SOUTH PACIFIC COMMISSION

A REVIEW OF THE SOUTH PACIFIC ALBACORE TROLL FISHERY 1985—1992

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ABSTRACT

Information on the South Pacific albacore troll fishery has been accumulated since 1985 through a combination of exploratory fishing, high seas tagging and observer programmes. Over 4,000 daily fishing records were used to describe trends in this fishery. Median daily catches per vessel in the Subtropical Convergence Zone (STCZ) and around Australia and New Zealand (AUNZ) during 1991—92 were 125 and 39 respectively, and highest catches were $1{,}544 \cdot d^{-1}$ and $812 \cdot d^{-1}$ respectively. Average CPUE during 1991—92 were 51.2 and 18.9 per 100 line·hours for both regions respectively. Catch rates in the STCZ were consistently higher than in the AUNZ. The 1991—92 STCZ catch rates were the lowest on record, and were ~60 per cent of the level obtained during the peak season of 1986—87. Albacore caught in the STCZ tended to be larger than those caught in the AUNZ. The size composition of the albacore catch exhibited up to three distinct modes in some seasons. On average, 24 per cent of the albacore hooked were lost prior to being hauled aboard. On average, seven per cent of the albacore caught were discarded, mainly because of bad injuries or small size (<57 cm). The number of albacore examined that exhibited net marks during 1991—92 was negligible, which reflected the cessation of gillnet fishing activity.

RÉSUMÉ

Des informations ont été obtenues sur les ligneurs qui pêchent le germon du Pacifique Sud depuis 1985 par l'entremise d'un programme de pêche expérimentale, d'un programme de marquage en haute mer et d'un programme d'observateurs. Plus de 4,000 fiches de pêche journalières ont été utilisées pour décrire les tendances dans cette pêcherie. Les taux de prises journalières médianes dans la zone de convergence du Pacifique sud (STCZ) et dans la région de la Nouvelle Zélande et de l'Australie (AUNZ) pendant 1991—92 étaient de 125 et 39 germons par bateau respectivement, et les plus haut taux de prises étaient de $1{,}544 \cdot j^{-1}$ et de $812 \cdot j^{-1}$ respectivement. Les prises par unité d'effort pendant 1991—92 étaient de 51.2 et 18.9 par 100 lignes·heures pour les deux régions respectivement. Les prises par unité d'effort étaient toujours plus élevées dans la STCZ que dans la AUNZ. Les prises par unité d'effort dans la STCZ pendant 1991—92 ont été les plus basses enregistrées jusqu'à présent, et elles étaient 60 pour cent du niveau atteint pendant la saison record de 1986—87. Les germons capturés dans la STCZ avaient tendance à être plus gros que ceux de la AUNZ. Les distributions de tailles des germons montrent jusqu'à trois bosses distinctes pour certaines saisons. En moyenne, 24 pour cent des germons accrochés aux hameçons s'échappent avant d'être embarqué a bord. En moyenne, sept pour cent des germons attrapés sont rejetés parce qu'ils sont sévèrement blessés ou trop petits (<57 cm). Une fraction négligeable des germons examinés pendant 1991—92 possédait des marques de filet, ce qui reflète une élimination totale des activités de la flottille de pêche au filet maillant.

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1. INTRODUCTION

Exploratory surveys conducted during 1968—73 in the coastal waters of New Zealand revealed that albacore tuna (*Thunnus alalunga*) could be exploited commercially by troll gear on a seasonal basis (Roberts 1974, 1980). Information on the tuna fishing potential of the central South Pacific was also obtained through oceanographic cruises conducted between 1965 and 1985 by scientists from the Institut français de recherche scientifique pour le développement en coopération (ORSTOM) (Grandperrin and Le Guen 1986, Hallier and Le Gall 1986). During 1985—87, further exploratory troll fishing was conducted during research cruises headed by scientists from ORSTOM, the US National Marine Fisheries Service (NMFS) and the New Zealand Ministry of Agriculture and Fisheries (MAF). This showed that a viable high seas troll fishery for albacore could take place during December—April in the region of the Subtropical Convergence Zone (Knox 1970), mainly within the area bounded by 35—47°S and 170—130°W (Laurs 1986, Laurs et al. 1986, Pianet and Grandperrin 1990). This zone (STCZ) extends across the South Pacific, and is characterised by a thermocline depth of < 50 m, sea surface temperatures (SST) of 16—19°C, and salinities of ~34—36 ppt (Laurs et al. 1986). It is analogous to the North Pacific Transition Zone, which also supports large albacore fisheries (Laurs and Lynn 1991).

Favourable survey results led to the rapid development of a commercial troll fishery for albacore around New Zealand from 1974, and in high seas along the SCTZ from 1985 (SPC 1991). Data on fleet composition and fishing conditions in the troll fishery were obtained from fishing logs submitted voluntarily by commercial fishermen to US agencies (Majors et al. 1989, Coan et al. 1990, Rensick 1991, Coan and Rensick 1991) or to French Polynesian agencies when unloading in Papeete (Yen and Wrobel 1989). More detailed information, including size composition data, was recently provided through the fishery observer programme set up by MAF and the Tuna and Billfish Assessment Programme (TBAP) of the South Pacific Commission (SPC) to monitor developments in the commercial troll and gillnet fisheries targeting albacore. Observers usually embarked on vessels as they left the major ports; once the fishing grounds were reached, they monitored activities for one to four week periods on as many vessels as possible until the end of the season. Observer records obtained during 1989 provided the first accurate description of commercial troll fishing activities which served as the basis for the initial stock assessment studies conducted at the SPC (Hampton et al. 1989). This observer programme has since expanded to cover the entire troll fishing area and period (Hampton et al. 1991, Labelle and Murray 1992). During 1991—92, seven observers monitored fishing activities conducted over the period December—May between Tasmania (~148°E) and Easter Island (~110°W).

Troll fishery data were also collected during research cruises when troll gear was used for exploratory fishing (Murray and Bailey 1986, Laurs et al. 1986). From 1985 to 1992, vessels equipped with troll gear were also used by scientists from NMFS, MAF and SPC to catch, tag and release South Pacific albacore throughout the principal troll fishing grounds (Pianet et al. 1990, Laurs et al. 1986, Labelle and Sharples 1991). Tagging records and associated data on fishing conditions were supplied each year by various agencies to the TBAP, which maintains a regional tagging database used for stock assessment purposes (SPC 1992).

Data on the South Pacific albacore troll fishery, in the form of logbook submissions, exploratory troll fishing logs, observer records and tagging cruise records, were compiled to characterise the fishery. The purpose of the present report is to describe the trends in fleet composition, fishing methods, effort distribution, catch rates, loss rates, albacore size distribution, incidence of net marks and other external injuries, by-catch composition, and gillnet vessel incidence. Pertinent observations reported by fishery observers and taggers were also included when necessary to account for developments within the fleet.

2. DATA COLLECTION AND COMPILATION

2.1 Data collected

The type, accuracy and completeness of data recorded on troll fishing vessels vary considerably. At the lower end of the spectrum are skippers who only record fishing periods and total catch. At the opposite end are research vessels that continuously monitor several factors during each cruise such as position, oceanographic and atmospheric conditions, types of fishing gear deployed, catch rates, catch composition, by-catch, fish gut contents, and zooplankton densities in the water column. Factors such as manpower, equipment, logbooks, crew experience and vessel type affect the amount and quality of data collected routinely. To standardise the data collection process, all TBAP—MAF observers and taggers working on troll boats systematically recorded additional data needed to quantify fishing effort and catch rates for basic stock assessment work. The factors monitored for this purpose included:

(a) amount and species composition of by-catch;
(b) length and external condition of albacore caught;
(c) number and species of fish discarded;
(d) number of albacore hooked but not hauled aboard while fishing (drop-offs);
(e) SST and other physical factors that seemingly affected catch rates;
(f) fishing method used, and daily fishing periods;
(g) number and attributes of gillnet vessels sighted.

With the exception of (b) and (d), standard self-explanatory procedures were used to monitor each of the above factors. Further details are provided for the two exceptions.

2.1.1 Albacore length and condition

Efforts were made to measure as many albacore as possible each day and examine these for external injuries. During tagging cruises, observers measured all albacore tagged and a portion of those kept on board. Fork length was measured from the tip of the snout (with the mouth closed) to the end of the median caudal fin ray, and measurements were rounded down to the lower centimetre. Girths were measured by passing a plastic measuring tape around the body, perpendicular to the long axis, behind the insertion point of the pelvic fins. If pectoral fins were present when the fish was measured, the tape was passed under one fin and over the other one folded against the body. Girth measurements were rounded down to the nearest 0.5 cm. Weights were measured to the nearest 0.1 kg, preferably with motion-compensated electronic scales, or with a hand-held beam balance suspended from an overhang.

The types of injuries recorded by observers and taggers consisted mainly of shark bites to the body, cuts to the mouth area caused by troll gear, and external scars thought to be caused by encounters with gillnets. Hampton et al. (1991) introduced a method to categorize gillnet injuries, which was subsequently modified by Labelle and Murray (1992). This latter classification scheme was used to standardise all historical records, and describe trends in various injury categories:

Code 0: No loss of skin or scales on landing, fins undamaged;
Code 1: Continuous lateral stripes, 5—10 mm apart, located along the thickest part of the body;
Code 2: Brush-like skin abrasions, which terminate just prior to the point of maximum girth;
Code 3: Areas of exposed muscle visible where the skin and scales were scraped away. Exposed patches are ~25—50 mm wide, 50—100 mm long, and located < 30 mm from the dorsal or ventral mid-line in the area of maximum girth.
Code 4: Lateral stripes which are faint, older, less distinct and somewhat interrupted, which are indicative of an older gillnet injury that healed several months ago.

2.1.2 Drop-off rates

To determine the incidence of albacore drop-offs, observers conducted repeated observations interspersed through time on as many vessels as possible. Observers closely monitored as many fishing lines as possible for periods ranging from a few minutes to 16 hours. Estimates of the number of albacore which became unhooked while being hauled aboard included all those lost after being hooked for more than 10 seconds. Albacore in this category were referred to as 'drop-offs', and the ratio of drop-offs to the catch plus drop-offs was defined as the loss rate. By definition, this represents the fraction of all strikes that did not translate into a definite catch. An underlying assumption is that all such strikes are caused by albacore. Fishermen and observers determined if the hooked fish were albacore based on their appearance during hauling operations, the catch composition, and the struggling pattern exhibited by the fish.

