SOUTH PACIFIC COMMISSION

SOUTH PACIFIC ALBACORE OBSERVER PROGRAMME
SUMMARY REPORT, 1988—1991

Marc Labelle[1] and Talbot Murray[2]

1. Tuna and Billfish Assessment Programme
South Pacific Commission
B.P. D5
Noumea Cedex
New Caledonia

2. Fisheries Research Centre
Ministry of Agriculture and Fisheries
P.O. Box 297
Wellington
New Zealand

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ABSTRACT

Since 1986, observers have been placed on board commercial fishing vessels to monitor the activities of the troll fleet targeting South Pacific albacore. During the 1990—91 season, approximately 381 observer days were invested in monitoring activities, and 39,175 fish were sampled. Average catch rates per vessel in the Tasman Sea, New Zealand waters, and the Subtropical Convergence Zone (STCZ) during the 1990—91 season were 23, 28 and 151 fish per vessel per day respectively. Catch per unit of effort was similar to that of the 1989—90 season, but was substantially lower than in the 1988—89 season. Fish caught in the STCZ tended to be larger than those caught in the other two regions. The size composition of STCZ catches during the 1990—91 season was unlike that observed during previous seasons. Albacore exhibiting driftnet marks accounted for less than two per cent of the fish examined, fewer than in the 1989—90 season. This trend reflects the general reduction in driftnet fishing activity since the 1988—89 season.

RÉSUMÉ

Depuis 1986, des observateurs ont été placés à bord des ligneurs pour superviser la pêche des germons du Pacifique Sud. Pendant la saison 1990-91, les observateurs ont passé approximativement 381 jours sur les bateaux, et 39175 germons ont été échantillonnés. Les taux de prises journalières moyennes par bateau dans la mer de Tasman, les eaux côtières de la Nouvelle-Zélande, et la zone de convergence du Pacifique sud (STCZ) pendant la saison 1990-91 étaient de 23, 28 et 151 germons par bateau/jour respectivement. Les prises par unité d'effort ont été similaires à celles de l'année antérieure, mais supérieures à celles de la saison 1988-89. Les germons capturés dans la STCZ avaient tendance à être plus gros que ceux des deux autres régions. La distribution de tailles des germons de la STCZ durant la saison 1990-91 n'est pas comparable à celle des autres saisons. Moins de deux pour cent des germons examinés durant la saison 1990-91 portaient des marques de filets maillants, ce qui représente une réduction par rapport aux années antérieures. Ceci correspond à une réduction générale des activités de la flottille de pêche au filet maillant depuis la saison 1988-89.

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1.1 South Pacific albacore fisheries

Albacore (*Thunnus alalunga*) have been exploited in the South Pacific by Japanese longliners since 1952, and by those of Korea and Taiwan since 1958 and 1963 respectively (Wang, 1988). Catches have fluctuated between 25,000 t and 40,000 t since 1960. Production model estimates of maximum sustainable yield for the longline fishery were about 35,000 t, assuming that about 2,000 t are taken by a surface fishery each year (Wetherall and Yong, 1987; Wang et al., 1988).

A troll fishery for albacore has also operated since 1974 in New Zealand coastal waters, with annual catches ranging from 1,000 to 3,000 t. Exploratory troll fishing in 1985—1986 and 1986—1987 suggested that a viable surface fishery could take place in high seas areas along the Subtropical Convergence Zone (STCZ: 35—40°S, 170—130°W) east of New Zealand during the December—April period. Preliminary opinions were that this fishery could probably support an annual catch of 10,000—15,000 t without substantially reducing longline catches (SPC, 1986). The surface fishery has developed rapidly since then. During 1987—88, 44 troll vessels of American, Canadian and Fijian origin caught about 3,600 t of albacore in the STCZ. During the 1988—89 season, 54 troll vessels from the United States, Canada, New Zealand and French Polynesia caught about 3,700 t of albacore in the STCZ, while nearly 5,000 t was caught by some 200 trollers off the west coast of New Zealand. During the 1990—91 season, about 75 troll vessels from the United States, French Polynesia, Fiji and New Zealand participated in the STCZ fishery.

The Japanese driftnet fleet began fishing for albacore in the South Pacific in 1983—84, mainly in the Tasman Sea with a fleet of about 20 vessels. During 1988, Japanese driftnetters took about 4,800 t, while seven Taiwanese large-mesh pelagic driftnet vessels caught about 1,000 t. The number of driftnet vessels operating in the South Pacific during 1988—89 was estimated at 64 Taiwanese, 67 Japanese and one South Korean driftnet vessels. The Japanese fleet fished mainly in the Tasman Sea early in the season (Dec.—Feb.) and then moved to the STCZ. The Taiwanese and Korean vessels operated primarily in the STCZ. Based on limited catch rate information available, and the assumption that the fleet size is at the lower limit of the range reported, the driftnet catch for the 1988—89 season was estimated at ~25,000 t (SPC, 1991).

As early as 1988 South Pacific Island countries began to express concern regarding the potential for overfishing the South Pacific albacore stock. A consultation sponsored by the Forum Fisheries Agency (FFA), the South Pacific Commission (SPC) and the Food and Agriculture Organization of the United Nations (FAO) took place in Suva, Fiji, during November 1988. The consultation noted the limited information available on conditions in the surface fishery and on the level of interaction among troll, driftnet and longline fisheries. As a consequence, it strongly endorsed a proposal for data collection during the 1988—89 season, consisting of detailed fishery monitoring, aerial surveillance and placement of observers on commercial troll vessels. The 1988—89 observer programme provided a large body of data on the STCZ troll and driftnet fishing activities (see Hampton et al., 1989), which served as the basis for the initial stock assessment studies conducted at the SPC.

The relatively high catches observed during 1988—89, particularly by the driftnet fleets, reinforced concerns about fishing levels throughout the region. Pacific Island states involved in commercial fishing and in the processing/transshipping of albacore catches sought to improve assessments of catch levels and of the status of the stock. To address concerns regarding recent levels of exploitation, the albacore observer programme was expanded in 1989—90 to cover the entire season and area of troll vessel operation. Observers were also placed on board a Japanese driftnet vessel for two research cruises. The results of these surveys were reported respectively by Hampton et al. (1991) and Sharples et al. (1991).

Driftnet fishing activity in the South Pacific decreased following the consensus adoption of resolutions 44/225 and 45/197 of the 44th and 45th United Nations General Assemblies. These resolutions aimed at a progressive reduction in driftnet fishing in the South Pacific and its cessation by July 1991. During the 1989—90 season, 20 Japanese and 11 Taiwanese driftnet vessels are known to have fished; only nine Taiwanese driftnet vessels fished in 1990—1991. If distant water fishing nations comply with the UN resolution, driftnet fishing should cease in the South Pacific after July 1991. The resolutions will remain in force until a scientifically based management regime is in place.

1.2 Observer programme

The albacore observer programme was initiated following recommendations by the 1988 consultation and has continued during subsequent summer troll fishery seasons. The programme has been co-ordinated by SPC and the New Zealand Ministry of Agriculture and Fisheries (MAF) each year. During 1990—91, the observer programme was expanded with the help of the Fisheries Division of the Fijian Ministry of Primary Industries (MPI). Observers were trained personnel recruited from the MAF Fisheries Scientific Observer Programme and staff from the Fiji Fisheries Division. Briefing and debriefing were conducted by scientific staff of MAF Fisheries Pelagic Research Group (on return to New Zealand) or by staff of the Fiji Fisheries Division (on return to Fiji). Programme objectives and sampling protocols were developed jointly by scientists from the SPC Tuna and Billfish Assessment Programme, the MAF Fisheries Pelagic Research Group, and the US National Marine Fisheries Service (NMFS) in Hawaii.

This report summarises the results of the South Pacific albacore observer programme conducted during the 1990—91 season. In order to highlight developing trends in catch rate and catch composition, comparisons are made with the results of past observer programmes. Since the statistics collected by observers were also collected during the SPC—MAF albacore tagging cruises, data from both sources were combined, whenever possible, to provide greater sample sizes for examining trends and allow for a broader coverage of the performance and catch composition of the troll fishery. In the present report, the term 'observer' will therefore refer both to the actual observers and to the technicians working on board troll vessels used during the tagging cruises, when the same data were collected.

2. OBJECTIVES OF THE OBSERVER PROGRAMME

The objectives of this programme were to collect biological data relevant to stock assessment of South Pacific albacore, and to document the fishing activities of troll and driftnet vessels in the Tasman Sea, along the east coast of New Zealand (ECNZ), and in the STCZ. The principal observer activities were to:

(a) Record the daily catch of albacore and by-catch on board troll vessels;
(b) Record length of the albacore caught and examine their physical condition for injuries;
(c) Record the species, frequency and lengths of other fish discarded;
(d) Record the number of fish that became unhooked before being brought on board (drop-off);
(e) Record oceanographic conditions and other physical factors which might affect catch rates;
(f) Record fishing methods, fishing conditions and characteristics of albacore behaviour;
(g) Record sightings of driftnet vessels, noting vessel characteristics and operations if possible.

3. OPERATIONAL SUMMARY

Observations were conducted on board albacore troll vessels from New Zealand (1988—91), the United States (1989—91), and Fiji (1990—91) at the invitation of vessel masters, owners or managers. Observers embarked on ships as they left major ports at the start of the season. Once the fishing grounds were reached, the observers usually monitored fishing activities for a two-week period, then boarded another vessel for the subsequent two-week-period. The location of the vessels monitored during the fishing and tagging periods are presented in Figure 1. The vessels monitored each season, the total duration of the survey period and the area covered by the vessels during the survey periods have increased each year since 1988 (Table 1).

During 1988—89, one tagger collected information during the Vessel 4 tagging cruise, and one observer was at sea for 73 days over two distinct time-periods. During the later periods, separate areas within the STCZ were covered, namely to the east (late season) and west (early season) of longitude 150°W. During the 1989—90 season, the Vessel 4 tagging cruise and observer surveys allowed for a continuous coverage of the entire season (Nov.—Apr.) and the three distinct troll fishing areas: the Tasman Sea, the ECNZ and the STCZ. During the 1990—91 season, extensive tagging cruises combined with the observer surveys allowed for an even better coverage of the same region over a longer period of time (Dec.—May). It should be noted that, each season, efforts were made to place observers on board troll vessels which conducted some exploratory fishing in new areas and/or during unusual time-periods. This was done mainly to gain additional knowledge on the distribution and relative abundance of albacore within the areas covered.

