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Coromandel scallop stock assessment for 1999

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EXECUTIVE SUMMARY

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The Coromandel scallop fishery was surveyed by dredge in May 1999 to predict start-of-season recruited biomass. For comparison with historical surveys, start-of-season biomass (scallops 100 mm or more shell length) was estimated as 300 t with a *c.v.* of 19%. The 1997 and 1998 assessments led to estimates of 1670 and 1337 t with c.v.s of 20 and 13%, respectively. The 1999 start of season biomass at the commercial MLS of 90 mm was estimated as 752 t with a c.v. of 18%, compared with a 1998 estimate of 2700 t with a c.v. of 15%. Estimates of recruited biomass in 1999 are the lowest since surveys began in 1978. About 11% of recruited biomass at the MLS of 90 mm is contained with areas proposed for closure to commercial fishing. Provisional Yield (PY) was estimated as 210 t (greenweight) and CAY was estimated as 272–328 t (depending on the reference rate of fishing mortality adopted). An assumed average recovery rate of 13.5% (meat from green) leads to estimates of PY = 28 t, and CAY = 37–44 t. The gazetted conversion factor of 12.5% leads to lower estimates of yield. Exclusion of biomass in areas proposed for closure would reduce estimated yield by about 11%.

1. INTRODUCTION

1.1 Overview

This report summarises research and catch information for the Coromandel Controlled Fishery (Cape Rodney to Town Point in the Bay of Plenty). Yield estimates for the commercial season beginning July 1999 are derived using methods after Cryer (1994) and Annala et al. (2000). This work was funded by the Ministry of Fisheries under project SCA9801.

1.2 Description of the fishery

Scallops support regionally important commercial fisheries and an intense non-commercial interest between Tauranga and Cape Rodney. The Coromandel controlled scallop fishery (including the Hauraki Gulf) supports 22 boats and is managed as a controlled fishery. The dividing line between this fishery and the Northland scallop fishery (which is managed under the QMS) 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 and self-tipping "box" dredges are preferred to the ring bag designs in common use in southern fisheries. Many effort controls and daily catch limits have been imposed in the past, but the fishery is now limited by explicit seasonal catch limits specified in meatweight, together with some additional controls on dredge size, fishing hours, and non-fishing days. Catch and catch rates from this fishery are variable both within and among years, a characteristic of scallop fisheries world-wide (Shumway & Sandifer 1991).

Fishing is conducted within a number of discrete beds 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). 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 Coromandel fishery area was 100 mm until 1995. Starting with the 1995 commercial season in 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 (VCAs) 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.

1.3 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 on the biology has become available subsequently other than an unpublished Ph.D. thesis by Morrison (1998).

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 to about 60 m deep (to 85 m in the Chatham Islands), but are more common in the Coromandel fishery in depths of 10 to 30 m. Growth rates are spatially and temporally variable; growth to 100 mm takes 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 an hermaphroditic species, each individual carrying both male and female gonads at the same time. Most individuals are sexually mature at 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 hashes, 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. Cryer (1994) showed that recruited biomass in a 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.

2. Review of the fishery

2.1 TACCs, catch, landings, and effort data

The Coromandel fishery is managed as a Controlled Fishery. Catch (Table 1) is limited by seasonal limits which have the same effect as a TACC. Seasons run from 15 July to 21 December each year.

Catch rates are variable both within and among seasons, but effort and CPUE information are not presented here because they are discussed in a separate document (Cryer 2000) which addresses the extent to which (declines in) CPUE can be used to estimate biomass.

2.2 Other information

The incidental impacts of commercial scallop dredges were examined under MFish contract AKSC03 in 1996–97 (Cryer & Morrison 1997). Individual-based modelling and stochastic yield-per-recruit (YPR) analysis suggest that neither the 100 mm MLS in force in Northland nor the PY method of estimating yield in Northland and Coromandel fisheries were optimal (in terms of maximising long term average landings).

2.3 Recreational and Maori customary fisheries

There is an intense amateur interest in scallops throughout the Coromandel fishery. Amateurs usually dive or use small dredges but, in some circumstances, they collect scallops by hand 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.

Estimates of catch by recreational fishers in 1993–94 (Bradford 1997) are 60–70 t from the area shared with the Coromandel commercial fishery. Commercial landings from the Coromandel controlled 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.

2.4 Other sources of fishing mortality

Quantitative information is available on the incidental impacts on scallop growth and mortality of encounters with commercial dredges of several designs (Cryer & Morrison 1997). 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 a 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 suggested that the current MLS of 90 mm was close to optimal (in terms of maximising long term average landings) for the Coromandel fishery.

Table 1: Catch limits and landings (t greenweight or meatweight) from the Coromandel fishery since 1980. "Landed" figures come from the landed section of the Catch Effort and Landing (CELR) form and "Estimated" figures from the effort section and are pro-rated to sum to the total landed greenweight. "Hauraki" includes areas 2X and 2W, "Whitianga" includes 2L and 2K, "Barrier " includes 2R, 2S, and 2Q, "Bay of Plenty" includes areas 2A–2I. Catch limits since 1992 specified on permits in meatweight. "Approximate greenweight" assumes the gazetted conversion factor of 12.5% and probably overestimates the real greenweight. * Landings in 1991 include about 400 t from Colville; –, no catch limits set. Data for 1998 up to 30 September only, landings data provisional.

