

Table 2. Green sea urchin landings (t) and effort for British Columbia, by fishing season (Oct. to Mar.), 1986/87 to 1995/96, as reported on sales slips and harvest logbooks.

Season	Licence Type	# of Licences Issued	Vessels with Landings	Fishing Days	Average Fishing Days/Vessel	Landings (t)	Landed Value (\$) <sup>1</sup> ·10 <sup>3</sup>	Whole Landed Value (\$/t)	Mean CPUE (t/vessel day)	Mean CPUE (kg/diver hr)	Total Diver Hours	Average Hr/Diver Day	Total # Divers	Average Hr/Vessel Day
86/87 <sup>1</sup> 86/87 <sup>2*</sup>	Permit <sup>4</sup>		2	4	2.0	n/a 2	n/a	n/a	0.50	175 <sup>5</sup>	14 <sup>6</sup>	n/a	1 <sup>++</sup>	3.38 <sup>5</sup>
87/88 <sup>1</sup> 87/88 <sup>2*</sup>	Z		29	290	10.0	212 207	n/a	n/a	0.71	157 <sup>5</sup>	1,216 <sup>6</sup>	2.94 <sup>57</sup>	51 <sup>++</sup>	4.57 <sup>5</sup>
88/89 <sup>1</sup> 88/89 <sup>2*</sup>	Z		63	688	10.9	475 378	n/a	n/a	0.55	118 <sup>5</sup>	2,418 <sup>6</sup>	2.84 <sup>57</sup>	120 <sup>++</sup>	4.67 <sup>5</sup>
89/90 <sup>1</sup> 89/90 <sup>2*</sup>	Z		93	1095	11.8	642 484	1,104	1,719	0.44	115 <sup>5</sup>	3,690 <sup>6</sup>	2.46 <sup>57</sup>	175 <sup>+</sup>	3.79 <sup>5</sup>
90/91 <sup>1*</sup> 90/91 <sup>2*</sup>	Z		51	923	18.1	455 353	977	2,147	0.38	86 <sup>5</sup>	3,310 <sup>6</sup>	2.61 <sup>57</sup>	109 <sup>+</sup>	4.25 <sup>5</sup>
91/92 <sup>1*</sup> 91/92 <sup>2*</sup>	Z		44	1508	34.3	783 749	2,535	3,237	0.50	87 <sup>5</sup>	7,523 <sup>6</sup>	2.87 <sup>57</sup>	156	5.72 <sup>5</sup>
92/93 <sup>1*</sup> 92/93 <sup>2*</sup>	Z		53	1987	37.5	978 954	4,531	4,633	0.48	69 <sup>5</sup>	11,824 <sup>6</sup>	3.09 <sup>5</sup>	204 <sup>++</sup>	6.77 <sup>5</sup>
93/94 <sup>1*</sup> 93/94 <sup>2*</sup>	Z		52	1267	24.4	576 533	3,134	5,440	0.42	57 <sup>5</sup>	7,618 <sup>6</sup>	2.94 <sup>57</sup>	189 <sup>++</sup>	7.37 <sup>5</sup>
94/95 <sup>1*</sup> 94/95 <sup>2*</sup>	Z		42	673	16.0	224 221	1,602	7,153	0.33	62 <sup>5</sup>	3,161 <sup>6</sup>	2.70 <sup>57</sup>	103 <sup>++</sup>	5.23 <sup>5</sup>
95/96 <sup>1*</sup> 95/96 <sup>2*</sup> 95/96 <sup>3</sup>	Z	49	36 39 39	442 500 547	12.3 12.8 14.0	135 157 157	919 <sup>8</sup>	6,807	0.31 0.31 0.29	66 <sup>5</sup>	2,201 <sup>6</sup>	2.82 <sup>57</sup>	90 <sup>++</sup>	4.75 <sup>5</sup>
96/97 <sup>1*</sup> 96/97 <sup>2*</sup> 96/97 <sup>3</sup>	Z	49	31 32 32	419 458 467	13.5 14.3 14.6	133 150 150	838 <sup>8</sup>	6,303	0.32 0.33 0.32	65 <sup>5</sup>	2,300 <sup>6</sup>	2.59 <sup>57</sup>	73 <sup>++</sup>	5.03 <sup>5</sup>
97/98 <sup>1*</sup> 97/98 <sup>2*</sup> 97/98 <sup>3</sup>	Z	49	27 27 27	376 423 na	13.9 15.7 na	143 160 160	895 <sup>8</sup>	6,726	0.32 0.38 na	82	1,958	2.56	59	4.63

<sup>1</sup> preliminary data.

<sup>2</sup> from sales slip data

<sup>3</sup> from harvest logbooks

<sup>4</sup> from validation logs

<sup>5</sup> scientific permits were issued to 38 vessels for fall 1987 to spring 1988 fishery. 1987 landings and fishing days are from harvest logs as green sea urchins were not separated from reds on sales slips until mid-1998. Note a vessel can hold more than one licence.

<sup>6</sup> excludes records with missing fishing hours (effort)

<sup>7</sup> incomplete records of fishing hours (effort) for all years

<sup>8</sup> excludes records with missing diver identification

<sup>9</sup> preliminary values likely lower than actual

<sup>+</sup> possibly one or two more (due to sales slips with no CFV #, or missing diver codes)

<sup>++</sup> probably several more (due to missing diver codes)

Table 3a. Summary of green sea urchin landings (tonnes) by management area for the South Coast by fishing season (Oct. to Mar.), 1988/89 to 1996/97, as reported on sales slips, harvest logs and (for 1995/96 to 1997/98) validation logs. (\* preliminary sales slip data for 1993/94 to 1997/98; “-” = area closed). Totals were calculated using sales slips from 1988/89 to 1994/95 and validation logs from 1995/96 to 1997/98.

PACIFIC FISHERY MANAGEMENT AREAS																			
East Coast Vancouver Island										West Coast Vancouver Island									
Season	11	12	13	14	15	16	17	18	19	28	29	20	21	23	24	25	26	27	Annual Landings
sales sl 88/89	2.8	93.0	171.8	17.0	7.4	0.3	15.4	53.8	74.5	15.0	9.8	1.5		2.5	9.5				474.3
sales sl 89/90		327.9	129.8	5.6			36.1	87.6	23.8	1.8	0.5	2.1		0.4	1.8			12.6	630.0
sales sl 90/91	0.9	105.4	153.4			0.1		121.9	51.1	4.0		15.7							452.5
sales sl 91/92	1.0	388.4	203.5	3.1	1.3	4.1	1.1	42.6	50.5	4.3	18.6	61.4	0.3		0.4			2.0	782.6
harv log 91/92	0.0	353.7	206.1	1.4			0.1	23.1	66.3	0.0	25.4	76.1			0.1				752.4
sales sl 92/93	43.4	645.4	189.6			1.9		18.9	36.2	1.7	2.6	36.2							975.9
harv log 92/93	70.8	631.4	154.1			1.3	0.5	26.0	38.6	1.6	2.8	26.7							954.0
sales sl 93/94*	1.5	250.9	102.1	0.9	1.0		0.8	28.3	60.7	0.4	0.8	16.2	3.8		0.4	0.4			468.2
harv log 93/94	27.6	214.1	92.6			0.7	1.7	39.9	46.3	0.5	0.0	16.9							440.6
sales sl 94/95*	2.3	93.8	56.5	1.1	0.0	0.3	0.0	15.5	16.4	0.0	0.1	9.4	-	0.0	0.0	0.0	0.0	0.0	195.4
harv log 94/95	6.9	92.6	53.6	0.0	0.0	0.0	0.2	15.1	16.0	0.0	-	10.8	-	0.0	0.0	0.0	0.0	0.0	195.1
sales sl 95/96*	-	46.3	49.8	-	-	-	0.4	10.6	18.0	0.0		6.0	-	-	-	-	-	-	131.1
harv log 95/96	0.7	60.5	54.8	-	-	-	0.4	12.2	18.3	0.0	0.1	6.1	-	-	-	-	-	-	157.3
val logs 95/96	-	61.9	53.8	-	-	-	0.4	13.0	18.0	0.0		5.7	-	-	0.2	-	-	-	153.0
sales sl 96/97*	1.8	70.3	21.7	-	-	1.5	0.0	23.3	7.8	0.0	-	7.1	-	-	-	-	-	-	133.4
harv log 96/97*	2.8	77.0	27.0	-	-	-	0.0	18.1	17.4	0.0	(0.4)	7.1	-	-	-	-	-	-	149.9
val logs 96/97	2.8	76.9	27.2	-	-	-	0.0	18.5	17.4	0.0	-	7.1	-	-	-	-	-	-	149.9
harv log 97/98*	2.4	76.5	40.0	-	-	-	0.7	16.3	17.4	0.0	-	6.8	-	-	-	-	-	-	159.9
val log 97/98	2.4	76.5	39.9	-	-	-	0.7	17.0	16.7	0.0	-	6.8	-	-	-	-	-	-	159.9
Total																			
88/89 to 97/98	57.1	2120.1	1127.6	27.7	9.7	6.7	54.5	417.1	365.3	27.2	32.4	162.1	4.1	2.9	12.3	0.4	0.0	14.6	4441.7
% of Total	1.3	47.7	25.4	0.6	0.2	0.2	1.2	9.4	8.2	0.6	0.7	3.6	0.1	0.1	0.3	0.0	0.0	0.3	