2.2 Statistical treatment

Irrespective of the data source (observer, tagger, logbook, cruise reports), a complete daily fishing record had to include, at a minimum, a calendar date, a latitude and longitude at a given time of day, the number of lines trolled that day, the fishing period (in hours) and the number of albacore caught. Records considered to be unreliable or incomplete were not used for further analysis. If discrepancies were detected between corresponding fishing records obtained from different sources, both records were deleted unless the discrepancy could be resolved. If observations on specific factors had not been made during certain trips, the associated records were not used in the specific analyses. Whenever possible, correction factors were applied to SST records if the vessel's instruments had been recently calibrated. As of 20 October 1992, 4014 fishing records were available for analysis.

Descriptive statistics were generated to reveal trends across seasons and regions, and analyses were conducted mainly to assess the effects of certain factors. The statistics generated included the mean SST, the mean daily fishing period (in hours), the mean number of lines trolled per day, the mean daily catch per vessel, the mean fork length (in cm), the mean catch per unit of effort (CPUE) expressed as the catch per 100 line·hours, and the fraction of fish sampled in each injury category. All estimates were stratified by region, month and year. Six time periods were used for temporal stratification: November—December (combined), January, February, March, April, and May—June (combined). Two regions were used for the spatial stratification: *(a)* the area bounded by 34—47°S, east of 170°W (STCZ), and *(b)* the area west of 170°W within latitudes 34—42°S (AUNZ), which includes the Tasman Sea and coastal waters east of New Zealand to the edge of the Chatham Rise. These regions were selected because (*i*) there are differences in the nature of the two fisheries (coastal vs. oceanic), and (*ii*) consistently low catch rates have been reported in the area of 170—178°W, suggesting an apparent discontinuity in stock distribution and vulnerability to trolling.

The equations used to estimate the mean SST, albacore fork length, daily catches, CPUE, and number of lines used per stratum were described by Labelle and Murray (1992). If data on catch, lines or hours were missing for a particular record, the record was not used for estimating CPUE. All statistical tests were conducted by means of the SYSTAT microcomputer programme (Wilkinson 1989).

3. RESULTS AND OBSERVATIONS

3.1 Troll fishery characteristics

The commercial troll fleet targeting South Pacific albacore in the STCZ expanded steadily from 1985. Two US troll vessels conducted exploratory fishing that year (Laurs 1986), and seven vessels fished during the following season (Yen 1989). Additional vessels from the US and other

South Pacific countries subsequently entered the fishery, and the total troll fleet increased from 44 to 75 between 1987 and 1991 (Labelle and Murray 1992). During 1991—92, the fleet included 71 vessels, and >80 per cent of these were of US origin, with 10 per cent from New Zealand, 5 per cent from French Polynesia, and ~1 per cent each from Canada, Fiji, Western Samoa and Cook Islands. This fleet consists of modified tuna longliners, squid jigboats, swordfish gillnetters, shrimp trawlers, bottom and side trawlers, US pole-and-line boats, and North Pacific salmon trollers. Troll catches in the STCZ increased from about 89 mt in 1985 (Coan and Rensick 1991), peaked at ~5,500 mt during the 1990—91 season, and dropped to ~4,000 mt during 1991—92.

The New Zealand (NZ) troll fleet targeting albacore in coastal waters and the Tasman Sea is even less homogeneous, and can include trawlers, seiners, and longliners fitted with troll gear (Garvey 1991). During the 1988—92 period, the size of this troll fleet fluctuated between 150 and 250 vessels (Murray 1989, SPC 1991). Fishing has traditionally taken place over the shelf along the north-west side of the South Island, where fishermen seek albacore concentrated near the warm water fronts that progress southward during the season. Fishing on the south-east side of the North Island tends to be more sporadic, as participation levels fluctuate in response to reported catch rates. Albacore catches of the NZ troll fleet increased from 1974 onwards, peaked at ~4500 mt in 1988—89 (Garvey 1991), decreased to 2,000—3,000 mt during 1989—91 (SPC 1991), and were about 1,100 mt during 1991—92.

In Australia, albacore have been exploited mainly by sport fishermen since the 1970s. Commercial troll fishermen began targeting albacore during 1991—92 following increased publicity about the potential of this resource (Caton 1991). Troll fishing vessels participating in the fishery were mainly modified bluefin pole-and-line vessels. During 1991—92, eight troll vessels conducted exploratory fishing mainly in coastal waters in latitudes 35—44°S, and total catches were ~70 mt (Chapman et al. 1992).

During the observer programme, efforts were made to cover all troll fisheries targeting albacore to provide a representative sample of the entire South Pacific albacore troll fleet. As a result, fishing records were obtained for a total of 70 vessels which conducted commercial or exploratory troll fishing in various regions between 1985 and 1992 (Table 1). These vessels ranged from 5.6 to 53.6 m in length ($\bar{x}$=23.9), and 3 to 360 mt in hold capacity ($\bar{x}$=60.6). These vessels also varied considerably in terms of total tonnage (5—593 mt, $\bar{x}$=111), crew size (1—18, $\bar{x}$=4.8), lines trolled (7—31, $\bar{x}$=15), electronic equipment, outrigger placement and deck layout. By and large, there was a general tendency for vessels to conform to the typical North Pacific albacore troll fishing vessels as described by Dotson (1980).

In addition to variation in vessel attributes, observers also reported differences in experience levels among fishermen. Most of the skippers interviewed had some experience in hook-and-line fisheries, accumulated either in the New Zealand bluefin tuna fishery or in the North Pacific troll fisheries for tuna and salmon. Fishermen with little experience usually teamed up with veterans during their first season. Fishermen tended to worked in small groups, using similar fishing strategies. In the STCZ, fishermen usually started the season by heading for the traditional grounds centred around 39°S, 165°W. Vessels then started searching for thermal fronts with SSTs of 16—19°C and gradients of 0.5—1.0°C per km. This approach was established after Laurs et al. (1986) reported high catch rates when fishing across such fronts on the northern edge of the STCZ. Fronts are often located co-operatively by dispersing over large areas and communicating SSTs and catch rates over the radio. Depth sounders, sonar, water coloration discontinuity and floating objects were also commonly used to locate and remain with tuna aggregations. When repeated strikes occur while cruising, the vessel speed is reduced from 7 to 3 knots, and the fishermen then 'work the school' by making repeated passes over the area. When relatively high catch rates are obtained, some vessels broadcast their location, and others join them until catch rates decline again.

Table 1. Characteristics of troll vessels surveyed

Vessel code	Vessel type	Nation registry	Length (m)	Breadth (m)	GRT (mt)	Hold (mt)	Freezer type	Crew (n)	Lines (n)	Survey period
V1	Com.	US	23.7	7.4	(100)	84	Brine	4	15	2
V2	Com.	NZ	53.6	8.5	345	360	Blast	10	22	4
V3	Com.	NZ	34.0	5.8	79	64	Blast	8	19	1
V4	Res.	NZ	28.0	8.2	268	10	Ice	6	12	6
V5	Com.	NZ	32.4	6.4	144	71	Blast	8	25	3
V6	Com.	US	22.2	6.9	(100)	45	Brine	3	15	4
V7	Com.	NZ	32.4	6.4	143	74	Blast	8	20	4
V8	Com.	NZ	51.0	9.5	298	150/150	Blast+Brine	10	27	2
V9	Com.	NZ	52.8	8.5	345	300	Blast	16	31	1
V10	Com.	US	20.9	5.5	71	30	Brine	3	17	2
V11	Com.	US	20.0	6.0	(80)	64	Brine	5	18	1
V12	Com.	US	17.3	4.5	62	32	Brine	2	9	2
V13	Com.	NZ	34.0	6.0	80	78	Blast	7	20	1
V14	Com.	US	31.5	6.6	162	100	Blast	5	20	1
V15	Com.	FJ	24.6	5.8	(100)	55	Brine	5	16	1
V16	Com.	FJ	26.2	5.1	99	10	Brine	15	13	1
V17	Com.	US	23.5	6.7	136	46	Blast	4	22	2
V18	Com.	US	34.5	7.3	173	114	Blast	5	16	1
V19	Com.	US	23.5	6.7	116	77	Brine	3	13	1
V20	Com.	CI	23.8	6.8	132	73	Blast	4	20	3
V21	Com.	US	22.8	6.4	117	65/15	Blast+Brine	5	18	3
V22	Com.	US	18.2	5.2	57	23/32	Blast+Brine	2	12	1
V23	Com.	NZ	12.9	5.0	29	10	Blast		13	1
V24	Com.	AU	18.0	5.5	70	35	Brine	3	16	1
V25	Com.	AU	18.7	5.5	57	10	Ice	4	7	1
V26	Res.	US	(50.5)	(10.2)	(593)	(20)	(Blast)	18	9	2
V27	Com.	US	24.0	6.5	(100)	64	Brine	3	13	2
V28	Com.	US	22.0	7.0	70	59	Brine	5	10	3
V29	Com.	CN	24.4	(6.4)	110	60	Brine	6	12	1
V30	Com.	CN	27.7	(7.8)	127	66/70	Brine+Blast	6	14	2
V31	Com.	US	21.0	(6.3)	70	50	Brine	5	12	1
V32	Com.	US	20.7	(6.3)	63	39	Brine	4	14	1
V33	Com.	US	15.5	(5.0)	87	30	Brine	3	10	1
V34	Com.	US	19.0	(5.0)	50	32	Brine	4	11	2
V35	Com.	US	20.0	(6.0)	60	25/25	Brine+Blast	4	14	2
V36	Com.	FP	(23.2)	(6.0)	130	5050	Brine+Blast	4	17	2
V37	Com.	FP	(24.4)	(7.0)	(100)	(65)	(Brine)	(2)	31	1
V38	Com.	US	(16.0)	(5.5)	(65)	(32)	Brine	2	13	2
V39	Com.	CN	(20.0)	(6.0)	(65)	(30)	(Brine)	3	13	1
V40	Com.	US	(18.0)	(5.5)	(65)	(40)	Brine	3	10	2
V41	Com.	US	(22.2)	(6.5)	(80)	(65)	(Brine)	4	10	1
V42	Com.								17	1
V43	Com.	US	(27.5)	(7.8)	(125)	(130)	Brine	8	29	1

Vessel names have been coded for purposes of confidentiality. Abbreviations were used for the following categories: Commercial (Com.), Research (Res.), United States (US), New Zealand (NZ), Canada (CN), Fiji (FJ), Cook Islands (CI), Australia (AU), French Polynesia (FP). Survey periods indicate the number of seasons for which fishing records were provided. Figures within parentheses were estimated by observers. Number of lines and crew are estimated means.