	Catch limits		Landed		Estimated			
Season	Meat	Approximate greenweight	Meat	Green	Hauraki Gulf	Whitianga	Barrier Islands	Bay of Plenty
1974				26	0	26	0	0
1975				76	0	76	0	0
1976	–	–		112	0	98	0	14
1977	–	–		710	0	574	0	136
1978	–	–		961	164	729	3	65
1979	–	–		790	282	362	51	91
1980	–	–		1005	249	690	23	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	79	574	25	323	176	50
1996	88	704	80	594	25	359	193	18
1997	105	840	89	679	26	473	165	15
1998	110	880	19	204	1	199	2	1

3. RESEARCH

3.1 Stock structure

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

3.2 Resource surveys

Scaled length frequency distributions from six major areas of each the Coromandel fishery since 1994 are shown in Figures 2–4. The fraction of scallops above the MLS of 90 mm varies considerably from bed to bed and abundance in most beds varies considerably among years. Full details of the dredge surveys conducted in May 1999 which led to these data are given by Cryer & Parkinson (1999b).

3.3 Other studies

K.A.R. Walshe (1984) estimated the parameters of the von Bertalanffy growth function for scallops in Bay of Plenty and Hauraki Gulf beds using Gulland's (1964) method of analysing tag return data. He found both K and L_∞ to be different for these two areas (1.20 *vs.* 0.38 y^{-1} and 116 *vs.* 141 mm, respectively). Walshe's estimates 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, and 95 mm has therefore been used as a "critical size" to divide scallops likely to recruit from those unlikely to recruit by the start of each season. Analysis of L.G. Allen's (unpublished) data by Cryer & Parkinson (1999b) suggested that the growth rate of scallops close to 100 mm long was variable between years and with depth. This could render start-of-season biomass estimates sensitive to growth rate between survey and season and to the depth distribution of scallop biomass. The implications of these results have not been examined in detail, so 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 grow to 100 mm by the start of the season, and that scallops of 85 mm or over at the time of the survey are likely to grow to 90 mm by the start of the season. In the past, the start-of-season biomass of 100 mm scallops has been used to estimate yield for both fisheries (notwithstanding the lower MLS in the Coromandel fishery), although alternative yield estimators using the predicted start-of-season biomass of 90 mm scallops were presented for the first time in 1998.

Walshe (1984) and Allan & Jorgensen (1984) examined the natural mortality rate of scallops in the Whitianga bed (Table 5). They generated several estimates of M with an average of about 0.47. Because estimates made using enclosures (M = 0.42 and 0.46 for seabed and lantern cages, respectively) are likely to be underestimates, a value of 0.50 was assumed for yield estimates in this assessment.

3.4 Biomass estimates

Diver surveys of the Whitianga beds were carried out almost annually between 1978 and 1997 (Table 4) but were discontinued in 1998 in favour of (cheaper) dredge surveys. Other beds within this fishery were surveyed only sporadically, mostly by dredge, until 1994, after which composite surveys covered most commercially exploited beds each year. The most recent survey was described by Cryer &

Parkinson (1999b). 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 1999b).

Table 2: Parameters of von Bertalanffy growth equations estimated by the GROTAG method using tag-recapture data from three years in the Whitianga scallop population (unpublished data of K.A.R. Walshe and L.G. Allen), from throughout the Coromandel fishery between 1992 and 1997, and from Whitianga recoveries from depth ranges 0–15, 16–25 m and 26–35 m (Whitianga). The assumed parameters p = 0.01 and s = 2.00 (proportion of contamination by outliers and the standard deviation of measurements) come from repeat measurements by six research staff in 1996, g40 and g95 are the estimated average annual increments for scallops of 40 and 95 mm, respectively, at tagging, u and w describe the estimated amplitude and phase of seasonal fluctuation in growth, and L_∞ and K are the estimated parameters of a length-based von Bertalanffy growth equations.

		GROTAG parameters				von Bertalanffy	
Year	N	g40	g95	u	W	L_∞	K
1982 Whitianga only	69	52.40	13.81	0.600	0.676	114.7	1.210
1983 Whitianga only	596	47.50	9.13	0.286	0.461	108.1	1.197
1984 Whitianga only	147	30.32	5.94	0.901	0.389	108.4	0.586
1992–97 fishery wide	138	49.86	10.26	0.667	0.790	108.8	1.366
Whitianga mean 10.6 m	34	60.07	15.12	0.412	0.880	113.5	1.700
Whitianga mean 21.1 m	63	33.66	6.83	2.798	0.632	109.0	0.669
Whitianga mean 29.7 m	31	31.24	6.79	7.206	0.437	110.3	0.588

Table 3: Historical estimates of the instantaneous rate of natural mortality M from the Whitianga bed.

