An Overview of the New Zealand Jack Mackerel Fishery: Catch Composition, Catch Trends, Seasonality and Length-Frequency Composition

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Abstract

The New Zealand jack mackerel fishery targets three species, *Trachurus declivis*, *T. novaezelandiae* and *T. murphyi*. First catches were documented in 1946, but the targeted fishery, assumed to be *T. declivis*, started in the mid-1960s, with annual catches increasing to 20,000 t by the time jack mackerels were included in the New Zealand Quota Management System in 1986-87. In 1986 it was also first recognised that *T. murphyi* contributed to the increasing New Zealand jack mackerel catch. Commercial catches of jack mackerels are not reported separately by species, so observer and shed sampling programmes were implemented to estimate species proportions. The contribution by *T. murphyi* has differed substantially between areas, and over time. By 1986-87, all of the catch in the eastern-most JMA 3 area on the Chatham Rise consisted of *T. murphyi*. This species first appeared in catches in the other areas around 1987-88, increasing to 40% by 1994-95, and decreasing again to <10% by 2001-02. Estimated catches of *T. murphyi* increased from zero in 1986-87 to over 25,000 t in 1995-96, lagging slightly behind the similarly rapid rise in total South Pacific catches. New Zealand catches then declined to 2,400 t by 2002-03, increasing slightly to 4,645 t by 2005-06, again lagging a year or two behind the decline in total South Pacific catches. CPUE analysis shows that catch rates also underwent a steep decline after 1996. Length-frequency composition has remained relatively constant from 40-60 cm, while age composition has increased steadily, consistent with an ageing New Zealand population. Geographic distribution of catches over time shows initial appearance around the Chatham Islands in 1984-85, westward expansion from 1986-87 to 1994-95 as catches increased, followed by an eastward contraction to 2006-07, as catches declined. Most of this information supports the hypothesis that *T. murphyi* in the New Zealand region are a small, and perhaps periodically separated, component of a larger South Pacific stock which undergoes periodic expansions or migrations.

Introduction

The history of the New Zealand fishery for jack mackerels (*Trachurus* species) can be traced back to first documented catches in 1946. In the early years jack mackerel were not sought after and were typically discarded, and so recorded catches remained very small (below 25 tons) until 1967. Early catches were thought to consist only of the greenback horse mackerel, *Trachurus declivis*. In the mid-1960s, New Zealand fishermen started targeting jack mackerel using purse-seine nets around the North Island, and Japanese trawlers in the region also started making significant catches (Jones 1988). By 1975 jack mackerel was considered to be one of the dominant fish on the New Zealand continental plateau north of Cook Strait (Nosov & Platoshina 1975) and by 1986–87 the combined New Zealand jack mackerel fishery had developed into a substantial targeted fishery, with an overall TAC in that fishing year of 20,000 t.

Suggestions that there may be more than one species of jack mackerel in New Zealand waters date back to Hector (1872), but it was not until 1977 that morphometric work (Stephenson & Robertson 1977) and biochemical studies (Gauldie *et al.* 1977) demonstrated that an endemic New Zealand jack mackerel, *T. novaezelandiae*, also contributed to catches. It was only in 1986 that it was first recognised that *T. murphyi* (which is similar in appearance to *T. declivis*) was also present in New Zealand waters. Whether this widespread species had been present in the New Zealand region beforehand is unknown, but the subsequent rapid increase in availability and contribution to catches

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by *T. murphyi*, followed by an equally rapid decline in availability of this species, has been a dominant and interesting characteristic of the fishery. This paper provides an overview of the New Zealand fishery for jack mackerel species, and presents specific information on the increase and decline in contribution of *T. murphyi* to New Zealand catches.

Management of the New Zealand Jack Mackerel Fishery

Jack mackerels were included into the New Zealand Quota Management System in 1986-87, to be managed in four Quota Management Areas (QMAs) (Figure 1). Catches are managed using annual Total Allowable Commercial Catch limits (TACCs) in each of these four QMAs, and individual quotas (IQs) issued to fish allocated percentages of the annual TACCs. Jack mackerels in these different QMAs are not considered to constitute separate biological stocks, but are managed as separate management units (referred to in New Zealand as 'Fishstocks') for purposes of managing fishing effort and TACC in the different regions.

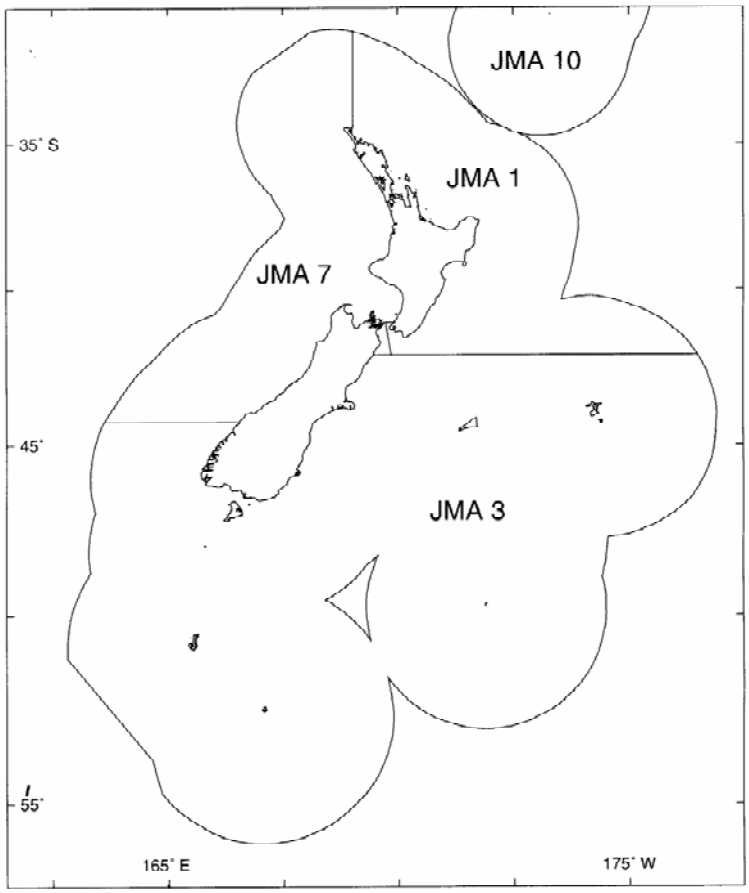

Figure 1. Map showing the geographic boundaries of the New Zealand jack mackerel (JMA) Fishstock / quota management areas referred to in the text.

Monitoring of Catch, Effort, Size and Age

Under monitoring and reporting requirements associated with the Quota Management System, New Zealand fishermen are required to submit trip-by-trip (for purse-seine and small inshore trawlers) or tow-by-tow (for larger trawlers) catch and effort returns for all fishing operations. Examples of the Catch, Effort and Landing Return (CELR) used by purse-seine vessels, and of the Trawl Catch, Effort and Processing Return (TCEPR) used by larger trawlers are provided in Appendix A. These returns provide detailed data for all jack mackerel fishing operations, including fishing positions (either Lat/Lon for trawl tows or New Zealand statistical area for purse-seine), effort (number of sets or tows,

size of gear) and catches. The four JMA management areas are further divided into 116 smaller statistical areas, so fairly accurate catch position information is available, even for purse-seine operations that do not report tow-by-tow fishing positions.

In addition to the catch / effort returns, New Zealand conducts regular sampling programs to obtain representative length-frequency data, and to collect otoliths, using scientific observers (mainly on larger trawl vessels) or shed sampling programmes for landed fish (for smaller purse-seine operations). Jack mackerels are not separated into separate species by fishermen on catch returns, and are simply reported as jack mackerel (JMA). These sampling programmes therefore provide essential data on catch composition, to allow proportions of the three jack mackerel species in catches in the QMAs to be estimated. Appendix B shows the total number of *T. murphyi* measured, total number of otoliths collected and the size ranges of fish sampled, under these programmes.

Provided adequate arrangements can be made to protect commercial confidentiality of individual vessel, company and fishing position information (such as by aggregating data into suitable strata), these data can be provided by New Zealand for use in jack mackerel stock assessments.

New Zealand Jack Mackerel Catches and Catch Rates

Given the multi-species nature of the New Zealand jack mackerel fishery, this description covers all three species. Most of the information below can be found in the annual Fisheries Assessment Working Group Plenary Reports produced annually by the New Zealand Ministry of Fisheries (the most recent being MFish Science Group 2008).

JMA 1: The JMA 1 jack mackerel catch is largely (about 96% of annual landings) taken by the purse seine fishery operating in the Bay of Plenty and on the east Northland coast, which was, prior to 1992, dominated by *T. novaezelandiae*, but included a small component of *T. declivis*. Between 1991–92 and 1995–96 the proportion of *T. murphyi* in the catch increased considerably, and markets were developed for these larger jack mackerels, but by 1996–97 their low value resulted in less targeting of large fish. In recent years the proportion of *T. novaezelandiae* has been variable with an initial return to more than 95% in 1999–00 and 2000–01, a decline to 46% in 2003–04, and an increase to 81% in 2004–05. Only minor trawl bycatches of jack mackerel has been recorded in JMA 1.

