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Coromandel and Northland scallop stock assessments for 1998

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1. Executive Summary

Northland and Coromandel scallop fisheries were surveyed by dredge in May 1998 to predict start-of-season recruited biomass. For the Northland and Coromandel fisheries, start of season biomass (scallops of 100 mm or greater) was estimated as 1547 t and 1337 t with *c.v.*s of 15.5 and 13.0%, respectively. For comparison, the 1997 assessment led to estimates of 3520 t and 1670 t with *c.v.*s of about 20%.

Provisional Yield (PY) was estimated as 1145 t and 937 t (green weight) for the Northland and Coromandel fisheries respectively. CAY was estimated as 590–704 t in Northland and 938–1132 t in the Coromandel fishery (depending on the reference rate of fishing mortality adopted). Assumed average recovery rates of 13.5% (meat from green) for both fisheries lead to estimated values of PY = 155 t and 126 t for Northland and Coromandel, and CAY = 80–95 t and 127–153 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 1998 are derived using methods after Cryer (1994) and Annala *et al.* (1998). This work was funded by the Ministry of Fisheries under project SCA9701.

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). The number of vessels participating in the fishery may since have declined. The Coromandel fishery (including the Hauraki Gulf) supports 22 licences in a controlled fishery, although the number of vessels used to fish against these licences has decreased in recent years.

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 redefined 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 meat weight, 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 for scallops.

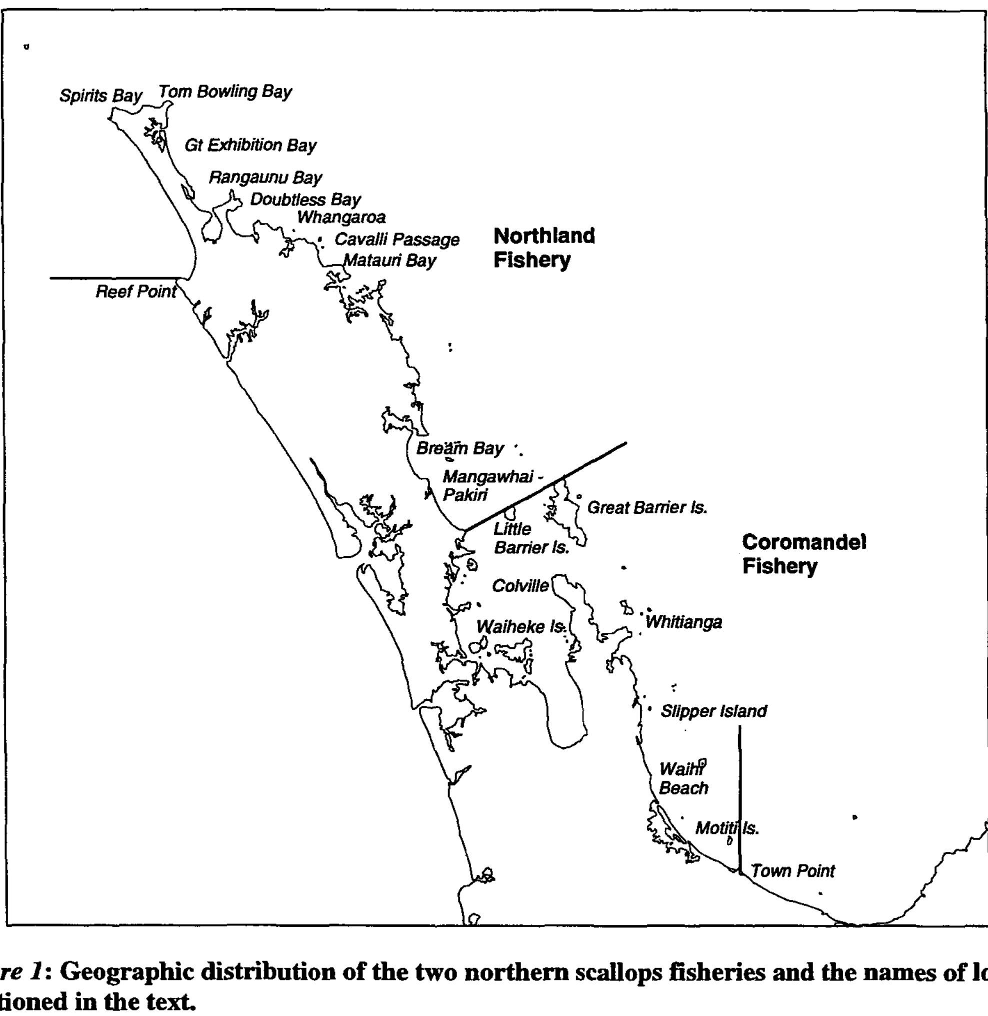

***Figure 1*: Geographic distribution of the two northern scallops fisheries and the names of locations mentioned in the text.**

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 on the biology has become available subsequently, other than an unpublished Ph.D. thesis by Morrison (1997) and studies of the incidental impacts of commercial dredges (Cryer & Morrison 1997) and recreational dredges (Morrison & Cryer 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 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, and the Coromandel fishery remains a controlled fishery. An explicit TACC of 189 t was in force for the Northland fishery in the 1997–98 (scallop) fishing year, although the Coromandel fishery is limited by seasonal catch limits, specified on fishing permits, which have the same effect.