Method	Estimate	Reference
Two census method (Regier 1962 method)	0.50	Walshe 1984
Change of yearclass abundance 2+ – 3+	0.37	Walshe 1984
Change of yearclass abundance 3+ – 4+	0.59	Walshe 1984
Tagging (seabed enclosures)	0.42	Walshe 1984
Tagging (commercial beds)	0.46	Walshe 1984
Tagging (lantern cages)	0.46	Allan & Jorgenson 1984

The bed at Whitianga has been one of the mainstays of the Coromandel fishery since the fishery began. Biomass has varied by a factor of almost five, with seemingly little link to fishing pressure (Cryer 1994). Recent years have been relatively poor (six of the seven lowest estimates in the history of the fishery were between 1993 and 1998, Table 4), and the most recent survey in 1999 suggested the smallest population since surveys began in 1978. Anecdotal reports from fishers suggest that the worst ever fishing at Whitianga was experienced in 1989 and, although no survey was conducted in that year, the indications are that the 1999 season is likely to be worse.

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. Following very low estimates in 1994 to 1996, the biomass at Waiheke appeared to increase in 1997. The precision of the estimate in 1997 was poor, but a very similar result (with better precision) in

1998 strengthened the inference that this population was recovering. Unfortunately, the biomass estimate for 1999 was very low.

The bed at Little Barrier Island was highly productive in the mid 1990s, but the two most recent surveys have shown relatively low populations. Low biomass at this site was preceded by marked changes to length frequency distributions, with abundant cohorts of small animals essentially disappearing in 1997. The 1999 biomass is the smallest on record.

Commercial catch rates in the 1998 season were poor (Cryer 2000), despite the reduced MLS of 90 mm which should have led to higher and more stable catch rates than the previous 100 mm MLS. There are many possible reasons why catch rates were so poor when 1998 surveys predicted an "average" year by recent standards. These possibilities include CPUE not proportional to biomass, a large mortality event, poor growth (making the "critical size" for estimating start-of-season biomass too optimistic), biomass close to or below the lower confidence limit of the survey estimate, or a combination of all of these. In addition, an average recovery of 13.5% meat from greenweight was assumed for yield estimation, and extraction of scallops at very much lower recovery rates would lead to more scallops being killed for each tonne of meat. Low recovery rates would therefore lead to initial catch rates being slightly lower than anticipated, but could lead to a much more rapid decline in catch rates than anticipated if fishing continues.

Table 4: Estimated recruited biomass (at the time of surveys) of scallops of 95 mm or greater shell length 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 1, 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	–	1 386	–	–	–	–
1979	–	368	–	–	–	–
1980	–	1 197	–	–	–	–
1981	–	1 092	–	–	–	–
1982	–	725	–	–	–	–
1983	–	998	–	–	–	–
1984	800	1 092	–	–	–	*1 892
1985	2 000	966	–	–	–	*2 966
1986	1 500	1 313	–	–	–	*2 813
1987	–	1 628	–	–	–	–
1988	–	–	–	–	–	–
1989	–	–	–	–	–	–
1990	608	767	–	–	–	*1 375
1991	266	824	–	–	–	*1 090
1992	73	1 272	–	–	–	*1 345
1993	41	748	–	735	–	*1 524
1994	3	481	–	153	–	*637
1995	26	445	258	58	451	1 277
1996	28	619	346	19	222	1 244
1997	508	623	402	70	199	1 839
1998	506	641	99	12	120	1 414
1999	18	176	19	0	87	325

The instantaneous rate of fishing mortality ($F_{apparent}$, estimated iteratively using Cryer & Morrison's (1997) version of the Baranov equation and assuming M = 0.50) was low for the Whitianga bed and very low elsewhere in the fishery during 1998. The mean rate of fishing mortality ($F_{apparent}$) for the Whitianga bed was about 1.2 between 1980 and 1994, increased to about 1.6 between 1995 (when surveys covering almost all of the fishery began) and 1997, but decreased markedly to about 0.5 in 1998 (Table 5). For the Little Barrier bed, the rate between 1980 and 1994 cannot be estimated, but the average fishing mortality 1995–98 was about 1.1, decreasing to 0.02 in 1998. The Bay of Plenty and Waiheke Island beds were fished less intensively than Whitianga and Little Barrier Island in 1995–97 (average fishing mortality was about 0.1 in both beds), but fishing mortality was lower still in 1998 (less than 0.01 in both beds).

Table 5: Estimated apparent rate of fishing mortality ($F_{apparent}$) for scallops of 100 mm or greater shell length in the main areas of the Coromandel scallop fishery since 1980. $F_{apparent}$ was estimated by iteration assuming a 5 month fishing season and natural mortality of M = 0.50 spread evenly through the year. Dashes indicate inadequate data available for the estimate.

	Hauraki Gulf	Whitianga	Barrier Islands	Bay of Plenty	Overall
1980	–	1.093	–	–	–
1981	–	1.495	–	–	–
1982	–	0.923	–	–	–
1983	–	1.585	–	–	–
1984	1.351	0.829	–	–	–
1985	0.354	0.410	–	–	–
1986	0.116	0.750	–	–	–
1987	–	0.526	–	–	–
1988	–	–	–	–	–
1989	–	–	–	–	–
1990	0.219	>3.000	–	–	–
1991	0.382	>3.000	–	–	–
1992	–	1.003	–	–	–
1993	–	0.447	–	–	–
1994	–	0.411	–	–	–
1995	–	1.706	1.511	0.129	0.763
1996	–	1.148	1.066	0.098	0.840
1997	0.066	1.898	0.657	0.070	0.571
1998	0.002	0.453	0.024	0.009	0.184
Mean 1980–94	0.484	1.191	–	–	–
Mean 1995–97	0.066	1.584	1.078	0.099	0.725

3.5 Yield estimates

3.5.1 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.

