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The New Zealand hoki fisheries from 1983 to 1993

S. L. Ballara and R. J. Hurst

New Zealand Fisheries Technical Report No. 46

ISSN 0113-2180

1997

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Published by NIWA
Wellington
1997

ISBN 0-478-08411-0

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PO Box 14 901, Wellington, New Zealand.

The *New Zealand Fisheries Technical Report* series in part continues the *Fisheries Research Division Occasional Publication* series. The *New Zealand Fisheries Occasional Publication* series contains mainly conference proceedings and bibliographies.

Edited by M. F. Beardsell
Set in 10 on 11 Times Roman
Printed by Madison Printing Company Limited

Cover photograph by Neil Bagley

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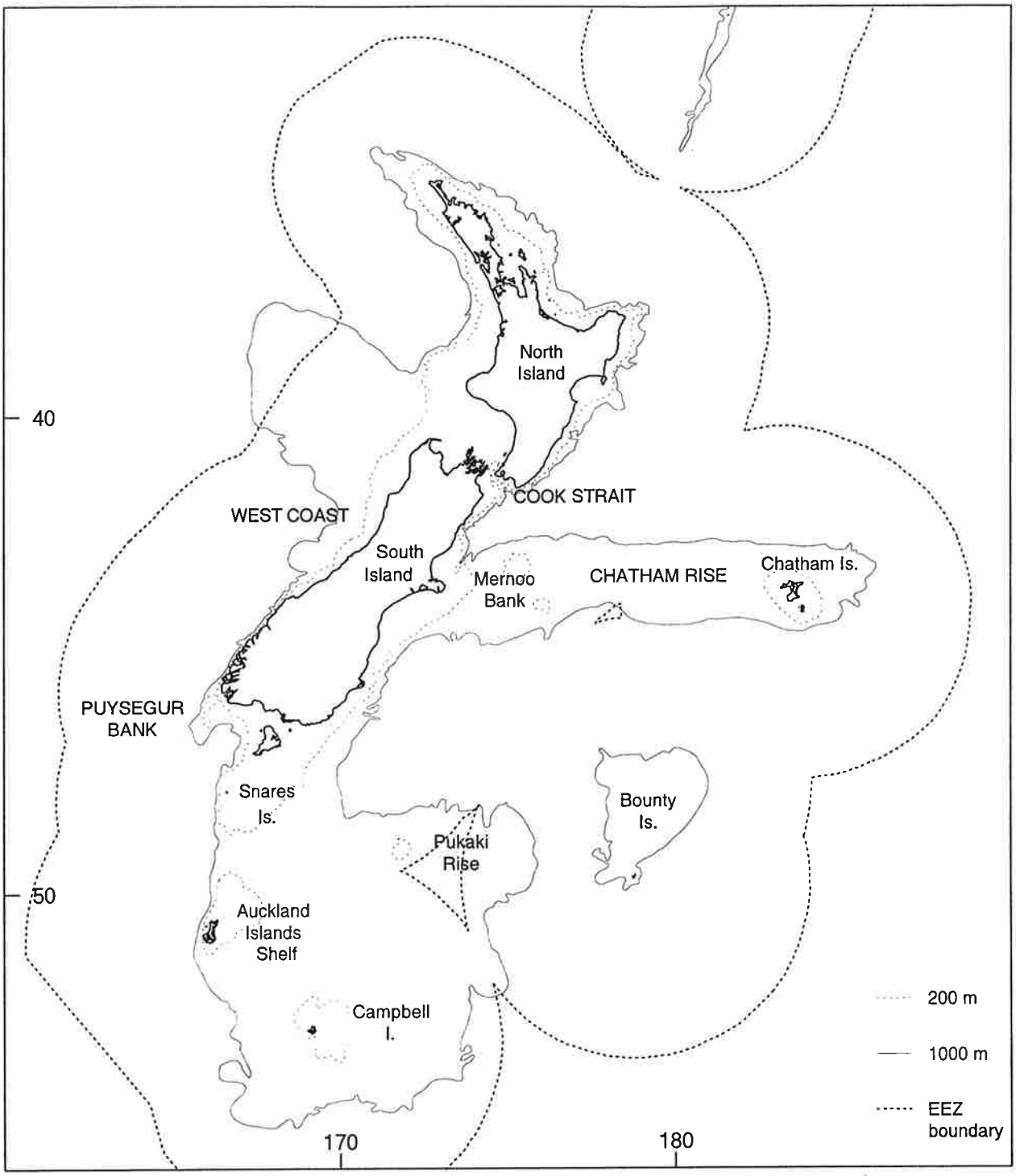

Figure 1a: The New Zealand 200 n. mile Exclusive Economic Zone (EEZ), main hoki fisheries (in capitals), and places mentioned in the text. The Southern area includes the Snares shelf and the Sub-Antarctic (Pukaki Rise, Auckland Islands Shelf, Campbell Plateau, and the Bounty Platform).

Abstract

Ballara, S. L. & Hurst, R. J. 1997: The New Zealand hoki fisheries from 1983 to 1993. ***New Zealand Fisheries Technical Report No. 46.*** **43 p.**

This report describes the commercial development of the New Zealand hoki (*Macruronus novaezelandiae*) fishery from 1983 to 1993. This has been a significant period of change for the fishery, with catches increasing from about 50 000 t to a maximum of 250 000 t, development of major spawning fisheries, and, more recently, the development of non-spawning, higher quality product fisheries. These changes have required the development of comprehensive commercial databases and more sophisticated stock assessment modelling techniques. Trends in data from the commercial catch and effort and scientific observer databases from 1983 to 1993 are summarised, including fishing location, annual and seasonal catches, bycatch, gear and fleet composition, product types, fish size frequencies, and spawning condition. The importance of these data for stock assessment and management of the fishery is discussed.

Introduction

Hoki fisheries worldwide

The hoki, *Macruronus novaezelandiae*, is a deepwater fish of the hake family Merluciidae, which occurs around New Zealand, Australia, and South America. New Zealand has the largest fishery (currently about 200 000 t annually). In Australia, hoki (known as blue grenadier) are found from New South Wales to southern Western Australia, including the coasts of Tasmania and across the Great Australian Bight (Tilzey 1994). Catches in 1993 totalled 4000 t. A closely related species, *Macruronus magellanicus,* off southern Chile and Argentina supported a fishery of about 130 000 t in 1993 and total annual catches of between 130 000 and 270 000 t from 1987 to 1992 (FAO 1995).

New Zealand hoki

Hoki are widely distributed throughout the New Zealand 200 n. mile Exclusive Economic Zone (EEZ) from 34° to 54° S and from 10 to over 900 m depth. Most adult hoki are found around the South Island (Figure 1a) between 300 and 800 m. They are a highly productive species with relatively fast growth (Livingston *et al.* 1992, Horn & Sullivan 1996) and high rates of estimated natural mortality (0.25 for females, 0.3 for males).

Adult hoki are thought to form two separate stocks (Figure 1b): a western stock which is resident in the Southern area, which includes the Snares shelf and the Sub-Antarctic area, and migrates to the west coast South Island (WCSI) to spawn in winter; and an eastern stock which is resident on the Chatham Rise and migrates to Cook Strait to spawn in winter (Livingston 1990a, Livingston *et al.* 1992). The spawning season occurs mainly between July and August when hoki form dense daytime aggregations which disperse off the bottom at night when eggs are released in mid water (Zeldis 1993). The planktonic eggs and larvae are dispersed to nursery grounds, predominantly on the Chatham Rise, where juveniles of both stocks are considered to mix (Livingston 1990a).

The New Zealand fishery

Patchell (1982) reviewed the history of the hoki fishery to 1982. The fishery was developed by foreign fishing vessels in the early 1970s and catches peaked at almost 98 000 t in 1977 (Table 1). After the declaration of the EEZ in 1978, and the introduction of quotas, catches were limited to 60 000 t overall with a 20 000 t limit on the WCSI fishery. Patchell (1982) also summarised catches and catch rates, fishing patterns, known spawning areas, fish size structure, larval distribution, and stock size estimates. He proposed seasonal spawning migration and larval dispersal patterns and concluded that the evidence suggested hoki in the New Zealand region were a unit stock.

Since the early 1980s, the hoki fishery and its management have developed significantly. Hoki is now the largest commercial fishery, with the 1995–96 fishing year Total Allowable Commercial Catch (TACC) set at 240 000 t. (A fishing year is a fishery management year from 1 October of one year to 30 September of the next year, e.g., 1995–96 is from 1 October 1995 to 30 September 1996.) For each year up to 1992–93, the TACC has varied between 200 000 and 250 000 t and hoki has become the most valuable species, with export earnings of about $180 million dollars a year (Parker 1994). More than half of the catch is now taken during the winter

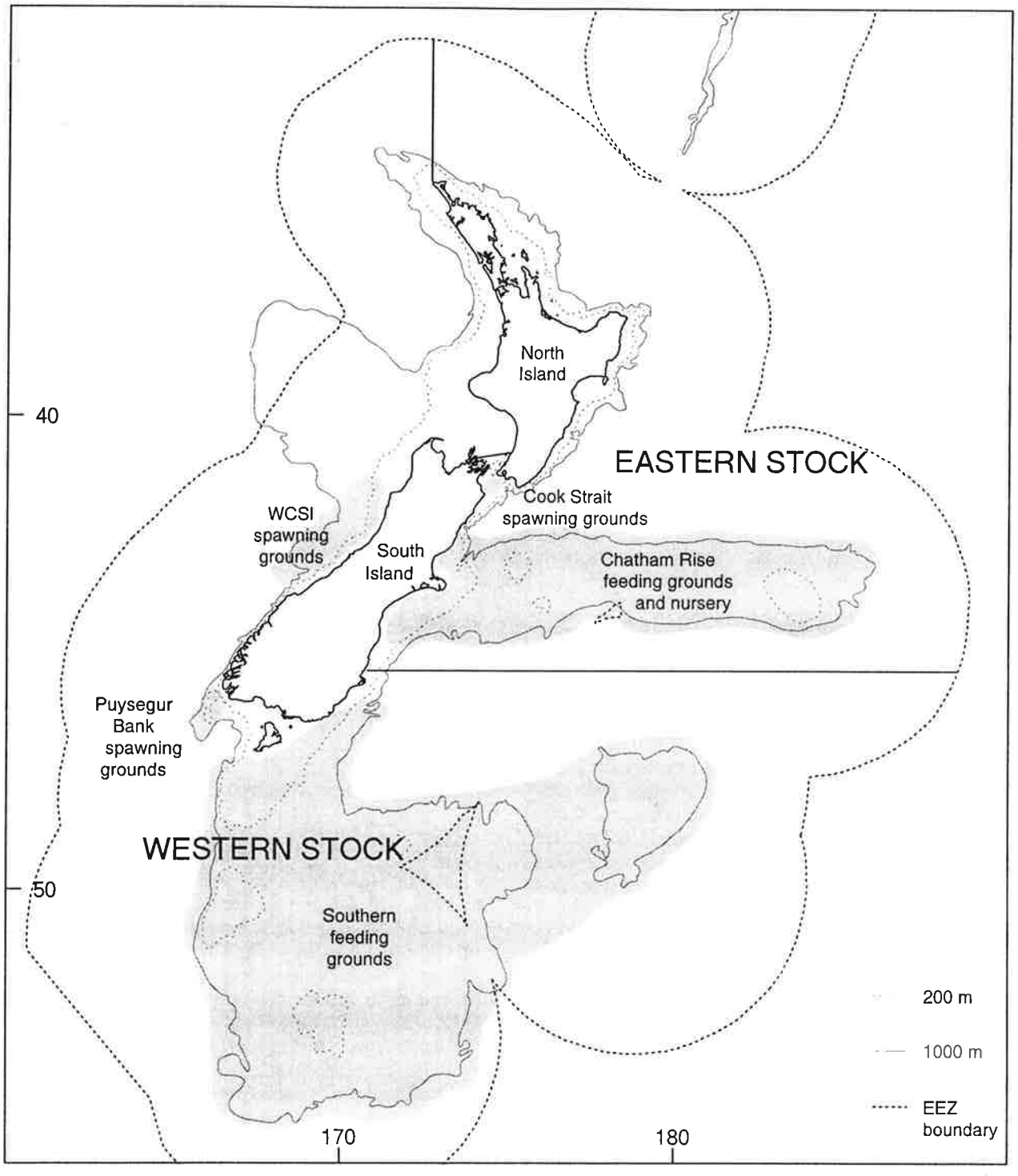

Figure 1b: Boundaries of the eastern and western stocks and main hoki fisheries areas.

Puysegur (Table 2, *see also* Figure 1a). The rest is taken throughout the year, mainly off the east coast of the South Island (ECSI), the Chatham Rise, and the Southern area.

Studies of commercial and research data from 1983 to 1993 led to the discovery of a Cook Strait spawning ground (Uozumi 1988, Murdoch & Chapman 1989, Livingston 1990b, Murdoch *et al.* 1990), an alternative two stock (eastern and western) hypothesis (Livingston 1990b), stock structure development (Kalish *et al.* 1996, Livingston *et al.* 1996), development of a variety of methods to monitor relative abundance (acoustic: Cordue 1988, 1989, 1991, 1994a; trawl: Chatterton & Hanchet 1994, Horn 1994a, 1994b, Schofield & Horn 1994, Ingerson *et al.* 1995, Ingerson & Hanchet 1995, Livingston *et al.* 1996; catch-per-unit-effort (cpue):

Table 1: Annual trawl catches (t) of hoki from the New Zealand EEZ, 1969 to 1983 by calendar year, 1983-84 to 1987-88 by fishing year (Oct-Sept). (Source: Fisheries Statistics Unit)

Year	U.S.S.R.	Japan	South Korea	New Zealand Domestic	New Zealand Chartered	Total
1969		95				95
1970		414				414
1971		411				411
1972	7 300	1 636				8 936
1973	3 900	4 758				8 658
1974	13 700	2 160		125		15 985
1975	36 300	4 748		62		41 110
1976	41 800	24 830		142		66 772
1977	33 500	54 168	9 865	217		97 750
1978*	† 2 028	1 296	4 580	678		8 581
1979	4 007	8 550	1 178	2 395	7 970	24 100
1980	2 516	6 554		2 658	16 042	27 770
1981	2 718	9 141	2	5 284	15 657	32 802
1982	2 251	7 591		6 982	15 192	32 018
1983	3 853	7 748	137	7 706	20 697	40 141
1983–84	4 520	7 897	93	9 229	28 668	50 407
1984–85	1 547	6 807	35	7 213	28 068	43 670
1985–86	4 056	6 413	499	8 280	80 375	99 623
1986–87	1 845	4 107	6	8 091	153 222	167 271
1987–88	2 412	4 159	10	7 078	216 680	230 339

* Catches for foreign licensed and New Zealand chartered vessels from 1978 to 1984 are based on estimated catches from vessel logbooks. Few data are available for the first 3 months of 1978 because these vessels did not begin completing these logbooks until 1 April 1978.

† Soviet hoki catches are taken from the estimated catch records and differ from official MAF statistics. Estimated catches are used because of the large amount of hoki converted to meal and not recorded as processed fish.

Table 2: Total estimated catch of hoki by area and TACC for 1982–83 to 1992–93 and catches reported to the Quota Management System (QMS), in tonnes *

Fishing year	Estimated total catch WCSI	Puysegur	Southern areas	Cook Strait	Chatham Rise	N.Z. total	TACC	QMS total
1982–83†	15 000	4 800	7 000	200	6 000	33 000	60 000	-
1983–84	20 900	5 800	12 000	400	8 000	50 000	60 000	-
1984–85	22 000	3 500	9 000	400	7 000	50 000	60 000	-
1985–86	69 800	2 000	10 000	300	16 000	99 000	120 000	-
1986–87	122 000	1 000	11 000	300	16 000	175 000	250 000	158 171
1987–88	220 000	1 000	5 000	600	15 000	255 000	250 000	216 206
1988–89	188 000	3 000	5 000	7 000	7 000	210 000	250 000	182 000
1989–90	165 000	8 000	10 000	14 000	13 000	210 000	251 844	209 000
1990–91	154 000	4 000	18 000	26 500	12 500	215 000	201 897	210 000
1991–92	105 000	5 000	34 000	25 000	46 000	215 000	201 897	210 000
1992–93	98 000	2 000	26 000	21 000	43 000	195 000	202 155	192 000

* Estimated catches are based on corrections to the QMS data. Catch records from 1985–86 to 1988–89 are estimated because of some discrepancies between figures reported to the QMS and presumed actual catches, arising from the use of low conversion factors to convert surimi product weight to greenweight of hoki. Catch records from 1989–90 to 1992–93 are also estimated because of minor error corrections to QMS data.

† From 1 Jan 1983.

Vignaux 1992, 1993, 1994), validation of ageing techniques (Horn & Sullivan 1996), more knowledge of nursery areas, recruitment patterns, and proportion of adults spawning: (Vignaux *et al.* 1995, Livingston & Schofield 1996), and more sophisticated population modelling to determine current and potential yields (*see,* for example, Cordue 1993, 1994a, 1994b, Cordue *et al.* 1992, Sullivan *et al.* 1995).

This report describes the commercial development of the hoki fishery in New Zealand from 1983 to 1993, using the commercial catch and effort and scientific observer and market sampling databases. It summarises location of fishing effort, annual and seasonal catch trends, bycatch, gear and fleet composition, product types, fish size frequencies, and spawning condition from these databases, and indicates how these data contribute to the assessment and management of the New Zealand hoki fishery.

Data sources and presentation

Commercial catch data

Two main data sources were used for commercial catch statistics: data collected by the Fisheries Statistics Unit (FSU) of the Ministry of Agriculture and Fisheries (MAF) up to 1987–88 and the Quota Management System (QMS) from 1986–87, now operated by the Ministry of Fisheries (MFish). These data included detailed commercial catch-by-tow information recorded in Trawl Catch and Effort Processing Return (TCEPR) logbooks by most vessels operating in the hoki fishery. A proportion of the catch was recorded by smaller vessels (less than 43 m) using Catch and Effort Landing Returns (CELR) on a daily catch and landing for whole trip basis. The main fishery where this occurs is in Cook Strait where only vessels of less than 43 m are allowed to operate.

Error checking of the data was carried out by examining outliers in the data, comparing them to other tows, amending where possible or deleting.

To examine trends, catches were plotted by area (WCSI, Cook Strait, Puysegur, Chatham Rise, Southern), fishing year or spawning season, month, tow position, fishing method (bottom trawl, midwater trawl), processing type at sea (whole fish on ice, head and gut, fillet, surimi), depth, and bycatch rate (expressed as a percentage of hoki caught, where hoki was reported to be targeted).

Scientific observer and market sampling data

In 1986, a Scientific Observer Programme (SOP) was started, mainly to sample catches by deeper water vessels fishing on hoki, orange roughy, and squid. This programme has expanded and now samples most of the major middle depth, deepwater, and tuna fisheries. Data are also collected to ensure compliance with MFish reporting requirements.

To determine the age structure from the WCSI fishery, each year since 1986 the SOP collected size frequency data and otoliths. Sampling effort was spread over the fleet to obtain fleet coverage and reasonable sample sizes for length and age coefficient of variations. These were achieved in most years, although variations occurred in some years because of MAF compliance requirements (e.g., estimation of correct surimi conversion factors, estimation of bycatch species). Maturity stages of female hoki were also recorded to determine the timing and location of spawning. These data have been collected from other areas since 1987.

The SOP length frequency data presented in this report were scaled up to the total weight of the sampled catch, and to the total weight of the catch by the whole fishery in each area for each year for which there were adequate samples. For the WCSI, samples were also scaled by week of capture.

Observers were not placed on board vessels operating in the Cook Strait fishery, and catch sampling data have been collected since 1988 through a market sampling programme which samples fish at ports of landing, mainly Nelson. Length frequency data presented here have been scaled by month to total catch.

Within individual SOP and market samples, the mean length and changes in proportion of each ovarian stage was plotted for female hoki to determine any trends over the spawning season or fishing year.

The New Zealand fishery, 1983–93

Overview

The hoki fishery is predominantly a trawl fishery in which about 98% of the catch is target fished (hoki reported as targeted). Hoki are also taken as bycatch in the other major middle depth trawl target fisheries (hake, ling, squid, jack mackerel, silver warehou, scampi).

In 1983, the hoki catch totalled about 40 000 t, of which 15 000 t came from the then only known spawning fishery, the WCSI. The quota was still set at 60 000 t with a 20 000 t catch limit on the WCSI (Hurst *et al.* 1988). From 1 April 1983, hoki was managed under the Deepwater Trawl Allocation Policy, which allocated hoki quota to New Zealand companies. From October 1983, the full policy was implemented and from then the fishery was managed in fishery years from 1 October to 30 September, with yearly allocations set at about 41 000 t.