Table 3b. Summary of green sea urchin landings (tonnes) by management area for the North Coast by fishing season (Oct. to Mar.) 1988/89 to 1995/96, as reported on sales slips. ( \* preliminary data for 1993/94 to 1995/96). The fishery was closed in the North Coast during the 1996/97 and 1997/98 fishing seasons.

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Season	PACIFIC FISHERY MANAGEMENT AREAS										Annual Landings
	1	2E	3	4	5	6	7	8	9	10	
88/89		0.4				0.7					1.1
89/90	12.3										12.3
90/91						2.6					2.6
91/92	0.4										0.4
92/93									1.7		1.7
93/94*				93.5	1.0	3.8	0.2	0.2	8.5	0.1	107.3
94/95*				27.3					0.9		28.2
95/96*				4.0							4.0
96/97	-	-	-	-	-	-	-	-	-	-	-
97/98	-	-	-	-	-	-	-	-	-	-	-
Total 88/89 to 97/98	12.7	0.4	0	124.8	1.0	7.1	0.2	0.2	11.1	0.1	157.6
% of Total	8.1	0.3	0	79.2	0.6	4.5	0.1	0.1	7.0	0.1	

Table 4. Summary of green sea urchin landings (tonnes) by South Coast management areas and month in 1996/97 and in 1997/98, as reported on harvest logs.

		SOUTH COAST MANAGEMENT AREAS																			
		East Coast Vancouver Island											West Coast Vancouver Island								
Month		11	12	13	14	15	16	17	18	19	28	29		20	21	23	24	25	26	27	SOUTH COAST (t)
1996	Nov.	0.0	5.9	2.0	-	-	-	0.0	3.8	5.7	0.0	-		0.9	-	-	-	-	-	-	18.3
	Dec.	1.0	31.0	7.7	-	-	-	0.0	4.5	7.2	0.0	-		3.0	-	-	-	-	-	-	54.4
1997	Jan.	1.8	39.9	4.9	-	-	-	0.0	6.3	3.5	0.0	0.4		1.2	-	-	-	-	-	-	58.0
	Feb.	0.0	0.2	12.4	-	-	-	0.0	3.5	1.1	0.0	-		2.0	-	-	-	-	-	-	19.2
	Area Totals	2.8	77.0	27.0	-	-	-	0.0	18.1	17.5	0.0	0.4		7.1	-	-	-	-	-	-	149.9
		East Coast Vancouver Island											West Coast Vancouver Island								
Month		11	12	13	14	15	16	17	18	19	28	29		20	21	23	24	25	26	27	SOUTH COAST (t)
1997	Nov.	0.2	4.3	0.7	-	-	-	0.0	0.0	0.8	0.0	-		0.0	-	-	-	-	-	-	6.0
	Dec.	0.9	41.6	8.2	-	-	-	0.3	12.5	16.3	0.0	-		4.6	-	-	-	-	-	-	84.4
1998	Jan.	0.0	30.6	28.8	-	-	-	0.0	3.4	0.2	0.0	-		2.1	-	-	-	-	-	-	65.1
	Feb.	1.2	0.0	2.2	-	-	-	0.2	0.0	0.0	0.0	-		0.0	-	-	-	-	-	-	3.6
	Mar.	0.1	0.0	0.0	-	-	-	0.2	0.4	0.0	0.0	-		0.0	-	-	-	-	-	-	0.7
	Area Totals	2.4	76.5	39.9	-	-	-	0.7	16.3	17.3	0.0	-		6.7	-	-	-	-	-	-	159.8

Table 5. Green sea urchin landings reported on sales slips compared to harvest logbook records, by fishing season (Oct. to Mar.), 1986/87 to 1997/98.

Season	Sales Slips (t)	Sales Slips (lb)	Harvest Logbooks (lb)	% of Logbook Returns	
86/87	n/a	n/a	5,220	n/a	
87/88	212	467,460	456,952	97.8%	
88/89	476	1,048,531	832,625	79.4%	
89/90	642	1,416,203	1,067,996	75.4%	
90/91	455	1,003,330	778,926	77.6%	
91/92	783	1,726,356	1,650,855	95.6%	
92/93	978	2,156,154	2,103,210	97.5%	
93/94	576	1,269,091	1,174,527	92.6%	
94/95	224	493,432	487,590	98.8%	
95/96*	135	297,742	346,874	116.5%	
			346,201(val.)	116.3%	
96/97*	133	294,186	330,526	112.4%	
			330,504(val.)	112.3%	
97/98*	143	315,264	352,561	111.8%	
			352,547(val.)	111.8%	

\* Preliminary Data

Note: The above data assumes that all sales slips have been submitted annually, which may not always be the case. Sales slips landings for 1987 and 1988 are actually logs combined with a best guess from sales slips, as there was not a separate species code assigned to green sea urchins until the fall fishery in 1988.

Licence limitation was announced in 1989 for the 1991 fishery. Licence eligibility was based on landings from two of the three years 1987, 1998, and 1989. Fishers who knew they would not meet the landing criteria to get a limited licence were not inclined to submit harvest logbooks at the end of 1989 or in 1990, as they knew they could not renew their licence.

Table 6. Dynamic production model estimates for the parameters  $\alpha$ ,  $\beta$ ,  $\gamma$  and their standard errors (in brackets) for the regression of equation 4. Regression coefficients ( $r^2$ ), probability levels (p-values), and calculation from these parameters of the values of  $r$ ,  $q$ , and  $k$  are as described in the text. Management parameters MSY (maximum sustainable yield) and effort at MSY are calculated as described in the text.

	Regression Parameters				Management Parameters				
	$\alpha$	$\beta$	$\gamma$	Model ( $r^2$ )	$r$ (yr) <sup>-1</sup>	$q$ (diver hr) <sup>-1</sup>	$k$ (t)	MSY (t)	effort at MSY (diver hr)
South -inside Northern region (PFMA 11,12,13)	0.829 (0.222)	-0.0001 (0.00002)	-0.0074 (0.0021)	0.72	0.829	0.0001	2317	480	5144
p-level	0.007	0.010	0.011	0.012					
South - inside Southern region (PFMA 17-20,28)	0.445 (0.235)	-0.0003 (0.0001)	-0.0020 (0.0028)	0.49	0.445	0.0003	871	97	876
p-level	0.10	0.05	0.50	0.097					

Table 7. Legal-sized ( $\geq 55$  mm test diameter) green sea urchin biomass (estimated from surveys), change in biomass between fall and early spring, total effort during the fishing season (diver hours), removals by the fishery during the fishing season (from harvest logbooks), and exploitation rates for fishing seasons 1995, 1996, 1997 at Stephenson Islets, PFMA 12, eastern Queen Charlotte Sound.