3.5.2 Estimation of Current Annual Yield (CAY)

The choice among reference mortality rates for estimating yield is not a simple one. It is probably useful for this discussion to use Caddy's (1998) notation of target reference points (TRP) and limit reference points (LRP) where reference points can be measures of fishing mortality (F) or biomass (B). F_{max} from a yield-per-recruit model was the classical TRP (Caddy 1998), but may be too high as a target (Annala *et al.* 2000) and has more recently been generally regarded as an LRP (a "threshold" beyond which fishing mortality should not be increased) and $F_{0.1}$ has been substituted as a "target" (Caddy 1998). Mace (1994) recommended $F_{40\%}$ as a "default" TRP in the "common situation where there is adequate information to place bounds on all relevant life history parameters except those characterising the stock-recruit relationship". Mace's (1994) simulations showed that, in her model, $F_{40\%}$ was similar to $F_{0.1}$ when recruitment and maturity schedules coincided, and approximated F_{MSY} for fisheries of average to high resilience to fishing. She also affirmed Mace & Sissenwine's (1993) proposition that the default overfishing threshold should be 20% B_0 for stocks of at least average resilience to fishing. However, Myers et al. (1994) considered this threshold (20% of virgin stock size) the least desirable and the least precautionary of those they examined.

Based on these published recommendations, Cryer & Morrison's (1997) estimates of $F_{40\%}$ (0.514), $F_{0.1}$ (0.508), and F_{max} (0.650) (all assuming M = 0.50) were used to estimate yield as CAY. Yield estimates based on $F_{40\%}$ and $F_{0.1}$ should probably be preferred as targets over that based on F_{max} (which might be considered a limit). Because of the derivation of these estimates, they should be applied to the modified version of the Baranov equation given by Cryer & Morrison

$$CAY = \frac{F_{ref}}{F_{ref} + \frac{5M}{12}} * \left[1 - e^{-\left(F_{ref} + 5M/12\right)}\right] * B_{jul} \qquad (1)$$

where B_{jul} is the estimate of recruited biomass in July. In this formulation of the Baranov equation, natural mortality is assumed to act in tandem with fishing mortality for the first five months of the year, the length of the current Coromandel commercial scallop season.

The recruited biomass of scallops 90 mm in shell length or greater in the Coromandel fishery was estimated by Cryer & Parkinson (1999b) to be 752 t greenweight in 1999. CAY was calculated using this biomass and each of the reference fishing mortality rates $F_{0.1}$, F_{max}, and $F_{40\%}$ as follows (the conversion rate from greenweight to meat was assumed to be 13.5% (Cryer & Parkinson 1999a)):

For $F_{40\%}$, CAY = 0.7116 * 0.5144 * 752 = 275 t (green) or 37 t (meat)

For $F_{0.1}$, CAY = 0.7092 * 0.5115 * 752 = 272 t (green) or 37 t (meat)

For F_{max}, CAY = 0.7573 * 0.5761 * 752 = 328 t (green) or 44 t (meat)

These estimates of CAY would have a c.v. at least as large as that of the estimate of start-of-season recruited biomass (18%), and relate to the surveyed beds only (almost all significant beds were surveyed in 1999).

Additional closed areas were proposed for the 1999 season in the Coromandel fishery, and it has been suggested that the biomass within any such closures should not be included in estimates of CAY. Cryer & Parkinson (1999b) estimated that 11% of the biomass of scallops 90 mm or greater at the start of the season were likely to be in proposed closures. If the proposed closures are adopted, then the yield estimates should be reduced by 11% as follows:

At $F_{40\%}$, CAY = 275 * 0.89 = 245 t (green) or 33 t (meat)

At $F_{0.1}$, CAY = 272 * 0.89 = 242 t (green) or 33 t (meat)

At F_{max}, CAY = 328 * 0.89 = 292 t (green) or 39 t (meat)

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

3.5.3 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 un-surveyed beds is estimated as the product of the variability factor (Annala et al. 2000; $M > 0.35$, $c = 0.6$ for scallops) and the historical average landings from the unsurveyed beds. PY is estimated only for comparison with historical estimates of yield.

For Coromandel scallops in 1999 (Cryer & Parkinson 1999b), start-of-season recruited biomass (100 mm or greater) is estimated at 299 t (greenweight) with a c.v. of 19%, giving a lower tail to the 95% confidence distribution of 185 t. Historical average landings from the only major unsurveyed beds at Great Barrier Island (1980–94) were about 25 t, giving:

PY = 185 t + 0.6 * 25 t = 210 t (greenweight) or 28 t (meat)

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

3.5.4 Estimation of yield using in-season "depletion analysis"

Cryer (2001) examined the proposition that in-season analysis of catch and effort data could be used to estimate biomass and yield. Despite the availability of full and extensively groomed catch and effort data, however, depletion analysis generated statistically significant biomass estimates in only four out of eight years for the two main beds (at Whitianga and Little Barrier Island), and these estimates were not correlated with preseason survey estimates. He concluded that depletion analysis was unsuitable as a means of estimating biomass or yield in this fishery.