Since 1991–92, targeted jack mackerel landings in JMA 1 have represented more than 80% of their total catch in this area. The majority of JMA 1 catch over these years has been taken from only two statistical areas, 008 and 009 (Bay of Plenty), between June and November. Considerably less has been taken in statistical areas 002 and 003, although high catches were recorded from these areas in 1993–94 and 1994–95. Landings in JMA 1 before 1989–90 were generally well below the quota of 5,970 t, with the maximum in 1986–87 being only slightly above 4,000 t. Landings increased to 7,529 t in 1992–93, followed by a substantial increase to the highest recorded value of 14,256 t in 1993–94, which was more than twice the original quota and exceeded the quota of 8,000 t set for that year. In 1994–95 reported landings (7,832 t) were half those of 1993–94. Landings from 1994–95 to 1997–98 were around 7,000 t. Since 1997–98 landings have fluctuated with no real pattern between a low of 2,866 t in 1999–00 to the high of 9,418 t in 2004–05.

JMA 3: The jack mackerel catch in JMA 3 is almost exclusively *T. murphyi*, for which little targeting occurred before 1992–93. During the 1990s, targeting increased and accounted for the majority of catch (about 90% between 1991–92 and 1996–97) but, after contributing virtually the entire JMA 3 jack mackerel catch from 1994-95 to 1997-98, has decreased again to about 65% since 2002-03. The balance of the catch in this area comes from trawl bycatch on the Chatham Rise and in the Southland / Sub-Antarctic region. A purse seine fishery has operated between the Clarence River mouth and the Kaikoura Peninsula, peaking at 4,400 t in 1992–93 and averaging more than 3,000 t between 1989–90 and 1993–94. Purse seine catches have shown a steady decline since then, dropping from 1,000 t in 1994–95, to 100 t in 2001–02 and 2002–03, to zero in 2003–04.

Table 1. Reported New Zealand landings (t) and TACCs of jack mackerel by Fishstock from 1983–84 to 2006–07.

QMA	JMA 1		JMA 3		JMA 7		JMA 10		Total	
	Landing	TACC	Landing	TACC	Landing	TACC	Landing	TACC	Landing	TACC
1983–84	3,682	–	715	–	12,464	–	0	–	16,880	–
1984–85	1,857	–	1,223	–	16,013	–	0	–	19,659	–
1985–86	1,173	–	2,228	–	10,002	–	0	–	14,773	–
1986–87	4,056	5,970	1,638	2,700	19,815	20,000	0	10	25,509	28,680
1987–88	3,108	5,970	1,883	2,700	17,827	22,697	0	10	22,818	31,377
1988–89	2,986	5,970	1,919	2,700	17,402	26,008	0	10	22,308	34,688
1989–90	4,226	5,970	4,013	2,700	21,776	32,027	0	10	30,102	40,707
1990–91	6,472	5,970	6,403	2,700	17,786	32,069	0	10	30,661	40,749
1991–92	7,017	5,970	5,779	2,700	25,880	32,069	0	10	38,676	40,749
1992–93	7,529	5,970	15,399	2,700	24,767	32,536	83	10	47,778	41,216
1993–94	14,256	8,000	9,115	9,000	22,377	32,536	0	10	45,748	49,546
1994–95	7,832	10,000	11,519	18,000	18,913	32,536	0	10	38,264	60,547
1995–96	6,874	10,000	19,803	18,000	12,270	32,536	0	10	38,947	60,547
1996–97	6,912	10,000	15,687	18,000	12,056	32,536	0	10	34,655	60,547
1997–98	7,695	10,000	15,452	18,000	14,292	32,536	0	10	37,439	60,547
1998–99	5,767	10,000	15,111	18,000	13,574	32,536	0	10	37,439	60,547
1999–00	2,866	10,000	10,306	18,000	7,889	32,536	0	10	21,061	60,547
2000–01	8,360	10,000	2,744	18,000	15,703	32,536	0	10	26,806	60,547
2001–02	5,247	10,000	5,000	18,000	22,338	32,536	0	10	32,586	60,547
2002–03	6,172	10,000	2,225	18,000,	26,084	32,536	0	10	34,483	60,547
2003–04	7,396	10,000	,705	18,000	28,888	32,536	0	10	36,989	60,547
2004–05	9,418	10,000	716	18,000	36,507	32,536	0	10	46,641	60,547
2005–06	9,924	10,000	5,000	18,000	27,782	32,536	0	10	42,706	60,547
2006–07	5,293	10,000	1,857	18,000	32,039	32,537	0	10	39,189	60,547

Increased availability of jack mackerels caused by the influx of *T. murphyi* resulted in increased quotas in JMA 1 and JMA 3, to 8,000 t and 9,000 t respectively for the 1993–94 fishing year, and a further increase to 10,000 t and 18,000 t respectively for the 1994–95 fishing year. The latter increases were made under the proviso that they be accounted for by increased catches of *T. murphyi* only; combined landings of *T. declivis* and *T. novaezelandiae* in JMA 1 and JMA 3 were not to exceed the original quotas of 5,970 t and 2,700 t respectively. Industry agreed to these limits and voluntarily introduced monitoring programmes to provide the necessary catch composition information.

Total landings in JMA 3 over the period 1984–85 to 1988–89 were relatively constant, and below the quota of 2,700 t. Landings increased over subsequent years to peak in 1992–93 at almost three times that of the preceding year and more than five times the quota. Under the first of two consecutive annual increases to the JMA 3 TACC in 1993–94, landings were slightly above the first increased limit set, but then fell below the higher TACC level in 1994–95. The lower 1994–95 catch relative to that in 1992–93 has been attributed to the delayed implementation of the quota, less targeting of jack mackerel, and reduced bycatch in the squid trawl fishery. The reduced effort is thought to be a result of marketing difficulties for the relatively lower valued *T. murphyi*. Landings in JMA 3 increased markedly in 1995–96 to 19,803 t, exceeding the quota, with catches remaining stable around 15,500 t over the three subsequent years. More recently, landings have decreased to levels well below the TACC, with only 2,225 t recorded in 2002–03, 705 t in 2003–04 and 716 t in 2004–05. The 5,000 t taken in 2005–06 was therefore unexpected, given that the majority of catch is of *T. murphyi*, which has shown strong declining trends in other areas.

JMA 7: Landings in JMA 7 represent the greatest proportion of total landings and are mainly taken by chartered trawlers. Landings fluctuated between 17,402 t and 25,880 t from the mid-1980s through the mid-1990s. The marked decrease to 12,270 t in 1995–96 is attributed to changes in fishing strategies. In particular, mid-water trawling. has been banned between 02h00. and 04h00 under a code of practice implemented since 1995–96 to eliminate dolphin bycatch in JMA 7. The major fishing company then withdrew from the fishery for much of the season, and there were ongoing difficulties marketing the

relatively low valued *T. murphyi*. From 1995–96 to 1998–99, landings were in the range 12,056 t – 14,292 t. Recently, combined species landings have increased steadily from 15,703 t in 2000–01 to 28,883 t in 2003–04 and 36,497 t in 2004–05. The 2004–05 landings were 3,961 t in excess of the TAC. This increase in JMA 7 landings has been attributed to market demand and cuts in quotas for other more preferred species.

Proportion of *Trachurus murphyi* in New Zealand Catches

Taylor & Julian (2008) provide a useful summary of estimates of annual proportions of the various JMA species in New Zealand commercial catches in JMAs 1, 3 and 7, presented separately for different years in previous reports by Taylor (1999, 2000b, 2002 and 2004). The estimated proportions of *T. murphyi* (JMM) in New Zealand jack mackerel catches in JMA 1 (from shed sampling of the purse-seine fishery), and in JMAs 3 and 7 (from scientific observer data collected on trawl trips) are summarised in Table 2 and plotted in Figure 2. (Note that no data are available for purse-seine catch proportions prior to 1994-95, although it is clear from the catch increases that JMM was contributing to increasing catches in similar proportion to catches observed in JMA 7. Purse-seine proportions from 1985-86 to 1993-94 have therefore been estimated from a sigmoid curve through JMA 7 trawl proportions one year later.)

New Zealand is currently developing a Bayesian estimation procedure to help refine the estimates of species proportions for years / seasons where the number of samples is low. It is likely that there will be some small changes to the species-specific catch history once these improved estimation procedures have been developed. Estimates of *T. murphyi* provided in this paper should therefore be considered preliminary. However, improved estimation procedures are not expected to change these proportion estimates substantially.