<b>Survey</b>	<b>Legal-sized Biomass (kg)</b>	<b>Standard Error of Biomass (kg)</b>	<b>Change in Biomass (kg)</b>	<b>Effort (diver hrs)</b>	<b>Fishery Removals (kg)</b>	<b>Exploitation Rate (%)</b>
October 1995	55980	11378	7282	86	6209	11
March 1996	48698	11833				
November 1996	43691	9102	10013	118	9715	22
February 1997	33679	5917				
November 1997	38685	7282	-4551	131	11167	29
March 1998	43236	9557				
November 1998	70088	21846				
Means	47722			112	9030	21

Table 8. Calculations of quota recommendations for green sea urchins in South Coast management areas. The ranges of quotas recommended for the 1999-2000 fishing season are in boldface.

		Pacific Fishery Management Area - East Coast Vancouver Island												
		11	12	13	14	15	16	17	18	19	20	28	29	Total
MSY (t)		19.2	302.4	158.4				5.5	39.3	34.1	15.2	2.8		576.9
Precautionary reduction MSY (t)	0.5 *	9.6	151.2	79.2				2.8	19.7	17.1	7.6	1.4		288.6
Precautionary reduction 0.35*MSY (t)		6.7	105.8	55.4				1.9	13.8	11.9	5.3	1		201.8
Precautionary reduction 0.25*MSY (t)		4.8	75.6	39.6				1.4	9.8	8.5	3.8	0.7		144.2



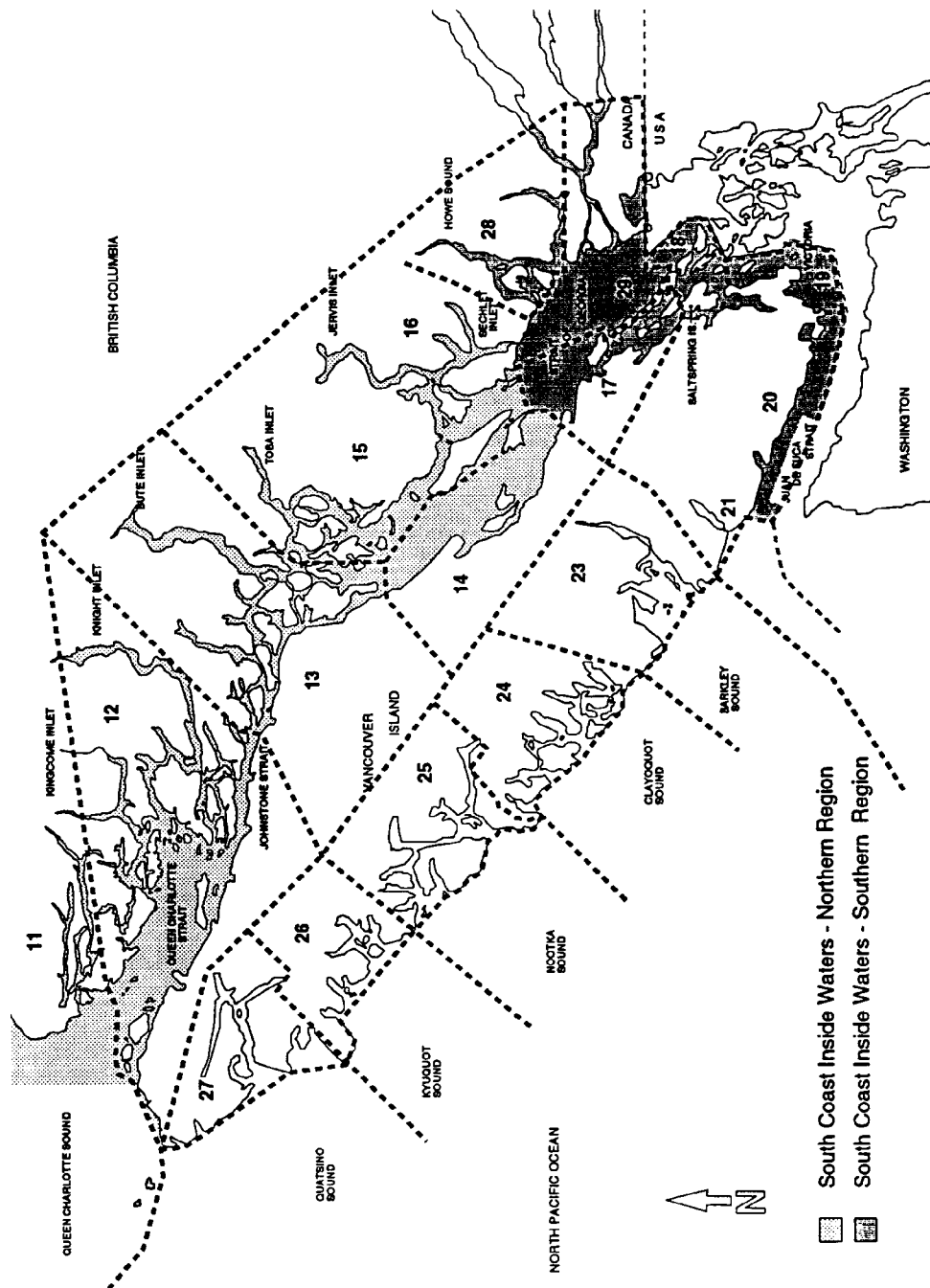


Fig. 1. Pacific Fishery Management Areas for the South Coast of British Columbia, with green sea urchin regions indicated.