3.6 Models

Yield and egg per recruit models were developed for Coromandel commercial dredge fisheries for scallops by Cryer & Morrison (1997) under MFish project AKSC03. This modelling, incorporating the incidental effects of dredging on the growth and mortality rates of scallops, allowed the application of reference fishing mortality rates such as $F_{0.1}$, F_{max}, and $F_{40\%}$ for the first time in 1998.

4. Management implications

The 1999 biomass is, for poorly understood reasons, the lowest ever recorded in this fishery. There have been large fluctuations in biomass in the past 20 years, although years of low biomass have sometimes been followed by years of high biomass. However, the biomass in 1998 was low in most parts of the fishery, and had declined further in 1999.

Cryer (2001) considered three main options for the poor performance of the fishery compared with pre-season surveys in 1998: that 1998 was a year of high mortality or low growth rates between survey and season; that the real pre-season biomass was much lower than the survey estimate (despite the low c.v. of 15%); or that the 1998 biomass was concentrated in deep water where growth appears to be much slower than it is in shallow water (Cryer & Parkinson 1999a). The very low survey estimates of biomass in 1999 (Cryer & Parkinson 1999b), the "disappearance" of juvenile cohorts between 1998 and 1999 (Cryer & Parkinson 1999b, see also Figure 2), and the steep decline in average catch rate in 1998 (Cryer 2001) strongly suggest that high mortality occurred between survey and season in 1998 and may have continued since. The cause of this mortality is not known, but an associated and very visible "black gill" condition was reported in several species of filter feeding bivalves around the Coromandel Peninsula in 1999 (Diggles et al. 2000). Diggles et al. concluded that the black gill condition was probably not indicative of a causative disease agent (although Rickettsiales like organisms were found in animals with the condition), and suggested that broad scale environmental conditions were probably responsible in some way.

Whatever the cause of high mortality in 1998 and 1999, considerable caution should be exercised when setting catch limits. The lack of strong correlation between biomass and fleet average catch rate in the Whitianga bed (Cryer 2001) suggests that it may be possible for fishers to catch or kill a large proportion of scallops 90 mm shell length or larger before the fishery becomes uneconomic. The consequences of such a depression in recruited and spawning biomass are not known as the current commercial MLS of 90 mm has been in force only since 1995. Maturation of scallops at 60 mm shell length, well below the MLS, does not appear to protect this stock from serious depression of spawning biomass, probably because small scallops carry few eggs compared with larger individuals. Stochastic egg-per-recruit (EPR) modelling (Cryer & Morrison 1997) suggested that, assuming knife edge recruitment at 90 mm, fishing at $F_{0.1}$ or F_{max} would reduce the lifetime fecundity of a cohort to about 33–40% of its virgin level. Population fecundity in a given year would be reduced to the same level under constant recruitment. EPR modelling (Cryer & Morrison 1997) suggested that unrestrained fishing mortality could reduce population fecundity to less than 15% of its virgin level under constant recruitment, especially if there were large incidental effects on small but mature scallops of 60–90 mm shell length. The recent series of low biomass years in the Coromandel fishery suggest that recent average recruitment has been low, and equilibrium estimates of population fecundity relative to virgin levels are likely to be optimistic. Thus, under the 90 mm MLS, failure to restrain fishing mortality could result in depression of the effective spawning stock size below 15% of the unfished level. Relationships between stock size and subsequent recruitment have been published for some scallops stocks (e.g., Peterson & Summerson 1992) suggesting that it would be prudent to restrain fishing mortality below F_{max} as a precaution against recruitment over-fishing. Full stochastic population modelling would be useful to examine the possible effects of variable recruitment and growth on the estimates of reference fishing mortality given for this stock by Cryer & Morrison (1997).

