Kelp Inventory, 1989

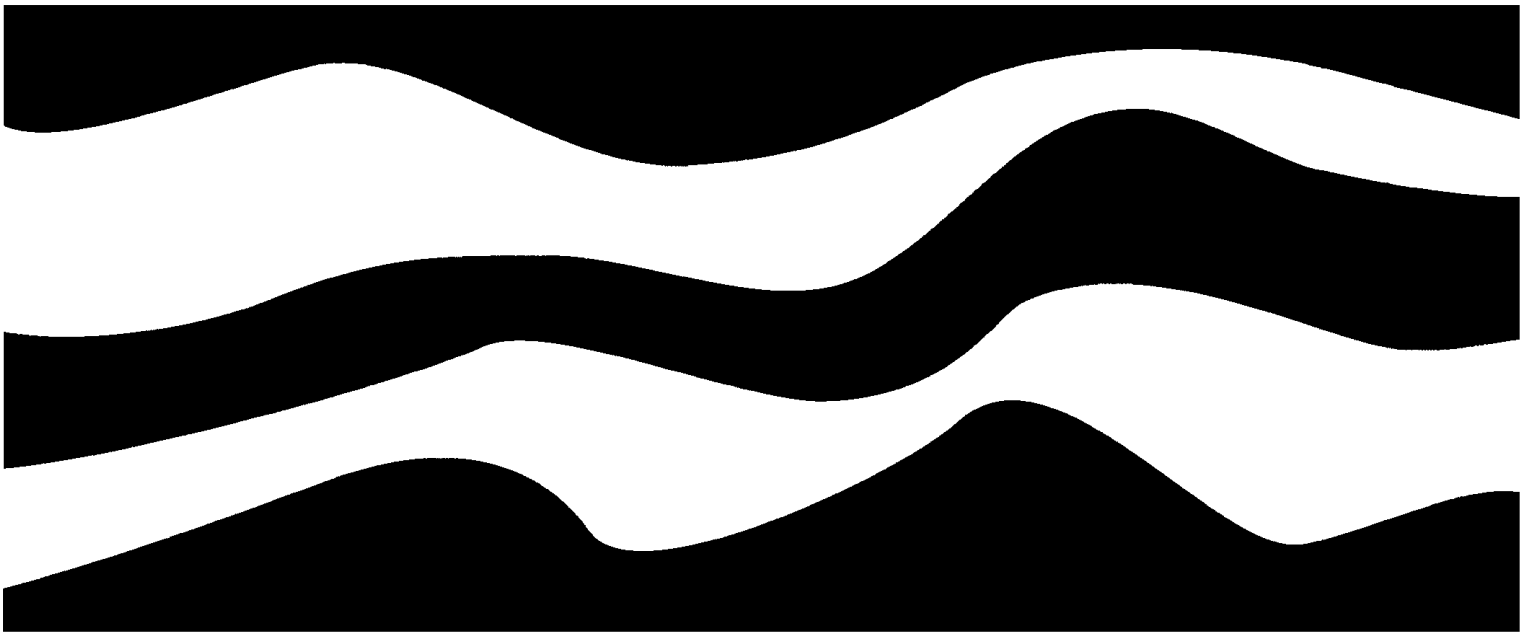
The Vancouver Island and Malcolm Island Shores of Queen Charlotte Strait

Including a summary of historical inventory information for the area

IEC Collaborative Marine Research and Development Ltd.

BRITISH COLUMBIA

Ministry of Agriculture and Fisheries
Aquaculture and Commercial Fisheries Branch



KELP INVENTORY, 1989

THE VANCOUVER ISLAND AND MALCOLM ISLAND SHORES OF QUEEN CHARLOTTE STRAIT

Including a summary of historical inventory information for the area

prepared by

I. R. Sutherland
IEC Collaborative Marine Research
and Development Ltd.

Fisheries Development Report No. 36

Aquaculture and Commercial Fisheries Branch
Ministry of Agriculture and Fisheries
Province of British Columbia

March, 1990

-

ABSTRACT

A modification of the Kelp Inventory Method (KIM-1) developed by Foreman (1975) was used to estimate the total standing crop biomass and kelp bed area of *Nereocystis* luetkeana and *Macrocystis* integrifolia along the northern shore of Vancouver Island from Thomas Point eastward to the Cluxewe River and along the west and north shores of Malcolm Island for September 9, 1989. Results indicated that 20,956 tonnes of N. luetkeana, 15,656 tonnes of M. integrifolia and 1,322 tonnes of N. luetkeana and M. integrifolia in mixed beds were present. Total bed surface areas of N. luetkeana, M. integrifolia and mixed beds were estimated to be 271.9, 467.3 and 21.7 hectares, respectively. Three charts are presented which show the position, extent, species, and density of every discernable kelp bed within the survey area. For management purposes the area is divided into permanent, numbered, kilometer wide blocks.

Results of the present inventory are compared with historical inventory estimates in Part 2 of the report. Information on bed area, biomass and species composition over a 15 year period are presented in tabular and chart formats and discussed.

-

ACKNOWLEDGEMENTS

The author wishes to thank Michael Coon, Bob Cox, Ted Pobran and Ken Albrecht, of the Ministry of Agriculture and Fisheries, who braved the elements to collect kelp biomass and density data. The Tidal Information Division at the Institute of Ocean Sciences provided tidal height data for the area as required. Michael Coon and Bob Cox reviewed the report and made many constructive comments. Thanks are also due to all the people through the years who worked long hours in all kinds of weather to collect information on kelp beds in the inventory area.

-

TABLE OF CONTENTS

PART 1. Kelp Inventory 1989

INTRODUCTION

Nereocystis luetkeana (Mertens) Postels and Ruprecht and *Macrocystis* integrifolia Bory form beds along extensive portions of the British Columbia coast. In 1975 the Provincial Government undertook a program to locate and quantify the standing crop of these economically important kelps using the inventory method (KIM-1) developed by Foreman (1975). Since that time major kelp stocks have been inventoried throughout the province (Coon, 1981. Coon et al., 1977, 1979, 1980, 1981, 1982. Field et al., 1975, 1977, 1978. Sutherland, 1989).

This report contains the results of a 1989 survey of the Vancouver Island and Malcolm Island shorelines of Queen Charlotte Strait (Figure 1) by the Aquaculture and Commercial Fisheries Branch of the Ministry of Agriculture and Fisheries. The Ministry provided field sampling data and aerial photography under contract to IEC Collaborative Marine Research and Development Ltd. for completion of the inventory.

Accurate and comprehensive data on the standing crop of kelp in British Columbia provide a basis for allocating these resources through licensing and for establishing area specific harvest quotas. Business community interest in stocks of *Nereocystis* and *Macrocystis* in the survey area resulted in the provincial government holding a public competition in 1989 for a license to harvest. Any harvests will be regulated by quotas based upon the present and subsequent inventories as well as upon results of harvest studies carried out by the Province between 1978 and 1982.

Comprehensive assessments of harvesting impacts are planned in conjunction with harvest activities. Kelp beds are important to other marine species, and kelp inventory charts and data will be of value to those preparing environmental impact statements, or conducting surveys of herring spawn, abalone and sea urchins (Coon, 1977).

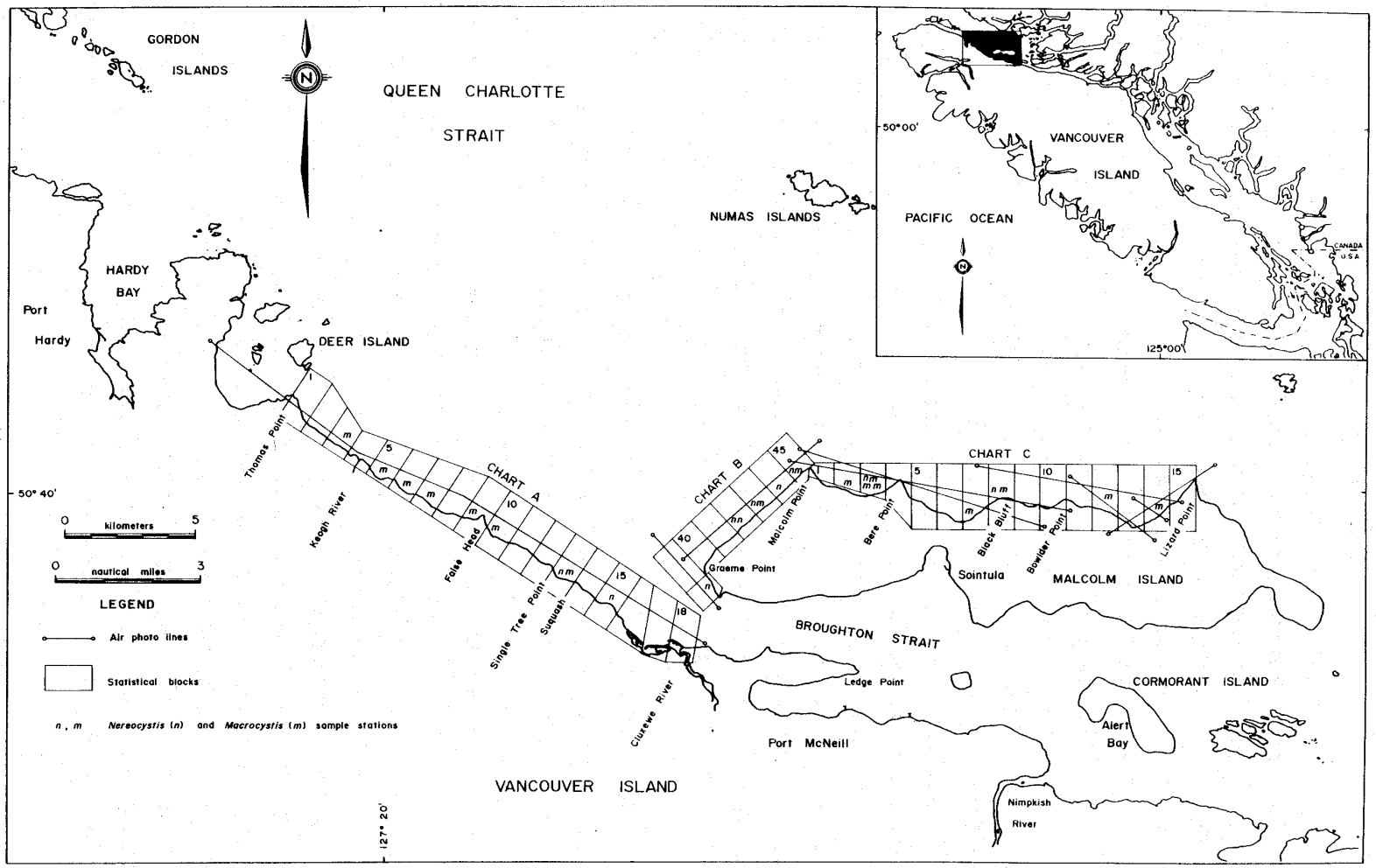


Figure 1. Southern Queen Charlotte Strait, showing the areas of Vancouver Island and Malcolm Island inventoried for floating kelp resources and the division of the area into inventory charts (see Appendix). Also included are the layout of statistical blocks, aerial photographic flight lines and locations of biomass sampling stations.

METHODS

The standing crop biomass and kelp bed areas of *Nereocystis* and *Macrocystis* were estimated by a modification of the kelp inventory method (KIM-1) developed by Foreman (1975). While the basis of the KIM-1 method has remained the same, certain steps have changed through time to improve accuracy. Modifications of this method as stated by Coon et al. (1977), Field et al. (1977) and Sutherland (1989) were used in this study. A further change was introduced in this inventory with the estimation of *Macrocystis* bed density from field transect counts as described below.

Briefly the KIM-1 technique involves obtaining 24 cm. format, 1:7,200 scale, black and white, infrared (IR) aerial photography of the kelp bed and shoreline in the desired region. The black and white IR negatives are used to prepare charts of the coastline and offshore kelp beds. On these charts, the survey area is divided into 1 kilometer wide statistical blocks. Bed areas for each of the six bed types described below are determined for each block.

The KIM-1 technique identifies six bed types on the basis of:

a) species - *Macrocystis* or *Nereocystis* or mixed (42% *Nereocystis* and 58% *Macrocystis*; Foreman, 1975); and

b) plant or frond density - low density (less than 10 plants or fronds per 10 square meters) or high (greater than 10 plants or fronds per 10 square meters).

Note: *Macrocystis* density determined from field transects suggests that the actual density of fronds is higher than predicted by the KIM-1 technique. It follows that the division to high and low density *Macrocystis* beds is at a higher level than 10 fronds per 10 square meters. While *Macrocystis* density values determined from field transects were applied to all *Macrocystis* areas, high and low density beds have been kept separate on the chartwork and in area measurements, to allow comparison with previous inventories.

Field crews obtain samples of kelp from the area for mean weight per plant (*Nereocystis*) or frond (*Macrocystis*) determination, near the time that the beds are photographed. Prior to work at Porcher Island in 1981 (Coon, 1981), vertical biomass distribution data for *Nereocystis* was used to produce estimates of biomass at various harvesting depths relative to ML. In order to minimize costly field work, the time consuming weighing of each

1 meter increment of *Nereocystis* was discontinued. A different thallus structure for *Macrocystis* allows efficient collection of this data.

Wet weight and total length were determined for each, *Nereocystis* plant sampled at 10 randomly located stations in the survey area (Figure 1; Charts A - C, Appendix). The mean biomass per plant statistic for *Nereocystis* used in subsequent calculations is derived from the mean of 10 sample station means of wet weight per plant. Vertical biomass distribution data and mean biomass per frond data were collected for *Macrocystis* at 17 randomly located sample stations in the survey area. The mean biomass per plant value reported for *Macrocystis* is also the mean of the sample station means.

