition throughout the population. Failure of this assumption may underlie a number of the problems identified in fitting the model to the observations, and that may indicate process error in the model caused by the lack of seasonal and age-specific movement of albacore.

Whereas these differences between the model and observed estimates may be due simply to observation error, their consistent pattern may represent process error relating to the lack of seasonal movement between northern and southern strata in the south Pacific region. The failure of the model to achieve a consistent fit to the length frequency time series over all fisheries was compensated to some extent by the selectivity parameter estimates for the longline fisheries. Estimates for fisheries in the northern strata show low selection of juvenile fish that contrasted with those for fisheries in the southern regions where higher selectivity for younger fish was estimated. This contrast in selectivity pattern would imply functional differences in the characteristics of the longline fishery's operation between strata, which may be unlikely. The differences in estimated selectivity may be acting as a proxy for age-specific movement between the regions that determines the age composition of the population available to the stratum-specific fisheries.

The model fit to the troll catch length frequency observations conflicted between the NZ and SCTZ fisheries operating adjacent southern strata. This difference occurs despite the similar and highly domed selectivity-at-age functions for the two fisheries. The cause of this discrepancy may also be reflected in the large effort deviations estimated for the NZ troll fishery, and the consistent increasing trend in catchability for the NZ troll fishery estimated from 1995 to 2003, whereas a decline was estimated for the troll fishery in the adjacent southern stratum. The large negative effort deviations most likely represent mis-specification of the availability of juvenile fish to the southern strata. An alternative interpretation is the variability in availability to the fishery induced by changes in oceanographic conditions, e.g. El Nino period. It was suggested that it might be necessary to estimate age-specific movement in regional assessments (Langley & Hampton 2005).

An explanation offered for the lack of fit to the NZ troll length frequency observations entailed differences in the cohort strengths between spatial strata (Langley & Hampton 2005). This implies the single stock assumption underlying the model that assigns homogeneity in cohort strengths between strata, is not consistent with the observations. An alternative explanation might be that age-specific movement accounts for observed differences in the annual age compositions of catches from the NZ and STCZ troll fisheries. This process may also be advanced as an explanation of the high number of observed recaptures of tagged albacore in 1993 and 1994. Given that most tagged fish were juveniles released in the southern strata, northward movement of small fish would result in their recapture in the northern regions. This process was not implicit within the assumptions of the single stratum model that was unable to predict the observation.

These discrepancies between predictions and observations highlight the importance of obtaining information of utility for addressing the model uncertainties, relating to movement. Combined with temporal-spatial patterns in CPUE, seasonality in length frequency between strata provides an indirect observation of age-specific seasonal migrations from which movement parameters may be inferred. Length frequency data in the southern strata reveals seasonal differences in size composition of the population available to the fishery. Relative to the northern strata, there is only a moderate amount of data available since the mid-1990s in the southern strata. The NZ CPUE and length frequency data is therefore of high utility to addressing uncertainty in albacore movement. This is of significance to NZ assessment, particularly as this process determines the availability of albacore to the NZ domestic fisheries.

Data conflict

The conflict between the catch rates of the Taiwanese longline fisheries and the length frequency data of the longline fishery was reflected in a consistent temporal trend in the residuals from the fit to the longline length frequencies for fish in the large size classes. The model estimates of decadal trends in recruitment appear to reconcile the data conflict, and the compensatory nature of these estimates in relation to the data conflict creates considerably uncertainty in the resulting estimates of stock abundance (Langley & Hampton 2005). Thus, information from which recruitments may be estimated directly, i.e. independent observations from which year class strengths may be inferred, are of high utility to the regional assessment. Length frequency data from the NZ troll fishery has been identified as highly significant in this context (Langley & Hampton 2005), and the close correspondence of the troll CPUE adds to this significance.

Recommendations for improving a NZ stock assessment

The sustainable yield available to the NZ fisheries will depend upon both the absolute abundance of the regional population, and factors affecting availability, including migration patterns between latitudinal zones, year class strength variability, and environmental variables. Model estimates for these quantities and processes underpin predictions of sustainable removals by the NZ fisheries. Therefore a primary feature of the NZ assessment will be to improve the estimation of the quantities and processes governing this albacore availability in the NZ EEZ.