In 1985–86, the TACC was increased to 100 000 t, with no area restrictions. There was also a one-off administrative allocation of about 30 000 t for companies experimenting with surimi production. This increase was based on an acoustic survey of the WCSI during the spawning season and a number of trawl surveys during the early 1980s which covered the main hoki fisheries outside the spawning area. In the following fishing year, 1986–87, the first in the new QMS, the TACC was increased to 250 000 t, also with no area restrictions. At this time only one spawning fishery had been identified and it was assumed hoki were a single stock.

Except for restrictions on chartered vessels and vessels over 43 m fishing inside the 12-mile Territorial Sea and various closed areas, allocated quota can be taken from any part of the EEZ, except for the Kermadec Fishery Management Area which has an administrative TACC of

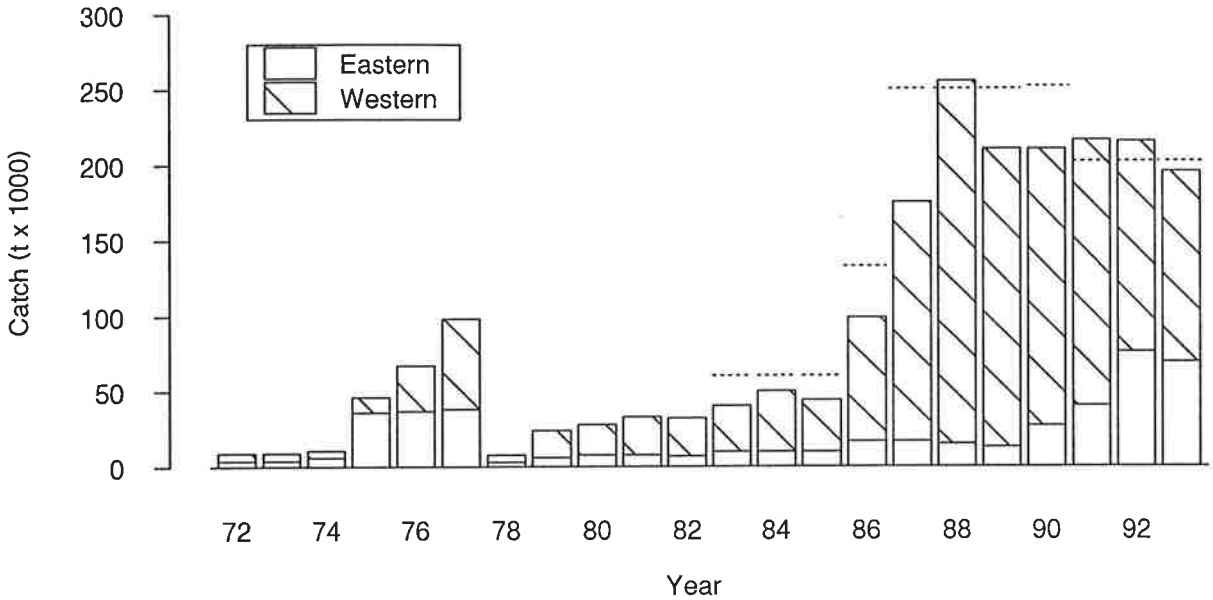

Figure 2: Total New Zealand hoki catch estimated from reported landings for calendar years 1972 to 1983 and fishing years (1 October to 30 September) 1983–84 to 1992–93. Dotted lines represent TACC level for the fishing years 1983–84 to 1992–93.

10 t. On the WCSI, the 25-mile line closes much of the hoki spawning area in the Hokitika Canyon and most of the area south of the Cook Canyon to vessels over 43 m in length. In Cook Strait the whole spawning area is closed to vessels over 43 m.

Reported catches by area since 1983 are given in Table 2. Estimated total catches are also given, based on corrections made to the QMS data. From 1986-89 these corrections were required mainly because of a low conversion factor of 4.3 used to convert surimi product to greenweight (i.e., whole fish) of hoki caught. Data collected by the SOP were used to correct the surimi catches and to establish a new conversion factor of 5.8, implemented from the 1990 season. Since then, only minor discrepancies in reported catches have been detected and corrected.

The reported hoki catch peaked in 1987–88 at 2 000 t and then declined to about 195 000 t in 1992–93. Population modelling results suggested that the current biomass had dropped to about half of the virgin biomass (Sullivan & Cordue 1990) and the 1990–91 TACC was reduced to about 202 000 t. Since 1987–88, the proportion of the catch coming from the WCSI has also declined, from about 86% to about 50% of total catch in 1992–93 (Table 2). Other areas which increased significantly in importance in later years include the Chatham Rise, the Southern area, and Cook Strait. The breakdown of catches by the two stocks (eastern and western) is shown in Figure 2.

The distribution of tows catching more than 5 t of hoki for each fishing year from 1982–83 to 1992–93 is shown in Figure 3. In the earlier years, larger catches were concentrated mainly on the WCSI, Puysegur, eastern Snares, localised areas in the Sub-Antarctic, and west of Mernoo Bank. In later years, the distribution of large catches expanded, especially in Cook Strait, across the Chatham Rise and in deeper water to the east of the Snares shelf.

Fleet structure

The hoki fishery was developed by larger (generally over 65 m) Japanese and Soviet vessels in the early 1970s (*see* Table 1). Smaller Korean vessels entered the fishery in the mid 1970s, just before the EEZ was declared. These vessels dominated the hoki fishery between 1987–88 and 1992–93 (Table 3), although they were increasingly being operated under charter arrangements with New Zealand fishing companies. Since the late 1980s, vessels from Norway, Poland, the U.S., and China have also entered the fishery.

Japanese, Russian, and Korean vessels have concentrated their effort on hoki on the WCSI during the spawning season. During the late 1980s, many of these were surimi vessels which needed to fish on the spawning grounds to maintain the high catch rates required for surimi production. Non-surimi vessels also fished all year round for hoki at lower catch levels on the Chatham Rise and in the Puysegur and Sub-Antarctic areas where hoki have been targeted but are also bycatch in other fisheries. In contrast, the Norwegian vessels (mainly fillet vessels) predominantly fished for hoki outside the spawning season on the feeding grounds of the Chatham Rise and Southern areas. They have also fished on the WCSI during July and August, sometimes passing through Puysegur.

The number of larger (over 43 m) New Zealand vessels has increased since 1985–86 (Table 4). These vessels operate during and outside the spawning season in a similar manner to the foreign headed and gutted and fillet vessels. There has also been an increase in the number of New Zealand vessels just under the 43 m limit which are permitted to fish inside the areas closed to larger trawlers. The timing of this ties in closely with the development of the Cook Strait hoki fishery, although the smaller vessels are also able to operate inside the 25-mile closed area in the WCSI fishery. These vessels mostly land whole product into nearby ports.

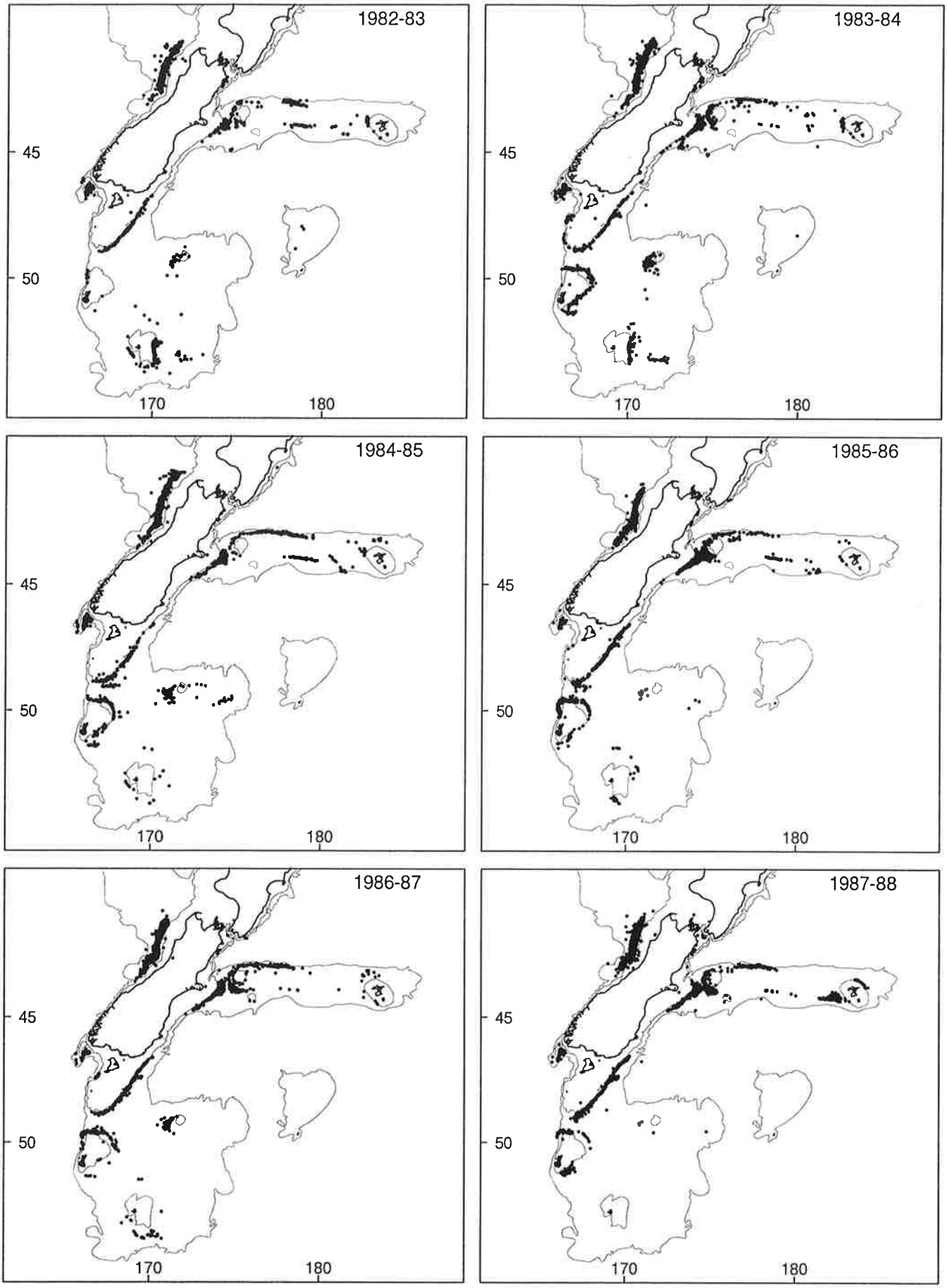

Figure 3: Positions of all commercial hoki catches over 5 t by fishing year (1 October to 30 September).

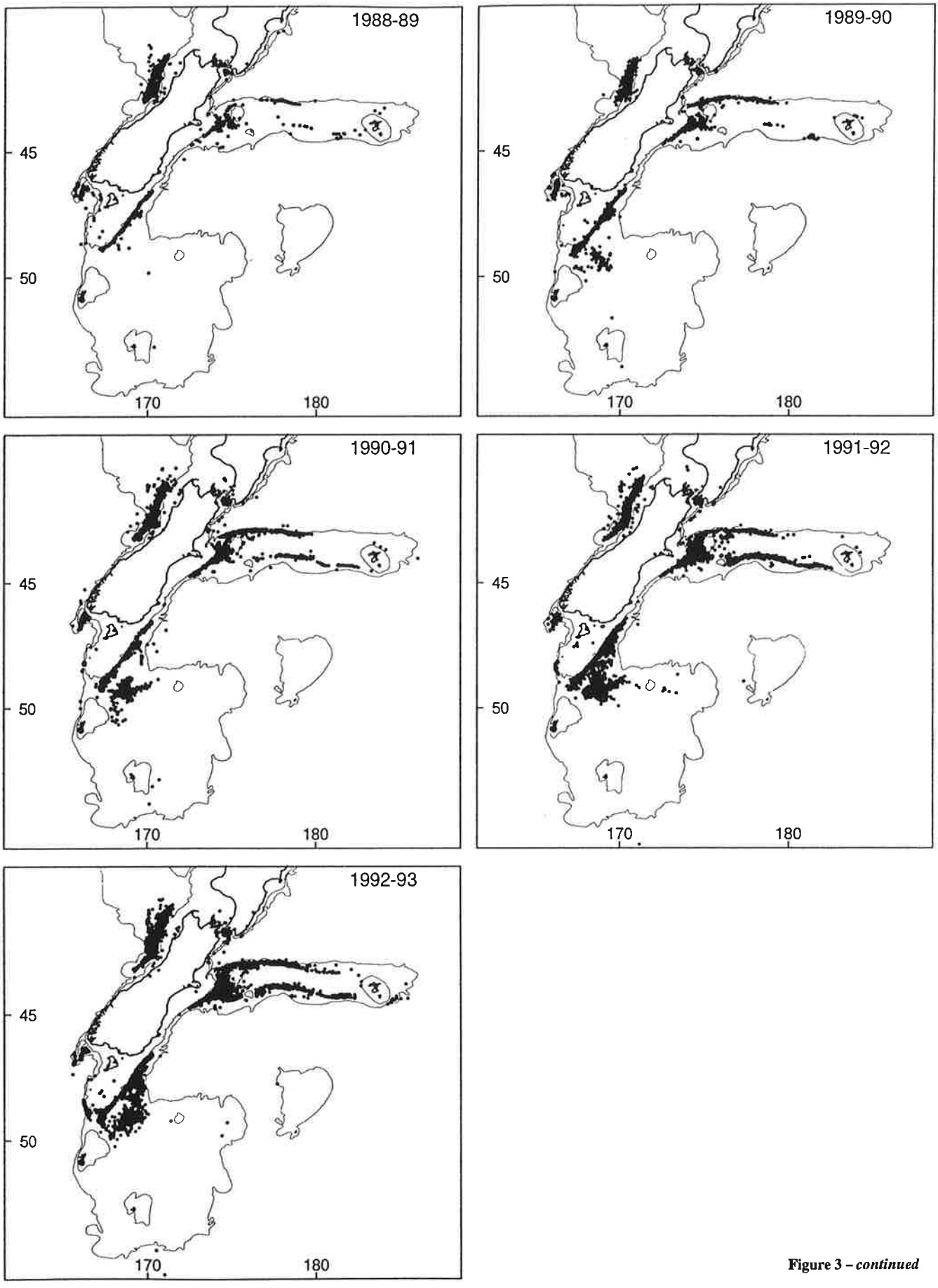

Figure 3 – ***continued***

Table 3: Number of foreign vessels targeting hoki by size category in metres *

Fishing year	Japan		Korea		USSR		Norway		Poland	USA	China
	<65	≥65	<65	≥65	<65	≥65	<65	≥65	≥65	≥65	≥65
1982–83	6	10	3	0	13	10	-	-	-	-	-
1983–84	5	11	6	0	11	11	-	-	-	-	-
1984–85	4	12	5	0	6	8	-	-	-	-	-
1985–86	4	16	10	0	7	13	-	-	-	-	-
1986–87	8	21	8	1	6	9	-	-	-	-	-
1987–88	6	26	12	1	2	12	-	-	-	-	-
1988–89	3	31	8	0	0	16	-	-	-	-	-
1989–90	2	27	9	0	0	27	2	2	-	-	-
1990–91	4	17	9	3	2	32	4	2	-	-	-
1991–92	5	18	8	3	0	33	4	3	1	1	1
1992–93	3	15	7	3	0	22	3	2	1	1	2

* Only vessels filling out TCEPR and FSU "foreign" logbooks.

Table 4: Number of NZ vessels targeting hoki by size category in metres

Fishing year	Vessel size category (m)				
	up to 30*	30–42	42–43	43–64	over 65
1982–83	165	7	1	1	1
1983–84	187	6	1	1	1
1984–85	203	6	1	1	1
1985–86	181	6	1	1	2
1986–87	164	5	1	0	4
1987–88	141	6	1	0	4
1988–89	132	7	3	0	4
1989–90	161	5	4	2	5
1990–91	195	6	3	2	2
1991–92	202	6	2	2	4
1992–93	208	7	3	3	3

* Unable to distinguish between target hoki and non-target hoki vessels for this category.

The west coast South Island fishery

The WCSI fishery (Figure 4) is the largest hoki fishery and operates on spawning aggregations from late June to early September. Before the declaration of the EEZ, the highest catch of hoki was 54 000 t in 1977. From 1982–83 to 1984–85, the WCSI catch was restricted to 20 000 t of the 60 000 t total quota. The removal of area restrictions for the 1986 season (1985–86 spawning season in winter 1986) and increases in the quota resulted in a dramatic increase in fishing effort and catch on the WCSI (Table 2, Figure 5). Catches rose from less than 20 000 t to a peak of 220 000 t in the 1988 season, 86% of the total New Zealand catch. WCSI catches have since declined to 98 000 t in the 1993 season, but still averaged about 70% of the total hoki catch in the period 1983 to 1993.

Season catches always peak during July and August, when about 80–90% of the season's total is caught. Hoki aggregations are mainly found in 300–700 m depth around the Hokitika Canyon and in the northern area (Figure 6). They are often taken in deeper water (700–1000 m), in both areas, at the start of the season and in shallower water from late July. However, during September in the 1992 and 1993 seasons hake was targeted in deeper water in both areas in a small proportion of tows. In the mid 1980s, most of the catch was taken from the Hokitika Canyon, but since the 1988 season the proportion of the catch taken from this area has declined (*see* Figure 5). Catches in the northern areas increased steadily and exceeded the Hokitika Canyon catch in the 1992 season. These northern catches have remained relatively steady for the last 3 years. The pattern of daily catches since the 1986 season (Figure 7) shows even more clearly how the Hokitika Canyon fishery has contracted, both in catch and season length. An example of the location of tow positions for a "typical" recent season (1991) is shown in Figure 8; earlier data for 1987 and 1988 were reported by Hurst (1987, 1988).

From 1987 to 1990 Japanese surimi vessels dominated the WCSI fishery and took about 60% of the catch each year (Figure 9a). However, since 1990 the surimi component of the catch has decreased to 17% in 1993, with a corresponding increase in the proportion of headed and gutted or fillet product. Only very small amounts have been landed whole by smaller New Zealand domestic trawlers. Most vessels operating on the WCSI used bottom trawls before 1986. The large increase in quota led to the need for bulk catching capacity and large midwater trawls became the most common method used (Figure 9b).

The proportion of reported bycatch in hoki targeted catches has never exceeded 16% and has been less than 10% since 1986 (Figure 9c). Hake is the main bycatch species, ranging from 1 to 5% of the hoki catch. Ling bycatch has declined from about 3% before 1986 to less than 1%, probably as a result of the change to midwater trawling. Silver warehou bycatch has varied between 0.5 and 2% of the hoki catch, and appears to be dependent on the depth fished by the hoki fleet (i.e., in years when they fish shallower, more silver warehou are caught). Frostfish have been increasing as a reported bycatch species since 1986, and over the last few years have risen to over 1% of the hoki catch. Gemfish was a moderately important bycatch species, at 1–2 % of the hoki catch until 1986, but the proportion has since declined to 0.1% in 1993.

Throughout the expansion of the WCSI hoki fishery, bycatch levels of both fish and non-fish species were carefully monitored by the SOP, and reported total catches were adjusted for species such as hake and ling using SOP data (Table 5). In an attempt to reduce the bycatch of ling and hake, midwater trawling was used more extensively in 1987 (*see* Figure 9b). The rate of ling bycatch decreased, but the estimated total catch exceeded the TACC in some years by as much as 164% for hake, 46% for ling, and 69% for silver warehou). Raising of the hake TACC in 1991–92 resulted in a reduction in overruns.

Incidental mortality of seals drowned in fishing nets was identified as a major issue in 1989, when several hundred deaths were reported (Mattlin 1994). The issue was reviewed and recommendations on fishing practices designed to minimise mortality were made (Anon. 1990). The introduction of a code of practice resulted in a reduction in the estimated number of seal deaths in 1991 and 1992 (Baird 1994).

Expansion of the fishery in the 1986 season also led to loss of fish through burst nets unable to cope with the volume of fish. Dumping of offal and other fish waste on the fishing grounds during the WCSI spawning season was also considered to be a potential problem (Livingston & Rutherford 1988). Pollution hazards were studied and a code of practice was developed to control levels of dumping and oxygen depletion.

The Cook Strait fishery

In 1987 the Cook Strait hoki fishery began with the discovery there of spawning hoki (Livingston 1990a). Since then the fishery has developed from less than 500 t to over 20 000 t a year (*see* Table 2). The fishery is entirely within the closed area and therefore restricted to domestic vessels under 43 m. Most of the catch is taken during July and August, but a few vessels have fished there in April, May, and September in 1992 and 1993 (Figure 10).