The density of *Nereocystis* is determined directly from the photographs with the aid of a microscope and using the KIM-1 point-intercept method (Foreman, 1975). An updated point-intercept to density regression for *Nereocystis*, as developed by Foreman and Cabot (1979), was employed in this inventory. Length measurements merged relative to MWL were used to produce a table of cumulative percents of plants in 1 meter increments above and below MWL. These cumulative percentages were used to convert the density observed from the photography to total or bottom density (Sutherland, 1989). Calculations using data from previous inventories (Coon et al., 1977, 1979, 1980, 1981, 1982. Field et al., 1977, 1978) have shown this method produces total standing crop estimates differing from those produced using the original KIM-1 method by an average of 2 percent (SD = 3, n = 7).

Macrocystis density in this inventory has been determined in the field from counts along underwater transepts. In the KIM-1 method, *Macrocystis* density was derived using the point intercept method (Foreman, 1975) similar to that presently used for *Nereocystis*. Beginning in 1982, as a result of perceived underestimation of *Macrocystis* biomass by the KIM-1 technique, densities for this species have been estimated from counts by SCUBA divers of the numbers of fronds found within one meter on either side of randomly established 40 meter long transects on the bottom. This provides frond numbers from 80 square meter sections of the bottom at each sample station. Transects for this inventory were located at the 17 randomly determined biomass sample stations. The mean density per square meter statistic for *Macrocystis* was derived from the mean of the 17 station means.

The kelp biomass per block is determined by multiplying the mean weight per plant or frond values by the observed plant or frond densities and multiplying this product by the observed bed areas. All biomass estimates in this report are of total standing crop. Changes to

the method described above have required changes to the method of calculating mixed bed biomass. Mixed bed biomass per hectare for each kilometer block has been calculated as follows:

Mean biomass per hectare of low or high density mixed kelp	=	.42 X	mean biomass per hectare of low or high Nereo.	+	.58 X	mean biomass per hectare of Macro.

The kelp bed area and *Nereocystis* density estimates given in this report are derived from September 9, 1989 photography. Ideal conditions prevailed at the time of photography. Kelp bed areas could be seen plainly and water penetration appeared good. The tidal height at the time of photography was within the optimal range (Mean Water Level +/- .6m; Foreman,1975). All water depth and tidal height calculations were based on actual tidal measurements from Port Hardy as provided by the Federal Department of Fisheries and oceans. Port Hardy tidal height values were used directly for the Vancouver Island area while the Malcolm Island sites were converted to Alert Bay values as recommended by the Department. The tidal heights at the time of photography and at the time of depth measurements made during biomass sampling are required to relate all data to mean water level for further calculations on the distribution of biomass and density through the water column.

RESULTS

Charts A through C (Appendix) illustrate the disposition of kelp bed resources by bed type along the inventory area (Figure 1.). Coverage along Vancouver Island extends from Thomas Point to the Cluxewe River and along Malcolm Island from Pultney Point to Lizard Point. The numbering and placement of the kilometer wide statistical blocks follows a previously established system for the area. It will be noted from Chart C and Figure 1 that the near shore portions of the kelp beds between Malcolm Point and Bere Point are not represented. This is due to incomplete photographic coverage.

Table 1 presents the field-determined mean biomass per plant (wet weight) estimates obtained from means of ten *Nereocystis* and seventeen *Macrocystis* sampling stations in the inventory area. A total of 202 *Nereocystis* plants and 516 *Macrocystis* fronds were sampled at these stations September 9 to 13, 1989.

Table 1: *Nereocystis* mean biomass per plant and *Macrocystis* mean biomass per frond estimates from September 9,10,11,12 and 13, 1989 field samples as used to calculate biomass estimates for the 1989 Vancouver Island - Malcolm Island inventory area.

Nereocystis mean biomass/plant =	6.8 kg.	10 stations	SD = 2.5
Macrocystis mean biomass/frond =	.7 kg.	17 stations	SD = .3

Table 2: Cumulative percent of plants present at one meter increments relative to mean water (MWL) for samples of *Nereocystis* from 10 random sample stations in the Vancouver Island - Malcolm Island inventory area on September 9-13, 1989.

Meter	Mean Percent Plants at Increment (10 stations)
+5	1
+4	5
+3	14
+2	39
+1	63
MWL	89
-1	96
-2	99
-3	100
-4	100
-5	100
-6	100
-7	100

Table 3. The cumulative number, cumulative biomass and mean weight per frond at one meter increments relative to mean water level for all *Macrocystis* plants sampled in the Vancouver Island - Malcolm Island inventory area on September 9-13, 1989. Also included are the mean percent cumulative biomass present at each increment as calculated from the means of the 17 stations sampled.

Meter	Cumulative fronds	Cumulative Biomass(kg)	Mean Cumulative Biomass per frond (kg.)	Mean Percent Cumulative Biomass at increment (17 stations)
+8	1	.1	.1	
+7	4	.5	.1	
+6	5	1.6	.3	
+5	12	4.5	.4	1
+4	25	11.3	.5	2
+3	71	28.6	.4	6
+2	117	57.0	.5	13
+1	168	102.4	.6	25
MWL	209	159.6	.8	41
-1	276	218.0	.8	58
-2	324	268.5	.8	73
-3	398	310.6	.8	85
-4	447	339.9	.8	93
-5	485	357.8	.7	98
-6	504	365.9	.7	100
-7	516	368.4	.7	100

A summary of cumulative numbers of *Nereocystis* plants collected in the above sampling is expressed as percent of sample totals in Table 2. This table shows the vertical distribution of plant numbers in 1 meter increments above and below mean water level (MWL), and was used to calculate the density correction factor as described by Sutherland (1989).

The vertical distribution of cumulative *Macrocystis* frond biomass and numbers, the mean cumulative biomass per frond and the mean percent of cumulative biomass at 1 meter increments above and below mean water level (MWL) are shown in Table 3. The percent figures are means of 17 stations and indicate generally the percent of total standing crop biomass that would be available at each cutting height relative to mean water level.

A summary of the tide level at the time of photography and the conversion factor used to change the observed *Nereocystis* density to total (or bottom) density for each block is presented in Table 4.

Table 4: The tidal level at the time of photography and the *Nereocystis* conversion factors used to convert density values observed on the photography to total density as used in biomass calculations.

Block Nos.	Tidal Level(m)	*Nereocystis* Conversion Factor
Vancouver Is. 1-18 and Malcolm Is. 1-15, 38-45	MWL	1.12

The *Macrocystis* density value derived from the 17 transect counts performed on September 9 to 13, 1989, and used in biomass calculations is shown in Table 5.

Table 5. *Macrocystis* density value used in total standing = p estimates for the inventory area.

Mean number of fronds per square meter of *Macrocystis* bed	= 4.79	17 stations	SD = 2.41

Tables 6, 7 and 8 present estimates of kelp bed areas, density and biomass for each block in Charts A through C.

Tables 9, 10 and 11 summarize the bed area and biomass estimates, the percent biomass and the percent composition of bed area for each bed type in each chart area, respectively.

A total of 20,956 tonnes of *Nereocystis*, 15,656 tonnes of *Macrocystis* and 1,322 tonnes of mixed kelp were estimated to lie along the 41 kilometers of shoreline inventoried. The major concentrations were found to be between the Keogh River and False Head (Blocks 5-10; 6,741.9 tonnes), along the west coast of Malcolm Island (Blocks 40-44; 12,445.5 tonnes), at Black Bluff (Blocks 7 and 8; 3,090.7 tonnes) and at Lizard Point (Blocks 14 and 15; 2,984.9 tonnes). Chart area A was found to contain mainly *Macrocystis*, chart area B mainly *Nereocystis*, while area C contained quantities of both species.

Table 6. Estimates of kelp bed area MW biomass for the Vancouver Island shore of Queen Charlotte Strait: Thomas Point to the Cluxewe River. September, 1989. See Chart A (appendix).

B = Biomass (metric tonnes) ha = hectare D = Density (no. of plants or fronds/hectare)

CHART A Block	Nereocystis - Low Density					Nereocystis - High Density					Macrocystis						Mixed - Low Density			Mixed - High Density			Total	Total
	Photo. xD	Bottom xD	Area (ha)	xB/ha	B	Photo. xD	Bottom xD	Area (ha)	xB/ha	B	Bottom xD	Low D Area (ha)	High D Area (ha)	Total Area (ha)	xB/ha	B	Area (ha)	xB/ha	B	Area (ha)	xB/ha	B	Area (ha)	B
1	5,430	6,082	.67	41.4	27.7						47,900	1.12	1.75	2.87	33.5	96.1							3.54	123.9
2											47,900	2.58	10.38	12.96	33.5	434.2							12.96	434.2
3											47,900	3.59	5.75	9.34	33.5	312.9							9.34	312.9
4											47,900	11.18	1.87	13.05	33.5	437.2							13.05	437.2
5											47,900	6.74	28.97	35.71	33.5	1,196.3							35.71	1,196.3
6											47,900	5.94	32.12	38.06	33.5	1,275.0							38.06	1,275.0
7											47,900	7.25	22.93	30.18	33.5	1,011.0							30.18	1,011.0
a											47,900	7.31	20.61	27.92	33.5	935.3							27.92	935.3
9											47,900	2.01	26.52	28.53	33.5	955.8							28.53	955.8
10											47,900	19.39	21.46	40.85	33.5	1,368.5							40.85	1,368.5
11											47,900	4.26	12.39	16.65	33.5	557.8							16.65	557.8
12	5,430	6,082	2.39	41.4	98.8	25,170	28,190	.61	191.7	116.9	47,900	1.96	5.36	7.32	33.5	245.2	.88	36.8	32.4	.13	99.9	13.0	11.33	506.4
13	5,430	6,082	1.97	41.4	81.5	25,170	28,190	.91	191.7	174.4	47900	2.47	6.46	11193	33.5	299.2	.08	36.8	2.9				11.89	558.0
14	5,450	6,104	3.11	41.5	129.1	25,170	28,190	.07	191.7	13.4	47 90[)	.35	3.59	3.94	33.5	132.0							7.12	274.5
15	5,450	6,104	3.04	41.5	126.2	25,170	28,190	.37	191.7	70.9	47,900	.11	.96	1.07	33.5	35.8							4.48	233.0
16	5,450	6,104	3.52	41.5	146.1	25,170	28,190	1.21	191.7	232.0														
17																							4.73	378.1
18	5,760	6,451	1.88	43.9	82.5	25,170	28,190	.54	191.7	103.5	47,900	.4	1.77	2.17	33.5	72.7							4.59	258.7
Chart A Totals:			16.58		691.9			3.71		711.2		76.66	202.89	279.55		9,364.9	.96		35.3	.13		13.0	300.93	10,816.3

Table 7. Estimates of kelp bed area and biomass for the west shore of Malcolm Island: Pultney Point to Malcolm Point. September, 1989. See Chart B (appendix).

CHART A Block	Nereocystis - Low Density					Nereocystis - High Density					Macrocystis						Mixed - Low Density			Mixed - High Density			Total	Total
	Photo. xD	Bottom xD	Area (ha)	xB/ha	B	Photo. xD	Bottom xD	Area (ha)	xB/ha	B	Bottom xD	Low D Area (ha)	High D Area (ha)	Total Area (ha)	xB/ha	B	Area (ha)	xB/ha	B	Area (ha)	xB/ha	B	Area (ha)	B
38	5,070	5, 680	4.45	38.6	171.9	22,220	24,890	1.24	169.3	209.9												5.69	381.7	
39	5,060	5,670	2.45	38.6	94.5	22,490	25,190	.23	171.3	39.4												2.68	133.9	
39A	5,170	5,790	22.89	39.4	901.3																	22.89	901.3	
40	5,170	5,790	44.65	39.4	1,758.1	22,490	25,190	13.07	171.3	2,238.8												57.72	3,996.9	
41	5, OM	5,680	6.97	38.6	269.2	22,490	25,190	4.33	171.3	741.7	47,900	1.34	1.99	3.33	33.5	111.6							14.63	1,122.5
42	4,960	5,560	18.56	37.5	701.7	20,620	23,090	7.57	157.0	1,188.6	47,900	1.17	9.81	10.98	33.5	367.8							37.11	2,25a.1
43	4,980	5,580	13.47	37.9	511.1	23,320	26,120	12.29	177.6	2,182.9	47,900	1.47	6.78	8.25	33.5	276.4				.66	94.0	62.1	34.67	3,032.4
44	5,040	5,650	12.64	38.4	485.6	26,460	29,630	6.13	201.5	1,235.1	47,900	1.45	5.34	6.79	33.5	227.5				.84	104.1	87.4	26.40	2,035.6
45	5,520	6,180	7.31	42.0	307.2	26,460	29,630	1.12	201.5	225.7	47,900		2.74	2-74	33.5	91.8	.85	37.1	31.5	.29	104.1	30.2	12.31	656.3
Chart B Totals:			133.39		5,200.6			45.98		8,062.0		5.43	26.66	32.09		1,075.0	.85		31.5	1.79		179.6	214.10	14,548.7

Table 8. Estimates of kelp bed area and biomass for the north shore of Malcolm Island: Malcolm Point to Lizard Point. September, 1989. See Chart C (appendix).