Table 1. Summary of observer coverage on troll vessels in the South Pacific albacore fishery[1]

Fishing season	Vessel (coded)	Survey period	Survey time	Area covered Latitude	Longitude	Albacore caught	Albacore sampled
1988—89	Vessel 1	Mar.— Apr.	25	37.9—39.2 S	145.9 W — 136.1 W	2676	2514
	Vessel 2	Dec.— Feb.	45	36.1—40.9 S	176.5 E — 154.0 W	9426	7452
	Vessel 3	Jan.	3	37.3—38.0 S	158.5 W — 155.1 W	n/a	448
	Vessel 4	Jan.—Jun.	26	37.3—44.8 S	167.2 E — 179.4 E	1385	914
1989—90	Vessel 5	Mar.	10	38.4—39.4 S	149.5 W — 148.0 W	5176	2873
	Vessel 2	Nov.—Dec.	37	34.3—41.5 S	157.6 E — 176.4 E	4499	2195
	Vessel 2	Jan.—Mar.	74	38.0—41.1 S	176.7 E — 147.8 W	25604	25309
	Vessel 6	Mar.	3	39.2—39.5 S	149.5 W — 149.3 W	1703	436
	Vessel 7	Nov.— Dec.	25	32.6—41.5 S	179.1 E — 167.0 E	2443	718
	Vessel 7	Mar.— Apr.	22	35.8—40.3 S	149.0 W — 143.7 W	4907	4831
	Vessel 8	Mar.— Apr.	27	36.0—40.4 S	149.8 W — 144.2 W	6642	6092
	Vessel 9	Jan.— Mar.	52	38.5—41.1 S	174.6 W — 147.2 W	17606	13266
	Vessel 4	Jan.— Feb.	20	37.3—42.3 S	169.3 E — 174.1 E	1090	815
1990—91	Vessel 10	Jan.— Feb.	29	39.1—41.2 S	163.3 W — 153.5 W	7160	5944
	Vessel 11	Feb.— Mar.	34	39.2—43.1 S	153.6 W — 142.5 W	8064	5874
	Vessel 2	Dec.— Jan.	25	37.3—38.5 S	171.6 W — 159.0 W	5695	4771
	Vessel 2	Mar.	12	34.9—40.6 S	154.3 W — 142.4 W	1123	1012
	Vessel 12	Feb.— Mar.	26	40.1—42.7 S	154.0 W — 139.8 W	5549	3933
	Vessel 13	Dec.— Jan.	19	37.5—41.7 S	173.5 E — 158.6 W	3238	3121
	Vessel 3	Jan.— Feb.	29	38.2—40.7 S	163.9 W — 153.5 W	6346	5581
	Vessel 16	Dec.— Mar.	119	34.1—41.2 S	173.0 E — 153.0 W	4356	3959
	Vessel 4	Jan.— Mar.	22	36.3—43.3 S	155.2 E — 174.1 E	804	625
	Vessel 14	Apr.— May	28	36.6—42.6 S	151.0 W — 147.1 W	3492	3275
	Vessel 15	Mar.— May	39	34.8—42.3 S	160.5 W — 149.7 W	885	705

1.The survey time consists of the number of days fishing activities were monitored (excluding travelling days). Number of albacore sampled refers to those which were measured for length. Vessel names are coded for purposes of confidentiality.

3.1 Troll vessel characteristics and fishing strategies

Several vessel types have been converted for the high seas troll fishery. They include tuna longliners, squid jigboats, swordfish gillnetters, shrimp trawlers, bottom and side trawlers, US pole-and-line boats, salmon and/or albacore trollers, and others. A general technical description of US albacore troll vessels and fishing gear is given by Dotson (1980). Troll vessels on which observers have worked (Table 2) vary considerably in size, number and placement of outriggers, number of lines fished and fishing strategies. While most troll vessels share some features, differences due to vessel deck plans and crew composition lead to variation in the number and types of fishing lines operated. The electronic equipment also varies among vessels, further contributing to the range of fishing strategies used to locate and remain with concentrations of albacore. Given that the South Pacific high seas albacore fishery is relatively recent, experience levels of captains and crews differ substantially. Experience in the NZ coastal or the North Pacific albacore fisheries makes up for the lack of high seas experience, and as the fishery gets older, the spectrum of fishing strategies is becoming more uniform.

Pertinent vessel characteristics and fishing strategies employed by skippers of the vessels monitored during this programme are summarised in the Appendix. The surveys indicate that many skippers share similar techniques. A major source of auxiliary information used to locate fishing areas is the sea-surface temperature maps produced from satellite imagery, which are received by weather fax from land stations or from APT receivers on the grounds. Depth sounders, sonar, hull-mounted temperature recorders, and radio reports from other vessels are commonly used to locate tuna aggregations.

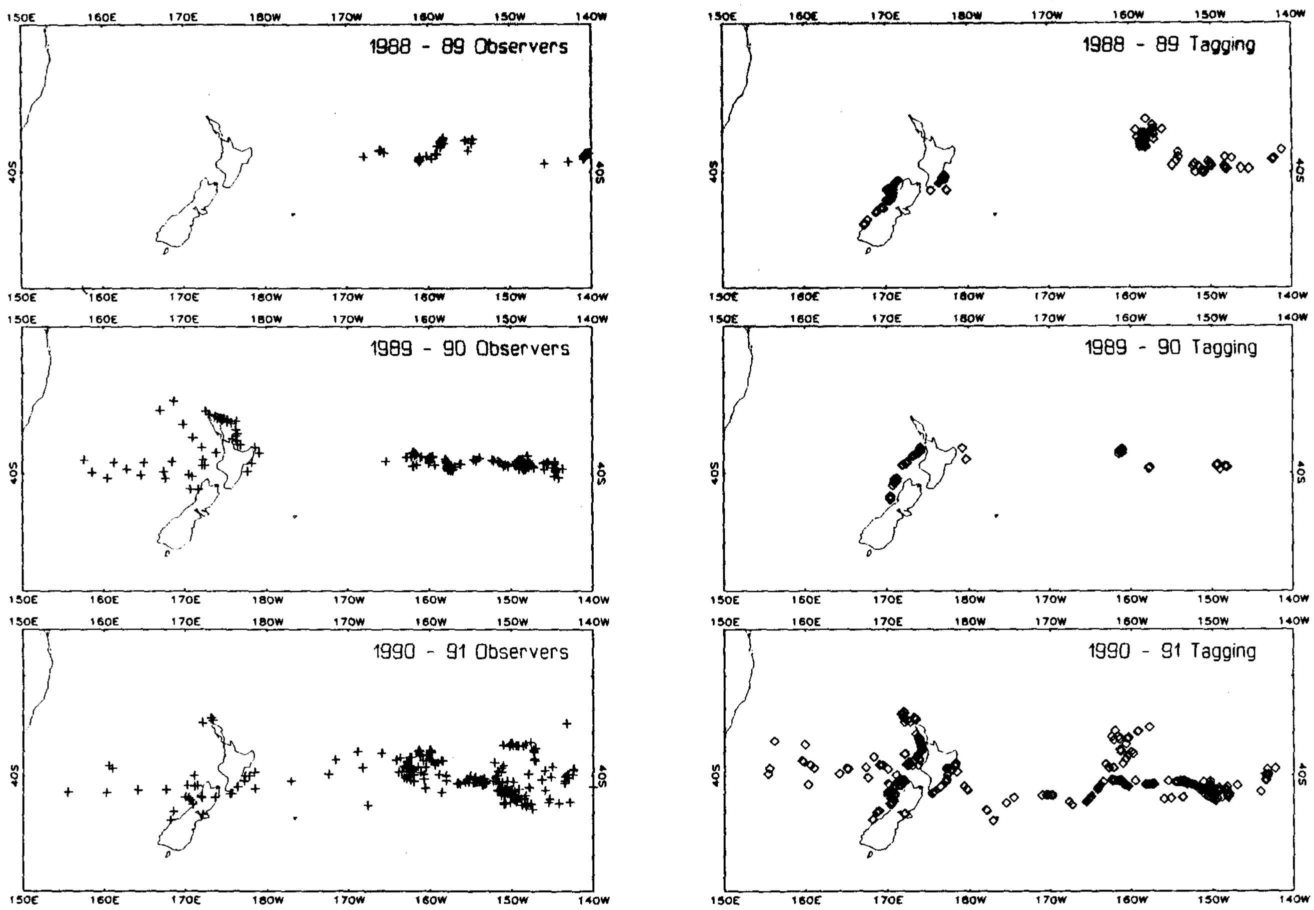

Figure 1. Location of fishing vessels during observer surveys and tagging activities, 1988—91

Incidental catches from lines deployed while in transit, sightings of feeding birds, surface turbulence, floating objects and strong temperature gradients (> 0.1°C) are also considered as potential indicators of tuna aggregations. When fish are detected or caught, the vessel usually begins fishing in a circle around or across the area. Sonars are generally used to remain with the subsurface schools during the fishing period. If a subsurface school of fish is detected, but does not respond to lures, vessels equipped with GPS integrated course plotters often record the position and return later for further fishing.

3.2 Sampling procedures by observers

Observers generally attempted to measure the length of as many albacore as possible from each day's catch. During periods of high catches or rough weather, efforts were made to collect lengths, girths and weights of at least 25 randomly chosen fish during four or five periods throughout the day. Efforts were also made to examine all fish measured for physical injuries and driftnet marks (see Section 3.3). During tagging cruises, efforts were made to sample all tagged fish released, and a variable portion of the untagged fish was 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 previous whole centimetre. Girth measurements were made by passing a plastic measuring tape around the fish, perpendicular to the long axis, at a point just posterior to the insertion point of the pelvic fins. If pectoral fins were still present, the tape was passed over one pectoral fin folded flush against the body and under the other. This was the easiest method under such conditions, and gave identical results to the previously described method. Girth measurements were rounded down to the previous 0.5 cm. No girth measurements were collected on board vessels during 1990—91, as the available data sets were considered to be sufficient.

Table 2. Characteristics of troll vessels monitored during the observer programme

Vessel name (coded)	Registered nation	Length (m)	Breadth (m)	GRT (t)	Hold (t)	Freezer system	Crew (n)	Lines[1] (n)
Vessel 10	US	19.0	5.0	n/a	36	Brine	2	15
Vessel 5	NZ	28.0		144	70	Blast	8	14
Vessel 1	US	23.7	7.4	n/a	84	Brine	4	15
Vessel 11	US	20.0	6.0	n/a	64	Brine	5	18
Vessel 2	NZ	53.6	8.5	345	300	Blast	10	24—36[2]
Vessel 6	US	22.2		n/a	45	Brine	3	15
Vessel 12	US	17.3	4.5	62	32	Brine	2	9
Vessel 7	NZ	32.7	6.4	143	n/a	Blast	8	23
Vessel 8	NZ	51.0		298	150	Blast	10	27
Vessel 13	NZ	34.0	6.0	80	78	Blast	7	20
Vessel 9	NZ	52.8	8.5	345	n/a	Blast	16	31
Vessel 3	NZ	34.0	5.8	79	64	Blast	8	19
Vessel 16	Fiji	26.2	5.1	99	9.5	Brine	15	13
Vessel 4	NZ	28.0	8.2	268	10	Ice	6	12—13
Vessel 14	NZ	31.5	6.6	162	100	Blast	5	20
Vessel 15	Fiji	24.6	5.8	n/a	55	Brine	5	14—18[3]

1. Maximum number of lines that was normally fished by the vessel during the last year it carried an observer.
2. During calm weather this vessel deployed one or two dories which each fished up to six lines each.
3. During the period the observer was on board only 14 lines were fished.

