INTERNAL REPORT

EAST COAST ABALONE ASSESSMENT: 2001

David Tarbath, Malcolm Haddon and Craig Mundy

October 2001

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Published by the Tasmanian Aquaculture and Fisheries Institute, University of Tasmania 2001

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Summary

This report has been prepared in response to a request from the Tasmanian Abalone Council (TAC) for information about the status of East Coast abalone stocks prior to their general meeting at which decisions about the 2002 total allowable catch for the Eastern Zone will be made. Concern has arisen amongst divers about the level of fishing and declining stocks on the East Coast, because catches and catch-rates began to decline after peaking in 1998.

The terms of reference for this report were very specific: to obtain from sites representative of the major part of the East Coast fishery (Blocks 22 to 29) information about size at sexual maturity and population size-composition, and to make use of gross changes in effort required to collect samples to estimate changes in relative abundance.

Samples were collected at 35 sites. Information from these sites was compared with that gained from these and other sites in previous years to highlight any biological changes that might have occurred as a result of fishing. We were particularly interested in changes that might indicate reduced recruitment, both to the fishery as pre-recruits (next year's crop) and to the population generally in terms of potential for ongoing sustainability.

At each site, we projected two years of growth onto the average size at which abalone become sexually mature. The Management Plan for the fishery includes a stated objective that to maintain biomass and recruitment, abalone shall be allowed to grow to a size where they have had two breeding seasons prior to recruitment to the fishery. By comparing the projected size at two years beyond sexual maturity with the current 132-mm size-limit, we assessed the adequacy of the size-limit in meeting the management objective.

Our conclusions are summarised as follows:

- Size-limits on the East Coast are too small to adequately support the Management Plan objective "to allow abalone to grow to a size where they have had two breeding seasons…"

- The East Coast fishery is largely dependent upon annual recruitment for most of the catch.

- At the majority of sites sampled, the relative abundance and rates of collection of pre-recruits and juveniles were sufficiently high to suggest that the fishery would continue to supply adequate levels of catch in the short term, although catch-rates may be reduced.

- On the east coast of Maria Island and on parts of the coast between Wineglass Bay and Bicheno, relative abundance and rates of collection of pre-recruits and juveniles are particularly low, and may not sustain present levels of fishing.

- By increasing size-limits in line with average projected sizes the Management Plan objective for East Coast stocks north of Eaglehawk Neck will be achieved. However stocks to the south which grow to a larger size will be less adequately protected. Because of variation in growth, some populations will inevitably be over-protected, while others will receive insufficient protection.

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1. Introduction

This report has been prepared in response to a request from the Tasmanian Abalone Council (TAC) for information about the status of East Coast abalone stocks prior to their general meeting at which decisions about the 2002 total allowable catch for the Eastern Zone will be made. Concern has arisen amongst divers about the level of fishing and declining stocks on the East Coast, because catches and catch-rates began to decline after peaking in 1998.

The information in this report was initially requested by the TAC Executive on June 29, and was supported by DPIWE at a meeting between representatives of the TAC, Tasmanian Aquaculture and Fisheries Institute and Department of Primary Industry, Water and Environment on July 27. It was agreed that field-work for the study would be instigated immediately, and that current work, already underway at TAFI, would be reprioritised and deferred.

The terms of reference for the survey were very specific. The area to be surveyed would cover the major abalone producing areas from Bicheno south to Schouten Island, Maria Island and the Forestier and Tasman Peninsulas. The assessment would be based upon size-composition, size at onset of sexual maturity and sampling time.

The study thus has two objectives:

- To estimate average size at sexual maturity at representative sites, and given growth rates from earlier work, calculate minimum sizes that ensure reproductive capability as specified by the Management Plan.

- To assess trends in relative abundance of pre-recruit and legal-size abalone.

2. Methods

2.1 Collecting Samples

To increase the chance of obtaining fully representative samples, we attempted to collect samples only when weather conditions enabled access to the shallowest part of abalone habitat. Invariably though, low easterly swells persisted throughout the limited sampling period available (August to September) and we were forced to work in less than optimum conditions. Because the shallow margins are prime abalone habitat for both adults and juveniles, this undoubtedly has affected the quality of some of our samples. Our experience is that abalone are generally more abundant in the shallows, and that we can catch them faster there than at the depths in which we were all too frequently compelled to work. We have also found that juveniles are much easier to collect from boulders in the shallows than in deeper water.

2.1.1 Sampling protocols

The strategy used to collect samples for estimating size at maturity is a procedure that has been developed by abalone researchers at TAFI. At each site, approximately 200 abalone are randomly selected and shucked. Shell-length and sex of each abalone is recorded. The time taken to collect the sample and the names of the divers is noted. If less than 50 immature abalone have been taken, then, to increase the precision of maturity analysis, extra quantities of abalone smaller than 140 mm are selectively collected to increase their number.

This study compares samples obtained in 2001 with samples obtained in previous years. Earlier sampling was often driven by different research needs, such as estimation of growth and mortality from aged shells, and tended to collect much larger (up to 800) numbers of abalone from fewer sites: hence only a few of our East Coast sampling sites have been repetitively visited. In 1995, a size-composition study was conducted in Block 27. At all sites except one (Little Bluestone Bay), approximately 400 abalone were collected, measured and released: hence we do not have a complete range of information for those sites.

2.1.2 Site selection

Sites are selected on the basis that they are representative of the immediate area fished by divers. The sites selected in 2001 and sites selected in previous years were generally chosen on the advice of divers that knew the region.

2.2 Determining Size At Sexual Maturity

The size at sexual maturity is an average for a population and is defined as the size at which 50 percent of a representative sample shows mature gonad development i.e. it was believed that they were capable of reproducing and contributing to the population. In the case of abalone with only marginal gonad development, judgement was made after cutting through the gonad and searching for eggs or spermatic tissue.

Size at 50 percent sexual maturity is determined by regression of binomial proportions (mature/immature) by 1-mm size class. This produces an estimate of the size at which 50 percent of the sample have become sexually mature. The method is explained fully in earlier reports by Tasmanian abalone researchers (Nash *et al.*, 1994; Officer, 1999; Tarbath, 1999b; Tarbath and Officer, 2001).

2.3 Predicted Growth From Size At Sexual Maturity

The Tasmanian abalone fishery is managed under a policy that allows abalone to reproduce before they are caught, and specifies a management objective “to allow abalone to grow to a size where they have had two breeding seasons through the use of appropriate size limits” (Anonymous, 2000). However, the current (132-mm) size-limit was not determined empirically but was developed to meet management requirements.

To determine appropriate size-limits, two population parameters are required; average size at maturity (above), and growth-rates. The growth of animals is then projected from the size at sexual maturity for each location at half-yearly increments using a transformation of the Von Bertalanffy Growth Function. This technique has been described in detail in earlier reports (Officer, 1999; Tarbath and Officer, 2001).

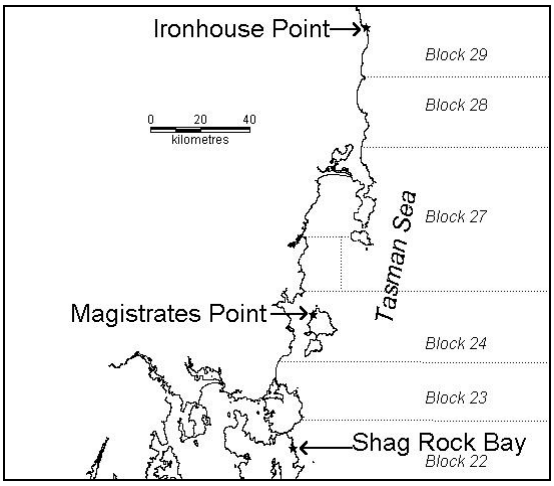

Fig. 1. The three East Coast sites at which abalone tagging studies took place between 1992 and 1997.

This study uses growth-rates of abalone from earlier tagging studies conducted on the East Coast (Fig. 1) (Nash, 1995; Tarbath, 1999a). The most northern site was at Ironhouse Point (south of Falmouth) in Block 29, and growth rates from this site were applied to size-at-maturity data from sites at Schouten Island (Block 27) north to Long Point (Block 29). A tagging study at Magistrates Point (Maria Island) provided growth information for sites from Block 24 (Maria Island) and Block 23 (Forestier Peninsula). Tasman Peninsula (Block 22) growth estimates were made using tag increments from a growth study at Shag Rock Bay, south of Eaglehawk Neck. Growth parameters are summarised below (Table 1).

Table 1. Growth parameters from East Coast tagging studies: 1992 to 1997

The Von Bertalanffy growth parameters k and L_∞, their standard errors and the number of growth increments (n) from studies undertaken at three sites are listed.

Region	Site	k	*s.e.*	L_∞	s.e.	n
Blocks 27, 28, 29	Ironhouse Point	0.52	0.07	152.6	0.9	1153
Block 23, 24	Magistrates Point	0.40	0.02	160.6	1.2	821
Blocks 22	Shag Rock Bay	0.44	0.02	182.2	2.2	336

2.4 Size-Composition Analysis

Length data from approximately random samples collected at each site (i.e. excluding any length data from targeted samples) are plotted in standard length-frequency histograms that show the position of the present 132-mm size-limit. The histograms show the proportion of the sample available to the fishery on the right-hand side of the size-limit and potential recruitment on the left hand side. Samples from surveys conducted in previous years are also shown, and by comparing the size-composition at each site between years, any changes in relative abundance between juveniles and the fished part of the population become apparent.

Because emergence from crypsis tends to coincide with sexual maturation, catchability of immature abalone is variable, and dependent upon prevailing environmental conditions and habitat. Thus samples become more representative of the population from which they were taken as the abalone increase in size.