B = Biomass (metric tonnes) ha = hectare D = Density (no. of plants or fronds/hectare)

CHART A Block	Nereocystis - Low Density					Nereocystis - High Density					Macrocystis						Mixed - Low Density			Mixed - High Density			Total	Total
	Photo. xD	Bottom xD	Area (ha)	xB/ha	B	Photo. xD	Bottom xD	Area (ha)	xB/ha	B	Bottom xD	Low D Area (ha)	High D Area (ha)	Total Area (ha)	xB/ha	B	Area (ha)	xB/ha	B	Area (ha)	xB/ha	B	Area (ha)	B
1						26,500	29,680	1.74	201.8	351.2	47,900	3.97	3.98	7.95	33.5	266.3	.32	40.1	12.8	.9	104.2	93.8	10.91	724.1
2						26,500	29,680	1.59	201.8	320.9	47,900	3.69	8.88	12.57	33.5	421.1	.08	40.1	3.2	.02	104.2	2.1	14.26	747.3
3	6,470	7,250	5.21	49.3	256.9	26,500	29,680	3.59	201.8	724.5	47,900	2.58	7.09	9.67	33.5	323.9	.59	40.1	23.7	1.54	104.2	191.7	20.90	1,520.7
4	6,430	7,200	2.53	49.0	123.9	26,500	29,680	1.38	201.8	278.5	47,900	.16	.21	.37	33.5	12.4				.28	104.2	29.2	4.56	444.0
5											47,900	6.19	2.46	5.65	33.5	289.8	.9	40.0	36.0	.2	80.7	16.1	9.75	341.9
6											47,900	3.47	7.34	10.91	33.5	362.1							10.81	362.1
7	6,430	7,200	2.58	49.0	126.3	26,500	29,680	1.89	201.8	381.4	47,900	5.58	14.01	19.59	33.5	656.3	.24	40.0	9.6	.25	80.7	20.2	24.55	1,193.8
8	6,430	7,200	6.91	49.0	338.3	26,500	29,680	5.98	201.8	1,206.9	47,900	.94	5.77	6.71	33.5	224.8	.23	40.0	9.2	1.13	104.2	117.7	20.96	1,896.9
9						26,500	29,600	1.11	201.8	224.0	47,900	5.76	6.52	12.28	33.5	411.4							13.39	635.4
10	6,490	7,270	.84	49.4	41.5	24,230	27,140	1.34	184.6	247.3	47,900	1.33	8.04	9.37	33.5	313.9	3.5	40.2	140.7	.88	80.7	71.0	15.93	814.4
11											47,900	7.74	8.78	16.52	33.5	553.4							16.52	553.4
12											47,900	3.6	6.42	10.02	33.5	335.7							10.02	335.7
13											47,900	.18	.24	.42	33.5	14.1							.42	14.1
14	5,800	6,500	13.70	44.2	605.5						47,900	9.25	18.8	28.05	33.5	939.7	5.62	38.0	213.5	.78	80.7	62.9	48.15	1,821.7
15	5,210	5,830	20.54	39.6	814.3	24,230	27,140	1.35	184.6	249.1	47,900	1.62	1.09	2.71	33.5	90.8	.25	36.1	9.0				24.85	1,163.2
Chart C Totals:			52.31		2,306.7			19.97		3,984.0		56.06	99.63	155.69		5,215.6	11.73		457.8	6.28		604.8	245.98	12,568.8

Table 9: Summary of biomass and kelp bed area estimates by chart area (see Figure 1) and bed type for the 1989 Vancouver Island - Malcolm Island inventory area.

Chart	Geographic area	Biomass (metric tonnes)	Area (hectares)
	Low Density *Nereocystis*		
A	Thomas Point to the Cluxewe River	692	16.6
B	Pultney Point to Malcolm Point	5,201	133.4
C	Malcolm Point to Lizard Point	2,307	52.3
	High Density *Nereocystis*		
A	Thomas Point to the Cluxewe River	711	3.7
B	Pultney Point to Malcolm Point	8,062	46.0
C	Malcolm Point to Lizard Point	3,984	20.0
	Low and High Density *Macrocystis*		
A	Thomas Point to the Cluxewe River	9,365	279.6
B	Pultney Point to Malcolm Point	1,075	32.1
C	Malcolm Point to Lizard Point	5,216	155.7
	Low Density Mixed		
A	Thomas Point to the Cluxewe River	35	1.0
B	Pultney Point to Malcolm Point	32	.9
C	Malcolm Point to Lizard Point	458	11.7
	High Density Mixed		
A	Thomas Point to the Cluxewe River	13	.1
B	Pultney Point to Malcolm Point	180	1.8
C	Malcolm Point to Lizard Point	605	6.3
	Totals by species		
	Nereocystis	20,956	271.9
	Macrocystis	15,656	467.3
	Mixed	1,322	21.7
	Totals by chart area		
	Chart A	10,816	300.9
	Chart B	14,549	214.1
	Chart C	12,569	246.0
	Total of all species for entire inventory area	37,934	761.0

Table 10: Percent composition of low and high density *Macrocystis* and mixed bed total biomass in each chart area. The last column gives percent composition of the total biomass for the entire 1989 Vancouver Island - Malcolm Island inventory area.

Chart:	A	B	C	Combined
Nereocystis				
-low density	6.4%	35.7%	18.4%	21.6%
-high density	6.6%	55.4%	31.7%	33.6%
Macrocystis				
-high and low	86.6%	7.4%	41.5%	41.3%
Mixed				
- low density	.3%	.2%	3.6%	1.4%
-high density	.1%	1.3%	4.8%	2.1%

Table 11: Percent composition of low and high density *Nereocystis*, *Macrocystis* and mixed bed estimates of surface area in each chart area. The last column gives percent composition of bed area for the entire 1989 Vancouver Island - Malcolm Island inventory area.

Chart:	A	B	C	Combined
Nereocystis				
-low density	5.5%	62.3%	21.3%	26.6%
-high density	1.2%	21.5%	8.0%	9.1%
Macrocystis				
-low density	25.6%	2.5%	22.8%	18.2%
-high density	67.4%	12.5%	40.5%	43.3%
Mixed				
-low density	.3%	.4%	4.8%	1.7%
-high density	.0%	.8%	2.6%	1.1%

DISCUSSION

Large kelp beds are found throughout the inventory area. Area B, with the shortest shoreline length, contained the largest portion of the inventory area's biomass (38%) and the lowest surface area (28%). Area A had the largest kelp bed surface area (40%) and the lowest biomass (29%). This situation is possible because of the proportion of *Nereocystis* to *Macrocystis* in these areas. *Macrocystis* beds have a mean biomass per square meter of 3.35 kg. Over the entire inventory area, low density *Nereocystis* averages 4.05 kg. while high density *Nereocystis* averages 18.30 kg. Area A is composed mainly (87% of Area A's biomass and 93% of its bed area) of *Macrocystis* while Area B has large areas of *Nereocystis* (91% of Area B's biomass and 84% of its area). Area C contained 33% of the inventory area's biomass and 32% of its surface area. It is composed of more similar quantities of both species, contains the most irregular bed areas and also the majority of the mixed kelp beds in the inventory area.

Biomass estimates contained in the present inventory are higher than indicated in previous work in the area (refer to Part 2). Increases in, *Nereocystis* estimates can be largely attributed to the high mean biomass per plant value of 6.8 kg. This exceeds previous values for the area as well as for all other reported inventory areas in the province. The *Macrocystis* density values resulting fruit the underwater transect counts are also higher than in previous work in the area. This results in a higher total standing crop estimate.

Prior to 1989, inventory results were reported as biomass above mean water level. Changes to techniques noted in the method, and the requirement for total standing crop information for harvest quota determination have resulted in the reporting of total standing crop biomass. Total standing crop biomass is always higher than the biomass above mean water level for these species and care should be used when comparing estimates from past inventory work.

Further information on the inventory area is contained in Part 2 of this report.

PART 2. Historical Summary of Inventory Information for the Area

INTRODUCTION

The coastal upland in the vicinity of the inventory area is in general of low relief and slopes gradually into the waters of Queen Charlotte Strait to form extensive nearshore shallows. Sand, mud, pebble, boulder and bedrock substrates are found to varying extents through the depth range suitable for the formation of *Nereocystis* and *Macrocystis* beds (generally the 0 meter tide level to the -10 meter tide level). In the inventory area, substrate suitability appears to be an important factor governing the presence and aerial extent of kelp beds.

Biophysical factors such as substrate suitability, available light, species growth patterns, storm events, temperature, salinity and nutrient character of the surrounding water, presence of grazers, degree of exposure to waves, etc. influence the presence and character of floating kelp stocks. Kelp bed area, species composition, density, plant or frond length, weight, character and distribution through the water column undergo changes throughout the year and between years.

Studies centering on the floating kelps N. luetkeana and M. integrifolia have taken place since 1974 in the area covered by the present inventory. Research efforts were funded by the Province; Provincial staff studied *Macrocystis* (Coon, 1982), and Dr. R.E. Foreman of the University of British Columbia studied *Nereocystis* (Foreman, 1984). The main study area for *Macrocystis* was located along the Vancouver Island shore of the inventory area (primarily Blocks 6 9, Chart A) while *Nereocystis* was studied along the western shore of Malcolm Island (primarily Blocks 40 - 45, Chart B).

Several estimates of the kelp stock biomass and bed area were made in the inventory area between 1974 and 1989. This part of the report describes some of these results from reports by Foreman (1974, 1982, 1984) and Coon (1983) and unpublished data from the Province. Investigations to determine biophysical reasons for increases or declines in estimates are beyond the scope of this report.

Seasonal variation in kelp biomass is significant but is not described in this report. The August/September time period is employed primarily to represent the period of maximum *Nereocystis* biomass.

Prior to 1989, kelp biomass was reported as biomass above mean water level (MWL). In order to standardize the values for this report and standardize comparisons as much as

possible, ML biomass values have been changed to total biomass, where applicable, through the use of combined biomass and density correction factors (Coon et al, 1976 and Foreman, 1975). Correction factors appropriate for each data set have been used except for the 1978 and 1980 *Macrocystis* and mixed biomass values for Chart Area B, where 1974 values for the area were used. Correction factors used are shown in Table 12.

Table 12. Combined biomass and density factors used to correct mean water level biomass to total standing crop biomass.

Area	Month/Year	*Nereo*	Source	*Macro.*	Source	Mixed	Source
Vancouver Island	Aug./74	1.10	(Foreman, 1982)	2.82	(Foreman, 1975)	2.03	(Foreman, 1975)
	Sep./78	1.24	(Foreman, 1982)	3.16	(B.C. Gov't. data)	n/a	
	Aug./80	1.286	(Foreman, 1982)	2.56	(B.C. Gov't. data)	n/a	
	Sep./83	n/a		n/a		n/a	
	Sep./89	n/a		n/a		n/a	
West Malcolm Is.	Aug./74	1.595	(Foreman, 1982)	1.70	(Foreman, 1975)	1.41	(Foreman, 1975)
	Sep./78	1.24	(Foreman, 1982)	1.70*	(Foreman, 1975)	1.41*	(Foreman, 1975)
	Aug./80	1.27	(Foreman, 1982)	1.70*	(Foreman, 1975)	1.41*	(Foreman, 1975)
	Sep./83	n/a		n/a		n/a	
	Sep./89	n/a		n/a		n/a	
North Malcolm Is.	Aug./74	1.28	(Foreman, 1975)	1 .70	(Foreman, 1975)	1.41	(Foreman, 1975)
	Sep./83	n/a		n/a		n/a	
	Sep./89	n/a		n/a		n/a	

n/a = not applicable * 1974 correction factor used

Table 13. Estimates of kelp bed area and total biomass for the northern shore of Vancouver Island: Thomas Pt. and the Cluxewe River (Chart Area A, Blocks 1 - 16) (Sources of data: Foreman, 1975; Provincial Government data; 1989 inventory.)
B = Biomass (metric tonnes) ha = hectare

	Nereocystis				Macrocystis						Mixed					
	Low Density		High Density		Low Density		High Density		L+H	L+H	Low Density		High Density		Total	Total
Inventory Date	Area (ha)	Total B	Area (ha)	Total B	Area (ha)	Total B	Area (ha)	Total B	Area (ha)	Total B	Area (ha)	Total B	Area (ha)	Total B	A (ha)	B (tonnes)
August 26, 1974	14.41	337	15.18	1,122	49	183	169.84	2,338	214.33	2,521	3.11	47	8.79	684	255.82	4,710
September 14, 1983	18.34		2.58		165.84		92.42		258.26						279.18	
September 9, 1989	14.70	609	3.17	608	76.26		201.12		277.38	9,292	.96	35	.13	13	296.34	10,558

Table 14. Estimates of kelp bed area and total biomass for the west shore of Malcolm Island: Graeme Point to Malcolm Pt. (Chart Area B, Blocks 40 - 45) (Sources of data: Foreman, 1982; Provincial Government data; 1989 inventory.)
B = Biomass (metric tonnes) ha = hectare

	Nereocystis				Macrocystis						Mixed					
	Low Density		High Density		Low Density		High Density		L+H	L+H	Low Density		High Density		Total	Total
Inventory Date	Area (ha)	Total B	Area (ha)	Total B	Area (ha)	Total B	Area (ha)	Total B	Area (ha)	Total B	Area (ha)	Total B	Area (ha)	Total B	A (ha)	B (tonnes)
August 26, 1974	119.11	2,228	54.82	5,230	.38	9			.38	9			17.10	712	191.37	8,178
September 11, 1978	97.80	1,910	59.00	4,573			12.10	158	12.1	158			13.78	469	182.68	7,111
August 22, 1980	80.10	2,531	53.10	5,282	.9	5	3.40	61	4.3	66	2.65	66	17.40	836	157.55	8,781
September 14, 1983	59.18		15.66		9.51		21.33		30.84						105.68	
September 9, 1989	103.60	4,033	44.51	7,813	5.43		26.66		32.09	1,075	.85	32	1.79	180	182.84	13,132

Table 15. Estimates of kelp bed area and total biomass for the north shore of Malcolm Island: Malcolm Pt. to Lizard Pt. (Chart Area C, Blocks 1 - 15) (Sources of data: Foreman, 1975; Provincial Government data; 1989 inventory.)
B = Biomass (metric tonnes) ha = hectare

	Nereocystis				Macrocystis						Mixed					
	Low Density		High Density		Low Density		High Density		L+H	L+H	Low Density		High Density		Total	Total
Inventory Date	Area (ha)	Total B	Area (ha)	Total B	Area (ha)	Total B	Area (ha)	Total B	Area (ha)	Total B	Area (ha)	Total B	Area (ha)	Total B	A (ha)	B (tonnes)
August 26, 1974	10.83	191	68.13	4,639	2.18	7	69.43	677	71.61	683	.9	7	39.46	1,019	190.93	6,539
September 14, 1983	32.61		8.48		61.76		76.87		138.63		1.76		.32		181.80	
September 9, 1989	52.31	2,307	19.97	3,984	56.06		99.63		155.69	5,216	11.73	458	6.28	605	245.98	12,569

Estimates of bed area and total biomass (total standing crop at the time of the photography) in the August/September period are presented for each chart area as a whole as follows: Chart Area A, Blocks 1 - 16, for 1974, 1983, and 1989 (Table 13); Chart Area B, Blocks 40 - 45, for 1974, 1978, 1980, 1983, and 1989 (Table 14); Chart Area C, Blocks 1 - 15, for 1974, 1983, and 1989 (Table 15). This information is presented graphically in later sections (Chart Area A; Chart Area B; Chart Area C). Chart Areas A and B as referred to in Part 2 do not include same blocks from Part 1 of this report for which historical information is lacking.