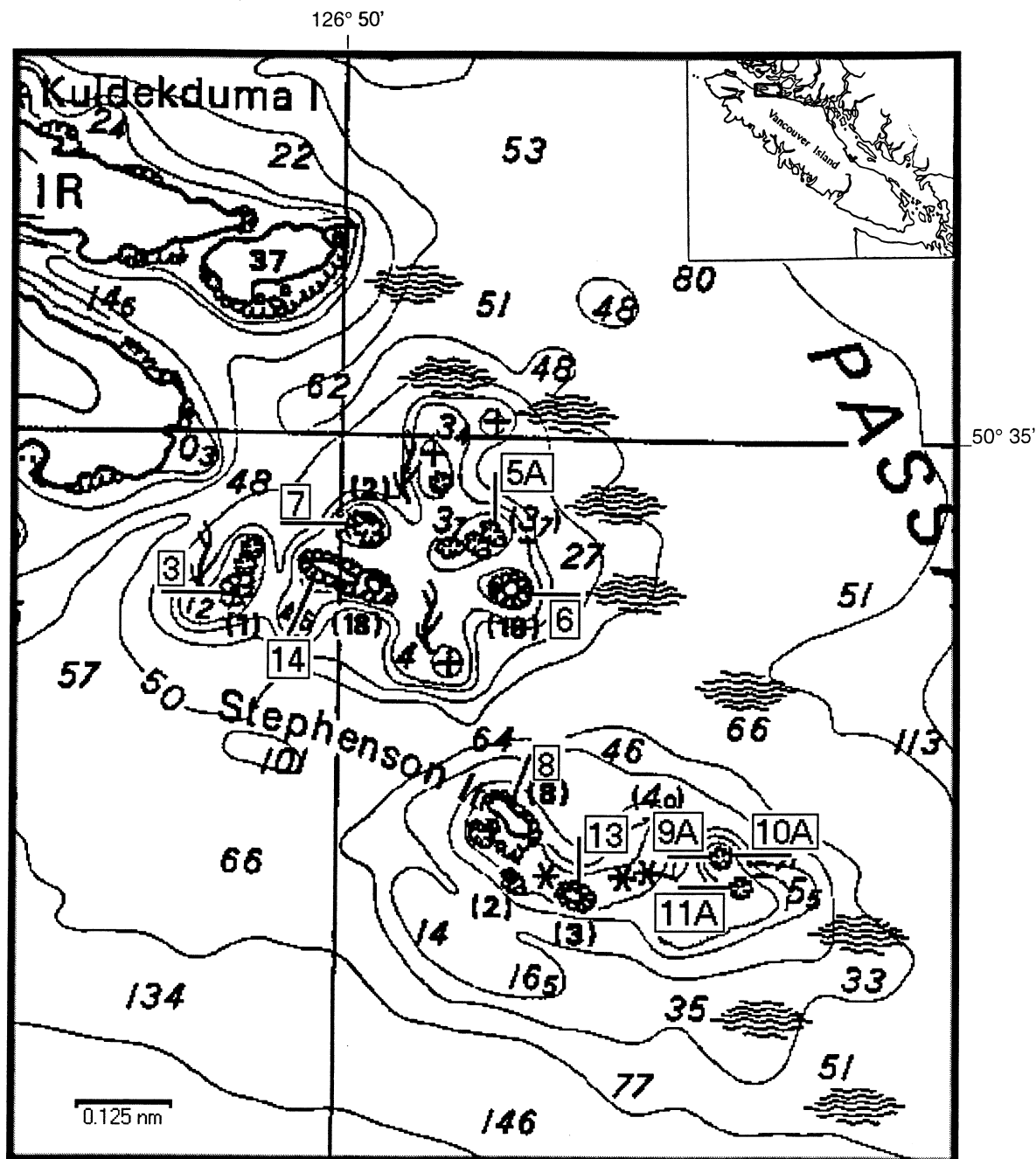


Fig. 2a. Stephenson Islets location of the fishery-independent surveys conducted at the beginning and end of each fishing season from October 1995 to November 1998, eastern Queen Charlotte Strait, B.C.



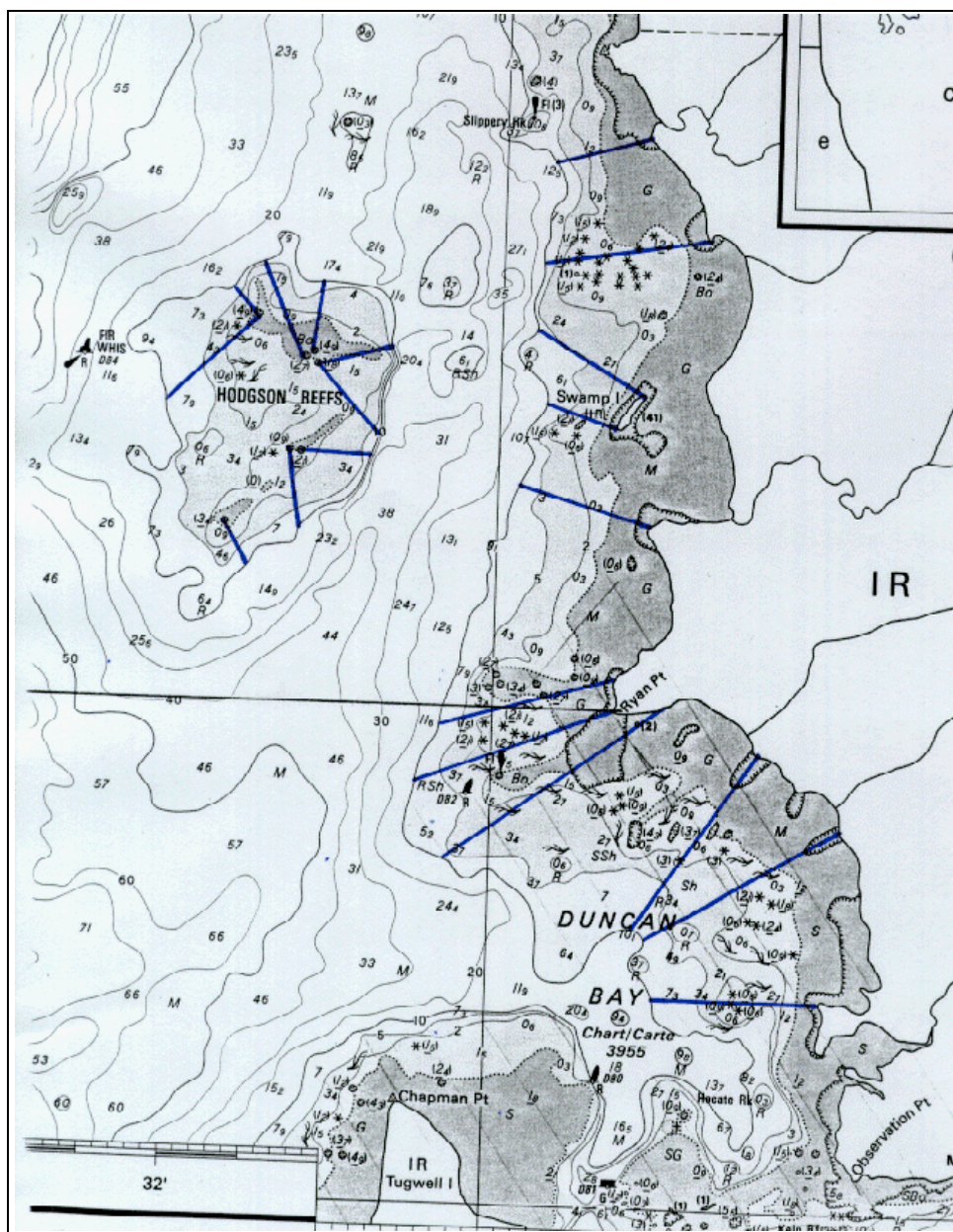


Fig. 3. Locations of the fishery-independent surveys conducted in May and June 1998 in Pacific Fisheries Management Area 4, on the North Coast of B.C. Offshore location is Hodgson Reef.