From Figure 2 it can be seen that virtually the entire catch of jack mackerels in the developing trawl fishery on the eastern Chatham Rise consisted of JMM by about 1985/86, at a time when JMM was not yet contributing to catches in JMA 1 or JMA 3. JMM proportions in catches in these other areas increased steadily from 1989-90 to reach about 40% by 1995-95, subsequently declining from about 1996-96 onwards to below 10% by 1999-00 in JMA 1, and 2001-02 in JMA 7. Proportions of JMM in catches in JMA 3 have remained mostly above 50%, although with strong fluctuations, and periods of decline, in recent years.

These estimated JMM proportions were used to estimate annual catches of JMM in the three QMAs from the total reported catches shown in Table 1. Resultant estimated catches of JMM by QMA area are summarised in Table 3, and plotted in Figure 3, in comparison with total reported Chilean jack mackerel catches in the South Pacific Ocean.

Figure 3 shows the rapid increase in estimated New Zealand catches of JMM from around zero in 1986-87 to a peak of over 25,000 t in 1995-96, followed by a similarly steep decline in catch to only 2,400 t in 2002-03. The start of the increased contribution of JMM to New Zealand catches appears to have lagged a few years behind the rapid increase in South Pacific jack mackerel catches, which had been increasing steadily from 1976 onwards, but increased very rapidly after 1987. The subsequent decline in New Zealand JMM catches also seems to have lagged a couple of years behind the rapid decline in South Pacific catches that occurred from 1996 to 2000. The recent slight increase in South Pacific jack mackerel catches also seems to be reflected in an upturn in New Zealand JMM catches in recent years.

Table 2. Estimated annual proportions of *Trachurus murphyi* in New Zealand jack mackerel catches by quota management area from 1985-86 to 2005-06. (Shaded cells show proportions estimated for purse-seine catches prior to availability of sampling information, using JMA 7 trawl proportions one year later.)

Fishing Year	JMA 1 Purse seine	JMA 3 Trawl	JMA 7 Trawl
	Estimated		
1985-86	0.00	1.00	0.00
1986-87	0.00	0.00	0.00
1987-88	0.00	0.79	0.00
1988-89	0.01	1.00	0.07
1989-90	0.03	0.70	0.01
1990-91	0.09	1.00	0.03
1991-92	0.17	1.00	0.09
1992-93	0.33	0.86	0.17
1993-94	0.41	0.76	0.35
1994-95	0.45	0.96	0.34
1995-96	0.13	0.98	0.41
1996-97	0.30	1.00	0.15
1997-98	0.42	0.98	0.14
1998-99	0.30	0.85	0.12
1999-00	0.01	0.65	0.19
2000-01	0.01	0.83	0.19
2001-02	0.01	0.66	0.05
2002-03	0.02	0.32	0.06
2003-04	0.09	0.97	0.06
2004-05	0.07	0.76	0.07
2005-06	0.00	0.54	0.07

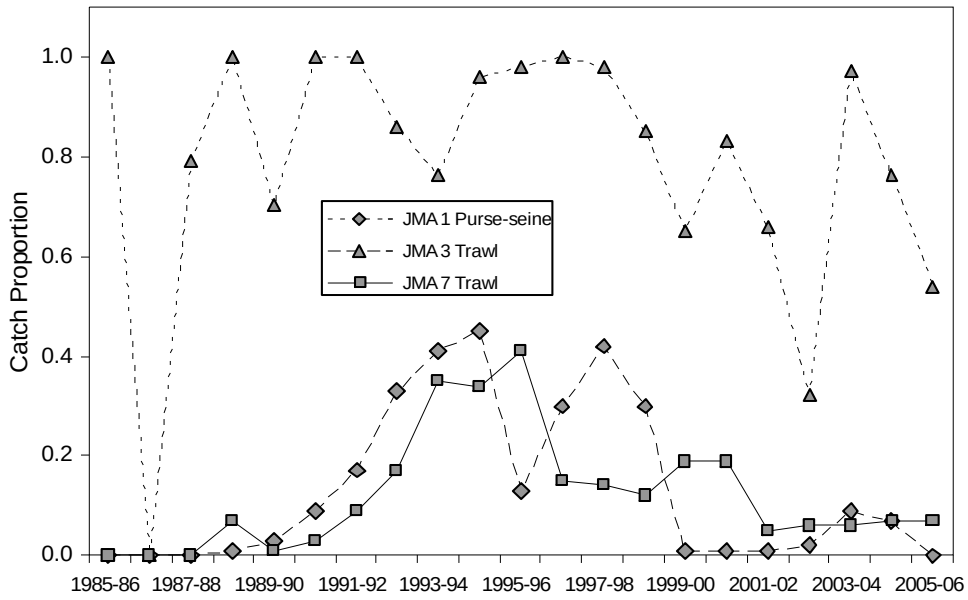

Figure 2. Estimated annual proportions of *Trachurus murphyi* in New Zealand jack mackerel catches by quota management area from 1985-86 to 2005-06.

Table 3. Reported New Zealand combined annual catch of all jack mackerels (JMA) by quota management area, and estimated annual catches of *T. murphyi* (JMM) by management area derived using the species proportions in Table 1. (Shaded cells show catch estimates from proportions estimated for purse-seine catches prior to availability of sampling information, using JMA 7 trawl proportions one year later.)

Fishing Year	JMA Catch (t)			JMA Total	JMM Catch (t)			JMM Total	S Pacific Total
	JMA 1	JMA 3	JMA 7		JMA 1	JMA 3	JMA 7		
1983-84	3,682	715	12,464	16,861	?	?	?	?	2,324,010
1984-85	1,857	1,223	16,013	19,093	Estimated	?	?	?	2,148,841
1985-86	1,173	2,228	10,002	13,403	0	2,228	0	2,228	1,960,897
1986-87	4,056	1,638	19,815	25,509	0	0	0	0	2,681,782
1987-88	3,108	1,883	17,827	22,818	0	1,488	0	1,488	3,245,699
1988-89	2,986	1,919	17,402	22,307	30	1,919	1,218	3,167	3,654,628
1989-90	4,226	4,013	21,776	30,015	127	2,809	218	3,154	3,828,452
1990-91	6,472	6,403	17,786	30,661	582	6,403	534	7,519	3,953,748
1991-92	7,017	5,779	25,880	38,676	1,193	5,779	2,329	9,301	3,376,607
1992-93	7,529	15,399	24,767	47,695	2,485	13,243	4,210	19,938	3,376,871
1993-94	14,256	9,115	22,377	45,748	5,845	6,927	7,832	20,604	4,261,941
1994-95	7,832	11,519	18,913	38,264	3,524	11,058	6,430	21,013	4,955,186
1995-96	6,874	19,803	12,270	38,947	894	19,407	5,031	25,331	4,378,843
1996-97	6,912	15,687	12,056	34,655	2,074	15,687	1,808	19,569	3,597,117
1997-98	7,695	15,452	14,292	37,439	3,232	15,143	2,001	20,376	2,025,758
1998-99	5,767	15,111	13,574	34,452	1,730	12,844	1,629	16,203	1,423,447
1999-00	2,866	10,306	7,889	21,061	29	6,699	1,499	8,226	1,540,494
2000-01	8,360	2,744	15,703	26,807	84	2,278	2,984	5,345	2,508,834
2001-02	5,247	5,000	22,338	32,586	52	3,300	1,117	4,470	1,750,078
2002-03	6,172	2,225	26,084	34,481	123	712	1,565	2,401	1,736,048
2003-04	7,396	705	28,888	36,989	666	684	1,733	3,083	1,779,215
2004-05	9,418	716	36,507	46,641	659	544	2,556	3,759	1,663,541
2005-06	9,924	5,000	27,782	42,706	0	2,700	1,945	4,645	1,828,999