For a portion of each Chart Area, estimates of bed area, density and total biomass by block are presented for the August/September period as follows: Chart Area A, four one-half nautical mile wide blocks (A - D) at False Head, 1974, 1978, 1980, 1983 and 1989 (Table 16); Chart Area B, six one kilometer wide blocks (40 - 45), 1974, 1978, 1980, 1983 and 1989 (Table 17); Chart Area C, four one-half nautical mile wide blocks (A - D) at Bowlder Point, 1974, 1983 and 1989 (Table 18). The use of one-half nautical mile or one kilometer block size for each area was regulated by the format of the historical information available. Inventory chart segments and graphic presentations are included in later sections (Chart Area A; B; C).' While providing an estimate of the actual kelp stocks present, the kelp inventory process and its results are influenced by many associated factors such as the accuracy and randomness of field sampling, the methods used, the person(s) doing the work and conditions at the time of photography (waves, actual tidal height, sun angle, and current).

Changes in the methodology used for Inventory work have complicated interpretation of the estimates. While the goal of each method is the accurate estimation of actual kelp stocks, the results vary markedly. Comparisons of inventory estimates between methods and with harvested quantities are discussed in later sections (*Macrocystis* Density Estimation; Harvest Results and Inventory Estimates).

CHART AREA A

Chart Area A extends along northern Vancouver Island from Thomas Point to the Cluxewe River. *Macrocystis* is the predominant species and forms beds more than 0.5 kilometer wide in places.

Kelp bed area and total biomass estimates along sixteen kilometers of shoreline from Chart Area A for the August/September periods of 1974 and 1989 are compared in Table 13 and Figure 2. Biomass information is not available for 1983, but bed area information is included. Biomass estimates for 1974 (Foreman, 1975) employed the KIM-1 method while the 1989 estimates used changes incorporated in this report.

Declines of *Nereocystis* bed and mixed bed areas and biomass are evident from the estimates. These bed types formed approximately 16% of the kelp bed area for Chart Area A in 1974 and only 6% in 1989. *Macrocystis* area and biomass estimates increased from 214.3 hectares and 2,521 tonnes in 1974 to 277.4 hectares and 9,292 tonnes in 1989.

Included in Table 16 are kelp bed area, mean density and total biomass estimates for each of the four one-half nautical mile blocks at False Head for the August/September periods of 1974, 1978, 1980 and 1989. Biomass information is not available for 1983, but bed area information is included. All estimates in this table were produced using the KIM~1 method, with the exception of 1989B which uses the modified version. Kelp bed area and biomass estimates for this area are compared in Figure 3 and the inventory chart segments are presented in Figure 4. Photography for all years was at MWL+/-.6 meters.

Declines in *Nereocystis* and mixed bed area and biomass noted in Chart Area A as a whole are also evident in this smaller section. Area and biomass estimates of 7% and 14% in 1974 had declined to 0% by 1989, respectively. *Macrocystis* bed area in the four blocks ranged fru,t72.9 in 1978 to 97.7 hectares in 1989. KIM-1 derived biomass estimates for *Macrocystis* increased from 1,026 tonnes in 1974 to 2,222 tonnes in 1980 and declined to 1,685 tonnes in 1989 (1989A, Table 16).

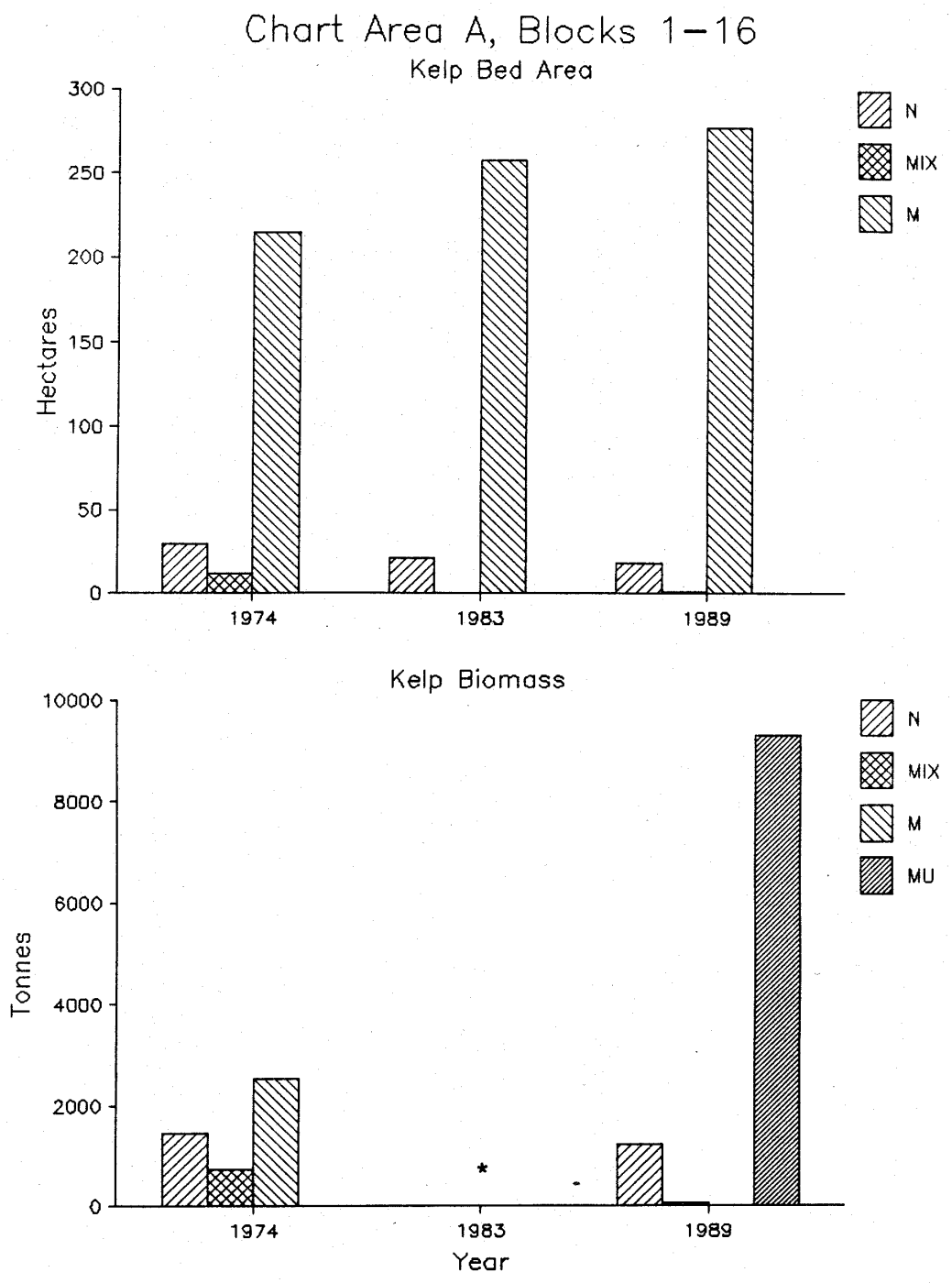


Figure 2. Bar graphs of kelp bed area and biomass estimates between 1974 and 1989 for blocks 1-16, Chart Area A.
N = *Nereocystis*, MIX - Mixed beds, M = *Macrocystis*,
MU = *Macrocystis* using underwater transects for density estimation, * = no data.

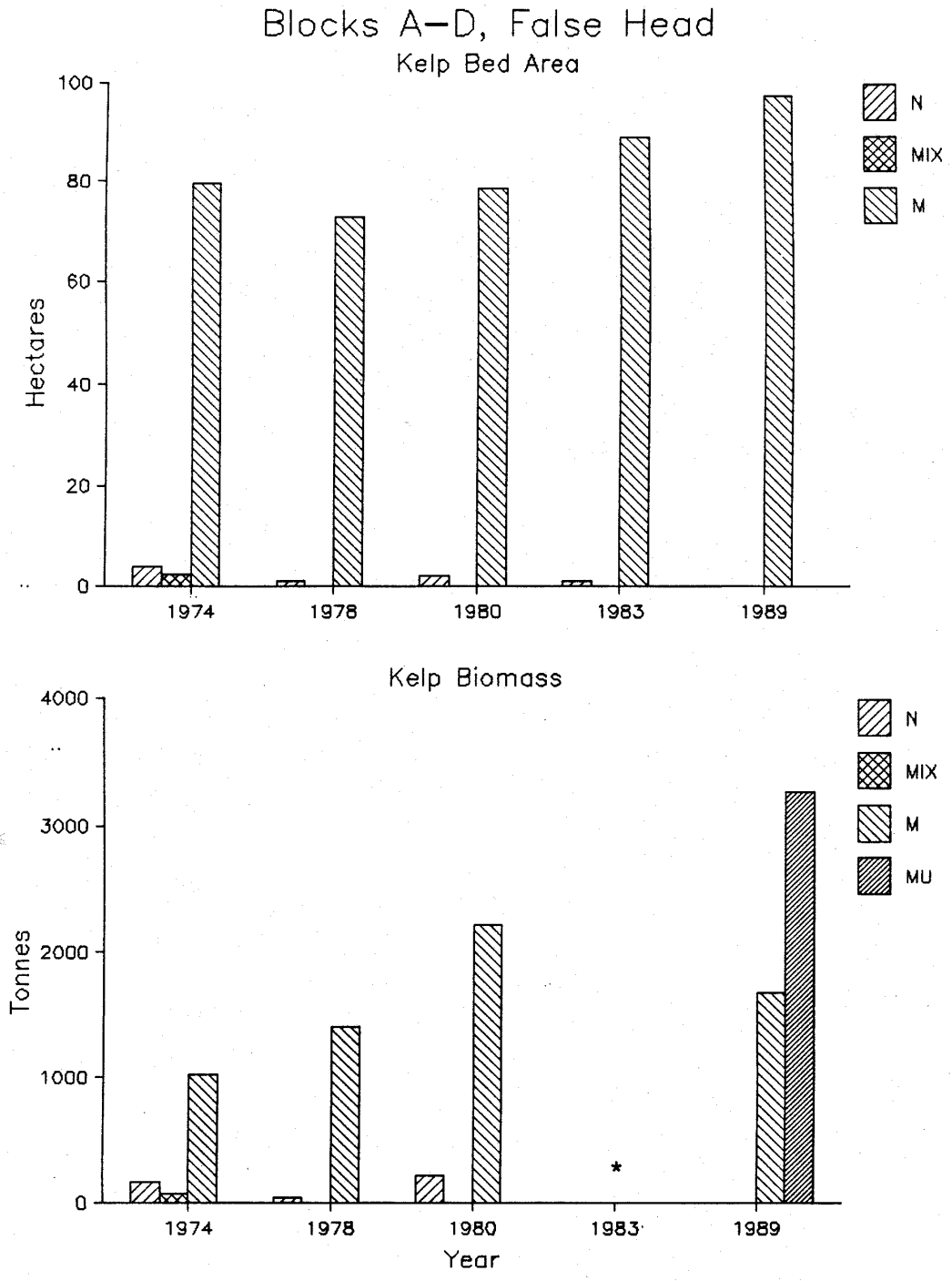


Figure 3. Bar graphs of kelp bed area and biomass estimates between 1974 and 1989 for blocks A-D, Chart Area A.
N = *Nereocystis*, MIX - Mixed beds, M = *Macrocystis*,
MU = *Macrocystis* using underwater transects for density estimation, * = no data.