5. ACKNOWLEDGMENTS

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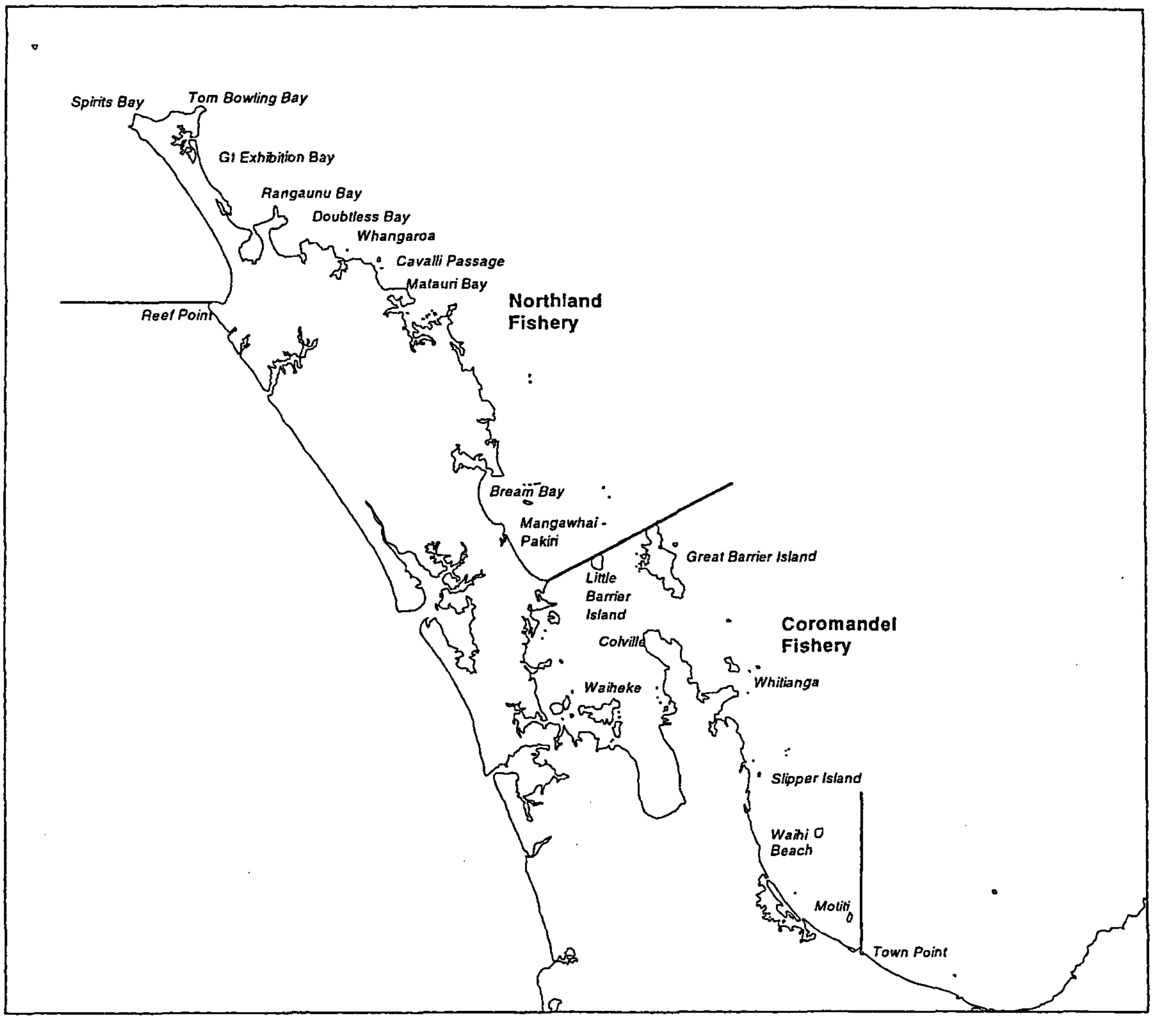

Figure 1: Geographic distribution of the two northern scallops fisheries and the names of locations mentioned in the text.