In the absence of tagging information, uncertainty in movement processes must be addressed through inference from indirect information such as temporal and spatial patterns in length frequencies, CPUE, and possibly age-specific catch rates. Given the apparent consistency in visually inferred patterns in troll CPUE and length frequencies, it is important to identify factors affecting catch rates besides stock abundance. Unwin et al. (2005) concluded that fishing operation and environmental data on a fine spatial scale would improve on the standardised troll CPUE model. This is supported by the findings for a similar surface fishery where localised oceanographic features (thermocline depth) determine the availability of albacore to the fishery (Goñi & Arrizabalaga, 2005). Improving the spatial resolution by which troll catch and effort data is reported would improve the utility of this information for the regional and, hence, NZ stock assessment.

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Table 1: Summary of biological information collected for albacore by observers on board tuna longline vessels in the NZ EEZ from 1987 to 2004.

Observation type	**Sample size**	**Collection period**	**Status of information**
Length frequency	69 232	1987 to 2004	Annual summaries, sex- and area-specific estimates
Length-weight	53 437	1987 to 2004	Annual, sex- and area-specific estimates
Sex ratio	1 822	1987 to 2004	Annual estimates
Stomach contents	1 421	1994 to 2004	Average over all years, major taxa identified
Capture life status	44 052	1992 to 2004	Annual, sex- and area-specific estimates

Table 2: Summary of length frequency parameters for albacore caught by longline in the NZ EEZ derived from observers, categorised by region of capture and sex. n = total sample size. Taken from Griggs (2005).

Year	n	minimum	maximum	average	std. dev.
1987	273	43	112	85.8	10.5
1988	572	40	109	89.1	8.8
1989	488	49	108	87.0	11.1
1990	2052	45	120	87.5	10.5
1991	3271	51	115	86.7	11.5
1992	2446	49	115	83.7	10.5
1993	3162	51	112	86.6	9.0
1994	888	54	110	85.0	12.3
1995	1745	45	118	73.2	10.8
1996	2695	51	109	76.4	10.2
1997	4963	52	113	80.2	9.9
1998	8937	41	112	84.5	9.3
1999	1896	52	112	87.2	9.7
2000	1062	54	113	86.6	11.0
2001	8414	38	125	79.0	9.8
2002	1360	37	121	87.0	8.8
2003	21522	42	115	74.3	10.9
2004	3486	42	114	77.1	9.8

	n	minimum	maximum	average	std. dev.
Males	1761	51	113	87.5	11.3
Females	1507	57	115	87.0	9.6
North	63743	37	125	79.1	11.2
South	5489	40	121	88.3	11.5
North, males	1364	51	113	87.1	11.3
North, females	1159	57	111	87.2	9.7
South, males	397	64	113	89.1	11.1
South, females	348	65	115	86.4	9.4

Table 3: Estimated length-weight relationship parameters (wt = a lgth^b, wt in kg, lgth in cm) for NZ albacore sampled from the NZ longline and troll fisheries, and that derived by SPC. n = sample size, n/a = not available.

	n	a	b	R^2
Longline	31 273	3.61×10^{-5}	2.86	0.91
Troll	3 626	4.41×10^{-5}	2.81	0.94
SPC	n/a	6.96×10^{-6}	3.24	n/a

Table 4: Number of sets, number of hooks, total albacore catch, and mean nominal CPUE (albacore per 1000 hooks), by year, for longliners operating in north and eastern areas from 1993 to 2004[1], based on TLCER returns. (Taken from Unwin et al. 2005).

Year	Number of sets	Number of hooks (× 1000)	Number of albacore landed	Mean CPUE
1993	1 259	1 651.6	33 284	28.81
1994	1 446	1 237.4	49 247	45.51
1995	1 725	1 481.1	49 126	37.18
1996	1 458	1 229.3	47 251	39.50
1997	1 504	1 335.7	52 283	40.39
1998	2 503	2 478.0	112 811	47.85
1999	4 214	4 418.7	126 606	28.97
2000	5 259	5 799.3	97 958	17.26
2001	6 221	7 188.3	165 086	23.39
2002	6 673	7 875.8	171 552	21.68
2003	5 937	7 156.7	190 180	26.53
2004	3 730	4 355.3	86 914	19.56
Total	**41 929**	**46 207.3**	**1 182 298**	**27.14**

[1] January to September

Table 5: Number of sets, number of hooks, total albacore catch, and mean nominal CPUE (albacore per hook-day), by year, for surface troll vessels operating in north and west coast areas from 1993 to 2004[1], based on CELR returns.