Landings for the 1980 to 1997 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*: Catch limits and landings (t green weight or meat weight as specified) from the Northland Scallop 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 green weight. "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 meat weight, and were for 1997 specified as a formal TACC (in meat weight). The approximate green weight equivalent given here assumes the gazetted conversion factor and recovery rate of 12.5% which probably overestimates the green weight equivalent. *, split by area not available; –, no catch limits set, or no reported catch (for Spirits Bay)**

	Catch limits (t)		Landed catch (t)		Estimated catch (t, green)		
Season	Meat	Approx. green	Meat	Green	Whangarei	Far North	Spirits Bay
1980	–	–	–	238	*	*	*
1981	–	–	–	560	*	*	*
1982	–	–	–	790	*	*	*
1983	–	–	–	1 171	78	1 093	–
1984	–	–	–	541	183	358	–
1985	–	–	–	343	214	129	–
1986	–	–	–	675	583	92	–
1987	–	–	–	1 625	985	640	–
1988	–	–	–	1 121	1 071	50	–
1989	–	–	–	781	131	650	–
1990	–	–	–	519	341	178	–
1991	–	–	–	854	599	255	–
1992	–	–	–	741	447	294	–
1993	–	–	–	862	75	787	1
1994	–	–	–	1 634	429	1 064	142
1995	–	–	214	1 469	160	810	499
1996	189	1 508	132	954	55	387	512
1997	189	1 508	126	877	22	378	477

3.2 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 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).

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.

***Table 2*: Catch limits and landings (t green weight or meat weight as specified) from the Coromandel Scallop 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 green weight. "Hauraki" includes beds in areas 2X and 2W, "Whitianga" includes beds in 2L and 2K, "Barrier" includes beds in 2R, 2S, and 2Q, and "Bay of Plenty" includes beds in areas 2A–2I. Catch limits for 1992 onwards were specified on permits in meat weight. The approximate green weight equivalent given here assumes the gazetted conversion factor and recovery rate of 12.5% which probably overestimates the green weight equivalent. * Landings in 1991 includes ~ 400 t from highly unusual settlement at Colville; –, no catch limits set**

	Catch limits (t)		Landed catch (t)		Estimated catch (t, green weight)			
Season	Meat	Approx. green	Meat	Green	Hauraki	Whitianga	Barrier	Bay of Plenty
1980	–	–	–	1 005	249	690	0	77
1981	–	–	–	1 170	332	743	41	72
1982	–	–	–	1 050	687	385	49	80
1983	–	–	–	1 553	687	715	120	31
1984	–	–	–	1 123	524	525	62	12
1985	–	–	–	877	518	277	82	0
1986	–	–	–	1 035	135	576	305	19
1987	–	–	–	1 431	676	556	136	62
1988	–	–	–	1 167	19	911	234	3
1989	–	–	–	360	24	253	95	1
1990	–	–	–	903	98	691	114	0
1991	–	–	–	1 392	*472	822	98	0
1992	154	1 232	–	901	67	686	68	76
1993	132	1 056	–	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

Estimates of catch by recreational fishers in 1993–94 (Bradford 1997) are 40–60 t (green weight) 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 1997) 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

Full details of the dredge surveys conducted throughout the Northland and Coromandel fisheries in May 1998 were given by Cryer & Parkinson (1998). The abundance of scallops in most beds varied considerably among years, but the 1998 survey showed, for most beds, the lowest biomass on record. Exceptions to this generality were the Rangaunu Bay bed in the Northland fishery and Whitianga and Waiheke Island beds in the Coromandel fishery.

4.3 Other studies

Estimates of growth rate from tagging studies in the 1980s by K.A.R. Walshe (1984) and by L.G. Allen (unpublished data) have been re-analysed using more appropriate methods (Table 3). The estimates of Walshe (e.g., 1983) have been used for many years to estimate the expected growth of scallops between the midpoint of surveys and the start of the season. Growth curves derived by Walshe, by analysis of Allen's (unpublished) data, and by analysis of tag return data from 1992–97, suggest that scallops of 95 mm length or greater may grow to the legal size of 100 mm during the period between survey and season, but that there is considerable heterogeneity among years and with depth (*see* Table 3 and Cryer & Parkinson 1999).