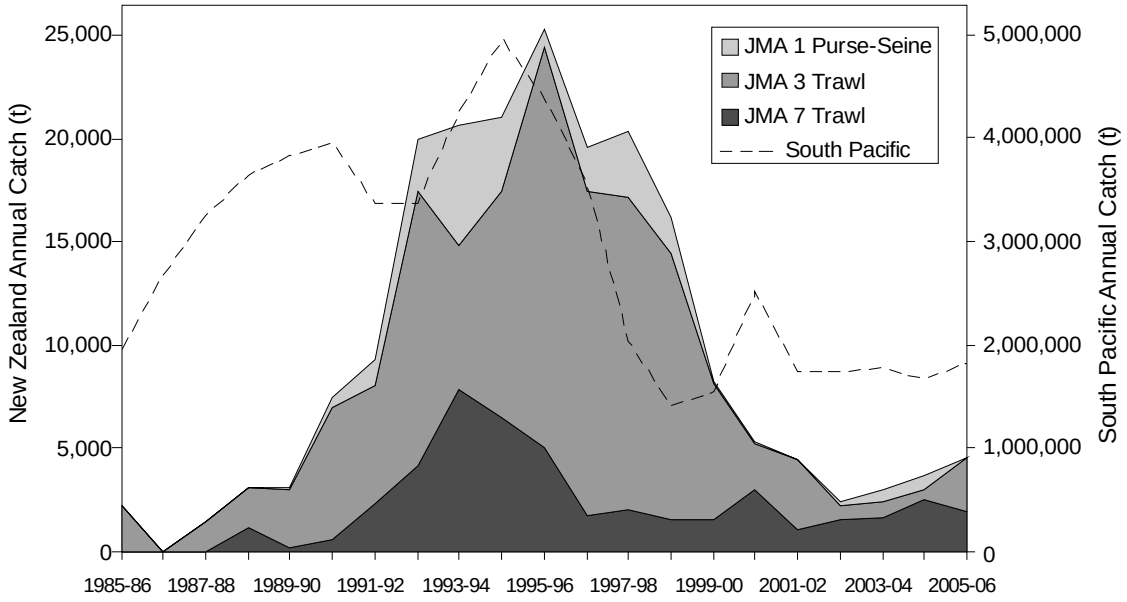

Figure 3. Annual new Zealand catches of *Trachurus murphyi* by quota management area from 1985-86 to 2005-06, estimated from proportions of *T. murphyi* in jack mackerel catches shown in Figure 2, compared with total annual catches of Chilean jack mackerel in the South Pacific Ocean.

New Zealand *Trachurus murphyi* Catch Rates

Data from the New Zealand jack mackerel trawl fishery have been used to conduct first exploratory analyses of catch rates for *T. murphyi*. The participants in this trawl fishery have changed over time, and two groups of vessels are apparent in the fishery. One group ('past' vessels) operated from 1990 to about 1998, and a second group ('present' vessels) operating from somewhere between 1992 and 2001 to the present, with an increase in fishing power from the past to the present vessels (Taylor *et al* 2008). The present vessels have higher catch rates, particularly before 1998. Before 2000 the present vessels towed for longer, at higher speeds, and at greater depths. Present vessels are larger and their tows are nearly all mid-water trawl vessels, with greater wingspread and headline height compared with the past vessels. However, two of the present vessels have operated consistently from 1992 until now, allowing catch rate data from the two groups of vessels to be combined into a standardised CPUE analysis able to model this vessel effect.

For this analysis, a core set of 11 vessels was selected with at least 50 non-zero tows for *T. murphyi* for five or more years over the analysis period (Taylor *et al* 2008). Initial standardised CPUE analysis for these vessels (Figure 4) shows that high catch rates characterised the period of high catches from 1991-92 to 1996-97. Catch rates declined rapidly by almost 75% from 1996 to 1998, apparently reflecting a decrease in regional abundance which resulted in the steep decline in New Zealand *T. murphyi* catches from 1997-98 to 2000-01. The decrease in New Zealand catch rates also coincides closely with the decline in total South Pacific catches of *T. murphyi*, suggesting a link between catch declines across the South Pacific after 1996.

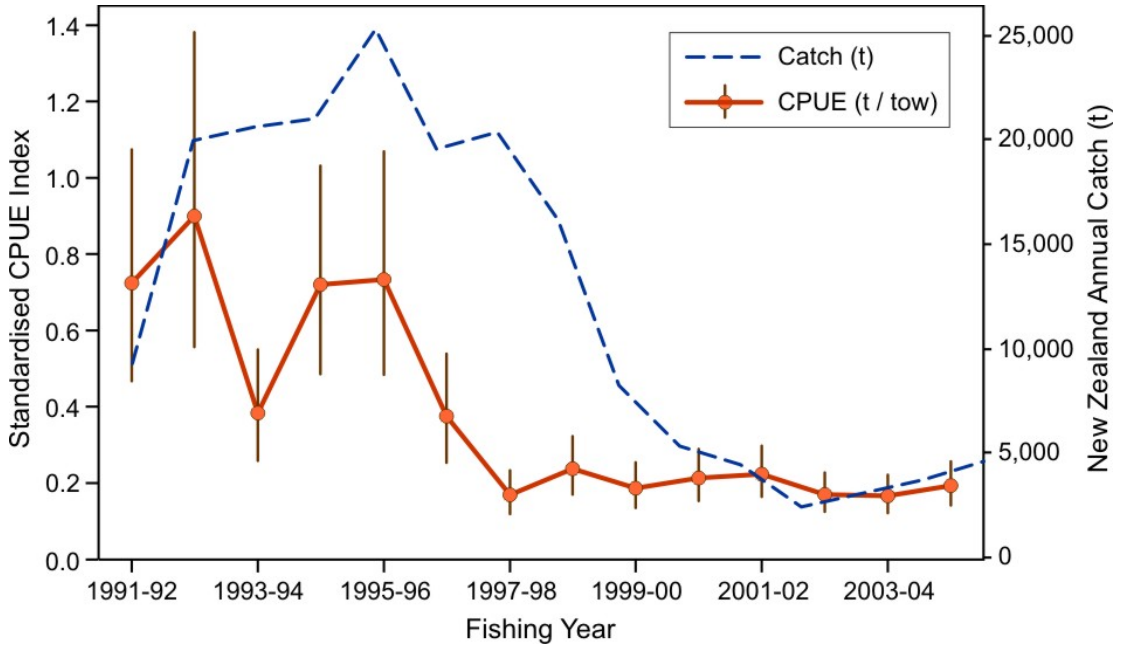

Figure 4. Standardised catch rates of *Trachurus murphyi* (tons per tow) and total catch (t) from 1991–92 to 2004–05 for vessels participating in the New Zealand jack mackerel trawl fishery (adapted from Taylor *et al* 2008).

Geographic Distribution of Catches

Figure 5 shows a sequential time-series of distribution maps of JMM catches in New Zealand waters from 1984-85 through to 2006-07, covering the entire period of the increase and subsequent decline in JMM contribution to New Zealand jack mackerel catches (from Taylor *et al* 2008).

