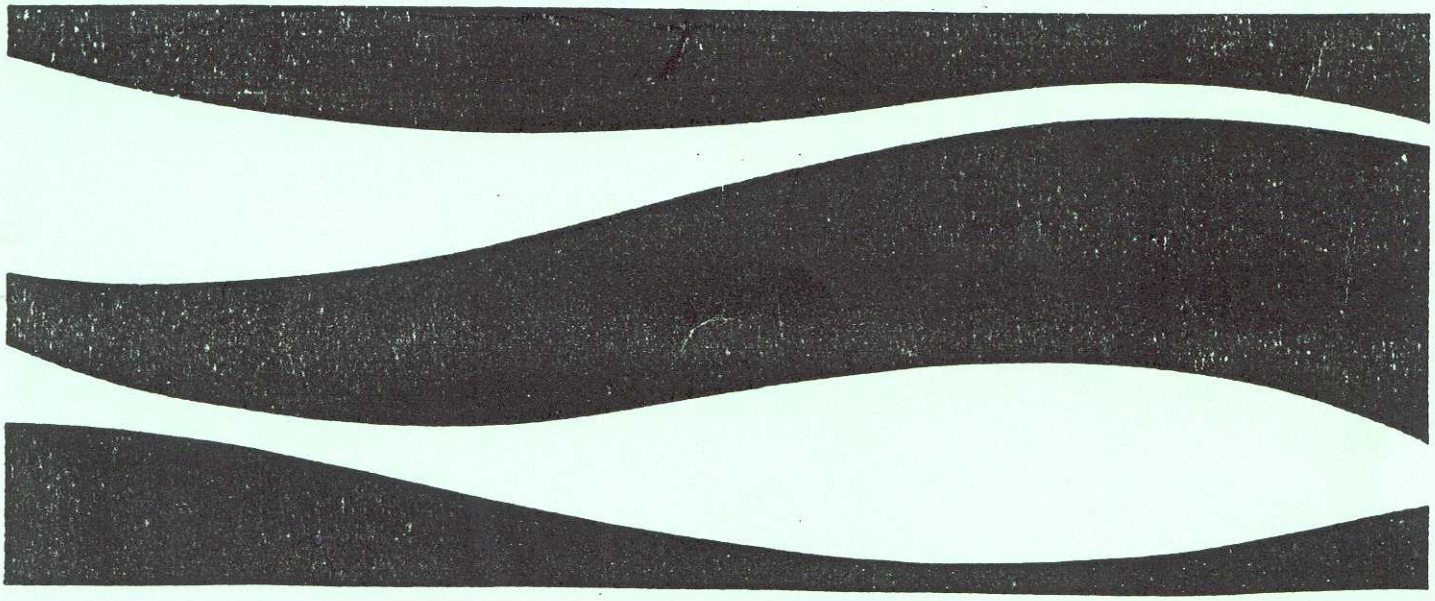
FOR REVIEW

Kelp Inventory, 1996

Porcher Island, Goschen Island, Banks Island and The Estevan Group

IEC Collaborative Marine Research
and Development Ltd.

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



KELP INVENTORY, 1996

PORCHER ISLAND, GOSCHEN ISLAND, BANKS ISLAND AND THE ESTEVAN GROUP

prepared by

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IEC Collaborative Marine Research
and Development Ltd.

Fisheries Development Report No. 39

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

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ABSTRACT

Infrared aerial photographs and biological data collected in the field were used in a modification of the Kelp Inventory Method (KIM-1) developed by Foreman (1975). Estimates were made of the kelp bed area and total standing crop biomass of *Nereocystis luetkeana* and *Macrocystis integrifolia* along the southwest shores of Porcher Island, Goschen Island and Prager Islands, the north and northwest shores of Banks Island and the west shores of the Estevan Group for Aug. 24 and 25, 1996. Results indicated that 41,232 tonnes of *N. luetkeana*, 16,160 tonnes of *M. integrifolia* and 2,260 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 741, 313 and 36 hectares, respectively. Eleven chart sheets are presented which show the position, extent, species, and density of every discernible kelp bed within the survey area. For inventory and management purposes the area is divided into numbered, kilometer wide blocks.

Portions of the 1996 Estevan Group inventory area are compared with overlapping areas from a 1976 survey. Melville Island and Dunira Island to the north of the inventoried areas and Kitasu Bay and Higgins Pass to the south were not covered by the aerial photography required for complete inventory work but results of biological sampling in these areas are summarized.

Acknowledgments

Michael Coon, Ed Black, Barron Carswell, Bill Harrower and Christine Hodgson of the Ministry of Agriculture, Fisheries and Food organized and coordinated various aspects of the project. Clyde Smith, Willie Beynon and Patty Menning of the Tsimshian Tribal Council, Ken Cripps, Louis Mason and Ernest Mason of the Kitasu Fisheries Program and Michael Coon, Bill Harrower and Christine Hodgson of the Ministry of Agriculture, Fisheries and Food collected the field data. Dan Reiners of McElhanney Consulting Services Ltd. provided computer mapping services. Rick Deagan of the Ministry of Agriculture, Fisheries and Food modified and finalized the chart sheets and coordinated publications. Hauts-Monts Pacific and the Ministry of Environment, Lands and Parks provided aerial photographic coverage of the area. The Ministry of Agriculture, Fisheries and Food provided licensing statistics and information on kelp use in British Columbia. Mr. Bodo R. de Lange Boom, tides and currents analyst at the Canadian Hydrographic Service, provided tidal height data for the inventory area.

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1996 North Coast Inventory Areas

Kelp Bed Area (hectares)	*Nereocystis*	*Macrocystis*	Mixed	Total
Porcher Island/ Goschen Island	192.94	27.44	0.75	221.13
Banks Island	423.70	219.37	34.50	677.57
Estevan Group	124.49	66.37	0.58	191.44
Total:	741.13	313.18	35.83	1,090.14

Biomass (tonnes)	*Nereocystis*	*Macrocystis*	Mixed	Total
Porcher Island/ Goschen Island	12,096.8	1,415.9	47.7	13,560.4
Banks Island	22,863.7	11,319.5	2,180.5	36,363.7
Estevan Group	6,271.3	3,424.7	32.2	9,728.2
Total:	41,231.8	16,160.1	2,260.4	59,652.3

Nereocystis mean biomass/plant:	4.88 kg.
Macrocystis mean biomass/frond:	0.73 kg.
Mean density of *Macrocystis* bed:	7.07 fronds/sq.m.

Areas not covered by aerial photography

Melville Island/Dunira Island

Nereocystis mean biomass/plant:	3.67 kg.
Macrocystis mean biomass/frond:	1.36 kg.
Mean density of *Macrocystis* bed:	4.62 fronds/sq.m.

Kitasu Bay/Higgins Pass

Nereocystis mean biomass/plant:	1.96 kg.
Macrocystis mean biomass/frond:	0.57 kg.
Mean density of *Macrocystis* bed:	4.84 fronds/sq.m.

One 14 kilometer section of coast in the Estevan Group was also surveyed 20 years previously in 1976. Changes in methods used and differences in tide height at the time of photography between the two inventories should be considered for their influence on results. Estimates for the area of overlap in the inventories varied by species as shown below but, overall, the 1996 bed area and biomass were about half of 1976 estimates.

	Area (ha)				**Tonnes**			
	N	M	Mix	Total	N	M	Mix	Total
1976:	256.20	12.03	5.50	273.73	14,662	118	167	14,947
1996:	107.93	35.96	0.58	144.47	5,236	1,856	32	7,123
1996 as % of 1976:	42%	299%	11%	53%	36%	1576%	19%	48%

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INTRODUCTION

Nereocystis luetkeana (Mertens) Postels and Ruprecht and *Macrocystis integrifolia* Bory are large, canopy-forming kelp species that are found in beds along extensive portions of the British Columbia coast. Beginning 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*, 1976, 1979, 1980, 1981, 1982; Field, 1996; Field *et al*, 1975, 1977, 1978; Sutherland, 1989, 1990, 1996).

The present report contains the results of a 1996 survey of portions of the northern coast of British Columbia by the Aquaculture and Commercial Fisheries Branch of the Ministry of Agriculture, Fisheries and Food. Areas covered include the southwest shores of Porcher Island, Goschen Island and Prager Islands; the north and northwest shores of Banks Island from Deadman Inlet to Kingkown Inlet; and the west shores of the Estevan Group from Otter Passage north of Trutch Island to Oswald Bay (see Figure 1). These areas were priorized and chosen from areas of interest and known kelp abundance in the region. Biological data collected in the field in 1995 has been combined with digitized mapping of the kelp resource from 1996 aerial photography to produce estimates of the area covered by kelp beds and their total standing crop biomass.