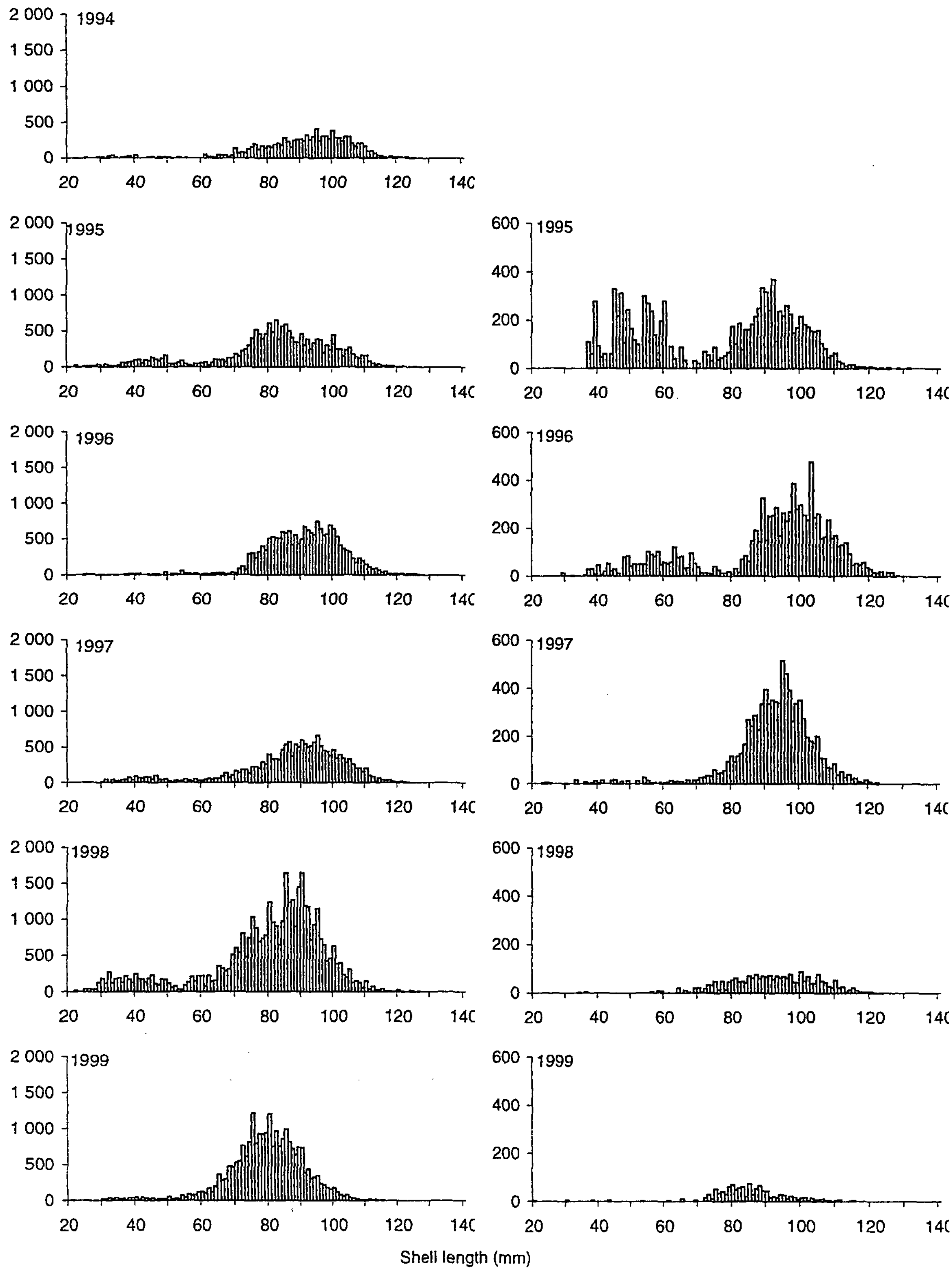

Figure 2: Approximate scaled length frequency distributions (thousands of animals) for the Coromandel scallop fishery, 1994 to 1999, corrected for dredge efficiency. Left panel, Whitianga and environs; right panel, Little Barrier Island.

