New Zealand Fisheries Assessment Research Document 98/7

Coromandel and Northland scallop stock assessments for 1997

M. Cryer

NIWA
PO Box 109 695
Newmarket
Auckland

March 1998

Ministry of Fisheries, Wellington

This series documents the scientific basis for stock assessments and fisheries management advice in New Zealand. It addresses the issues of the day in the current legislative context and in the time frames required. The documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Coromandel and Northland scallop stock assessments for 1997

M. Cryer

N.Z. Fisheries Assessment Research Document 98/7. 14 p.

1. Executive Summary

Northland and Coromandel scallop fisheries were surveyed using a combination of dive and dredge methods in March–May 1997 to predict start-of-season recruited biomass. For the Northland and Coromandel fisheries, start of season biomass was estimated as 3520 t and 1670 t (greenweight) with *c.v.*s of 21.6% and 19.3%, respectively. Provisional Yield (PY) was estimated as 2000 t and 1037 t (greenweight) for the two fisheries. Assumed average recovery rates of 13.5% (meat from green) for both fisheries lead to estimated values of PY = 270 t and 140 t, respectively. The use of the gazetted conversion factor of 12.5% leads to lower estimates of yield.

2. Introduction

2.1 Overview

This report summarises research and catch information for northern scallop fisheries, the Northland fishery (Reef Point at Ahipara to Cape Rodney) and the Coromandel controlled fishery (Cape Rodney to Town Point in the Bay of Plenty). Yield estimates for the commercial season beginning July 1997 are derived using a method based on that of Cryer (1994). This work was funded by the Ministry of Fisheries under project AKSC01.

2.2 Description of the fishery

Scallops support regionally important commercial fisheries and an intense non-commercial interest between Tauranga and Cape Reinga. The Northland commercial fishery supported about 38 vessels until April 1997 when it was introduced to the Quota Management System (QMS), whereas the Coromandel fishery (including the Hauraki Gulf) supports 22 boats and remains a controlled fishery. The dividing line between the two fisheries runs from Cape Rodney to the northernmost tip of Great Barrier Island (Figure 1) and has recently been defined in legislation. All commercial fishing is by dredge, fishers in both fisheries preferring self-tipping "box" dredges to the ring bag designs in common use in southern fisheries. A wide variety of effort controls and daily catch limits has been imposed in the past, but both fisheries are now limited by explicit seasonal catch limits specified in meatweight, together with some additional controls on dredge size, fishing hours, and non-fishing days. The catch limit for the Northland fishery is now formally established as a TACC under the QMS, with a fishing year of 1 April to 31 March. Catch and catch rates from both northern commercial fisheries are variable both within and among years, a characteristic typical of scallop fisheries worldwide (Shumway & Sandifer 1991).

Within both fisheries, fishing is conducted within a number of discrete beds. The main commercial beds in the Coromandel fishery are found north of Whitianga, east of Waiheke Island, around Little Barrier Island, and in the Bay of Plenty (principally off Waihi, and around Motiti and Slipper Islands). The main beds of the Northland fishery were historically found in Bream Bay, Rangaunu Bay, Doubtless Bay, and from Whangaroa to Matauri Bay. Since 1995, fisheries have developed in Spirits and Tom Bowling Bays in FMA 9 (*see* Figure 1). The scallop fisheries in FMA 9 were managed separately from those in FMA 1 until the Northland fishery was moved to the QMS, when all scallop fishery areas between Ahipara and Cape Rodney were included within a single Northland QMA.

Recreational and Maori customary fishing is undertaken in suitable areas throughout both fisheries, more especially in enclosed bays and harbours, many of which are closed to commercial fishing.

The minimum legal size (MLS) for scallops for commercial and amateur fishers throughout the Northland and Coromandel fishery areas was 100 mm until 1995. Starting with the 1995 season on 15 July 1995, the MLS for scallops taken commercially from the Coromandel fishery was reduced to 90 mm as part of a package of measures which also included further voluntary closed areas and reduced commercial catch limits. This package was introduced to address concerns expressed by all user groups over the impact of scallop dredging on juvenile scallops.

2.3 Literature Review

General descriptions of the biology of the New Zealand scallop, *Pecten novaezelandiae*, were given by Bull (1988) and Cryer (1994), and little new information has become available subsequently other than an unpublished Ph.D. thesis by Morrison (1997).

The New Zealand scallop is one of several species of "fan shell" bivalve molluscs found in New Zealand waters. They have a characteristic round shell with a flat upper valve and a deeply concave lower valve. Scallops inhabit waters of up to about 60 m deep (up to 85 m in the Chatham Islands), but are more common in depths of 10 to 30 m. Growth rates are spatially and temporally variable: growth to 100 mm taking anything between 1.5 and 3.5 years. The maximum age of scallops in unexploited populations is thought to be about 6 or 7 years.