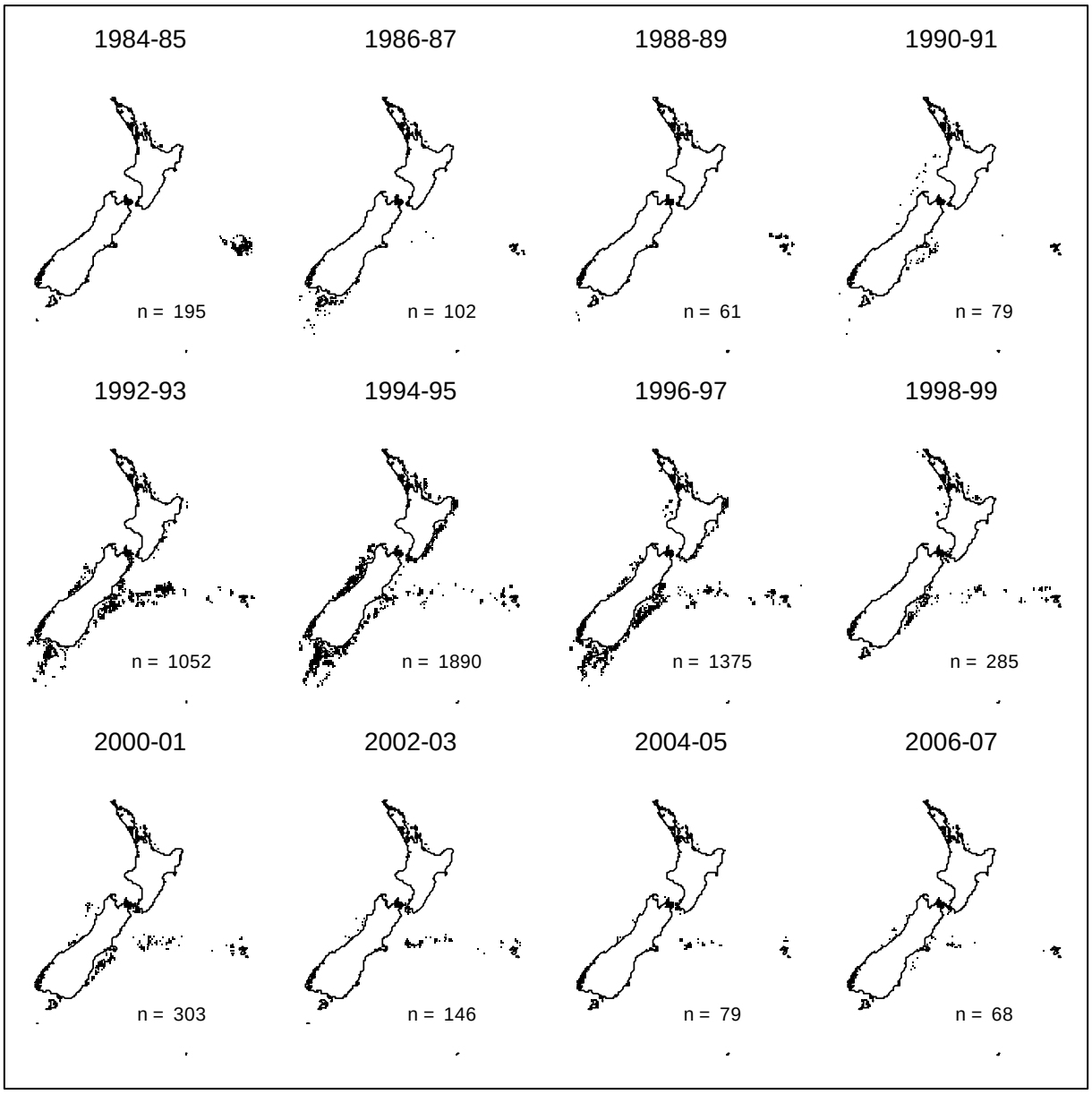

Figure 5. Biennially aggregated (calendar years) distribution of tows in which *T. murphyi* was caught around New Zealand from 1984-85 to 2006-07, showing expansion and contraction of *T. murphyi* distribution in the New Zealand EEZ (from research trawl and scientific observer data) (reproduced from Taylor *et al* 2008).

These maps show a steady westwards progression, and then eastwards retraction, of JMM catches in the New Zealand EEZ as catches increased and then declined. *T. murphyi* first appeared in New Zealand catches in significant quantities in 1984-85 in the far eastern end of the EEZ, around the Chatham Islands, in JMA 3. From 1986-87 to 1992-93, the species increasingly contributed to catches westwards in JMA 3 across the Chatham Rise, down the South Island east coast and into the southern end of the South Island (Taylor *et al* 2008). By 1994-95, *T. murphyi* was contributing substantially to catches across the whole of JMA 3, around the entire South Island. From about 1991 onwards, *T. murphyi* also increasingly contributed to catches around the north Island, initially in the northern Bay of Plenty region, and then further west onto the North Island west coast.

From 1996-97 onwards, the distribution of catches then shows the reverse trend, decreasing first along the New Zealand west coast, and then the north coast, coinciding with the decline in catch rates and total *T. murphyi* catches. By 2004-05, this species was again only being caught in significant

quantities towards the east, along the Chatham Rise and, by 2006-07, mainly being caught around the Chatham Islands again.

Length & Age Frequency Composition

Length-frequency distributions of *T. murphyi* sampled by shed-sampling or scientific observer programs are show in Figure 6 for JMA 3 and JMA 7 in 1991, and in Figure 7 for JMA 3 from 1992-93 to 2000-01 (from Taylor *et al* 2008).

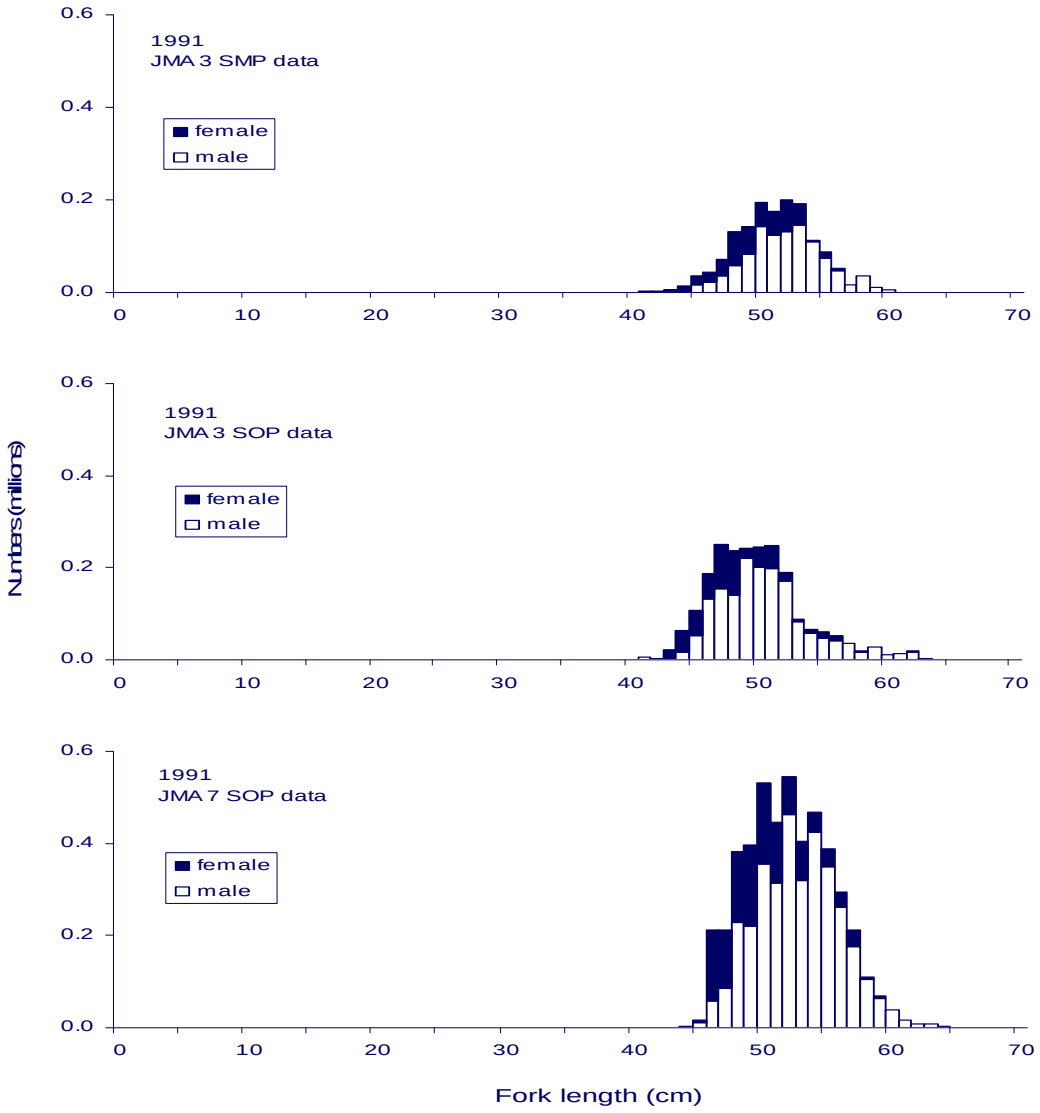

Figure 6. Scaled length frequency distributions of *Trachurus murphyi* sampled in JMA 3 and JMA 7 by shed monitoring (SMP) and scientific observer (SOP) programmes in 1991, showing size distributions of males and females (reproduced from Taylor *et al* 2008).

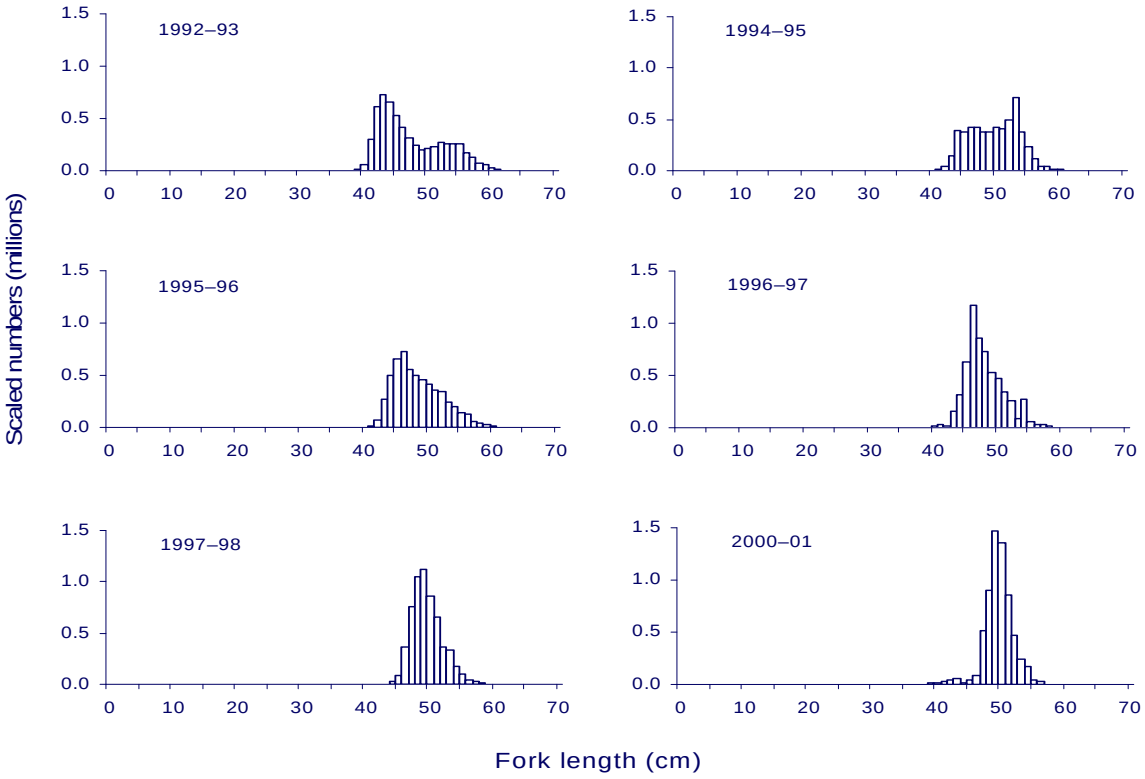

Figure 7. Scaled length frequency distributions of *Trachurus murphyi* sampled in JMA 3 from 1992-93 to 2000-01, all sexes combined (reproduced from Taylor *et al* 2008).