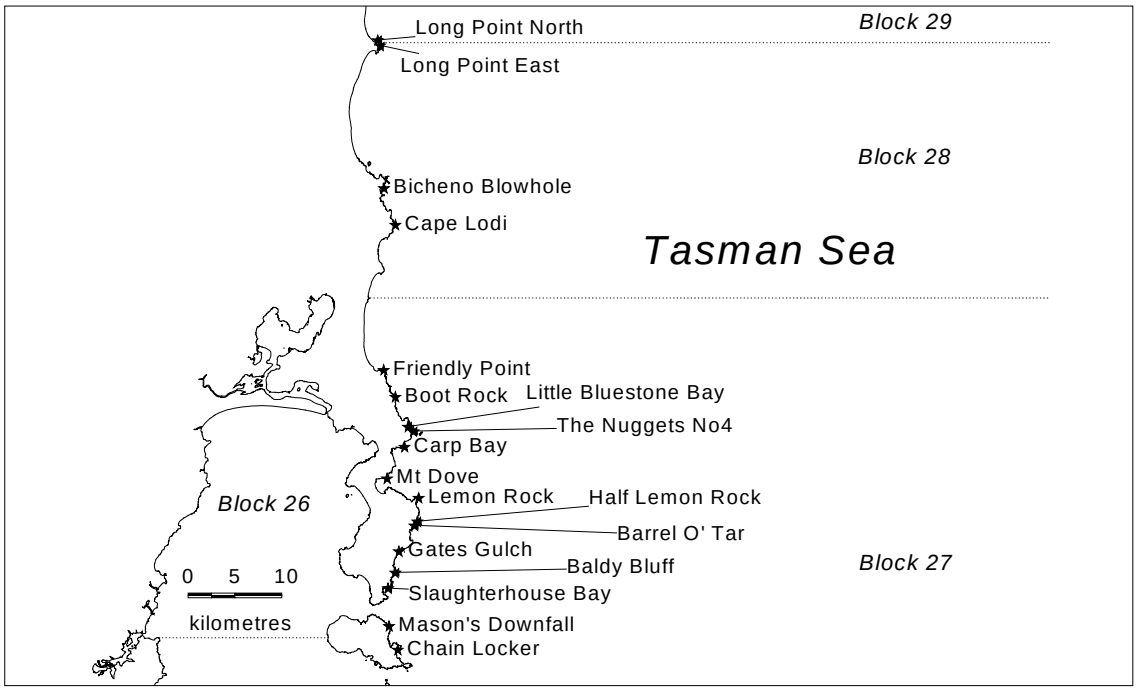

Fig. 2. Sites sampled, Blocks 27 to 29, July and August 2001.

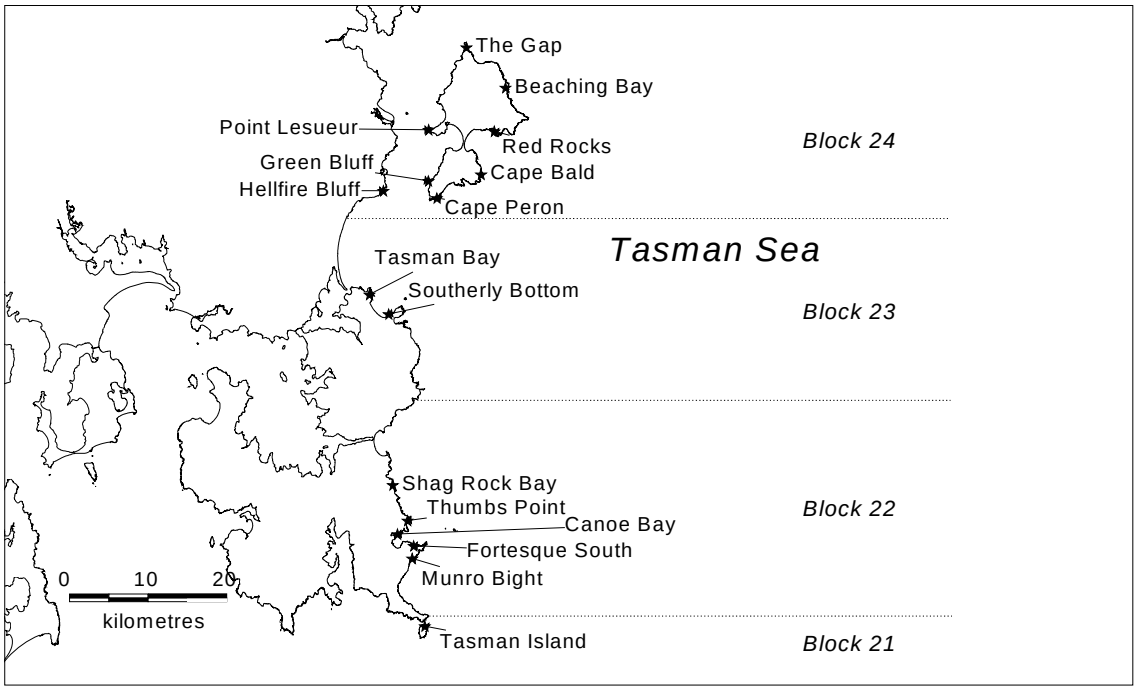

Fig. 3. Sites sampled, Blocks 24 to 21, August and September 2001.

2.5 Research Dive Catch-Rates

Catch-rates are only a crude measure of abundance of abalone. Nevertheless, to determine if there have been obvious trends in the research data, an illustration of catch-rates is given here.

Catch-rates for each sample were determined by dividing the number of abalone collected by the time spent collecting them. They are presented unstandardised (i.e. no allowances have been made for the use of different sampling protocols, divers, and spatial, temporal and seasonal variation).

3. Results

3.1 Projected Growth From Size At Sexual Maturity

3.1.1 Size at sexual maturity

The average size at sexual maturity for each of the sampled sites, and other relevant sites sampled previously is shown below (Table 2). The average size at sexual maturity for each region is also shown. Average size at maturity increases from north to south, the most southern site (Tasman Island – the Landing) being substantially larger than other sites.

Table 2. Size at 50 percent sexual maturity

For each site sampled in 2001, and relevant sites from previous years, the size at which 50 percent of the sample were sexually mature is shown, with upper and lower 95 percent confidence limits in brackets.

Site	2001	2000	1999	1998	1992 - 1995
Blocks 27, 28, 29					
Long Point N	116.5 (114.4-118.2)	114.4 (112.6-116)			
Long Point E	112.4 (108.6-115.1)				
Long Point S					100.5 (96.94-103.1)
Bicheno Blowhole	108.7 (102.5-112.7)				
Cape Lodi	106.2 (102.8-109.3)				101.7 (99.75-103.5)
Friendly Point	108.6 (103.7-112.9)				
Boot Rock	105.2 (101.3-108.4)	110.8 (106.6-113.8)			
Nuggets #4	96.2 (91.42-99.89)	101.1 (96.03-104.9)			
Little Bluestone	115.2 (112.1-117.9)				109.6 (106.3-112.2)
Carp Bay	102.3 (97.43-106.1)				
Mt. Dove	112.3 (109-115.2)				
Lemon Rock	113.0 (107.4-116.6)				
Half Lemon Rock	114.1 (111.8-116.2)	116.0 (114.1-117.7)			
Barrel'O Tar	114.8 (111.4-117.6)				
Gates Gulch	111.5 (106.7-115)	107.8 (102.7-111.5)			
Baldy Bluff	109.2 (105.8-112.2)				
Slaughterhouse	121.4 (117.9-123.9)				
Masons Downfall	107.8 (103.6-111)				
Chainlocker Bay	114.5 (111-117.3)				
mean size Blocks 27, 28, 29	110.5				
Blocks 23, 24					
The Gap	102.3 (96.67-106.7)			106.4 (103.7-108.5)	
Beaching Bay	112.7 (101.8-118.4)				
Red Rocks	117.4 (114.2-119.9)		116.3 (113.1-119)		
Point Leseur	110.3 (106.8-113.1)			95.8 (93.15-98.06)	97.9 (95.96-99.71)
Cape Bald	116.1 (111.6-119.4)				
Green Bluff	116.3 (113.1-119)				
Cape Peron	115.6 (109.6-119.6)		109.4 (103.1-113.6)		
Hellfire Bluff	106.5 (100.7-110.7)		103.8 (98.51-107.5)		
Tasman Bay	105.7 (102.9-108)			116.8 (115-118.4)	
Southerly Bottom	106.0 (103.4-108.5)				
mean size Blocks, 23, 24	110.9				
Block 22					
Shag Rock Bay	117.4 (113.3-120.5)				121.8 (116.2-127.6)
Shag Rock Bay					115.5 (112.7-117.8)
Thumbs	115.6 (110.5-119.6)				
Canoe Bay	112.3 (108.7-115)			111.1 (109.3-112.7)	
Fortescue (south)	114.0 (109.1-117.5)				
Munroe Bight	105.4 (99.53-109.3)				
mean size Block 22	112.9				
Block 21					
Tasman Island	124.0 (119.7-127.5)				

3.1.2 Protection of stocks by size-limits

Listed by site and grouped by region, Table 3 indicates the degree of protection given by the 132-mm size-limit. It shows size at 50 percent sexual maturity, growth parameters, and estimated shell-lengths following onset of sexual maturity in half-yearly increments. The mean size for each of these regions and sub-divisions is calculated for each successive six months following onset of sexual maturity. It should be noted that this description of growth does not yet include seasonal differences and so the mid year steps are only approximate.

Table 3. Estimates of annual shell length following onset of sexual maturity

Sites are grouped by region, showing the size at 50% sexual maturity peculiar to each site, and the von Bertalanffy growth parameters used to calculate successive growth at six monthly intervals from that size. The mean (average) size for each region is also shown: it is from these that the suitability of a particular size-limit may be judged, and the degree of protection afforded the stock. Projected growth at two years is highlighted.