Portions of the present survey area were described previously by inventories that took place in 1976 (Coon *et al*, 1980; Field *et al*, 1977). In the 20 years that have elapsed, seasonal and annual variation as well as longer-term changes and large scale oceanic events (El Niño), have affected the local stands of large kelps. One 14 kilometer section of coast in the Estevan Group overlapped in 1976 and 1996 inventories and changes in kelp bed extent and composition are compared.

At the time of 1995 field sampling for the inventory, field crews also collected additional data at Melville Island/Dunira Island to the north and Kitasu Bay/Higgins Pass to the south that were not covered by aerial photography (see Figure 1). This data has been summarized and included in a section at the end of the report.

The main use of marine plants in British Columbia is for the herring spawn-on-kelp industry. In 1996, 38 licenses were issued for the harvest of *Macrocystis* for this purpose and 110.0 tonnes were landed (BCMAFF, 1996). Additional licenses were issued for

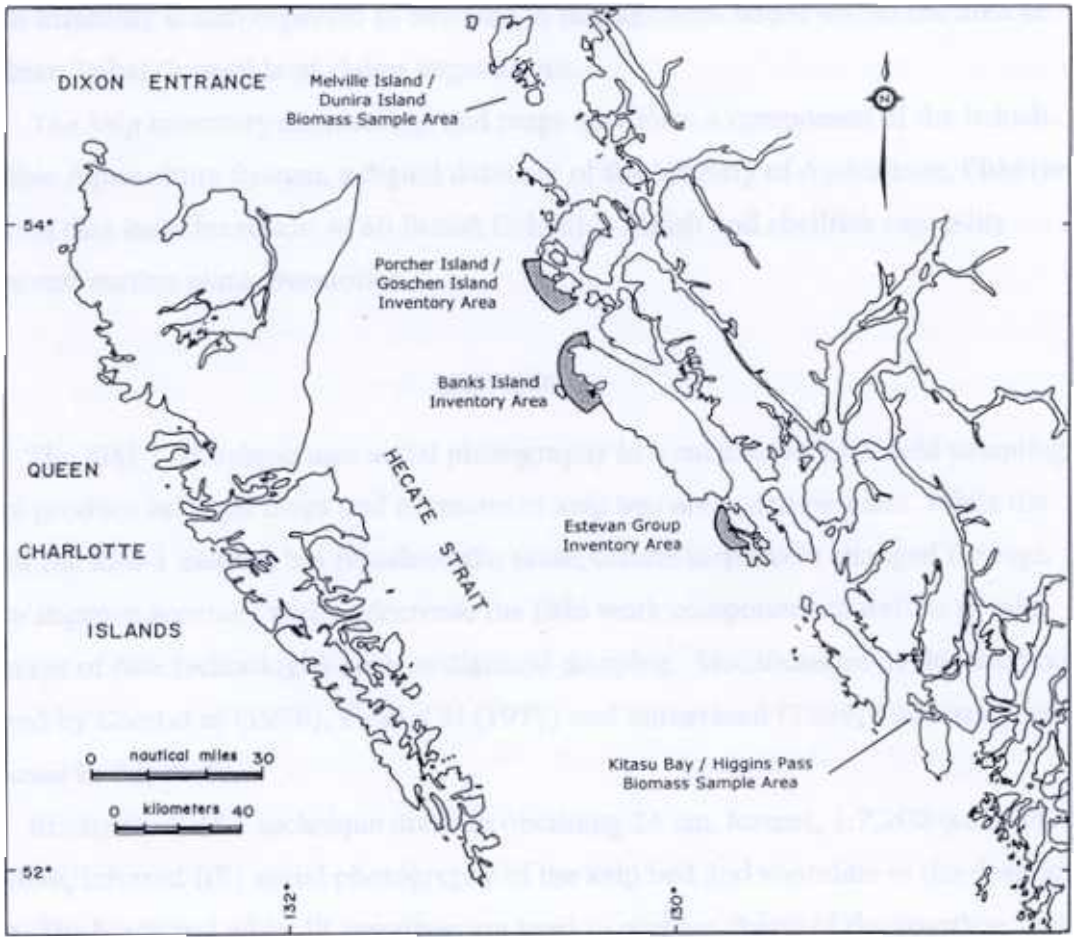

Figure 1. Map of the northern British Columbia coast showing inventory areas for August 24 and 25, 1996 (shaded). Also shown are areas where only field samples were taken.

other species including *Nereocystis* and *Laminaria* (8 licenses; 35.0 tonnes), and *Salicornia* (2 licenses; 1.5 tonnes landed) which were processed into dried and fresh products for human consumption or manufactured into fertilizer. 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.

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 for herring spawn, abalone, sea urchins, sea otters and other species. The

present inventory is also expected to be of aid in management issues within the area of Tsimshian Tribal Council land claims negotiations.

The kelp inventory data, results and maps now form a component of the British Columbia Aquaculture System, a digital database of the Ministry of Agriculture, Fisheries and Food that includes results of all British Columbia finfish and shellfish capability studies and marine plant inventories.

METHODS

The KIM-1 technique uses aerial photography in combination with field sampling data to produce kelp bed maps and estimates of kelp bed areas and biomass. While the basis of the KIM-1 method has remained the same, certain steps have changed through time to improve accuracy and/or decrease the field work component as well as to take advantage of new technologies such as digitized mapping. Modifications of this method as stated by Coon *et al* (1976), Field *et al* (1977) and Sutherland (1989, 1990 and 1996) were used in this study.

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 the offshore kelp beds. The kelp bed charts produced are divided to sections, or blocks, that are 1 kilometer in width along the shore for statistical purposes. Kelp bed surface area data is derived from these charts.

The technique identifies six bed types on the basis of:

a) species - *Macrocystis* or *Nereocystis* or mixed (considered to be 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).

The low and high density separation at 10 plants or fronds per 10 square meters is arbitrary and has been used in all inventories in British Columbia to date. Its purpose is to allow increased accuracy of density estimates based on the photography (for *Nereocystis* in recent inventories) by dividing the random samples for the point intercept method (Foreman, 1975) to more similar groupings of low and high density bed types. *Macrocystis* density values determined from field transects suggest 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. In the present survey *Macrocystis* density values determined from field transects were applied to all *Macrocystis* bed areas. High and low density *Macrocystis* beds have been kept separate on the charts and in area measurements, however, to provide detail as presented in previous inventories.

Due to budget , manpower and schedule considerations, aerial photography and field data collection could not be undertaken concurrently. Near the time of year that the beds were photographed, although the year previous, field crews obtained samples of kelp from the inventory area to determine mean weight per plant (*Nereocystis*) or frond (*Macrocystis*) and recorded numbers of plants along transects on the sea floor to determine density for *Macrocystis*. Density for *Nereocystis* and bed area for both species were determined from analysis and mapping of the aerial photographs. Kelp biomass was determined by multiplying the mean weight per plant or frond values by the plant or frond densities and multiplying this product by the observed bed areas. All biomass estimates in this report are of total standing crop.

The Ministry of Agriculture, Fisheries and Food provided field sampling data and aerial photographs under contract to IEC Collaborative Marine Research and Development Ltd. who undertook the initial air photo interpretation and mapping of the kelp beds. McElhanney Consulting Services Ltd. was contracted to digitize the mapped kelp bed polygons using monorestitution techniques. The company also placed the statistical kilometer blocks, calculated the areas of kelp bed polygons, provided computer data files (ARCINFO spatial data set) and 1:20,000 scale maps of the inventory areas. IEC then completed the data analysis for the inventory and produced the present report. In cooperation with IEC, the Ministry modified the maps for accuracy, ease of viewing and to make them suitable for reproduction.

Nereocystis

In this inventory, wet weight was determined for whole *Nereocystis* plants as they were sampled at randomly located stations in the survey area. The mean biomass per plant statistic for *Nereocystis* used in subsequent calculations is derived from the mean of sample station means of wet weight per plant.