P. novaezelandiae is a hermaphroditic species, each individual carrying both male and female gonads at the same time. Most individuals are sexually mature at a size of about 60 mm, although larger individuals have disproportionately larger gonads. They are extremely fecund and can spawn several times each year (although not all of these spawning events lead to successful spat settlement). Larval development lasts for about 3 weeks, depending on water temperature. Initial spat settlement is by byssus thread attachment to some surface free of sediment (shell hash, hydroids, spat bags etc.). The characteristic scallop shell does not develop until a few days after the spat loses the byssus thread and settles to the seabed.

Scallops grow rapidly (albeit with considerable variation), have high natural mortality, and exhibit highly variable recruitment. Such a life history results in fluctuating biomass, catch, and CPUE in most fisheries for scallops, and reliance on relatively few year-classes (Caddy & Gulland 1983; Orensanz *et al.* 1991; Shumway & Sandifer 1991). New Zealand stocks are not an extreme example, though Cryer (1994) showed that recruited biomass in any given year could not be predicted from historical biomass estimates, nor even from the biomass in the previous year together with estimates of intervening removals by commercial fishing.

3. Review of the Fishery

3.1 TACCs, catch, landings, and effort data

The Northland fishery was transferred to the Quota Management System (QMS) in April 1997, while the Coromandel fishery remains a controlled fishery. An explicit TACC of 189 t is in force for the Northland fishery, although the Coromandel fishery is limited by seasonal catch limits, specified on fishing permits, which have the same effect.

Landings for the 1980 to 1996 seasons are shown for the Northland fishery in Table 1 and the Coromandel fishery in Table 2. Seasons run from July to the following February in the Northland fishery and from July to December in the Coromandel fishery.

Table 1: Landings (t greenweight) from the Northland Scallop Fishery since 1980. "Whangarei" includes all beds south of Cape Brett, "Far North" includes all beds from Cape Brett to North Cape, and "Spirits Bay" includes all beds to the west of North Cape. Catch limits for 1996 were specified on permits in meatweight, and are for 1997 specified as a formal TACC (in meatweight). The approximate greenweight equivalent given here assumes the gazetted conversion factor and recovery rate of 12.5% which probably overestimates the greenweight equivalent. *, data for estimation of split by locality not yet available. Data for 1996 probably incomplete

	Catch limits (t)		Landings (t)			
Season	Meat	Approx. green	Total	Whangarei	Far North	Spirits Bay
1980	–	–	238	*	*	*
1981	–	–	560	*	*	*
1982	–	–	790	*	*	*
1983	–	–	1171	78	1093	–
1984	–	–	541	183	358	–
1985	–	–	343	214	129	–
1986	–	–	675	583	92	–
1987	–	–	1625	985	640	–
1988	–	–	1121	1071	50	–
1989	–	–	781	131	650	–
1990	–	–	519	341	178	–
1991	–	–	854	599	255	–
1992	–	–	741	447	294	–
1993	–	–	862	75	787	1
1994	–	–	1634	429	1064	142
1995	–	–	1619	*	*	450
1996	189	1508	1011	*	*	*

3.2 Other information

There is no other information on commercial fisheries relevant to this assessment, although the incidental impacts of both commercial and amateur scallop dredges were examined under MFish contracts AKSC02 and AKSC03 in 1996–97 (Cryer & Morrison, unpublished results, Morrison & Cryer, unpublished results). The full implications of this work for the assessment and management of these stocks are not yet clear, but modelling and yield per recruit (YPR) analysis strongly suggest that neither the 100 mm MLS in force in Northland nor the current method of estimating yield in Northland and Coromandel fisheries are optimal (in terms of YPR).

Table 2: Landings (t greenweight) from the Coromandel Controlled Scallop Fishery since 1980. * Landings in 1991 includes ~ 400 t from highly unusual settlement at Colville. Catch limits since 1992 have been specified on permits in meatweight, the approximate greenweight equivalent given here assumes the gazetted conversion factor and recovery rate of 12.5% which probably overestimates the greenweight equivalent. †, data for split by locality not yet available. Data for 1996 probably incomplete

	Catch limits (t)		Landings (t)				
Season	Meat	Approx. green	Total	Hauraki	Whitianga	Barrier	Bay of Plenty
1980	–	–	1005	249	690	0	77
1981	–	–	1170	332	743	41	72
1982	–	–	1050	687	385	49	80
1983	–	–	1553	687	715	120	31
1984	–	–	1123	524	525	62	12
1985	–	–	877	518	277	82	0
1986	–	–	1035	135	576	305	19
1987	–	–	1431	676	556	136	62
1988	–	–	1167	19	911	234	3
1989	–	–	360	24	253	95	1
1990	–	–	903	98	691	114	0
1991	–	–	1392	*472	822	98	0
1992	154	1232	901	67	686	68	76
1993	132	1056	455	11	229	60	149
1994	66	528	323	17	139	48	119
1995	86	686	707	†	†	†	†
1996	88	704	584	†	†	†	†