The distribution of tows (for those vessels which reported exact locations) for 1990–93 is shown in Figure 11. This fishery has been divided into three main areas: Terawhiti Sill, Nicholson Canyon, and Cook Strait Canyon. Cook Strait Canyon has consistently been the most important area (Figure 12). The other two areas increased in importance up to 1993.

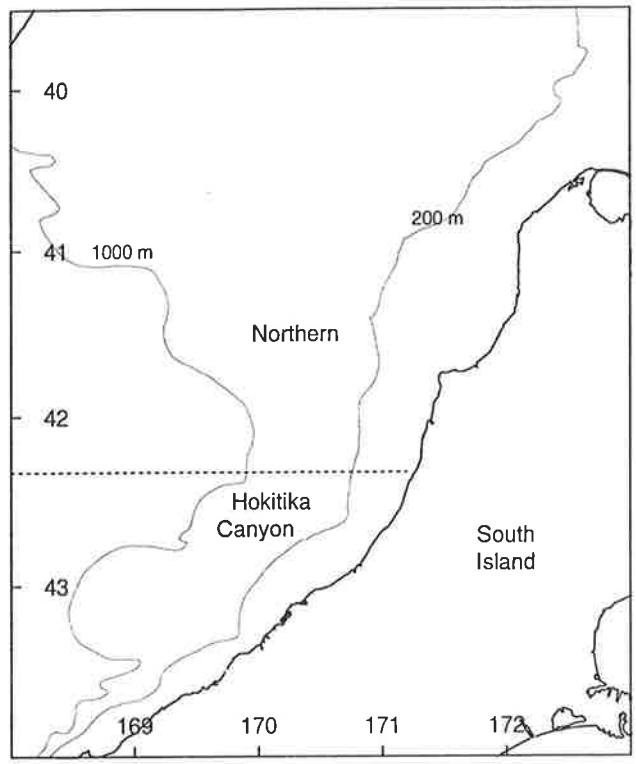

Figure 4: The west coast South Island hoki fishery areas.

As most of the vessels in this fishery are small and operate close to port, most of the fish are landed whole (green) (Figure 13a), mainly into Nelson and to a lesser extent into Picton and Wellington. A small amount is headed and gutted, or filleted. Midwater trawling is now the main method used (Figure 13b), as in the WCSI spawning fishery.

Since 1987–88 hoki catches have been very clean with only small amounts of bycatch (Figure 13c). The main bycatch species has been ling, which has reduced from 6% to 0.4% of the hoki catch as the amount of midwater trawling has increased. Small catches of bluenose and silver warehou make up to 0.5% of the hoki catch by weight.

The Puysegur fishery

Catches of hoki from the Puysegur Bank (Figure 14) have been relatively low, ranging from 1000 to 8000 t (*see* Table 2). The fishery is based on the Puysegur spawning season, and encompasses both the start and finish of the spawning season (Figure 15) as vessels head to and from the WCSI spawning grounds. Catches have mainly been processed to fillets or headed and gutted product (Figure 16a) and a small amount of surimi was produced in 1988–89 by Japanese vessels. Bottom trawling has been the main fishing method used, except from 1988–89 to 1990–91 when more of the catch was taken by midwater trawling (Figure 16b).

The main bycatch species at Puysegur is ling, which has ranged from 2 to 22% of the hoki catch (Figure 16 c), with lower bycatch rates when the amount of midwater

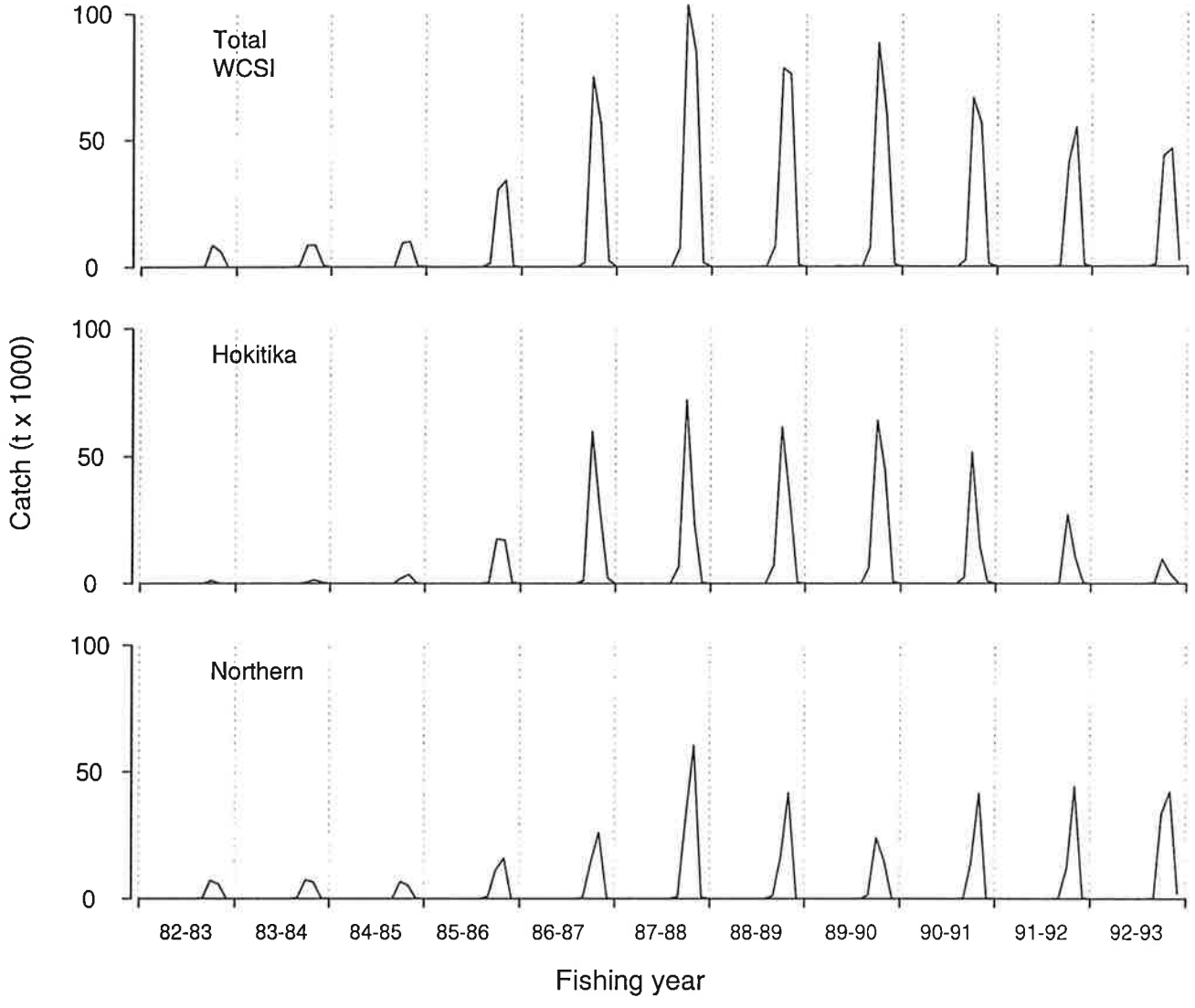

Figure 5: Monthly catches for each fishing year taken in west coast South Island (WCSI), Hokitika, and Northern areas. The start of the fishing year (October) is at the dotted lines.

Table 5: Reported and estimated catches, percent discrepancies, and TACC, in tonnes, for ling, hake, and silver warehou on the WCSI for 1987–88 to 1992–93 *

Fishing year	Ling				Hake				Silver warehou			
	rep	est	%	TACC	rep	est	%	TACC	rep	est	%	TACC
1987–88	1 853	1 777	-4	2 008	3 019	3 009	0	3 000	2 947	3 059	+37	1 815
1988–89	2 956	2 844	-4	2 150	6 835	8 696	+27	3 004	1 605	1 936	+21	1 821
1989–90	2 453	3 171	+29	2 176	4 903	8 741	+78	3 004	2 316	2 487	+7	2 128
1990–91	2 531	3 149	+24	2 192	6 189	8 246	+33	3 310	2 121	2 950	+39	2 128
1991–92	2 251	2 728	+21	2 192	3 027	-	-	6 770	1 388	-	-	2 500
1992–93	2 475	2 817	+14	2 192	7 154	-	-	6 835	1 231	-	-	2 504

Data sources Annala (1994); Colman & Vignaux (1992); Horn (1993); Langley (1992).

* Percent discrepancies were calculated for ling, hake, and silver warehou on observed vessels, as a proportion of hoki catch, stratified over different time periods. The proportion calculated for each species was applied to all hoki reported landings for each time period and summed for each species to give estimated catches.

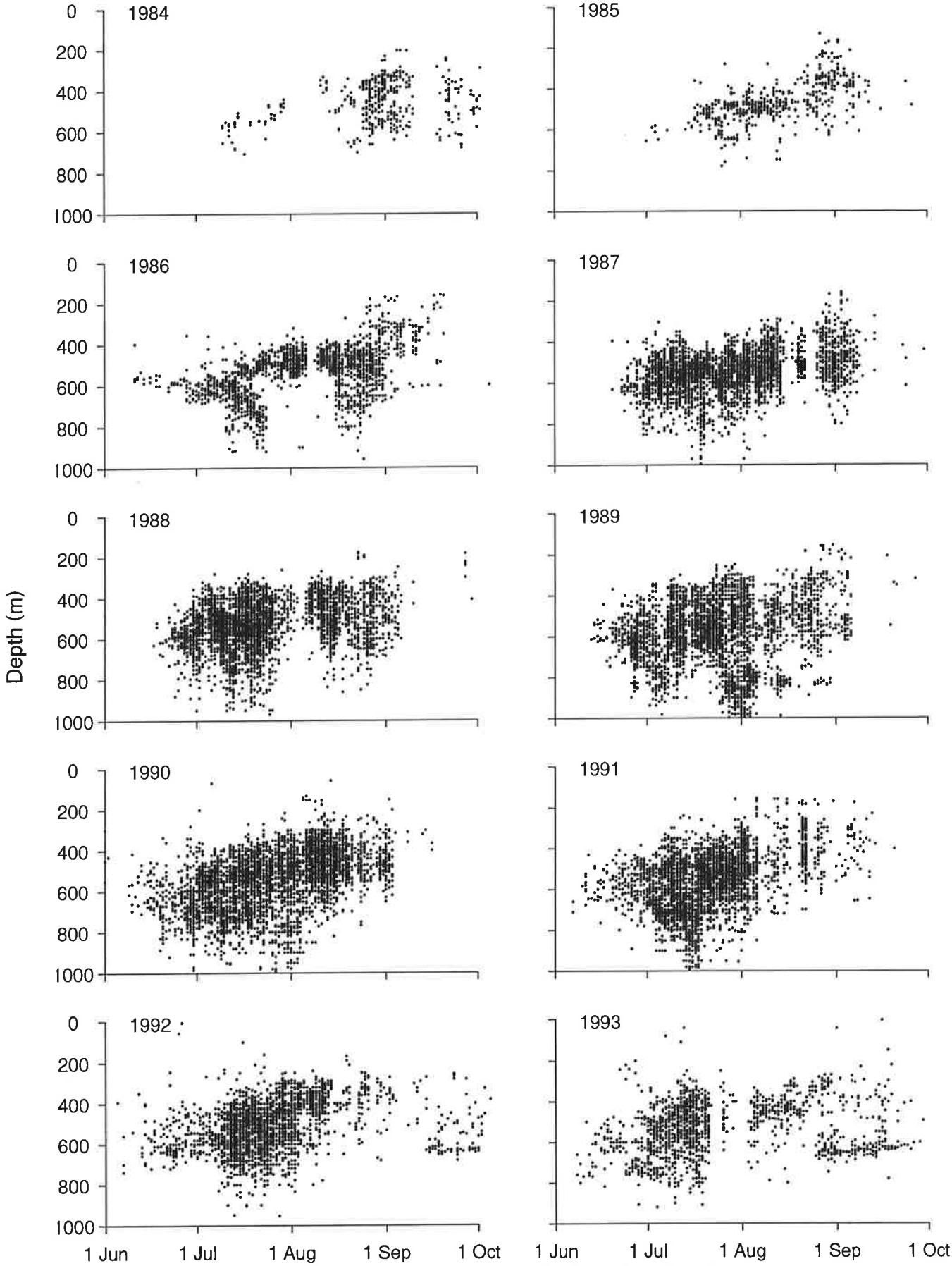

Figure 6: Tow depths from June to October for each season on the WCSI: (a) Hokitika, (b) Northern areas.

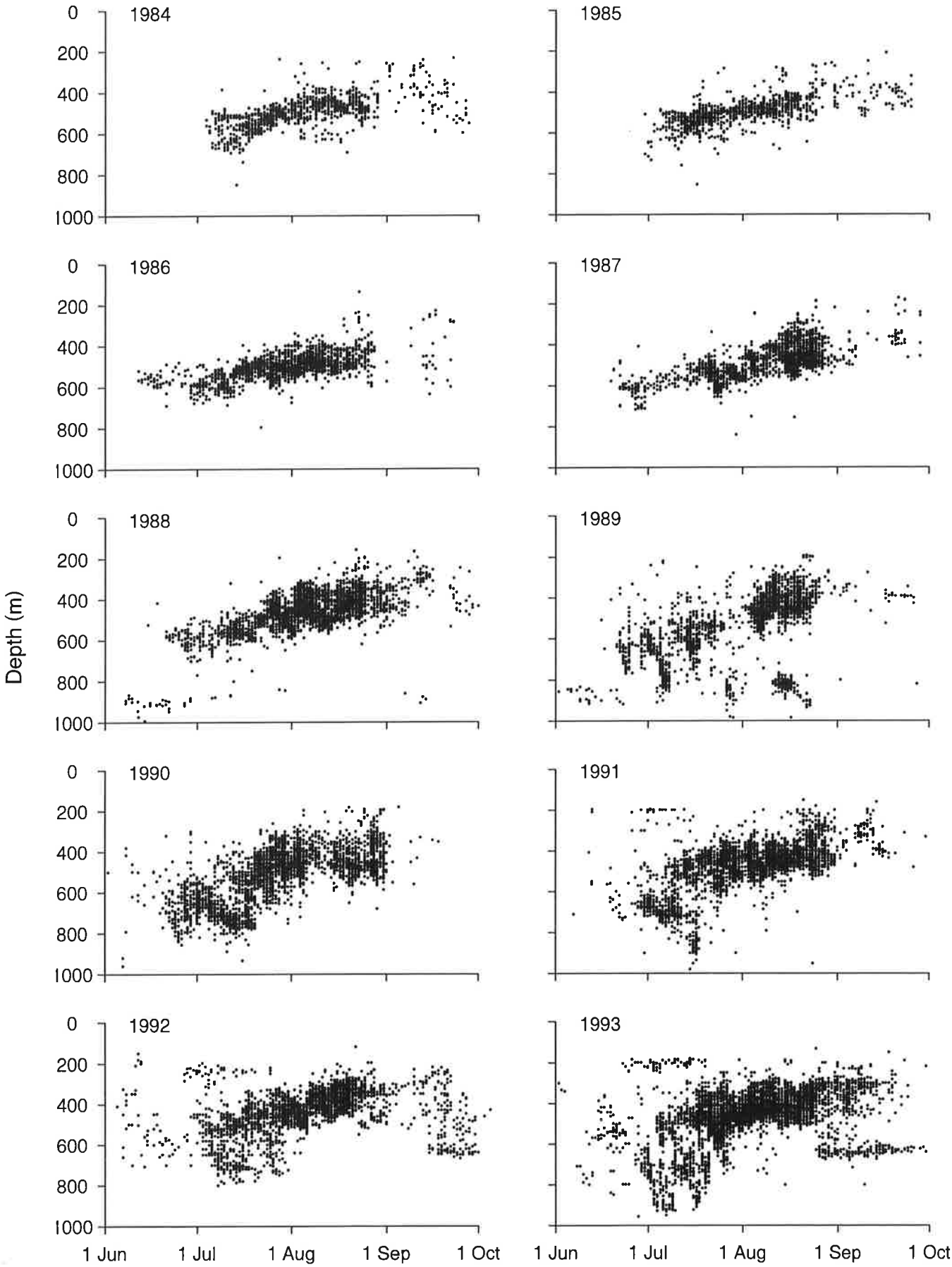

Figure 6 – ***continued.***

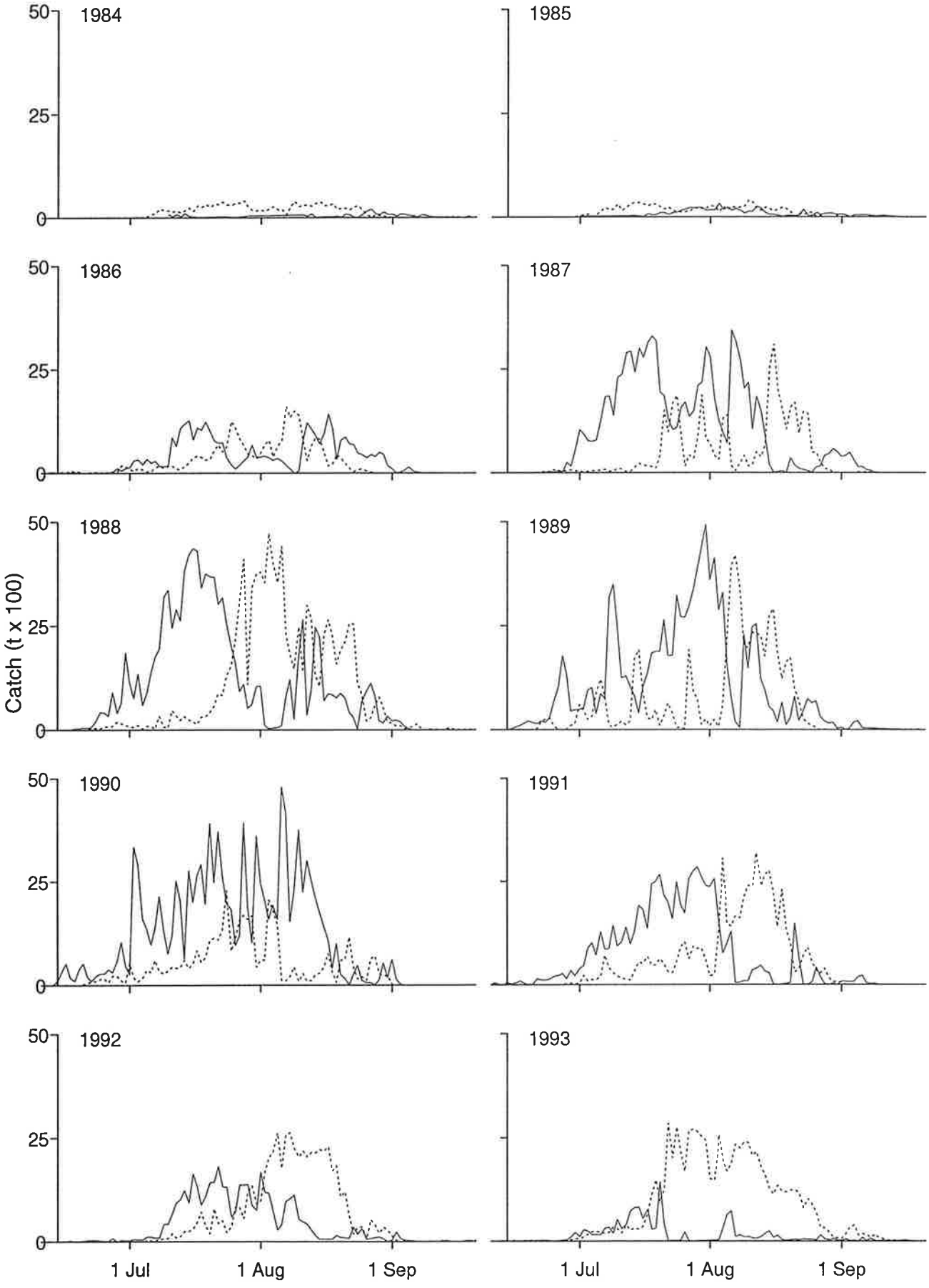

Figure 7: Estimated daily catches from the Hokitika (solid lines) and Northern (broken lines) areas for each season on the WCSI.