Year	Number of sets	Number of hooks	Number of albacore landed	Mean CPUE
1993	4 653	57 051	310 337	10.85
1994	6 203	74 624	455 589	14.59
1995	4 739	56 260	426 751	19.18
1996	3 249	38 892	250 116	14.09
1997	3 556	42 764	242 971	11.01
1998	3 232	38 188	278 685	14.25
1999	2 408	27 941	237 588	17.54
2000	4 680	54 841	403 225	21.93
2001	4 566	53 007	307 833	11.55
2002	5 204	61 004	361 589	11.44
2003	4 454	55 728	363 174	12.20
2004	2 678	35 090	230 437	12.42
Total	**49 622**	**595 390**	**3 868 295**	**14.26**

[1] January to September

Table 6: Reported catches (t) of albacore by calendar year for the New Zealand domestic and chartered vessel fleets and for the South Pacific Ocean (SPO). (Taken, and modified, from Sullivan et al. 2005).

Year	NZ fisheries waters	SPO	Year	NZ fisheries waters	SPO	Year	NZ fisheries waters	SPO
1972	240	39 512	1983	720	25 092	1994	5 255	41 606
1973	432	47 324	1984	2 534	24 704	1995	6 159	37 331
1974	898	34 743	1985	2 941	32 328	1996	6 320	31 442
1975	646	23 595	1986	2 044	36 586	1997	3 628	32 011
1976	25	29 077	1987	1 236	25 042	1998	6 525	44 218
1977	621	38 735	1988	672	37 863	1999	3 903	35 542
1978	1 686	34 674	1989	4 884	48 562	2000	4 428	40 341
1979	814	27 071	1990	3 011	34 124	2001	5 349	53 469
1980	1 468	32 536	1991	2 450	32 693	2002	5 566	63 003
1981	2 085	34 783	1992	3 481	37 246	2003	6 744	62 320
1982	2 434	30 788	1993	3 327	34 670	2004	4 455	55 582

Source: WCPFC Tuna Fishery Yearbook 2004 and NZ Annual Report to WCPFC for 2005.

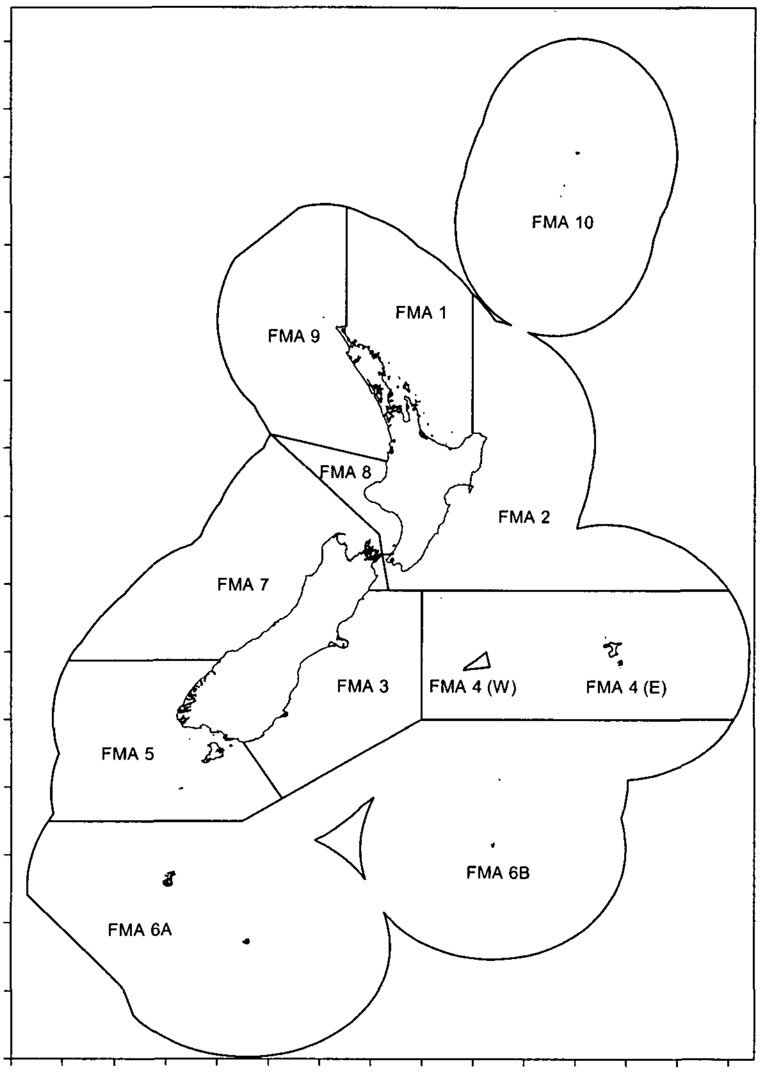


Figure 1: Location of NZ Fisheries Management Areas.