Region	Site	Length at 50% sexual maturity	von Bertalanffy growth parameters		Estimated length 0.5 to 5 years following onset of sexual maturation									
			k	L_∞	0.5	1.0	1.5	**2.0**	2.5	3.0	3.5	4.0	4.5	5.0
Blocks 27, 28, 29														
	Long Point N	116.5			125	131	136	**140**	143	145	147	148	149	150
	Long Point E	112.4			122	129	134	**138**	142	144	146	148	149	150
	Bicheno Blowhole	108.7			119	127	132	**137**	141	143	145	147	148	149
	Cape Lodi	106.2			117	125	131	**136**	140	143	145	147	148	149
	Friendly Point	108.6			119	126	132	**137**	141	143	145	147	148	149
	Boot Rock	105.2			116	124	131	**136**	140	143	145	147	148	149
	Nuggets #4	96.2			109	119	127	**133**	137	141	143	146	147	148
	Little Bluestone Bay	115.2			114	123	130	**135**	139	142	144	146	148	149
	Carp Bay	102.3	0.52	152.6	124	130	135	**139**	142	145	147	148	149	150
	Mt. Dove	112.3			122	129	134	**138**	142	144	146	148	149	150
	Lemon Rock	113.0			122	129	134	**139**	142	144	146	148	149	150
	Half Lemon Rock	114.1			123	130	135	**139**	142	145	146	148	149	150
	Barrel'O Tar	114.8			123	130	135	**139**	142	145	146	148	149	150
	Gates Gulch	111.5			121	128	134	**138**	141	144	146	147	149	150
	Baldy Bluff	109.2			119	127	133	**137**	141	143	146	147	148	149
	Slaughterhouse Bay	121.4			129	134	138	**142**	144	146	148	149	150	150
	Masons Downfall	107.8			118	126	132	**137**	140	143	145	147	148	149
	Chainlocker Bay	114.5			123	130	135	**139**	142	145	146	148	149	150
mean size: all sites Blocks 27, 28, 29		110.5			120	128	133	**138**	141	144	146	147	149	149
Blocks 23, 24														
	The Gap	102.3			113	122	129	**134**	139	143	146	149	151	153
	Beaching Bay	112.7			121	128	134	**139**	143	146	149	151	153	154
	Red Rocks	117.4			125	132	137	**141**	145	148	150	152	153	155
	Point Leseur	110.3			119	127	133	**138**	142	145	148	150	152	154
	Cape Bald	116.1	0.40	160.6	124	131	136	**141**	144	147	150	152	153	155
	Green Bluff	116.3			124	131	136	**141**	144	147	150	152	153	155
	Cape Peron	115.6			124	130	136	**140**	144	147	150	152	153	155
	Hellfire Bluff	106.5			116	124	131	**136**	141	144	147	150	152	153
	Tasman Bay	105.7			116	124	130	**136**	140	144	147	150	152	153
	Southerly Bottom	106.0			116	124	131	**136**	141	144	147	150	152	153
mean size: all sites Blocks 23, 24		110.9			120	127	133	**138**	142	146	148	151	152	154
Block 22														
	Shag Rock Bay	117.4			130	140	149	**155**	161	165	168	171	173	175
	Thumbs	115.6			129	139	148	**155**	160	164	168	171	173	175
	Canoe Bay	112.3	0.44	182.2	126	137	146	**153**	159	163	167	170	173	174
	Fortescue (south)	114.0			127	138	147	**154**	159	164	168	170	173	175
	Munroe Bight	105.4			121	133	142	**150**	157	162	166	169	172	174
mean size: all sites Blocks 22, 23		112.9			127	138	146	**153**	159	164	167	170	173	174
Block 21														
	Tasman Island	124.0	0.44	182.2	135	145	152	**158**	163	167	170	172	174	176

3.2 Size-composition

Size-composition data for each site is shown as length-frequency distributions. Where sites have previously been visited, the size-structure from those samples is included. Comparison between sites over time will show changes to the size-structure of populations. Unless otherwise stated, sample size is approximately 200 abalone.

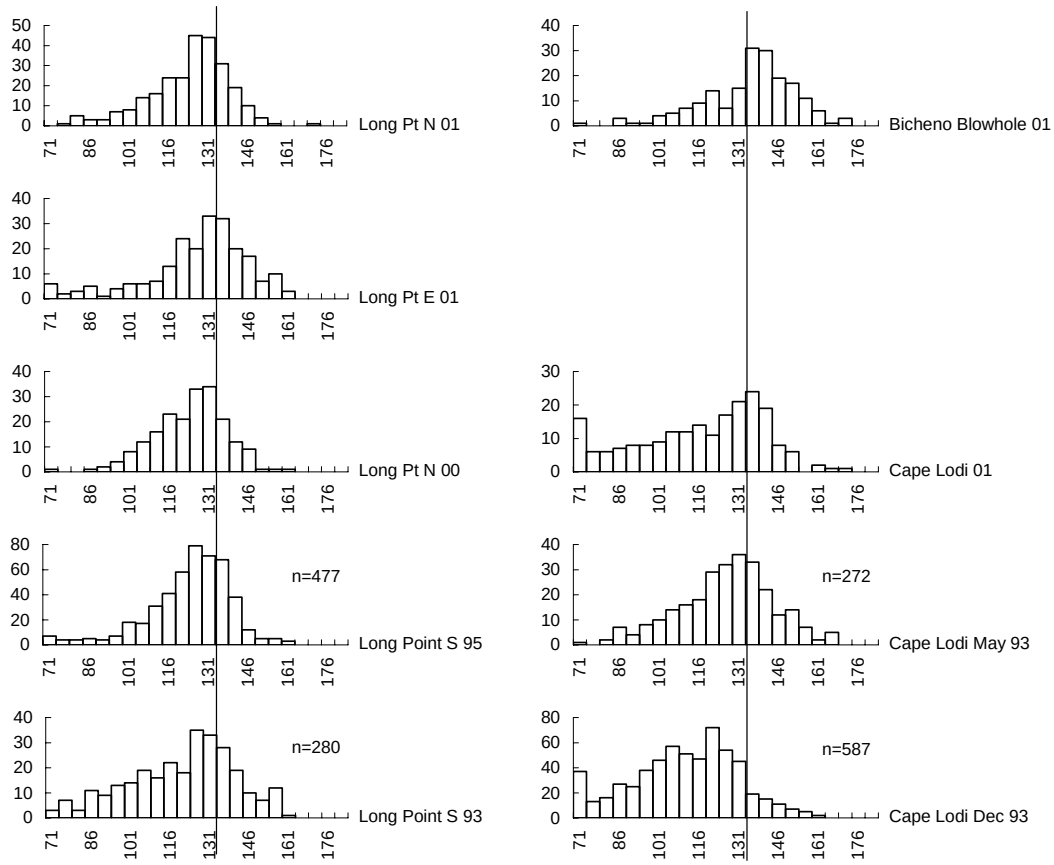

Fig. 4. Size-composition of sites sampled in Block 28. The samples at Long Point have been collected in different places because sea conditions prevented access to abalone habitat at earlier sites. The size-composition of the samples from Cape Lodi in 1993 is consistent with heavy fishing pressure during the winter and a fishery that is dependent on the emergence of legal-size animals and the growth of recruits.

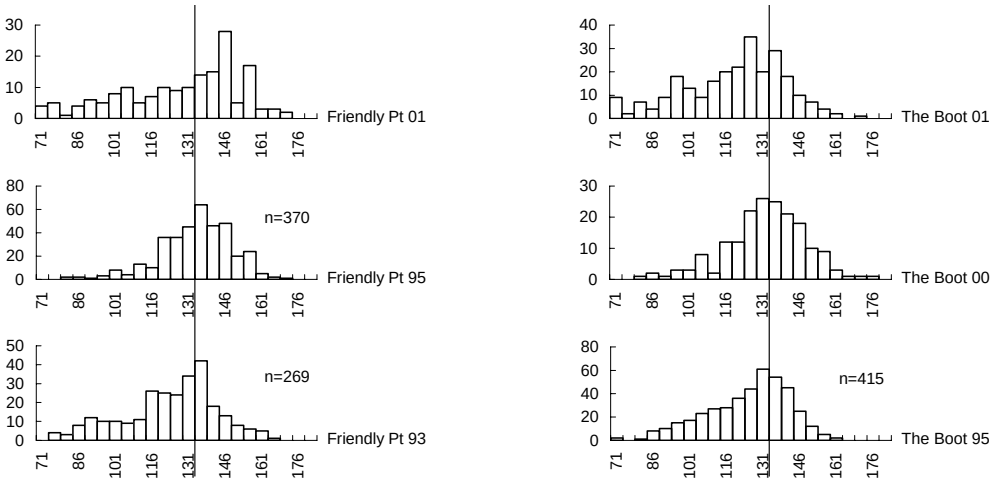

Fig. 5. Size-composition of sites sampled in the northern part of Block 27. Adequate samples were difficult to collect from Friendly Point in 2001 because abalone were particularly scarce.