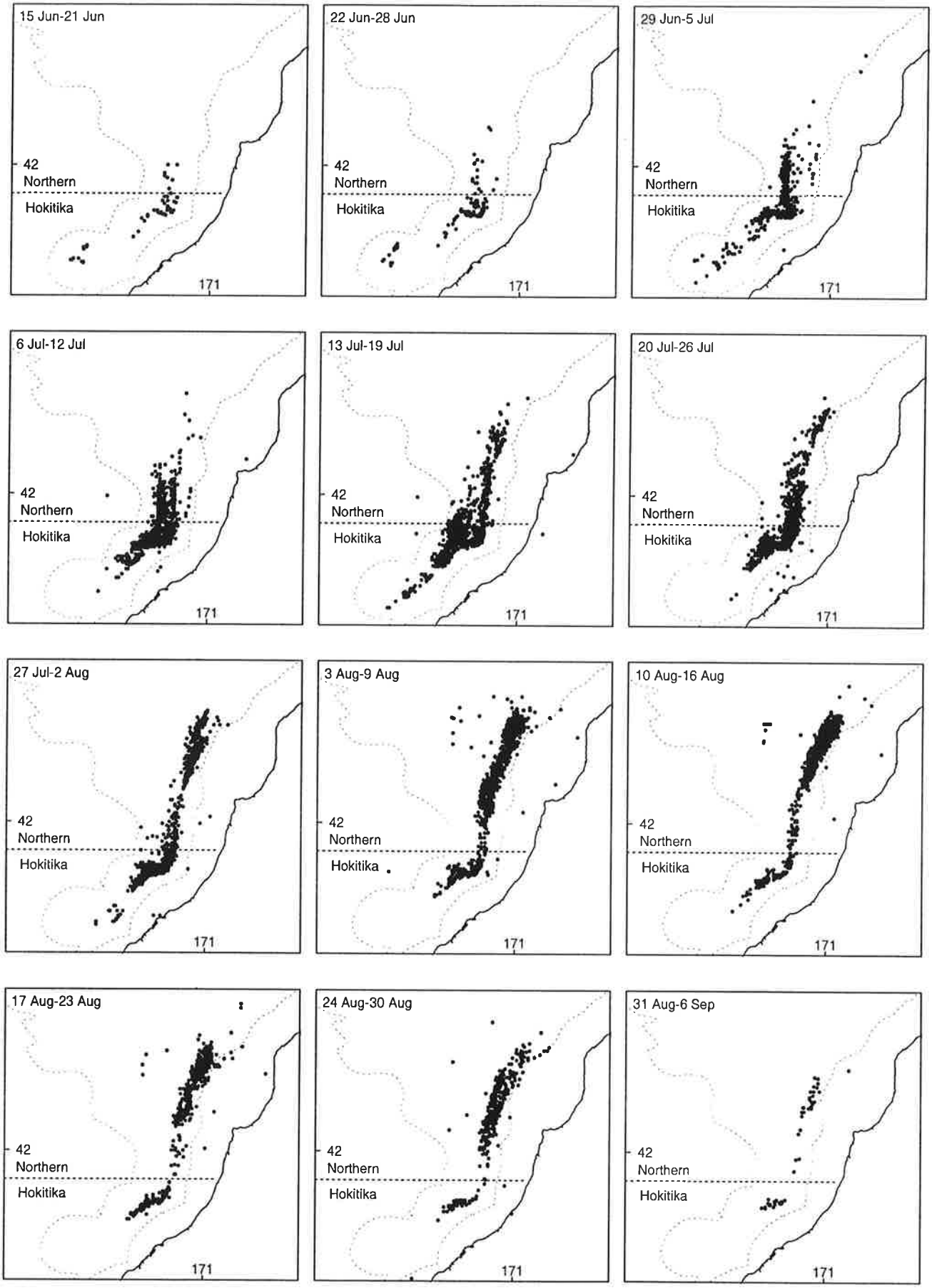

Figure 8: Positions of all tows by week on the WCSI, 1991 season.

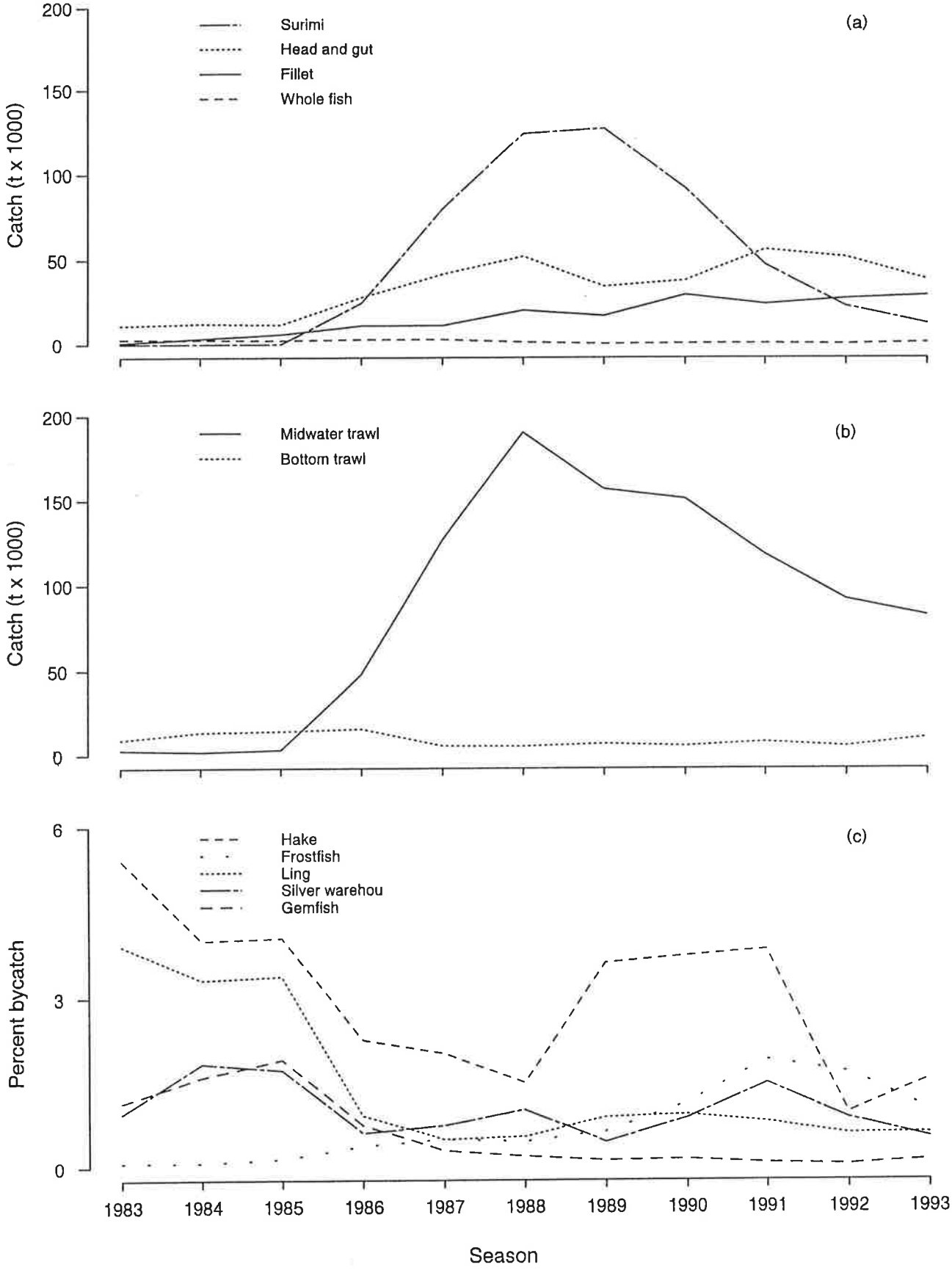

Figure 9: WCSI fishery: (a) total catches by process type; (b) total catches by gear type; (c) bycatch as a percentage of hoki target catch.

trawling is increased. On the southeast of the Puysegur Bank, fishing effectively targets both hoki and ling (Ballara & Sullivan 1994). Other species to make up 1–6% of the hoki catch are squid, hake, and silver warehou.

The Southern fisheries

The Southern area contains five sub areas; the eastern and western Snares slope (*see* Figure 14), and the Sub-Antarctic areas which include Auckland, northeast Auckland, Pukaki, and Campbell. Catches in the Southern areas have fluctuated during the period and increased to over 20 000 t in 1991–92 and 1992–93 (*see* Table 2). In general, the fishery operates throughout the year, except for July and August when vessels are fishing on the WCSI (Figure 17).

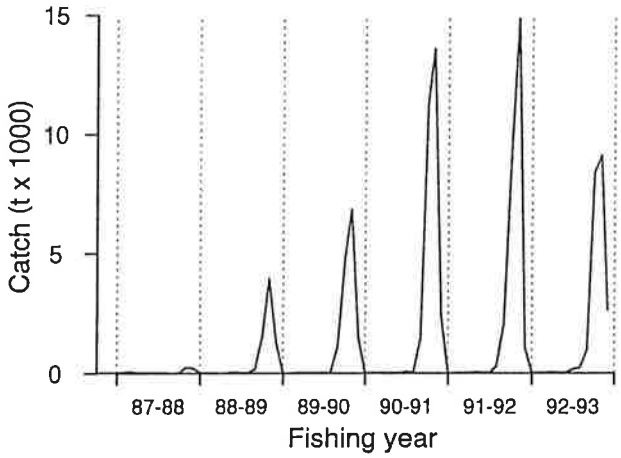

Figure 10: Monthly catches for each season in Cook Strait. The dotted lines mark the start of the fishing year (October).

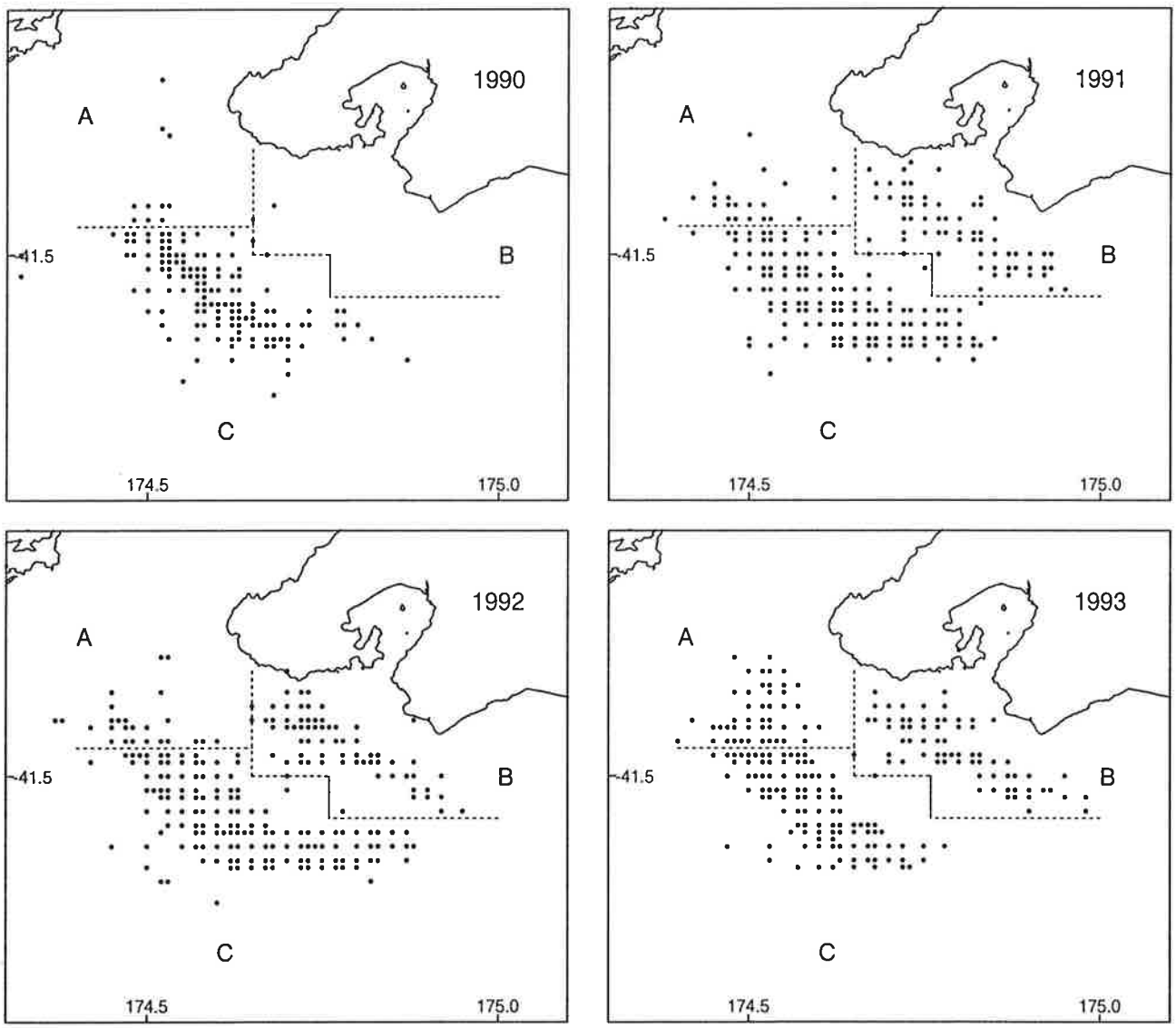

Figure 11: Tow positions recorded in the Cook Strait hoki fishery, 1990–93. A, Terawhiti Sill; B, Nicholson Canyon; C, Cook Strait Canyon.

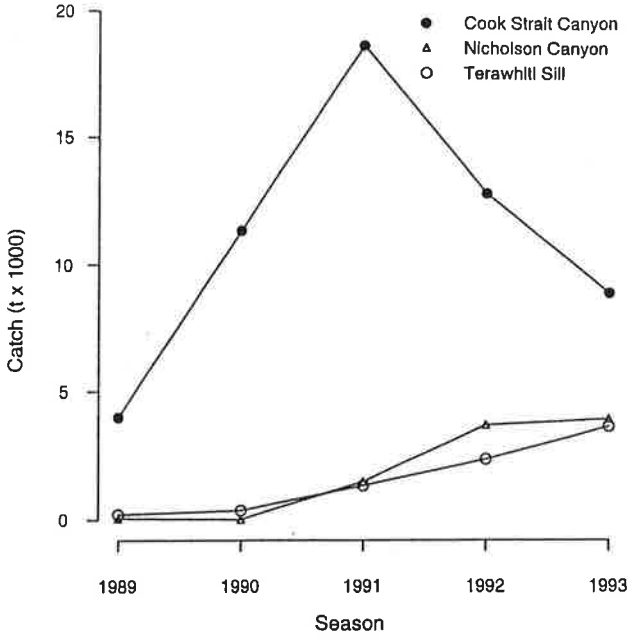

Figure 12: Catches by area in the Cook Strait hoki fishery seasons 1989–93 where position was reported.

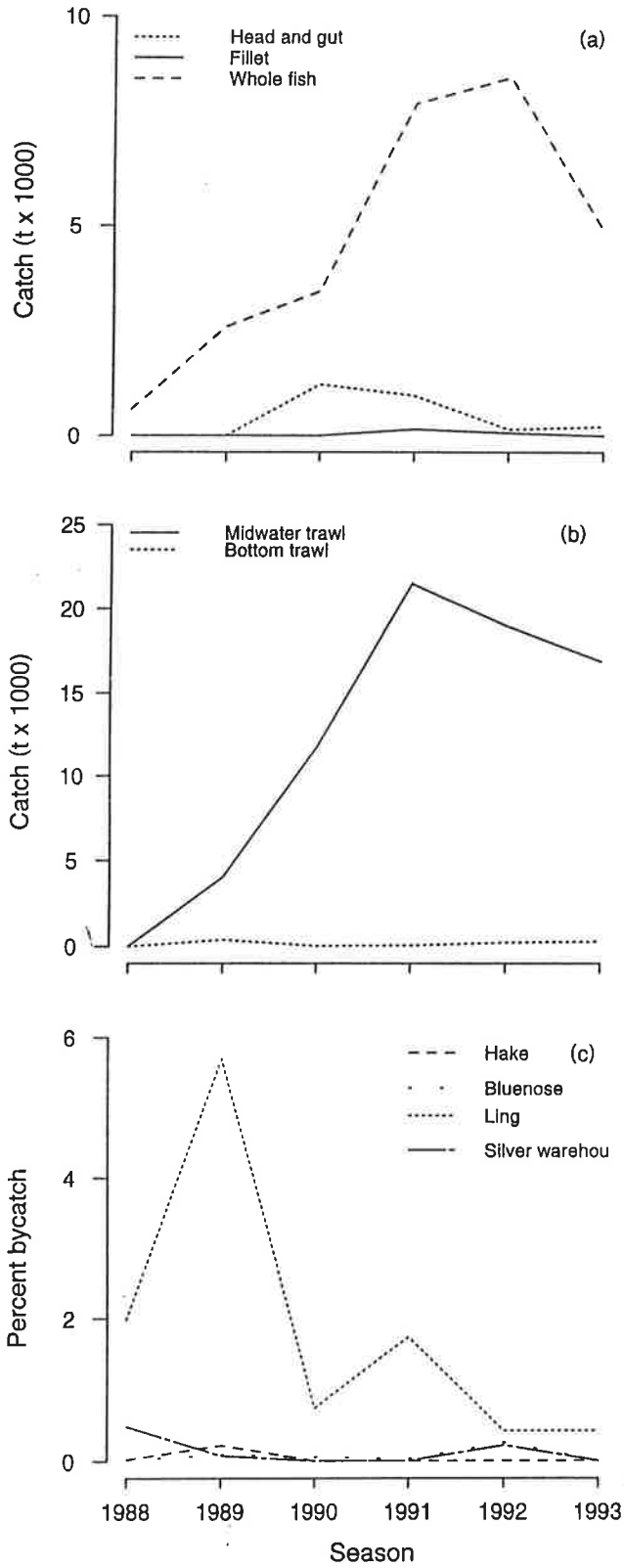

Figure 13: Cook Strait fishery: (a) total catches by process type;(b) total catches by gear type; (c) bycatch as a percentage of hoki target catch.

The largest and most consistent fishery in the Southern area is located mainly on the eastern edge of the Snares shelf. This area has been fished each year with peak catches occurring in autumn, just before the main spawning season. Relatively small catches were reported from the Pukaki, Campbell, and Auckland areas up until 1987–88 (*see* Figure 17). These areas have since decreased Two new areas to be developed in recent years are the the northeast Auckland area, mainly in the pre-spawning period, but partly in the post-spawning period. In October and November, both fisheries are probably targeting fish returning from spawning on the WCSI. Hoki are also caught in October and November in a recently developed hake target fishery in this area.

Hoki from this area were processed mainly as headed and gutted product up until 1989–90 (Figure 18a). The proportion of fillet product then increased as Norwegian vessels entered the fishery. A small amount of surimi was processed in 1986–87 by Japanese vessels. New Zealand vessels fishing in the Sub-Antarctic have increased catches since 1991–92 and have mainly produced fillets, with some headed and gutted product. Bottom trawling has been the dominant fishing method used throughout the period (Figure 18b).

The percentage bycatch rate has decreased from 72% in 1982–83 to 18% in 1992–93 (Figure 18c). This is presumably as a result of increasing knowledge of how and when to target pre- and post-spawning migrations, and the reduction of hoki targeting in other areas such as the Campbell Plateau and the Pukaki Rise. This has resulted in a decreased southern blue whiting bycatch (32% to less than 1%) and an increase in species such as hake. Ling bycatch has remained fairly static and squid and silver warehou have fluctuated.