Table 1. Characteristics of troll vessels surveyed (continued)

Vessel code	Vessel type	Nation registry	Length (m)	Breadth (m)	GRT (mt)	Hold (mt)	Freezer type	Crew (n)	Lines (n)	Survey period
V44	Com.	US	(17.1)	(5.4)	(65)	(80)	Blast	3	12	4
V45	Com.	US	(17.0)	(5.6)	(65)	(30)	Brine	3	12	5
V46	Com.	FP	(28.0)	(7.0)	(125)	(75)	Blast	6	20	1
V47	Com.	US	(23.8)	(6.8)	(115)	(78)	(Blast)	3	20	2
V48	Com.	FP	(28.0)	(7.0)	(125)	(130)	(Blast)	4	16	1
V49	Com.	US	(23.0)	(6.5)	(85)	(60)	(Brine)	2	19	2
V50	Com.	US	(16.8)	(5.5)	(65)	(30)	Brine	2	15	3
V51	Com.	US	(17.1)	(5.4)	(65)	(32)	Brine	2	14	4
V52	Res.	FR	(37.0)	(8.0)	(326)	(8)	(Blast)	11	12	1
V53	Com.	US	(21.4)	(7.0)	(80)	(45)	(Brine)	2-3	15	1
V54	Com.	US	(16.8)	(5.5)	(65)	(30)	Brine	3	(13)	5
V55	Com.	US	(23.0)	(6.7)	(85)	(72)	Brine	3	(13)	2
V56	Com.	US	(26.5)			(59)	Brine	4	14	1
V57	Com.	US	(19.2)	(5.8)	(79)	(45)	Brine	2	18	3
V58	Com.	US	(22.0)	(6.4)	(80)	(70)	Brine	4	(12/15)	1
V59	Com.	NZ	5.6	1.5	(5)	(3)	Ice	1	(12/15)	1
V60	Com.	NZ	13.8	3.5	(20)	(12)	Ice	2	(12/15)	1
V61	Com.	NZ	12.5	4.1	(24)	(16)	Ice	2	(12/15)	1
V62	Com.	US	(17.5)	(5.7)	(65)	(40)	Brine	2	15	1
V63	Com.	US	(23.8)	(6.8)	(115)	(72)	(Brine)	3	13	1
V64	Com.	US	(24.0)	(7.0)	(115)	(72)	(Blast)	3	18	1
V65	Com.	US	(15.9)	(5.5)	(70)	(32)	(Brine)	2	(8)	1
V66	Com.	US	(19.2)	(6.2)	(80)	(50)	Brine	3/4	(11)	2
V67	Com.	US	(22.8)	(6.6)	(80)	(65)	Brine	3/4	13	1
V68	Com.	US	(21.0)	(6.2)	(80)	(80)	Brine	(3/4)	12	1
V69	Com.	US	(22.0)	(6.5)	(80)	(65)	(Brine)	5	14	1
V70	Com.	US	(23.8)	(6.7)	(100)	(75)	(Brine)	4	(12/16)	1

Notes as per previous table section.

3.2 Troll fishery developments

Several important developments have taken place in the fishery since 1985. Reports of higher than average catches for vessels with sonar led to a progressive increase in the number of vessels with this equipment (P. Sharples, pers. comm.). Since 1990, 'reefer' vessels have been used in the STCZ to supply troll vessels during the season, and transport catches back to the canneries. This has allowed troll vessels to remain longer on the fishing grounds, venture into previously unfished areas, and reduce operating costs. Since 1988—89, the New Zealand Meteorological Services has used satellite imagery to produce maps of sea surface isotherms between New Zealand and 150°W. The maps are transmitted by fax to troll vessels twice a week during the season. Similar maps of Australian coastal waters have also been distributed more recently by the Division of Fisheries of the Commonwealth Scientific and Industrial Research Organization (CSIRO) (see Chapman et al. 1992). Skippers who fished in the STCZ for several seasons reported that the availability of SST maps had not led to drastic changes in fishing strategies, because satellites do not cover all fishing grounds and because the accuracy coverage of the maps is often reduced by cloud cover. However, observers reported that troll fishermen made efforts to concentrate fishing activities in locations where fronts had been identified by satellites.

During the 1990—91 and 1991—92 seasons, attempts were made to catch albacore by means of pole-and-line techniques as used in the North Pacific. Baitfish caught in New Zealand (mainly *Sardinops neopilchardus* and *Aldrichetta forsteri*) were transported to the grounds in holding tanks on board two Japanese-style pole-and-line vessels that also used troll gear. The experiment was not very successful because sufficient live bait could not be held for the entire season, or captured in sufficient quantities on the fishing grounds using *bouki-ami* nets. However, in one instance about two hundred albacore were lured to the surface, captured, tagged and released within less than one hour (P. Sharples, pers. comm.). The *Katsuo-Maguro Tsuchin*, a Japanese pole-and-line vessel, also reported large by-catches of albacore while fishing commercially for skipjack in the Tasman Sea during 1991—92. These facts have led several fishermen to express interest in combining baitfish and troll techniques in the future, and further investigations of the potential of this technique are already under way (see Chapman 1992b).

One of the most noticeable developments affecting the troll fishery was the rapid expansion of the drift gillnet fishery in the Tasman Sea and STCZ (Sharples et al. 1991, Hampton et al. 1989, Hampton et al. 1991, Labelle and Murray 1992). Japanese gillnet vessels began fishing in the South Pacific during 1983, but the major expansion occurred during 1988 when ~132 Japanese and Taiwan vessels were reported to target albacore (SPC 1991). However, this fleet has now ceased operating in compliance with the United Nations resolutions 44/225 and 45/197. Observers indicated that troll fishing activities were often disrupted by the nets, and that a large fraction of the albacore caught near the nets had external injuries (Labelle and Sharples 1991). Based on these data, and the similarity in size of albacore caught by troll and gillnet vessels, competition between the two fleets was suspected, but the impact on catch rates could not be quantified given the available information (SPC 1991).

The troll fishery is characterised by a considerable amount of co-operation among troll fishermen, with little or no competition within the fleet, and no evidence of over-capacity. Fishing conditions have changed noticeably over the years and technology has evolved. Such developments need to be accounted for when drawing inferences based on trends in catch rates (Hilborn and Walters 1992). However, this fishery is not as evolved as its North Pacific counterpart, where remote sensing data and highly sophisticated fishing advice are provided to the fishermen (see Laurs et al. 1984, Kleiber and Perrin 1991). Furthermore, there is still a considerable amount of knowledge that could be used to improve fishing efficiency. Observers reported that not all available techniques developed to increase catch rates and minimise losses are used by all fishermen. These include using moderate cruising speeds (~6—7 knots), trolling from towed skiffs, reducing speed while hauling (3—4 knots), and using proper hook sizes and line deployment patterns (Chapman 1992a). Albacore aggregations could be found more effectively on a collaborative basis by searching more systematically over larger areas. Lures could be trolled deeper (sub-surface fishing) by means of diving boards and lead balls as used in the North Pacific salmon troll fishery to increase catch rates by minimising the prop wash effects on the visibility of the lures, and because albacore usually remain near or above the thermocline (Laurs and Lynn 1991). Laurs et al. (1986) reported consistently good catches in the warm water eddies surrounded by cooler waters, yet not all fishermen concentrate fishing activities in such areas.

3.3 Distribution of fishing effort

Of the 70 vessels sampled by observers and port samplers, 55 provided fishing records covering a single fishing period, usually less than two weeks long. For the remaining vessels, fishing records covered longer periods or several trips which often took place during successive seasons. Fishing records were available for 3 vessels during 1985—86, but vessel coverage expanded subsequently, ranging from 13 to 21 vessels between 1986 and 1990, and increasing to 28 and 32 vessels during the 1990—91 and 1991—92 seasons respectively.

Greater coverage of the fleet was also accompanied by a general increase in the number of daily fishing logs obtained, particularly for the STCZ region where samples increased from 94 records in 1985—86, to 1726 in 1991—92 (Table 2).

Table 2. Number of daily fishing records, average SST, and mean CPUE for each region/season/month stratum, 1985—92

Stats/ region	Season	Dec.	Jan.	Feb.	Mar.	Apr.	May+	STATS
Records								**Sum**
AUNZ	'85–86			22	13			35
AUNZ	'86–87	23	4	17				44
AUNZ	'87–88		8	10	8			26
AUNZ	'88–89	3	6	10		6		25
AUNZ	'89–90	59	16	5			7	87
AUNZ	'90–91	16	28	11	19			74
AUNZ	'91–92	14	28	3	14	15	1	75
STCZ	'85–86			53	41			94
STCZ	'86–87		37	19	13	3		72
STCZ	'87–88	33	29	6	65	54		187
STCZ	'88–89	58	138	105	111	26		438
STCZ	'89–90	2	58	61	101	22		244
STCZ	'90–91	94	285	246	195	61	6	887
STCZ	'91–92	122	535	576	425	65	3	1726
SST								**Mean**
AUNZ	'85–86			18.0				18.0
AUNZ	'86–87	17.9	17.9	17.1				17.5
AUNZ	'87–88		19.0	19.9	16.3			18.4
AUNZ	'88–89	17.5	21.1	19.9		17.1		19.4
AUNZ	'89–90	18.0	18.3	20.9			16.7	19.6
AUNZ	'90–91	18.3	17.3	17.7	17.3			17.4
AUNZ	'91–92	17.4	18.3	18.6	16.4	17.9	16.2	17.8
STCZ	'85–86			18.0	18.2			18.1
STCZ	'86–87		18.5	18.5	17.7	16.9		17.9
STCZ	'87–88	18.2	18.1	18.0	17.6	18.6		18.1
STCZ	'88–89	16.6	17.5	18.8	18.3	18.4		18.3
STCZ	'89–90	19.3	19.1	18.2	18.0	17.8		18.3
STCZ	'90–91	18.6	19.1	19.6	17.8	17.4	17.8	18.5
STCZ	'91–92	17.5	17.6	17.7	17.9	18.1	16.3	17.8
CPUE								**Mean**
AUNZ	'85–86			20.4	15.3			17.9
AUNZ	'86–87	24.4	112.5	63.2				87.9
AUNZ	'87–88		60.0	68.0	21.9			50.0
AUNZ	'88–89	3.9	157.1	55.4		22.5		78.3
AUNZ	'89–90	38.5	38.0	131.3			12.9	84.7
AUNZ	'90–91	12.4	22.5	11.9	50.7			28.4
AUNZ	'91–92	8.5	10.5	0.5	39.2	25.5	1.8	18.9
STCZ	'85–86			130.3	70.3			100.3
STCZ	'86–87		149.4	72.8	29.3	241.7		123.3
STCZ	'87–88	111.8	62.8	89.7	194.9	105.8		113.3
STCZ	'88–89	103.5	125.3	154.3	100.3	71.4		112.8
STCZ	'89–90	78.7	128.2	115.4	93.7	104.6		110.5
STCZ	'90–91	70.0	89.4	128.1	54.0	38.6	10.0	77.5
STCZ	'91–92	53.4	113.3	38.6	38.0	14.8	3.8	51.2

Blanks indicate that no records are available for that stratum. All means cover the January–April period.