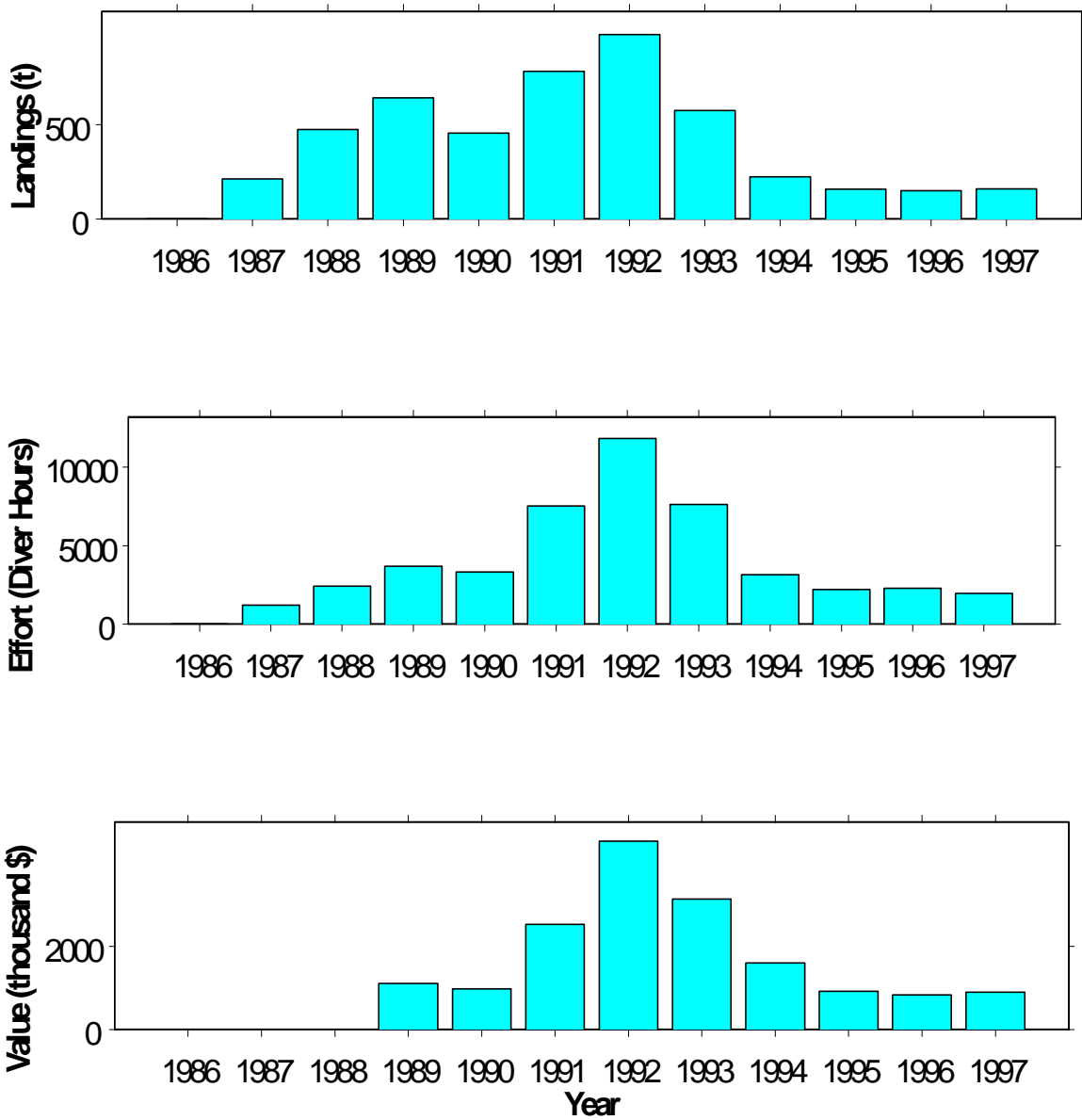


Fig. 4. (Top) Landings (from sales slip data up to 1995, then from harvest and validation logs); (Middle) derived total effort (text equation 1); and (Bottom) landed value for the green sea urchin fishery in B.C. Data are presented on the basis of a fishing season (October of year  $i$  to March of year  $i+1$ ).

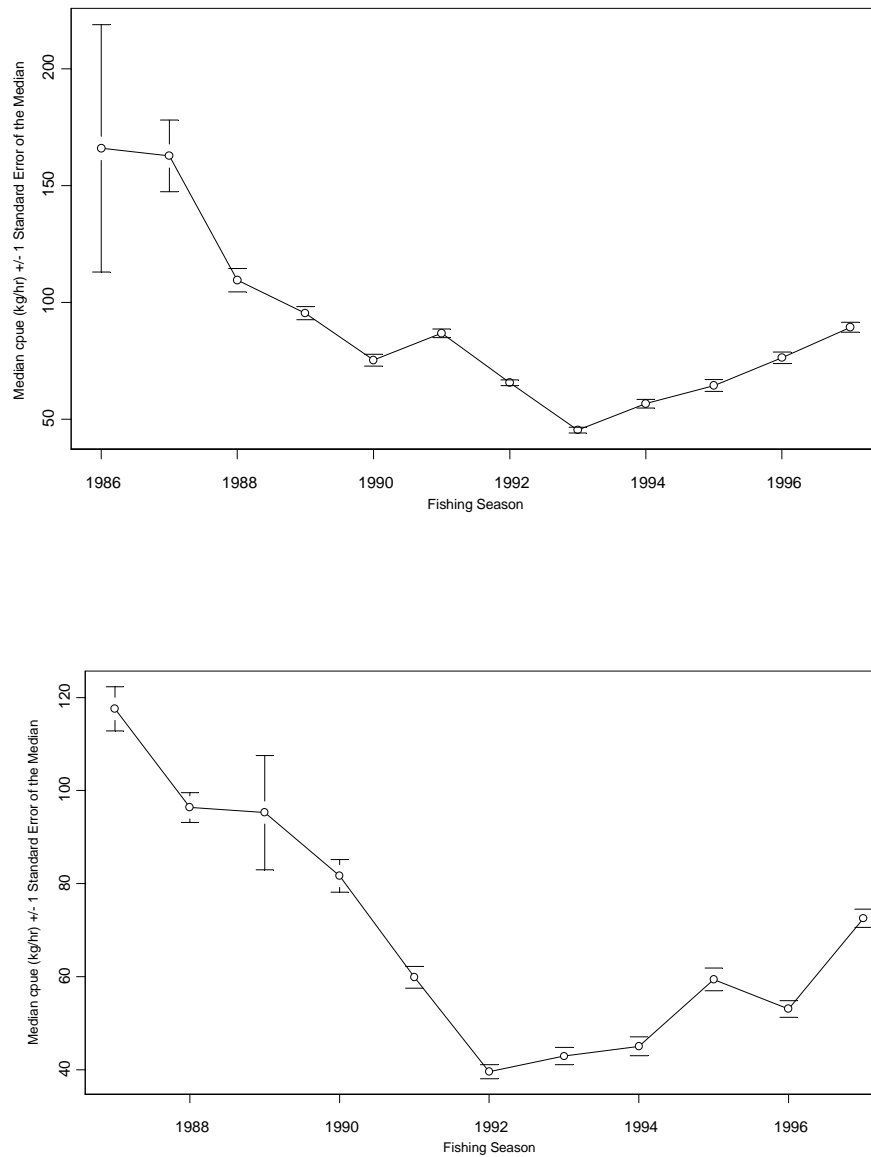


Fig. 5. Median catch per unit of effort  $\pm$  1 standard error (kg/diver hour) on a fishing season basis for the green urchin fishery in B.C.. Top: South Coast - inside waters northern component (PFMA 11, 12, 13); Bottom: South Coast - inside water southern component (PFMA 17-20,28).

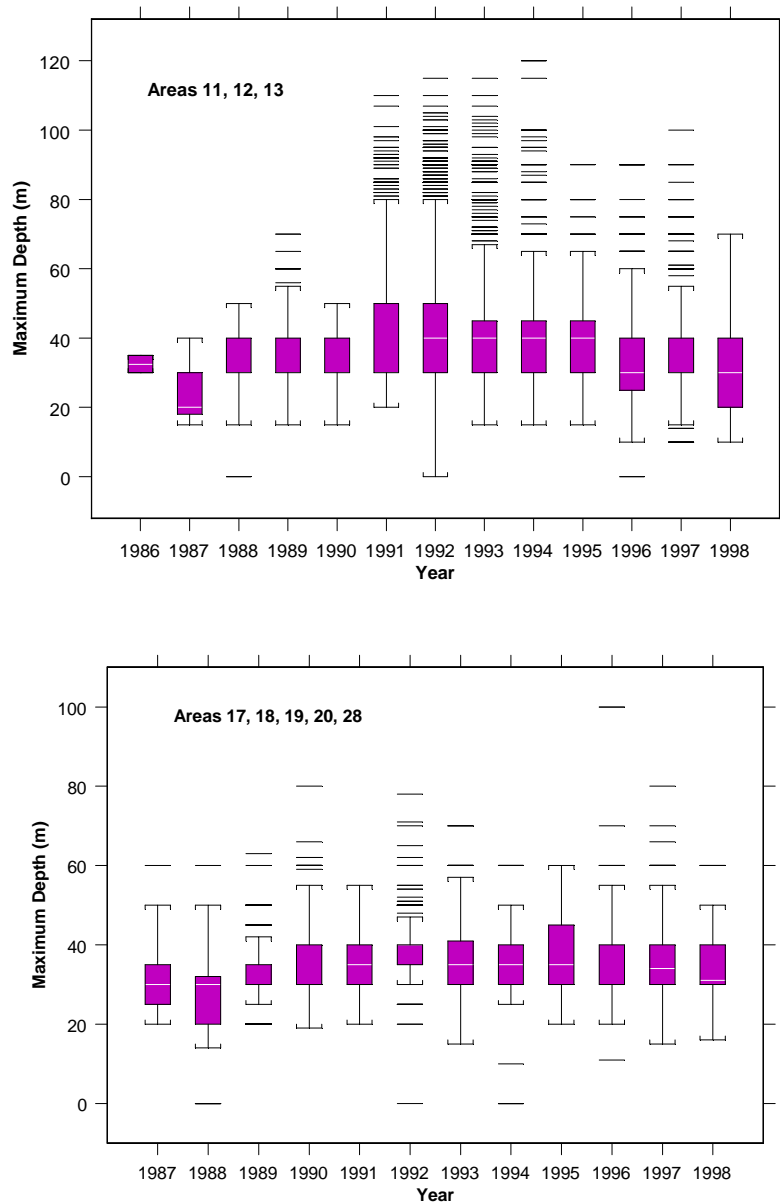


Fig. 6. Box and whisker plots of maximum depths fished as recorded in harvest logbooks. White bar within box is the median, the upper and lower box edges define the 75<sup>th</sup> and 25<sup>th</sup> percentiles (interquartile distance), the whiskers represent values that fall within 1.5 times the interquartile distance, and separate lines represent outliers.