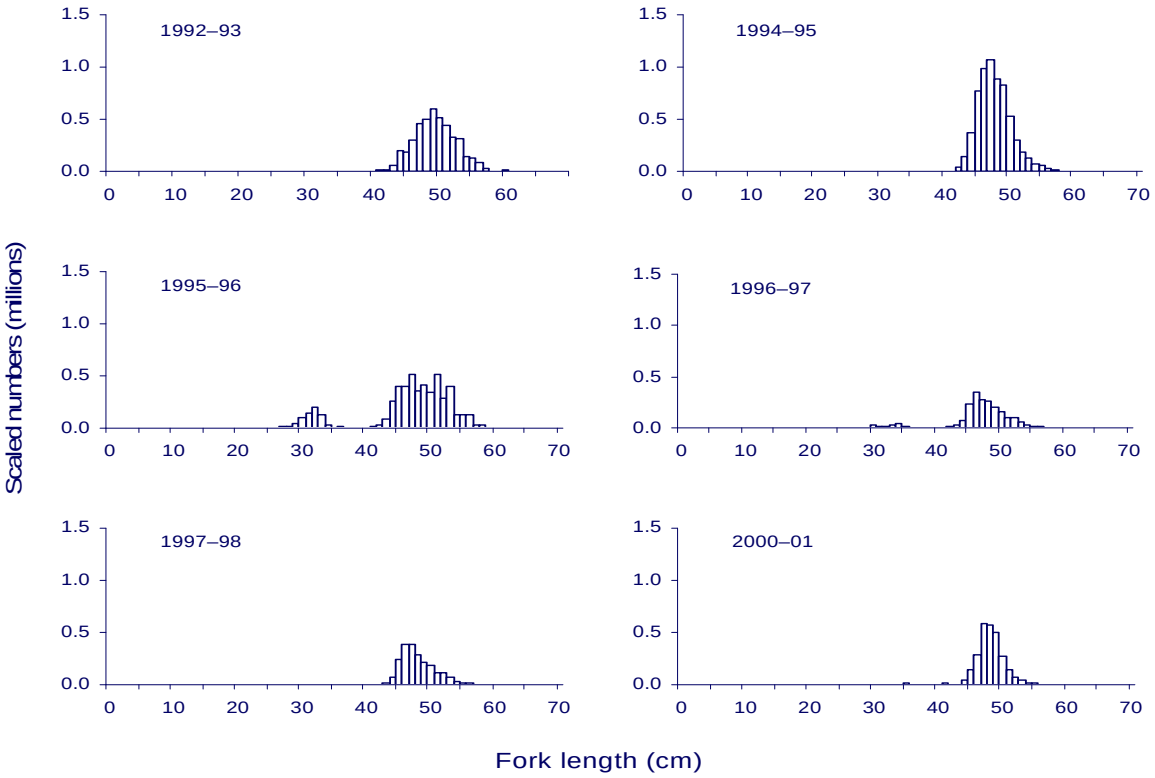

Figure 8. Scaled length frequency distributions of *Trachurus murphyi* sampled in JMA 7 from 1992-93 to 2000-01, all sexes combined (reproduced from Taylor *et al* 2008).

Despite the substantial changes seen in catch rates and total catches, there has been little change in length frequency distributions between 1991 and 2005 , generally showing a single mode ranging from about 40 to 60 cm. There is also little difference between size ranges between JMA 3 and JMA 7, although with some larger fish in 1991 and some smaller fish in JMA 7 between 1995 and 1997.

Initial ageing of *T. murphyi* caught in New Zealand waters has recently been completed, although the estimates still need to be validated. Initial growth is rapid, slowing at 6–7 years, and *T. murphyi* appears to reach a maximum observed age of 32 years. Age-frequency distributions for fish caught in JMA 3 and JMA 7 are shown in Figures 9 and 10.

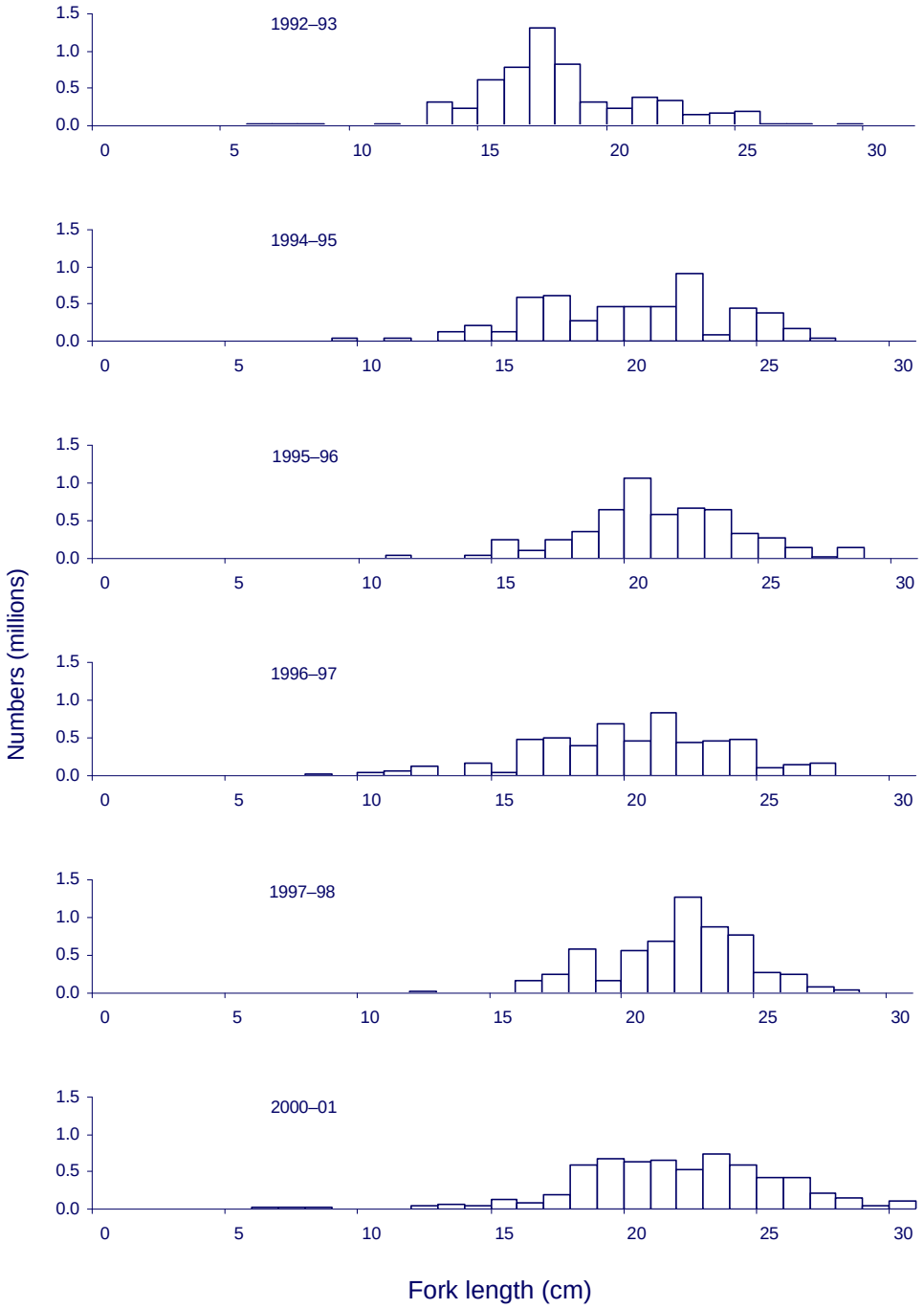

Figure 9. Estimated age frequencies of *Trachurus murphyi* sampled in JMA 3 from 1992-93 to 2000-01 (reproduced from Taylor *et al* 2008).