3.3 Recreational, and Maori customary fisheries

There is an intense amateur interest in scallops throughout the Northland and Coromandel fisheries. Fishing for scallops by amateurs is by dive, small dredge or, in some circumstances, hand collection from intertidal areas. To some extent, management of northern scallop fisheries has concentrated on spatial separation of commercial and amateur fisheries through the closure of harbours and enclosed waters to commercial dredging. There remain, however, areas of contention and conflict, some of which were addressed between 1995 and 1997 through voluntary closures in the Coromandel fishery.

Estimates of catch by recreational fishers in 1993–94 (Bradford 1997) are 40–60 t (greenweight) from the area shared with the Northland commercial fishery and 60–70 t from the area shared with the Coromandel commercial fishery. Commercial landings from the Northland fishery in the most comparable period (July 1994 to February 1995 scallop season) were about 1300 t, suggesting that, in that year, the recreational catch of scallops was probably less than 5% of total removals. Commercial landings from the Coromandel fishery in the most comparable period (July to December 1994 scallop season) were about 300 t, suggesting that, in that year, the recreational catch of scallops was about 20% of total removals.

3.4 Other sources of fishing mortality

Quantitative information is available (Cryer & Morrison, unpublished results) on the incidental impacts on scallop growth and mortality of encounters with commercial dredges of several designs. This information was gathered as part of MFish Project AKSC03 during the 1996–97 fishing year. Individual-based population modelling and yield per recruit analysis strongly suggest that incidental effects, especially on mortality rates, are highly influential in the determination of yield from scallop dredge fisheries. Despite the high incidental mortality rates associated with the current box dredge, this design was found to be optimal (of the three tested, and for MLS of 85 mm or more) in terms of yield per recruit, largely as a result of its higher catching efficiency compared with the ring bag and Japanese "Keta Ami" designs. This work concentrated on the Coromandel fishery and suggested that the current MLS of 90 mm was close to optimal. However, substituting some data from the Northland fishery and making assumptions regarding the applicability for Northland of data collected in the Coromandel fishery allows inferences to be drawn about the Northland fishery. The most important of these inferences is that the current MLS of 100 mm and the current method of estimating yield are probably not optimal in terms of yield per recruit.

4. Research

4.1 Stock structure

Little is known of the stock structure of New Zealand scallops. It is currently assumed for management purposes that Northland and Coromandel fisheries are separate from one another and from the various west coast harbours, Golden Bay, Tasman Bay, Marlborough Sounds, Stewart Island, and Chatham Island fisheries.

4.2 Resources surveys

Scaled length frequency distributions from six major areas of each the Northland and Coromandel fisheries are shown in Figures 2 and 3. The fraction of scallops above the MLS (100 mm in Northland, 90 mm in Coromandel) varies considerably from bed to bed and generally increases with decreasing latitude. The abundance of scallops in most beds varies considerably among years.

4.3 Other studies

Estimates of growth rate from tagging studies were made by K.A.R. Walshe (pers. comm., Table 3) and these have been used for many years to estimate the expected growth of scallops between the midpoint of surveys and the start of the season. Both growth curves derived by Walshe suggest that scallops of 95 mm length or greater are likely to grow to the legal size of 100 mm during the period between survey and season. Tagging studies conducted as part of MFish project AKSC03 and length frequency analyses have produced broadly similar estimates of growth rate for scallops of close to 100 mm length, and are not considered sufficiently different at this stage to modify the normal assumed critical size of 95 mm. It is assumed for the purpose of predicting start of season biomass that scallops of 95 mm or over at the time of the survey are likely to achieve 100 mm by the start of the season, and the start-of-season biomass of 100 mm scallops is used to estimate yield for both fisheries (notwithstanding the lower MLS in the Coromandel fishery).

Table 3: Estimated parameters of the Von Bertalanffy growth equation for Whitianga and Waiheke (Hauraki Gulf) scallop populations as derived from tagging experiments by K.A.R. Walshe (pers. comm.) in the early 1980s

	L_∞	K	t_0
Whitianga population	140.6	0.378	-0.0004
Hauraki Gulf population	115.9	1.200	0.0000

4.4 Biomass estimates

4.4.1 Northland fishery

Most of the important Northland beds south of North Cape have been surveyed annually since 1992. Surveys were by dredge only in 1992, by diver only in 1993, and by both methods between 1994 and 1997 (Table 4). The beds in Spirits and Tom Bowling Bays have been surveyed only in 1996 and 1997. There has been sporadic fishing in this area for many years which increased markedly in 1995. Where dredges are used in surveys, absolute biomass estimates are made by correcting for the efficiency of dredge in use. Dredge efficiency is estimated by comparison of dredge counts with diver counts in experimental areas (Cryer & Parkinson 1997).