Some vessels carried motion-compensated electronic scales which were used to weigh fish. On vessels without such scales, albacore were weighed with a 15 kg hand-held beam balance, suspended from an overhang. Weight was recorded to the nearest 0.1 kg. On some vessels weights were not recorded, since neither scales nor balances were available. Very few weight measurements were collected during the 1990—91 season, because of practical difficulties in supplying adequate scales to all observers.

3.3 Classification of driftnet damage

Early in the 1988—89 South Pacific albacore observer programme, large numbers of troll-caught albacore were found to exhibit distinct patterns of skin and scale loss. Damage which appeared to be recent was frequently seen when troll and driftnet vessels were fishing in the same areas. These observations suggested that the damage was caused during escapement from a driftnet. This assumption was subsequently verified by dropping freshly caught unscarred albacore through a section of discarded or lost driftnet found at sea. In repeated trials unscarred albacore of various sizes received marks similar to those of freshly caught damaged fish. The classification procedure developed for the 1989—90 season, as described by Hampton et al. (1991), was slightly modified and used to account for the incidence of driftnet injuries in troll-caught albacore for the entire 1988—91 period. The following categories of driftnet damage were used for classification:

Damage Code 0: No loss of skin or scales on landing, fins entire. Fish with old marks are excluded from this category;

Damage Code 1: Continuous multiple stripes appearing as slight skin discolouration running laterally along the thickest part of the body about 5—10 mm apart. On close examination the discoloured striping results from skin loss;

Damage Code 2: Minor damage similar to the previous category, but the skin abrasion has brush-like patterns, which distinctively terminate at locations anterior to the point of maximum girth. This pattern suggests that the fish was not able to pass through the net. Large albacore previously assigned to code 4 during the 1988—89 season (see Hampton et al., 1989) are now included in this category;

Damage Code 3: The most serious category of net damage. Areas of exposed muscle are visible where the skin and scales have been scraped away. Exposed patches are typically 25—50 mm wide, 50—100 mm long, and are usually located within 30 mm of the dorsal or ventral mid-line in the area of maximum girth. Damage to the second dorsal, anal and caudal fins is common. The first dorsal and pectoral fins are also occasionally damaged;

Damage Code 4: Similar to first category except that the stripes are older, less distinct and are somewhat interrupted. These fish appear to have been damaged by a driftnet previously, and to have recovered after some time at liberty (possibly one year). This includes the unspecified 'Aged marks' category used by observers during the 1989—90 season.

In addition to the above, observers also checked the fish for the presence of small, round, concave holes induced by the mesopelagic shark (*Isistius brasiliensis*), large external cuts to the body caused by larger epipelagic sharks, and injuries to the mouth area typically caused by troll fishing gear.

3.4 Statistical treatment

The data set used for the present report included most sampling records obtained since 1988 from commercial troll fishing vessels and the troll vessels used for tagging cruises. Data records which were considered unreliable, incomplete or had not yet been entered into the database were not used for the analysis. In addition, due to the small discrepancies that exist between the data records of tagging cruises versus those of observer surveys, records collected on some vessels during certain time periods could not be used for conducting specific analyses. For analysis of catch composition, length data associated with the untagged fish caught during the NZ tagging cruises since 1986 were not incorporated since these were not available. For analysis of drop-off rates, observer data collected before 1990—91 could not be used since no accurate records were kept of the number of fish hooked that freed themselves before being brought on board. For the analysis of driftnet mark incidence, none of the records collected during the tagging cruises conducted by MAF were used, since the fish tagged and released on board commercial fishing vessels and Vessel 4 (used for tagging) were not usually inspected for such marks.

Only a subset of the records provided by observers was analysed for this report. The variables of interest were: Date (dd/mm/yy), vessel name, vessel nationality, latitude, longitude, sea-surface temperature (SST), daily fishing period (Last catch time — first catch time, in hours), number of lines, daily albacore catch, number of fish sampled each day, mean fork length (cm) of the fish sampled that day, and the incidence of driftnet-marked fish in the catch. Temperature correction factors were applied to certain records if the vessel's instruments had been recently calibrated. The estimates generated consisted of the mean SST, the average survey period (d) each month, the mean daily fishing period (h), the mean number of fishing lines used per day, the mean daily catch per vessel, the sample mean fork length (in cm), the mean catch per unit of effort (CPUE) expressed as the catch per 100 line-hours, and the average number of fish in each injury category, expressed as a fraction of the total catch.

For reporting of fishery statistics, the estimates were stratified by region, month and year. The three regions selected were respectively defined as; *(a)* the area bounded by 30°—47°S, east of 170°W (STCZ); *(b)* the areas of 30°—42°S by 173°E—170°W and, to the west, the south island of New Zealand up to 170°W (ECNZ); and *(c)* the area between New Zealand and Australia bounded by 30°—47°S and 173°E—149°E (Tasman Sea). The time-period used consisted of November—December (combined), January, February, March, April, and May—June (combined). Averages for each time/area stratum were calculated as follows;

Equation 1:

$$\text{Mean temp.} = \frac{\sum_{i=1}^{I}\sum_{j=1}^{J} T_{i,j}}{\sum_{i=1}^{I}\sum_{j=1}^{J} \text{records}_{i,j}}$$

Equation 2:

$$\text{Mean fork length} = \frac{\sum_{i=1}^{I}\sum_{j=1}^{J} \overline{L}_{i,j} \cdot n_{i,j}}{\sum_{i=1}^{I}\sum_{i=1}^{J} n_{i,j}}$$

Equation 3:

$$\text{Mean CPUE} = \frac{100 \cdot \sum_{i=1}^{I}\sum_{j=1}^{J}\text{catch}_{i,j}}{\sum_{i=1}^{I}\sum_{i=1}^{J}\text{lines}_{i,j} \cdot \text{hours}_{i,j}}$$

where:

$T_{i,j}$ = SST record from vessel i, day j, in a given stratum;
$L_{i,j}$ = Mean fork length of albacore sampled on vessel i, day j, in a given stratum;
$n_{i,j}$ = Number of fish sampled on vessel i, day j, in a given stratum;
$\text{catch}_{i,j}$ = Albacore catch on vessel i, day j, in a given stratum;
lines, hours = Number of lines and fishing period in hours on vessel i, day j, in a stratum;
I, J = Total number of vessels and days surveyed within a given stratum.

Estimates of the mean daily fishing period and of the mean number of lines used were calculated according to Eq. 1 after substituting the corresponding figures for SSTs. If data on catch, lines or hours were missing for a particular record, then that record was not used for estimating CPUE.

4. RESULTS AND OBSERVATIONS

4.1 Albacore catch, effort and CPUE

Comparisons of fishery statistics are hampered by the fact that sampling rates were not constant across all regions, years (seasons) and months. This is largely because troll boats are not distributed uniformly in space and time within the season, so systematic surveys could not be conducted concurrently in all regions at fixed time intervals. As a result, it might be premature at this stage to assess the influence of specific factors on catch rates by means of conventional statistical methods. Still, some recurrent trends are apparent each year, which make it possible to hypothesise on the nature of underlying relationships.

The duration of the monitoring period increased each year, and was about 99 observer days (d) in 1988—89, 270 d in 1989—90, and 382 d in 1990—91. The increase during the last season was mostly attributed to the fact that a large tagging cruise was being conducted by the SPC at the same time as the observer programme was under way. It should be emphasised that, by and large, observers and taggers tended to be interspersed among the bulk of the fleet. Assuming that the number of observer days spent in each region/month is somewhat indicative of the level of fishing activity in that stratum (Table 3), it appears that the main fishing season in the Tasman Sea is during the early part of the year (Nov.—Feb.).

The season appears to be even shorter in the ECNZ, where fishing activity was non-existent during February. Even if the 1990—91 season is omitted (deleting the effects of extensive tagging cruises), the level of activity in the STCZ was greater than at the two other locations and was distributed over a longer period of time. Whether or not this pattern reflects the actual distribution of fishing effort cannot be ascertained simply on the basis of the observer data, but will be known once the catch and effort records in the SPAR database are complete. Still, the CPUE averaged across all months when fishing occurred was consistently greater in the STCZ than in the other two regions for all years (Table 3). Overall CPUE, averaged across all months and years, was at least twice as high in the STCZ area, as in the Tasman and ECNZ ($\bar{x}$ CPUE ≈ 80, 31, 21 respectively). The higher catch rates in the STCZ definitely induce some fishermen to leave the other two regions in mid-season. After early April, fishing conditions deteriorate in the STCZ, and during May—June, CPUE drops to the lowest level of the season. As a result, fishermen tend to leave the STCZ gradually after April.

Although catch rates in the STCZ are generally better than in the two other areas during the later part of the season, a comparison across regions indicates that, during the early part of the season, CPUE in the Tasman can be comparable to that of the STCZ (Table 3). Average CPUE in the Tasman was highest during January 1989 (82.7), and was comparable to that of the STCZ in that month. ECNZ CPUE was highest during December 1989 (61.8), and exceeded that observed for the STCZ during December 1990. However, CPUE in the ECNZ and Tasman Sea was at its lowest level during the same month in later years, which reflects the strong variation in catch rates that characterises these regions. By contrast, CPUE in the STCZ, though generally higher, exhibited less month-to-month variation during the season, and generally peaked after January.

In the SCTZ, maximum year-to-year variation in CPUE occurred during April (range: ~ 40—118). An examination of the CPUE trends across years for the January—April period indicates that fishing conditions in the STCZ during 1990—91 were similar to those of the 1988—89 season ($\bar{x}$ CPUE = 79.4 and 74.8 respectively), but were not as good as those encountered during 1989—90 ($\bar{x}$ CPUE = 112.7). This observation agrees with comments made by troll fishermen. No clear trends are apparent for the other two regions, perhaps because of the low sampling rates used.

Daily fishing periods, averaged across all fishing seasons, were shortest in the ECNZ ($\bar{x}$=10.7 h), intermediate in the Tasman Sea ($\bar{x}$=12.7 h) and longest in the STCZ ($\bar{x}$=13.7 h). Given the definition of fishing periods used in the present report (number of hours between first and last catch each day), such results might be viewed as a reflection of fishing conditions in each region, which is why the trends in fishing periods roughly parallel the CPUE trends. However, it should also be noted that the vessels operating in the coastal area of the ECNZ tend to be smaller, have smaller crews, and may simply operate over a shorter time-period each day, irrespective of fishing conditions, than those which venture into high seas areas. To some extent this is reflected by trends in the number of fishing lines used, since there exists some relationship between vessel size and the number of lines it can handle. Estimates of the number of lines used each day, averaged across all months and years, were lowest for the ECNZ ($\bar{x}$=11.1), slightly greater for the Tasman Sea ($\bar{x}$=13.0) and highest for the STCZ area ($\bar{x}$=17.4). The possible relationship between the catch rates and the number of lines used on each boat could not be assessed for lack of sufficient samples. Similarly, the influence of fleet size on catch rates could not be assessed, as observers did not estimate the number of troll vessels operating in specific locations at given times.