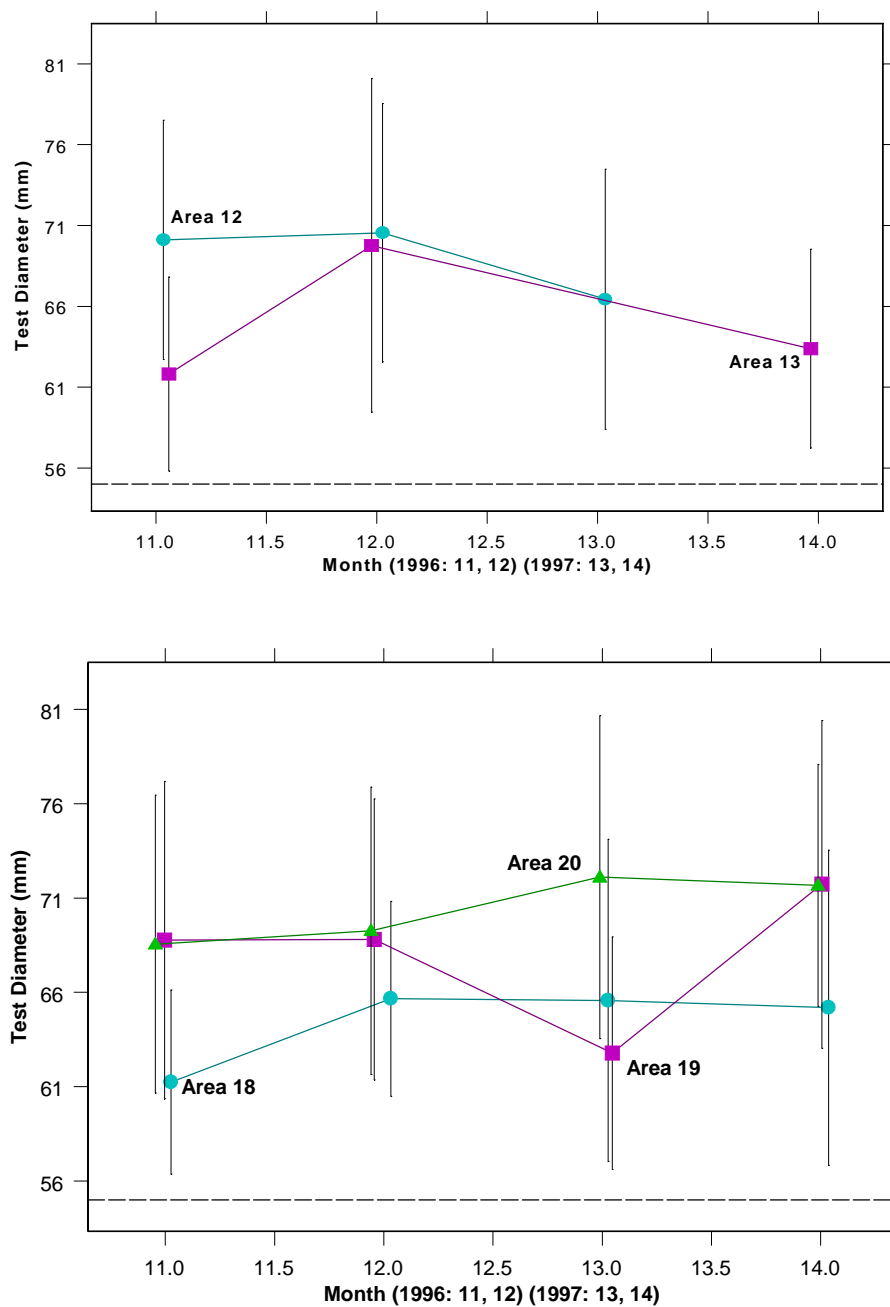


Fig. 7. Means and standard deviations of test diameters measured from commercial fishery landings, by PFM Area and month for the 1996 fishing season (November, December 1996; January, February 1997). Dashed line indicates the minimum legal size of 55 mm.



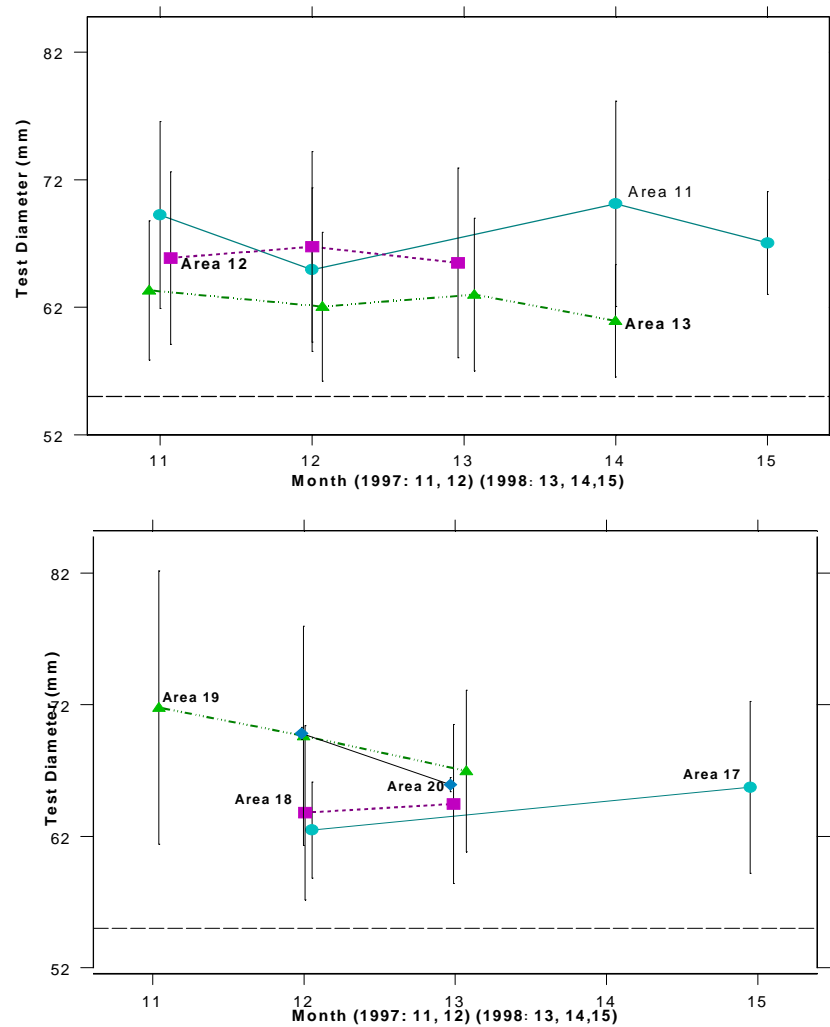


Fig. 8. Means and standard deviations of test diameters measured from commercial fishery landings, by PFM Area and month for the 1997 fishing season (November, December 1997; January, February, March 1998). Dashed line indicates the minimum legal size of 55 mm.