Table 4: Estimated recruited biomass of scallops (at the time of surveys) in various component beds of the Northland scallop fishery since 1992. – indicates no survey in a given year. Estimates of biomass given for 1993 are probably negatively biased, especially for Rangaunu Bay (*), by the restriction of diving to depths under 30 m, and all estimates before 1996 are negatively biased by the lack of surveys in Spirits Bay (†). Totals also include biomass from less important beds at Mangawhai, Pakiri, around the Cavalli Passage, in Great Exhibition Bay, and Tom Bowling Bay when these were surveyed. Commercial landings in each year for comparison can be seen in Table 1, wherein "Far North" landings come from beds described here as "Whangaroa", "Doubtless" and "Rangaunu"

						Biomass (t)
Year	Bream Bay	Whangaroa	Doubtless	Rangaunu	Spirits Bay	Total
1992	1 733	–	78	766	–	†3 092
1993	569	172	77	*170	–	*1 094
1994	428	66	133	871	–	†1 611
1995	363	239	103	941	–	†1 984
1996	239	128	32	870	3 361	5 098
1997	580	117	50	1 038	1 513	3 974

4.4.2 Coromandel fishery

Diver surveys of the Whitianga beds have been carried out almost annually since 1978 (Table 5). Other beds were surveyed only sporadically, mostly by dredge, until 1994, after which composite surveys covered most commercially exploited beds each year. The two most recent surveys are described by Cryer & Parkinson (1997). Where dredges are used in surveys, absolute biomass estimates are made by correcting for the efficiency of dredge in use. Dredge efficiency is estimated by comparison of dredge counts with diver counts in experimental areas (Cryer & Parkinson 1997).

The bed at Whitianga has been one of the mainstays of the Coromandel fishery since the fishery began. Biomass has varied by almost a factor of five, with seemingly little link to fishing pressure (Cryer 1994). Recent years have been relatively poor (four of the five lowest estimates in the history of the fishery), but none as poor as the second survey during the initial development stages of the fishery in 1979. Anecdotal reports from fishers suggest that the worst fishing at Whitianga was experienced in 1989 and it is unfortunate that no survey was conducted in that year.

Historically, the second most important bed in the Coromandel fishery was at Waiheke. This bed underwent a rapid decline in the late 1980s and was essentially unfished between 1993 and 1996. The 1995 and 1996 survey estimates were both higher than the extremely low estimate in 1994, and the 1997 survey strengthens the suggestion that some improvement in this bed may have occurred. The precision of biomass estimates by individual bed from these surveys is usually poor (*c.v.* over 40%), but the consistent increase in estimates for Waiheke since 1994 is encouraging.

Table 5: Estimated recruited biomass of scallops in various component beds of the Coromandel scallop fishery since 1978. – indicates no survey in a given year, * not all beds surveyed, estimate of total biomass probably significantly biased low. Commercial landings in each year for comparison are given in Table 2, wherein "Bay of Plenty" landings come from beds described here as "Waihi" and "Motiti"

						Biomass (t)
Year	Waiheke	Whitianga	L. Barrier	Waihi	Motiti	Total
1978	–	1386	–	–	–	–
1979	–	368	–	–	–	–
1980	–	1197	–	–	–	–
1981	–	1092	–	–	–	–
1982	–	725	–	–	–	–
1983	–	998	–	–	–	–
1984	800	1092	–	–	–	*1892
1985	2000	966	–	–	–	*2966
1986	1500	1313	–	–	–	*2813
1987	–	1628	–	–	–	–
1988	–	–	–	–	–	–
1989	–	–	–	–	–	–
1990	608	767	–	–	–	*1375
1991	266	824	–	–	–	*1090
1992	73	1272	–	–	–	*1345
1993	41	748	–	735	–	*1524
1994	3	481	–	153	–	*637
1995	26	445	258	58	451	1277
1996	28	619	346	19	222	1244
1997	508	623	402	70	199	1839

4.5 Yield Estimates

4.5.1 Estimation of Maximum Constant Yield (MCY)

MCY is not normally estimated for scallops and, given the highly variable nature of most wild scallop fisheries, is likely to be close to zero.

4.5.2 Estimation of Current Annual Yield (CAY)

Given the lack of a reliable estimate of reference fishing mortality, CAY cannot be estimated directly for scallops. Cryer (1994) described a method of estimating yield for scallops in the Coromandel fishery, but this yield estimate is more properly defined as Provisional Yield as it can be updated "in-season".

Estimates of reference fishing mortality should become available after the start of the 1997 scallop fishing season (using information derived from MFish projects AKSC03 and AKSC02) and it may be possible to estimate CAY using these rates for the 1998 season.