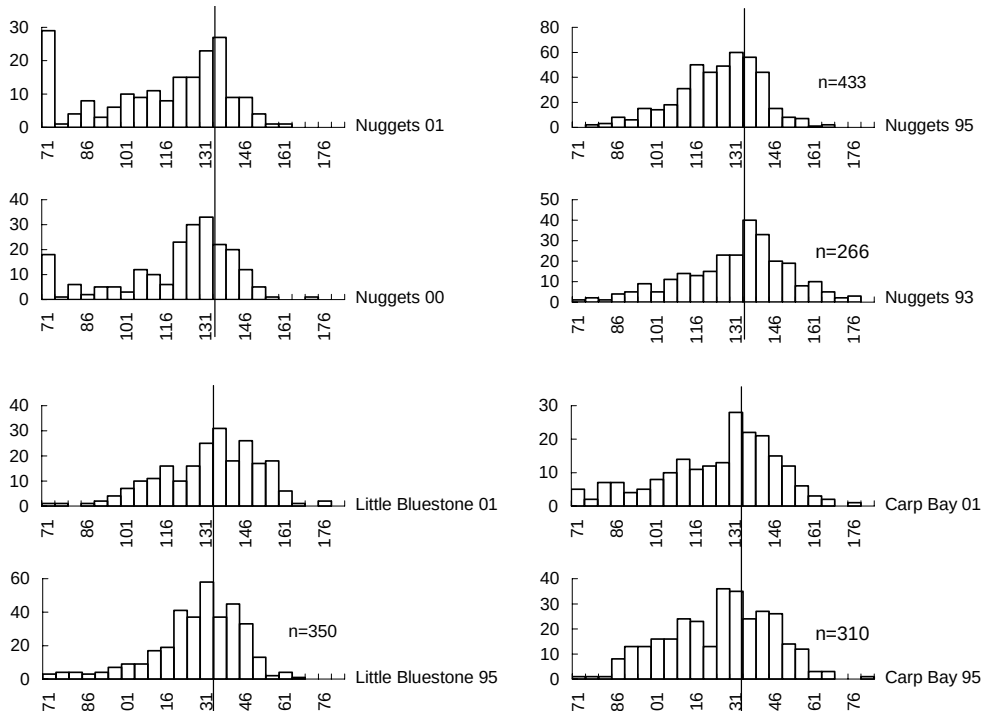

Fig. 6. Size-composition of samples from Block 27 sites north of Wineglass Bay. The site at the Nuggets sampled in 2000 and 2001 is different from that sampled earlier, so they are not entirely comparable.

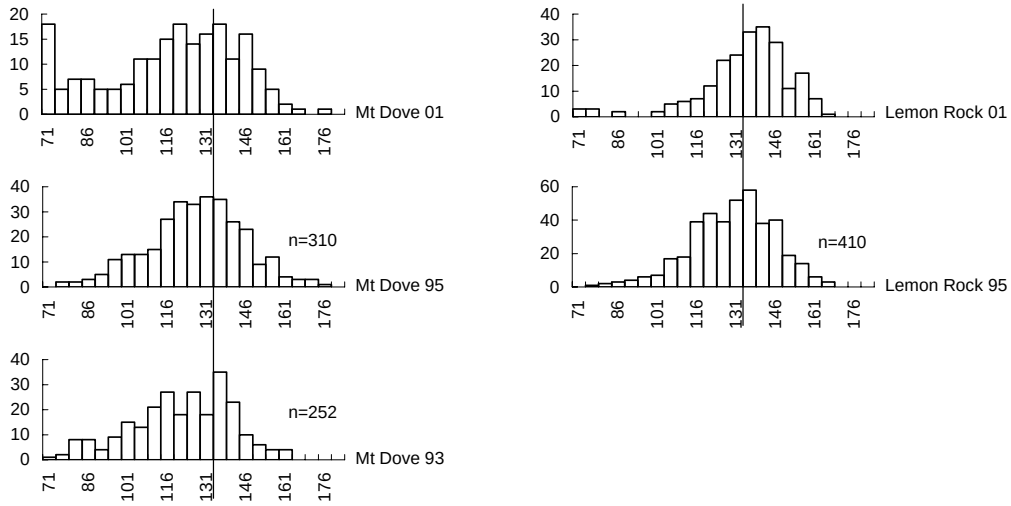

Fig. 7. Sites sampled from the northern and southern sides of Wineglass Bay, Block 27. The Mt Dove site is amongst a group of boulders where Mt Dove (middle peak of the Hazards) meets the sea. The Lemon Rock site is in the small bay north and west of the Rock.

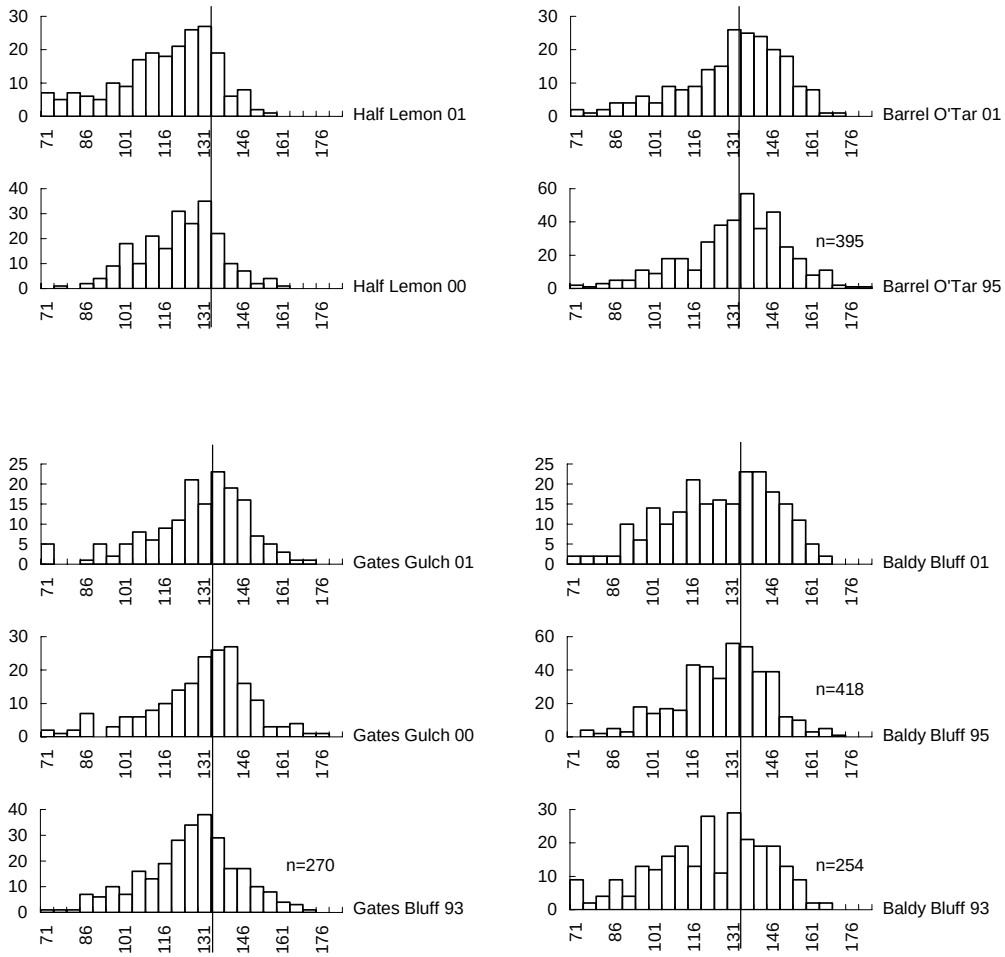

Fig. 8. Size-composition of Block 27 sites south of Wineglass Bay. The site at Gates Bluff in 1995 is about 200 metres east of Gates Gulch. Abalone were particularly scarce in Gates Gulch in 2001.

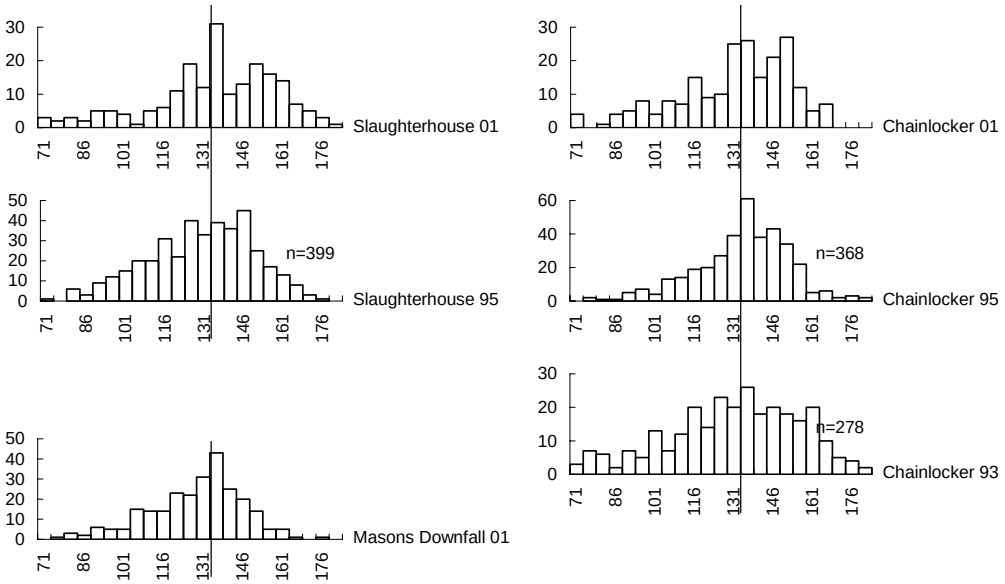

Fig. 9. Size-composition of abalone from Block 27 sites at the southern end of the Freycinet Peninsula (Slaughterhouse Bay) and Schouten Island (Masons Downfall and Chainlocker Bay). Abalone were particularly abundant at Masons Downfall.