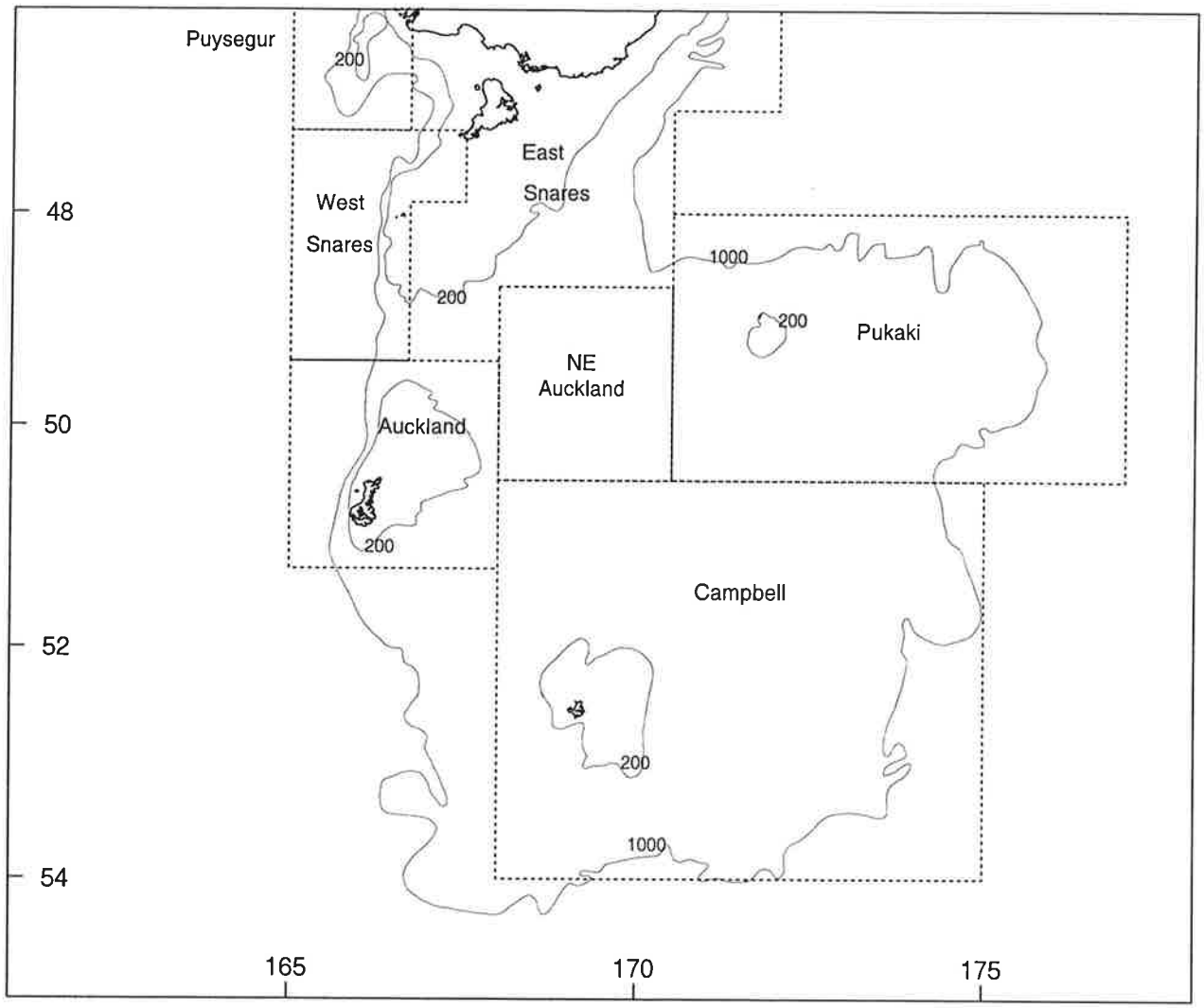

Figure 14: Puysegur and Southern hoki fishery areas.

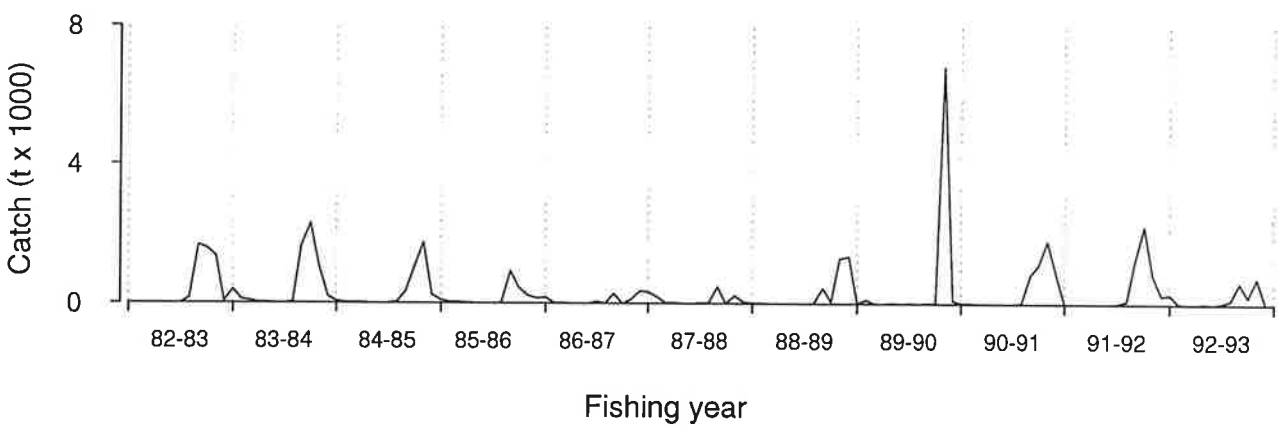

Figure 15: Monthly catches for each fishing year at Puysegur. The dotted lines mark the start of the fishing year (October).

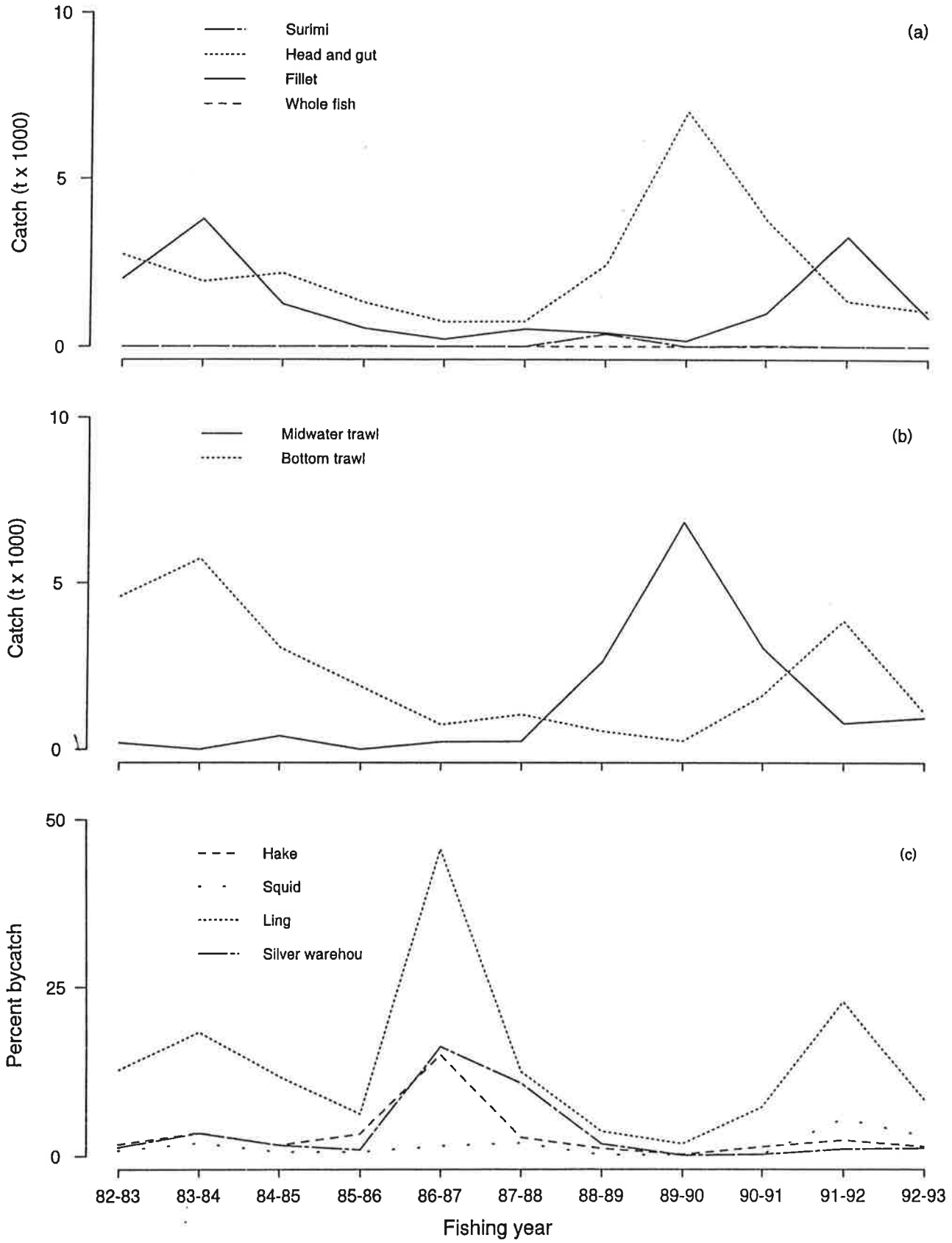

Figure 16: Puysegur fishery: (a) total catches by process type; (b) total catches by gear type; (c) bycatch as a percentage of hoki target catch.

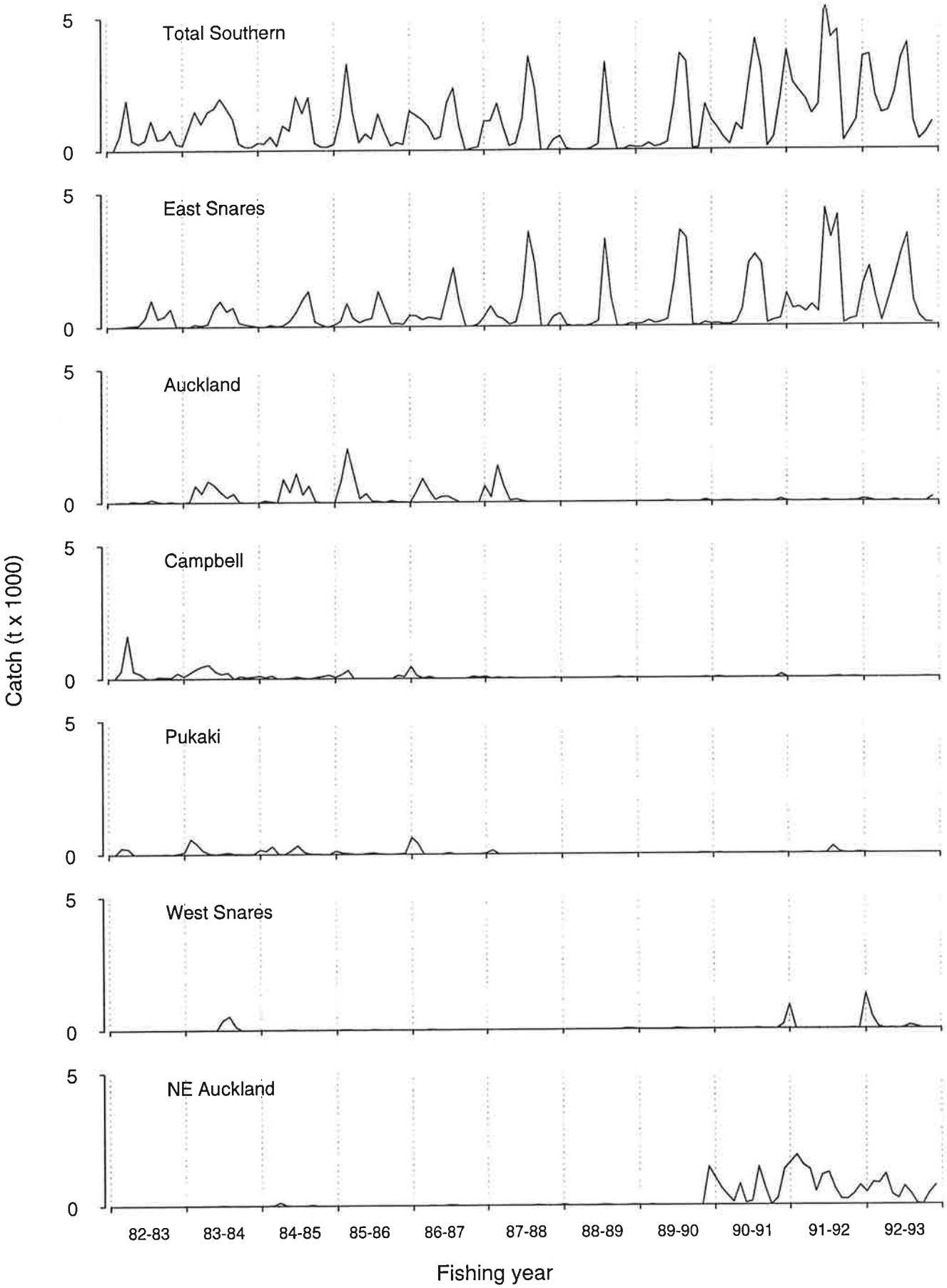

Figure 17: Monthly catches for each fishing year in the Southern fishery area and subareas. The dotted lines mark the start of the fishing year (October).

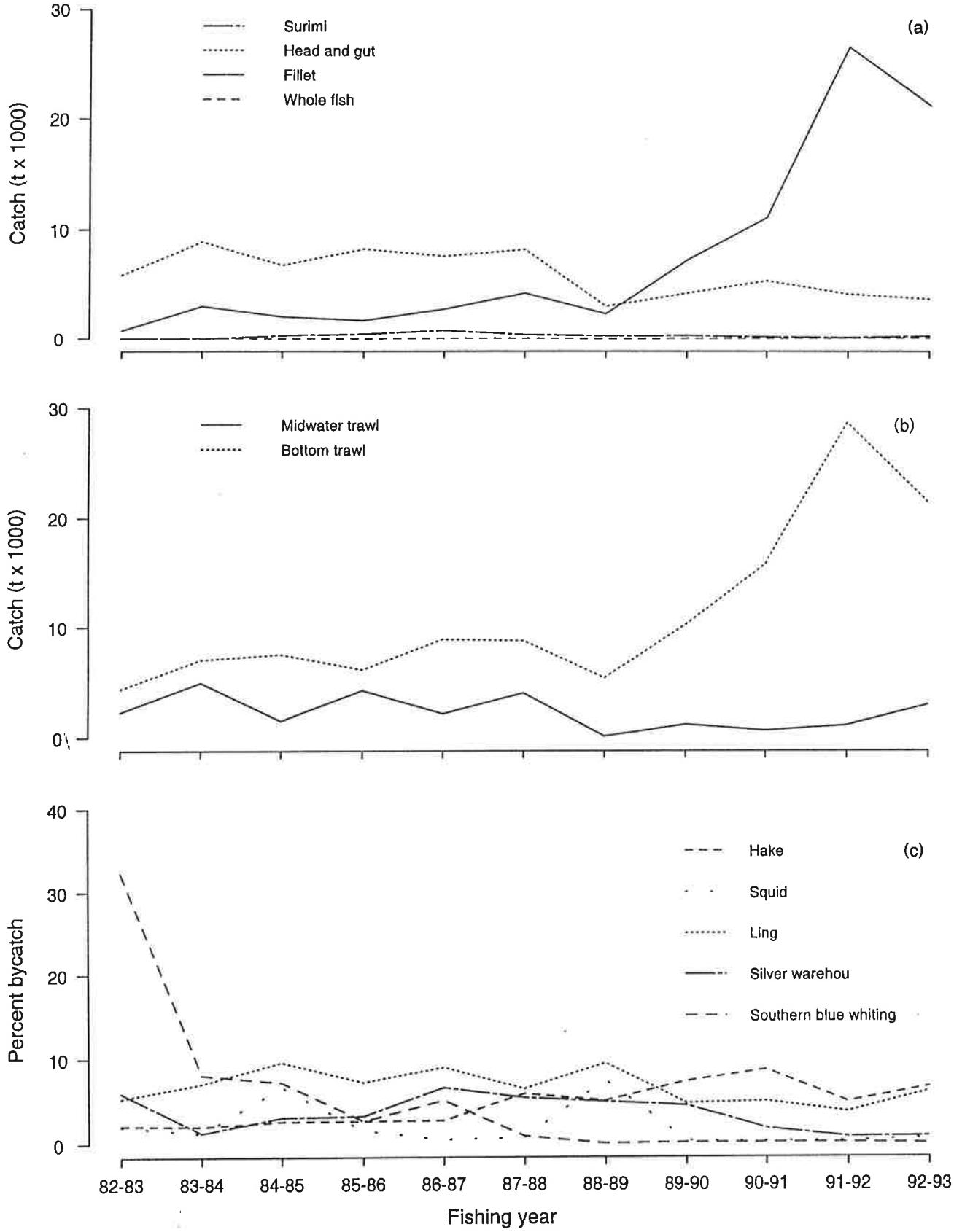

Figure 18: Southern fishery: (a) total catches by process type; (b) total catches by gear type; (c) bycatch as a percentage of hoki target catch.

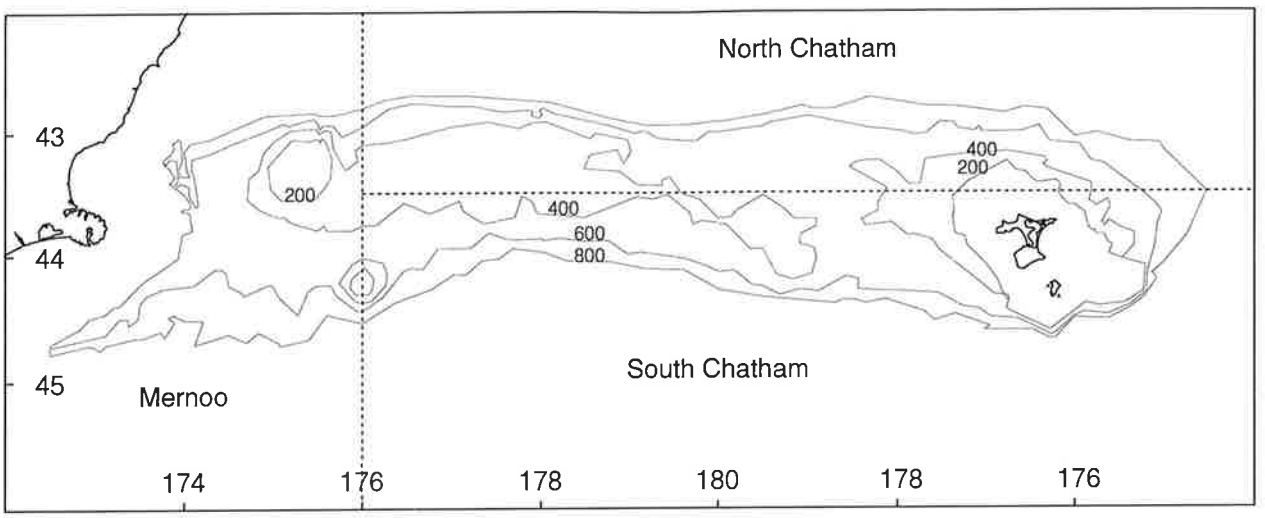

Figure 19: Chatham Rise hoki fishery areas.

The Chatham Rise fishery

The hoki fishery on the Chatham Rise has been split into three areas: Mernoo, north Chatham Rise, and south Chatham Rise (Figure 19). The annual catches fluctuated between 6000 and 16 000 t until 1991–92 and 1992–93 when over 40 000 t, or about 20% of the EEZ total, came from this area (*see* Table 2).

All three areas have been fished each year: Mernoo has consistently been the most important, but the catch from the rest of the Chatham Rise increased significantly from 1990–91 (Figure 20). As in the Sub-Antarctic areas, most fishing takes place outside the spawning season. The main peak in catches is during autumn, with a secondary peak sometimes occurring in spring.

Hoki have been processed as headed and gutted product since 1982–83 by Russian, Japanese, and Korean vessels, and as surimi from 1986–87 to 1992–93 by a few Japanese vessels (Figure 21a). Fillet production increased from 1988–89 as Norwegian and New Zealand vessels entered the fishery, and has been the dominant product type since 1989–90. A small amount of hoki has been landed whole (green) by New Zealand and Korean vessels. Most of the catch is taken by bottom trawling which has consistently been the main fishing method. Midwater trawling has increased during the period, to about 20% of the total in the last 3 years (Figure 21b).

Bycatch rates on the Chatham Rise have decreased from about 44% in 1982–83 to just over 12% in 1992–93. Ling, hake, and silver warehou were the main bycatch species, all individually below 10% (Figure 21c). The ling bycatch percentage dropped from 1982–83 to 1992–93 (6.6 to 2.5%), although ling catches increased. Hake bycatch varied between about 1 and 3% of hoki target catches. Silver warehou has ranged from 2 to 8%, and has been at about 2% since 1990–91. There is also a variety of other bycatch species (e.g., arrow squid, barracouta, white warehou, bluenose) and hoki is itself a bycatch of other middle-depth and deepwater target fisheries on the Chatham Rise (e.g., orange roughy, oreo, hake, silver warehou).