Nereocystis beds are made up of plants of varying lengths. The density of *Nereocystis* plants visible on the surface at the time of photography varies with tide height (ideally at Mean Water Level (MWL) $\pm$ 0.6 meters for the KIM-1 method; tide height for the present photography was at MWL) and is determined directly from the photographs with the aid of a microscope with ocular grid and using the KIM-1 point-intercept method (Foreman, 1975). A percent point-intercept to density regression for *Nereocystis*, as developed by Foreman and Cabot (1979), was employed in this inventory. The tidal heights at the time of photography relate density data from the photos to MWL for further calculations.

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 MWL. Beginning in 1981, in order to minimize the costly field work component, the time consuming weighing of each 1 meter increment of the plants was discontinued and length measurements of *Nereocystis* plants merged relative to MWL have been used to produce a table of cumulative numbers of plants in 1 meter increments above and below MWL. These cumulative numbers are used to convert the density observed from the photography to total or bottom density as follows:

$$\text{Total density at bottom} = (\text{Conversion factor}) \times (\text{Density derived from photography})$$

$$\text{Where the conversion factor} = \frac{\text{Total no. plants in all samples}}{\text{no. plants in all samples that would extend to sea surface at tidal height at time of photography}}$$

The original KIM-1 method used a conversion factor based on cumulative biomass in a similar manner. Calculations using data from previous inventories have shown that the present method, in practice, produces total standing crop estimates differing little from those produced using the original KIM-1 method (Sutherland, 1990).

For the present Inventory, plant length data was not available. The conversion factors used in the report were taken from the vertical profiles provided in previous reports for the areas or near to them as shown in Table 1. This substitution introduces a source of error in the overall standing crop estimate as vertical profiles from past inventories from Northern Vancouver Island and northward show that between 79% and

95% of plants (correction factors of 1.05 to 1.26) reach MWL +/- 0.6 meter, the tide height at the time of photography for the present inventory (see Table 2).

Table 1. *Nereocystis* density conversion factors (from density at MWL to total density) used in the present report and their sources.

Area Covered in Present Inventory	Correction Factor Used	Source Area	Source Document
Estevan Group	1.26	Estevan Group and Campania Island	Field *et al*, 1977
Porcher I., Goschen I. and Banks I.	1.15	Goschen Island to Tree Knob Group	Coon *et al*, 1980

Table 2. Percentages of *Nereocystis* plants in samples extending to MWL (± 0.6 meters) and calculated density conversion factors (from density at MWL to total density) for various northern British Columbia inventories.

Inventory Area	Source Document	% of plants reaching MWL	Conversion Factor
Northern Vancouver Island	Coon *et al*, 1981	95%	1.05
NE Vancouver Island and Malcolm Island	Sutherland, 1990	89%	1.12
Estevan Group and Campania Island	Field *et al*, 1977	79%	1.26 *
Goschen Is. to Tree Knob Group (exposed)	Coon *et al*, 1980	87%	1.15 *
Dundas Group	Field *et al*, 1978	87%	1.14
North and West Graham Island, (QCI)	Coon *et al*, 1979	96%	1.04
*= values used in present report	Average values:	88%	1.13

Macrocystis

Wet weight was also determined for whole *Macrocystis* fronds from samples at randomly located stations in the survey area. The mean biomass per frond value reported for *Macrocystis* is the mean of the sample stations means.

In the KIM-1 method, *Macrocystis* density was derived using the point intercept method 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 sea bottom at each sample station. *Macrocystis* density in this inventory was determined in the field from such counts in the vicinity of biomass sampling stations.

Mixed *Nereocystis* and *Macrocystis*

Changes to the method described above have required modification of the method used to calculate mixed bed biomass. Total 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 ha. of low or high *Nereocystis*	+	.58 X	Mean biomass per ha. of *Macrocystis*

The 0.42 and 0.58 figures in the equation are derived from the ratio found to occur in samples used in development of the KIM-1 method. Low or high density is not considered for the *Macrocystis* portion of the calculation.

RESULTS

Aerial Photography and Tidal Data

Kelp bed area for all bed types and density estimates for *Nereocystis* provided in this report are based on the aerial photography for the inventory area which was flown between 11:14 and 11:54 on August 24, 1996 and between 13:05 and 13:55 on August 25, 1996 (Pacific Standard Time). This places the timing of the photography within the desired 10:00 to 14:00 range that provides proper sun angles for best IR picture quality. Conditions were good for the photography with clear weather, little wave action and minimal glare. All film sections were usable for kelp bed interpretation.

Tidal data and correction factors were provided by the Canadian Hydrographic Service, Institute of Ocean Sciences. As recommended by the Service, observed water level data from the tidal gauges at Bella Bella and Prince Rupert were corrected to the inventory areas using secondary port corrections as follows: secondary port of Griffith Harbour for Porcher Island, Goschen Island and Banks Island; and secondary port of Block Islands for the Estevan Group. Tidal height at the time of photography was within the MWL $\pm$0.6 meter KIM-1 tidal range. Over the inventory area height varied from the upper end of the range at the Estevan Group (MWL +0.5 to +0.6 meters), to close to MWL at Banks Island (MWL +0.2 to -0.3 meters) and to the lower end of the range at Porcher Island/Goschen Island (MWL -0.4 to -0.5 meters).

Inventory Areas and Statistical Block Locations

Figures 2 through 4 show the locations of statistical blocks at the west side of the Porcher Island/Goschen Island area, the north and west sides of the Banks Island area and the west side of the Estevan Group, respectively. Chart Sheets 1 through 11 (included in Appendix) illustrate the disposition of kelp bed resources by bed type along the 70 statistical kilometer blocks of the inventory area. Placement of the kilometer wide blocks has been kept as similar as possible to the 1976 inventory layouts for comparison but blocks have been re-numbered consecutively over the 1996 inventory areas.

Mean Biomass per Plant or Frond and Density

Table 3 presents the field-determined mean biomass per plant and frond (total wet weight) estimates obtained from means of 14 *Nereocystis* and 21 *Macrocystis* sampling stations within the overall inventory area. A total of 142 *Nereocystis* plants and 496 *Macrocystis* fronds were sampled at these stations September 12 to 15, 1995. Considerable variability exists between stations (see standard deviation values reported). Maximum and minimum station mean biomass values were 9.96 kg. and 1.06 kg. per *Nereocystis* plant and 1.48 and 0.2 kg. per *Macrocystis* frond.

The *Macrocystis* density value derived from transect counts performed on the same dates and at the same locations as *Macrocystis* biomass samples were taken is shown in Table 4. The standard error value of 0.65 fronds per square meter represents 9% of the mean and falls within the 20% criterion established for the method (Sutherland, 1990). 11,880 *Macrocystis* fronds were counted on 1,680 square meters of bottom over 21 stations. Maximum and minimum *Macrocystis* mean station densities from transects were 12.48 and 2.46 fronds per square meter.

Mean biomass for both species and *Macrocystis* density statistics for two areas outside the inventory (Melville Island/Dunira Island and Kitasu Bay/Higgins Pass) have been calculated separately and are presented in a section at the end of this report.

Kelp Bed Area and Biomass Estimates

41,232 tonnes of *Nereocystis*, 16,160 tonnes of *Macrocystis* and 2,260 tonnes of mixed kelp, totaling 59, 652 tonnes, were estimated to lie within the 70 kilometer blocks inventoried over the three areas. *Nereocystis* made up 69% of the total biomass, *Macrocystis* made up 27% while mixed kelp made up 4% of the total. Of the 1,090

Figure 2. Map of the Porcher Island and Goschen Island inventory area for 1996 showing the layout of statistical blocks 1 to 14, chart sheets 1-3 on which they are included in the appendix and the air photo flight lines.