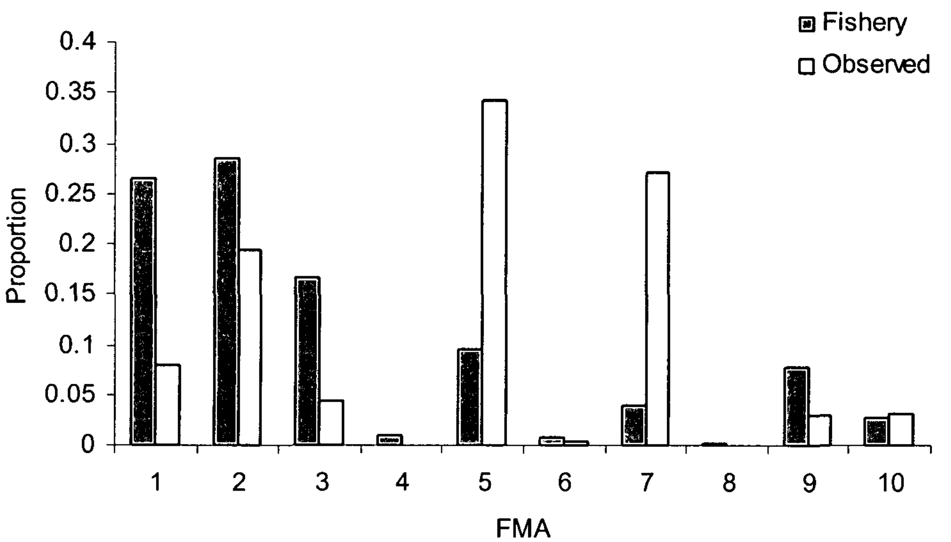


Figure 2: The average (1987 to 2004) proportion of total tuna longline effort (number of sets) in Fishery Management Areas (FMAs) compared with the average proportions in each area observed as part of the Ministry of Fisheries observer programme.