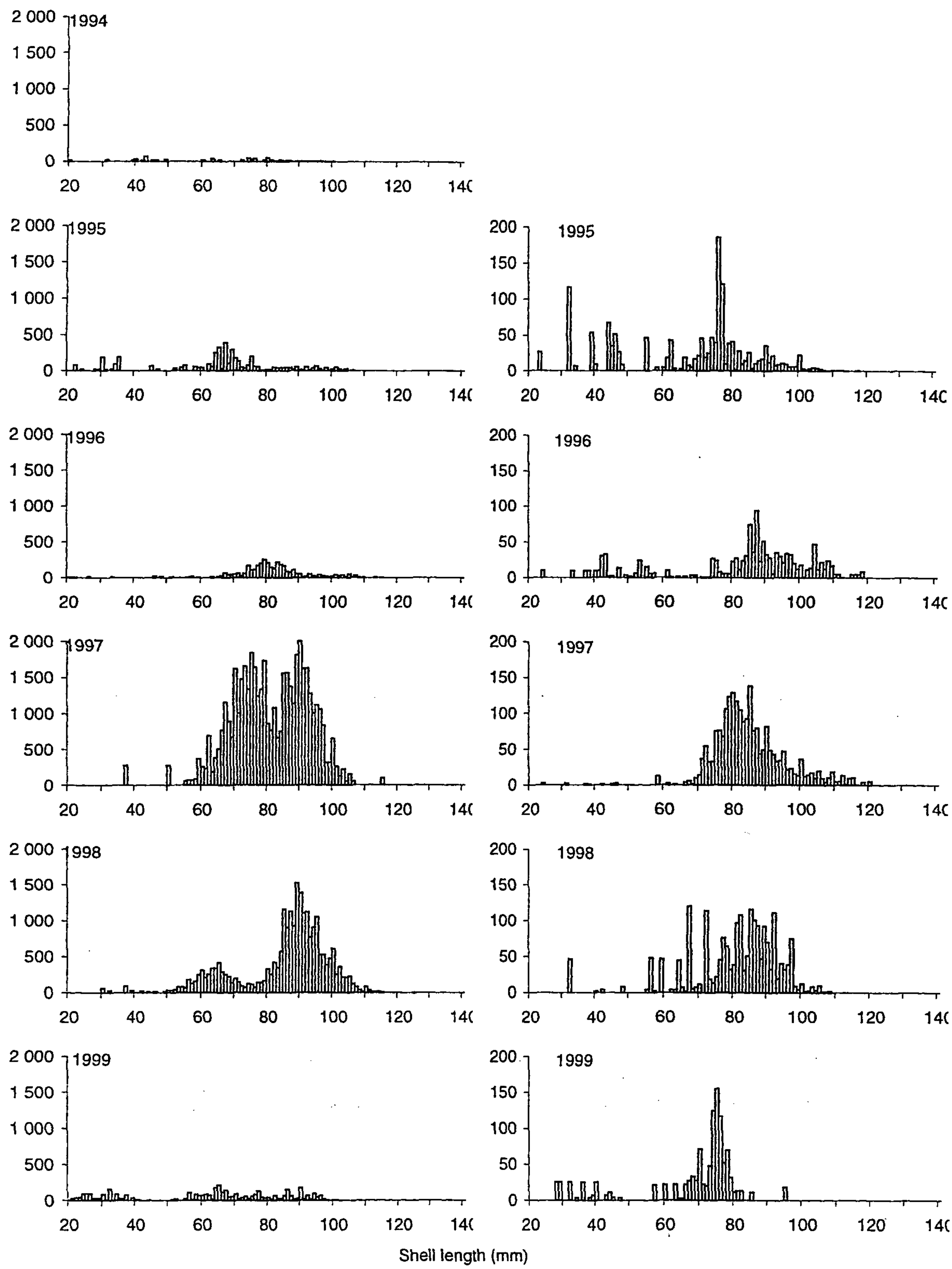

Figure 3: Approximate scaled length frequency distributions (thousands of animals) for the Coromandel scallop fishery, 1994 to 1999, corrected for dredge efficiency. Left panel, Waiheke Island; right panel, Colville and western Coromandel Peninsula.

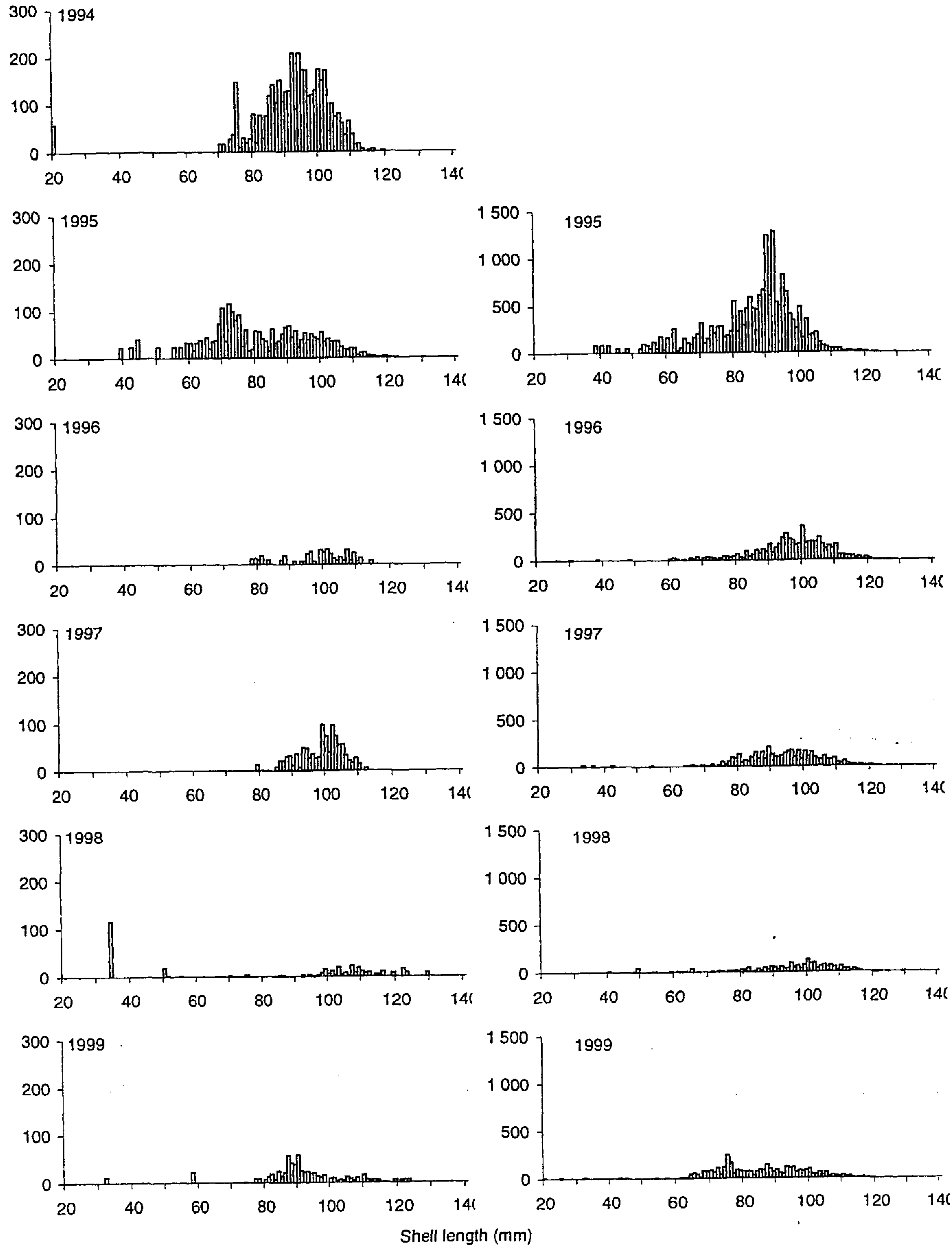

Figure 4: Approximate scaled length frequency distributions (thousands of animals) for the Coromandel scallop fishery, 1994 to 1999, corrected for dredge efficiency. Left panel, Waihi (Katikati Entrance); right panel, Motiti Island and Papamoa Beach.