4.5.3 Other Yield Estimates

4.5.3.2 Estimation of Provisional Yield

Provisional Yield (PY) (Cryer 1994) is estimated as the lower limit of a 95% confidence distribution for the estimate of start-of-season recruited biomass, plus an amount to account for beds not surveyed before the season. The amount added for unsurveyed beds is estimated as the product of the variability factor (Annala & Sullivan 1997; $M > 0.35$, $c = 0.6$ for scallops) and the historical average landings from the unsurveyed beds.

4.5.3.2 PY for the Northland fishery in 1997

For Northland scallops in 1997 (Cryer & Parkinson 1998), start-of-season recruited biomass (100 mm or greater) is estimated at 3520 t (greenweight) with a *c.v.* of 21.6%, giving a lower limit to the 95% confidence distribution of slightly over 1999 t. Fishers have highlighted no significant unsurveyed beds, so:

$$PY = 2000 \text{ t} + 0.6 * 0 \text{ t} = 2000 \text{ t (greenweight)}$$

The TACC for Northland scallops is specified in meatweight, and an assumed average recovery rate for the forthcoming season is required to convert the estimate of yield in greenweight to meatweight. The historical average recovery rate recorded for scallops in the Coromandel fishery (*see* Cryer & Parkinson 1997) is 13.5%, compared with the gazetted conversion factor of 8.0 (which equates to a recovery rate of 12.5% meat from green). In meatweight, therefore, yield can be estimated as:

$$PY = 2000 \text{ t} * 0.135 = 270 \text{ t (meat, based on historical recovery), or}$$
$$PY = 2000 \text{ t} * 0.125 = 250 \text{ t (meat, based on the gazetted conversion factor).}$$

Northland fishers and processors claim that average recovery from Northland scallops may be greater than 13.5% as they are usually larger and fatter than scallops from the Coromandel fishery. If this is true, then the above meatweight estimates of yield would be conservative. However, there is little hard information upon which to judge these claims, and the high variability of conversion rates spatially and temporally (within and between seasons) would suggest some caution should be exercised in predicting high average recovery rates throughout a season.

The level of risk to the putative Northland scallop stock of fishing at the estimated PY level cannot be determined.

4.5.3.2 PY for the Coromandel fishery in 1997

For Coromandel scallops in 1997 (Cryer & Parkinson 1997), start-of-season recruited biomass (100 mm or greater) is estimated at 1670 t (greenweight) with a *c.v.* of 19.3%, giving a lower tail to the 95% confidence distribution of 1022 t. Historical average landings from the only major unsurveyed beds at Great Barrier Island (1980–94) were about 25 t, giving:

$$PY = 1022\ t + 0.6 * 25\ t = 1037\ t\ \text{(greenweight)}$$

Catch limits for the Coromandel fishery are also specified in meatweight, and the average recovery rate of 13.5% is probably appropriate as long as the scallops do not remain in very poor condition throughout the 1997 season.

$$PY = 1037 * 0.135 = 140\ t\ \text{(meat, based on historical recovery), or}$$
$$PY = 1037 * 0.125 = 130\ t\ \text{(meat, based on the gazetted conversion factor).}$$

The level of risk to the putative Coromandel scallop stock of fishing at the estimated PY level cannot be determined.

4.6 Models

Yield and egg per recruit models were developed for Coromandel and, by inference, Northland commercial dredge fisheries for scallops by Cryer & Morrison (unpublished results) under MFish project AKSC03. This modelling, incorporating the incidental effects of dredging on the growth and mortality rates of scallops, has allowed the estimation of reference fishing mortality rates such as $F_{0.1}$ and, for some cases F_{max}, but these were not available at the start of the 1997 scallop season. This information could be used to revise the method of estimating yield and setting catch limits for one or both fisheries in 1998.

5. Management Implications

In previous years, catch limits for Northland and Coromandel fisheries have been established on the basis of pre-season estimates of PY. These catch limits are reviewable upwards during the season after reviews of catch and effort information.

PY should provide a conservative estimate of the available yield during a forthcoming scallop season but, in practice, fishers have sometimes experienced difficulty in taking catch limits which sum to PY in years when density is low. It may be that, in years when a significant fraction of the total population in either fishery is present at low density over large areas, the method of estimating yield derived by Cryer (1994) is not appropriate. It may be possible to examine this problem by estimating critical "commercial densities" of scallops and using them to detect and delete from yield calculations areas where density is too low to support commercial fishing, although this is currently beyond the scope of the assessment project.

Yield and egg per recruit analyses from MFish Project AKSC03 may enable MFish to base the management of these fisheries more on traditional estimates of yield (*see* Annala & Sullivan 1997).

6. Acknowledgments

This work was funded by the Ministry of Fisheries under contract AKSC01.