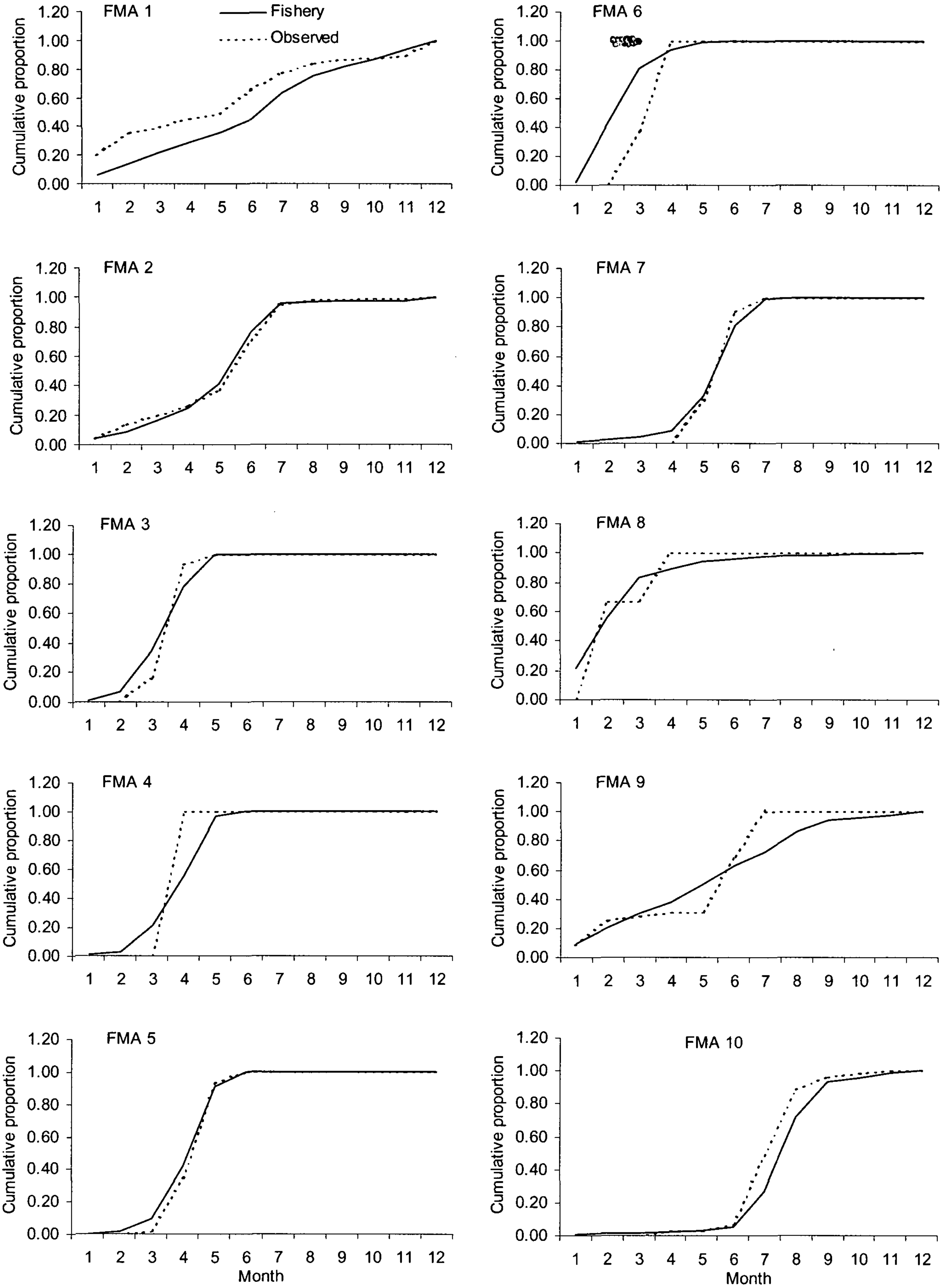


Figure 3: The cumulative proportion of tuna longline sets in each month (average 1987 to 2004) as occurs in the fishery (Fishery) compared with those observed under the Ministry of Fisheries observer programme (Observed), and for each Fisheries Management Area (FMA).