There has been insufficient analysis and modelling of the implications of variability in growth to consider modifying the current assumed critical size of 95 mm. It is therefore assumed for the purpose of predicting start of season biomass (and yield) 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 that scallops of 85 mm or over at the time of the survey are likely to achieve 90 mm by the start of the season. However, it is suggested that such analyses be undertaken soon.

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 start-of-season biomass of 90 mm scallops are presented for the first time this year.

***Table 3*: Parameters of length based 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. Walsh and L.G. Allen), from throughout the Coromandel and Northland fisheries between 1992 and 1997, and from Whitianga and Bream Bay recoveries from depth ranges 0–15, 16–25, and 26–35 m (Whitianga) or < 20 m and > 20 m (Bream Bay). 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 von Bertalanffy growth equations**

		GROTAG parameters				von Bertalanffy	
Year	N	g40	g95	u	w	L_∞	K
1982 Whitianga	69	52.40	13.81	-0.600	0.324	114.7	1.210
1983 Whitianga	596	47.50	9.13	-0.286	0.539	108.1	1.197
1984 Whitianga	147	30.32	5.94	-0.901	0.611	108.4	0.586
92–97 all data	227	51.40	11.09	0.792	0.779	109.8	1.392
92–97 Coromandel only	138	49.86	10.26	0.667	0.790	108.8	1.366
92–97 Northland only	89	52.88	11.70	0.793	0.727	110.6	1.382
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
Bream Bay, mean 18.4 m	28	52.99	8.81	2.425	0.779	106.0	1.626
Bream Bay, mean 21.4 m	24	50.56	11.37	1.459	0.420	111.0	1.247

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, by both methods between 1994 and 1997, and by dredge only in 1998 (Table 4). The beds in Spirits and Tom Bowling Bays have been surveyed only since 1996. 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 1998).

4.4.2 Coromandel fishery

Diver surveys of the Whitianga beds were carried out almost annually between 1978 and 1997 (Table 5) 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 two most recent surveys were described by Cryer & Parkinson (1998). 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 1998).

***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
1998	18	45	37	852	608	1 654

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), but the smallest population was found during the second survey during the early development stages of the fishery in 1979. Anecdotal reports from fishers suggest that the worst ever fishing at Whitianga was experienced in 1989 and it is unfortunate that no survey was conducted in that year.

***Table 5*: Estimated recruited biomass (at the time of surveys) 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 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	–	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

Historically, the second most important bed in the Coromandel fishery was at Waiheke Island. This bed declined rapidly in the late 1980s and was essentially unfished between 1993 and 1996. Following an extremely low biomass estimate in 1994, the biomass increased slightly in 1995 and 1996, and the 1997 survey suggested that a considerable recovery may have taken place. The precision of the Waiheke Island biomass estimate in 1997 was poor, but a very similar result with better precision in 1998 strengthens the inference that this population is now recovering.

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)

4.5.2.1. Northland fishery

The analysis and modelling by Cryer & Morrison (1997) was primarily aimed at the Coromandel fishery, but their model allows the incorporation of growth parameters more suited to the Northland fishery and the estimation of reference fishing mortality rates and, hence, CAY. For an assumed rate of natural mortality of M = 0.40, $F_{0.1}$ was estimated as 0.55, and F_{max} as 0.700. $F_{40\%}$ was not estimated. The following modified version of the Baranov equation given by Cryer & Morrison (1997) should be used in their application.

$$CAY = \frac{F_{ref}}{F_{ref} + \frac{7M}{12}} * \left[1 - e^{-\left(F_{ref} + 7M/12\right)}\right] * B_{jul} \qquad (1)$$

where B_{jul} is the estimate of recruited biomass in July. Natural mortality is assumed to act in tandem with fishing mortality for the first 7 months of the year, the length of the current Northland commercial scallop season.

The recruited biomass of scallops 100 mm in shell length or greater in the Northland fishery was estimated by Cryer & Parkinson (1998) to be 1547 t green weight in 1998. CAY was calculated using this biomass and the reference fishing mortality rates $F_{0.1}$ and F_{max} as follows (the conversion rate from green weight to meat was assumed to be 13.5%, Cryer & Parkinson 1998):

For $F_{0.1}$, CAY = 0.7021 * 0.5431 * 1547 = 590 t (green) or 80 t (meat)

For F_{max}, CAY = 0.7500 * 0.6068 * 1547 = 704 t (green) or 95 t (meat)

These estimates of CAY would have a *c.v.* at least as large as the estimate of start of season recruited biomass (13.0%).The level of risk to the putative Northland scallop stock of fishing at the estimated CAY level cannot be determined.

4.5.2.2. Coromandel fishery

New estimates of reference fishing mortality reported by Cryer & Morrison (1997) allow the estimation of CAY. For an assumed rate of natural mortality of M = 0.40, Cryer & Morrison (1997) estimated $F_{0.1}$ as 0.469, F_{max} as 0.600, and $F_{40\%}$ as 0.507. Because of the derivation of these estimates, they should be applied to the modified version of the Baranov equation given by Cryer & Morrison (1997).