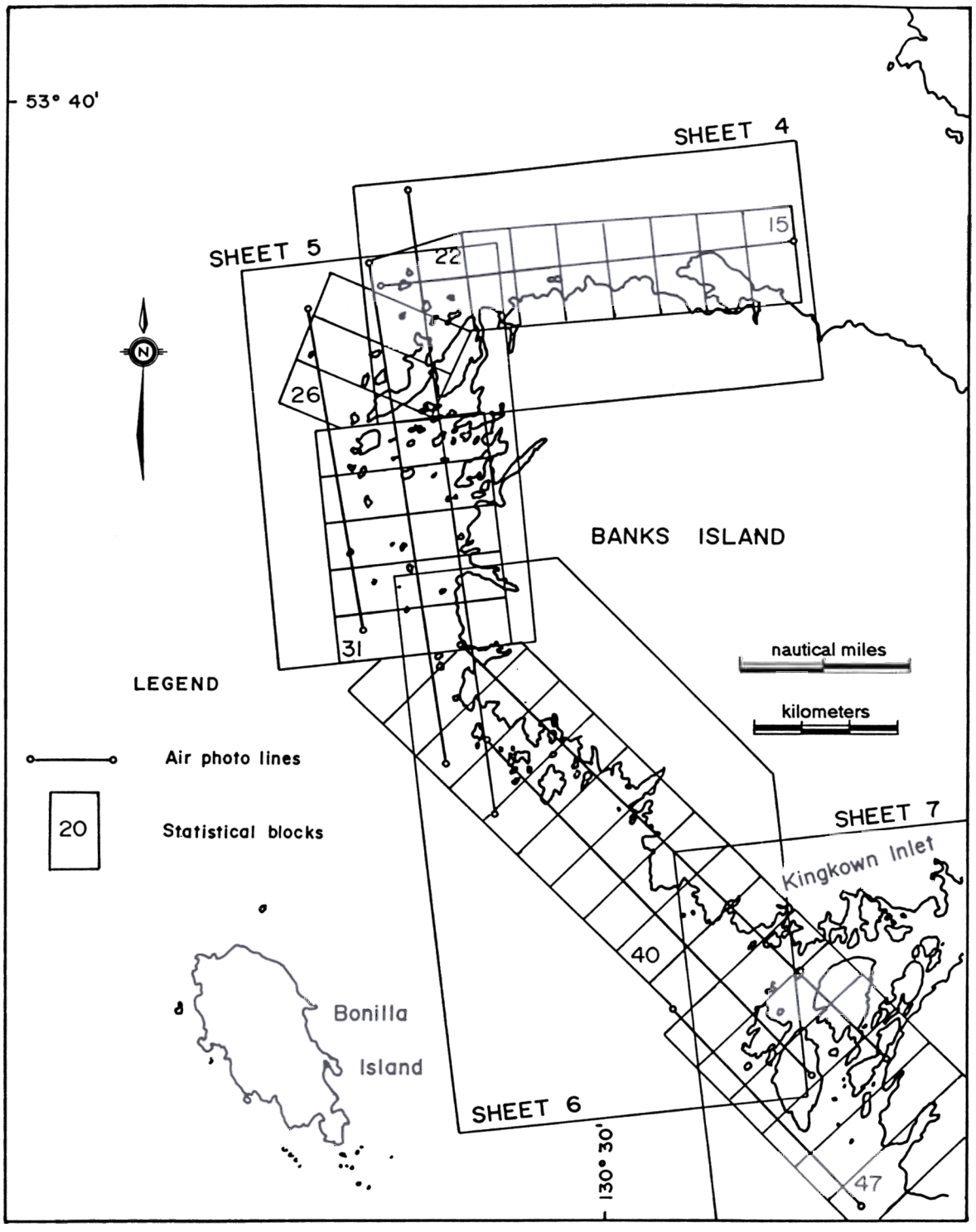

Figure 3. Map of the Banks Island inventory area for 1996 showing the layout of statistical blocks 15 to 47, chart sheets 4-7 on which they are included in the appendix and the air photo flight lines.

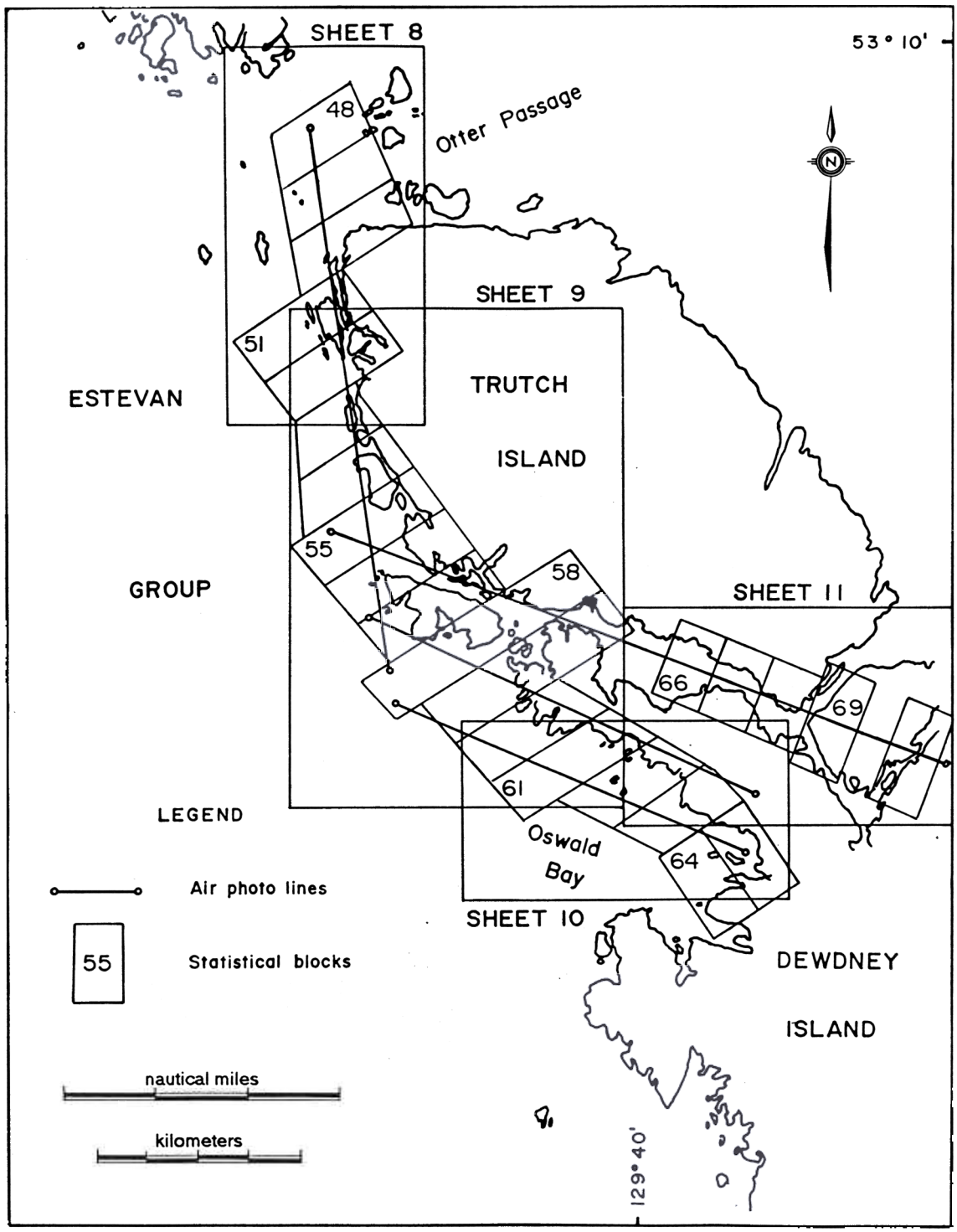

Figure 4. Map of the Estevan Group inventory area for 1996 showing the layout of statistical blocks 48 to 70, chart sheets 8 - 11 on which they are included in the appendix and the air photo flight lines.

Table 3. *Nereocystis* mean biomass per plant and *Macrocystis* mean biomass per frond values derived from Sept., 1995 field samples as used to calculate biomass estimates for the inventory area.

Nereocystis mean biomass/plant = 4.88 kg.	14 stations	SD = 2.50
Macrocystis mean biomass/frond = 0.73 kg.	21 stations	SD = 0.31

Table 4. Field determined *Macrocystis* density value derived from counts along Sept., 1995 transects used in total standing crop estimates for the inventory area.

Mean number of fronds per square meter of *Macrocystis* bed	= 7.07	21 stations	SD = 2.97

hectares of kelp bed in the inventory area, 741 hectares of *Nereocystis* made up 68%, 313 hectares of *Macrocystis* bed made up 29%, and 36 hectares of mixed bed made up the remaining 3%.

Tables 5 through 7 present estimates of kelp bed areas, density and biomass for bed types within each block of the three 1996 north coast inventory areas. Table 8 summarizes the data for the entire inventory area. Tables 9, 10 and 11 summarize the bed area and biomass estimates, the percent bed area and the percent biomass composition, respectively, for each bed type in each area.