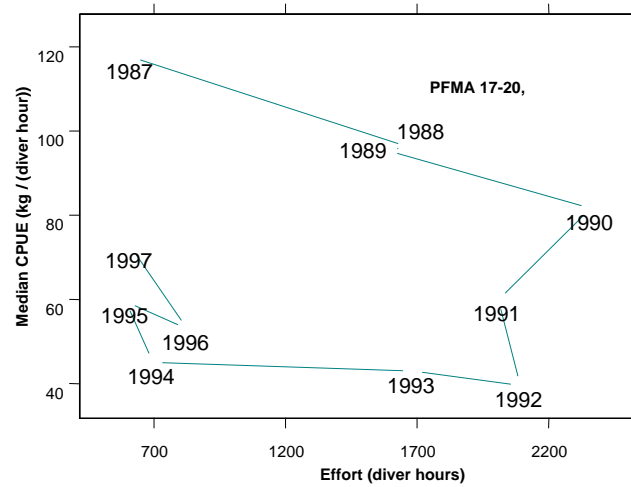
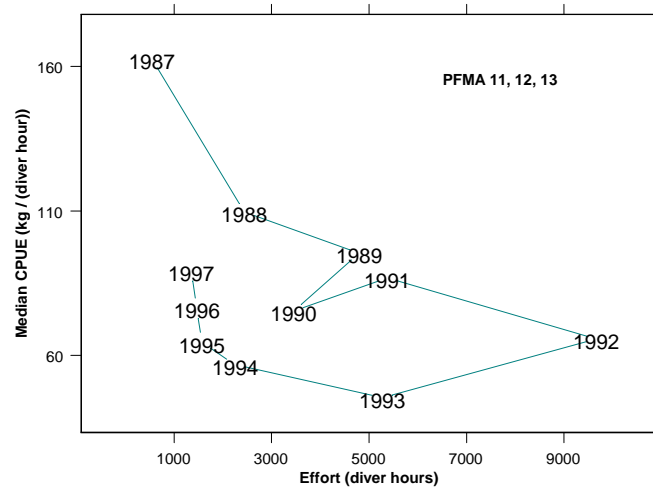


Fig. 9. Trajectories of catch per unit of effort *versus* effort for the South Coast - northern (Top) and southern (Bottom) regions. Fishing seasons are indicated.

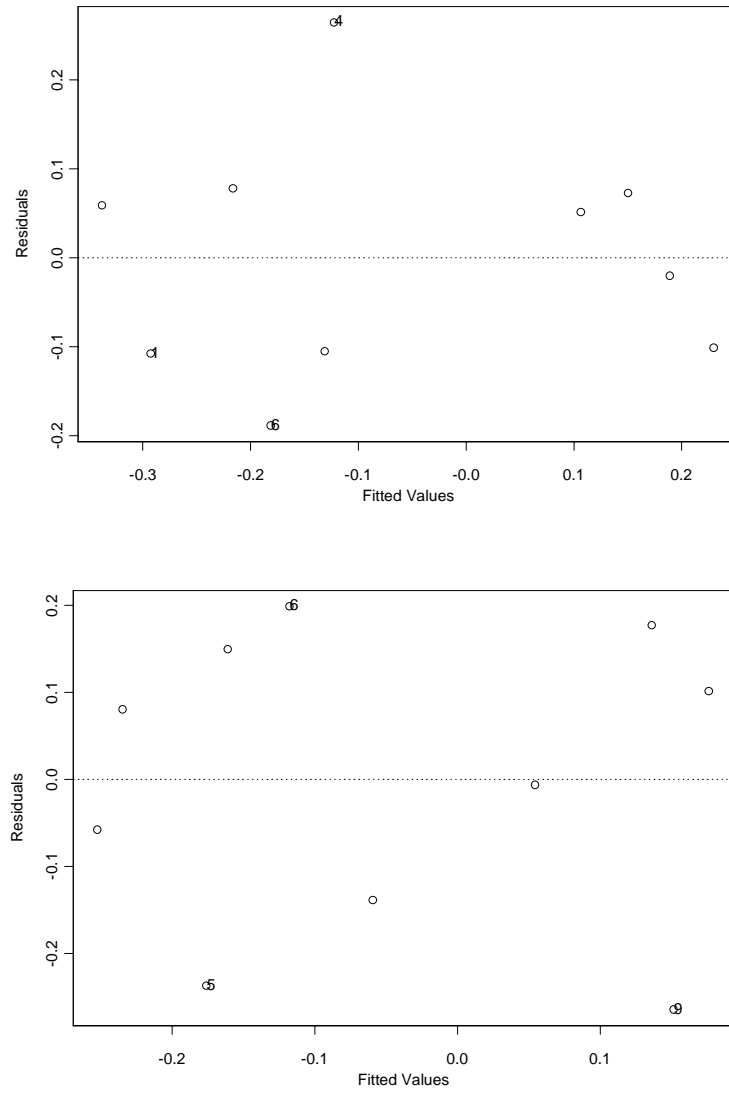


Fig. 10. Plots of residuals versus fitted values for the two biomass dynamic models. Top: Areas 11-13; Bottom: Areas 17-20, 28. Number next to symbols identify outliers, coded by consecutive fishing season, with 1 equal to 1988.

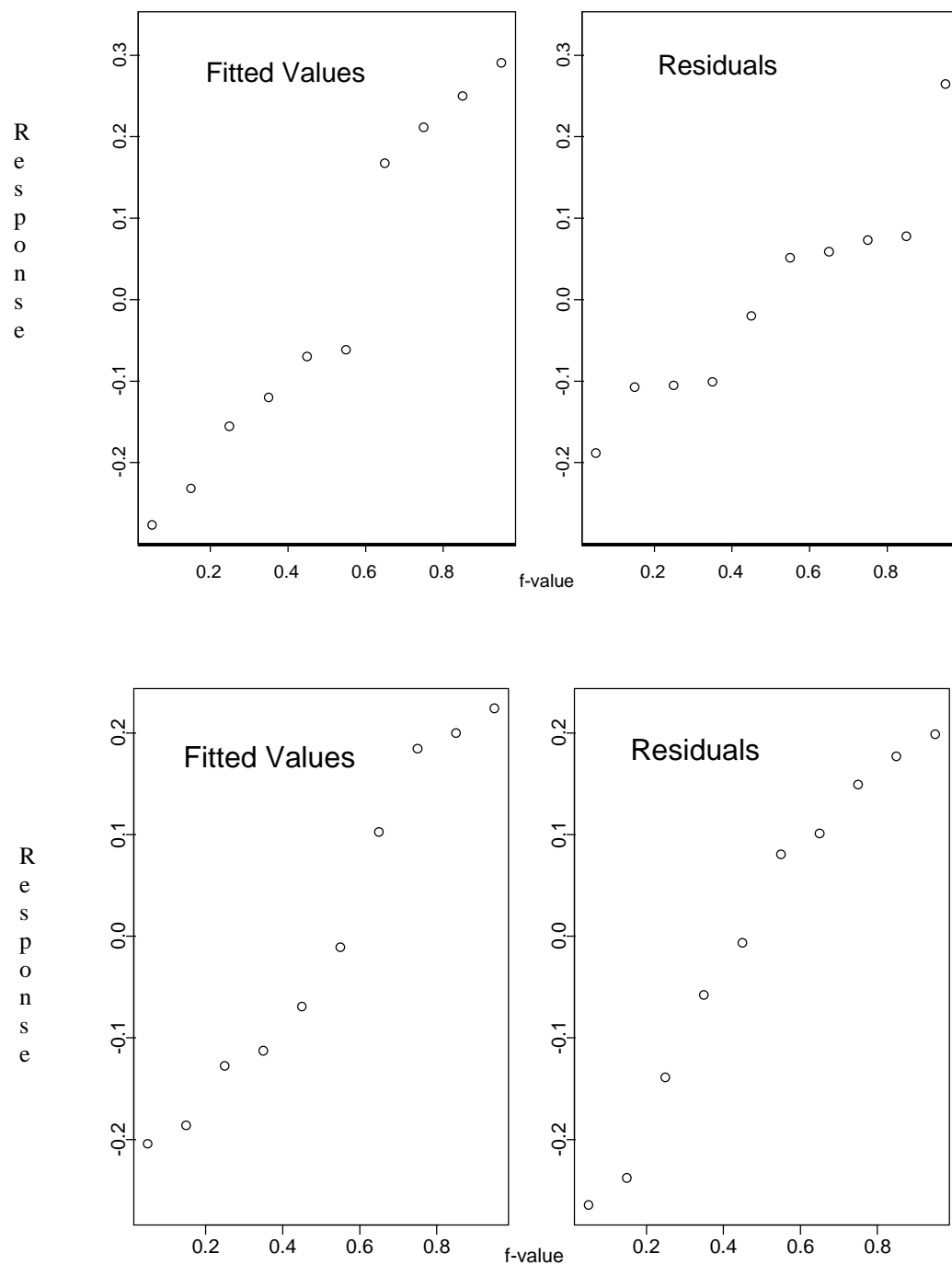


Fig. 11. Plots of the biomass dynamic model fitted values and residuals versus the response variable (log of CPUE ratio between two time periods - see Equation 4). Top: model for Areas 11-13; bottom: model for Areas 17-20, 28.