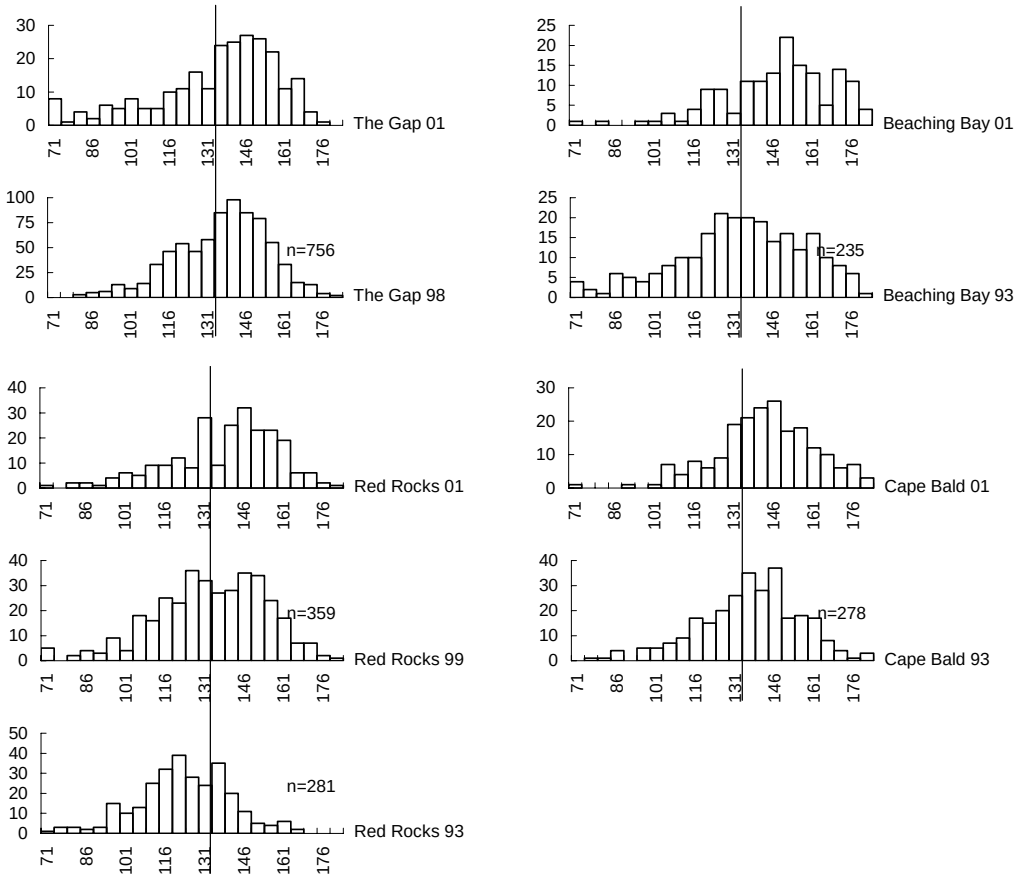

Fig. 10. Size-composition of samples from four sites on the northern and eastern shores of Maria Island (Block 24). The Gap is at the northern end of the island, two hundred metres east of the Marine Reserve boundary. In 2001, at no sites were abalone abundant, and juvenile abalone were particularly scarce at the more southern three sites.

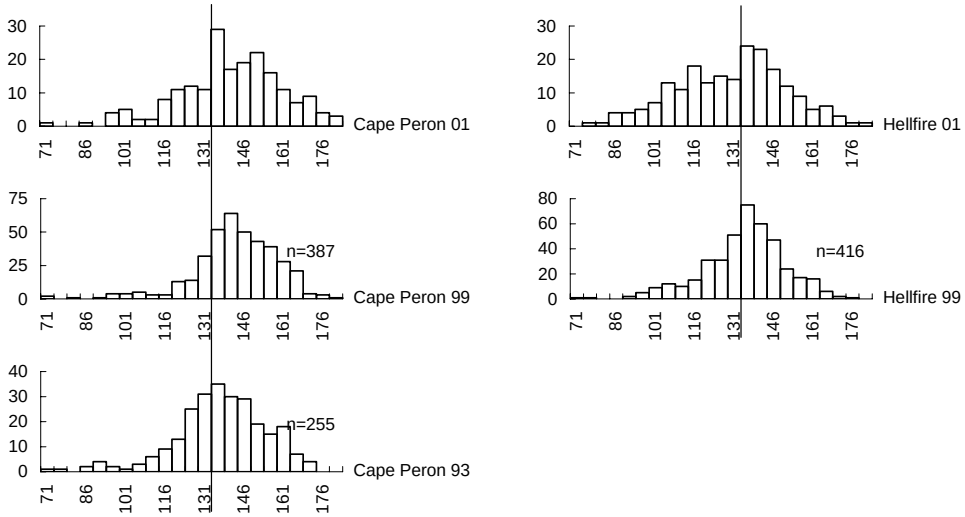

Fig. 11. Size composition of abalone from Block 24: the south-eastern end of Maria Island (Cape Peron) and Hellfire Bluff. Note the low abundance of juveniles and presence of relatively large abalone at Cape Peron during the past two years.

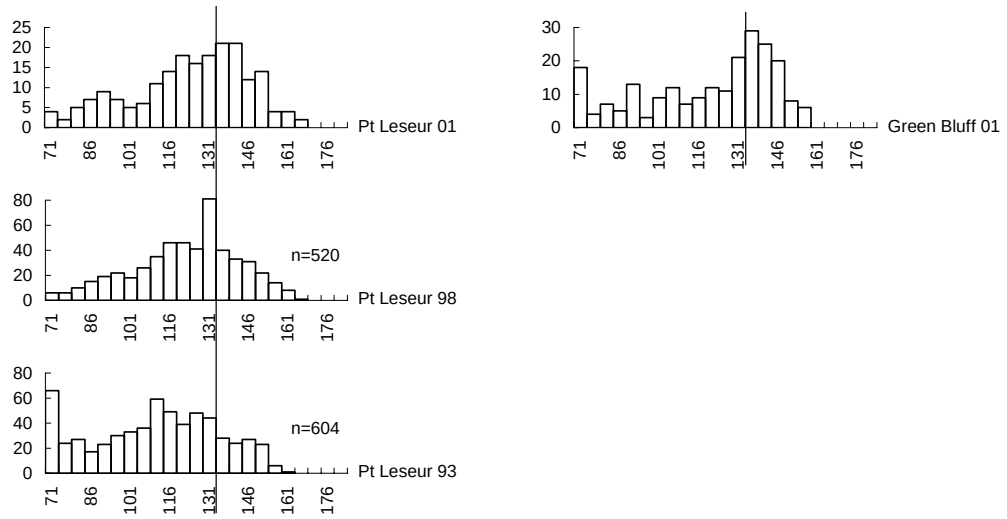

Fig. 12. Size-composition of abalone collected from two sites in Mercury Passage (Block 24). Note the shift in distribution of size-classes at Point Leseur (also known as Long Point) which is also reflected in an increased size at sexual maturity (Table 2).

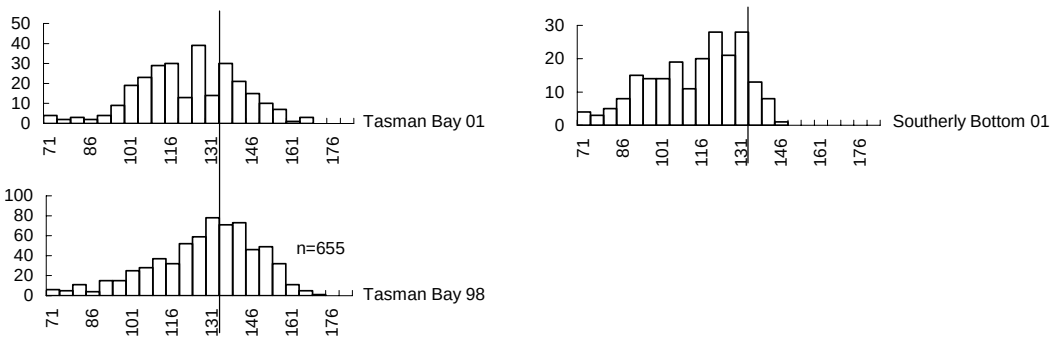

Fig. 13. Size-composition of samples from Block 23. Note high relative abundance of juveniles and extreme paucity of larger abalone in sample from Southerly Bottom.

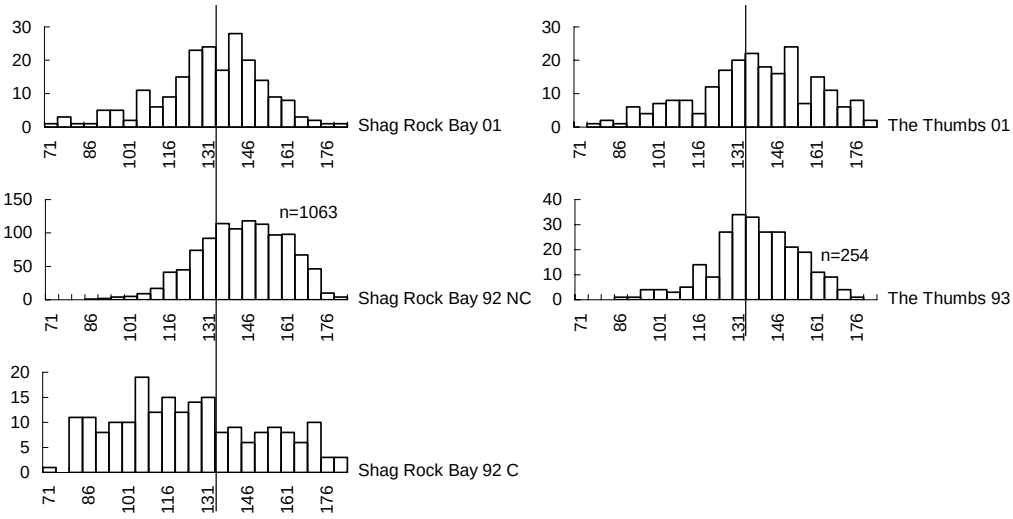

Fig. 14. Size-composition of samples from Block 22, from between Eaglehawk Neck and Fortescue Bay. Note presence of relatively large abalone.