Porcher Island/ Goschen Island

The aerial photography of the Porcher Island/Goschen Island area (see blocks 1-14 on chart sheets 1-3) was limited to a single flight pass in width which did not cover the full offshore extent of the kelp beds. This is evident in examination of the charts produced and by comparison with previous inventory work in the area (Coon *et al*, 1980). Within the photographic coverage, however, extensive beds of 221 hectares were estimated to contain 13,560 tonnes of kelp, primarily *Nereocystis* (193 hectares and 12,097 tonnes). 27 hectares of *Macrocystis* beds with estimated biomass of 1,416 tonnes were found over the 4 kilometers of Porcher Island shore immediately north of Cape George but not elsewhere. This area also contained less than 1 hectare of mixed beds.

Table 5. Estimates of kelp bed area and biomass for Porcher Island and Goschen Island - August 25, 1996. See Sheets 1-3 (appendix)
B = Biomass (metric tonnes) ha = hectare D = Density (no. of plants or fronds/hectare)

SHEETS 1-3	*Nereocystis* - Low Density					*Nereocystis* - High Density					*Macrocystis*						Mixed - Low Density			Mixed - High Density			Total	Total
											Low D	High D	Total											
Block	Photo. Mean D	Bottom Mean D	Area (ha)	Mean B/ha	B	Photo. Mean D	Bottom Mean D	Area (ha)	Mean B/ha	B	Bottom Mean D	Area (ha)	Area (ha)	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	B
	5,460	6,280	1.04	30.6	31.8	14,300	16,450	0.61	80.3	49.0													1.65	80.8
2	5,380	6,190	8.79	30.2	265.5	14,300	16,450	2.92	80.3	234.5	70,700	5.12	4.60	9.72	51.6	501.6				0.64	63.6	40.7	22.07	1,042.3
3	6,430	7,390	4.78	36.1	172.6	14,300	16,450	5.35	80.3	429.6	70,700	3.43	4.62	8.05	51.6	415.4				0.11	63.6	7.0	18.29	1,024.6
4	6,430	7,390	3.15	36.1	113.7	16,920	19,460	1.21	95.0	115.0	70,700	0.34	2.74	3.08	51.6	158.9							7.44	387.6
5										0.0	70,700	1.33	5.26	6.59	51.6	340.0							6.59	340.0
6	4,990	5,740	12.76	28.0	357.3	18,250	20,990	3.24	102.4	331.8													16.00	689.1
7	6,100	7,020	26.81	34.3	919.6	20,610	23,700	10.80	115.7	1,249.6													37.61	2,169.2
8	4,730	5,440	17.42	26.5	461.6	19,540	22,470	21.98	109.7	2,411.2													39.40	2,872.8
9	5,150	5,920	12.91	28.9	373.1	22,170	25,500	20.70	124.4	2,575.1													33.61	2,948.2
10	5,760	6,620	2.46	32.3	79.5	19,530	22,460	3.48	109.6	381.4													5.94	460.9
	5,720	6,580	8.03	32.1	257.8	15,890	18,270	5.88	89.2	524.5													13.91	782.3
	5,180	5,960	4.94	29.1	143.8	15,890	18,270	1.21	89.2	107.9													6.15	251.7
1	5,940	6,830	4.32	33.3	143.9	15,890	18,270	1.12	89.2	99.9													5.44	243.8
1	5,940	6,830	6.44	33.3	214.5	15,890	18,270	0.59	89.2	52.6													7.03	267.1
Blks. 1-14 Totals:			113.85		3,534.7			79.09		8,562.1		10.22	17.22	27.44		1,415.9	0.00		0.0	0.75		47.7	221.13	13,560.4

Table 6. Estimates of kelp bed area and biomass for Banks Island - August 24 and 25, 1996. See Sheet 4-7 (appendix)
B = Biomass (metric tonnes) ha = hectare D = Density (no. of plants or fronds/hectare)

SHEETS 4-7	*Nereocystis* - Low Density					*Nereocystis* - High Density					*Macrocystis*						Mixed - Low Density			Mixed - High Density			Total	Total
											Low D	High D	Total											
Block	Photo. Mean D	Bottom Mean D	Area (ha)	Mean B/ha	B	Photo. Mean D	Bottom Mean D	Area (ha)	Mean B/ha	B	Bottom Mean D	Area (ha)	Area (ha)	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	B
15	5,230	6,010	2.01	29.3	58.9	18,430	21,190	0.76	103.4	78.6	70,700	1.18	1.43	2.61	51.6	134.7							5.38	272.2
16	5,230	6,010	3.55	29.3	104.0	18,430	21,190	1.84	103.4	190.3	70,700	0.42	0.45	0.87	51.6	44.9				1.27	73.4	93.2	7.53	432.4
17	5,660	6,510	4.05	31.8	128.8	18,430	21,190	2.96	103.4	306.1	70,700	4.71	5.67	10.38	51.6	535.6	1.51	43.3	65.4	1.62	73.4	118.9	20.52	1,154.8
18	6,040	6,950	2.09	33.9	70.9	18,430	21,190	3.37	103.4	348.5	70,700	16.17	18.48	34.65	51.6	1,787.9	0.54	44.2	23.9	1.28	73.4	94.0	41.93	2,325.2
19	5,110	5,880	1.21	28.7	34.7					0.0	70,700	17.12	15.29	32.41	51.6	1,672.4	0.20	42.0	8.4	0.44	29.9	13.2	34.26	1,728.7
20	5,030	5,780	5.78	28.2	163.0	15,630	17,970	1.16	87.7	101.7	70,700	13.02	14.24	27.26	51.6	1,406.6	1.22	41.8	51.0	2.58	66.8	172.3	38.00	1,894.6
21	4,750	5,460	21.27	26.6	565.8	17,000	19,550	3.61	95.4	344.4	70,700	8.17	7.34	15.51	51.6	800.3	0.66	41.1	27.1	0.85	70.0	59.5	41.90	1,797.1
22	6,460	7,430	7.15	36.3	259.5	17,000	19,550	2.77	95.4	264.3	70,700	4.33	2.47	6.80	51.6	350.9	3.27	45.2	147.8	11.38	70.0	796.6	31.37	1,819.1
23	6,240	7,180	4.48	35.0	156.8	18,010	20,710	7.93	101.1	801.7	70,700	0.21	0.34	0.55	51.6	28.4	0.32	44.6	14.3	3.40	72.4	246.2	16.68	1,247.4
24	6,340	7,290	12.85	35.6	457.5	18,030	20,730	7.04	101.2	712.4	70,700	4.29	2.42	6.71	51.6	346.2	0.77	44.9	34.6	0.65	72.4	47.1	28.02	1,597.8
25	6,970	8,020	8.52	39.1	333.1	19,900	22,890	6.00	111.7	670.2	70,700	5.08	4.84	9.92	51.6	511.9				0.56	76.8	43.0	25.00	1,558.2
26	5,690	6,540	10.29	31.9	328.3	21,940	25,230	3.68	123.1	453.0	70,700	1.14	3.09	4.23	51.6	218.3	0.61	43.3	26.4	0.38	81.6	31.0	19.19	1,057.0
27	6,400	7,360	8.58	35.9	308.0	21,940	25,230	5.23	123.1	643.8	70,700	20.67	8.07	28.74	51.6	1,483.0							42.55	2,434.8
28	7,850	9,030	29.45	44.1	1,298.7	22,600	25,990	9.29	126.8	1,178.0	70,700	14.83	3.25	18.08	51.6	932.9	0.19	48.4	9.2	0.14	83.2	11.6	57.15	3,430.4
29	5,870	6,750	20.88	32.9	687.0	19,640	22,590	6.01	110.2	662.3	70,700	0.11	0.09	0.20	51.6	10.3							27.09	1,359.6
30	7,390	8,500	12.94	41.5	537.0	19,640	22,590	1.93	110.2	212.7													14.87	749.7
31	7,270	8,360	4.16	40.8	169.7	18,990	21,840	0.77	106.6	82.1													4.93	251.8
32	7,270	8,360	2.17	40.8	88.5	18,990	21,840	0.28	106.6	29.8	70,700	0.00	0.02	0.02	51.6	1.0				0.26	74.7	19.4	2.73	138.7
33	7,630	8,770	3.69	42.8	157.9	18,990	21,840	0.53	106.6	56.5													4.22	214.4
34	7,630	8,770	6.20	42.8	265.4	13,330	15,330	4.08	74.8	305.2	70,700	2.13	1.52	3.65	51.6	188.3							13.93	758.9
35	6,970	8,020	6.09	39.1	238.1	13,330	15,330	2.93	74.8	219.2	70,700	5.68	1.99	7.67	51.6	395.8							16.69	853.1
36	5,920	6,810	9.71	33.2	322.4	13,330	15,330	1.84	74.8	137.6	70,700	1.44	0.49	1.93	51.6	99.6							13.48	559.6
37	6,220	7,150	16.97	34.9	592.3	13,330	15,330	0.59	74.8	44.1	70,700												17.56	636.4
38	5,340	6,140	10.97	30.0	329.1	14,580	16,770	2.19	81.8	179.1	70,700												13.16	508.2
39	7,220	8,300	4.43	40.5	179.4	19,100	21,970	0.48	107.2	51.5	70,700	0.00	0.12	0.12	51.6	6.2							5.03	237.1
40	7,220	8,300	10.20	40.5	413.1	19,100	21,970	3.47	107.2	372.0													13.67	785.1
41	6,570	7,560	15.34	36.9	566.0	19,110	21,980	9.71	107.3	1,041.9													25.05	1,607.9
42	6,310	7,260	24.80	35.4	877.9	15,340	17,640	15.79	86.1	1,359.5	70,700	1.07	0.88	1.95	51.6	100.6				0.40	66.1	26.4	42.94	2,364.4
43	6,800	7,820	10.16	38.2	388.1	15,450	17,770	1.36	86.7	117.9	70,700	0.20	0.10	0.30	51.6	15.5							11.82	521.5
44	6,610	7,600	7.23	37.1	268.2	16,320	18,770	2.34	91.6	214.3	70,700	0.38	0.13	0.51	51.6	26.3							10.08	508.8
45	6,270	7,210	16.19	35.2	569.9	16,730	19,240	6.65	93.9	624.4	70,700	2.81	0.45	3.26	51.6	168.2							26.10	1,362.5
46	6,310	7,260	2.58	35.4	91.3	16,730	19,240	0.13	93.9	12.2	70,700	0.87	0.17	1.04	51.6	53.7							3.75	157.2
47	6,740	7,750	0.96	37.8	36.3	16,730	19,240	0.03	93.9	2.8													0.99	39.1
Blks. 15-47 Totals:			306.95		11,045.6			116.75		11,818.1		126.03	93.34	219.37		11,319.5	9.29		408.1	25.21		1,772.4	677.57	36,363.7