Table 16. Estimates of kelp bed area and total biomass for a 2 nautical mile section of kelp bed at False Head, northern Vancouver Island for Aug./1974, Sept./1978, Aug./1980, and Sept./1989; biomass estimates are not available for Sept./1983 but area estimates are included. MWL biomass estimates for 1974, 1978, 1980 and 1989A have been converted to total biomass using combined biomass and density correction factors. Note that methods change for the 1989B estimates. A harvested area of 2.21 hectares has been included in the estimate for Block B, 1978. (Sources of data: Foreman, 1975; Provincial Government data; 1989 inventory.)
B = Biomass (metric tonnes) ha = hectare D = Density (no. of plants or fronds/hectare)

		Nereocystis - Low Density				*Nereocystis* - High Density				*Macrocystis* - Low Density				*Macrocystis* - High Density				Mixed - Low Density				Mixed - High Density				Total	Total
	Block	Photo. x̄D	Area (ha)	x̄B/ha	B	Photo. x̄D	Area (ha)	x̄B/ha	B	Photo. x̄D	Area (ha)	x̄B/ha	B	Photo. x̄D	Area (ha)	x̄B/ha	B	Photo. x̄D	Area (ha)	x̄B/ha	B	Photo. x̄D	Area (ha)	x̄B/ha	B	A (ha)	B (tonnes)
Aug. 26	A									1,500	7.73	2.3	17	7,800	21.17	12.4	263									28.90	280
1974	B									3,200	1.27	5.1	6	11,200	15.05	17.8	267									16.32	274
	C									3,500	11.44	5.6	65	10,800	11.97	18.0	216									23.41	281
	D	8,000	2.74	29.0	80	21,300	1.14	77.3	88	2,100	1.37	3.4	5	12,400	9.60	19.5	187	2,000	1.47	6.9	10	17,700	1.00	61.5	62	17.32	431
	Totals:		2.74		80		1.14		88		21.81		93		57.79		933		1.47		10		1.00		62	85.95	1,265
Sept. 11	A									3,300	25.22	10.4	263	11,900	.81	37.6	30									26.03	293
1978	B									3,500	3.34	11.1	37	11,900	11.73	37.6	441									15.07	478
	C	8,400	.35	37.0	13					4,300	19.05	13.6	259	11,900	4.36	37.6	164									23.76	436
	D	8,400	.67	37.0	25					5,100	4.9	16.1	79	12,100	3.46	38.2	132									9.03	236
	Totals:		1.02		38						52.51		638		20.36		768									73.89	1,443
Aug. 22	A									5,800	19.25	17.9	345	12,500	7.05	38.4	271									26.30	616
1980	B									5,800	1.29	17.9	23	16,300	14.99	50.2	752									16.28	775
	C					18,500	.27	117.2	32	3,800	20.66	11.8	243	13,800	5.59	42.2	236									35.92	511
	D	Trace	.15		Trace	18,500	1.55	117.2	181	4,200	2.53	12.8	32	13,800	7.55	42.2	319									9.82	532
	Totals:		.15		Trace		1.82		213		43.73		644		35.18		1,578									80.88	2,435
Sept. 14	A									3,300	10.51			10,800	15.59											26.10	
1983	B									3,300	1.15			12,600	16.32											17.47	
	C					Trace	.09			3,100	23.48			12,000	9.48											33.05	
	D	7,100	.91							3,500	5.18			11,100	7.70											13.88	
	Totals:		.91				.09				40.32				49.09											90.41	
Sept. 9	A									2,860	7.19	5.3	38	11,060	22.24	20.4	453									29.43	490
1989A	B									2,860	1.89	5.3	10	14,750	17.38	27.1	472									19.27	482
	C									2,860	17.29	5.3	91	11,700	16.10	21.5	347									34.67	438
	D									2,860	3.77	5.3	20	11,700	11.88	21.5	256									19.87	276
	Totals:										30.14		159		67.60		1,527									97.74	1,685

Underwater transect method of *Macrocystis* density determination:

		Nereocystis - Low Density				*Nereocystis* - High Density				*Macrocystis*						Mixed - Low Density				Mixed - High Density				Total	Total
	Block	Photo. x̄D	Area (ha)	x̄B/ha	B	Photo. x̄D	Area (ha)	x̄B/ha	B	Total x̄D	Low D Area (ha)	High D Area (ha)	Total Area (ha)	x̄B/ha	B	Area (ha)	x̄B/ha	B	Area (ha)	x̄B/ha	B	A (ha)	B (tonnes)
Sept. 9	A									47,900	7.19	22.24	29.43	33.5	986							29.43	986
1989B	B									47,900	1.89	17.38	19.27	33.5	646							19.27	646
	C									47,900	17.29	16.10	33.39	33.5	1,119							33.39	1,119
	D									47,900	3.77	11.88	15.65	33.5	524							15.65	524
	Totals:										30.14	67.60	97.74		3,274							97.74	3,274

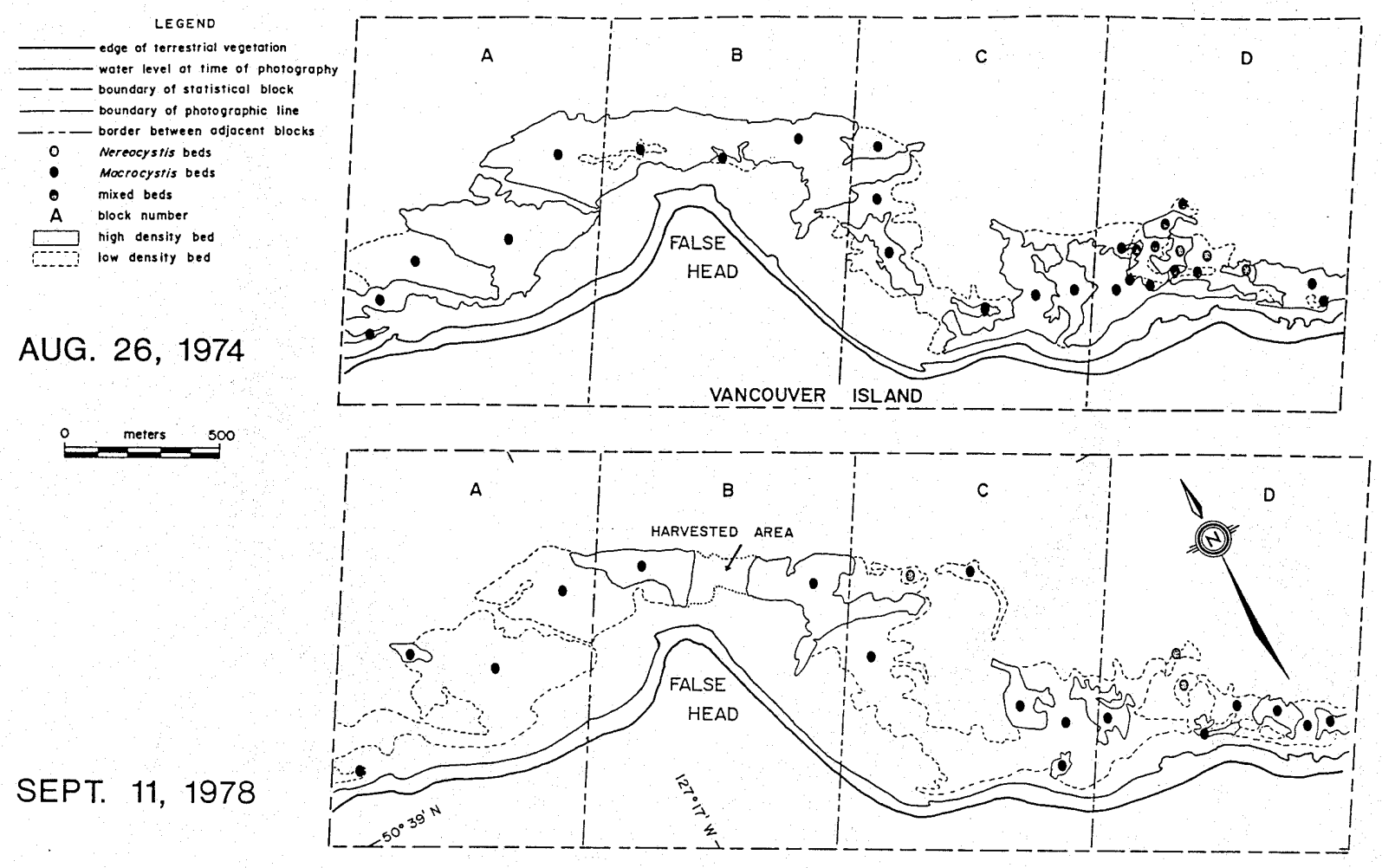


Figure 4. Kelp Inventory chart segments spanning a 15 year period for a 2 nautical mile section of coastline from Chart Area A at False Head, Vancouver Island. (Redrawn from: Foreman, 1975; Provincial Government data; 1989 inventory.)

Using the underwater transect method of estimating *Macrocystis* density for 1989, an estimate of 3,274 tonnes for 1989 is made (1989B, Table 16). Differences in the results derived by the two methods are examined in the *Macrocystis* Density Estimation section (page 33-35).

Figure 4 illustrates that while the general shape of the beds in blocks A to D is similar through time, changes do occur. *Nereocystis* beds have disappeared with time. It is interesting to note that no *Nereocystis* colonization took place after the 1978 *Macrocystis* harvest in block B. Year to year density fluctuations are evident.

CHART AREA B

Chart Area B is situated on the western shore of Malcolm Island. *Nereocystis* is the dominant floating kelp species in the area with beds extending more than a kilometer from shore off Graeme Point.

Kelp bed area and total biomass estimates along the six kilometers of shoreline between Graeme Point and Malcolm Point for the August/September periods of 1974, 1978, 1980 and 1989 are compared over the area as a whole in Table 14 and Figure 5. Table 17 presents information on a block by block basis. Biomass information is not available for 1983, but bed area information is included. Biomass estimates for 1974 through 1980 employed the KIM-1 method while the 1989 estimates used modifications incorporated in this report. These blocks are illustrated at MWL for 1974, 1983 and 1989 in Figure 6. The 1974 information in Table 17 and the chart segment in Figure 6 are derived from different sources and contain slight variations (Foreman, 1975 and 1982).

This area is dominated by *Nereocystis*, with mixed beds and *Macrocystis* beds amounting to less than 12% of the floating kelp biomass in all years. Mixed beds found until 1980 appear to have been largely replaced by *Macrocystis* in 1983 and 1989. *Nereocystis* bed area was maximal in 1974 (173.9 hectares) and minimal in 1983 (74.8 hectares). The 1989 biomass estimate of 11,846 tonnes is an increase of more than 50% from the 1980 estimate and due in part to the high mean biomass per plant statistic used in 1989.

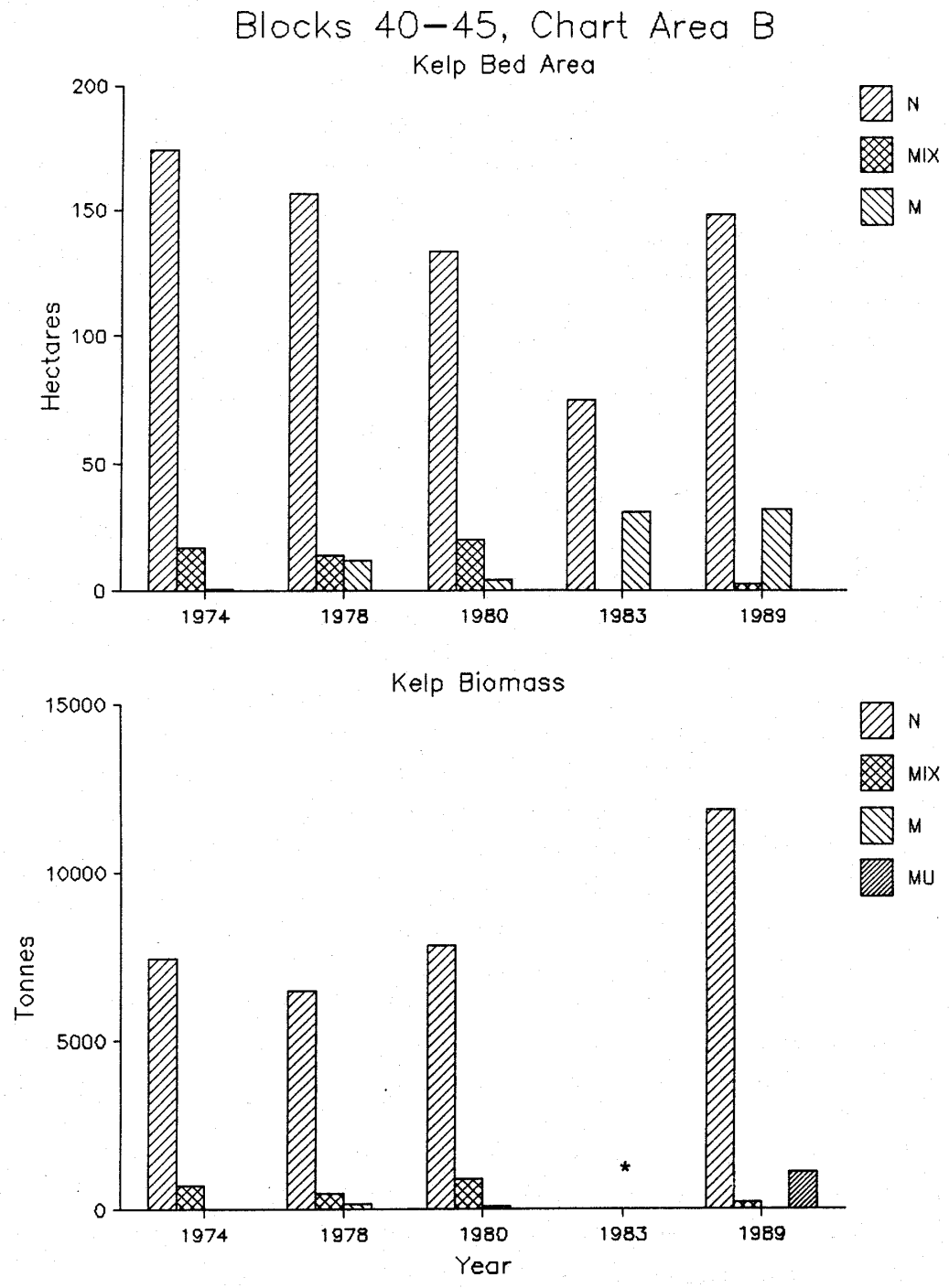


Figure 5. Bar graphs of kelp bed area and biomass estimates between 1974 and 1989 for blocks 40-45, Chart Area B.
N = *Nereocystis*, MIX - Mixed beds, M = *Macrocystis*,
MU = *Macrocystis* using underwater transects for density estimation, * = no data.