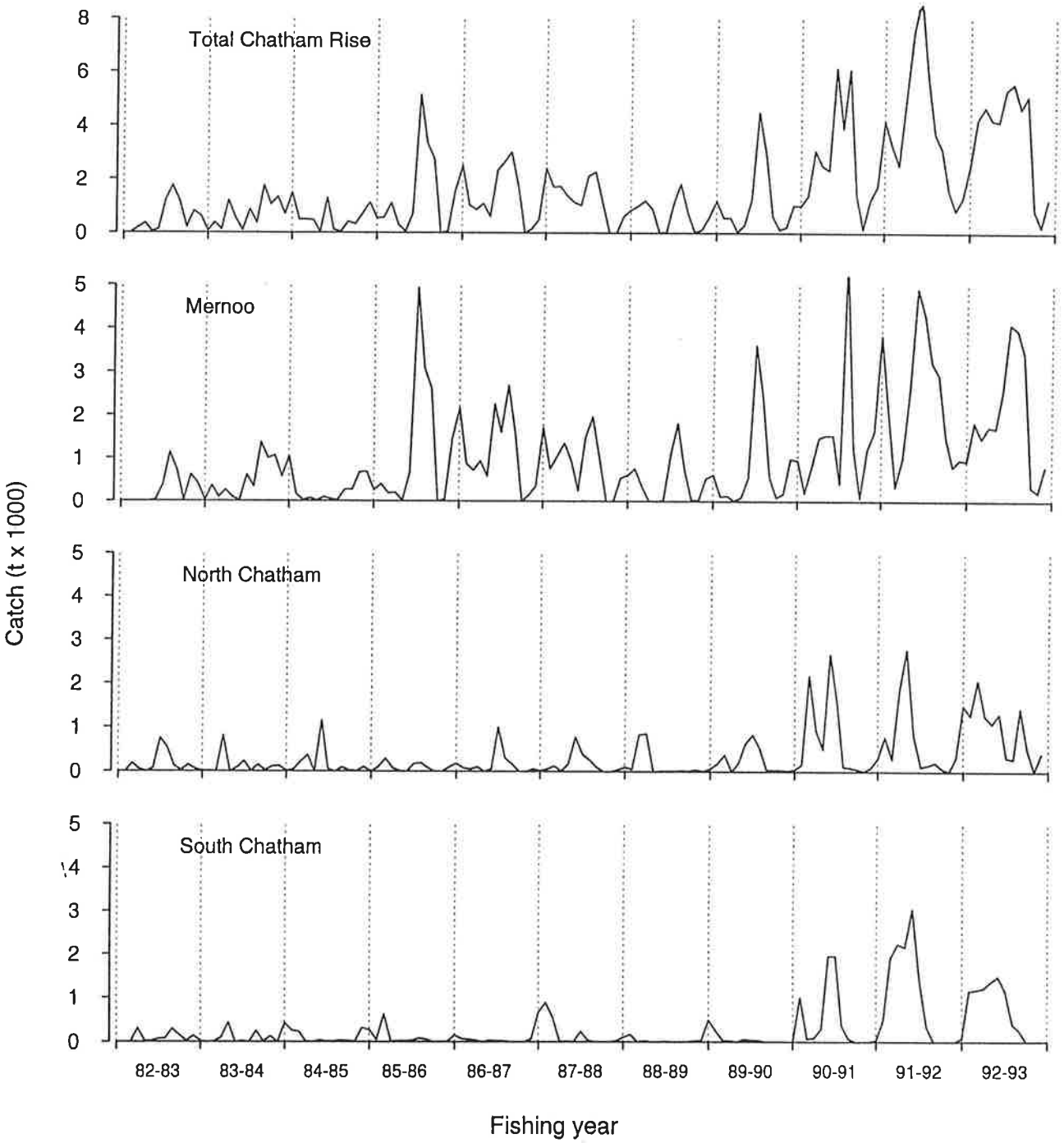

Figure 20: Monthly catches for each fishing year on the Chatham Rise and subareas. The dotted lines mark the start of the fishing year (October).

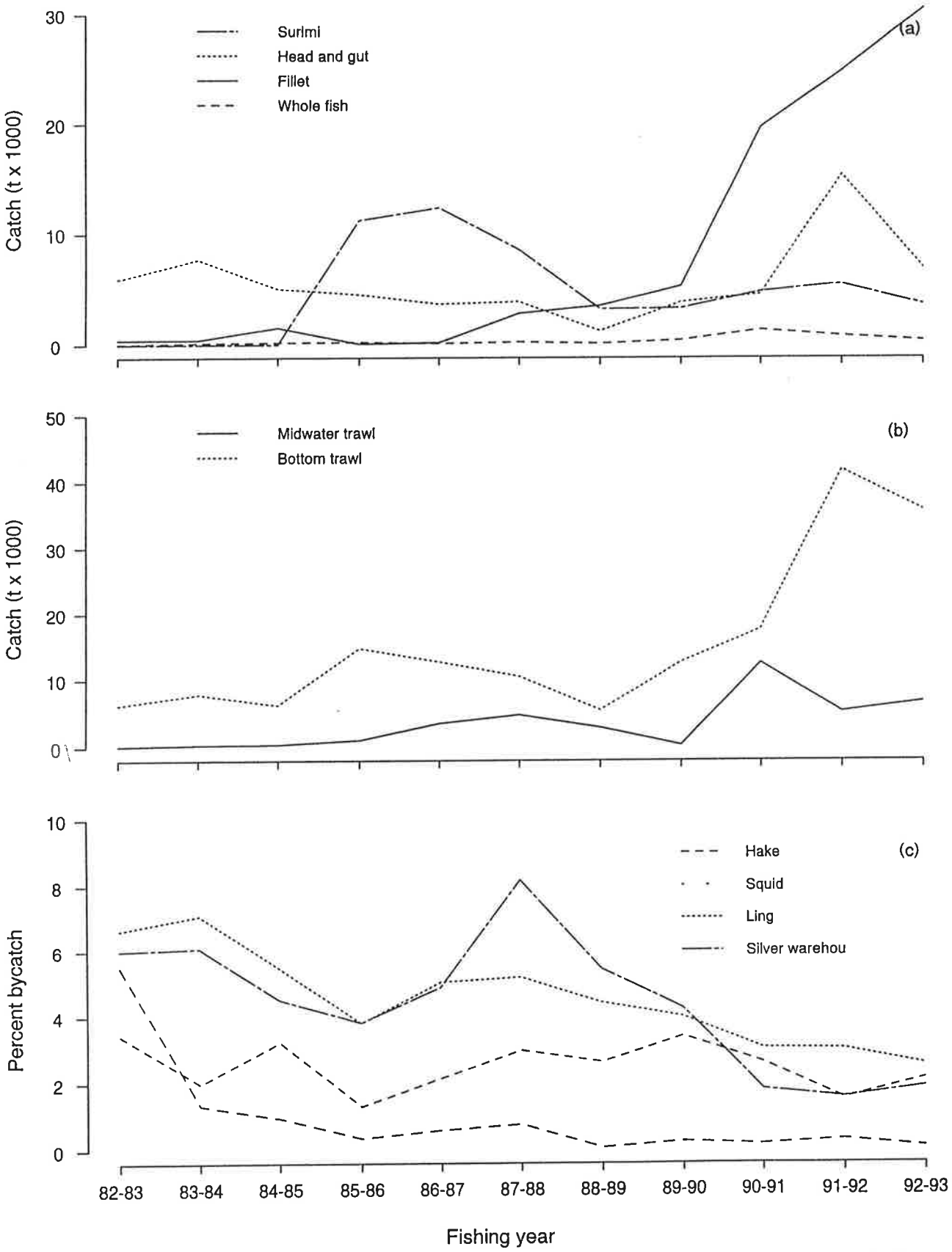

Figure 21: Chatham Rise fishery: (a) total catches by process type; (b) total catches by gear type; (c) bycatch as a percentage of hoki target catch.

Commercial biological data

Western stock fisheries

Size distribution

For the WCSI, data are available from 1986 to 1993 (Figure 22). Most hoki caught on the WCSI in winter are mature fish over 60 cm in length. At the start of the time series, the fishery was dominated by larger adult hoki (over 80 cm). As the fishery developed, the proportion of these larger fish decreased and the fishery appears to have become more strongly recruitment driven. The recruitment of the strong 1987 year class resulted in a bimodal size distribution in males in the 1991 season, and in females in the 1992 season. This 1987 year class first appeared at about 45 cm in 1989. By the 1993 season, this year class dominated the catches of both sexes. In this year, a small number of the 1991 year class first entered the fishery and this year class is estimated to be stronger than the 1987 year class (Ballara *et al.* 1997).

In general, male hoki recruit a year earlier than the females. For the year classes which appear relatively strong (1987, 1988, and 1991), males have begun to recruit at age 2 (40–45 cm) and females at age 3 (50–60 cm). The 1983 year class also appears to have recruited at age 3 in 1986, suggesting that this year class may have also been strong. The 1989 and 1990 year classes are considered to be relatively weak (Ballara *et al.* 1997) and show little sign of recruitment to the fishery.

Length frequency data from the Southern (Figure 23) and Puysegur (Figure 24) areas show similar patterns to those from the WCSI, with the 1987 year class starting to dominate at the end of the time series. However, the proportion of younger ages in the size frequencies appears to be greater than for the WCSI, possibly because there are more immature fish resident in the areas where the fishery operates. This is particularly noticeable in the Puysegur data, where the 1989 and 1990 year classes are more apparent as 2+ modes (50–60 cm in 1991–92 and 1992–93) than in the WCSI data. The Southern data are also taken at all times of the fishing year, and Puysegur data are taken over a short period during the spawning season.

During the spawning season on the WCSI, the mean length of male and female hoki generally decreased (Figure 25). Variations in the slope of the decline reflect both the change in proportion of larger fish at the beginning of the season, which appears to have decreased over time, and the presence of strongly recruiting year classes.

Changes in hoki size distributions in the Snares and northeast Auckland areas were examined for evidence of spawning migrations through these areas to the west coast, but data were sparse and inconclusive. However, an increase in catch rates (Figure 26) during the pre-spawning and post-spawning periods suggests that there may be movement through the area at these times. Data from Puysegur show an increase in size through to early August which does not appear to be consistent with spawning migration through the area, but may relate to spawning in the area in August and September (Ballara & Sullivan 1994).

Spawning activity

Changes in the proportion of ovarian stages recorded from commercial catches can be used to determine the presence and timing of spawning over the fishing season. Data collected from the WCSI fishery from mid June to early September were described by Langley (1993). As the proportion of maturing (stage 2) fish declined, the proportion of ripe (stage 3), spawning (stage 4), and spent (stage 5) fish increased. He used these and the mean fish size data to estimate a residence time for spawning females of 14–27 days. Data for Puysegur were presented by Ballara & Sullivan (1994), who found that catches sampled in July were of pre-spawning fish, and that spawning and spent fish were present in August–September.

In the Sub-Antarctic area most fish sampled were immature or resting (stage 1) for most of the year (Figure 27). Maturing fish were found between April and July and a few ripe fish were recorded in June, September, and October to the east of the Snares shelf, but no significant spawning area has been located. Spent fish were found usually between late August and mid November, presumably having returned from the Puysegur and WCSI spawning areas.

Eastern stock fisheries

Size distribution

Patterns in the size distribution of hoki from Cook Strait (Figure 28) are different from those observed in the spawning fishery on the WCSI in two main ways. Firstly, in Cook Strait, few fish less than 50 cm long are recorded, regardless of year class strength. As the samples were taken from landed catches, it is not known if this is due to the fleet's ability to successfully target schools of larger fish or to the discarding of smaller fish at sea. Secondly, the Cook Strait fishery appears to be dominated by the 1988 year class, whereas the WCSI fishery is dominated by the 1987 year class. This can be seen most clearly in the last 3 years of the time series for males, in which the Cook Strait 1988 year class modal peak (at about 61, 65, and 70 cm) is about 5 cm less than the 1987 modal peak on the WCSI. The main similarity to the WCSI fishery is that the 1989 and 1990 year classes appear to be very weak or absent in both areas.

Chatham Rise size distributions (Figure 29) show that this is the main nursery ground for hoki in the EEZ. The distributions are dominated by the pre-recruit year class modes and have a much lower proportion of fish over 80 cm long. The strong 1987 year class can be seen at 40–50 cm in 1988–89 and appears to substantially have moved out of the area by 1991–92. In contrast, the 1988 year

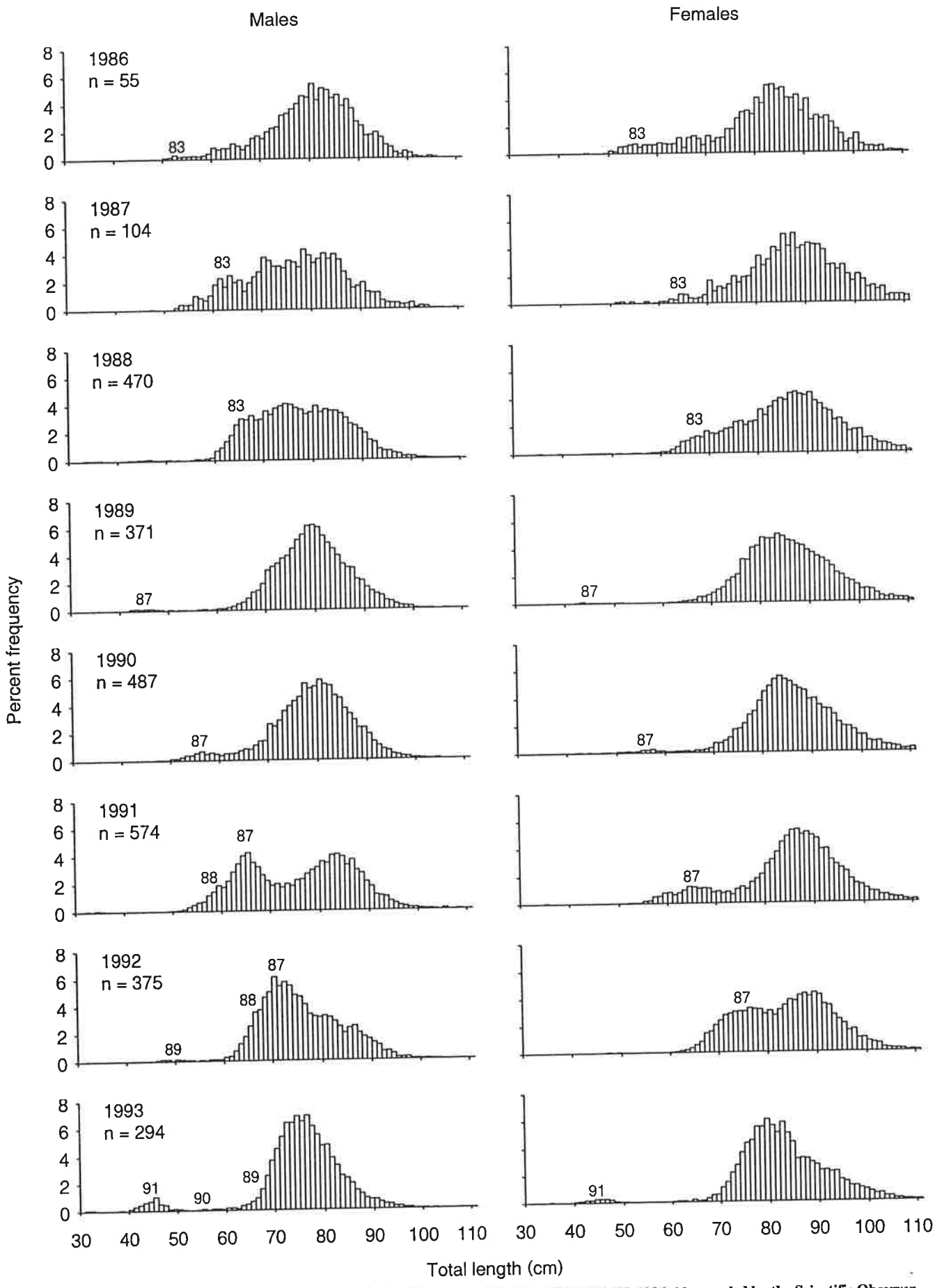

Figure 22: Length frequencies of male and female hoki taken in commercial catches from WCSI, 1986–93, sampled by the Scientific Observer Programme. (n is the number of samples; selected year classes are marked, e.g., 87 is the 1987 year class.)

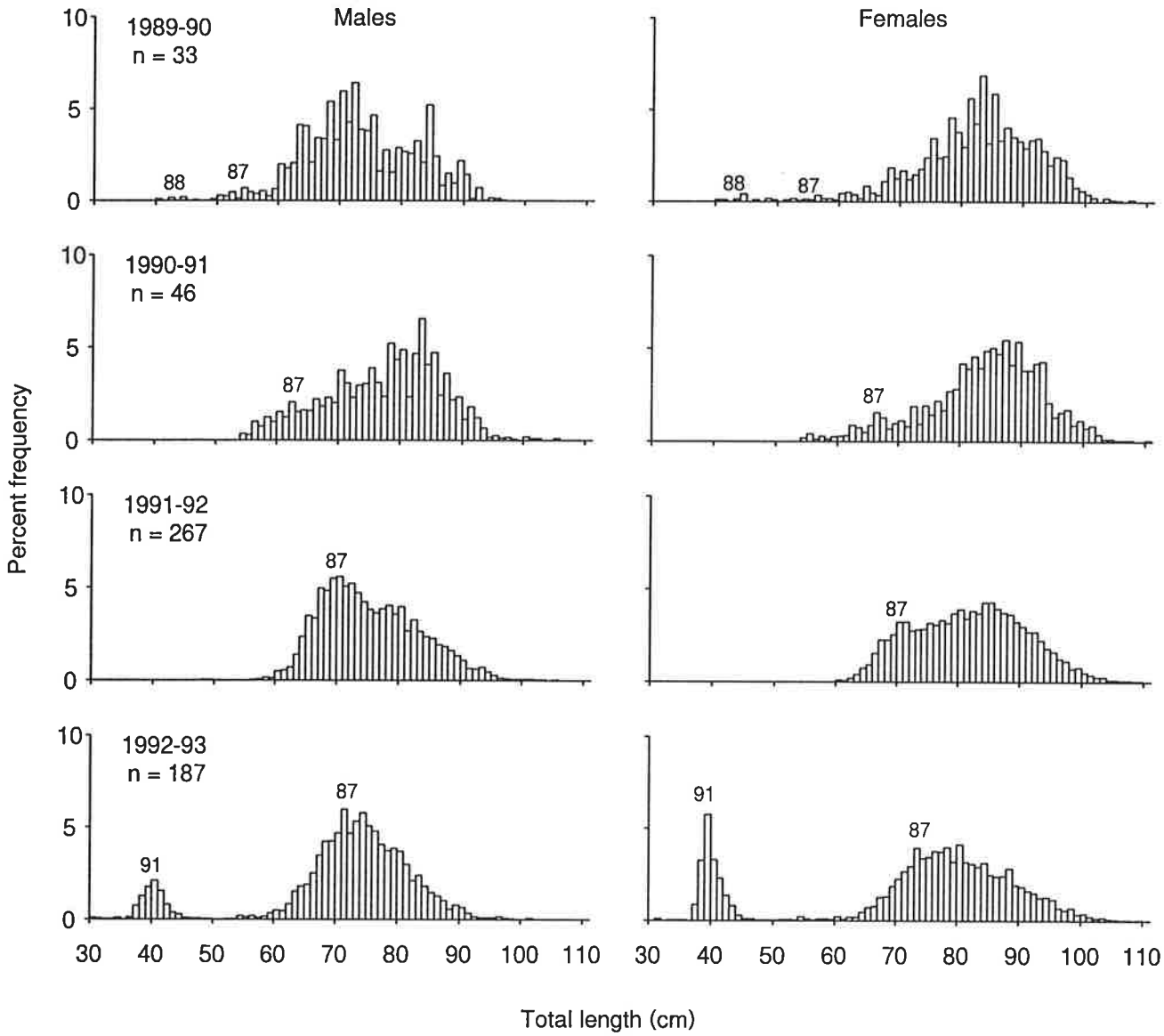

Figure 23: Length frequencies of male and female hoki taken in commercial catches from the Southern areas, 1989–90 to 1992–93, sampled by the Scientific Observer Programme. (n is the number of samples; selected year classes are marked, e.g., 87 is the 1987 year class.)

class appears to have remained longer in this area and dominates the last 2 years of the series, as in the other main eastern fishery in Cook Strait.

A declining trend in mean length during the spawning season is apparent in Cook Strait catches (Figure 30), but is less obvious than for the WCSI. This is due to there being proportionately fewer larger fish at the start of the season and possibly smaller sample sizes. In the Chatham Rise fishery, fish length is related to depth of tow (Figure 31).

Spawning activity

Gonad stage data from Cook Strait in 1992 and 1993 showed a similar seasonal trend in proportions of maturity stages (Figure 32) to the WCSI. The proportion of maturing fish (stage 2) decrease as the season progressed, with a corresponding increase in the spawning and spent stages (stages 4 and 5). Spawning and spent fish occurred throughout the sampling period from late June to October.

Chatham Rise hoki are immature or resting for most of the year: maturing fish are found in small proportions mainly from July to October (Figure 33). Spent fish are found in October to December. Ripe and spawning fish were not recorded on the Chatham Rise, though few samples were taken during the spawning season.

There are few data from east coast North Island hoki and they are not presented here. Most fish recorded were immature, resting, or maturing, but a few ripe fish were found in May and July.