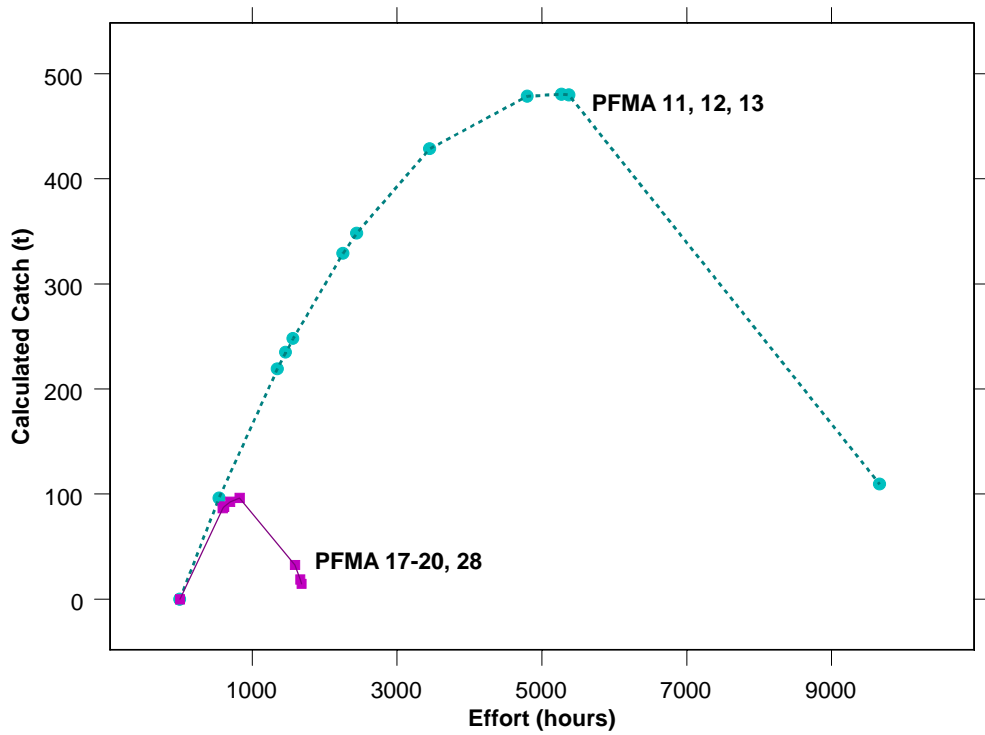


Fig. 12. Predicted Schaeffer model (text equation 5) for the biomass dynamic production model for the South Coast - inside waters northern region (PFMA 11-13) and southern region (PFMA 17-20, 28). Peak of the dome for each model represents the estimated MSY and effort at MSY.

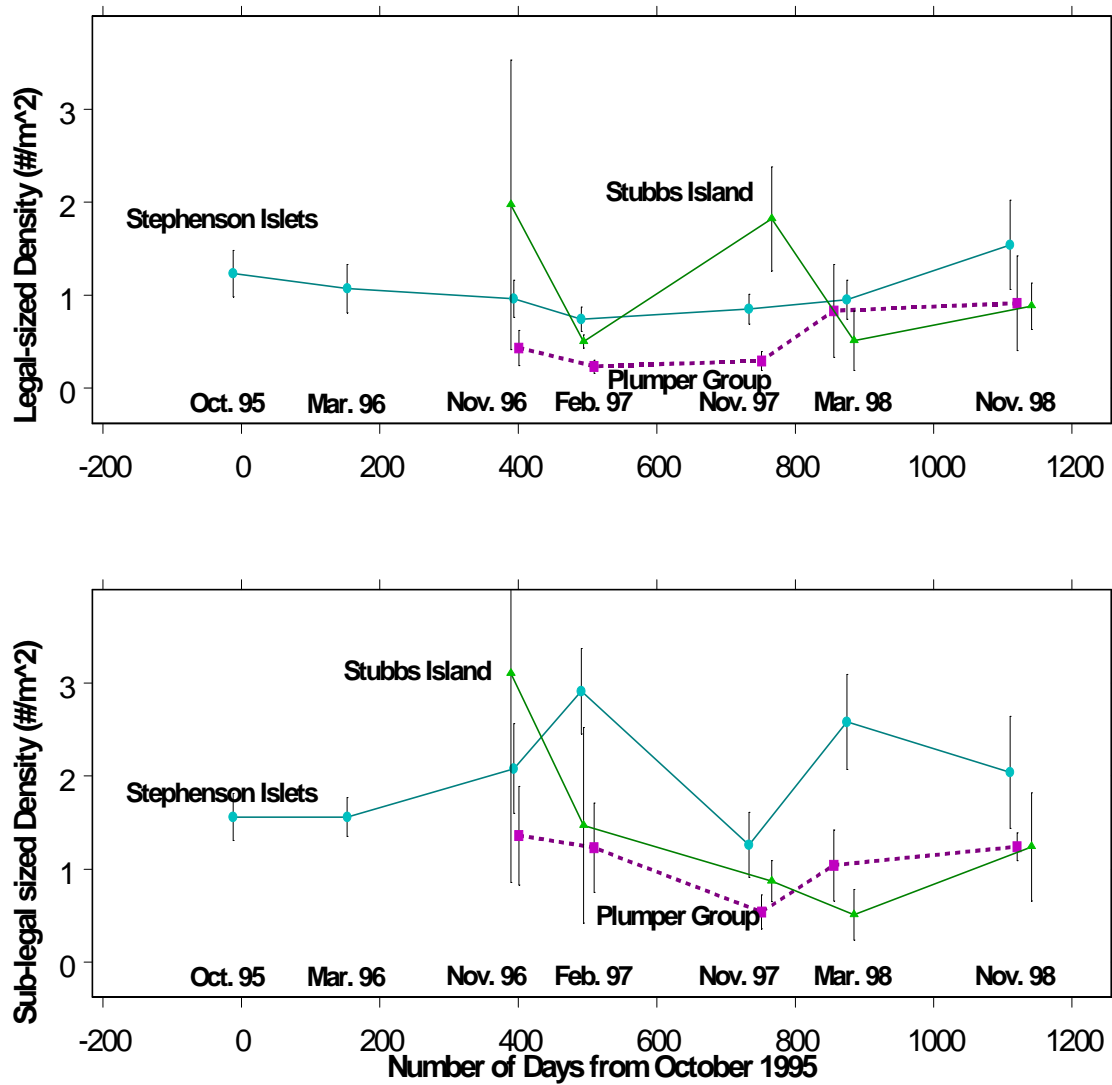


Fig. 13. Mean ( $\pm 1$  standard error) densities of green sea urchins, as sampled on surveys at Stephenson Islets, Stubbs Island, and the Plumper Group from October 1995 to November 1998. Top: legal-sized ( $\geq 55$  mm) densities; Bottom: sub-legal sized densities.