Table 17. Estimates of kelp bed area and total biomass for the west shore of Malcolm Island from Graeme Point to Malcolm Point (Blocks 40-45) for Aug./1974, Sept./1978, Aug./1980, and Sept./1989; biomass estimates are not available for Sept./1983 but area estimates are included. MWL biomass estimates for 1974, 1978 and 1980 have been converted to total biomass using combined biomass and density correction factors. Note that methods change for the 1989 estimates. (Sources of data: Foreman, 1975, 1982; Provincial Government data; 1989 inventory.)
B = Biomass (metric tonnes) ha = hectare D = Density (no. of plants or fronds/hectare)

		Nereocystis - Low Density				*Nereocystis* - High Density				*Macrocystis* - Low Density				*Macrocystis* - High Density				Mixed - Low Density				Mixed - High Density				Total	Total
	Block	Photo. x̄D	Area (ha)	x̄B/ha	B	Photo. x̄D	Area (ha)	x̄B/ha	B	Photo. x̄D	Area (ha)	x̄B/ha	B	Photo. x̄D	Area (ha)	x̄B/ha	B	Photo. x̄D	Area (ha)	x̄B/ha	B	Photo. x̄D	Area (ha)	x̄B/ha	B	A (ha)	B (tonnes)
Aug. 26	40	4,400	45.85	17.1	786	25,400	16.70	98.0	1,637																	62.55	2,424
1974	41	6,100	5.81	23.4	136	28,700	6.98	110.8	773													19,400	1.07	41.4	44	13.86	953
	42	4,900	12.94	19.1	247	20,700	8.58	79.8	685													22,700	4.61	48.5	224	26.13	1,156
	43	4,700	22.38	18.0	404	23,000	7.95	88.7	705	2,000	.38	22.5	9									16,100	3.97	34.4	137	34.68	1,254
	44	4,800	17.99	18.4	331	23,600	7.04	91.2	642													19,200	4.29	41.1	176	29.32	1,149
	45	5,900	14.14	22.9	324	26,900	7.57	104.0	787													19,600	3.12	42.0	131	24.83	1,242
	Totals:		119.11		2,228		54.82		5,230		.38		9										17.06		712	191.37	8,178
Sept. 11	40	4,000	60.0	18.04	1,083	19,800	14.4	98.4	1,273																	74.40	2,356
1978	41	4,300	6.5	19.07	124	18,900	8.0	84.2	674													15,500	2.06	33.1	68	16.56	866
	42	4,800	6.5	21.34	139	16,700	9.2	74.6	687					12,300	4.1	14.0	57					17,800	5.11	38.2	195	24.91	1,078
	43	4,600	3.1	20.50	64	18,000	10.6	80.0	848					11,800	6.3	13.5	85					17,700	1.57	37.9	60	21.57	1,056
	44	4,600	10.7	20.72	222	16,000	9.7	71.2	690					8,300	1.7	9.5	16					15,600	3.66	33.3	122	25.76	1,050
	45	5,700	11.0	25.44	280	12,700	7.1	56.5	401													8,400	1.38	18.0	25	19.48	706
	Totals:		97.8		1,910		59.0		4,573						12.1		158						13.78		469	182.68	7,111
Aug. 22	40	4,900	25.6	30.90	791	17,600	12.8	111.46	1,427																	38.40	2,218
1980	41	7,300	3.2	46.09	147	12,200	5.7	77.35	441	4,800	.7	5.44	4									1,300	.41	2.8	1	24,200	1.96	51.8	101	11.97	695
	42	4,800	5.3	30.33	161	10,800	11.2	68.73	770																	16,400	8.32	35.2	293	24.82	1,223
	43	6,100	8.3	38.50	320	18,700	14.1	118.18	1,666	6,300	.2	7.14	1	16,100	3.0	18.4	56									27,600	4.62	59.1	273	30.22	2,316
	44	4,600	29.7	29.13	865	17,200	7.9	108.92	860					12,000	.4	13.7	5	14,100	2.02	30.2	62	31,500	2.50	67.4	168	42.52	1,962
	45	4,900	8.0	30.90	247	13,300	1.4	84.32	118									7,100	.22	15.3	3					9.62	369
	Totals:		80.10		2,531		53.1		5,282		.9		5		3.4		61		2.65		66		17.40		836	157.55	8,781
Sept. 14	40	5,120	12.44			16,250	1.20							10,020	.04											13.68	
1983	41	7,110	5.49			16,250	.96			3,190	.42			10,020	2.08											8.95	
	42	7,110	13.24			16,250	4.07			3,190	2.16			10,020	7.31											26.78	
	43	6,250	17.19			16,250	6.95			3,190	2.71			11,750	6.19											33.04	
	44	6,120	10.82			16,250	2.48			3,190	1.99			11,700	4.63											19.92	
	45	6,120								3,190	2.23			11,700	1.08											3.31	
	Totals:		59.18				15.66				9.51				21.33											105.68	

Underwater transect method of *Macrocystis* density determination and percent numbers method of *Nereocystis* total density determination.

		Nereocystis - Low Density				*Nereocystis* - High Density				*Macrocystis*						Mixed - Low Density				Mixed - High Density				Total	Total
	Block	Photo. x̄D	Area (ha)	x̄B/ha	B	Photo. x̄D	Area (ha)	x̄B/ha	B	Total x̄D	Low D Area (ha)	High D Area (ha)	Total Area (ha)	x̄B/ha	B	Area (ha)	x̄B/ha	B	Area (ha)	x̄B/ha	B	A (ha)	B (tonnes)
Sept. 9	40	5,170	44.65	39.4	1.759	22,490	13.07	171.3	2,239													57.72	3,998
1989B	41	5,070	6.97	38.6	269	22,490	4.33	171.3	742	47,900	1.34	1.99	3.33	33.5	112							14.63	1,122
	42	4,960	18.56	37.8	702	20,620	7.57	157.0	1,188	47,900	1.17	9.81	10.98	33.5	368							37.11	2,258
	43	4,980	13.47	37.9	511	23,320	12.29	177.6	2,183	47,900	1.47	6.78	8.25	33.5	276				.66	94.0	63	34.67	3,033
	44	5,040	12.64	38.4	485	26,460	6.13	201.5	1,235	47,900	1.45	5.34	6.79	33.5	227				.84	104.1	87	26.40	2,035
	45	5,520	7.31	42.0	307	26,460	1.12	201.5	226	47,900		2.74	2.74	33.5	92	.85	37.1	32	.29	104.1	30	12.31	686
	Totals:		103.60		4,033		44.51		7,813		5.43	26.66	32.06		1,075	.85		32	1.79		180	182.84	13,132

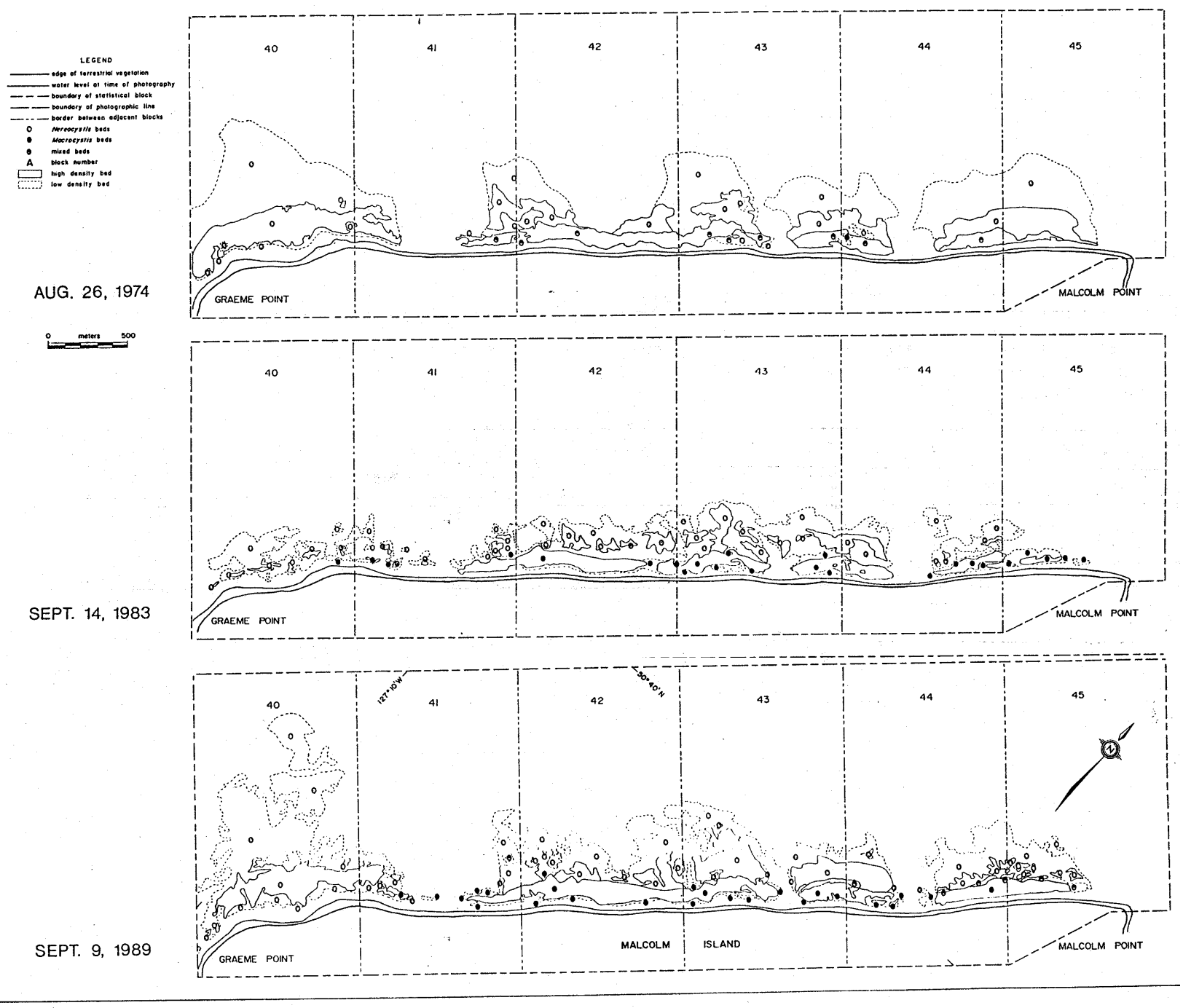


Figure 6. Kelp Inventory chart segments spanning a 15 year period for a 6 kilometer section of coastline from Chart Area B between Graeme Point and Malcolm Point, Malcolm Island. (Redrawn from: Foreman, 1975; Provincial Government data; 1989 inventory.)

CHART AREA C

Chart Area C covers several points and bays along the northern shore of Malcolm Island between Malcolm Point and Lizard Point and contains quantities of both *Nereocystis* and *Macrocystis*.

Kelp bed area and total biomass estimates along the fifteen kilometers of shoreline from Chart Area C on northern Malcolm Island for the August/September periods of 1974 and 1989 are compared in Table 15 and Figure 7. Biomass information is not available for 1983, but bed area information is included. Biomass estimates for 1974 employed the KIM-1 method while the 1989 estimates used modifications incorporated in this report.

Between Malcolm Point and Lizard Point, the *Nereocystis* area estimates ranged from a high of 79.0 hectares in 1974 to a low of 41.1 hectares in 1983. *Nereocystis* biomass estimates increased over this period from 4,829 tonnes in 1974 to 6,291 tonnes in 1989. This increase in biomass values while bed areas have decreased is possible in part due to the increase in mean biomass per plant values between 1974 and 1989.

Mixed bed area in Char-t Area C ranged from a high of 40.4 hectares in 1974 to a low of 2.1 hectares in 1983. Increases for 1989 in *Nereocystis* biomass per plant and *Macrocystis* frond density have produced a biomass estimate for mixed beds of 1,063 tonnes, very similar to the 1974 estimate of 1,026 tonnes.

Macrocystis results are the most markedly changed over the 15 year period. Bed area more than doubled from 71.6 hectares in 1974 to 155.7 hectares in 1989. Biomass estimates over this period increased more than seven times from 683 tonnes in 1974 to 5,216 tonnes in 1989. This appears to be the result of a combination of increased bed area and the higher density values produced by the modified method of *Macrocystis* density determination employed in 1989.

Included in Table 18 are kelp bed area, mean density per block and total biomass estimates for the four one-half nautical mile blocks at Bowlder Point for the August/September periods of 1974 and 1989.

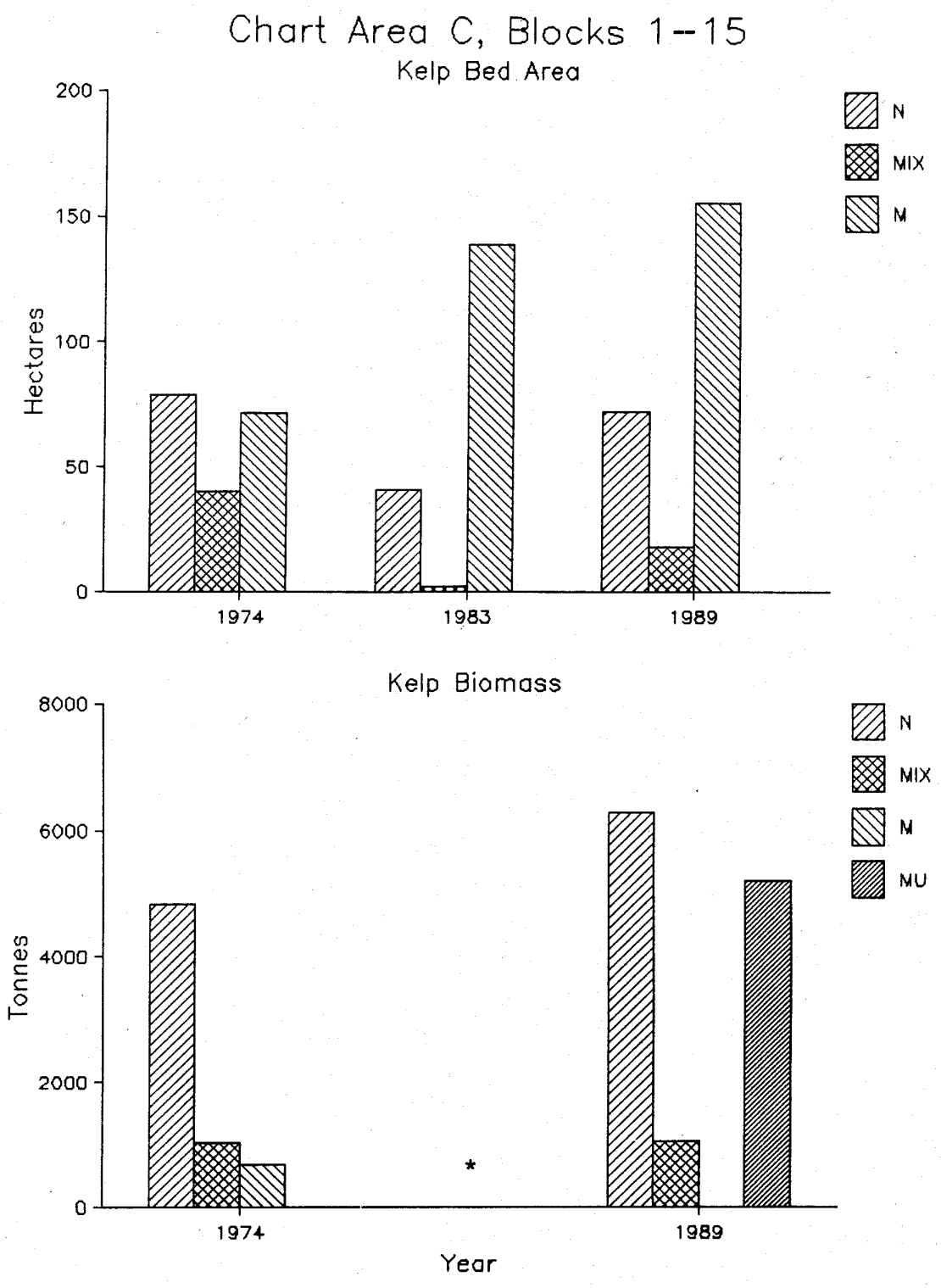


Figure 7. Bar graphs of kelp bed area and biomass estimates between 1974 and 1989 for blocks 1-15, Chart Area C.
N = *Nereocystis*, MIX - Mixed beds, M = *Macrocystis*,
MU = *Macrocystis* using underwater transects for density estimation, * = no data.