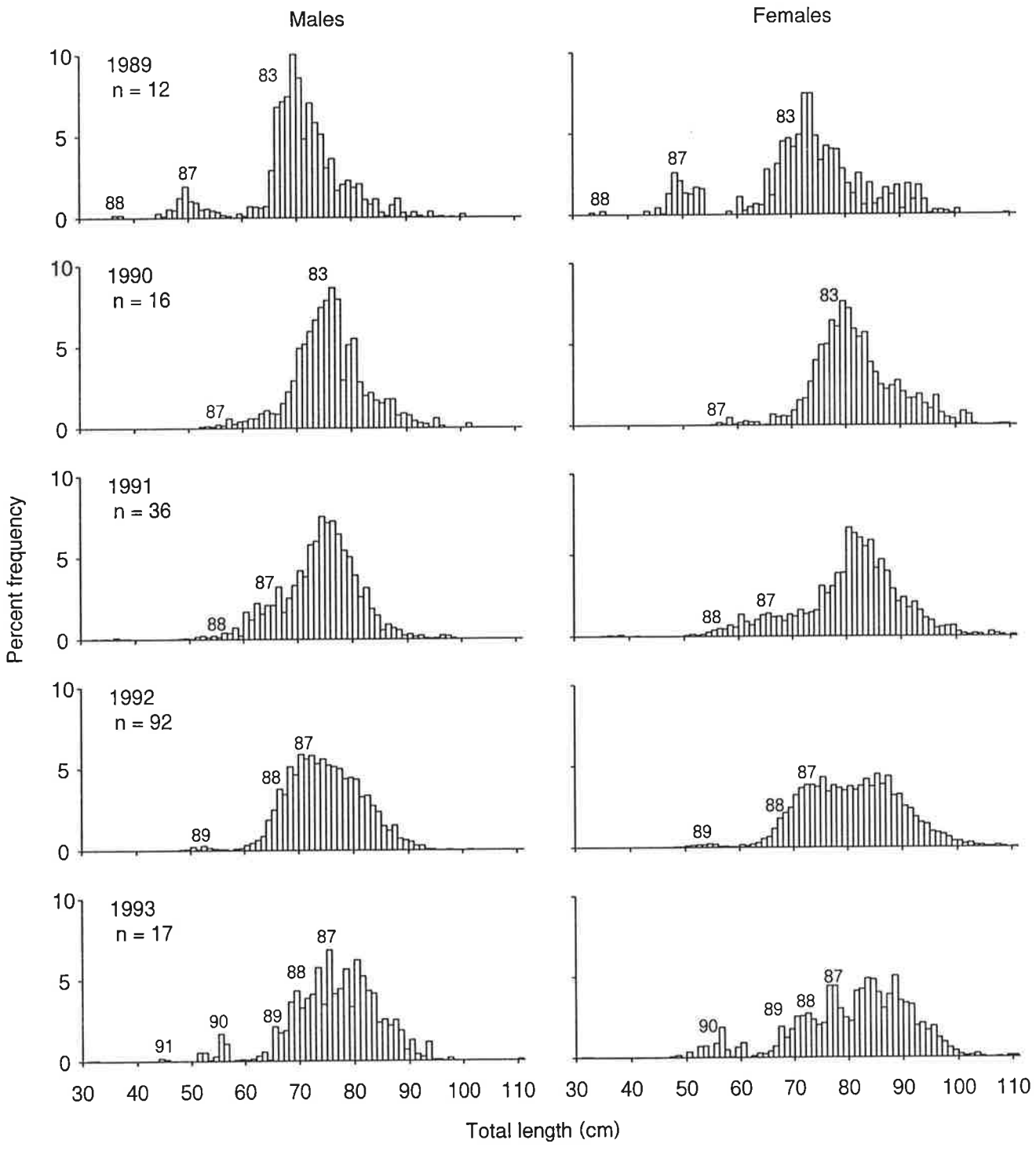

Figure 24: Length frequencies of male and female hoki taken in commercial catches from Puysegur, 1989–93 seasons, sampled by the Scientific Observer Programme. (n is the number of samples; selected year classes are marked, e.g., 87 is the 1987 year class.)

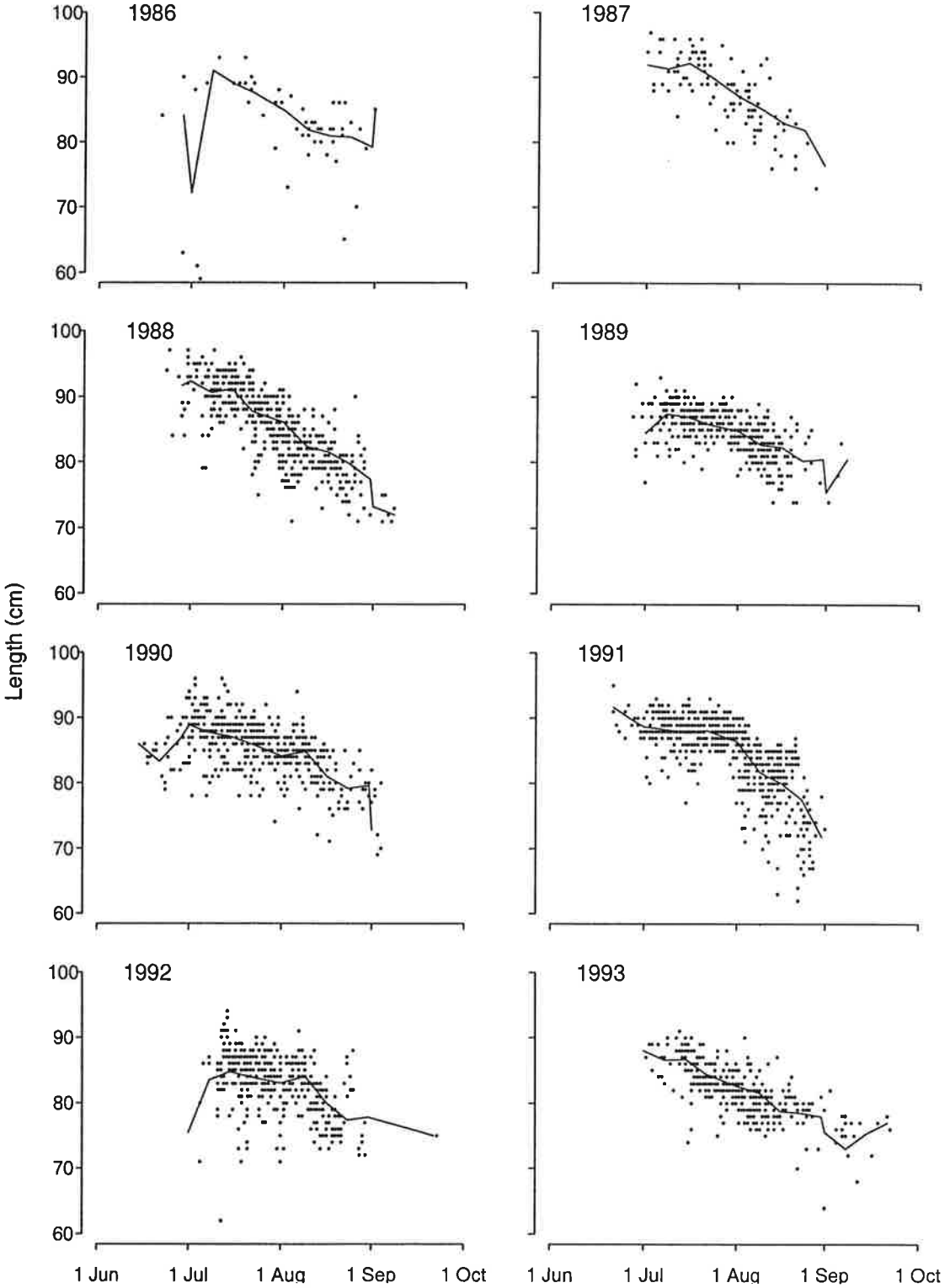

Figure 25: Mean length of female hoki per tow over the spawning season on the WCSI, 1986–93. The lines are mean length per week. (Sampled by the Scientific Observer Programme.)

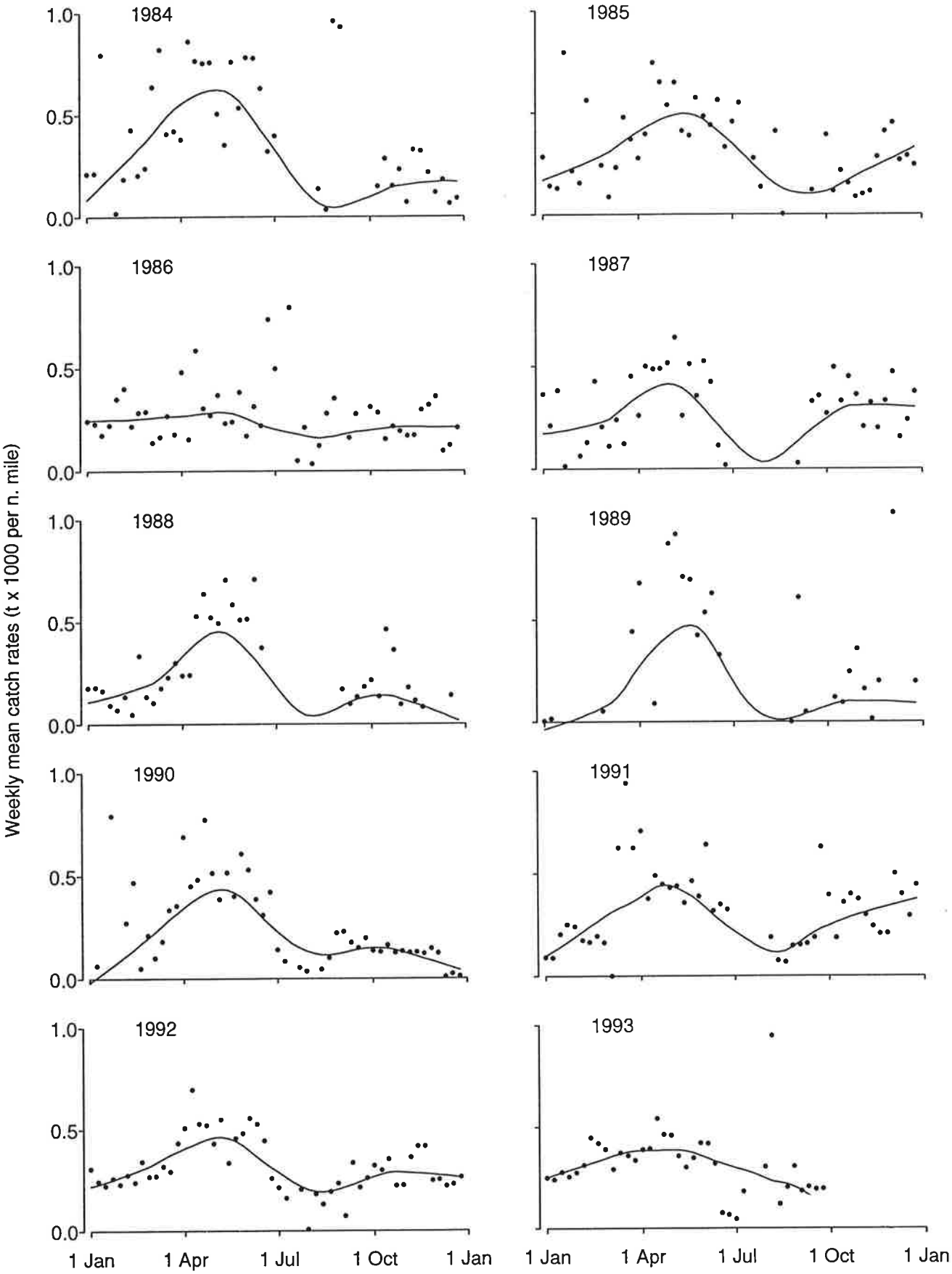

Figure 26: Mean weekly catch rates for the Southern areas for calendar years 1984–93. Lines are a loess ('S' regression model) fit.

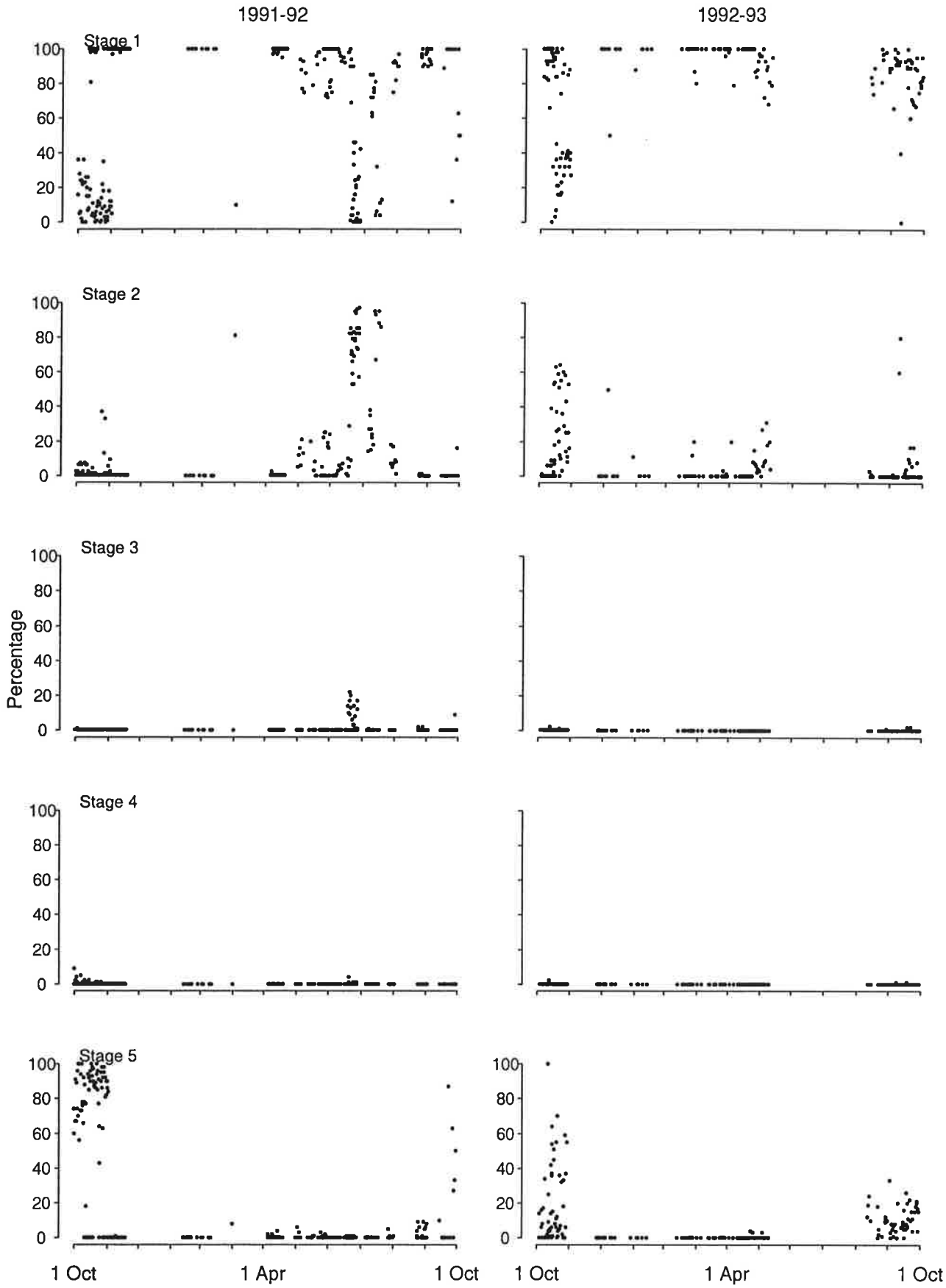

Figure 27: Percentage of female hoki at each ovarian stage in the Southern areas in the 1991–92 and 1992–93 fishing years.

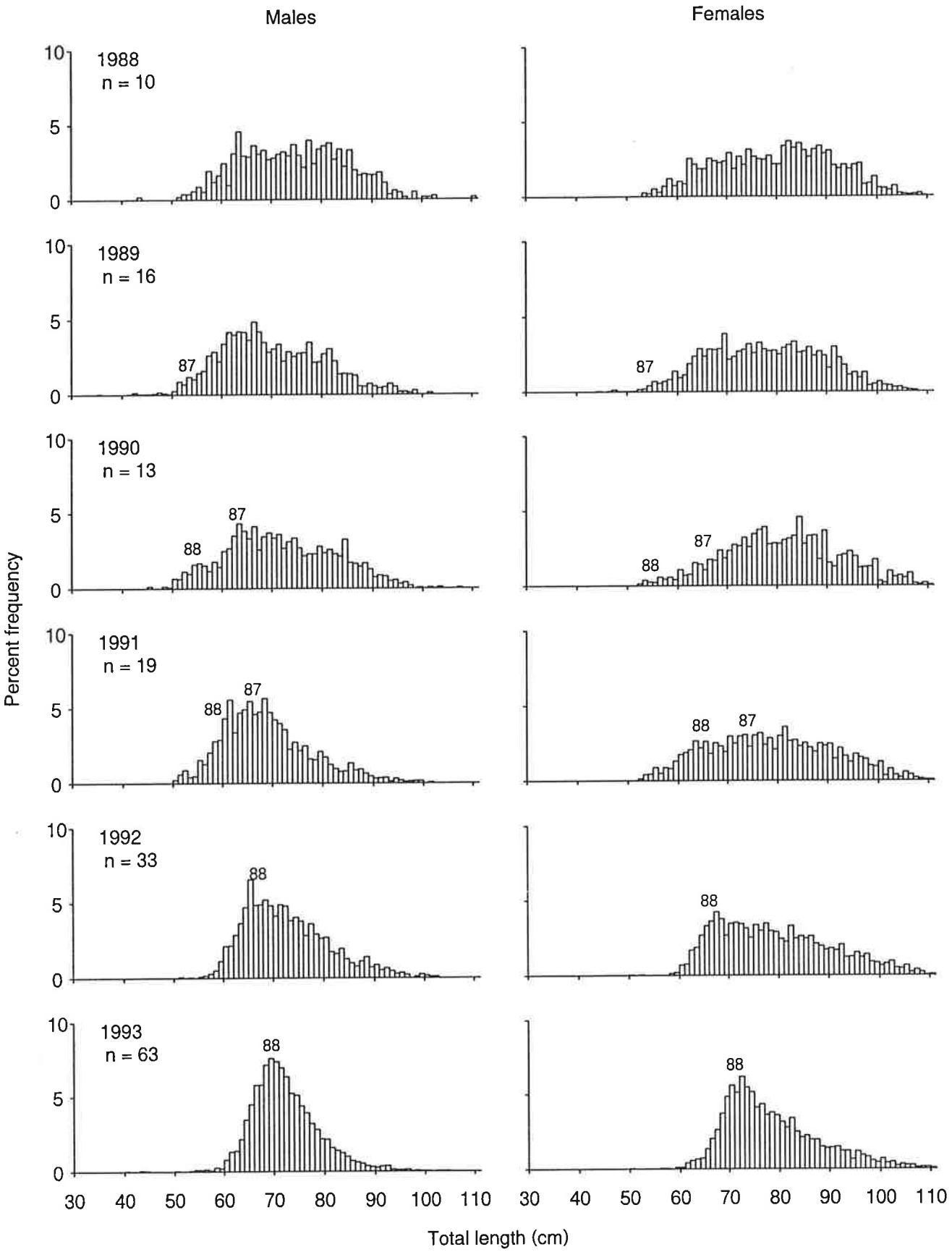

Figure 28: Length frequencies of hoki taken in commercial catches from Cook Strait, 1988–93, sampled by the Market Sampling Programme. (n is the number of samples; selected year classes are marked, e.g., 87 is the 1987 year class.)