Considerably more records were obtained for this region, in part due to the greater fishing and tagging activities conducted there. For this region, information was available for each month within the principal fishing period (Dec.—Apr.) 1987—88, unlike the AUNZ region for which fishing records are lacking for certain months.

Prior to 1990, fishing records were provided mainly by US vessels operating in the STCZ and NZ vessels fishing along the New Zealand coast. As a result, the data relate mainly to conditions inside New Zealand's EEZ and the area bounded roughly by 165—130°W and 35—42°S. Increased tagging and observer activities from 1990 onwards provided information on fishing conditions from Tasmania (~148° E.) to Easter Island (~110° W.) mainly within the latitudinal band of 30—47°S (Fig. 1). Since taggers and observers generally worked on board vessels interspersed among the fleet, the 1990—92 records were still considered representative of general fishing conditions within the fleet even though larger areas were covered.

Troll fishing effort in the STCZ appeared to be distributed in a bi-modal fashion in some years (eg. 1987—88, Fig. 1). Examination of the fishing records revealed that the apparent clustering was partly due to the relatively low number of records available, and movement of the fleet during the monitoring period. Each season, there was a tendency for the fleet to move eastward as the season progressed. During 1991—92, fishing activity was centred about 155°W in December, but shifted to 140°W by April. Laurs and Nishimoto (1989) noted a trend for STCZ troll fishing boats to move southward between January and March, and slightly back towards the north in April. Substantial migration of the fleet on a north—south basis was not apparent for all seasons during the 1985—92 period.

Laurs et al. (1976) noted marked annual variation in the locations of North Pacific albacore concentrations, which induced major latitudinal shifts in the location of the U.S. troll fishery off the North American west coast. Similarly, year-to-year variation in the location of principal fishing activity is apparent for the STCZ troll fleet (Fig. 2). Ellipses bounding 95 per cent of the reported locations of fishing activities for each season varied both in size and centre of activity. Variation in ellipse shapes is affected to some extent by coverage rates and fleet sizes, but albacore availability is undoubtedly a major determinant of the patterns observed. Ellipses were relatively small and centred near the same locations during the first three seasons. Larger areas of similar size were covered during 1988—89 and 1989—90, but the centre of activity shifted longitudinally by ± 5°. Larger areas were covered during the next two years, with similar shifts in centre of activity. Low catch rates were observed in 1990—91 (see section 3.4), the centre of activity was further south-west, and the area covered was considerably larger. The lowest CPUE occurred in 1991—92, and the fleet was spread over the largest area ever. These facts suggest that during good fishing seasons, albacore aggregations were centred on 38—40°S, 145—155°W, and covered areas extending latitudinally by ±2° and longitudinally by ±8°.

Observers noted that during the 1991—92 season, albacore stomachs rarely included juvenile Peruvian jack mackerel (*Trachurus murphyi*), which is the major prey item of albacore in the STCZ (Bailey 1989). The most common species found in the stomach of albacore was saury (*Scomberesox saurus*), which was rarely observed during previous surveys. Several unusually large plankton blooms were also encountered during the season. It could be hypothesized that the low catch rates and the unusual observations were induced by the concurrent El Niño event. However, similar conditions were not reported during the El Niño event of 1986—87, so this hypothesis is not supported by previous survey observations.

Fishing activities in the Tasman Sea and in coastal areas east of New Zealand were not monitored extensively during 1985—92 so there is considerable uncertainty about the distribution of troll fishing effort. Substantial coverage has been achieved since 1988, which confirmed that fishing activities are mainly centred along the west coast of New Zealand during the December—March period. Records of fishing conditions across the Tasman Sea were obtained primarily from exploratory research cruises conducted since 1989, so the fishing locations shown in Fig. 1 do not correspond exactly to the distribution of the commercial fleet in the Tasman Sea. However, fishing records obtained from commercial vessels in Australia during 1991—92 showed that trollers fish in slightly lower latitudes than those fishing around New Zealand.

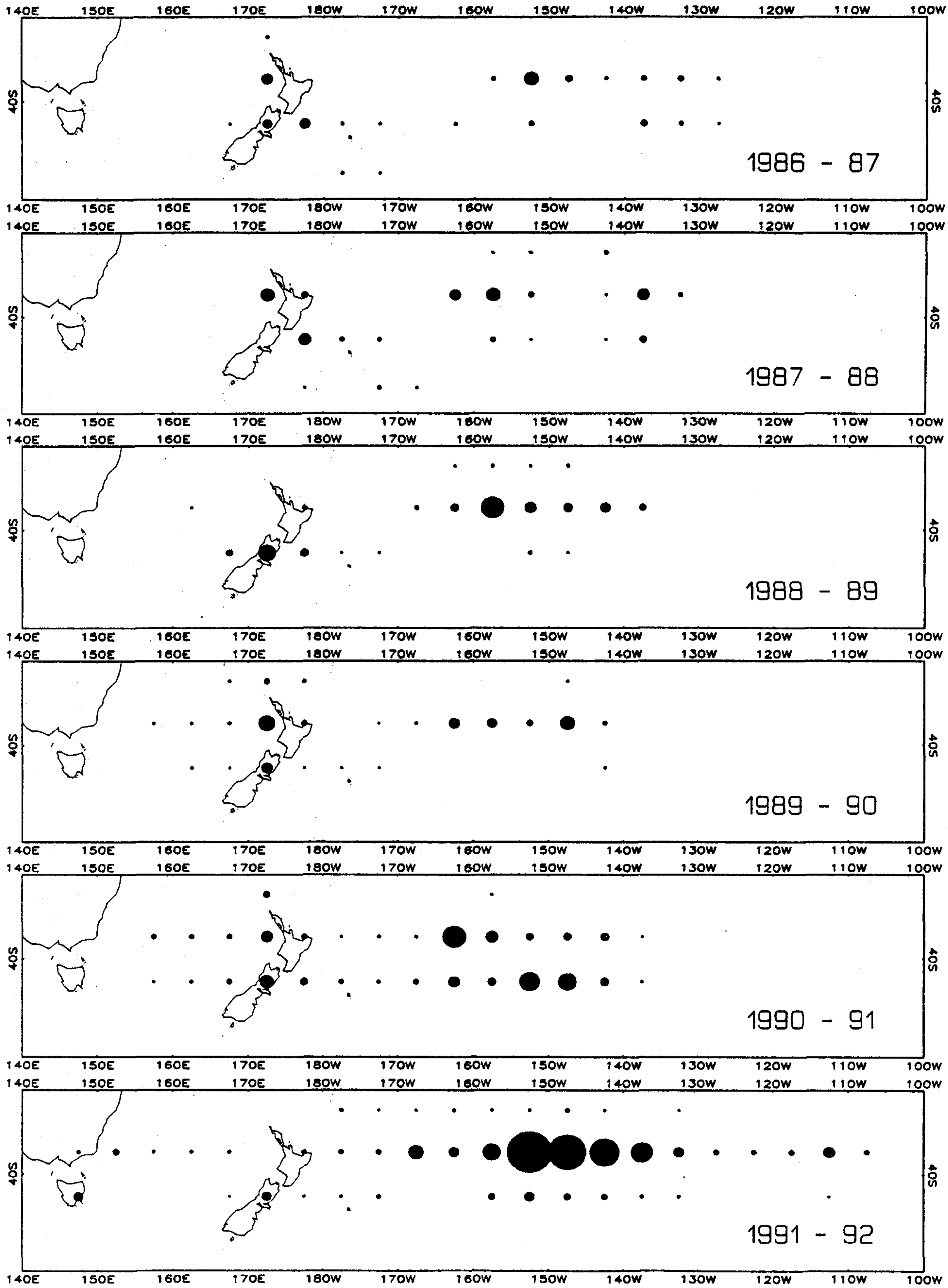

Figure 1. Position of the troll vessels on days when records were collected. Dot sizes are proportional to the sample sizes for given locations.

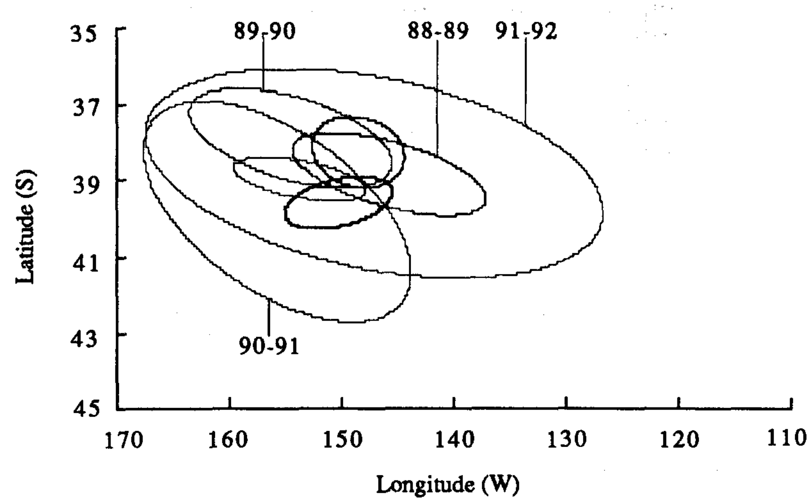

Figure 2. Spatial distribution of the STCZ fishing activities, 1985—92. Ellipses are centred on the mean latitude and longitude of fishing activities conducted during the December—April period. The ellipse bounds cover a two standard deviation spread around the mean location of fishing activity.