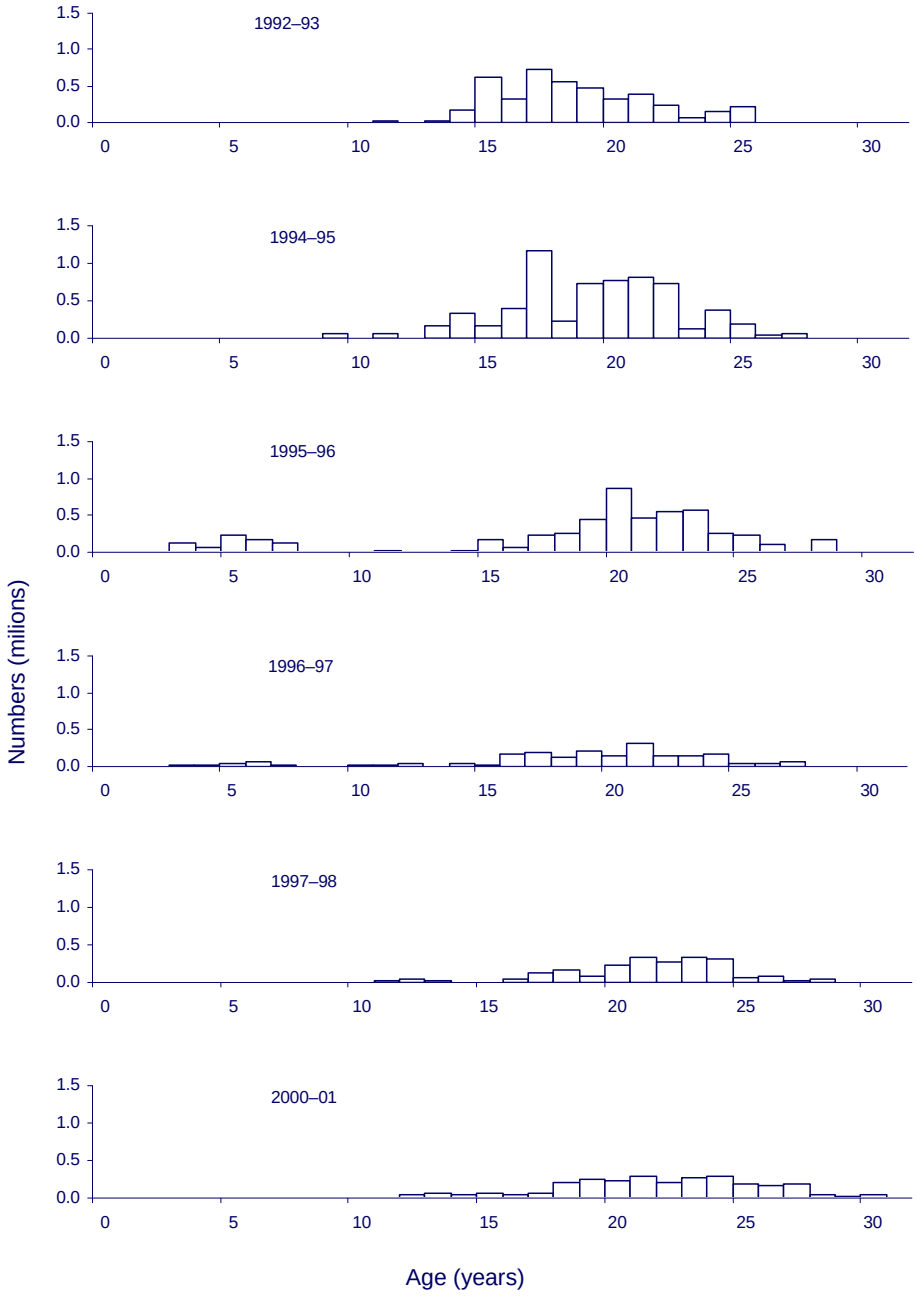

Figure 10. Estimated age frequencies of *Trachurus murphyi* sampled in JMA 7 from 1992-93 to 2000-01 (reproduced from Taylor *et al* 2008).

There appears to be little difference in the range of ages in New Zealand catches between 1991 and 2005, with most fish aged to be between 10 and 35 years of age (Taylor *et al* 2008). However, there are few fish older than 25 yr in the early 1990s, with maximum age increasing to 31 yr by 2000-01, and 35 yr by 2005, and an apparent steady increase in modal size over the period. This would suggest steady ageing of a remnant population, derived from some major influx into the region, with little subsequent recruitment. However, there are indications of appearance of small numbers of 3 - 7 year old fish in JMA 3 in 2000-01 and in JMA 7 in 1995-96 and 1996-97, suggesting some immigration at those times.

Jack Mackerel Biology

The three species of jack mackerel in New Zealand waters have different geographical distributions, but their ranges partially overlap. *T. novaezelandiae* predominates in waters shallower than 150m and warmer than 13°C; it is uncommon south of latitude 42°S. *T. declivis* generally occurs in deeper (< 300 m) waters less than 16°C, north of latitude 45°S. *T. murphyi* occurs to depths of least 500 m and has a wide latitudinal range (from 0°S at the Galapagos Islands and coastal Ecuador, to south of 40°S off the Chilean coast).

T. murphyi was first described in New Zealand waters in 1987. Its presence was recorded off the south and east coasts of the South Island in the mid-1980s. It expanded onto the west coast of the South Island and the North and South Taranaki Bights by the late 1980s, reaching the Bay of Plenty in appreciable quantities by 1992 and becoming common on the east coast of Northland by June 1994. However, this extensive distribution has decreased in more recent years and, since the late 1990s, its presence north of Cook Strait has been sporadic with occasional landings in the JMA 1 purse seine fishery north of East Cape and from the JMA 1 inshore trawl fishery south of East Cape.

All jack mackerel species can be caught by bottom trawl, mid-water trawl, or by purse seine targeting surface schools. Vertical and horizontal movement patterns are poorly understood, but jack mackerels are presumed to be generally off the bottom at night, and surface schools can be quite common during the day.

Jack mackerels have a protracted spring summer spawning season. *T. novaezelandiae* probably matures at about 26–30 cm fork length (FL) at an age of 3–4 years, and *T. declivis* matures when about 26–30 cm FL at an age of 2–4 years. Spawning occurs in the North and South Taranaki Bights, and probably in other areas as well.

The reproductive biology of *T. murphyi* in New Zealand waters is not well understood. Pre and post-spawning fish have been recorded from the Chatham Rise, Stewart-Snares shelf, Northland east coast and off Kaikoura in summer, but it is unknown whether there has been any resulting recruitment in New Zealand waters. A recent study showed that older size/age groups become increasingly dominant in catches as one moves westward from the South American coast, suggesting that an eastward migration of oceanic spawned larvae and juveniles occurs in the South Pacific.

Table 4. Estimates of key biological parameters for the three species of jack mackerel fished in New Zealand waters.

Parameter				Estimate	Source
***Natural Mortality* (M)**					
All				0.18	Horn (1991)
	considered best estimate for both endemic species from all areas.				
***Weight = a. length ^{b}* (Weight in g, length in cm fork length).**					
			All		
	a		*b*		
T. declivis	0.023		2.84		Horn (1991)
T. novaezelandiae	0.028		2.84		Horn (1991)
Von Bertalanffy Growth Parameters					
			All		
	L_∞	*k*	t_0		
T. declivis	46cm	0.28	-0.40		Horn (1991)
T. novaezelandiae	36cm	0.30	-0.65		Horn (1991)
T. murphyi	51.2cm	0.155	-1.4		Taylor (2002b)

Stock Structure Hypotheses

Relevant publications and information on stock structure of *T. murphyi* occurring in New Zealand waters, and possible relationships between these and jack mackerel in the remainder of the South Pacific Ocean, were reviewed by Taylor (2002a). The sequential expansion and contraction of geographic catch distribution, and the rapid increase and decrease in catches and catch rates of *T. murphyi* in New Zealand waters, between the mid-1980s and 2000, all indicate that a substantial invasion of New Zealand waters occurred in the early part of that period. The initial appearance of these fish in catches around the Chatham Islands, and the subsequent expansion into most areas around New Zealand, indicate that the invasion came from the east, following an extended period of increasing commercial *T. murphyi* catches across the South Pacific Ocean in areas in which a fishery had previously not been viable. The invasion of New Zealand waters therefore seems to have resulted from a substantial expansion of the South American *T. murphyi* resource across the entire South Pacific 'jack mackerel belt', into the New Zealand region.