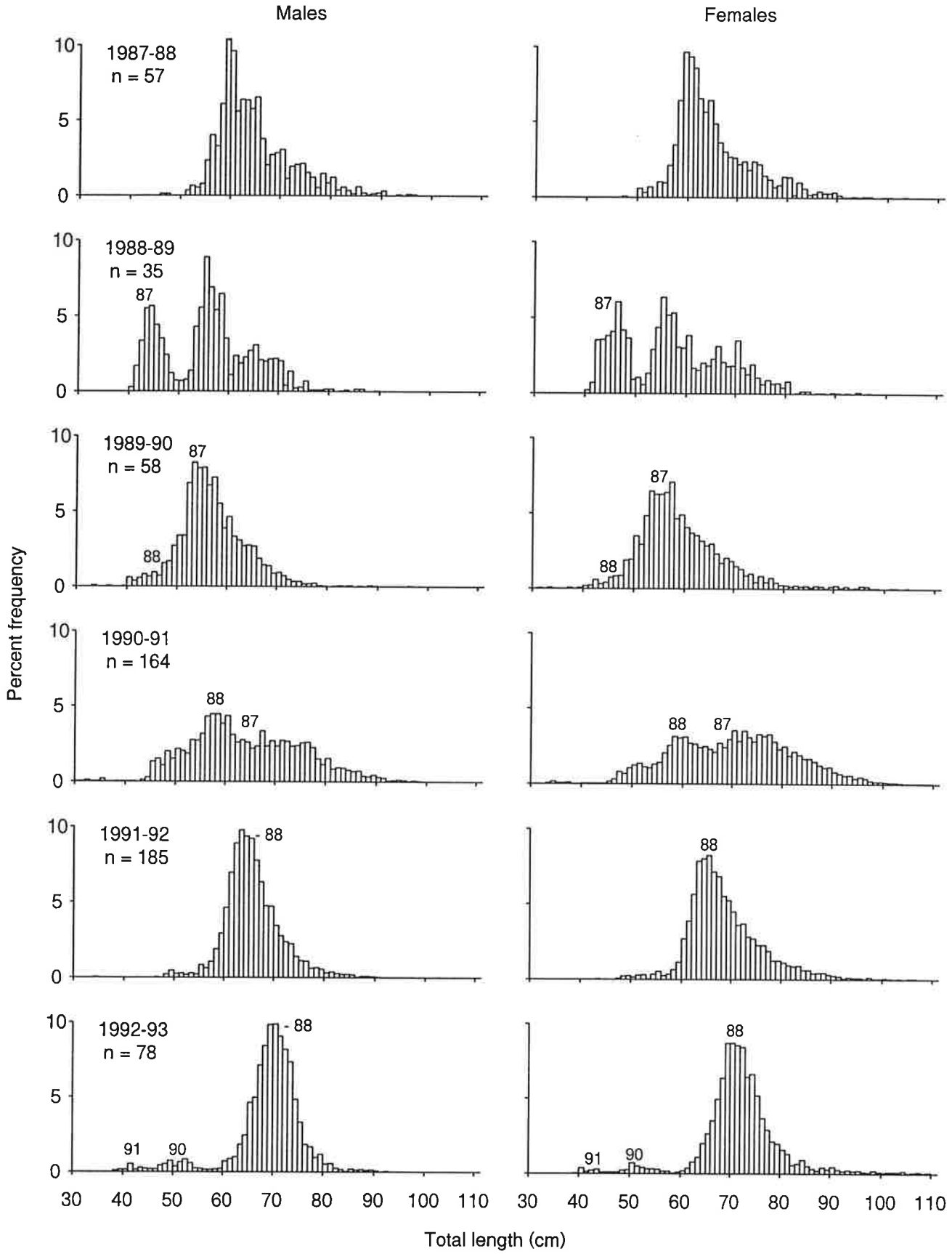

Figure 29: Length frequencies of hoki taken in commercial catches from the Chatham Rise 1988–93. Sampled by the Scientific Observer Programme. (n is the number of samples; selected year classes are marked, e.g., 87 is the 1987 year class.)

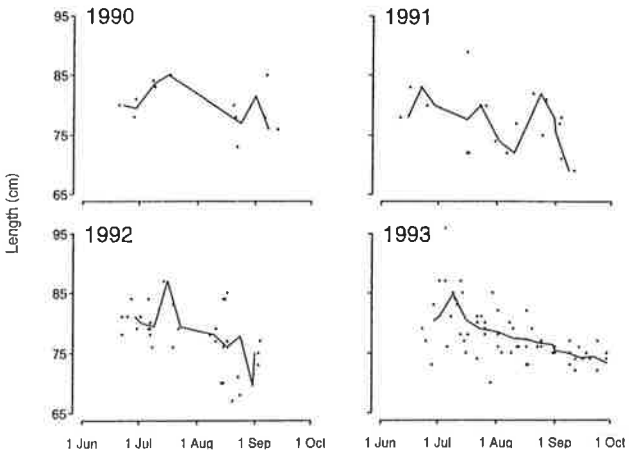

Figure 30 (above): Mean length of female hoki per tow from Cook Strait, 1990–93. The lines are mean length per week (sampled by the Market Sampling Programme; n is the number of samples.)

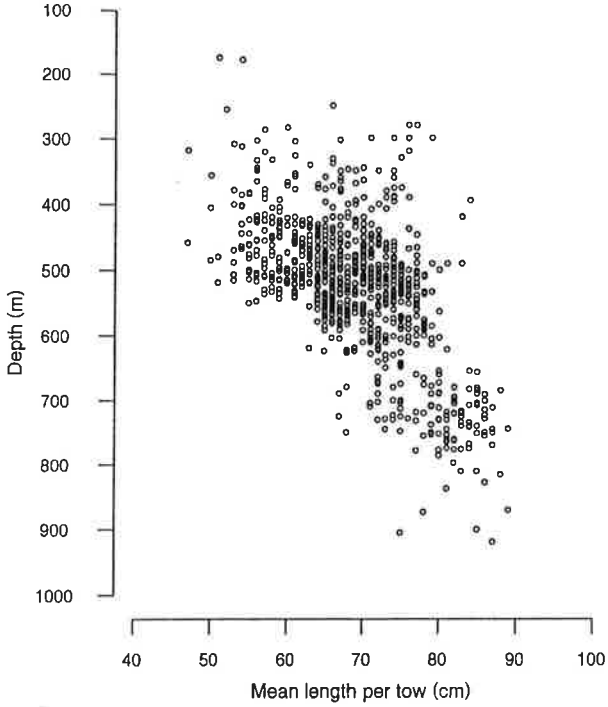

Figure 31 (right): Mean length of female hoki per tow, by depth, on the Chatham Rise (sampled by the Scientific Observer Programme.)

Discussion

Changes in the fishery, 1983–93

The hoki fishery has undergone major changes between 1983 and 1993. In the first 5 years the quota increased from 60 000 to 250 000 t, area restrictions were lifted, and fishing effort became focused on the WCSI spawning fishery, using bulk catching techniques to develop surimi production.

In the second 5 years a major new spawning fishery was developed in Cook Strait, the proportion of New Zealand owned vessels increased (particularly to operate in Cook Strait), fishing effort diversified into other areas such as the Chatham Rise and southern areas (often just before or after the main spawning period), and fishing methods moved away from bulk surimi to higher quality fillet production.

This rapid expansion had major effects on fishery management and research activities. The WCSI fishery, in particular, was associated with impacts on bycatch species, both fish and seals, and potential wastage and dumping problems. To a large extent these have been minimised by the use of midwater trawling methods, implementation of codes of practice, and reassessment of bycatch species catch levels. The need to improve research and stock assessment capabilities was also significant with the development of more rigorous fishery monitoring activities.

Hoki stock assessment, 1983–93

When management of the hoki fishery began in 1978 there was little data for a stock assessment. The first TAC of 60 000 t was set lower than the 1977 peak catch (98 000 t) to prevent overfishing of the relatively unknown stock. Francis & Fisher (1979) attempted the first assessment and estimated a 1976 biomass of 0.95 to 2.25 million tonnes, based on the commercial catch rates of the Japanese fleet relative to the cpue of *Shinkai Maru*, a Japanese research vessel used in joint exploratory research of the deepwater fisheries from 1974 to 1977.

Trawl surveys in the early 1980s suggested that there was a large hoki stock in the EEZ, of about 1.9 million tonnes (Hurst *et al.* 1988), but this was outside the spawning area and season and assumptions were required about the its catchability. It was not until the WCSI spawning grounds were acoustically surveyed in 1985 that an assessment of the spawning stock size on the WCSI was made (Patchell & Coombs 1986). As a result, the TACC was increased to 131 000 t in 1986 and to 250 000t for the 1986–87 fishing year, with no area limits.

More comprehensive commercial catch monitoring was developed in 1986. The main value of commercial data has been in the development of catch at age data which are divided into the two stocks (eastern and western) since 1989 (Sullivan & Coombs 1989), a time series of

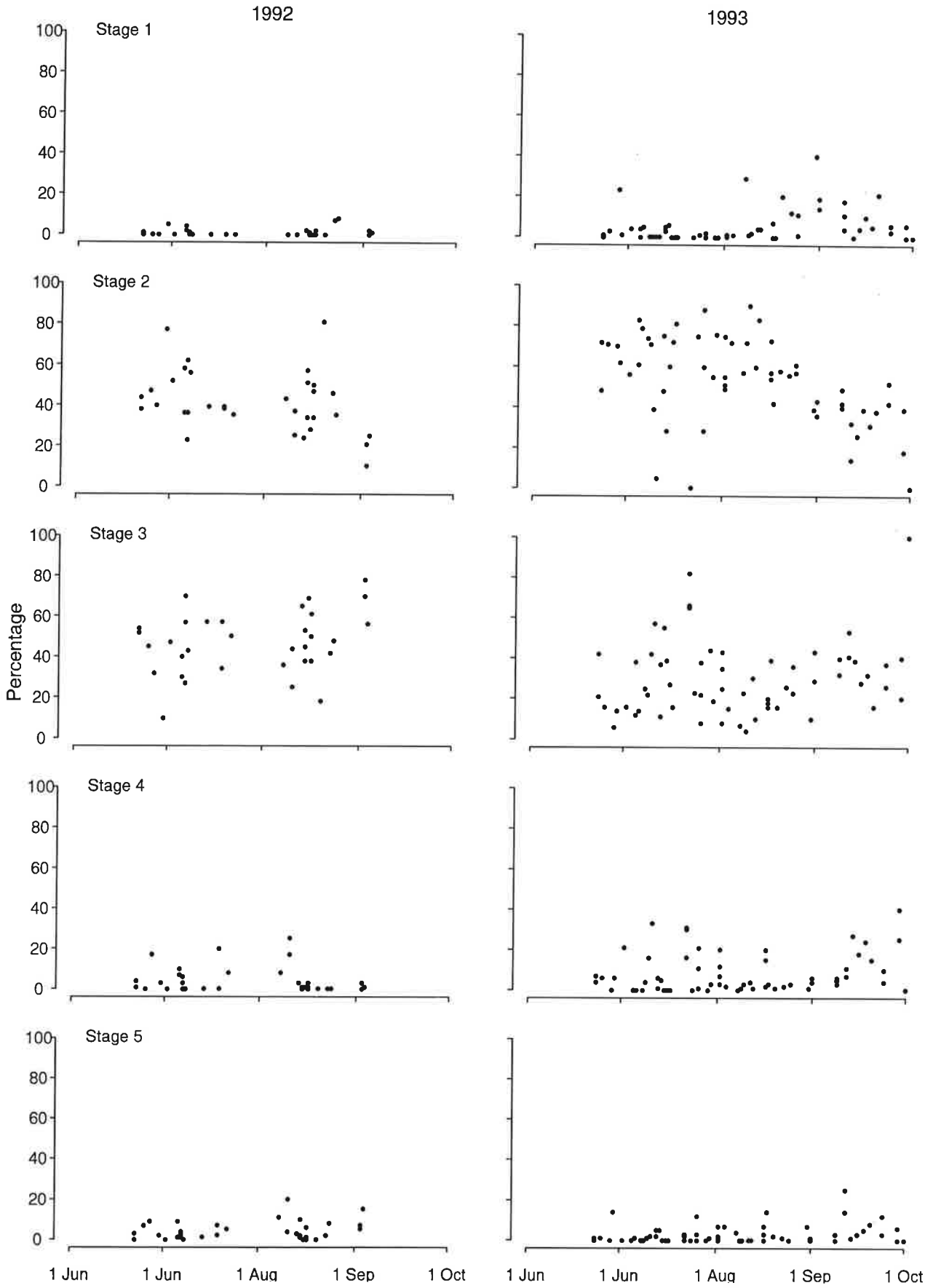

Figure 32: Percentage of female hoki at each ovarian stage from the Cook Strait area in the 1992 and 1993 fishing years (sampled by the Market Sampling Programme).

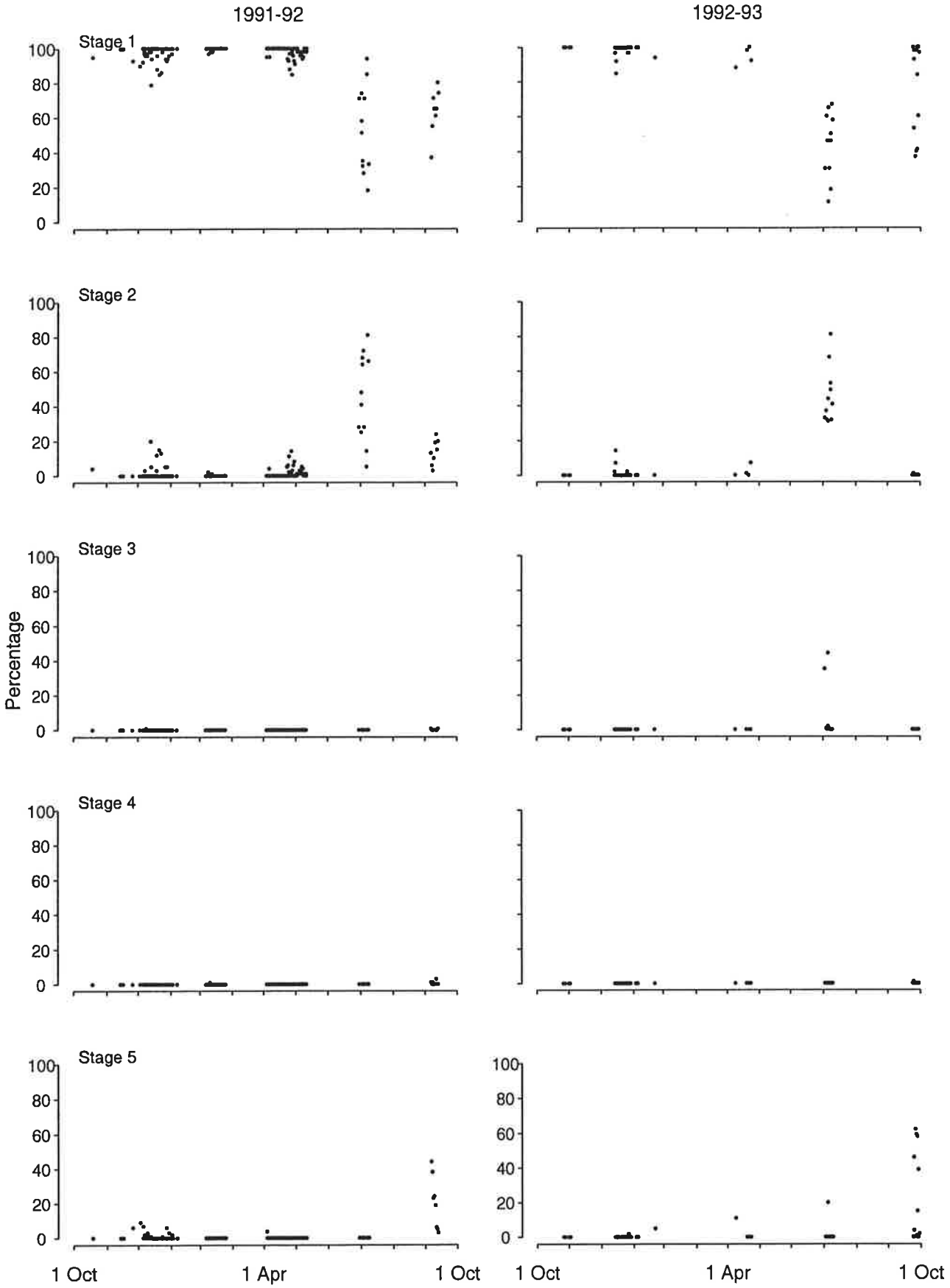

Figure 33: Percentage of female hoki at each ovarian stage from the Chatham Rise area in the 1992 and 1993 fishing years (sampled by the Scientific Observer Programme) .

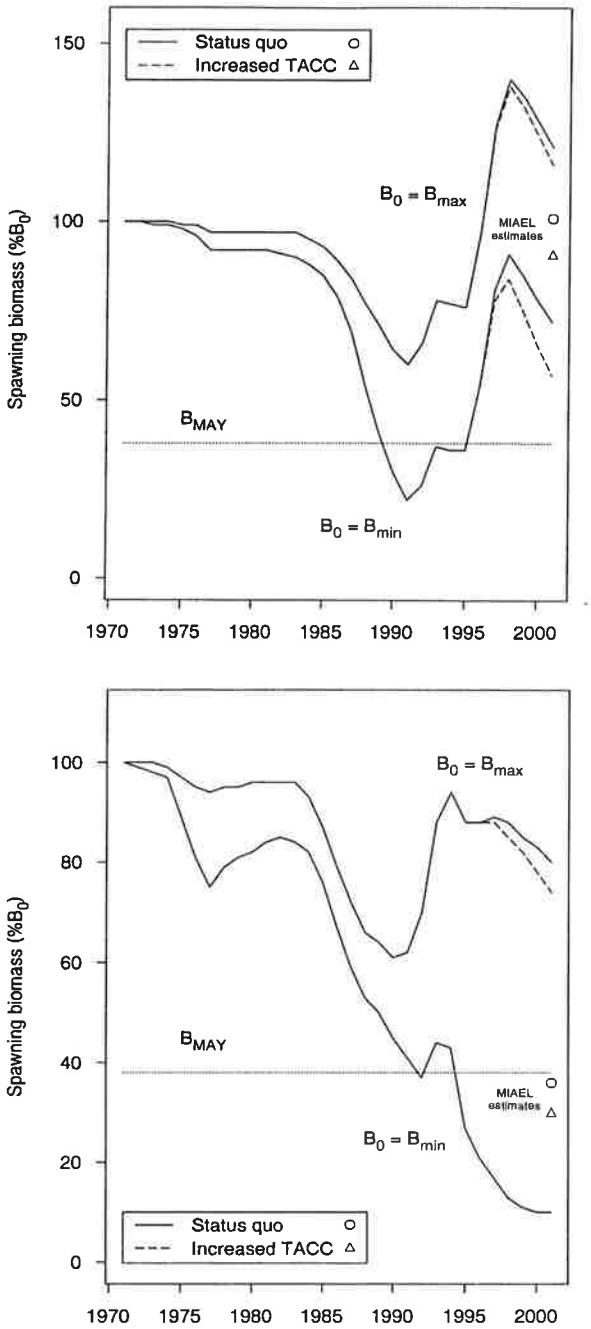

Figure 34: MIAEL (minimum integrated average expected loss) estimate of biomass in 2001, and the trajectories from minimum and maximum estimates of virgin biomass, for (a) the western stock and (b) the eastern stock under the status quo and increased TACC policies.

age structured data which has allowed a maturity ogive to be estimated (Sullivan & Cordue 1990), the relative strength of recruiting year classes to be estimated for the two stocks (Cordue 1993), the tracking of year classes through time and age validation (Horn & Sullivan 1996), and continuing reappraisal of stock structure hypotheses through examination of size and age structure by area. The commercial biological sampling data have also been used to develop understanding of spawning dynamics and to estimate residence time (Langley 1993, Ballara & Sullivan 1994), which is required for turning the acoustic estimates of relative biomass into absolute biomass.

By 1993, stock assessment of hoki had become much more sophisticated. All commercial and research data were being incorporated into the model, including time series of abundance indices (trawl, acoustic, and cpue), size (age) frequencies from the spawning fisheries, and estimates of important biological parameters such as proportion spawning, maturity ogives, and growth parameters. Cordue (1993) showed that short term risk for the status quo (200 000 t) and increased (250 000 t) TACC scenarios were low.

The most recent assessment of the biomass trajectory through the 1983 to 1993 period described in this report is shown in Figure 34 for the western and eastern stocks. The point estimate of B_0 for the western stock is 2.21 (range 1.27–3.80) million tonnes and for the eastern stock is 0.55 (range 0.28–1.10) million tonnes. The model shows that the western stock declined from 1988 to 1990, but increased subsequently as a result of recruitment of the strong 1987 and 1988 year classes. The projections of future biomass also suggest a large increase as a result of further strong recruitment predicted for the 1991 and 1992 year classes. The trajectory of the eastern stock also suggests an increase up until 1995, but is less optimistic over the next 5 years.

Continued monitoring of the performance of the fisheries and the size frequency of fish in them is essential for future assessments of the status of hoki stocks. In some areas, particularly those outside the spawning fisheries, catch sampling has been limited and the level of effort should probably be increased to better assess issues such as annual and area differences in year class strength, migration patterns, recruitment to adult fisheries, and the location of other potential spawning grounds.

Acknowledgments

We thank Kevin Sullivan for his input into an early draft of the manuscript and the efforts of all the MAF scientific observers since 1986 in collecting valuable scientific data from the hoki fisheries. We also thank Stuart Hanchet and Peter Horn for reviewing the manuscript and Mary Livingston for her constructive comments.

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