4.2 Albacore length composition

Some 11,464 fish were measured in 1988—89, 56,535 in 1989—90 and 39,175 in 1990—91, which accounted for more than 80 per cent of the fish caught each year by the vessels while they were being monitored. Most of the measurements were collected in the STCZ, where the largest catches were obtained. Length-frequency histograms based on the measurements taken clearly indicate the presence of distinct modes for all region/season strata (Fig. 2), which are believed to result from discrete spawning events. Year-to-year variation in the positioning of the modes is also apparent within each region, which could result from annual variation in growth rate, time of spawning or sampling period.

An examination of all histograms suggests the presence of successive modes at approximately 50, 58, 67 and 78 cm. The first mode is occasionally quite predominant in the Tasman Sea and ECNZ histograms, but is usually negligible in those of the STCZ. Market conditions are partly responsible for the absence of this first mode, since fishermen in the STCZ often release albacore < 55 cm because of the relatively low price paid by some canneries for fish in this category. However, observers noted that albacore in this size category accounted for a very small portion of the catch in the STCZ during the 1988—89 season (Hampton et al., 1989). Similar conditions also prevailed during the 1989—90 season, and most fish in this size category (< 5% of the daily catch) tended to be released without being measured by observers (P. Sharples, pers. comm.).

During the 1990—91 season, efforts were made to measure all fish captured before any discarding took place. As a result, albacore in this size category are represented more clearly in the length frequency histograms, but still accounted for only a small portion of the total sample. Relatively small albacore are usually not rejected by fishermen operating in the Tasman Sea and the ECNZ. Since small albacore account for a considerably greater portion of the catch in these regions than in the STCZ, it could be hypothesised that there exist real differences in the age structure of the populations of these two general areas, which could be a result of the migration pattern of young recruits.

The length-frequency histograms based on the region-by-year strata are a composite of all samples taken over several months, and as a result, the definition of the modes is partially obscured by the concurrent growth. For the STCZ, sufficient sample sizes allow for higher levels of resolution to be used. For this region, length-frequency histograms generated for successive months (Fig. 3) reveal clear trends in modal progression between December and March. Trends in modal progression are less clear for the April—May period, perhaps because of the immigration of individuals from elsewhere, and/or as a result of the fleet moving into new areas on the way home. Examination of the modal progressions provides crude estimates of growth rates, which appear to be in the order of ~0.7 cm per month for 60 cm fish. If sustained throughout the year, such rates would translate into an annual growth increment of ~8.4 cm, which is similar to the size difference between two successive modes centred on this size group.

Table 3. Summary of troll fishery statistics for South Pacific albacore, 1988—91

Statistic	Region	Season	Nov.—Dec.	Jan.	Feb.	Mar.	Apr.	May—Jun.
Sea temperature (mean °C.)	Tasman	'89—90		20.4	19.6			
	Tasman	'89—90	17.0	18.0	20.2			
"	Tasman	'90—91	17.7	17.0	18.4	17.4		
"	ECNZ	'88—89	17.5				16.6	
"	ECNZ	'89—90	19.0	18.2				16.7
"	ECNZ	'90—91	18.3	17.4		17.2		
"	STCZ	'88—89	16.7	17.6	18.8	18.8	18.3	
"	STCZ	'89—90		18.9	18.2	18.0	17.8	
"	STCZ	'90—91	18.3	18.8	19.7	17.8	17.3	17.8
Survey time (total days)	Tasman	'88—89		6.0	10.0			
	Tasman	'89—90	20.0	10.0	5.0			
"	Tasman	'90—91	6.0	14.0	18.0	15.0		
"	ECNZ	'88—89	3.0				6.0	
"	ECNZ	'89—90	28.0	7.0				7.0
"	ECNZ	'90—91	11.0	14.0		9.0		
"	STCZ	'88—89	2.0	34.0	9.0	10.0	15.0	
"	STCZ	'89—90		31.0	56.0	75.0	22.0	
"	STCZ	'90—91	12.0	61.0	94.0	63.0	57.0	7.0
Fishing period (average # hours)	Tasman	'88—89		15.3	10.9			
	Tasman	'89—90	14.7	13.7	13.4			
"	Tasman	'90—91	13.2	10.4	10.9	11.8		
"	ECNZ	'88—89	14.0				11.3	
"	ECNZ	'89—90	15.7	8.7				2.4
"	ECNZ	'90—91	10.1	12.1		11.1		
"	STCZ	'88—89	15.5	14.1	15.0	12.9	11.4	
"	STCZ	'89—90		14.2	14.2	13.6	12.4	
"	STCZ	'90—91	15.1	14.7	15.4	14.0	11.5	9.4
Number of lines (average daily)	Tasman	'88—89		12.0	11.6			
	Tasman	'89—90	17.5	12.0	12.2			
"	Tasman	'90—91	13.3	12.7	12.8	12.5		
"	ECNZ	'88—89	2.0				12.0	
"	ECNZ	'89—90	20.1	8.1				5.7
"	ECNZ	'90—91	15.2	12.8		12.9		
"	STCZ	'88—89		16.9	21.6	11.6	9.5	
"	STCZ	'89—90		18.9	21.0	22.9	24.5	
"	STCZ	'90—91	21.1	17.7	14.8	14.9	16.5	11.1
Albacore catch (average daily)	Tasman	'88—89		152.2	37.0			
	Tasman	'89—90	33.3	39.6	113.0			
"	Tasman	'90—91	9.0	4.6	35.3	40.9		
"	ECNZ	'88—89	6.7				16.2	
"	ECNZ	'89—90	195.2	19.3				0.7
"	ECNZ	'90—91	17.3	29.2		37.3		
"	STCZ	'88—89	177.5	221.5	168.8	65.3	134.9	
"	STCZ	'89—90		336.7	368.1	315.3	316.5	
"	STCZ	'90—91	145.3	247.8	298.4	124.1	77.1	12.3
Albacore length (average FL, cm)	Tasman	'88—89		57.0	60.1			
	Tasman	'89—90	66.3	61.6	57.8			
"	Tasman	'90—91	54.8	62.1	70.0	56.6		
"	ECNZ	'88—89					56.7	
"	ECNZ	'89—90	68.9	53.7				49.5
"	ECNZ	'90—91	61.1	56.6		59.7		
"	STCZ	'88—89	72.6	65.3	69.4	70.3	77.5	
"	STCZ	'89—90		67.7	67.4	68.0	67.3	
"	STCZ	'90—91	65.7	67.4	69.5	66.5	78.4	84.0
CPUE (catch per 100 line-hours)	Tasman	'88—89		82.7	29.1			
	Tasman	'89—90	12.3	24.1	69.1			
	Tasman	'90—91	5.1	3.5	25.1	27.7		
"	ECNZ	'88—89	20.8				11.9	
"	ECNZ	'89—90	61.8	15.6				5.4
"	ECNZ	'90—91	10.2	18.8		26.0		
"	STCZ	'88—89		84.9	52.2	43.6	118.3	
"	STCZ	'89—90		121.4	123.0	101.6	104.6	
"	STCZ	'90—91	45.8	94.2	125.0	58.0	40.2	10.0

One peculiar trait of the STCZ length-frequency histograms is the apparent reduction in the number of modes seen each season (Fig. 2). During the 1988—89 season, three distinct modes were apparent at about 59, 69 and 79 cm. These modes are less distinct in the 1989—90 histogram, because of the greater overlap in size ranges associated with relative age groups. The distinction between these modes was not readily apparent in the 1990—91 composite histogram, with members of the 59 cm and 79 cm modes being relatively less abundant than in previous year. It is interesting to note that this pattern is similar to those associated with the North Pacific albacore jigboat catches, which show one large mode followed by a very small one (see Majors et al., 1989; Coan et al., 1990).

Albacore in the North Pacific have been subject to intensive exploitation for a longer period of time than those in the South Pacific, so it could be hypothesised that the similarity is not just a coincidence, but the result of increasing exploitation pressures acting upon the size structure of this component of the South Pacific albacore population.

Large catches of albacore were made during the 1988—89 season by the driftnet fleet which intercepted mainly albacore associated with the 59 cm and 69 cm modes (Sharples et al., 1991). Relatively fewer albacore associated with the 59 cm mode would have been available for capture during the following season (as ~68 cm fish), and fewer still during the 1990—91 season, because they would have also been subject to a second period of exploitation by the driftnet fleet during the preceding year. Thus it could be hypothesised that the 79 cm mode is not apparent in the 1990—91 samples because fish of that size-class were subject to exploitation by the combined driftnet and troll fleets during the two preceding seasons, unlike their younger counterparts. However, this hypothesis does not account for the absence of the 59 cm mode in the 1990—91 histogram. This may simply reflect a reduction in the relative contribution of that size-class because of environmental conditions. Alternatively, the variation in size associated with the 69 cm mode might have increased to the point where the 59 cm mode was simply not apparent. Additional insight into this matter will be gained in the near future by subjecting the length frequency data to analysis by means of the MULTIFAN application, as done by Hampton et al. (1990).

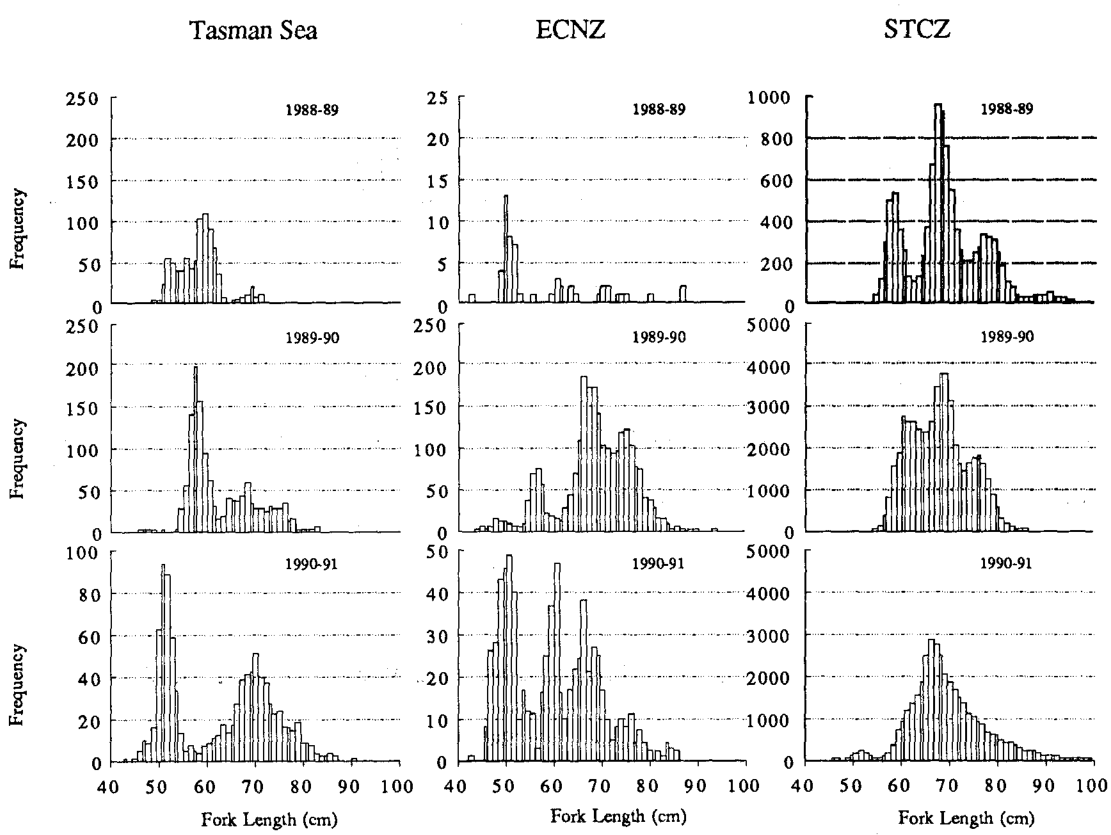

Figure 2. Length frequencies of albacore sampled during the observer programme. Each diagram is a composite of all measurements collected during cruises conducted in each region/year strata.