Thanks to all divers and to crew on board dredge boats for their assistance. Members of the Shellfish Fishery Assessment Working Group, Terese Kendrick, and Susie Iball reviewed early drafts. Mike Beardsell's comments considerably improved clarity and readability.

7. References

Annala, J.H. & Sullivan, K.J. 1997: Report from the Fishery Assessment Plenary, May 1997: stock assessments and yield estimates. Ministry of Fisheries, Wellington, N.Z. 382 p.

Bradford, E. 1997: Estimated recreational catches from Ministry of Fisheries North region marine recreational fishing surveys, 1993–94. N.Z. Fisheries Assessment Research Document 97/7. 16 p.

Bull, M.F. 1988: New Zealand scallop. N.Z. Fisheries Assessment Research Document 88/25. 16 p.

Caddy, J.F. & Gulland, J.A. 1983: Historical patterns of fish stocks. *Marine Policy 7:* 267–278.

Cryer, M. 1994: Estimating CAY for northern commercial scallop fisheries: a technique based on estimates of biomass and catch from the Whitianga bed. N.Z. Fisheries Assessment Research Document 94/18. 21 p.

Cryer, M. & Parkinson, D.M. 1997: Dive and dredge surveys of scallops in the Northland and Coromandel scallop fisheries, February–June 1996 and March–May 1997. Working document for Shellfish Fishery Assessment Working Group in 1996 and 1997 (Copy held by NIWA, Auckland.) 40 p.

Morrison, M. 1997: Population dynamics and exploitation of scallops, *Pecten novaezelandiae*, in the Hauraki Gulf. Unpublished Ph.D. thesis, University of Auckland, Auckland, N.Z.

Orensanz, J.M., Parma, A.M., & Iribarne, O.O. 1991: Population dynamics and management of natural stocks. Ch. 13 in S.E. Shumway (ed.) Scallops: Biology Ecology and Aquaculture. *Developments in Aquaculture and Fisheries Science*, Elsevier, Amsterdam.

Shumway, S.E. & Sandifer, P.A. (eds) 1991: Scallop biology and culture. Selected papers from the 7th International Pectinid Workshop. World Aquaculture Society, Baton Rouge, Louisiana, USA.