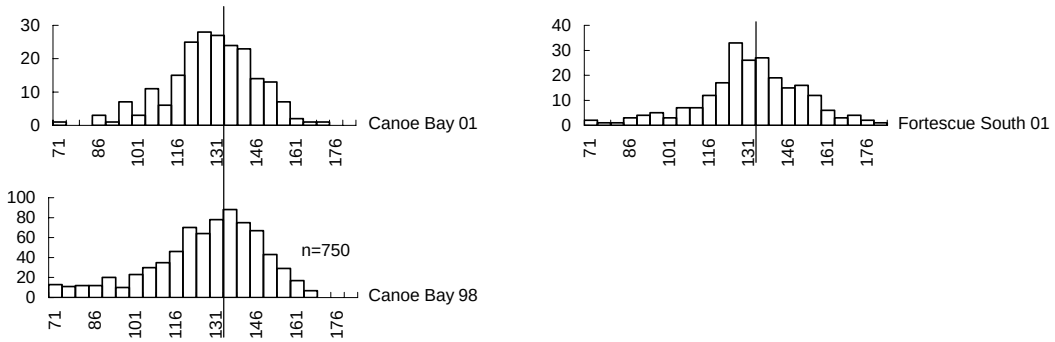

Fig. 15. Size-composition of samples collected from Fortescue Bay (Block 22). The southern site was at the base of a rockfall approximately 1.5 kilometres west of the Lanterns.

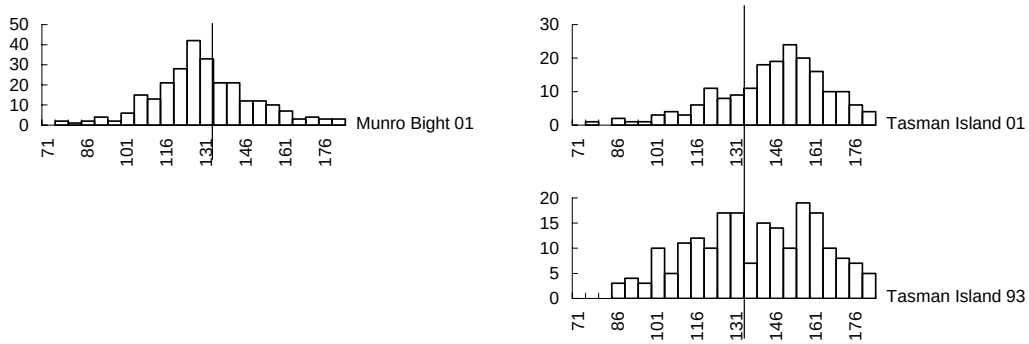

Fig. 16. Size-composition of samples collected from south of Fortescue Bay. All three samples featured large abalone, particularly those from Landing at Tasman Island (Block 21). The sample from Munro Bight (Block 22) was collected from the base of the first rockfall south-west from the Lanterns.

3.3 Research dive catch-rates

Raw (unstandardised) catch rates, measured in numbers of abalone landed per minute indicate either a slight downward trend or no trend through time (Table 4; Figure 17).

Table 4. Research dive catch-rates

Collection date, collection time, the total number of abalone collected, the number of legal-sized abalone (subset of the total) and catch-rates in number caught per minute are listed for each site. Catch-rates use unstandardised data, so comparison of catch-rates between sampling periods is probably meaningless unless substantial differences exist. No collection times are available for samples from Shag Rock Bay collected in 1992.

Site	Date	Time (minutes)	Total abs	Legal-size abs	Total abs/min	Legal-size abs/min
Long Point N	16/07/01	79	259	66	3.3	0.8
Long Point N	30/08/00	36	200	45	5.6	1.3
Long Point E	16/07/01	113	218	89	1.9	0.8
Long Point S	20/03/95	115	477	131	4.1	1.1
Long Point E	26/05/93	40	280	77	7.0	1.9
Bicheno Blowhole	13/08/01	174	184	118	1.1	0.7
Cape Lodi	13/08/01	118	207	61	1.8	0.5
Cape Lodi	28/05/93	80	272	95	3.4	1.2
Cape Lodi	16/12/93	300	587	59	2.0	0.2
Friendly Point	19/07/01	214	170	87	0.8	0.4
Friendly Point	15/05/95	146	370	210	2.5	1.4
Friendly Point	27/05/93	85	269	93	3.2	1.1
Boot Rock	19/07/01	92	207	71	2.3	0.8
Boot Rock	29/08/00	94	181	89	1.9	0.9
Boot Rock	15/05/95	95	419	143	4.4	1.5
Little Bluestone Bay	15/08/01	142	223	119	1.6	0.8
Little Bluestone Bay	03/04/95	183	350	135	1.9	0.7
Nuggets #4	17/07/01	118	192	51	1.6	0.4
Nuggets #4	29/08/00	99	215	61	2.2	0.6
Nuggets	15/05/95	96	433	133	4.5	1.4
Nuggets	27/05/93	45	266	140	5.9	3.1
Carp Bay	18/07/01	91	207	82	2.3	0.9
Carp Bay	15/05/95	160	312	110	2.0	0.7
Mt Dove	18/07/01	96	200	63	2.1	0.7
Mt Dove	17/05/95	136	310	116	2.3	0.9
Mt Dove	27/05/93	61	253	82	4.1	1.3
Lemon Rock	18/07/01	95	218	133	2.3	1.4
Lemon Rock	17/05/95	111	410	178	3.7	1.6
Half Lemon Rock	17/07/01	54	213	36	3.9	0.7
Half Lemon Rock	31/08/00	47	219	46	4.7	1.0
Barrel'O Tar	14/08/01	95	210	106	2.2	1.1
Barrel'O Tar	16/05/95	222	395	205	1.8	0.9
Gates Gulch	17/07/01	124	162	75	1.3	0.6
Gates Gulch	29/08/00	80	191	92	2.4	1.2
Gates Bluff	27/05/93	50	270	89	5.4	1.8
Baldy Bluff	26/07/01	63	224	97	3.6	1.5
Baldy Bluff	16/05/95	71	421	163	5.9	2.3
Baldy Bluff	27/05/93	52	255	85	4.9	1.6
Slaughterhouse Bay	26/07/01	112	196	119	1.8	1.1
Slaughterhouse Bay	16/05/95	145	399	187	2.8	1.3
Masons Downfall	26/07/01	49	255	114	5.2	2.3
Chainlocker Bay	15/08/01	100	213	113	2.1	1.1
Chainlocker Bay	18/05/95	187	369	216	2.0	1.2
Chainlocker Bay	23/03/93	156	279	139	1.8	0.9

Table 4. (continued)

Site	Date	Time (minutes)	Total abs	Legal-size abs	Total abs/min	Legal-size abs/min
The Gap	24/07/01	190	166	98	0.9	0.5
The Gap	03/06/98	322	756	469	2.3	1.5
Beaching Bay	25/07/01	135	151	119	1.1	0.9
Beaching Bay	25/03/93	90	150	122	1.7	1.4
Red Rocks	25/07/01	276	230	146	0.8	0.5
Red Rocks	07/05/99	140	153	182	1.1	1.3
Red Rocks	26/05/93	120	281	93	2.3	0.8
Cape Bald	27/08/01	147	200	144	1.4	1.0
Cape Bald	25/03/93	57	175	163	3.1	2.9
Cape Peron	27/08/01	155	194	137	1.3	0.9
Cape Peron	05/05/99	254	387	305	1.5	1.2
Cape Peron	25/03/93	87	185	157	2.1	1.8
Point Leseur	24/07/01	68	199	78	2.9	1.1
Point Leseur	04/06/98	169	520	149	3.1	0.9
Point Leseur	29/11/93	380	604	109	1.6	0.3
Green Bluff	24/07/01	62	218	88	3.5	1.4
Hellfire Bluff	24/07/01	106	205	101	1.9	1.0
Hellfire Bluff	16/03/99	230	416	248	1.8	1.1
Tasman Bay	08/08/01	79	190	82	2.4	1.0
Tasman Bay	18/03/98	220	655	288	3.0	1.3
Southerly Bottom	08/08/01	27	212	22	7.9	0.8
Shag Rock Bay	04/09/01	111	207	103	1.9	0.9
Shag Rock Bay	25/03/92	nr	nr			
Shag Rock Bay	1992	nr	nr			
Thumbs	05/09/01	79	186	129	2.4	1.6
Thumbs	12/05/93	160	254	152	1.6	1.0
Canoe Bay	04/09/01	95	211	85	2.2	0.9
Canoe Bay	23/04/98	300	750	326	2.5	1.1
Fortescue (south)	05/09/01	85	194	105	2.3	1.2
Munroe Bight	06/09/01	159	201	89	1.3	0.6
Tasman Island	06/09/01	112	191	96	1.7	0.9
Tasman Island	16/03/93	120	201	112	1.7	0.9