3.4 Trends in catch rates

Daily catches tended to be higher in the STCZ than in the AUNZ (Fig. 3). During the 1985—92 period, albacore catches of $\leq 60 \cdot d^{-1}$ were obtained on ~25 per cent of the fishing days conducted in the STCZ since 1985, and ~58 per cent of those in the AUNZ. The median daily catches were 125 and 39 for the two regions respectively. Maximum daily catches were 812 in the AUNZ and 1544 for the STCZ, but catches $>600 \cdot d^{-1}$ accounted for <1 per cent and ~3 per cent of the trips in each region respectively. Observers noted that when albacore catches exceeded $500 \cdot d^{-1}$, there were periods when albacore were hooked on all lines. Under such conditions, lines got tangled easily, and some crews could not haul them fast enough to remove the albacore. When this gear 'saturation' point was reached, some crews pulled in the outer lines and only operated the shorter stem lines. Rapid adjustments and short-term gear problems such as these are not routinely and accurately recorded on logsheets. As a result, the peak daily catches reported in the fishing logs would most likely be lower than those obtained under ideal conditions with no gear saturation effects.

An analysis of variance was conducted to assess the effects of effort (line·hours), time (month and year), SST and region (STCZ, AUNZ) on daily catches. The catch to effort relations were first compared across months for 1990—91 and 1991—92, since the largest sample sizes were available for these periods (Fig. 4). Linear regressions of daily catches against effort from individual records revealed a significant relation between the variables within each month from January onwards ($P < 0.025$). The relation was not apparent during December, suggesting that early in the season, the ability to find aggregations may have a greater effect on daily catches than effort. Considerable scatter around the regression lines is apparent for each month, presumably due to the effects of sample size, gear attributes, skipper experience, environmental conditions and random fluctuations. Detailed information on such factors is lacking for most fishing records, which precludes further assessment of their effects on daily catches.

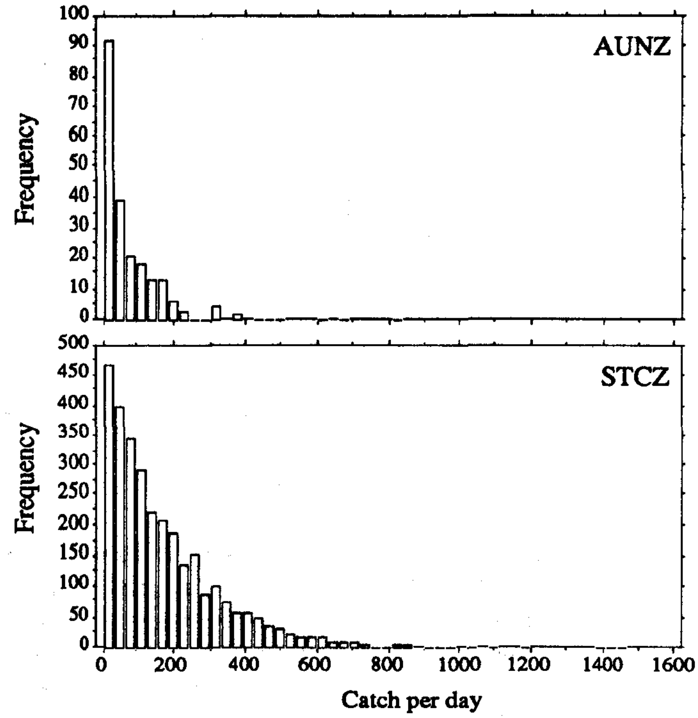

Figure 3. Frequency distributions of the number of albacore caught per boat per day. The datasets include all records associated with fishing periods > 9 h conducted between December and April 1985—92.

Sample sizes were sufficiently large to assess the effects of month, season, and effort on daily catches for January—May, 1988—92. A two-factor ANCOVA showed significant differences in daily catches among months and years for given levels of effort (Table 3). Significant covariate coefficients were obtained indicating that effort was a major determinant of daily catch rates. None of the covariate-factor interaction effects were found to be significant, as the slope of the regression of daily catches against effort was similar across years during the January—April period. These results indicate that troll vessels should pull as many lines as possible to maximise their daily catches, and that more albacore are susceptible to being caught during January and February. Kleiber and Perrin (1991) also showed significant differences in CPUE between time-area strata in the North Pacific albacore fishery.

Table 3. Analysis of Covariance (ANCOVA) summary results.

Source	SS	*df*	MS	F-ratio	*P*
Season	253296.870	3	84432.290	3.356	0.018
Month	286023.024	3	95341.008	3.790	0.010
Effort	310348.755	1	310348.755	12.336	0.000
Effort·Season	120287.232	3	40095.744	1.594	0.189
Effort·Month	112172.336	3	37390.779	1.486	0.216
Season·Month	258248.096	9	28694.233	1.141	0.330
Eff·Seas·Month	337140.442	9	37460.049	1.489	0.146
Error	6.88E+07	2733	25157.353		

The factors tested were season (1988—89 to 1991—92) and months (Jan.—Apr.), with effort (line·hours) selected as the covariate. *df* denotes the degrees of freedom, and *P* is the probability level.

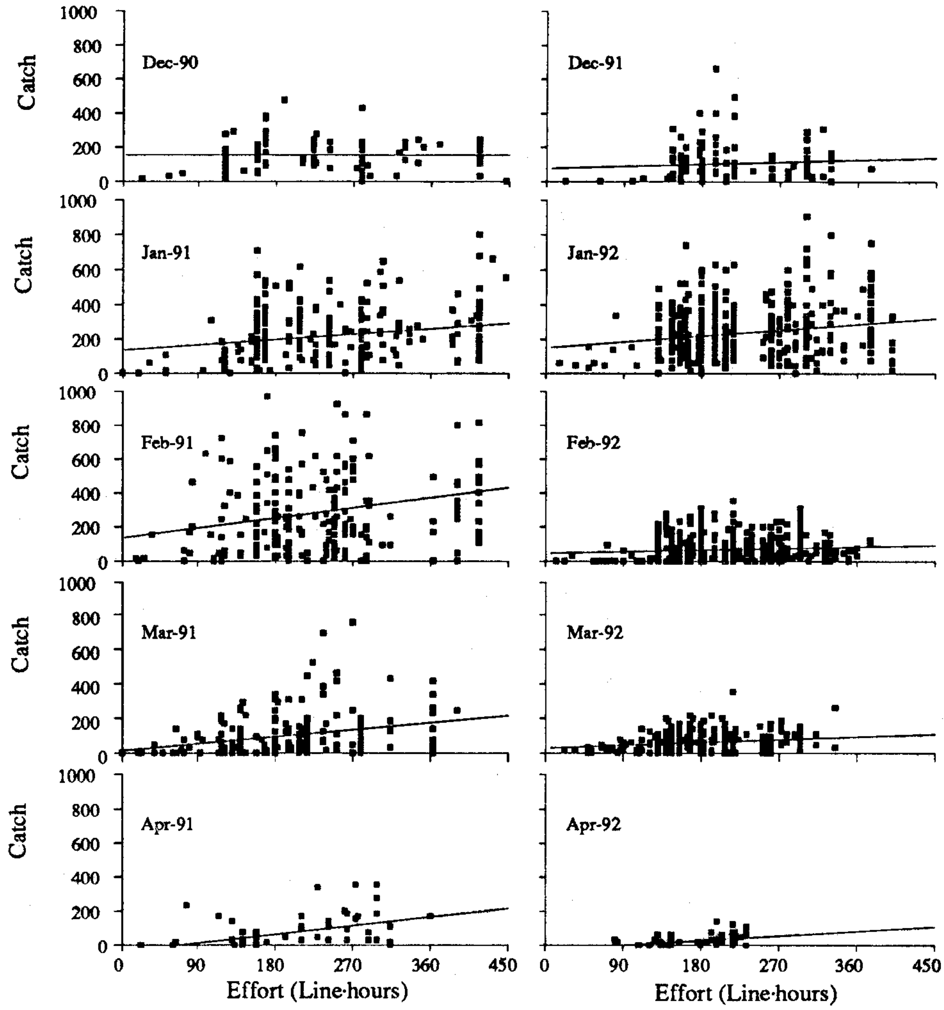

Figure 4. Daily catches (in pieces) against fishing effort during 1990—91, 1991—92. Each relation is based on the combined records of all troll vessels monitored each month.

An examination of daily catches in relation to SST showed that the largest catches (>1300·d^{-1}) were obtained within the SST range of 16.6—20.0°. Troll fishing in the STCZ is rarely conducted outside this SST range, and is largely concentrated in waters of 18° C. (Fig. 5), Laurs et al. (1986) noted that peak daily catches on one vessel were obtained within the SST range of 18.3—18.6° C. This would suggest that daily catches increase with increasing SST up to ~18.5°C, and decrease thereafter with further increase in SST (a dome-shape relation).

Temperature measurements were rescaled to |SST − 18.5| so that catch rates would increase with decreasing corrected SSTs if the hypothesized dome-shape relation existed. The previous ANCOVA analysis was then repeated (without the interaction factors) after including the corrected SSTs as an additional covariate. The influence of this variable on catch rates was not found to be statistically significant (P = 0.08). Diagnostic checks revealed no significant correlation between effort, corrected SSTs and time factors, although significant differences in SST were detected across months and years (two-factor ANOVA, P < 0.01). The possibility remains that SST can influence catch rates (as shown by Chapman et al. 1992), but longer time series of observations spread more evenly over the entire SST range will be needed to quantify such an effect.

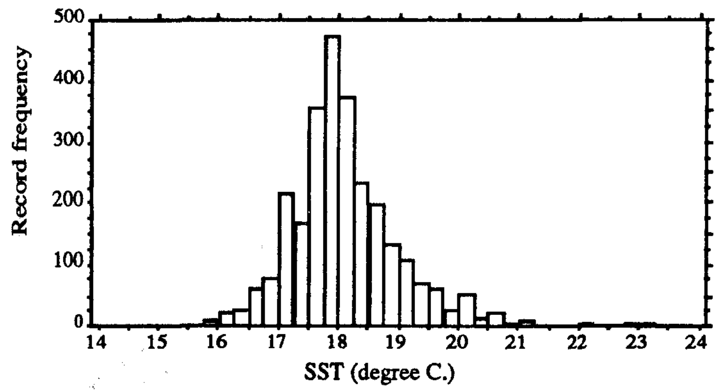

Figure 5. Distribution of daily SST when trolling in the STCZ, 1985—92

Comparisons of daily catch rates between the AUNZ and STCZ were hampered by the lack of sufficiently large sample sizes for certain periods, so comparisons were limited to the months of January and February during the six fishing seasons of 1986—92. The ANCOVA analysis was repeated with region, year and month as factors and effort as a covariate. All factors were found to have a significant effect on catch rates. Adjusted least-squares means of the STCZ catch rates exceeded those of the AUNZ by ~$100 \cdot d^{-1}$ for similar effort levels at corresponding times. This result supported claims by fishermen that fishing was 'better' in the STCZ.