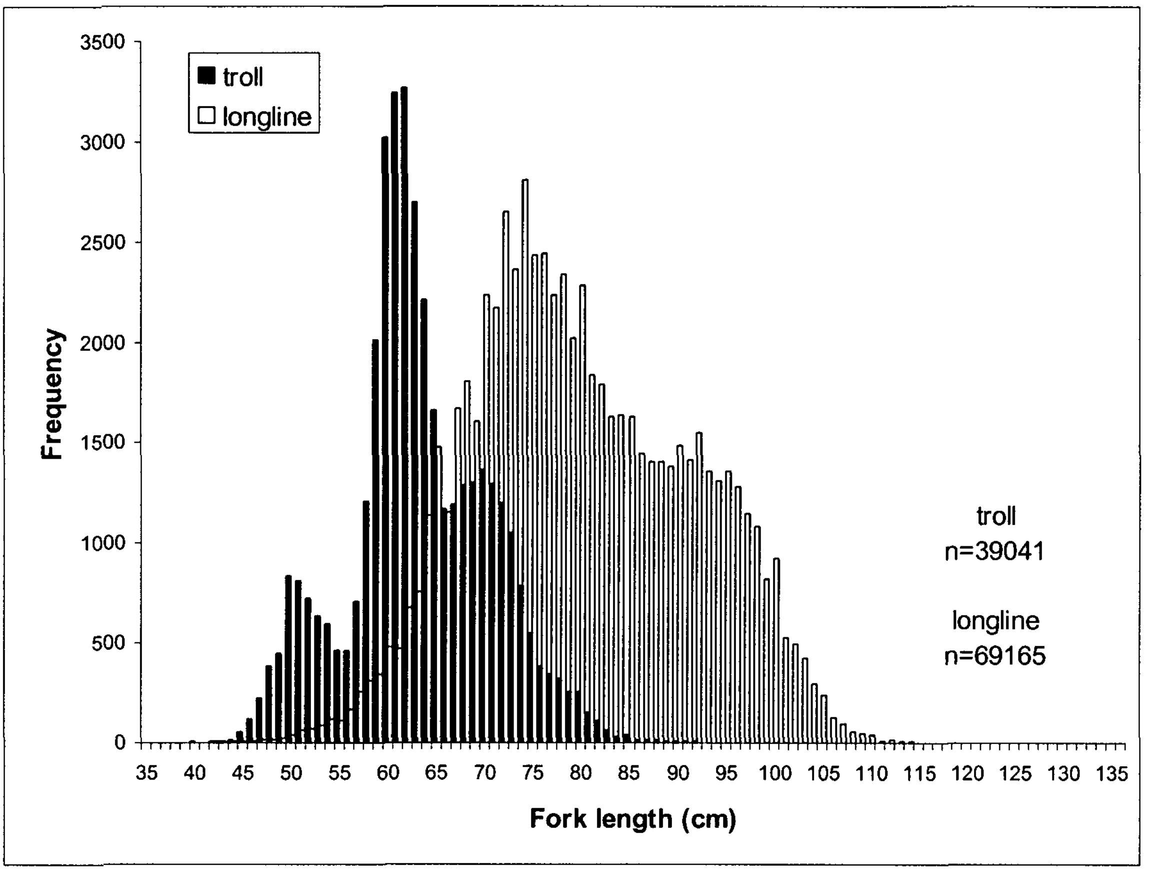


Figure 4: Length frequency distributions for albacore measured by observers on board tuna longline vessels (1987–2004), and albacore sampled from troll landings by port sampling (1997-2004).