Table 7. Estimates of kelp bed area and biomass for The Estevan Group - August 24, 1996. See Sheet 8-11 (appendix)
B = Biomass (metric tonnes) ha = hectare D = Density (no. of plants or fronds/hectare)

SHEETS 8-11	*Nereocystis* - Low Density					*Nereocystis* - High Density					*Macrocystis*						Mixed - Low Density			Mixed - High Density			Total	Total
												Low D	High D	Total									Area	
Block	Photo. Mean D	Bottom Mean D	Area (ha)	Mean B/ha	B	Photo. Mean D	Bottom Mean D	Area (ha)	Mean B/ha	B	Bottom Mean D	Area (ha)	Area (ha)	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	(ha)	B
48	5,830	7,350	0.95	35.9	34.1	18,540	23,360	0.83	114.0	94.6													1.78	128.7
49	5,830	7,350	5.70	35.9	204.6	18,540	23,360	3.20	114.0	364.8													8.90	569.4
50	5,400	6,800	3.94	33.2	130.8	19,280	24,290	1.62	118.5	192.0													5.56	322.8
51	5,220	6,580	8.31	32.1	266.8	18,170	22,890	1.60	111.7	178.7	70,700		0.27	0.27	51.6	13.9							10.18	459.4
52	6,230	7,850	9.55	38.3	365.8	18,170	22,890	2.18	111.7	243.5	70,700	1.98	2.10	4.08	51.6	210.5							15.81	819.8
53	5,860	7,380	5.42	36.0	195.1	18,170	22,890	1.21	111.7	135.2	70,700	0.20	0.01	0.21	51.6	10.8							6.84	341.1
54	5,830	7,350	8.93	35.9	320.6	17,160	21,620	2.01	105.5	212.1	70,700	0.14	0.83	0.97	51.6	50.1							11.91	582.8
55	5,670	7,140	7.23	34.8	251.6	17,160	21,620	0.71	105.5	74.9	70,700	1.20	0.94	2.14	51.6	110.4							10.08	436.9
56	7,520	9,480	8.58	46.3	397.3	17,160	21,620	1.67	105.5	176.2	70,700	5.10	2.40	7.50	51.6	387.0				0.17	74.2	12.6	17.92	973.1
57	6,650	8,380	5.74	40.9	234.8	17,160	21,620	0.32	105.5	33.8	70,700	2.33	0.96	3.29	51.6	169.8							9.35	438.4
58	6,870	8,660	11.13	42.3	470.8	19,250	24,260	0.75	118.4	88.8	70,700	5.03	0.68	5.71	51.6	294.6							17.59	854.2
59	7,200	9,070	9.85	44.3	436.4	19,250	24,260	1.64	118.4	194.2	70,700	3.29	1.08	4.37	51.6	225.5							15.86	856.1
60	6,350	8,000	5.31	39.0	207.1	19,250	24,260	0.11	118.4	13.0	70,700	1.34	1.84	3.18	51.6	164.1							8.60	384.2
61	6,870	8,660	8.36	42.3	353.6	19,250	24,260	0.36	118.4	42.6	70,700	0.33	1.21	1.54	51.6	79.5	0.41	47.7	19.6				10.67	495.3
62	7,450	9,390	4.67	45.8	213.9	19,250	24,260	0.25	118.4	29.6	70,700	0.59	0.35	0.94	51.6	48.5							5.86	292.0
63	7,450	9,390	1.33	45.8	60.9	19,250	24,260	0.08	118.4	9.5													1.41	70.4
64	7,450	9,390	0.32	45.8	14.7						70,700	3.03	1.96	4.99	51.6	257.5							5.31	272.2
65	7,450	9,390	0.63	45.8	28.9						70,700	0.88	0.88	1.76	51.6	90.8							2.39	119.7
66											70,700	7.64	0.65	8.29	51.6	427.8							8.29	427.8
67											70,700	1.24	0.00	1.24	51.6	64.0							1.24	64.0
68											70,700	8.39	0.45	8.84	51.6	456.1							8.84	456.1
69											70,700	3.69	0.42	4.11	51.6	212.1							4.11	212.1
70											70,700	2.64	0.30	2.94	51.6	151.7							2.94	151.7
Blks. 48-70 Totals:			105.95		4,187.8			18.54		2,083.5		49.04	17.33	66.37		3,424.7	0.41		19.6	0.17		12.6	191.44	9,728.2

Table 8. Total estimates of kelp bed area and biomass for Porcher Island, Goschen Island, Banks Island and the Estevan Group - August 24 and 25, 1996. See Sheets 1-11 (appendix) B = Biomass (metric tonnes) ha = hectare D = Density (no. of plants or fronds/ha)

	Nereocystis - Low Density		*Nereocystis* - High Density		*Macrocystis*				Mixed - Low Density		Mixed - High Density		Total	Total
					Low D	High D	Total							
	Area (ha)	B	Area (ha)	B	Area (ha)	Area (ha)	Area (ha)	B	Area (ha)	B	Area (ha)	B	Area (ha)	B
Total Blocks 1-70:	526.75	18,768.1	214.38	22,463.7	185.29	127.89	313.18	16,160.1	9.70	427.7	26.13	1,832.7	1,090.14	59,652.3

Banks Island

The Banks Island inventory area (see blocks 15-47 on chart sheets 4-7) is the largest of the three 1996 north coast inventory areas. Including 33 of the 70 kilometer blocks, it contains 62% (678 ha.) of the kelp bed area and 61% (36,364 tonnes) of the biomass. The northwest side of Banks Island covered by the inventory (blocks 29-47), north to the Borrowman Group (blocks 27,28), was predominantly made up of small beds with the exception of the Goring Reef area (blocks 41-42). Of the 268 hectares of bed area and 13,614 tonnes biomass in this northwest section, *Nereocystis* made up 92% of both bed area and biomass while Macrocystis made up 8% and mixed beds less than 1% of both bed area and biomass.