3.5 Losses due to fishing methods

During 1987—92, fishing practices were examined to determine the fraction of albacore hooked that escaped before being brought on board. A total of 720 different measurements was made over the six seasons, representing 3620 hours of observations on 17 different vessels. The overall mean loss rate, averaged across all vessels and years, was 24 per cent. Vessel-specific loss rates, averaged across all survey periods, ranged from 6.2 to 36.1 per cent, indicating considerable variation among vessels. Fishing conditions, vessel characteristics and crew experience were hypothesized to affect loss rates. Observers noted that transom height, cruising speed and albacore size appeared to affect the ability of deckhands to successfully haul albacore on board. Observers also noted that under rough weather, the swell affected the vessel speed. This occasionally induced excessive strain on hooked albacore such that their jaw would tear off. Under such conditions, changing vessel orientation helped minimise this problem.

Sea conditions (very calm, calm, mild, moderate and storm) were recorded by observers on 270 instances while monitoring loss rates; hook type (single or double) was recorded each time. Vessels fishing with single hooks (used for tagging purposes) exhibited greater loss rates than those using double hooks (28.3% against 20.9%), and log-likelihood ratio tests (Zar 1984) revealed significant differences in the drop-off to catch ratio between both vessel categories (P = 0.0001). Significant differences were also detected in the drop-off to catch ratio of vessels fishing with double hooks under different sea conditions (P = 0.0001). Loss rates were lowest when the sea was very calm (15.1%), higher under calm sea conditions (21.8%), and highest under moderate sea conditions (37.0%). Loss rates while fishing in rough seas were less than in moderate seas (26.8%), perhaps because greater care was given to the lines at such times.

Further investigations of the effects of hook types and fishing methods on loss rates were conducted during one of the 1990—91 tagging cruises. The loss rates of lines with regular double barbless hooks were compared to those with regular single barbless hooks (Table 4). Significant differences in the landed to drop-off ratios were detected between the two types of lines (χ^2 test, P = 0.0001), with substantially higher loss rates for the latter type of line (52% *vs* 9% respectively). Lines with small single hooks were characterised by higher loss rates (55.7%), but no significant differences in the landed to drop-off ratios were detected between regular single and small single hooks (χ^2 test, $P = 0.64$). Loss rates were comparable for extra-small single hooks and small single hooks, but extra-small double hooks had lower loss rates (41%). However, extra-small hooks often straightened out and were not considered suitable for extended use. Using regular double hooks reduced the loss rates but tended to cause more injuries than single hooks. The fraction of the albacore landed that were not tagged because of mouth, head or gill injuries (Rejects, Table 4) was greater for regular double hooks than for regular single hooks (~57% against 44%), but no significant difference was detected between the suitable to reject ratios (χ^2 test, $P = 0.94$). Using small single hooks failed to further decrease the fraction rejected.

Table 4. Loss and discard rates for different hook types and fishing methods

Hook type	Hook model	Survey time	Strikes	Lost	Landed	Rejects	Suitable	Strikes (hook·h)
Regular double	7-925-21-50	130.00	208	19	189	107	82	1.60
Regular single	7-925-21-50	594.84	911	474	437	190	247	1.53
Small single	*1665-7/0	38.49	70	39	31	15	16	1.82
E. small single	*1665-5/0	25.50	27	16	11	9	2	1.06
E. small double	1665-5/0	49.00	61	25	36	15	21	1.24
Skiff single		63.67	54	18	36	6	30	0.85
Vessel single		313.08	325	150	175	73	102	1.06

All hooks tested were supplied by Mustad Co. Survey times are in hours. Lost figures are the number of drop-offs. Albacore were classified as rejects if mouth or gill injuries were present, and suitable if no injuries were visible. Hook sizes were: Regular = 2.5 cm gap x ~4 cm shank; Small = 2.0 x 3.7 cm; E. small = 1.5 x 3.2 cm.
* Hooks with barbs crimped.

The catch reported by troll vessels is the nominal catch which usually comprises only albacore kept on board for sales. However, some of the albacore caught were occasionally discarded after being hauled aboard. During 1990—91, observers reported that ~1.7 per cent of the nominal catch was rejected by fishermen. Some of the albacore discarded had shark injuries, but most of those rejected were generally small (<57 cm) uninjured ones that were not in great demand by canneries (Labelle and Murray 1992). These were usually rejected while still alive, on the assumption that some might survive after release. Overall discard rates for the entire 1991—92 season were not estimated because observers were required to tag as many albacore as possible, including the small ones that might have been discarded. Accurate monitoring of discard rates during two of the 1991—92 cruises revealed that up to 47 per cent of the albacore hauled aboard were discarded on some days. However, the mean discard rate for the two cruises combined was ~7 per cent, and there was a tendency for daily discard rates to decrease as the season progressed and the average size of the albacore caught increased. This fact alone may explain why the mean discard rate observed during the two cruises was much higher than the figure reported for the entire 1990—91 season. Still, this finding suggests that discard rates can be significant in some instances, and particularly during periods when the contribution of small albacore is relatively high. The fraction of all drop-offs and discards which die eventually due to hook injuries could not be determined with the available data.

Based on the 1988—91 fishing records, Labelle and Murray (1992) estimated the average potential CPUE for the troll fleet after accounting for all drop-offs and discards. This estimate was 32 per cent higher than the actual overall CPUE for the troll fleet (51.1 albacore against 38.6 per 100 line·hours). The ratio of actual to potential CPUE (75.5%) can be considered as some relative measure of fishing efficiency. Potential CPUE might serve as a better indicator of albacore abundance, but reliable estimates could not be obtained since the vast majority of the daily fishing records available do not include details on loss and discard rates.

3.6 Albacore size composition and growth patterns

Prior to the 1988—89 season, less than 2,000 albacore measurements were obtained from troll catches in the South Pacific. Observer and tagging programmes conducted since then have led to a substantial increase in the number of measurements available for each month during the season. The number of measurements obtained subsequently ranged from 12,962 in 1988—89, to 57,330 in 1989—90, with 19,446 measurements obtained during the latest season (1991—92). Most measurements were collected in the STCZ, where the largest catches were obtained.

Length-frequency histograms usually show three distinct modes for each region/season stratum (Fig. 6), which are suspected to result from discrete spawning events. Based on an examination of the 1989—91 trends, Labelle and Murray (1992) hypothesized that the largely unimodal distribution observed in the STCZ during 1990—91 represented an anomaly, which might have been caused by the relatively large selection against the youngest age classes during the period of intense gillnet fishing activity (mainly 1988—89). The addition of new data sets (1985—88 and 1991—92) revealed largely unimodal patterns in 1987—88 and 1985—86, indicating that such distributions could occur in the population when gillnet fishing activity was reduced or absent.

Year-to-year variation in the position of the modes is also apparent within each region, which could result from annual variation in growth rate, time of spawning or sampling period. In the STCZ, the modes tended to be ~60, 69 and 77 cm, and most of the albacore measured were within the 60—80 cm size interval. Similarly, the modes in the AUNZ were around 50, 60, 69 and 77 cm, but the majority of the albacore measured were in the 50—70 cm interval. For most seasons, albacore caught in the STCZ were greater in average size than those caught in the AUNZ, with the difference ranging from 1.4 cm during 1989—90 to 9.7 cm in 1988—89. Differences in average size could result if troll fishing was conducted earlier in one region than the next. To determine if such results were caused by differences in the fishing periods, only the lengths of albacore caught during the months of February and March of the last six seasons were used for comparisons. The mean length of albacore caught in the STCZ exceeded that of albacore caught in the AUNZ during corresponding months in 9 comparisons out of 11. The magnitude of the differences ranged from 0 to 9.6 cm, and averaged 4.7 cm over the 11 possible comparisons where sufficient samples were available. Such results suggest that the size differences are not the result of differences in the sampling regimes.

The absence of the first mode in the STCZ cannot be accounted for by fishing practices since similar methods are used in both regions, and there is no greater tendency of discarding smaller albacore in either region. It is plausible that there exist differences in the size composition of the populations in these regions, which would imply the existence of different recruitment patterns to the two fisheries.

For the STCZ, sufficient samples were collected each month during the last four seasons to examine growth trends within the fishing period. Length-frequency histograms revealed clear trends in modal progression across successive months (Fig. 7). A cursory examination of the progression of the 60 cm modes during 1989, 1990 and 1992 shows that they moved 2—3 cm during a three-month period, which translates into growth rates of ~0.7—1.0 cm per month. If sustained throughout the year, this would translate into annual growth increments of ~8—12 cm, which corresponds roughly to the difference between successive modes centred on this size class as seen in Figures 6 and 7. Such growth estimates are also comparable to those obtained by analysis of tag release-recapture records, and extensive analysis of modal progressions by means of the MULTIFAN model (Hampton et al. 1990; Labelle 1991). Considerably higher growth rates are apparent for the larger modes during the March to April periods of 1989, 1991 and 1992, perhaps due to the immigration of individuals from elsewhere, and/or as a result of the fleet moving into new areas at the end of the season on the way home.