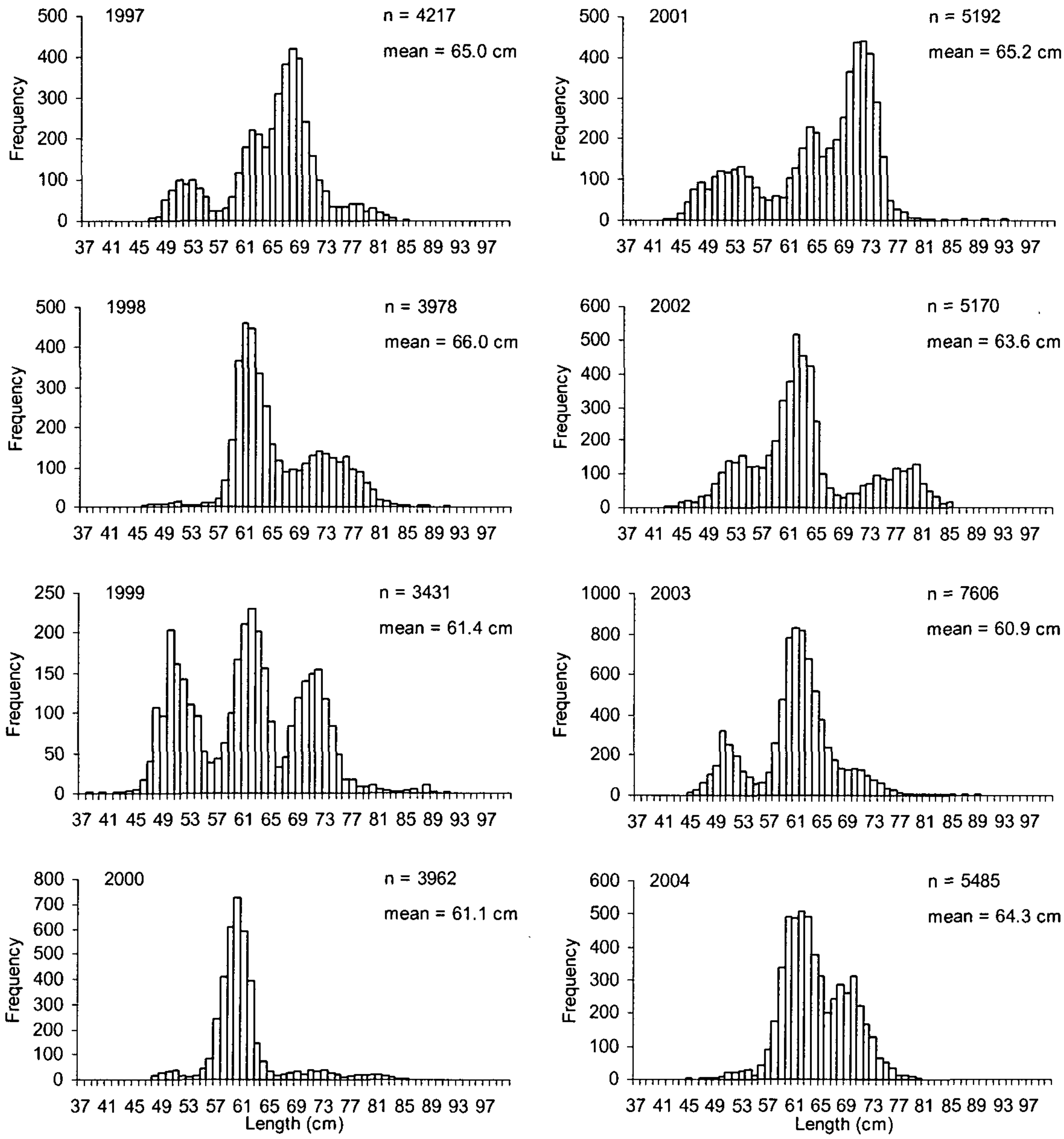


Figure 5: Annual length frequencies of port samples of troll landings from 1997 to 2004, (Taken from Griggs 2005).

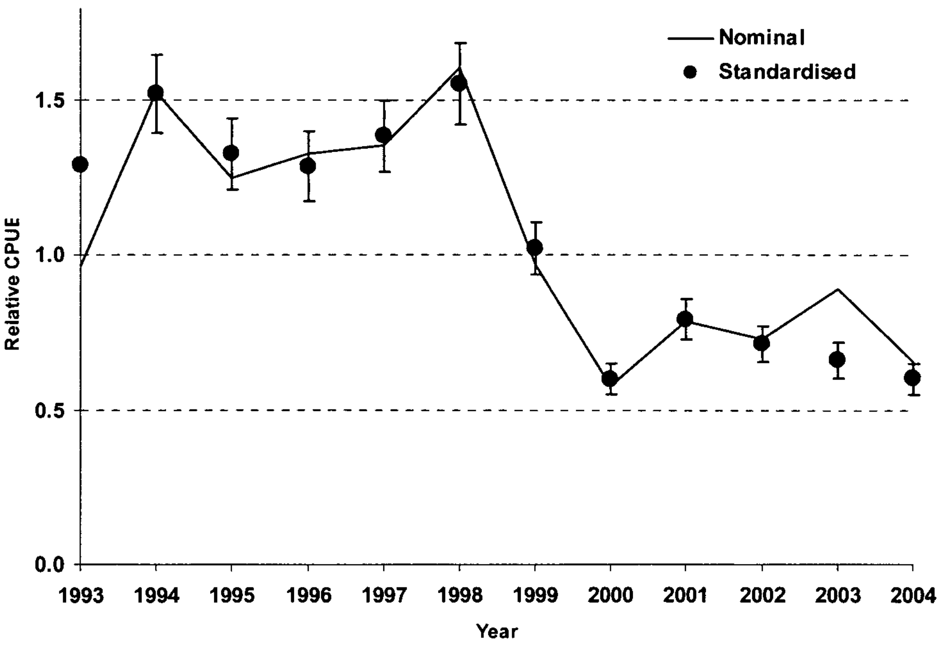
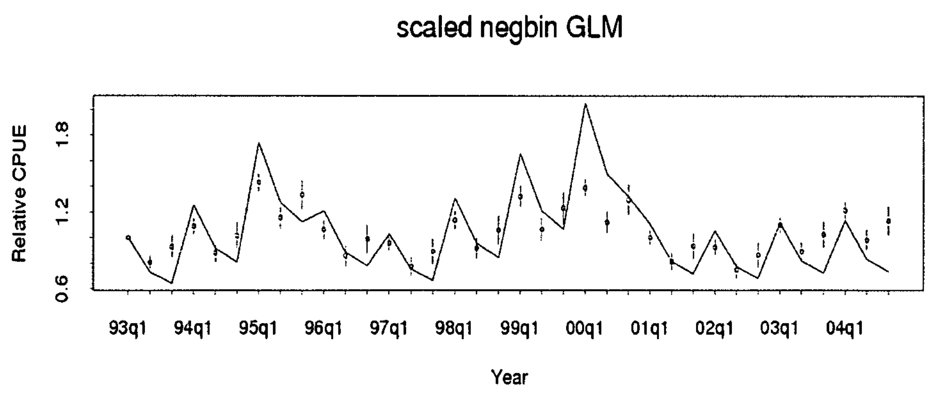


Figure 6: Nominal and standardised annual CPUE indices (normalised about the geometric mean for each time series) for the longline fishery, 1993-2004. Vertical bars indicate two standard errors. (Taken from Unwin et al. 2005).