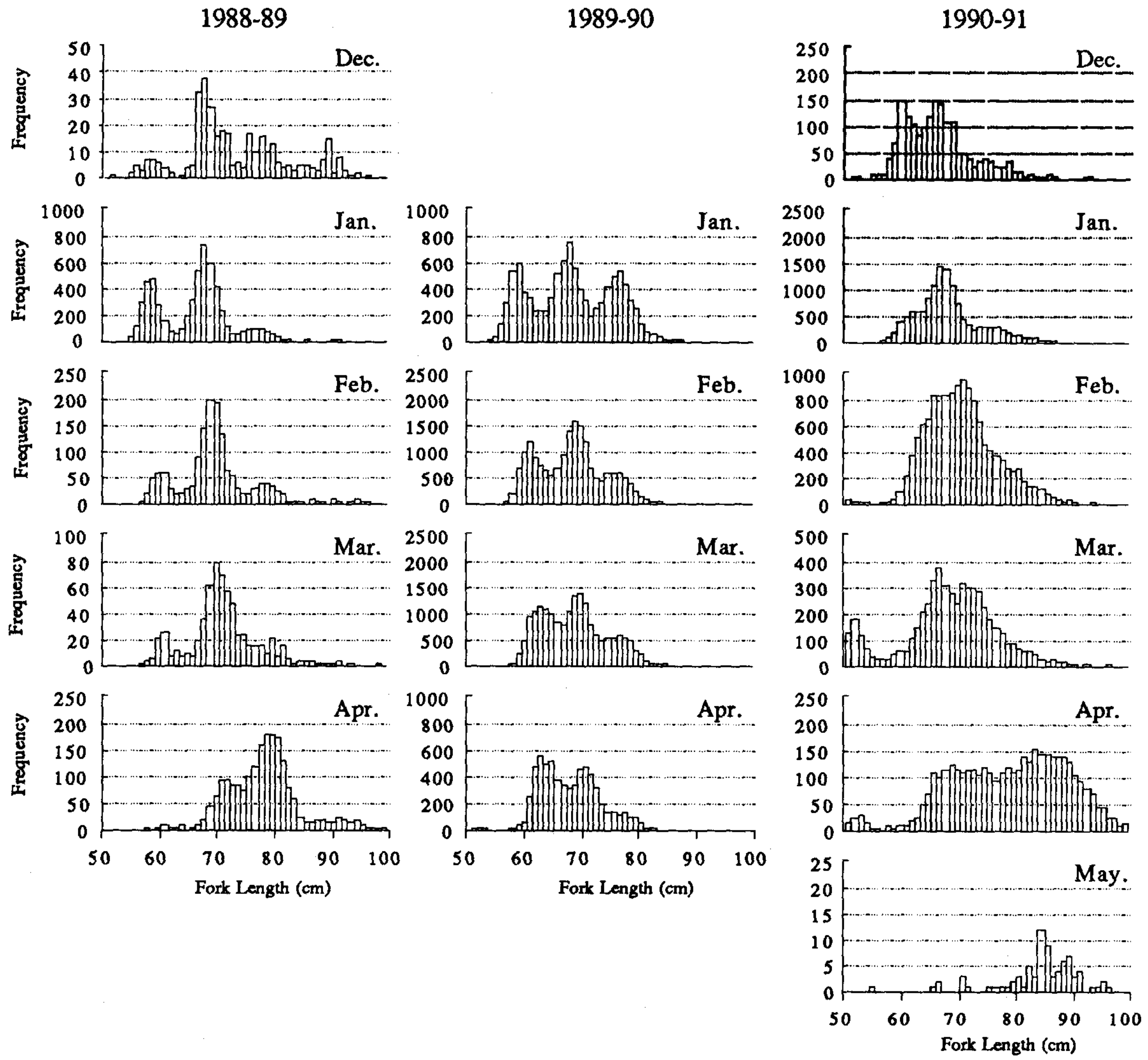

Figure 3. Length frequencies of albacore sampled each season in the STCZ. Each diagram is a composite of all measurements collected during the cruises. Note: no sampling in May 1989, 1990.

4.3 Incidence of driftnet-marked and troll-marked albacore

On an overall basis, about 94 per cent of the fish measured were examined for marks (Table 4). However, sampling rates were negligible or relatively low in the ECNZ and the Tasman Sea, because samples were collected by taggers who could not usually determine the type of net mark during tagging operations. The absence of large samples for certain strata precludes direct comparison of statistics across all seasons and regions, but some generalisations can be made on the basis of samples taken.

Driftnet marks were observed each season in the STCZ and the ECNZ where samples were taken, but not in the Tasman Sea. Net marks were observed on 0—14 per cent of the fish inspected. The incidence of new marks (codes 1—3) was greatest in 1988—89, when 14 per cent of the fish inspected were marked. The proportion of new marks decreased during 1989—90, and was highest in the STCZ (~4.5%). During 1990—91, new marks were observed in less than two per cent in all regions, and were highest in the Tasman Sea (1.71%). These results reflect the fact that the level of driftnet fishing activity has been decreasing steadily since the peak period of 1988—89. Concurrently 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%). During the 1990—91 season, it decreased even further, but was higher in the Tasman Sea (2.9%) than in the STCZ. This suggests that either driftnet fishing occurred in the Tasman Sea but was not detected by the sampling regime, or marked fish moved into the Tasman from elsewhere.

Table 4. Number of albacore examined by observers, 1988—91

Region	Year	Measured	Not examined	Code 0	Code 1	Code 2	Code 3	Code 4	Shark bite
TASM	1988—89	850	850	0	0	0	0	0	0
TASM	1989—90	1327	738	589	0	0	0	0	0
TASM	1990—91	943	532	392	2	5	0	12	0
ECNZ	1988—89	55	55	0	0	0	0	0	0
ECNZ	1989—90	2401	77	2308	16	0	0	0	0
ECNZ	1990—91	717	236	470	2	1	1	5	2
STCZ	1988—89	10559	2319	7070	864	247	59	0	0
STCZ	1989—90	52807	0	46294	1945	226	219	4119	4
STCZ	1990—91	37515	986	35584	222	105	45	530	43
TASM	1988—89	-	100.00	-	-	-	-	-	-
TASM	1989—90	-	55.61	100.00	-	-	-	-	-
TASM	1990—91	-	56.42	95.38	0.49	1.22	0.00	2.92	0.00
ECNZ	1988—89	-	100.00	-	-	-	-	-	-
ECNZ	1989—90	-	3.21	99.31	0.69	0.00	0.00	0.00	0.00
ECNZ	1990—91	-	32.91	97.71	0.42	0.21	0.21	1.04	0.42
STCZ	1988—89	-	28.71	85.80	10.49	2.97	0.71	0.00	0.00
STCZ	1989—90	-	0.0	87.67	3.68	0.43	0.41	7.80	0.01
STCZ	1990—91	-	2.63	97.41	0.61	0.29	0.12	1.45	0.12

1. Figures in the 'Measured' category represent the number of length measurements collected. Figures in the 'Not examined' category represent the number of fish measured that were not examined for external injuries. Figures in the lower section are the numbers in each category expressed as a percentage of the fish examined. The 'codes' are those referred to in Section 3.3.

Albacore within certain size ranges were particularly susceptible to certain types of driftnet injuries (Fig. 4). During the 1989—90 season, albacore exhibiting light skin discolouration (Code 1) tended to be smaller than average ($\bar{x}$ = 65 cm, st.d = 3.6 cm). By contrast, albacore with light skin abrasions terminating before the point of maximum girth (Code 2) were larger than average ($\bar{x}$ = 75 cm, st.d = 5.9 cm). Albacore with serious skin abrasions in areas of maximum girth were generally close to average in size ($\bar{x}$ = 70 cm, st.d = 3.6 cm). As expected, albacore with old driftnet marks were larger than average ($\bar{x}$ = 73 cm, st.d = 6.4 cm), and tended to overlap in size with albacore within the code 2 category. Unmarked albacore were distributed throughout the size range of fish caught by troll gear.

Similar patterns were observed during the 1988—89 and 1990—91 seasons, except that the length frequency modes associated with the various categories of fish were less distinct. Albacore with old driftnet marks were not observed during 1988—89, and were generally associated with the largest length frequency mode of 1989—90. This supports the notion that the external scars considered to be old marks were probably acquired during the previous season. During the 1988—89 season, albacore with skin discolouration (Code 1) were near average in size; this differs from the pattern observed subsequently. In theory, such an increase could result from changes in the selectivity of the gear used. Hampton et al. (1991) noted that driftnets with 178 mm mesh size were more common during the 1989—90 season than during the 1988—89 season, when 200 mm mesh size was more usual.

Hampton et al. (1991) noted that the ratio of the incidence of old marks to new ones provides a crude estimate of total mortality rate from one year to the next. Such ratios for the first two consecutive seasons (1988—89 to 1989—90, 1989—90 to 1990—91) were respectively estimated at 55.1 per cent and 32.2 per cent, with the average being 43.6 per cent. This translates into total mortality rates of 0.58, 0.725 and 0.647 per year.