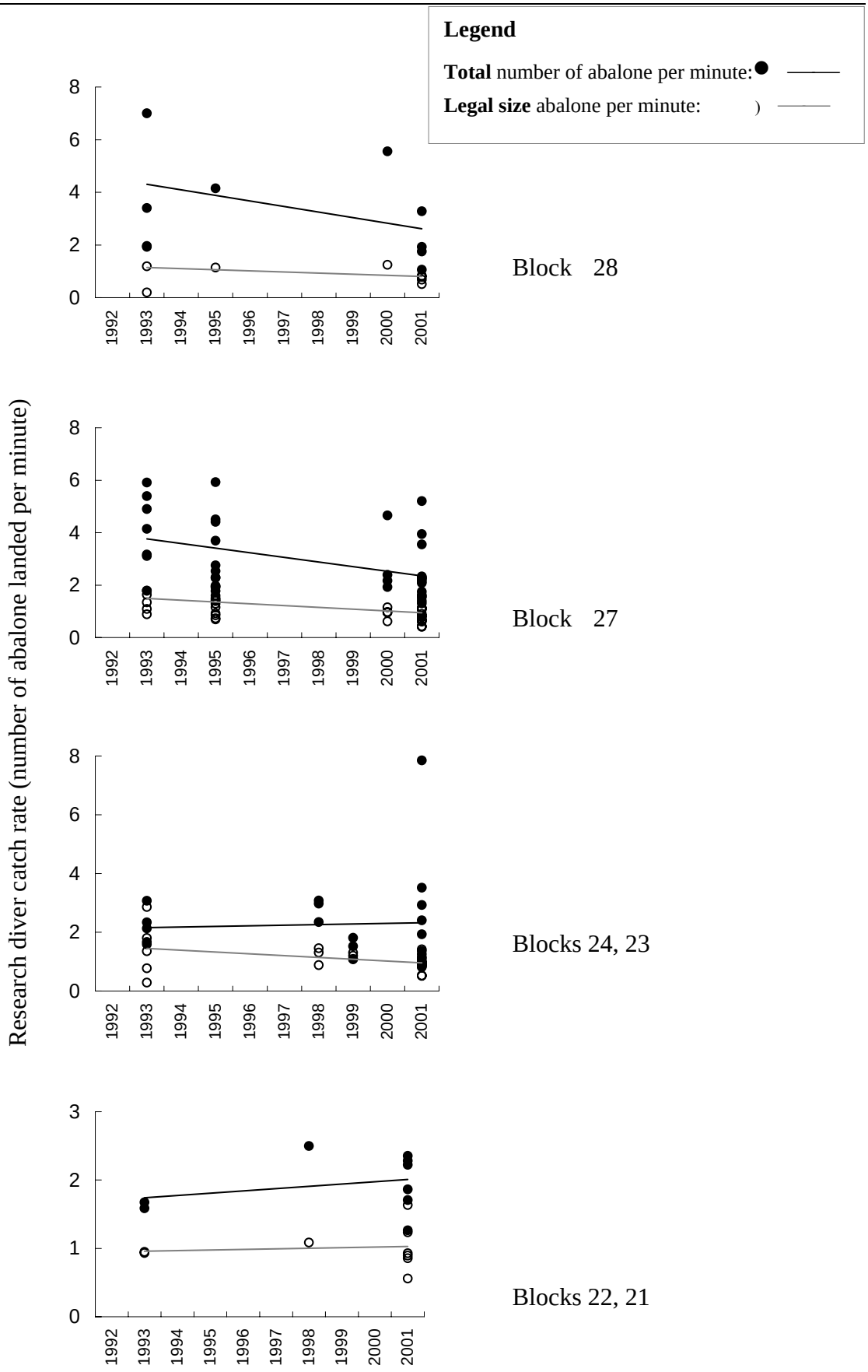

Fig. 17. Catch-rates (number of abalone per minute) from the samples collected and discussed in this report. Catch rates for both the total number of abalone per sample and the number of legal sized abalone are shown in the year in which they were caught.

4. Discussion

This study was prompted by a recent fall in divers' daily catch and catch-rates, and their perception that abalone abundance is diminishing on the East Coast (Blocks 22 to 29). Information from divers' catch dockets supports the view that the fishery has declined in terms of catch and catch-rate from a peak in 1998 (Fig. 18).

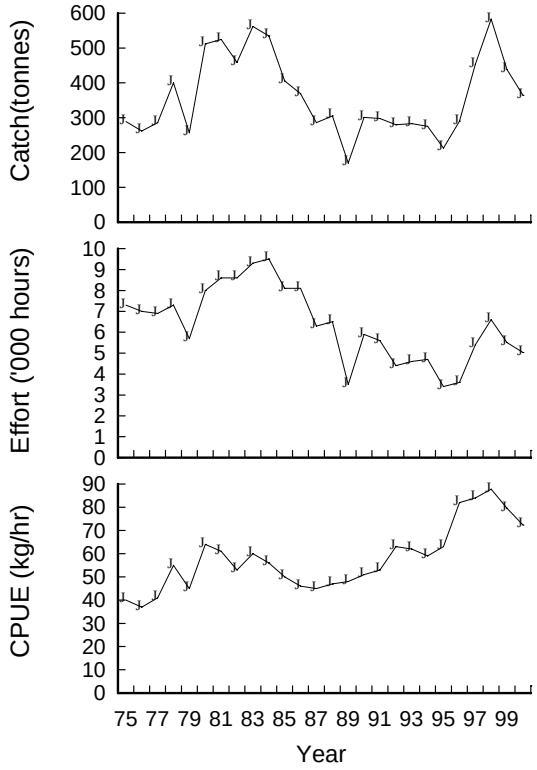

Fig. 18. Catch, effort and catch-rates for Tasmania's East Coast (Blocks 22 to 29), 1975 to 2000.

There have been earlier catch-rate declines, notably in the early and mid 1980's and in the mid 1990's. The 1980's decline prompted TAC reductions and, in 1987, an increase in the minimum size-limit from 127 mm to 132 mm. Catch-rates rose marginally until a peak in 1992, from where they again started to fall, prompting an investigation into the decline of the East Coast abalone fishery. A report prepared by the Department of Primary Industry and Fisheries in 1995 found no evidence for falling stock levels, apart from declining catch and catch-rates (Nash, 1996). In 1995 catch rates improved, and from that point climbed steadily upwards to the 1998 peak. In 2000, catch-rates were still relatively high but falling, compared to the period 1985 to 1995.

Raw catch and catch-rate data are poor indicators of abundance, because there are factors that affect the rate at which abalone are collected independent of the quantity of abalone on the bottom (Prince and Shepherd, 1992). If, for example, catch-rates from years in which abalone are collected in winter (when catch-rates are highest) are compared with years when there is a substantial summer fishery, allowances must be made for seasonal factors affecting catches, otherwise the comparison is invalid. Likewise, allowances should be made for technological advances made by divers over the course of the fishery. The ability for divers to collect abalone more efficiently may bolster falling catch-rates and hide stock declines.

It has previously been reported that the abundance of legal-sized abalone on the East Coast is falling (Tarbath et al., 2001). However, the extent of the fall is not known. Divers report diminishing catch-rates and are concerned for the future of the fishery. This report will address concerns about short-term recruitment and adequacy of size-limits. There is no biological information to enable us to estimate appropriate levels of catch directly: nevertheless, because of the potential for effort creep (i.e. divers becoming more efficient) obscuring any real decline in the Eastern Zone stocks, this report suggests caution when setting zonal TACs.

4.1 Growth Rates, Size At Sexual Maturity And Size-Limits

This study shows that the current 132-mm size-limit does not achieve the Management Plan objective of two seasons of reproduction prior to exposure to fishing. The average projected growth at two years beyond size at maturity for sites north of Eaglehawk Neck indicates a size-limit of at least 138 mm is required to achieve the Management Plan objective for most of the sites inspected. A lesser size-limit (e.g. 136 mm) will confer protection only for sites with smaller sizes at maturity (e.g. Cape Lodi, Boot Rock, Hellfire Bluff, Southerly Bottom), leaving the highly productive areas such as the coastline south of Wineglass Bay and most of Maria Island with insufficient protection. South of Eaglehawk Neck, where growth rates are higher and the average projected growth at two years beyond sexual maturity was 153 mm, a much larger size-limit is needed to meet the objective. However, such a size-limit would be impractical further north. Choosing a suitable size-limit inevitably will mean that some parts of the coast are over protected, while other parts receive insufficient protection.

Size at sexual maturity (average size at which 50 percent of the sample is sexually mature) was considerably larger than expected from previous research (Table 2). Size at maturity has increased at many sites that were revisited in 2001 (e.g. Point Leseur, Cape Peron, Little Bluestone Bay, Long Point), although 95 percent confidence intervals show some overlap with earlier samples (i.e. not significantly different). Other sites (Shag Rock Bay, Canoe Bay, Half Lemon and the recently sampled sites at Long Point displayed consistently high size at maturity over the past few years.

Both Tasman Bay and Munro Bight had surprisingly low size at maturity, which was confirmed by repeat sampling. The sample from Tasman Bay was significantly lower than a sample collected from the same place in 1998. However, the 1998 sample was collected in March. Seasonal variation in size at maturity has recently been observed in heavily fished populations, where samples collected in autumn had the highest size at maturity.

Size at maturity at Tasman Island (124 mm) is the highest observed in Tasmania. Some of the abalone collected at this site in 2001 were among the largest seen by TAFI researchers. Conversely, samples collected from the Nuggets in 2000 and 2001 show surprisingly small size at maturity. The site sampled is at the western end of the northern side of the innermost island, at depths ranging between 15 metres and the surface. The recent sample from this site appeared to have rounded, almost stunted shells that showed considerable staining from shell parasites.

In Tasmania, the maximum size of blacklip abalone tends to increase latitudinally from north to south (Tarbath, 1999a), and this trend is particularly evident in the growth parameters (L_∞) listed in Table 1. Abalone from the most southern site (at Shag Rock Bay, south of Eaglehawk Neck) grow to a particularly large size and are the largest recorded from growth studies of abalone by Tasmanian researchers around the whole of Tasmania. However, even at the most northern site, growth was relatively fast and comparable with growth-rates and maximum average sizes from abalone at the Actaeons in South East Tasmania. Growth rates and average maximum sizes are all faster and larger than those observed from a tagging study at Couta Rocks on the West Coast.