The remaining section in this inventory area including the Borrowman Group and the north side of Banks Island (blocks 15-28) contained the most extensive beds (410 hectares and 22,750 tonnes). In this section *Macrocystis* was more significant making up 49% (199 ha.) of the bed area and 45% (10,254 tonnes)of the estimated biomass. *Nereocystis* made up 43% of the bed area and 46% of the biomass; mixed beds accounted for the remaining 8% of bed area and 9% of the biomass. While most of the Banks Island area covered is irregular in depths and contains many shallow reefs, charts show the Larsen Harbour to Deadman Inlet foreshore on the north side (blocks 17-22) which has the largest *Macrocystis* beds contains flatter, more uniform bottom areas.

Estevan Group (Blocks 48-70)

The 23 statistical kilometer blocks on the west coast of the Estevan Group (blocks 48-70 and chart sheets 8-11) contain the lowest amount of kelp bed area (191 ha.) and biomass (9,728 tonnes) of the three 1996 inventory areas. The area contains numerous reefs and includes only small beds, of which 35% are *Macrocystis* by area and biomass (66 hectares and 3,425 tonnes), the remainder being *Nereocystis* (124 hectares and 6,271 tonnes) with a very small amount of mixed beds (<1 hectare and 32 tonnes). Both species were found throughout the outer coast, except at the offshore islands in Otter Passage to the north where *Nereocystis* was alone. Beyond its entrances, Langley Passage, a protected channel behind Nichol and Barnard Islands(parts of blocks 56-59 and blocks 66-70), contained only *Macrocystis.*

Table 9: Total standing crop biomass and kelp bed area estimates for each geographic area summarized by kelp species for the 1996 inventory area.

Area	Geographic area	Biomass (metric tonnes)	Area (hectare)
	Low Density *Nereocystis*		
Area 1	Porcher Island/ Goschen Island	3,534.7	113.
Area 2	Banks Island	11,045.6	306.
Area 3	Estevan Group	4,187.8	105.
	High Density *Nereocystis*		
Area 1	Porcher Island/ Goschen Island	8,562.1	79.
Area 2	Banks Island	11,818.1	116.
Area 3	Estevan Group	2,083.5	18.
	Low and High Density *Macrocystis*		
Area 1	Porcher Island/ Goschen Island	1,415.9	27.44
Area 2	Banks Island	11,319.5	219.37
Area 3	Estevan Group	3,424.7	66.37
	Low Density Mixed		
Area 1	Porcher Island/ Goschen Island	0.0	0.00
Area 2	Banks Island	408.1	9.29
Area 3	Estevan Group	19.6	0.41
	High Density Mixed		
Area 1	Porcher Island/ Goschen Island	47.7	0.75
Area 2	Banks Island	1,772.4	25.21
Area 3	Estevan Group	12.6	0.17
	Total of all species for entire inventory area:	59,652.3	1,090.14

Kelp Bed Area (hectares)	*Nereo*	*Macro*	Mix	Total
Porcher Island/ Goschen Island	192.94	27.44	0.75	221.13
Banks Island	423.70	219.37	34.50	677.57
Estevan Group	124.49	66.37	0.58	191.44
Total:	741.13	313.18	35.83	1,090.14

Biomass (tonnes)	*Nereo*	*Macro*	Mix	Total
Porcher Island/ Goschen Island	12,096.8	1,415.9	47.7	13,560.4
Banks Island	22,863.7	11,319.5	2,180.5	36,363.7
Estevan Group	6,271.3	3,424.7	32.2	9,728.2
Total:	41,231.8	16,160.1	2,260.4	59,652.3

Table 10. Percent composition of low and high density *Nereocystis, Macrocystis* and mixed bed area in each chart area. The last column gives percent composition of the kelp bed surface area for the entire 1996 inventory area.

Bed Area Area:	Porcher Island Goschen Island	Banks Island	Estevan Group	Combined
Nereocystis				
-low density	51.5%	45.3%	55.3%	48.3%
-high density	35.8%	17.2%	9.7%	19.7%
Macrocystis				
-high and low	12.4%	32.4%	34.7%	28.7%
Mixed				
-low density	0.0%	1.4%	0.2%	0.9%
-high density	0.3%	3.7%	0.1%	2.4%

Table 11. Percent composition of low and high density *Nereocystis, Macrocystis* and mixed bed total biomass in each chart area. The last column gives percent composition of the total biomass for the entire 1996 inventory area.

Biomass Area:	Porcher Island Goschen Island	Banks Island	Estevan Group	Combined
Nereocystis				
-low density	26.1%	30.4%	43.1%	31.5%
-high density	63.1%	32.5%	21.4%	37.7%
Macrocystis				
-high and low	10.4%	31.1%	35.2%	27.1%
Mixed				
-low density	0.0%	1.1%	0.2%	0.7%
-high density	0.4%	4.9%	0.1%	3.1%

Comparison With Previous North Coast Kelp Inventories

Sections of coast covered by the present inventory along the Porcher Island/Goschen Island and the Estevan Group shores were also included in past inventories (Coon *et al*, 1980; and Field *et al*, 1977).

Unfortunately, the 1996 aerial photography of the Porcher Island/Goschen Island area did not include the full offshore extent of kelp beds as covered in the 1976 survey.

precluding comparison of numerical results. Viewing of sections of kelp beds in the Porcher Island/Goschen Island area covered in both years, however, suggests that bed areas have remained similar with, perhaps, a trend towards more high density beds in 1996.

In the Estevan Group, a 14 kilometer section of the western shores of Trutch Island and Barnard Island including statistical blocks 51 to 63 and 65 overlaps well with 1976 coverage. Table 12 presents the kelp bed area and total standing crop biomass estimates for 1976 and 1996 in the overlap area by bed type. Figure 5 presents the information graphically by species. When all bed types are included for this area, the 1996 bed area and biomass estimates are roughly half of the 1976 estimate (53% and 48%, respectively).

In the 1976 inventory of the overlap area, *Macrocystis* made up 4% of the bed area and less than 1% of the total biomass; in 1996 the species reached 25% of the bed area and 26% of the biomass. *Macrocystis* bed area was found to be 3 times larger in 1996 than 1976 while the average biomass per hectare for the species in 1996 of 51.6 tonnes/ha. was 5.3 times the 1976 value of 9.8 tonnes/ha. when high and low density *Macrocystis* are not considered. Accordingly, the *Macrocystis* biomass estimate for 1996 was almost 16 times the 1976 estimate.

Table 12. Kelp bed area and total standing crop biomass estimates for a 14 kilometer region of overlap in 1976 and 1996 inventories of the Estevan Group by bed type and summarized by species. 1976 Blks. 67-68, 70-78, 80-82; 1996 Blks. 51- 63, 65. (1976 data adapted from Field *et al*, 1977); high and low denote density; N = *Nereocystis*; M = *Macrocystis*; Mix = mixed beds.

Area (hectares)

	Low N	High N	Low M	High M	High & Low M	Low Mix	High Mix	Total
1976	118.30	137.90	4.77	7.26	12.03	3.01	2.49	273.73
1996	95.04	12.89	22.41	13.55	35.96	0.41	0.17	144.47

	N	M	Mix	Total
1976	256.20	12.03	5.50	273.73
1996	107.93	35.96	0.58	144.47

Total Biomass (tonnes)

	Low N	High N		High & Low M	Low Mix	High Mix	Total
1976	3,780.6	10,881.5		117.7	43.9	123.4	14947.1
1996	3,803.6	1,432.1		1,855.5	19.6	12.6	7123.4

	N	M	Mix	Total
1976	14,662.1	117.7	167.3	14,947.1
1996	5,235.7	1,855.5	32.2	7,123.4

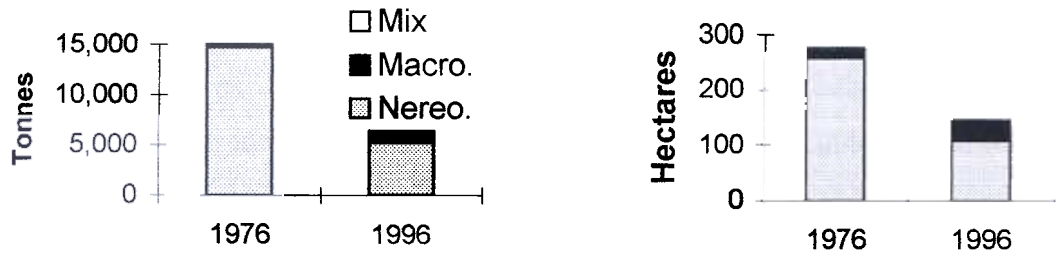

Figure 5. Bar charts showing changes in biomass and bed area by species for the 14 kilometer region of overlap in 1976 and 1996 inventories.