There are two possible hypotheses regarding the subsequent stock structure of *T. murphyi* in New Zealand waters since its appearance in the mid-1980s. These fish may now either constitute a separate stock originally established by fish migrating from South America, but now separate from South American stocks; or these fish may be part of a more extensive stock in the South Pacific, periodically supplemented by further migrations into New Zealand waters from the east. Most current evidence favours the latter hypothesis, of New Zealand jack mackerel being linked to either an extensive stock distributed in the South Pacific Ocean between latitudes 35–50°S, linking the coasts of Chile and New Zealand, or at least to an extensive SW Pacific Ocean stock (such as proposed by Kalchugin 1992).

Declines in catches and catch rates after 1996, and the eastwards contraction of the stock as catches declined, coincide closely with declines in the remainder of the South Pacific. There has been some evidence of successful local spawning, with juveniles observed from the South Taranaki Bight and south of East Cape), but not enough to support the hypothesis that the ongoing presence of medium sized fish in the New Zealand fishery is from local spawning. Periodic appearance of 3 - 7 year old fish in New Zealand waters in some years suggests ongoing immigration. This is supported by the sustained presence of *T. murphyi* on the Chatham Rise right through to 2004-05, despite virtual disappearance from other areas of the New Zealand EEZ, suggesting ongoing immigration from the east into the area around the Chatham Islands. There has been some reporting of an area of spawning in mid-South Pacific waters roughly 130° - 155° W, 35° - 40° S (Elizarov et al. 1993, Evseenko 1987), from which subsequent invasions may have originated. Most of the available data therefore seem to indicate that the New Zealand *T. murphyi* 'stock' is a small, and perhaps periodically separated, component of a larger South Pacific stock which undergoes periodic expansions or migrations.

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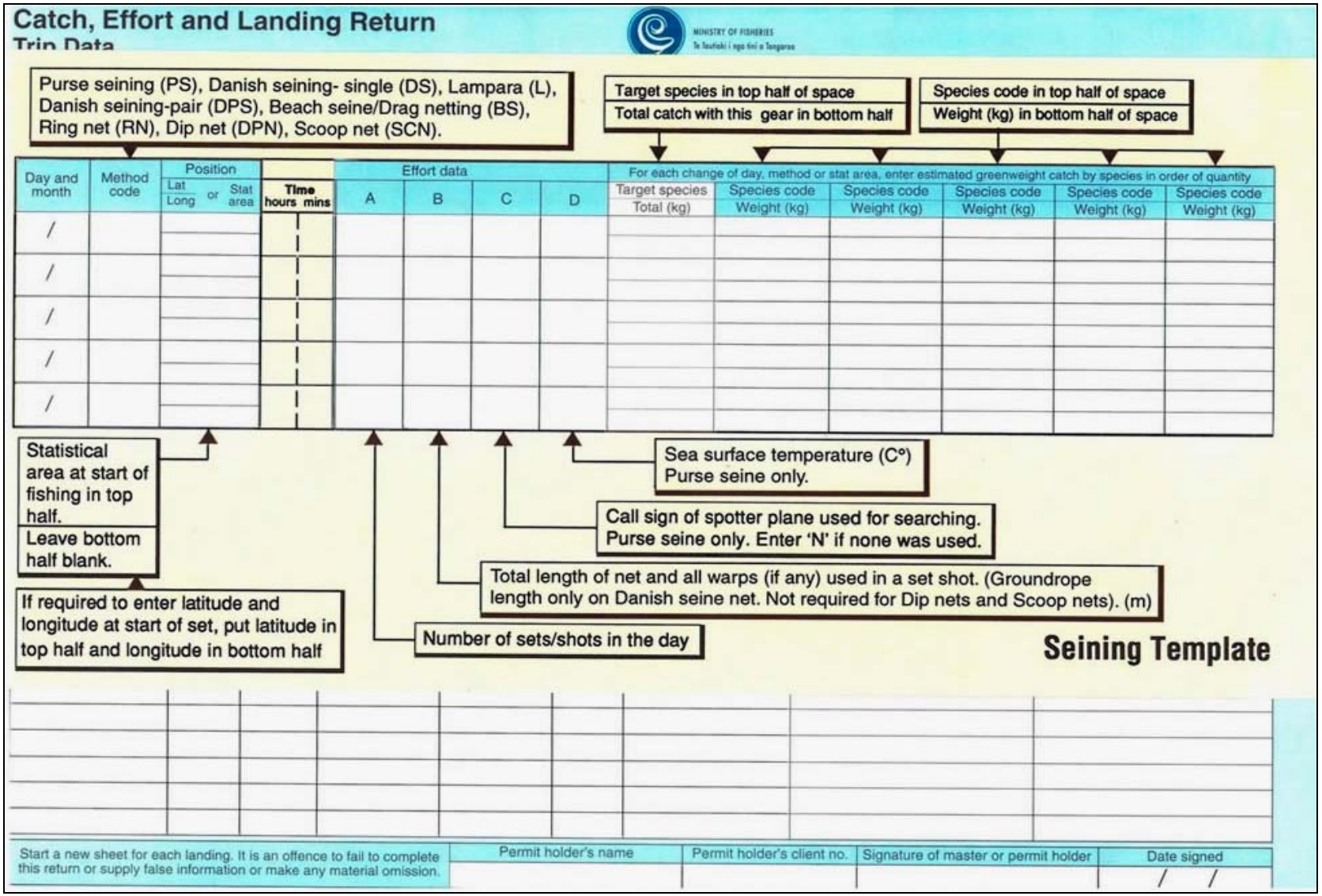
Appendix A

Examples of data returns / templates used for reporting catch and effort data for the New Zealand purse-seine and trawl fisheries

a) Purse -seine - Catch Effort Landing Return (CELR)



b) Trawl Catch, Effort and Processing Return (TCEPR)

MINISTRY OF FISHERIES
Te Tautiaki i nga tini a Tangaroa

Trawl, Catch, Effort and Processing Return

To be completed on each day at sea 515304

Date	Vessel's registration number (your vessel)	Vessel name (your vessel)
/ /		

Vessel registration number of other vessel (if pair fishing)

Position at midday (noon)			Water temperature at shot 1		Page	
Latitude		Longitude E/W	Surface	Bottom	of	
	S					

Shot	Time	Latitude Deg	Min		Longitude Deg	Min	E/W	Gear code / Headline height	Depth groundrope / Depth bottom	Trawling speed	Target species	Estimated catch by species in order of quantity: Quantity	Species code / Quantity (kg)	Species code / Quantity (kg)	Species code / Quantity (kg)	Species code / Quantity (kg)	Species code / Quantity (kg)
1 START				S								Total (kg)					
END				S													
2 START				S								Total (kg)					
END				S													
3 START				S								Total (kg)					
END				S													
4 START				S								Total (kg)					
END				S													
5 START				S								Total (kg)					
END				S													
6 START				S								Total (kg)					
END				S													

Daily Processing Summary

Species	Processed state	Number of processed units	Unit weight (kg)	Processed catch weight (kg)	Conversion factor	Calculated weight before processing (kg)

Species	Processed state	Number of processed units	Unit weight (kg)	Processed catch weight (kg)	Conversion factor	Calculated weight before processing (kg)

I declare that the information I have given on this return is correct and complete, and that I have read and understood the explanatory notes supplied with this return.

Product from offal only		Activity comment (Transhipping, steaming etc)	Permit holder's name	Permit holder's client number	Signature of master	Date signed
Meal (kg)	Oil (litres)					
						/ /

Appendix B

Summary of number of *T. murphyi* measured, minimum, mean and maximum lengths from New Zealand fisheries over 1986 - 2008

Year	No Measured	Min Length	Mean Length	Max Length
1986	110	53	58	62
1988	59	45	52	60
1989	939	37	56	63
1990	216	41	54	62
1991	3,903	31	51	64
1992	2,688	24	50	64
1993	10,487	29	51	64
1994	10,245	9	50	63
1995	8,672	15	49	68
1996	14,254	7	50	64
1997	6,514	16	49	62
1998	5,073	34	50	61
1999	6,219	24	49	65
2000	3,441	10	49	60
2001	3,684	35	49	60
2002	2,826	39	49	61
2003	690	30	50	59
2004	3,313	27	50	60
2005	4,921	16	50	61
2006	1,605	34	50	62
2007	3,955	30	50	65
2008	197	40	50	57
Total	94,011	7	51	68

Summary of number of *T. murphyi* otoliths, and the minimum, mean and maximum lengths of fish from which these were collected, from New Zealand fisheries over 1986 - 2008

Year	No Otoliths	Min Length	Mean Length	Max Length
1990	20	47	55	60
1991	288	41	51	60
1992	20	39	47	55
1993	179	41	54	63
1994	34	33	52	61
1995	71	41	52	61
1996	349	42	52	63
1997	92	43	50	61
1998	382	39	51	62
1999	38	46	51	58
2000	11	44	49	56
2002	3	49	50	51
2003	26	45	50	57
2004	626	33	49	81
2005	2,064	40	50	66
2006	813	40	50	62
2007	1,022	35	50	84
Total	6,038	33	51	84