Table 18. Estimates of kelp bed area and total biomass for a 2 nautical mile section of kelp bed at Bowlder Point, northern Malcolm Island for Aug./1974 and Sept./1989; biomass estimates are not available for Sept./1983 but area estimates are included. MWL biomass estimates for 1974 have been converted to total biomass using combined biomass and density correction factors. Note that methods change for the 1989 estimates. (Sources of data: Foreman, 1975; Provincial Government data; 1989 inventory.)
B = Biomass (metric tonnes) ha = hectare D = Density (no. of plants or fronds/hectare)

		Nereocystis - Low Density				*Nereocystis* - High Density				*Macrocystis* - Low Density				*Macrocystis* - High Density				Mixed - Low Density				Mixed - High Density				Total	Total
	Block	Photo. x̄D	Area (ha)	x̄B/ha	B	Photo. x̄D	Area (ha)	x̄B/ha	B	Photo. x̄D	Area (ha)	x̄B/ha	B	Photo. x̄D	Area (ha)	x̄B/ha	B	Photo. x̄D	Area (ha)	x̄B/ha	B	Photo. x̄D	Area (ha)	x̄B/ha	B	A (ha)	B (tonnes)
Aug. 26	A					25,300	3.04	86.9	264					11,400	2.41	13.1	32									5.45	296
1974	B					25,400	6.29	87.3	549					9,000	5.79	10.4	60									12.08	609
	C													4,400	8.46	5.1	43									8.46	43
	D													4,200	9.23	4.8	44									9.23	44
	Totals:						9.33		813						25.89		179									35.22	992
Sept. 14	A		1.18				.16				.57				2.04											3.95	
1983	B		.62				.11				4.41				7.47											12.61	
	C		2.37								1.77				8.38											12.52	
	D		.25								2.11				8.96											11.32	
	Totals:		4.42				.27				8.86				26.85											40.40	

Underwater transect method of *Macrocystis* density determination and percent numbers method of *Nereocystis* total density determination. (See methods section Part 1.)

		Nereocystis - Low Density				*Nereocystis* - High Density				*Macrocystis*						Mixed - Low Density				Mixed - High Density				Total	Total
	Block	Photo. x̄D	Area (ha)	x̄B/ha	B	Photo. x̄D	Area (ha)	x̄B/ha	B	Total x̄D	Low D Area (ha)	High D Area (ha)	Total Area (ha)	x̄B/ha	B	Area (ha)	x̄B/ha	B	Area (ha)	x̄B/ha	B	A (ha)	B (tonnes)
Sept. 9	A	6,490	.52	49.4	26	24,300	.34	184.6	63	47,900	.28	3.31	3.59	33.5	120	2.35	40.2	94	.45	80.7	36	7.25	340
1989B	B	6,490	.32	49.4	16	24,230	.97	184.6	179	47,900	3.01	8.13	11.14	33.5	373	1.15	40.2	46	.43	80.7	35	14.01	649
	C									47,900	7.27	7.76	15.03	33.5	504							15.03	504
	D									47,900	7.19	5.17	12.36	33.5	414							12.36	414
	Totals:		.84		41		1.31		242		17.75	24.37	42.12		1,411	3.50		141	.88		71	48.65	1,906

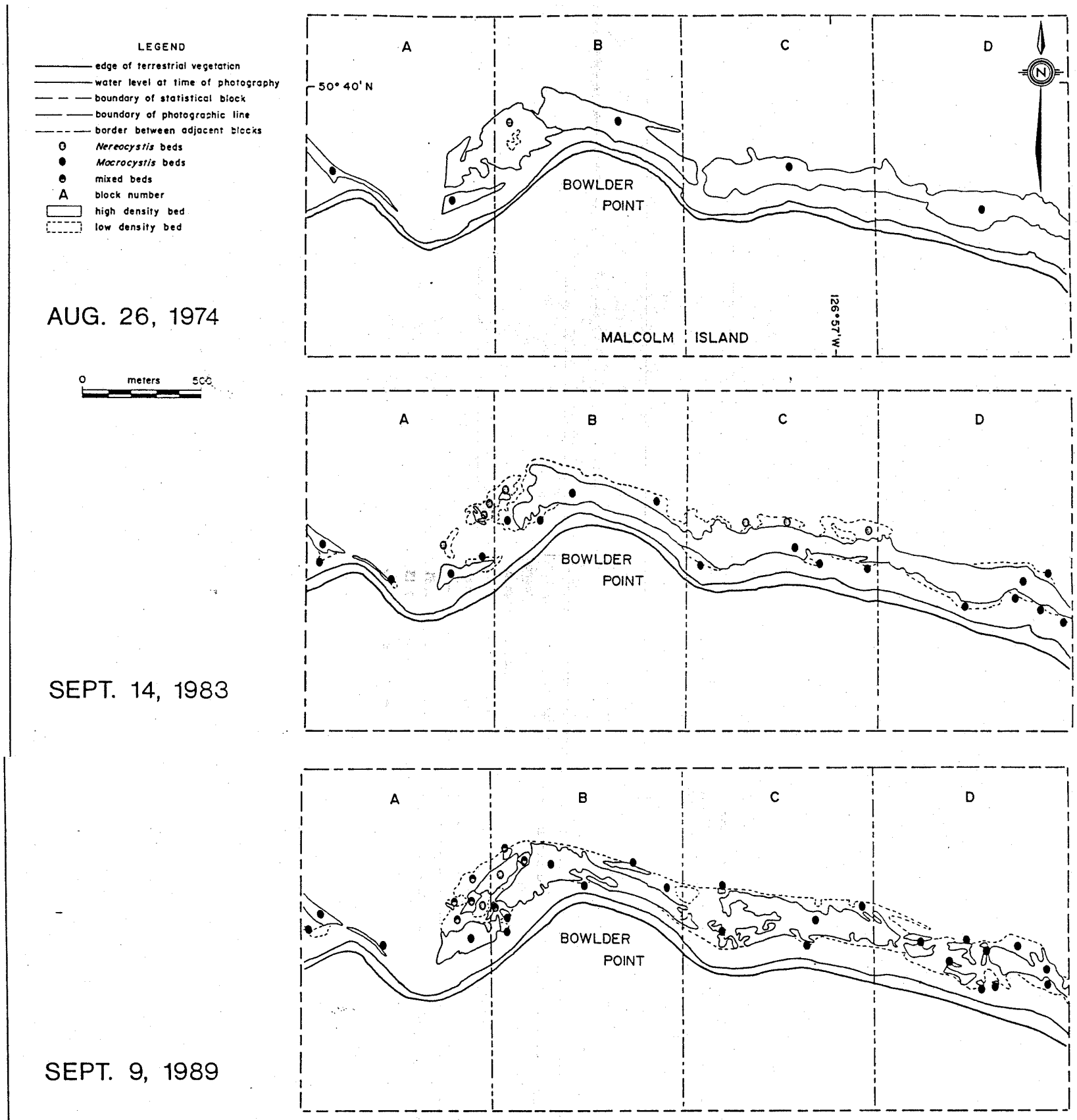


Figure 8. Kelp Inventory chart segments spanning a 15 year period for a 2 nautical mile section of coastline from Chart Area C at Bowlder Point, Malcolm Island. (Redrawn from: Foreman, 1975; Provincial Government data; 1989 inventory.)

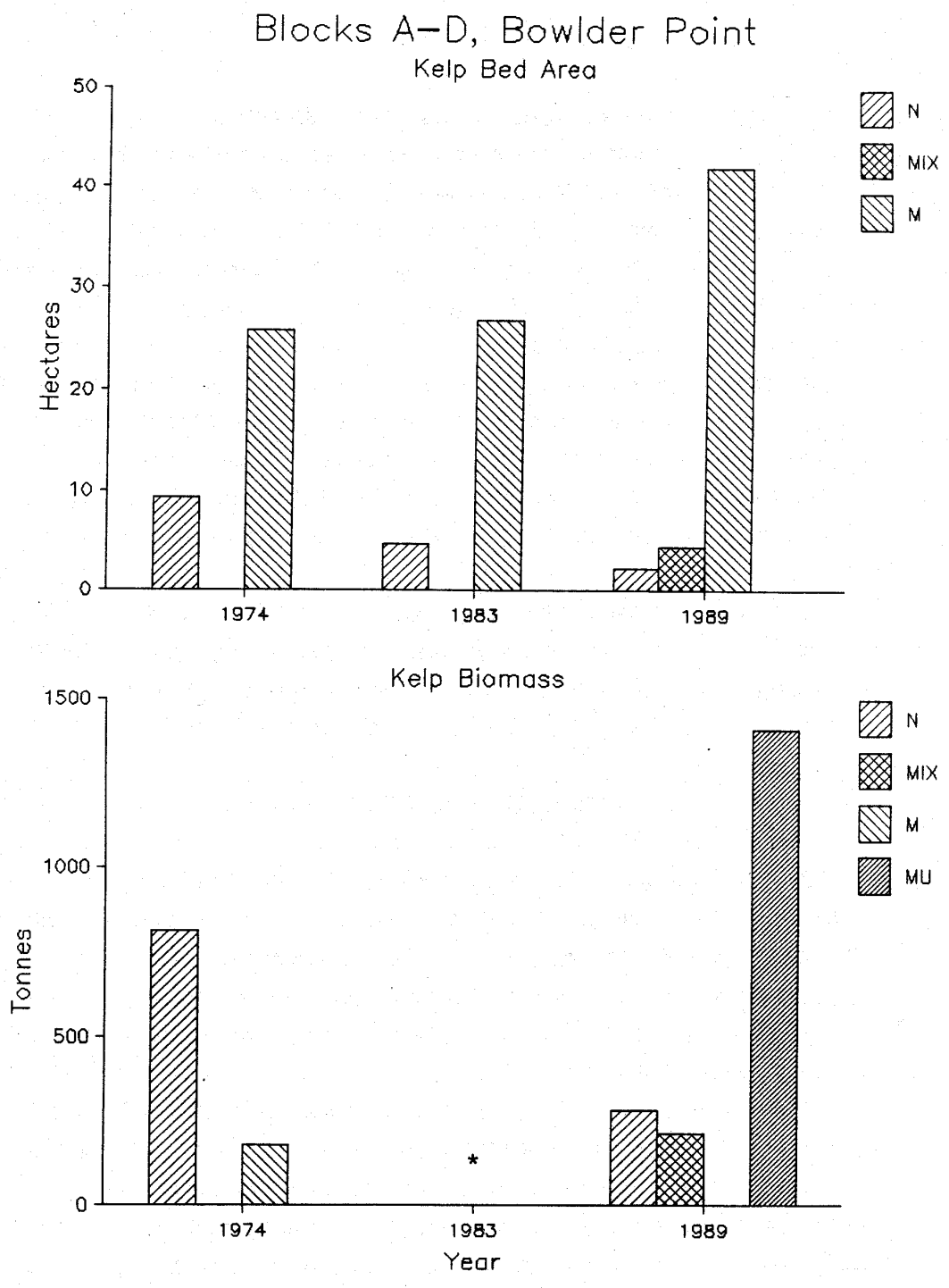


Figure 9. Bar graphs of kelp bed area and biomass estimates between 1974 and 1989 for blocks A-D, Chart Area C.
N = *Nereocystis*, MIX - Mixed beds, M = *Macrocystis*,
MU = *Macrocystis* using underwater transects for density estimation, * = no data.

Biomass information is not available for 1983, but bed area information is included. The biomass estimate for 1974 in this table was produced using the KIM-1 method while the modified version was used for 1989. Inventory chart segments for this area are presented in Figure 8 and kelp bed area and biomass estimates for this area are compared in Figure 9.

Changes in *Macrocystis* area and biomass estimates for blocks A-D over the period generally parallel the overall changes found in Chart Area C. *Nereocystis* bed area and biomass within the blocks were estimated to decline over the period from 9.3 hectares and 813 tonnes in 1974 to 2.2 hectares and 283 tonnes in 1989, respectively. No areas of mixed beds were found in 1974, but 4.4 hectares were located in 1989.

Figure 8 indicates that the *Nereocystis* bed in blocks A and B has been encroached upon by *Macrocystis* and there appears to have been a widening of the *Macrocystis* beds in general. Only in 1983 was an outer fringe of *Nereocystis* present in blocks C and D.