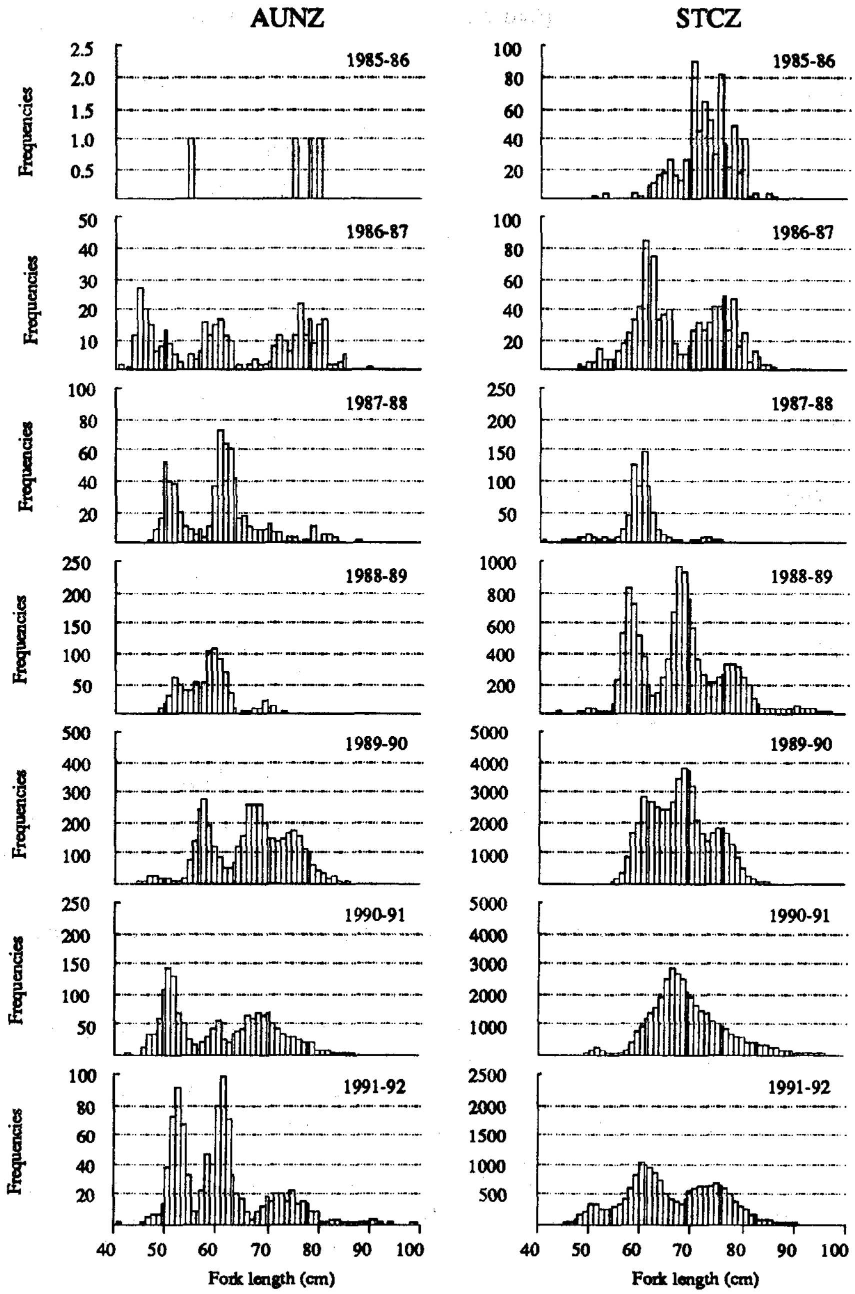

Figure 6. Frequency distributions of albacore sizes by region/season stratum, 1985-92

3.7 Gillnet mark incidence and effects on albacore condition

Since 1988, over 88 per cent of all albacore handled by observers and taggers in the STCZ have been examined for injuries. Negligible numbers were sampled in the AUNZ during 1988—89, but >50 per cent of the catch were examined during subsequent seasons. The lack of sufficient samples for certain time/area strata precludes the comparison of gillnet injury incidences across all seasons and regions, but the available data are still indicative of general trends over time.

In the STCZ, albacore bearing net marks were observed each year since 1988. During 1988—89 ~11 per cent of all albacore inspected had net marks, but this fraction decreased to ~1 per cent in 1991—92. The incidence of new marks (Codes 1—3) was greatest in 1988—89, but decreased to negligible levels (<1%) in 1991—92.

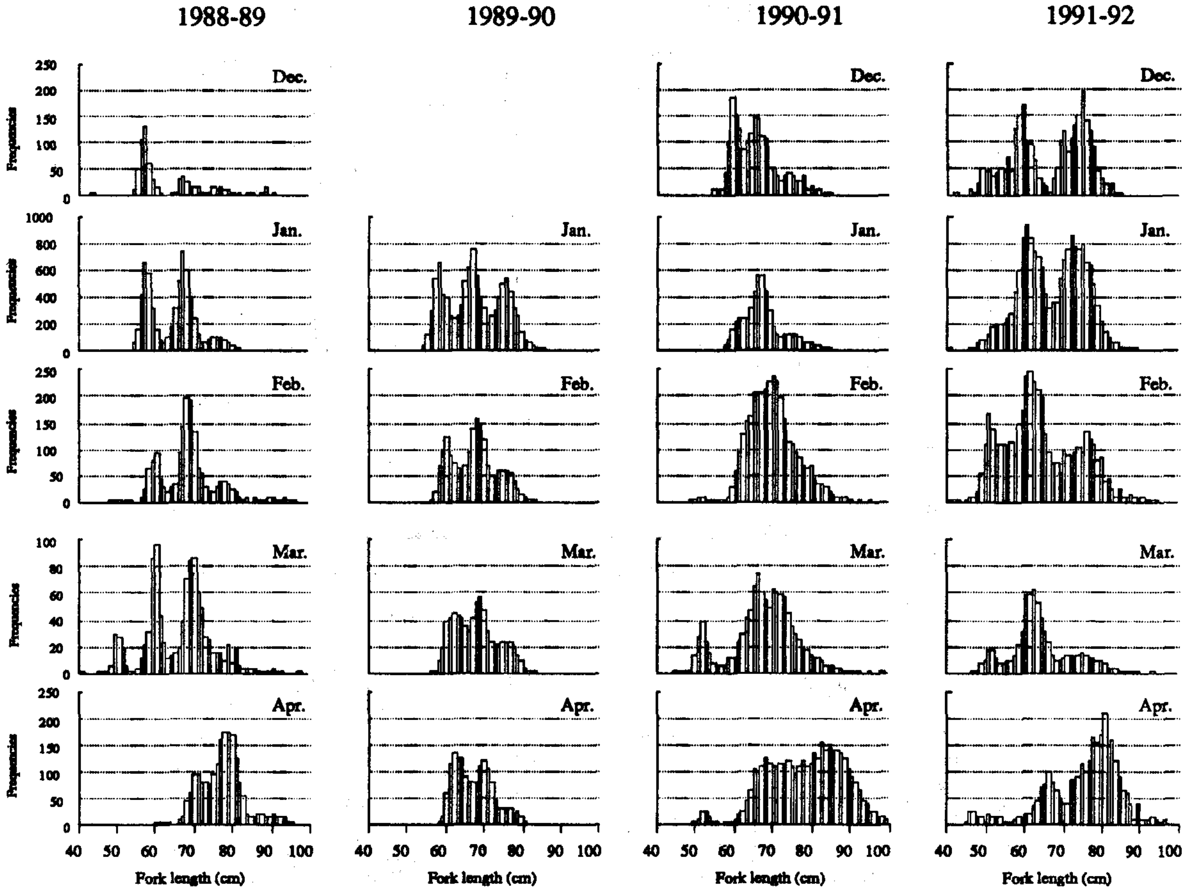

Figure 7. Frequency distributions of albacore sizes in the STCZ by month, 1988—92

This was accompanied by an increase in the proportion of unmarked albacore in samples each year (Fig. 8). These observations suggest that gillnet fishing decreased rapidly since the peak period of 1988—89, and had ceased before the 1991—92 troll fishing season. The incidence of old marks (Code 4), assumed to be ~1 year old, was negligible in 1988—89, and peaked during 1989—90 in the STCZ (~8%) as would be expected if old marks were inflicted during the previous season. The contribution of albacore with old marks subsequently decreased to negligible levels during 1991—92. Similar trends were observed in the AUNZ, although relatively fewer marked albacore were observed in samples. During 1989—90 and 1990—91, less than 4 per cent of the albacore sampled in the AUNZ had net marks, and no marked albacore were observed during 1991—92.

Albacore within certain size ranges were particularly susceptible to particular types of gillnet injuries (Fig. 9). The size distribution of uninjured albacore was nearly identical to that of the total catch each season. On average, albacore with light skin discolouration (Code 1) were smaller than those without injuries during the first 3 seasons. Based on the appearance of their injury, it is assumed that albacore in this category were smaller than average and could pass through the meshes of the nets. Albacore in the Code 1 category exceeded those in the Code 0 category in average size during 1991—92, but this is most likely due to a combination of classification error and insufficient sample sizes.

Albacore with light skin abrasions terminating before the point of maximum girth (Code 2) were larger than those in the Code 0 and Code 1 categories. This was expected since the type of injury exhibited by the Code 2 group indicates that they could not pass through the net, so members of this group would most likely be larger than average. The average size of albacore with serious skin abrasions (Code 3) was between that of albacore in the Code 0 and Code 2 categories.

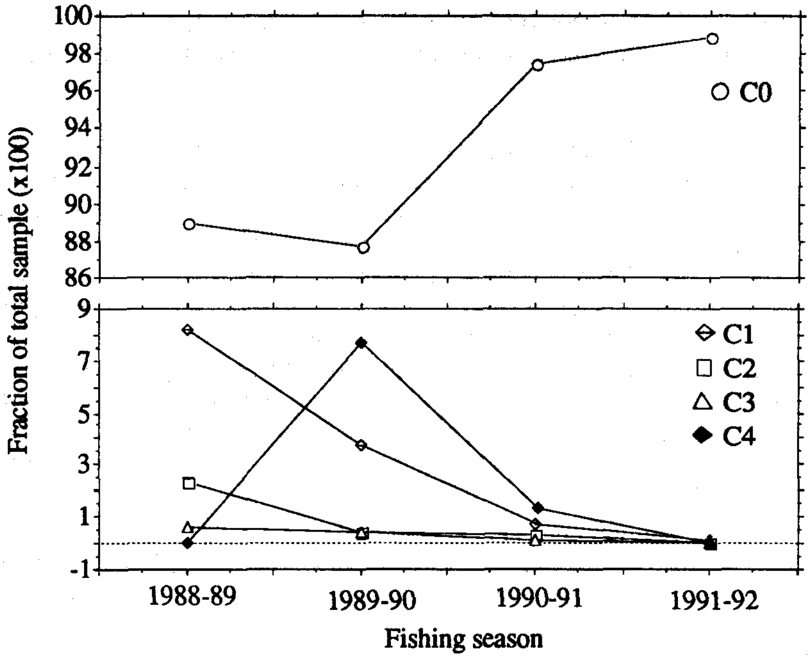

Figure 8. Relative contribution of albacore with gillnet injuries in the STCZ 1988—92, expressed as fractions of the albacore sampled each season. The gillnet injury abbreviations are none (C0), slight to severe (C1—C3), and old (C4).