Nereocystis bed area and biomass estimates declined over the 20 years and by 1996 are 42% and 36%, respectively, of the 1976 estimates. The species also makes up a lower portion of the total bed area and biomass. In the 1976 inventory estimate, 94% of the bed area and 98% of the biomass in the area of overlap was made up of *Nereocystis*; this has declined to 75% of the bed area and 74% of the biomass in 1996. Mixed beds are not extensive in the region of overlap, making up only 2% of the bed area in 1976 and less than 1% in 1996.

In comparing the results of the two inventories, it is important to consider the changes to methodologies and the manner of reporting the data that have taken place. When good aerial photographic coverage is available, kelp bed area determination can be quite exacting. Methods used for measuring area have taken advantage of new technologies but in general the process has changed little. The spatial extent of kelp beds in inventory work is determined by the air photo image available for interpretation. As described above, a lesser amount of kelp is able to reach the water surface as the tide height increases. Tide height at the time of the 1976 photography was one meter below MWL (for the KIM-1 method this is MWL -1m $\pm$ 0.6 m). In the 1996 photography tide height was at MWL (actually at the upper limit of MWL $\pm$0.6m) and less kelp should be visible. In theory the difference in density should be accounted for during correction of *Nereocystis* to total density for both years and for *Macrocystis* for 1976 and should not be a concern for *Macrocystis* for 1996. Decreases in the visible kelp bed extent with increasing tide height, however, may be a consideration. The kelp beds within the area of 1976 and 1996 inventory overlap are generally small. Whether due to tidal factors at the

time of photography or to actual decreases in bed extent, many of the beds charted in 1976 are visible as patches of reduced size in the 1996 photography.

Mean biomass per plant or frond and density estimation have both undergone changes. Both are used in combination with bed area to estimate kelp biomass. As shown in Table 13, mean biomass per plant and frond values are quite similar for 1976 and 1996.

Table 13. The mean total biomass per plant and frond for both the 1976 and 1996 Estevan Group inventories. (1976 data from Field *et al*, 1977)

Inventory Date	*Nereocystis*	*Macrocystis*
1976	4.67 kg.	0.69 kg.
1996	4.88 kg.	0.73 kg.

In the 1976 inventory work for the area, results were reported as biomass above MWL. 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 MWL for these species and care should be used when comparing estimates from past inventory work. *Nereocystis* density in both years and Macrocystis density for 1976 was derived using the point intercept method. In this comparison, 1976 values have been converted to total standing crop biomass using the appropriate combined biomass and density factors from the report. As mentioned above, 1996 calculations for *Nereocystis* total density used a conversion factor based on the vertical distribution of plant numbers from 1976. As the mean biomass per frond values differ little, increased density is largely the cause of the increase in *Macrocystis* biomass per hectare for 1996. *Macrocystis* density values for 1996 were derived from underwater transect counts which have been found, in practice, to result in biomass estimates 1.4 to 1.9 times those that result when KIM-1 density methods are used (Sutherland, 1990).

Melville Island/Dunira Island and Kitasu Bay/Higgins Pass field samples

Field sample data was obtained for two regions that were not covered by aerial photography. Table 14 presents the field-determined mean biomass per plant or frond (total wet weight) estimates obtained from *Nereocystis* and *Macrocystis* sampling stations

in the Melville Island/Dunira Island area to the north of the main inventory area on September 9, 1995 and Kitasu Bay/Higgins Pass area to the south on September 19 to 22, 1995 (see Figure 1). Table 15 presents the transect derived density per square meter values for *Macrocystis*.

Table 14. *Nereocystis* mean biomass per plant and *Macrocystis* mean biomass per frond estimates from Sept., 1995 field samples for areas not covered in inventory.

Melville Island/Dunira Island	September 9, 1995		
Nereocystis mean biomass/plant = 3.67 kg.	1 station (10 plants sampled)		
Macrocystis mean biomass/frond = 1.36 kg.	10 stations	SD = 1.08	
(station max. = 3.91 kg.; station min. = 0.21 kg.; 239 fronds sampled)			
Kitasu Bay/Higgins Pass	September 19 to 22, 1995		
Nereocystis mean biomass/plant = 1.96 kg.	4 stations	SD = 0.84	
(station max. = 2.57 kg.; station min. = 0.77 kg.; 47 plants sampled)			
Macrocystis mean biomass/frond = 0.57 kg.	26 stations	SD = 0.29	
(station max. = 1.34 kg.; station min. = 0.24 kg.; 1,070 fronds sampled)			

Table 15. Field determined *Macrocystis* density value from Sept., 1995 transect samples for areas not covered in inventory. Each station represents an 80 sq.m. transect.

Melville Island/Dunira Island	September 9, 1995		
Mean fronds/ sq.m. = 4.62	10 stations	SD = 2.75	
(station max. = 9.63/sq.m.;	station min. = 1.86/sq.m.)		
Kitasu Bay/Higgins Pass	September 19 to 22, 1995		
Mean fronds/ sq.m. = 4.84	27 stations	SD = .68	
(station max. = 17.9/sq.m.;	station min. = 0.00/ sq.m.)		

The *Nereocystis* mean biomass per plant values from field data are lower in both Melville Island/Dunira Island and Kitasu Bay/Higgins Pass (although only one *Nereocystis* sample was taken in the former) than in the inventory area covered by this report. *Macrocystis* mean biomass per frond is higher at Melville Island/Dunira Island than in the inventory area but is lower than the inventory area at Kitasu Bay/Higgins Pass. *Macrocystis* density is lower in both of these areas than in the inventory area.

DISCUSSION

Prior to 1974, methods used to estimate kelp stocks in British Columbia were limited by problems such as "poor repeatability, inaccuracy in estimating aerial 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 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* 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 have attempted to provide more accurate estimates of *Macrocystis* stocks and to streamline field work. 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 method (Sutherland, 1990). Further testing would be required to fully determine the accuracy of standing crop estimates, possibly by comparing actual harvest yield against the estimates generated by the inventory methods.

The mean biomass per *Nereocystis* plant for the inventory area, at 4.88 kg. was slightly below average for previous northern British Columbia coast surveys. Over the entire inventory area, low density *Nereocystis* beds averaged 3.6 kg. per square meter, high density *Nereocystis* beds averaged 10.5 kg. The mean biomass per *Macrocystis* frond for the inventory was 0.73 kg. which is at the lower end of the range northern British Columbia coast surveys. *Macrocystis* beds covered by the survey had a mean total biomass of 5.2 kg. per square meter. Low density mixed beds averaged 4.4 kg. and high density mixed beds averaged 7.0 kg. per square meter.

The major concentrations of kelp within the survey areas were found in the Porcher Island/ Goschen Island and Banks Island areas. The Porcher Island/ Goschen Island area was the smallest of the three north coast inventory areas surveyed in 1996. Although the photographic coverage did not extend to the full offshore extent of the kelp beds, it included considerable quantities of *Nereocystis*. The Banks Island inventory area covered the largest stretch of coast and contained the most kelp of all bed types in terms

of bed area and biomass and included some extensive beds of both species. The Estevan Group inventory area consisted primarily of small *Nereocystis* and *Macrocystis* beds along the many reef areas.

The largest *Nereocystis* beds were found in blocks 7-9 in Freeman Passage between Porcher Island and Goschen Island (sheet 2, Table 5), blocks 21, 28 and 29 off the north and northwest shores of Banks Island (Sheets 4 and 5, Table 6), and blocks 41,42 and 45 near the entrances to Kingkown Inlet (Sheet 7, Table 6). The largest *Macrocystis* beds were found in blocks 18-20, 27 and 28 off the north and northwest shores of Banks Island (Sheets 4 and 5, Table 6).

One 14 kilometer section of coast along the west shores of the Estevan Group was inventoried in 1976 and in 1996. Although changes in methodology and differences in tide height at the time of photography between the inventories cloud the issue, estimates showed an overall decline over the twenty year period to approximately half of the bed area and biomass. *Macrocystis* beds increased during the period while *Nereocystis* beds declined. Mixed kelp made up less than 2% of beds in both years.

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APPENDIX

Charts on Sheets 1 through 11 are enclosed in the following envelope in reduced format.