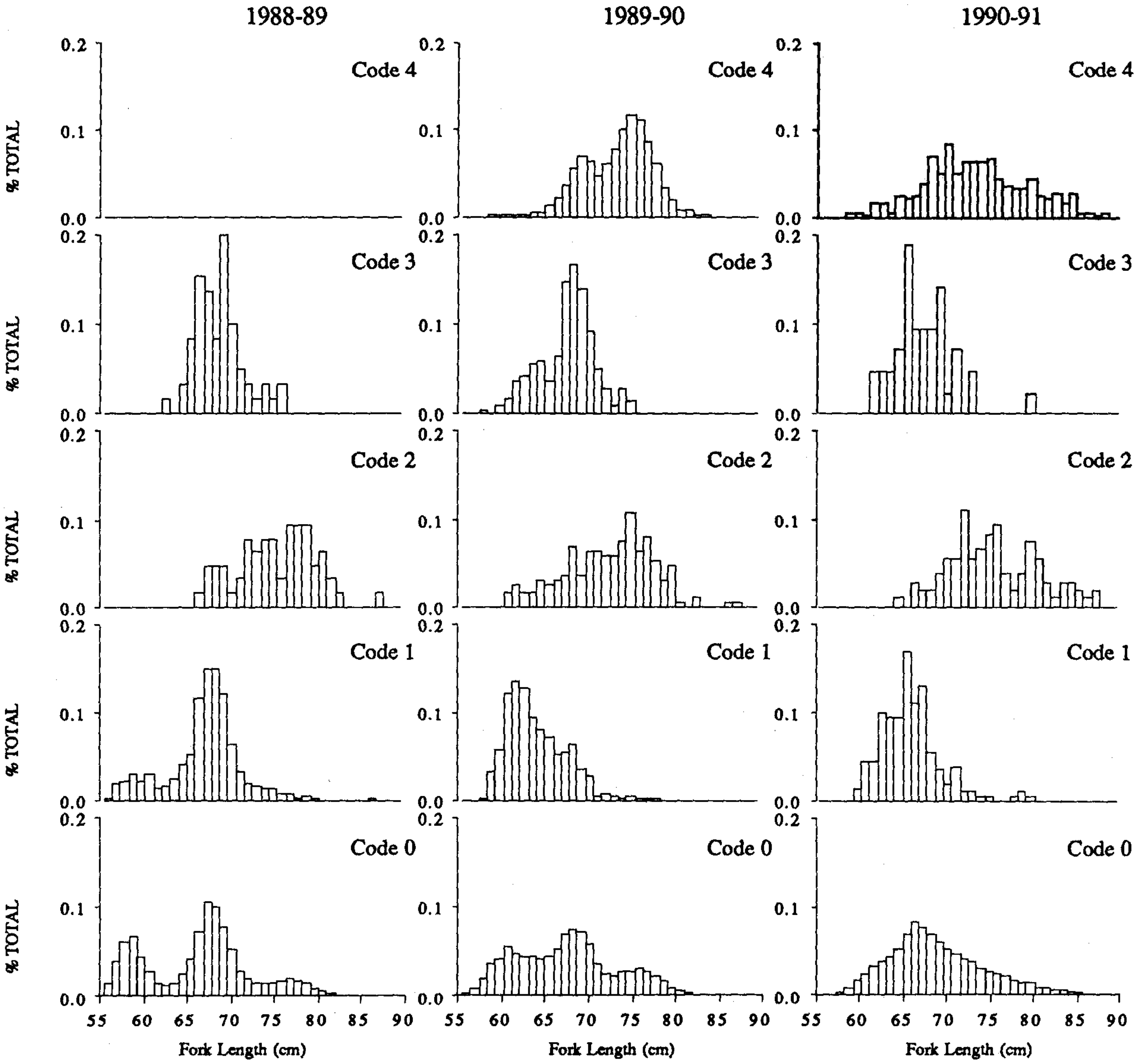

Figure 4. Relative incidence of driftnet injury categories (codes 0—4) by size class for fish sampled in the STCZ during the January—March period. The number of fish in a given size class is expressed as a fraction of the total sample size for each injury category.

4.4 Albacore length, weight and condition

Weight-to-length and length-to-girth relationships for unmarked and marked albacore sampled on troll boats during the 1988—89 and 1989—90 seasons were reported by Hampton et al. (1989, 1991). These authors estimated the weight-to-length relationship for unmarked albacore sampled during the 1989—1990 season to be $W = 0.00003251\ FL^{2.893}$ ($n = 9382$, $r^2 = 0.959$). It should be emphasised that this regression can be used to estimate weight from length, but not length from weight (see Ricker, 1975).

The length-to-weight relation, needed to estimate length of tagged albacore recovered using the available weight data, was determined for the STCZ population. To minimise the within-season variation in condition, only measurements collected during the January—March period of each season were used. Given weights (W) in kg, and fork lengths (FL) in cm, the relationships obtained were:

Equation 4:	$FL = 36.3020\ W^{0.33988}$	('88—89, $n = 1387$, $r^2 = 0.983$)
Equation 5:	$FL = 35.5386\ W^{0.33841}$	('89—90, $n = 7000$, $r^2 = 0.964$)

The above relationships suggest that albacore in the STCZ were in slightly better condition during 1989—90 than during 1988—89. Weight and girth measurements were not routinely collected during the

1990—91 season, so comparisons of condition factors with previous seasons were not possible. Hampton et al. (1991) noted that unmarked fish were in significantly better condition 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 fish 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).

4.5 Troll fishery by-catch

Background information on the amount of by-catch associated with average catch rates was difficult to obtain. One observer noted that the relative amount of by-catch seemed to be a function of trolling speed, with some vessels obtaining a higher fraction while on the way to fishing grounds. By far the most common fish caught in the STCZ while trolling for albacore was skipjack tuna (*Katsuwonus pelamis*), which accounted for ~0.05 per cent and 0.01 per cent of the catch on troll boats monitored during 1989—90 and 1990—91. Other fish commonly caught were mahi mahi (*Coryphaena hippurus*), kingfish (*Seriola grandis*), blue shark (*Prionace glauca*), thresher shark (*Alopias* sp.) barracouta (*Thyrsites atun*) and kahawai (*Arripis trutta*). The combined catch of these fish account for less than 0.01 per cent of the fish caught during these two seasons in the STCZ, but tended to make up a slightly greater fraction of the catch near the coast. Billfish were occasionally hooked but rarely landed. Seabirds occasionally hit lures in surface waters, but those hooked while an observer was on board were released alive by the crew. None of the observers ever reported seeing a marine mammal being hooked or injured by troll gear.

4.6 Losses due to fishing methods

During the 1989—90 season, an assessment was made of the number of albacore that unhooked themselves while hauling the line. During field surveys, albacore in this category were referred to as 'drop-offs'. These included all fish that remained on the hook for >10 seconds before escaping, and fish that were lost during the hauling operation or while being lifted aboard at the stern. For the present report, the ratio of drop-offs to catch plus drop-offs is defined as the escapement rate. By definition, this represents the fraction of all 'hits' that did not translate into a definite catch. An underlying assumption here is that all such hits are caused by albacore (unless noted otherwise). Fishermen infer that the majority of the fish hooked are albacore on the basis of their appearance during hauling operations, the catch composition, and the struggling pattern exhibited by the fish.

Observers reported that escapement rates varied considerably between days and vessels. Factors such as weather conditions, average fish size, vessel characteristics and crew experience are assumed to affect escapement rates. Under rough weather conditions, vessels usually troll down wind and up wind to stay in a good fishing position. The action of the swell passing the vessel can exert sufficient strain on the troll lines to pull hooks out of the mouth of the fish. Variation in the tension applied to the line as a result of the vessel changing orientation with respect to the swell is thought to cause most of the variation in drop-off rates. Some observers felt that the state of the electrical system on board the vessel also affected the escapement rate. This [unsubstantiated] hypothesis stemmed from observations that catch rates decreased when the vessel was plagued with electrical shorts. Transom height and hauling speed were also reported to affect escapement rates. Some observers also felt that larger fish escaped less often than small ones particularly in bad weather, but other observers felt that smaller fish were more likely to have their lower jaw torn off under such conditions.

Estimates of escapement rates were generated for the 1987—1991 period for each vessel/month stratum during which monitoring activities were conducted (Table 5). These estimates show a considerable amount of variation, ranging from 6 to 46 per cent. In some cases, small sample sizes undoubtedly contributed to the variation observed, so estimates based on larger samples obtained by pooling across strata are more representative of general trends. Variation among vessels was less, with escapement estimates ranging from 7 to 33 per cent. Seasonal escapement estimates averaged across all vessels within each season ranged from 20 to 33 per cent. On an overall basis, the average escapement estimate for the troll fleet monitored during the 1987—1991 period was 24 per cent. The escapement rates for vessels using single barbless hooks were above average. Fishing vessels using double barbed hooks had escapement rates which were below 20 per cent. Thus, a substantial portion of the fish hooked are not landed, but the fraction of these that eventually die due to hook injuries could not be determined.

The catch reported by albacore troll vessels is the nominal catch and is composed of fish which are landed on the vessel and retained for sale. In addition to the nominal catch and the drop-off group, some fish are discarded after being brought on board. During the observation period, the fraction discarded accounted for ~1.7 per cent of all fish brought on board, and generally consisted of very small albacore which were not in great demand by canneries. These were usually rejected while still alive, on the assumption that some would survive after release. By taking into account all losses, landings and rejects, the potential catches and CPUE can be estimated. The potential CPUE estimates (Table 5) show a considerable amount of variability between vessel/month strata, which is to a large extent attributable to the variation in escapement rates and survey period. The overall estimate of potential CPUE, based on all statistics pooled across vessels and survey periods, was about 51.1 fish per 100 line-hours. The corresponding actual CPUE, calculated without taking into account losses and discards, was about 38.6 fish per 100 line-hours. The ratio of actual to potential CPUE (75.5%) can be considered as some measure of the relative performance of the troll fleet in terms of its effectiveness in landing the fish hooked. Potential CPUE might also be considered a better indicator of abundance.

4.7 Losses due to shark damage

Observations on the driftnet vessel *Shinhoyo Maru* showed that a portion (<0.6%) of the catch was discarded because of shark damage that occurred while fish were in the net (Sharples et al., 1991). To determine the corresponding portion in troll catches, observers recorded each occurrence of damage inflicted by sharks. On troll vessels two types of shark damage were observed: small, concave bites made by the mesopelagic cookie cutter shark (*Isistius brasiliensis*), and substantial rips and bites made by large pelagic sharks, such as the blue shark (*Prionace glauca*). Albacore with cookie cutter bites were usually retained, while those attacked by larger sharks while being hauled in were much more seriously damaged and hence usually discarded. During the 1988—89 and 1989—90 seasons, shark damage was not reported to be a cause for discarding any of the catch. Some shark damage was observed during 1990 and 1991 in the ECNZ and STCZ (Table 4). Shark damage was apparent in as much as 0.42 per cent of the fish examined in one area, but less than 0.1 per cent of all albacore examined exhibited shark marks of any kind.

4.8 Driftnet vessel sightings

Driftnet vessel fleet composition, activity patterns and areas of operation were determined with the aid of vessel identities and positions reported by observers on US and New Zealand troll vessels, observers on the JAMARC research driftnet vessel *Shinhoyo Maru* (1989—90), officers aboard merchant ships (Union Steamship Co.) and RNZAF fisheries surveillance aircraft. The number of driftnet vessels operating in the South Pacific during 1988—89 was estimated at 64 Taiwanese, 67 Japanese and one South Korean vessels. During the 1989—90 season, 20 Japanese and 11 Taiwanese driftnet vessels were accounted for. The composite map of driftnet vessel sightings presented by Hampton et al. (1991) indicated that the spatial distribution of Taiwanese and Japanese driftnet 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 driftnet fishing activity, but the latter does not represent the total driftnet fishing area east of New Zealand because most reports were compiled from observers on board vessels fishing a relatively narrow latitudinal band. The actual area of driftnet fishing activity in the SCTZ will be established from the SPAR catch and effort database once all records are complete.