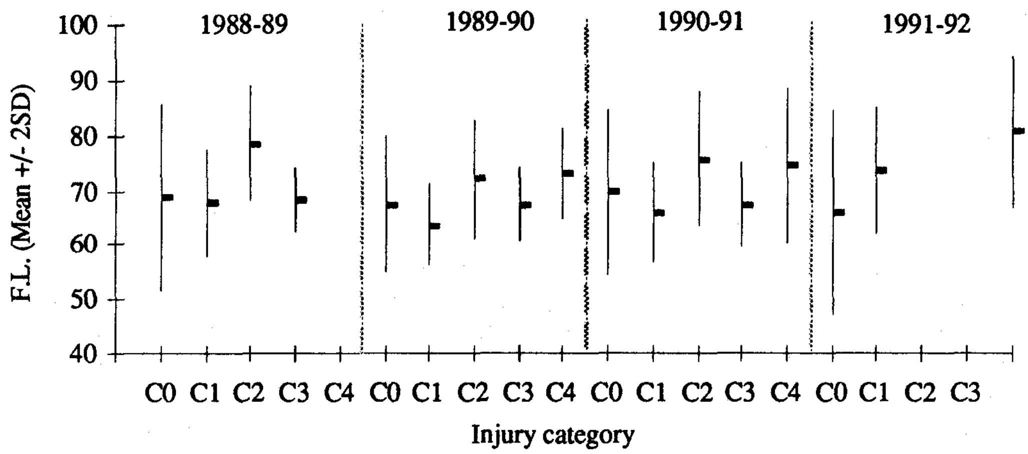

Figure 9. Size distribution (in cm) of albacore in each injury category, 1988—92. Vertical lines indicate the mean fork lengths (mid-bar), ±2 standard deviations. The injury abreviations are none (C0), slight to severe (C1—C3), and old (C4).

This indicates that the nets exert the strongest selective pressures on albacore that are close to the average size of troll-caught albacore. Accordingly, Sharples et al. (1991) reported that the mean size of albacore caught by gillnets was ~70 cm, which is almost identical to the average size of albacore in the Code 3 category. The average size of albacore with old gillnet marks (Code 4) was greater than those of albacore in all other categories. This would be expected if this group of albacore had grown for one year or more since their previous encounters with gillnets. Albacore in this category accounted for 90 per cent of all marked albacore observed during 1991—92.

Hampton et al. (1991) estimated survival rates from the proportion of old marks in one year to new ones in the previous year. Survival rates for the last three consecutive seasons were estimated to be 0.70, 0.32 and 0.86.

Hampton et al. (1989) noted that unmarked albacore were in significantly better condition (greater weight-to-length ratio) than marked ones within the STCZ, and that condition improved from January to May and from New Zealand to the STCZ. The authors attributed the better condition of the STCZ albacore to the greater productivity of the convergence zone, induced by the upwelling and shear zones between the subtropical and sub-antarctic water masses (Laurs et al. 1986). Based on measurements from the 1989—90 STCZ catches, Hampton et al. (1991) estimated the weight-to-length relation for unmarked albacore was $W = 0.00003251\ L^{2.893}$. The reverse relation (length-to-weight) is often used to estimate the length at recovery of tagged fish when only the weight is recorded. Using a subset of these data (Jan.—Mar. 1989, 1990), Labelle and Murray (1992) estimated the respective length-weight relations to be: $L = 36.3020\ W^{0.33988}$ and $L = 35.5386\ W^{0.33841}$. Labelle and Murray (1992) noted that unmarked albacore in the STCZ were in slightly better condition during 1989—90 than during 1988—89. Samples of weight and girth measurements collected since 1991 were not sufficient to formulate more accurate relations, or conduct further comparisons of condition factors across all seasons.

3.8 Incidence of injuries due to sharks and troll gear

On troll vessels two types of shark damage were observed: small, concave bites made by the mesopelagic cookie cutter shark (*Isistius brasiliensis*), and large rips and bites made by large pelagic sharks such as the blue shark (*Prionace glauca*). Albacore with cookie cutter bites were usually retained by fishermen, but those attacked by larger sharks were discarded. During the 1989—92 period, the proportion of albacore sampled with shark injuries was negligible in all region/season strata, and never exceeded <0.2 per cent in any season. Less than 0.1 per cent of the albacore examined had healed mouth injuries which seemed to have been caused by previous encounters with troll gear.

3.9 By-catch species composition and abundance

Information on the by-catch species composition was usually not recorded on fishing logs, so the figures reported were based on the 1990—91 and 1991—92 observer records. This sample consisted of observations on 20 vessels with a combined catch of 97,178 albacore. The most common by-catch species in the STCZ was skipjack tuna (*Katsuwonus pelamis*), which accounted for ~0.8 per cent of the total catch (albacore + other species). This estimate is greater than that reported by Labelle and Murray (1992) based on a smaller set of catch statistics (0.01—0.05%). Other fish occasionally caught were mahi mahi (*Coryphaena hippurus*), kingfish (*Seriola grandis*), blue shark (*Prionace glauca*), thresher shark (*Alopias* sp.) barracouta (*Thyrsites atun*) and kahawai (*Arripis trutta*). Billfish were occasionally hooked but rarely landed since they usually break the lines. The combined catch of all other species (excluding skipjack) accounts for ~0.1 per cent of the total catch.

Seabirds occasionally hit lures in surface waters, and in the rare instances that these were caught, they were released while in good condition by observers or crew members. None of the observers ever reported seeing a marine mammal being hooked or injured by troll gear. Observers noted that the amount of by-catch obtained was largely a function of the fishing location, with considerably more by-catch obtained while fishing in coastal regions. Trolling speed was also reported to affect the amount of by-catch, with some vessels obtaining a higher fraction while on the way to fishing grounds.

3.10 Gillnet vessel sightings

The number of drift gillnet vessels targetting albacore in the South Pacific was based on a combination of observer sightings, New Zealand Air Force surveillance flights, reports from merchant ship officers, and information supplied by various fishing nations (SPC 1991, Labelle and Murray 1992). From these sources, it was established that 64 Taiwanese, 67 Japanese and one South Korean vessel targeted albacore during 1988—89. About 11 Taiwanese and 20 Japanese vessels were accounted for during 1989—90. No reports of gillnet sightings in the Tasman Sea were received by Australian fisheries officials during the 1990—91 season (Ward and Chapman, 1991), but nine Taiwanese vessels operated in the STCZ (Labelle and Murray 1992). The composite map of gillnet vessel sightings presented by Hampton et al. (1991) indicated that the spatial distribution of Taiwanese and Japanese gillnet vessels overlapped and that the principal areas of activity were bounded by 34—40°S and 152—163°E (Tasman Sea), and 37—40°S and 143—164°W (STCZ). The first area covers the entire area of gillnet fishing activity, but the latter does not represent the total gillnet fishing area east of New Zealand because most reports were compiled from observers on board vessels fishing a relatively narrow latitudinal band.

During the 1991—92 season, no gillnet vessels were sighted by observers and taggers in the STCZ and AUNZ. However, a few albacore sampled in the STCZ exhibited fresh net marks. These marks could have been misidentified old marks, or caused by pieces of nets still floating around, or by gillnet vessels fishing just before the arrival of observers (Dec. 1991). Thus, gillnet fishing appeared to have ended in compliance with the United Nations resolutions 44/225 and 45/197, which called for a cessation of all gillnet fishing in the South Pacific by 1992.

4. SUMMARY

The major findings of this survey are as follows:

(a) Information on the South Pacific albacore troll fishery has been accumulated since 1985 through a combination of exploratory fishing, high seas tagging and observer programmes. Over 4,000 daily fishing records have been used to describe trends in this fishery.

(b) During 1991—92, the STCZ troll fleet consisted of ~71 vessels, which were mostly of US origin. Total catches in this region during 1991—92 were about 4,000 mt, which is ~25 per cent less than during the peak season of 1988—89. The AUNZ troll fleet is comparatively larger, but less homogeneous, and fishing activity tends to be more sporadic. Total catches in the AUNZ were generally smaller than in the STCZ, and were 1,100 mt in 1991—92. Median daily catches per vessel in the STCZ and AUNZ during the 1991—92 season were 125 and 39 respectively, and highest catch rates were $1{,}544 \cdot d^{-1}$ and $812 \cdot d^{-1}$ respectively. Average CPUE during the 1991—92 season was 51.2 and 18.9 per 100 line·hours for both regions respectively. Catch rates in the STCZ were consistently higher than in the AUNZ. The 1991—92 STCZ catch rates were the lowest on record, and were ~60 per cent lower than during the peak season of 1986—87.

(c) The number of albacore measured since 1988 ranges from ~12,000 to 54,000 per season. The size compositions of the AUNZ and STCZ populations differed slightly, with smaller albacore contributing more to the AUNZ population. The number of modes clearly visible in the length-frequency histograms ranged from one to three. The modal progression patterns suggest that 60 cm albacore grew at a rate of ~0.7—1.0 cm per month.

(d) On average, ~24 per cent of the albacore hooked were lost prior to being hauled aboard. However, loss rates varied considerably within the fleet. Sea condition, vessel speed, gear type and crew experience affected the loss rates. Albacore discarded were badly injured or relatively small (<57 cm). Discard rates varied considerably among vessels and tended to decrease as the season progressed. The maximum daily discard rate measured was 47 per cent, but the overall mean was 7 per cent.

(e) Over 88 per cent of the albacore examined since 1988 were inspected for gillnet marks. Albacore exhibiting fresh net marks accounted for ~11 per cent of the albacore examined during 1988—89, but this fraction decreased progressively to negligible levels in 1991—92. Less than 0.3 per cent of the albacore examined exhibited injuries due to shark bites or previous encounters with troll gear.

(f) Driftnet fishing activity targeted at South Pacific albacore increased during the 1980s, peaked during 1988—89, and then decreased progressively. No gillnet vessels were sighted by observers and taggers working on board troll fishing vessels in the STCZ and AUNZ during the 1991—92 albacore fishing season.

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