Relevant tag-derived growth information is available from only three East Coast sites (Table 1). The assumption is therefore made in this report that abalone between Long Point and Schouten Island grow at similar rates to those from the study site at Ironhouse Point; abalone from Maria Island, Mercury Passage and the northern part of the Forestier Peninsula grow similar to those at the Magistrates Point study site; and that abalone from between Eaglehawk Neck and Tasman Island grow similar to those from the Shag Rocks Bay study site. Consequently, while we recognise that our application of these growth rates is not ideal, they represent the best information currently available.

Growth information from tagging studies, not age-based growth rates is used in this report. Because tag-derived growth rates are from observed growth increments (as opposed to inferred growth rates from age-based studies), predicted growth increments are likely to be more reliable and without the problems that beset age-based growth estimates (adventitious rings, insufficient validation, etc.;(McShane and Smith, 1992)).

By applying growth rates from Magistrates Point and Ironhouse Point, it can be expected that 132-mm abalone will grow to 141 mm in one year. Increases in size-limit may therefore affect catch-rates for much of the year in which they are first implemented, particularly if market forces dictate that the East Coast is heavily fished early in the year before pre-recruits have had the opportunity to grow to legal size.

4.2 Yield-per-recruit

There is an additional advantage to increasing size-limits, in terms of increased yield to the fishery per number of abalone landed. Whole weight of abalone increase exponentially with shell-length:

$$\text{weight} = a * \text{shell-length}^{\,b}$$

From samples collected at five sites between Long Point and Tasman Island, the parameters to the shell-length/whole-weight regression are shown (Table 5).

Table 5. Percent increase in whole-weight per millimetre increase in shell-length
From five East Coast sites, the percentage increase in weight gained over 132-mm abalone, for abalone between 132 and 145 mm is shown, together with the parameters of the regression equation *a* and *b*.

Site:	Long Point South	Little Bluestone	Hellfire Bluff	The Gap	Canoe Bay
a	6.00E-05	1.00E-04	8.00E-05	4.00E-05	8.00E-05
b	3.1748	3.0293	3.1415	3.2581	3.1278
shell-length (mm)	Percent increase in whole weight				
132	0.0	0.0	0.0	0.0	0.0
133	2.4	2.3	2.4	2.5	2.4
134	4.9	4.7	4.8	5.0	4.8
135	7.4	7.0	7.3	7.6	7.3
136	9.9	9.5	9.8	10.2	9.8
137	12.5	11.9	12.4	12.9	12.3
138	15.2	14.4	15.0	15.6	14.9
139	17.8	16.9	17.6	18.3	17.5
140	20.5	19.5	20.3	21.1	20.2
141	23.3	22.1	23.0	24.0	22.9
142	26.1	24.8	25.8	26.9	25.7
143	28.9	27.4	28.6	29.8	28.4
144	31.8	30.2	31.4	32.8	31.3
145	34.7	32.9	34.3	35.8	34.2

At a shell-length of 138 mm, the weight gain over a 132-mm abalone is about 15 percent (Table 5). This does not imply that yields would be increased by that much should a 138-mm size-limit be adopted, but indicates fewer abalone need be collected to achieve the quota.

Natural mortality would reduce the number of abalone growing from 132 mm to any increased size-limit, but providing the increase is small, will have little effect upon the population yield. In this study, no attempt has been made to estimate size-limits for optimum yield. Adequate estimates of natural mortality are notoriously difficult to obtain (Nash, 1992; Shepherd and Breen, 1992) and greatly affect estimates of yield-per-recruit. Previous yield optimisation studies of Tasmanian abalone fisheries show that natural mortality will not significantly impact upon yield of abalone with similar growth characteristics and size-limits in the range above, provided that natural mortality is low (0.2 or less) (Officer, 1999).

4.3 Size-Structure And Recruitment

The size-composition of samples in Fig. 4 to Fig. 16 show that pre-recruits will enter the Easy Coast fishery next year and that because of high fishing mortality, it seems likely that most of them will be caught in that year.

Size-composition of samples needs to be interpreted in conjunction with the rate at which the sample was collected (Table 4). Samples may show adequate proportional representation of pre-recruits and legal-size abalone, but if they took three hours to collect as did the recent sample from Friendly Point, then there is clearly a problem with fishing the abalone population at that site.

The catch-rates referred to (Table 4) are a very approximate measure of abundance. Where sites have previously been sampled it is possible to compare the time taken to collect samples and make inferences about changes in abundance over that period. However, because there is variation between the way samples have been collected over time (different divers, sampling strategies) the accuracy of estimates of change is uncertain. In spite of this, consistent differences between years in the time taken to collect samples are apparent and it is possible that changes in stock abundance are responsible for these differences.

The samples from Long Point (Fig. 4) show high levels of juveniles and pre-recruits, with few adults and no large (>160 mm) abalone, which is indicative of high fishing pressure and a fishery dependent upon annual recruitment. Although less obvious in the 1993 sample, it is likely that this situation has prevailed here for many years. This distribution pattern is typical of the more heavily fished areas, such as the Nuggets (Fig. 6), Half Lemon Rock (Fig. 8) and Southerly Bottom (Fig. 13). At all these sites, samples were collected at high catch-rates, indicating that the populations are robust, in spite of the intensive levels of fishing.

At Cape Lodi (Fig. 4) in May 1993 there were quantities of small to medium sized legal abalone. However, by December, most had been caught. To the left of the size-limit, the chart shows large numbers of pre-recruits, which with rapid summer growth, emerge into the fishery the following autumn and winter. Divers experience poor catch-rates over summer, largely because the pre-recruits have yet to attain legal-size. This pattern of annual recruitment is typical of the East Coast fishery, and may have been so for the last twenty or more years. Provided fishing pressure is not excessive, reproduction from the pre-recruits and residual large abalone appears adequate to sustain the fishery. An increase in minimum size-limit would provide for more resilience against years of poor recruitment.

Greater numbers of legal sized abalone were found in samples from sites south of Wineglass Bay than further north (Fig. 8), indicating fishing pressure decreases with increasing distance from the ramp at Bicheno. At Barrel O' Tar Cliffs, a sample that included a large proportion of legal-sized abalone was collected relatively quickly. A diver working in the area reported catching 140 kilograms in 90 minutes, confirming our impressions that legal sized abalone were abundant at the site. We found similarly high levels of legal sized abalone at Baldy Bluff and Masons Downfall (Fig. 9).

Collecting samples from the east coast of Maria Island took much longer than sites on the Freycinet Peninsula (Fig. 10), suggesting abalone were present in much lower numbers. From the Gap south to Cape Peron, samples contained low numbers of juveniles, indicating recruitment is very poor on this coast. The site at the Gap (200 metres east of the Marine Reserve boundary) was inadequately sampled, the original 1998 site proving impossible to find. Nevertheless, it could be expected that greater numbers of juveniles would be present considering its proximity to the Reserve where abalone are particularly abundant.

In contrast, the western shore of Maria Island (Point Leseur and Green Bluff, Fig. 12) showed good quantities of pre-recruits. Samples here were collected quickly, and contained reasonable quantities of legal-size abalone. In spite of this, divers working 400 metres either side of the sampling site reported catch-rates of only 50 kilograms per hour.

Juveniles and pre-recruits were extraordinarily abundant at the Southerly Bottom site (Fig. 13). Catch-rates were highest here, and were only limited by our ability to remove abalone from the rock and put them in our nets. This was primarily due to large numbers of sub-legal abalone present, as there were very few legal-size abalone here.

Samples from south of Eaglehawk Neck contained more larger abalone than from further north, consistent with faster growth rates and greater maximum average size in the region (Fig. 14 to Fig. 16). At Tasman Island, abalone were very large. Juveniles and pre-recruits were generally well represented, although catch-rates were only moderate indicating that abalone were not particularly abundant. Strong representation in larger size-classes probably does not reflect lower fishing pressure than further north: rather the recruits are growing larger and faster, and attain a higher size before capture.

Research diver catch-rates for the major regions by site sampled since 1993 are shown in Fig. 17. Catch-rates generally show a slight decline since 1993, particularly catch-rates based upon the total number of abalone in the sample. The subset of legal-sized abalone declines at a lesser rate, suggesting that the smaller abalone are becoming less catchable. Once again, it should be noted that this CPUE data is not standardised by diver or by diving protocols, both of which could change the outcome of this analysis. In addition, recent sampling has been conducted more rigorously and looks at areas known to have low abalone abundance whereas previously many sites were selected because there were large numbers of abalone present.

5. Conclusions

The findings of this assessment may be summarised as follows:

- Size-limits on the East Coast are too small to adequately support the Management Plan objective “to allow abalone to grow to a size where they have had two breeding seasons…”

- The East Coast fishery is largely dependent upon annual recruitment for most of the catch.

- At the majority of sites sampled, the relative abundance and rates of collection of pre-recruits and juveniles were sufficiently high to suggest that the fishery would continue to supply adequate levels of catch in the short term, although catch-rates may be reduced.

- On the east coast of Maria Island and on parts of the coast between Wineglass Bay and Bicheno, relative abundance and rates of collection of pre-recruits and juveniles are particularly low, and may not sustain present levels of fishing.

- By increasing size-limits in line with average projected sizes the Management Plan objective for East Coast stocks north of Eaglehawk Neck will be achieved. However stocks to the south which grow to a larger size will be less adequately protected. Because of variation in growth, some populations will inevitably be over-protected, while others will receive insufficient protection.

6. Acknowledgments

We would like to acknowledge the hard work, long hours and unpaid overtime contributed by Tim Karlov, Stewart Dickson and Chris Jarvis towards this assessment.

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