During the 1990—91 season, no aerial surveillance flights were conducted over the STCZ, and not a single driftnet vessel was sighted by the two observers during the survey period (Dec.—May.). Information on the presence of driftnet vessels was obtained indirectly by monitoring radio communications between vessel skippers. On the basis of communication contents, the observers noted that skippers could not always determine with certainty whether or not the vessel sighted was a driftnetter, an associated supply vessel or a longliner. Given that driftnetters and longliners are rarely seen in the same area, it is often assumed that vessels operating in close proximity to one another are driftnetters. However, some driftnet vessels sightings were made during the tagging cruises conducted on board Vessel 16. The *Shing Feng* (?) was sighted (Feb 22: 41°13'S, 151°32'W), and the *Tefu No. 26* (Reg. #CT7-0082), and the *Nog Yung Chung* were observed drifting (Feb. 25—26: ~ 41°20'S, 150°30'W). The *Shye Shing No.1* (Reg.# CT4-0434, call sign BH2634) was also sighted the same day while engaged in setting a driftnet along with two other vessels which could not be identified. These three vessels were setting nets in a parallel direction right through the fleet of about 22 troll vessels, which were either fishing or in the process of unloading onto the carrier vessel *Moa Moa*. Based on a synthesis of the reports from observer and tagging cruises, it was estimated that about nine Taiwanese driftnet vessels operated in the STCZ during 1990—91.

No reports of driftnet sightings in the Tasman Sea were received by Australian fisheries officials during the 1990—91 season (Ward and Chapman, 1991). The sightings made suggest that the driftnet fleet operated in slightly lower latitudes than during the previous seasons (as did the troll fleet). Such results indicate that there has been a general reduction in the number of driftnet vessels fishing for albacore in the South Pacific since 1988.

Table 5. Estimates of escapement ratios and potential catches from the observer programme

Vessel Name	Survey Month	Survey Year	Escapement rate (stratum)	P. catch per 100 l-h (stratum)	Escapement rate (vessel)	P. catch per 100 l-h (vessel)
Vessel 10	Jan.	1991	0.12	228.1		
"	Feb.	1991	0.08	129.2	0.10	166.89
Vessel 11	Feb.	1991	0.08	320.0		
"	Mar.	1991	0.06	86.0	0.07	125.09
Vessel 17	Mar.	1987	0.29	33.0	0.30	32.99
Vessel 2	Dec.—Feb.	1990	0.23[2]	n/a		
"	Nov—Dec	1990	0.28	43.9		
"	Jan.	1991	0.13	98.0		
"	Mar.	1991	0.20	73.9	0.18	71.36
Vessel 12	Feb.	1991	0.19	413.4		
"	Mar.	1991	0.22	140.7	0.19	306.82
Vessel 4	Nov—Dec	1986	0.35	19.9		
"	Feb.	1987	0.18	41.9		
"	Jan.	1988	0.24	41.7		
"	Feb.	1988	0.15	41.8		
"	Mar.	1988	0.26	13.2		
"	Jan.	1989	0.24	109.1		
"	Feb.	1989	0.21	37.0		
"	Apr.	1989	0.24	15.5		
"	Jun.	1989	0.38	9.2		
"	Jan.	1990	0.23	31.2		
"	Feb.	1990	0.18	84.7		
"	Jan.	1991	0.28	10.7		
"	Feb.	1991	0.08	6.7		
"	Mar.	1991	0.33	66.9	0.23	35.72
Vessel 13	Nov—Dec	1990	0.22	30.3		
"	Jan.	1991	0.17	132.1	0.16	103.02
Vessel 14	Apr.	1991	0.13	99.0	0.14	98.96
Vessel 3	Jan.	1991	0.25	98.3		
"	Feb.	1991	0.25	68.4	0.25	88.03
Vessel 16	Nov—Dec	1990	0.46	12.1		
"	Jan.	1991	0.37	14.7		
"	Feb.	1991	0.32	90.6		
"	Mar.	1991	0.35	30.3	0.33	48.13
Vessel 15	Apr.	1991	0.17	127.0	0.20	131.74
All vessels	all months	1986—87	0.33	30.77		
"		1987—88	0.20	34.94		
"		1988—89	0.24	55.15		
"		1989—90	0.20	45.74		
"		1990—91	0.32	44.24		

1. Escapement rates = drop-offs + (catch + drop-offs). The estimates are tabulated by vessel/month stratum, by vessel (averaged over all survey periods), and by season (bottom section: averaged over all vessel and months within each season).

2. Estimates from Hampton et al. (1991). Original figures were unavailable at write-up time, and were not used for computation of other escapement and potential catch estimates.

4.9 Interactions between gear types

Several of the troll fishermen interviewed during the observer programme stated that schools of albacore altered their behaviour and were less responsive to troll lures if a driftnet vessel deployed its net amongst troll vessels engaged in fishing. Fishermen generally based their conclusions on an apparent reduction in catch rates and a greater difficulty in staying with schools, even when using sonar. Efforts made by observers to assess the validity of such assertions were not too successful, because troll vessels usually stopped fishing and left an area when driftnet vessels were in close proximity. The primary reason for changing areas was due to gear conflict between the troll and driftnet vessels, especially the potential for troll vessel entanglement in the nets and attendant hazards to vessel safety. However, one US troll fisherman interviewed by the senior author while unloading in Papeete reported substantially greater catch rates in the vicinity of driftnets. The strategy used by this fisherman consisted of trolling in a parallel direction to the net in an attempt to catch all albacore which were holding behind the net. This fisherman stated that this strategy worked very well for him and that his catch rate was often greater than that obtained on good days without driftnets nearby. Thus the conflicting reports received indicate that at least some troll fishermen have adopted new fishing strategies which work well in the presence of these vessels, despite the added navigational hazards they pose.

4.10 Miscellaneous sightings

During the 1988—89 and 1990—91 seasons, records were kept of marine mammals, turtles and other large marine organisms observed in surface waters. The 1988—89 records indicate the presence of several marine mammals (possibly small whales) during January at locations west of 159°W, and ~50 small dark dolphins (Jan. 16: 37°57'S, 155°06'W). The 1990—91 records taken on board commercial fishing vessels indicated the presence of 6—7 sperm whales (Dec. 29: 40°23'S, 176°30'W), other unidentified whales (Apr. 8: 42°13'S, 150°52'W), a large pod of killer whales (>25, Apr. 16: 37°35'S, 147°22'W), one leatherback turtle (Feb. 26: 41°46'S, 149°38'W), and one broad squid (Feb. 2: 40°23'S, 153°35'W). During the 1990—91 albacore tagging cruises, common dolphins (*Delphinus delphis*) were observed almost every day while fishing in coastal waters of New Zealand and in the Tasman Sea. Whales, dolphins and fur seals were also observed by the same vessel while operating near the Chatham Islands. Records from Vessel 16 also indicated sightings of two sperm whales (Jan. 24: ~40°S, 178°E), and a pod of medium-sized dolphins (~60—70, Feb 16: 40°40'S, 153°30'W).

5. MAJOR CONCLUSIONS OF THE 1990—91 OBSERVER PROGRAMME

The major conclusions of the 1990—91 observer programme on troll vessels are as follows:

(a) A total of 382 observer days was invested during the 1990—91 season in monitoring fishing activities of the troll fleet targeting on South Pacific albacore. This corresponds to a 38 per cent increase in monitoring efforts over the preceding year, due in part to the additional surveys conducted during the extensive tagging cruises on board Vessel 4 and Vessel 16.

(b) Average catch rates per vessel in the Tasman Sea, ECNZ and STCZ were 23, 28 and 151 fish per vessel per day respectively. The relative trend parallels the one observed during previous seasons. Catch per unit of effort for the January—April period was similar to that of the 1989—90 season, but was substantially lower than in the previous season (~79 fish per 100 line hours in 1990—91 versus ~112 fish per 100 line hours in 1989—90).

(c) Approximately 39,175 fish were measured in the 1990—91 season for assessment of catch composition. Although fewer fish were measured than in the previous year, this sample still accounted for over 80 per cent of the catches obtained on the vessels while they were being monitored. The size compositions of the fish measured in the Tasman Sea and the ECNZ were similar to those observed in previous years. By and large, albacore caught in the STCZ tended to be slightly larger than those caught in the two other regions. The size composition of the fish caught during 1990—91 in the STCZ was unlike that observed during previous seasons, since it was almost unimodal in structure, with the 59 cm and 79 cm modes absent. There appears to have been a substantial reduction in the relative size of these two modes since the 1989—90 season.

(d) Approximately 97.5 per cent of the fish measured in the 1990—91 season were examined for marks. Albacore exhibiting recent marks caused by driftnets accounted for less than 2 per cent of the fish examined, which is less than half the fraction observed during the 1989—90 season. Albacore with old marks accounted for less than 3 per cent of the fish examined during 1990—91, which was less than half the rate observed during the 1989—90 season. Such trends would be expected in view of the general reduction in driftnet fishing activity that has occurred since 1988—89.

(e) No driftnet vessels were sighted in the Tasman Sea, and only nine Taiwanese vessels operated in the STCZ. Driftnet fishing activity decreased considerably since the previous year and the principal area of activity appeared to be in slightly lower latitudes than observed during earlier years.

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APPENDIX: SUPPLEMENTARY INFORMATION

A. DESCRIPTION OF VESSEL CHARACTERISTICS AND FISHING STRATEGIES

Vessel 13: Built in Japan in 1973, this vessel has been registered in New Zealand since 1985. It has operated as a squid jigger, for trolling and handlining southern bluefin tuna in the NZ EEZ. The vessel entered the South Pacific high seas albacore troll fishery in February 1989. Outside the albacore fishery, the vessel was used to fish in New Zealand for southern bluefin tuna. During the observer period, up to 20 lines were used, with 4 off the stern, 4 off each aft outrigger, 2 off each midships outrigger and 4 off a forward outrigger. Hydraulic gurdies pulled the 8 starboard aft outrigger lines, with the rest hauled by hand. Extensive use was made of a range of electronic equipment including a GPS interfaced course plotter and a temperature recorder. Temperature gradients and locations of good catches were recorded on the plotter to assess directions of fish movement. This vessel was not equipped with a sonar but did have a 'sidescope' which is a combination of bottom and side-looking depth sounder. Sea-surface temperature (SST) charts were received on a regular basis but seldom used because of the poor receiver quality and the extensive cloud cover. Close monitoring of the various radio traffic was not a priority as it was on some of the other vessels observed.