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

where B_{jul} is the estimate of recruited biomass in July. Natural mortality is assumed to act in tandem with fishing mortality for the first 5 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 (1998) to be 2702 t green weight in 1998. 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 green weight to meat was assumed to be 13.5%, Cryer & Parkinson 1998):

For $F_{0.1}$, CAY = 0.7378 * 0.4704 * 2702 = 938 t (green) or 127 t (meat)

For F_{max}, CAY = 0.7826 * 0.5354 * 2702 = 1132 t (green) or 153 t (meat)

For $F_{40\%}$, CAY = 0.7526 * 0.4902 * 2702 = 996 t (green) or 135 t (meat)

These estimates of CAY would have a *c.v.* at least as large as the estimate of start of season recruited biomass (15.5%), and relate to the surveyed beds only (almost all significant beds were surveyed in 1998).

Various voluntary closed areas (VCAs) were proposed for the 1998 season in the Coromandel fishery, and it was suggested that the biomass within any such closures should not be included in estimates of CAY. Cryer & Parkinson estimated that 1.5% of the biomass of scallops 90 mm or greater at the start of the season was likely to be in VCAs proposed by industry. Further, Cryer & Parkinson estimated that 17.8% of the biomass of scallops 90 mm or greater at the start of the season was likely to be in VCAs proposed by recreational groups. The adoption of either set of VCAs would suggest that the yield estimates should be reduced by 1.5% or 17.8% as follows:

For the "commercial" VCAs,

At $F_{0.1}$, CAY = 0.7378 * 0.4704 * 0.985 * 2702 = 924 t (green) or 125 t (meat)

At F_{max}, CAY = 0.7826 * 0.5354 * 0.985 * 2702 = 1115 t (green) or 151 t (meat)

At $F_{40\%}$, CAY = 0.7526 * 0.4902 * 0.985 * 2702 = 981 t (green) or 133 t (meat)

For the "amateur" VCAs,

At $F_{0.1}$, CAY = 0.7378 * 0.4704 * 0.822 * 2702 = 771 t (green) or 104 t (meat)

At F_{max}, CAY = 0.7826 * 0.5354 * 0.822 * 2702 = 930 t (green) or 126 t (meat)

At $F_{40\%}$, CAY = 0.7526 * 0.4902 * 0.822 * 2702 = 819 t (green) or 111 t (meat)

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

4.5.3 Other Yield Estimates

4.5.3.1 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 1998

For Northland scallops in 1998 (Cryer & Parkinson 1998), start-of-season recruited biomass (100 mm or greater) is estimated at 1547 t (green weight) with a *c.v.* of 13.0%, giving a lower limit to the 95% confidence distribution of about 1145 t. Fishers have highlighted no significant unsurveyed beds, so:

$$PY = 1145\ t + 0.6 * 0\ t = 1145\ t \text{ (green weight)}$$

The TACC for Northland scallops is specified in meat weight, and an assumed average recovery rate for the forthcoming season is required to convert the estimate of yield in green weight to meat weight. The historical average recovery rate recorded for scallops in the Coromandel fishery (Cryer & Parkinson 1998) 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 meat weight, therefore, yield can be estimated as:

$$PY = 1145\ t * 0.135 = 154\ t \text{ (meat, based on historical recovery), or}$$

$$PY = 2000\ t * 0.125 = 143\ t \text{ (meat, based on the gazetted conversion factor).}$$

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 meat weight 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.

4.5.3.3 PY for the Coromandel fishery in 1998

For Coromandel scallops in 1998 (Cryer & Parkinson 1998), start-of-season recruited biomass (100 mm or greater) is estimated at 1337 t (green weight) with a *c.v.* of 15.5%, giving a lower tail to the 95% confidence distribution of 922 t. Historical average landings from the only major unsurveyed beds at Great Barrier Island (1980–94) were about 25 t, giving:

$$PY = 922\ t + 0.6 * 25\ t = 937\ t \text{ (green weight)}$$

Catch limits for the Coromandel fishery are also specified in meat weight, 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 1998 season (although Cryer & Parkinson 1998 showed that a recovery rate of 13.5% may be more difficult to maintain with larger proportions of scallops under 100 mm shell length in landings).

$$PY = 937 * 0.135 = 126\ t \text{ (meat, based on historical recovery), or}$$

$$PY = 937 * 0.125 = 117\ t \text{ (meat, based on the gazetted conversion factor).}$$

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 (1997) 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 $F_{0.1}$, F_{max}, and $F_{40\%}$. The choice among these reference mortality rates is not a simple one.

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. Catch limits have been reviewed upwards only once since this system was introduced in 1992 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.

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