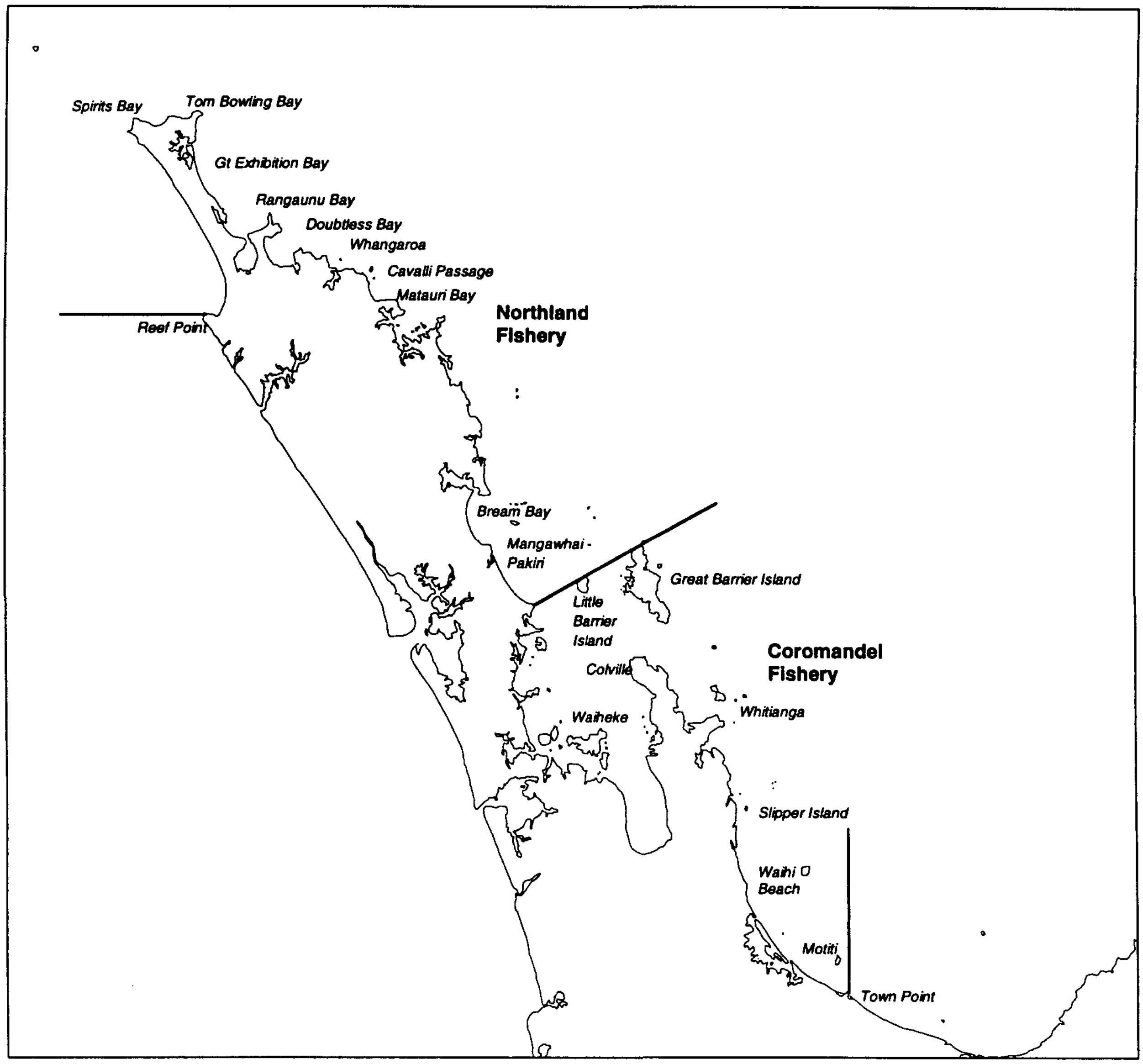

Figure 1: Northern scallop fishery areas (dividing lines are approximate) and locations cited in the text.