Vessel 2: Originally built as a Japanese longliner, this vessel was used as a mother ship and for trolling and handlining southern bluefin tuna. It was converted for the South Pacific high seas albacore fishery in 1988 with the addition of an adjustable stern platform that can be lowered from the main deck level to any height above the water, thus enabling fish to be landed easily in any weather. Up to 24 lines were fished, with 4—5 from the stern, 6—7 from each of the 2 outriggers and 3—4 from the starboard HIAB deck crane located on the bow. Fish on the HIAB lines were hauled through the starboard sea-door. Once landed, all fish had their pectoral fins removed and most were spiked in the head to minimise damage on deck before being blast frozen. Measurements were made after fin removal and spiking. The main fishing strategy in the STCZ was to search for temperature fronts, using a sea-surface temperature recorder. Satellite sea-surface temperature charts were also available on a regular basis. After locating a front, the vessel would fish in its vicinity for subsurface fish schools, with the aid of a depth sounder and sonar. If fish were present and weather permitted, the vessel would circle while fishing. A second strategy was to circle any logs or other floating objects encountered. When sea and weather conditions allowed it, 1 or 2 dories were launched with 2 crewmember on board. Usually the dories would fish up to 6 lines, 2 from the stern and 2 on each of 2 short poles. This method often resulted in catches of more than 200 fish per day.

Vessel 3: Originally built in Japan as a combination salmon driftnet and squid jig vessel, this vessel has been regularly used for squid jigging and albacore trolling in New Zealand domestic fisheries. More recently it has been used in the development of longlining for southern bluefin tuna in winter months. The vessel was equipped with 2 outriggers and fished up to 19 lines, with 4—5 from the stern and 6—7 from each outrigger. The depth sounder was relied upon to locate fish. All fish were pulled by hand. No pectoral fins were removed and fish were not spiked when landed. Fish were blast frozen and were periodically transshipped after freezing.

Vessel 12: Originally built as a shrimp trawler, this vessel was converted for longlining and albacore trolling by her owner. Up to 9 lines were trolled, 4 from each outrigger and 1 stern line. The lines were hydraulically hauled by gurdies, one port and one starboard. The fish when landed went into a 900 kg basket. When the basket was full the fish were stacked in the fish hold for freezing. The fishing strategy was to search for temperature fronts, using a sea-surface temperature recorder. Satellite sea-surface temperature charts were available as far east as 150°W. A depth sounder was the principal instrument used to locate fish. The vessel circled fish when located, if weather permitted, or tacked across the area by running up and down wind.

Vessel 10: Built in 1978 as a US albacore troller, the vessel has fished as a swordfish driftnet vessel, drum seiner and purse seiner. The vessel entered the South Pacific albacore fishery in 1990—91, although the captain and crew member had fished for the last 4 seasons in the STCZ. Up to 15 lines were fished, 3 off the stern and 6 off each outrigger. The longer lines on each outrigger were hauled by hydraulic gurdies; the remaining lines were pulled by hand. A GPS and depth sounder were the main equipment used to locate fish, but the vessel's sonar failed after the first few weeks. Without a weather facsimile receiver on board, sea-surface temperature information was relayed through the fleet via the APT satellite receivers.

Vessel 11: This vessel is a small US-style tuna pole-and-line boat used for skipjack and yellowfin tuna fishing off the coasts of southern California and Mexico. This boat first entered the South Pacific albacore fishery in the 1987—1988 season. Bait boats have numerous 'wells' in which they carry live bait; for the albacore fishery the wells were used to carry extra fuel. When wells were emptied they were used as spray brine freezer wells. Up to 18 lines were fished, 4 off the stern and 7 off each outrigger. Hydraulic pinch pullers were used to haul the longer lines, with the rest being pulled by hand. Only a depth sounder and satellite navigator were used when fishing, with the captain relying on his bait-fishing experience and especially on signs of surface activity (i.e. birds, jumping fish and schools breaking the surface). The radio was monitored constantly. Frozen anchovies were regularly used as chum.

Vessel 14: Originally built as a North Sea trawler, the vessel had most recently been used off Panama for shrimp. The boat entered the South Pacific for the first time in late February 1991 after being refitted. The boat travelled to the grounds via Panama before steaming south and west to 38°S, 136°W, before moving west to join the troll fleet. This vessel had not previously taken part in any albacore fishery but was expected to fish both the North and South Pacific albacore fisheries. The captain had extensive experience in the North Pacific albacore fishery although this was his first time fishing the STCZ. Up to 20 lines were fished at a time, 6 off each aft outrigger and 4 off each forward outrigger; all lines were pulled by hand. Equipment consisted of a GPS, course plotter, depth sounder, and sonar. The captain relied extensively on sonar to locate schools. During the latter part of the season, with much larger fish being caught (14—15 kg average), this vessel had difficulty lifting fish over the high stern (3—4 m above water) and each fish had to be gaffed.

Vessel 5: This vessel had not fished in the offshore albacore fishery until the 1989—1990 season. The captain and some crew members had extensive experience in the New Zealand albacore and southern bluefin fisheries. During 1989—1990, 10 lines were usually trolled from the outriggers and 4 lines off the stern. The outrigger lines were hauled hydraulically, while the stern lines were hand-hauled. In addition, 4 lines were trolled from a forward starboard outrigger. Forward outrigger lines were hauled by hand through the sea-door. The captain maintained regular radio contact with other vessels to find fishing areas and used the radar to identify areas of vessel concentration. In locating concentrations of fish, he relied heavily on a depth sounder to locate sub-surface schools. When good sounder marks were encountered, the area was circled until the fishing dropped off. Extensive use was made of the course plotter interfaced with a Global Positioning System (GPS) navigation unit to stay near productive fishing areas. During periods of strong wind (>25 knots) a strategy of fishing alternately with and against the weather was adopted, but there did not appear to be any difference in catch rate when fishing either way.

Vessel 6: The observer spent only 3 days on board this vessel during 1989—1990 while in transit between other vessels. The main fishing strategy was to use the sonar to locate a school of albacore. The school was then circled, with the sonar used to maintain the vessel's proximity to the school. Anchovies and pilchards were thrown liberally amongst the lines to encourage the albacore to stay with the vessel. When a school was located, its position was also recorded in the course plotter interfaced with the GPS so that these positions could be revisited later. The vessel usually towed 5 lines from each of 2 outriggers and 4 or 5 lines from the stern. Hydraulic haulers were used to haul the 10 outrigger lines.

Vessel 7: This vessel entered the offshore albacore fishery during 1989—1990. Up to 23 lines were fished at a time, 8 or 9 from each of 2 outriggers and 6 from the stern. A depth sounder was used to locate tuna schools, although it was not used to track schools continuously. Sea-surface temperature measured on board and satellite-derived temperature charts were used to indicate general areas of expected fish concentration.

Vessel 8: This vessel had not previously participated in any albacore fishery prior to the 1989—1990 season, but its captain and crew had considerable experience in the New Zealand albacore and southern bluefin fisheries. The vessel usually towed 27 lines which were all hand-hauled. The vessel maintained good catch rates by staying with other vessels, fishing along temperature gradients, and circling areas whenever albacore were caught. Other strategies included fishing around logs, stationary vessels and areas of bird activity.

Vessel 9: This New Zealand vessel had not previously participated in any albacore fishery prior to the 1989—1990 season, although the captain participated in the offshore fishery in 1988—1989. Up to 31 lines were fished. The main strategies were to search for strong temperature gradients using a sea-surface temperature recorder, or to fish in areas where other vessels were fishing. The vessel also used a colour depth sounder to look for sub-surface schools. When schools were located they were marked. Sunfish were also circled and their positions marked in case they submerged.

Vessel 16: This vessel was originally built in Japan as a pole-and-line boat. The vessel had recently been employed for skipjack and yellowfin tuna fishing in tropical areas. The vessel was used during the 1990—1991 SPC tagging programme, because the recently installed troll fishing gear was suitable for albacore fishing, and because scientists intended to assess the feasibility of tagging albacore by means the pole-and-ine gear. The vessel towed 4 lines from a port outrigger, 5 lines from the stern, and 4 lines from the starboard (tagging station) outrigger. When catch rates were high, chumming was usually conducted to attract albacore to the surface so that the pole-and-line gear could be used when the vessel was stopped. Fishing strategy in coastal NZ grounds was to fish in historically proven areas, using the depth sounder and SST charts as aids. In the Tasman Sea, efforts were made to fish in areas previously used by the Asian driftnet fleet, as well as areas which appeared to offer good prospects for high catches based on SST charts. The strategy in the STCZ was to search for temperature fronts and remain with the rest of the fleet as much as possible. All fish were pulled by hand. No pectoral fins were removed, and fish were not spiked when landed. Fish were frozen and were periodically transshipped after freezing. Fishing speed was typically lower than other vessels, and single barbless hooks were used for tagging purposes to minimise injuries. Occasionally, the skiff was used for catching and tagging purposes. Both factors undoubtedly affected the catch rate and the loss rate of this vessel.

Vessel 4: This vessel is operated by MAF primarily for research purposes and has been used for all albacore tagging cruises conducted by MAF since 1986. The vessel was originally designed for inshore trawling, but has been modified for trolling and tagging of albacore around NZ. It can tow 5 lines from each of 2 outriggers, and 6 other lines from the stern. However, for tagging purposes, it is mostly restricted to towing 12 lines in total. SST data received from its base by radio is relied upon when fishing in the Tasman Sea, but additional information from local fishermen is used in coastal waters.

B. OBSERVER ITINERARY FOR THE 1990—91 SEASON

24 Dec:	Observer arrived Wellington for briefing and packing for departure.
26 Dec:	Departed Nelson on board Vessel 13, bound for fishing grounds, fishing on the way.
02 Jan:	Joined the troll fleet at 37°39' S, 161°33.5' W.
13 Jan:	Transferred to Vessel 10.
15 Feb:	Boarded Vessel 11.
31 Mar:	Boarded Vessel 14.
28 Apr:	Left the fishing grounds for Pago Pago with the last six troll vessels.
08 May:	Arrived in Pago Pago.
13 May:	Departed Pago Pago for New Zealand.
24 May:	Arrived Whangarei, debriefed on arrival.

C. TEMPERATURE CORRECTIONS

Sea-surface temperatures were recorded using hull-mounted thermistors with bridge displays. Temperature corrections were determined where possible using a standard laboratory thermometer. Temperature corrections were applied to vessel temperature readings as follows: Vessel 13 (- 0.5° C), Vessel 10 (- 0.4° C), Vessel 11 (0.0° C), Vessel 14 (- 0.2° C), Vessel 2 (n/a), Vessel 3 (n/a).

D. TRANSSHIPPING IN THE STCZ DURING 1990—91

Two refrigerated carriers were chartered to service the high seas albacore fishery on the STCZ grounds, operating throughout the 1990—1991 season. Approximately 2,700—3000 tons of albacore were transshipped on the grounds during the 1990—1991 fishing season. One vessel completed two trips to American Samoa (~774 tons each) and one trip to Thailand (~730 tons). The other vessel completed two trips to American Samoa (~365 tons each).

A transshipment charge of $US 300 per short ton of fish was charged. Vessels were limited in the amount they were allowed to transship and were also allowed to purchase some fuel. The alternative to transshipment was at least a 7-day trip to canneries in American Samoa or Fiji or to the freezer store in Tahiti. The ability to transship allowed smaller vessels (17—27 t hold capacity) to participate in this high seas fishery and operate as profitably as an 80—100 t boat.