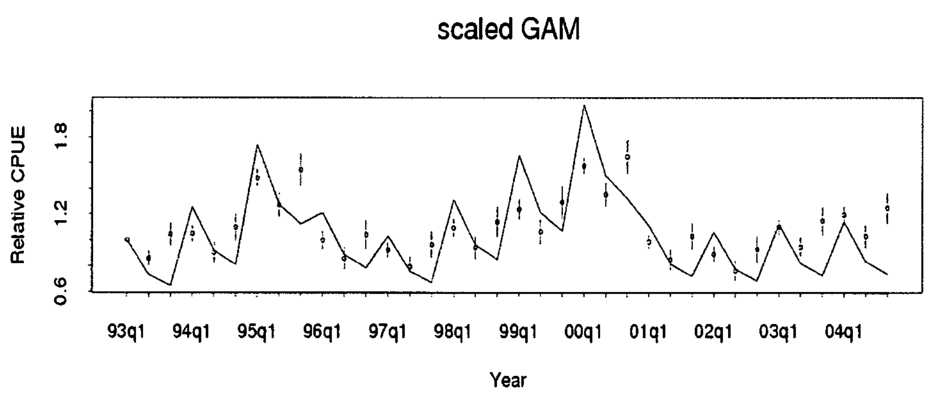


Figure 7: Quarterly time series of nominal and standardised CPUE for troll-caught albacore (line and circles respectively) estimated using the negative binomial GLM and quasi Poisson GAM. (Taken from Unwin et al. 2005).

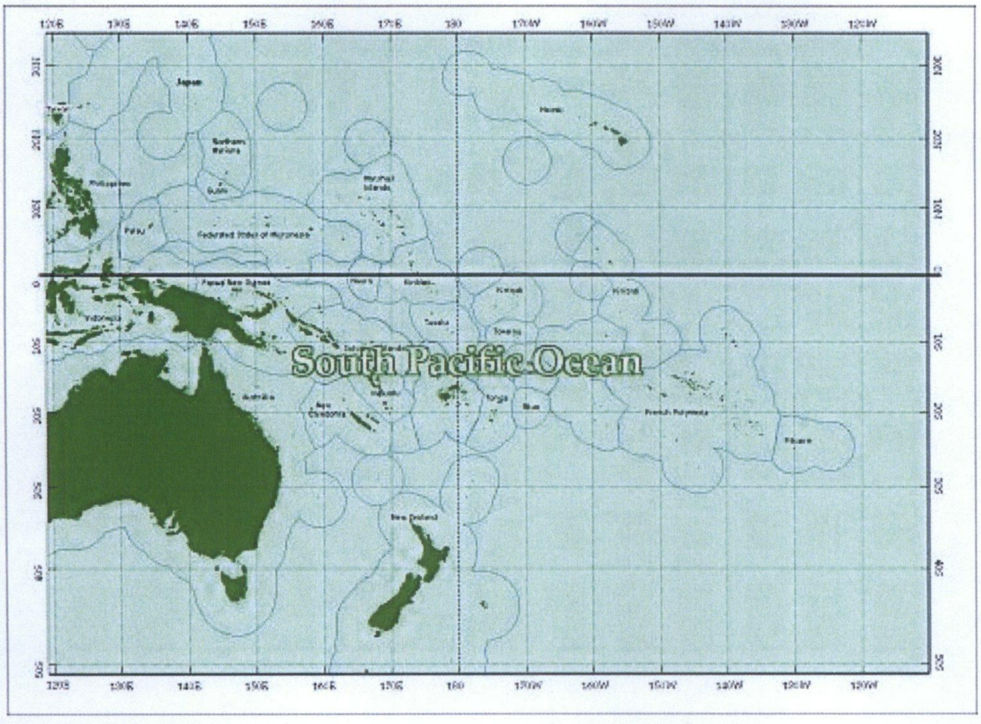


Figure 7: Defined boundaries of the South Pacific Ocean area for albacore assumed for the regional stock assessment and reporting of annual catch statistics to the Western and Central Pacific Fisheries Commission.