MACROCYSTIS DENSITY ESTIMATION

As previously mentioned, *Macrocystis* bed density has been estimated in two ways. The KIM-1 method uses percent point intercepts (similar to percent cover) on the aerial photography, while the present report has used randomly located underwater transects to estimate density. Establishing a relationship between the methods is important in evaluating results.

The point intercept method developed by Foreman (1975) is the basis of *Macrocystis* density values for all kelp inventory estimates prior to 1989. Percent point intercepts from aerial photography were related to frond density recorded along surface transects. The resulting regression equation was then used on a block by block basis to convert percent point intercept measurements from the photography to frond density at the time of photography.

The regression equation derived for *Macrocystis* in 1974 (Foreman, 1975) was in use until underwater transects replaced it. Using the same equation for all years and areas does not appear to be adequate, as mean plant and frond size and biomass are quite variable. Larger plants or fronds will occupy more space and should result in a higher ratio of percent point intercepts per plant or frond than smaller plants or fronds. Variable numbers of layers of fronds would also change over time frames ranging from hours (tidal effects) to months (seasonal effects) and years (annual effects). None of these possible sources of variation have been evaluated for their impact on KIM-1 derived estimates of frond density.

Underwater measurements of *Macrocystis* frond numbers along randomly placed

transects has been used to calculate average density for the inventory area -in the present report. Random locations for sample stations are chosen using a random numbers table and a numbered grid overlain on an existing inventory chart of the area. Transects are added until the standard error is less than 20% of the mean, a point considered to provide the best compromise between cost efficiency and accuracy. Mean density and error terms are calculated from the sample station data. A difficulty inherent with this method and that may lend bias to the sampling is that of locating the exact random sampling stations on broad expanses of water. Inventory charts are used as guides, but are drawn at MWL (whenever possible) while sampling takes place at all tide levels. This method has the advantage of being a direct measure of frond density, and therefore avoids the sources of variability which could impact the accuracy of KIM-1 derived estimates. While field costs for the underwater measurements are greater, it entails less time in estimating frond density from aerial photographs.

For 1980 and 1989, both the point intercept and transect methods were used to estimate *Macrocystis* biomass in Blocks A-D in Chart Area A at False Head. The results are shown in Table 19, and indicate that the transect method estimated 138% in 1980 and 193% in 1989 of the point intercept method estimates.

Table 19. Mean total *Macrocystis* biomass as estimated by both the point intercept and underwater transect methods for Blocks A-D at False Head in August, 1980 and September, 1989 (from unpublished Provincial Government data and the 1989 inventory).

Year	Point Intercept	Transect
1980	2,222 tonnes	3,078 tonnes
1989	1,686 tonnes	3,274 tonnes

HARVEST RESULTS AND INVENTORY ESTIMATES

In order to determine the accuracy of the KIM-1 inventory techniques, plots were harvested at the False Head *Macrocystis* (in 1978) and the Graeme Point *Nereocystis* (in 1978-80) study sites and compared with KIM-1 estimates. Kelp was harvested within specific tide limits by a modified Aquamarine Corp. H650 lake weed harvester and weighed.

One hectare plots were harvested from high density *Nereocystis* beds in Chart Area B at Malcolm Island. Harvested material combined with harvest induced litter was used to estimate actual standing = p values and compared with KIM-1 estimates (Foreman, 1984). Results from these experiments are shown in Figure 10 and indicate that KIM-1 overestimated standing crop by 1.8 to 2.2 kilograms per square meter, or approximately 20-40%.

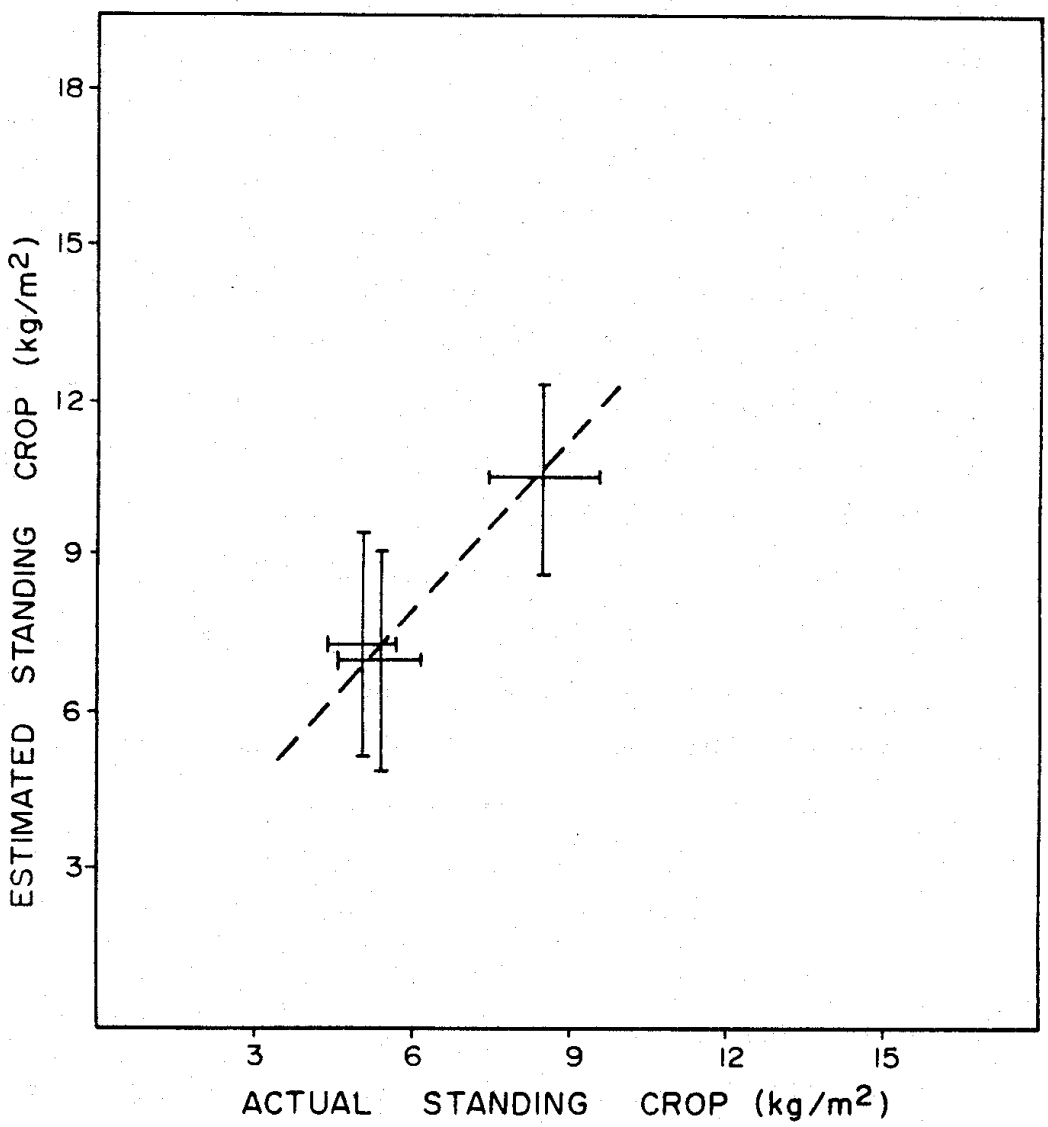


Figure 10. Comparison of KIN-1 derived estimated standing crop with standing crop derived by harvesting (from Foreman, 1984).

A single 2.2 hectare plot of high density *Macrocystis* was harvested 2 meters below MWL at False Head between late August and early September, 1978 and results were compared with KIM-1 estimates. Correction factors described by the KIM-1 method were applied to convert the estimate to the -2 meter level. During harvest operations, 58.8 tonnes of kelp was removed from the plot, a figure which does not include harvest induced litter. The KIM-1 method

predicted 15.6 tonnes, or approximately 27% of the harvested volume, to be available at that cutting height.

A second photographic flight was made at the completion of harvesting in September. Although the kelp in question had been harvested, adjacent high density kelp was used as an indicator of density, and an estimate was made of 45.3 tonnes available at 2 meters below MWL, or approximately 77% of the harvested volume.

While the actual *Macrocystis* biomass removed was underestimated by 23-73%, several factors combine to make the results of this test inconclusive. The pre-harvest flight was one meter above the optimum of MWL +/- .6 meters; the MWL-2 meter harvest depth was necessary when current in the area made most kelp inaccessible for MWL harvest, a situation that may have confounded the ML photography as well; and the mean biomass per frond and vertical biomass distribution information critical to the KIM-1 method was obtained at the end of July, and would have changed (normally lowered, producing a lower KIM1 biomass estimate) by the time of harvest.

DISCUSSION

The setting of harvest quotas as well as the logistical and financial planning of harvest operations require accurate assessments of kelp stocks. Prior to 1974, methods used to estimate kelp stocks in British Columbia were limited by problems such as "poor repeatability, inaccuracy in assessing areal extent and mean plant biomass, non-representative sampling, and lack of consideration of tidal influences" (Foreman, 1984). The KIM-1 method developed by Foreman (1975) has been found to be repeatable (Foreman, 1982), uses accurate measurements of area from aerial photographs, incorporates random sampling and considers the vertical distribution of kelp through the water column relative to tidal height.

KIM-1 biomass estimates for high density *Nereocystis* beds have shown overestimates of approximately 20-40% when compared with harvested quantities (Foreman, 1984). KIM-1 biomass estimates for high density *Macrocystis* beds appear to be underestimates but results of harvest tests are inconclusive. Changes to the KIM-1 method used in this report have attempted to provide more accurate estimates of *Macrocystis* stocks. Modifications to the method for *Nereocystis* appear to produce minor changes to estimates while those for *Macrocystis* have resulted in increases of up to 93% over the KIM-1 methods. While each test of stock estimates by harvesting requires a significant commitment, it is evident that further

testing of the accuracy of standing crop estimates generated by the two methodologies is required for the accurate assessment of kelp stocks. The best test will be to compare harvest yield against the estimates generated by the inventory methods.

In the 15 year period covered, the available data indicates a general decline in stocks of *Nereocystis* and an increase in those of *Macrocystis*. This is evident in the area measurements as well as biomass estimates, and cannot be entirely the result of the biomass estimation techniques. *Macrocystis* bed area increased in all Chart Areas. *Nereocystis* bed area in Chart Area A decreased over the period covered by the report while in Chart Areas B and C, a decrease to quite low area values in 1983 was followed by recoveries to almost the 1974 levels by 1989. El Niño oceanographic conditions in 1983 may have contributed to reduced kelp standing crop that year. Mixed bed area decreased to varying extents in all Chart Areas. The total kelp bed area of Chart Areas A and C have increased since 1974 while a slight decrease has taken place in Chart Area B.

REFERENCES

Coon, L.M., 1977. Marine plant management Program in British Columbia. A paper presented at the IXth International seaweed Symposium at Santa Barbara, California, U.S.A. in August, 1977 (Mimeo). 17 pp.

Coon, L.M., 1981. Kelp Inventory, 1981. Porcher Island. Unpublished data.

Coon, L.M., 1982. An assessment of kelp stocks in the Port Hardy-Malcolm Island region. Ministry of Environment internal report. 6 pp.

Coon, L.M., E.J. Field and Canadian Benthic Ltd., 1977. Nootka Sound Kelp Inventory, 1975. British Columbia Marine Resources Branch, Fish. Management Rep. No. 2 (2nd Edition). 27 pp.

Coon, L.M., W.G. Roland, E.J. Field, and W.E.L. Clayton, 1979. Kelp Inventory, 1976, Part 3. North and West Coasts Graham Island (Q.C.I.). British Columbia Marine Resources Branch, Fish. Management Rep. No. 13. 26 pp.

Coon, L.M., W.G. Roland, E.J. Field, W.E.L. Clayton, V. Jenson, 1980. Kelp Inventory, 1976, Part 4. Goschen Island to the Tree Knob Group. British Columbia Marine Resources Branch, Fish. Management Rep. No. 19. 18 pp.

Coon, L.M., W.G. Roland, E.J. Field, W.E.L. Clayton, V. Jenson, 1981. Kelp Inventory, 1976, Part 5. North Vancouver Island, Hope, Nigei and Balaklava Islands. British Columbia Marine Resources Branch, Fish. Management Rep. No. 20. 20 pp.

Coon, L.M., W.G. Roland, I.R. Sutherland, R.A. Hall, 1982. Kelp Inventory, 1978, Northwest Coast of Vancouver Island. British Columbia Marine Resources Branch, Fisheries Development Report No. 28. 16pp.

Field, E.J. and E.A.C. Clark, 1978. Kelp Inventory, 1976, Part 2. The Dundas Group. British Columbia Marine Resources Branch, Fish Management Rep. No. 11. 21 pp.

Field, E.J., L.M. Coon, W.E.L. Clayton and E.A.C. Clark, 1977. Kelp Inventory, 1976, Part 1. The Estevan Group and Campania Island. British Columbia Marine Resources Branch, Fish. Management Rep. No. 9. 19 pp.

Foreman, R.E., 1975. KIM-1. A method for inventory of floating kelps and its application to selected areas of Kelp Licence Area 12. Benthic Ecological Research Program Report 75-1. Report to Federal Fisheries and marine Service and Provincial Marine Resources Branch. 81 pp.

Foreman, R.E.. 1979. Supplementary evaluation of the KIM-1 Method for *Nereocystis*. Benthic Ecological Research Program Report 79-2. 18pp.

Foreman, R.E., E. Cabot and B. Oates, 1982. Studies on *Nereocystis* luetkeana I: Annual and seasonal dynamics of the floating kelp beds off the northwest coast of Malcolm Island. Report to the B.C. Marine Resources Branch, Ministry of Environment. 54pp.

Foreman, R.E., 1984. Studies on *Nereocystis* growth in British Columbia. Hydrobiologia 116/117, 325-332.

Sutherland, I.R., 1989. Kelp Inventory, 1989 Juan de Fuca Strait. B.C. Aquaculture and Commercial Fisheries Branch, Fisheries Development Rep. No. 35. 18pp.

APPENDIX

Charts A through C are enclosed in the following envelope.