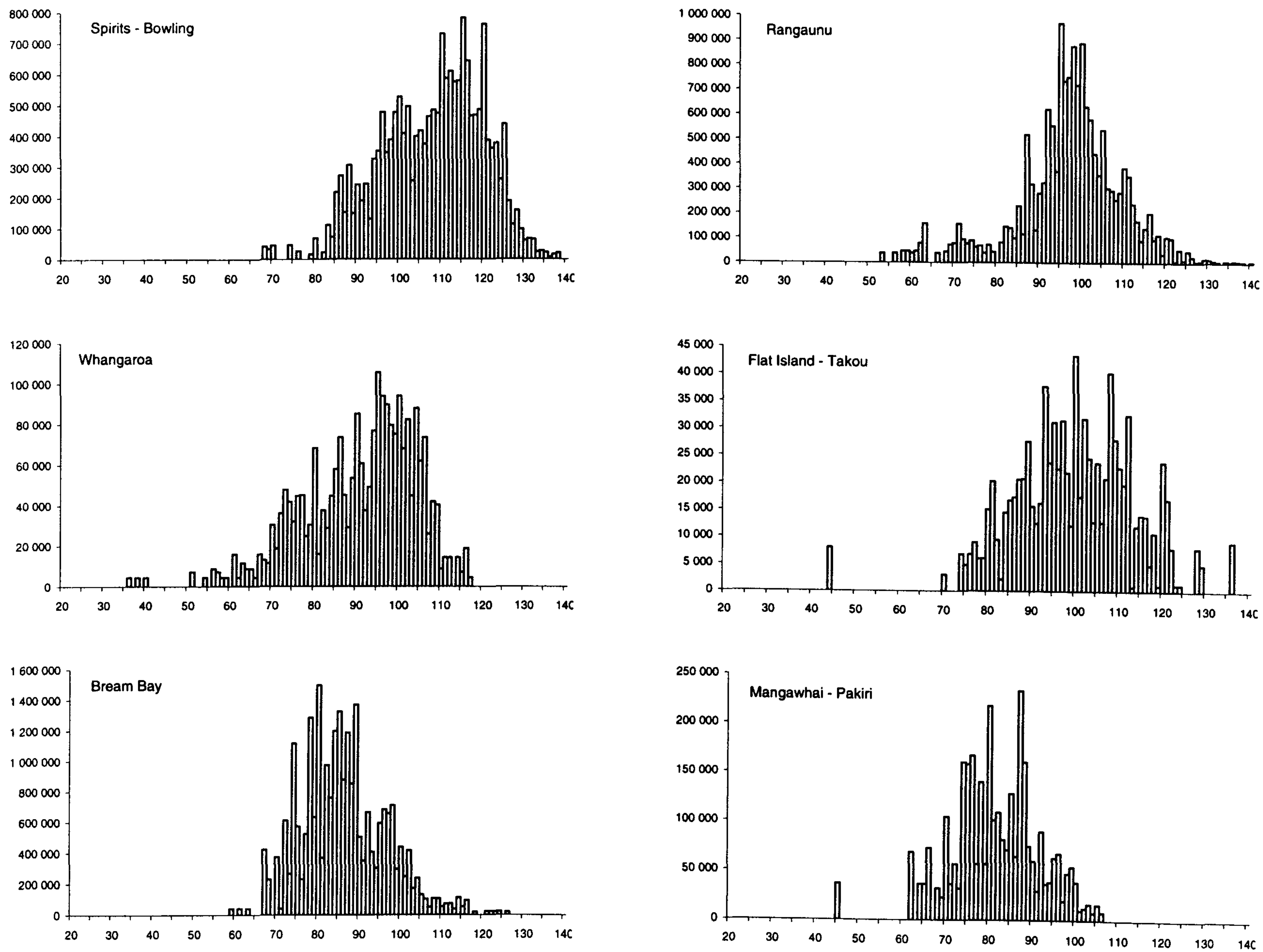

Figure 2: Scaled length frequency distributions for scallops in six identifiable areas (beds) of the Northland fishery surveyed in February–March 1997.

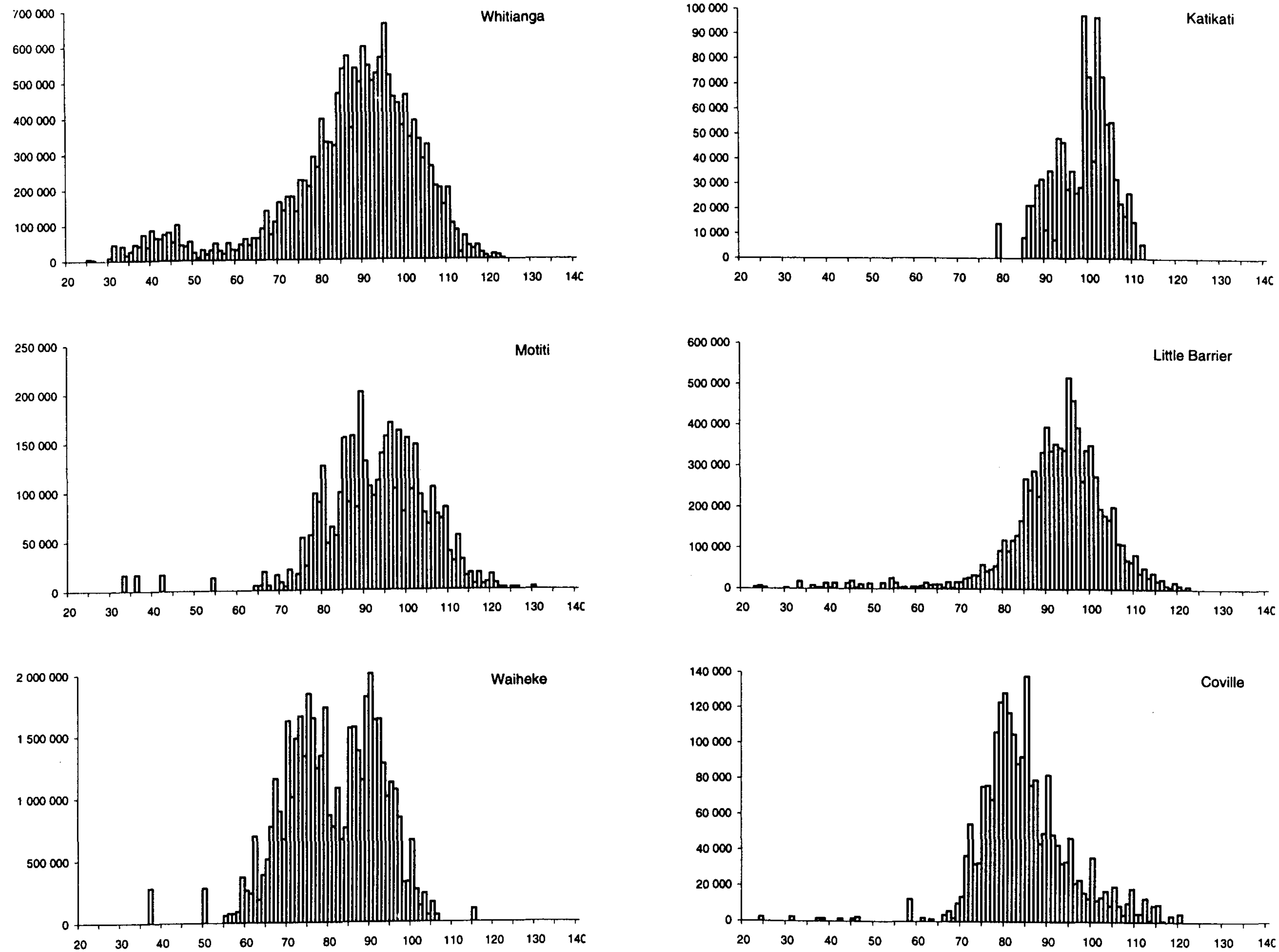

Figure 3: Scaled length frequency distributions for scallops in six identifiable areas (beds) of the Coromandel fishery from surveys in March–May 1997.