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

V. Karpouzi
M. Mamoser
B. Carswell
B.C. Ministry of Environment

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Oceans and Marine Fisheries Branch

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AREAS OF THE BRITISH COLUMBIA CENTRAL COAST FROM HAKAI PASSAGE TO THE BARDSWELL GROUP

Prepared by

I. R. Sutherland
IEC Collaborative Marine Research
and Development Ltd.
and
V. Karpouzi
M. Mamoser
B. Carswell
B.C. Ministry of Environment

for

Oceans and Marine Fisheries Branch, B.C. Ministry of Environment
Fisheries and Oceans Canada
B.C. Ministry of Agriculture and Lands
Heiltsuk Tribal Council

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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 portions of the Central Coast of British Columbia from Hakai Passage to the Bardswell Group for August/ September, 2007. Colour infrared photography and digital mapping of kelp polygons directly from georeferenced digital images were used for the first time. Results estimated that 7,082 tonnes of *N. luetkeana*, 27,695 tonnes of *M. integrifolia* and 2,513 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 278.9, 786.8 and 82.0 hectares, respectively. Nine maps are presented which show the position, extent, species, and density of every discernible kelp bed within the survey area. For management purposes the area is divided into numbered, kilometer-wide blocks.

Results of the 2007 inventory are compared with 1993 inventory estimates for areas common to both. Information on bed area, biomass and species composition in 1993 and 2007 are presented in tabular and graphic formats and discussed.

INTRODUCTION

Nereocystis luetkeana (Mertens) Postels and Ruprecht, commonly called bull kelp, and *Macrocystis integrifolia* Bory, or giant kelp, 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 Kelp Inventory Method (KIM-1) developed by Foreman (1975). The method in its basic form combines bed area, density and species information taken from infrared aerial photographs with field-determined information on bed structure and plant weight to provide species-specific biomass estimates for each kilometer-wide section of coastline within a survey area. The method has been used to inventory major kelp stocks throughout the province as shown in Figure 1 (Coon, 1981; Coon *et al*, 1976, 1979, 1980, 1981, 1982; Field, 1996; Field *et al*, 1977, 1978; Sutherland, 1989, 1990, 1996, 1998).

The main use of marine plants in British Columbia is for the herring Spawn-on-Kelp industry; in 2007, of 53 marine plant harvesting licenses were issued in the province, 22 of these were issued for the harvest of *M. integrifolia* for this purpose and 300.1 Metric tonnes were landed. Additional licenses were issued for other species including *N. luetkeana*, *Laminaria* spp*., Alaria marginata, Porphyra* spp., *Fucus gardneri,* and *Salicornia* spp., which were either processed into dried and fresh products for human consumption or manufactured into cosmetics, pharmaceuticals, and 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

The present report contains the results of a 2007 survey of portions of the Hakai Passage to the Bardswell Group on the Central Coast of British Columbia undertaken jointly by the Oceans and Marine Fisheries Branch (OMFB) of the B.C. Ministry of Environment (MOE), Fisheries and Oceans Canada (DFO), the B.C. Ministry of Agriculture and Lands (MAL), and the Heiltsuk Tribal Council. The survey covered the same coastal areas that were previously surveyed in 1993 and described by Field (1996; see Figure 1). The 2007 survey is intended to provide recent kelp bed area and biomass data for the survey region and also allows comparison with the 1993 results. In the 14

years that have elapsed between surveys, the local stands of large kelp have been affected by seasonal and annual variation, longer-term changes, and small and large scale biological and oceanic events.

Kelp beds are important to other marine species and kelp inventory maps 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 for the Heiltsuk Band and the Hakai Lúxvbálís Conservancy Area.

Kelp inventory data, results and maps now form a component of the British Columbia Coastal Resource Information Management System (http://ilmbwww.gov.bc.ca/cis/coastal/others/crimsindex.htm), a digital database that includes a wide variety of coast and marine resources such as aquaculture, shoreline classification, selected fisheries information and offshore oil and gas information.

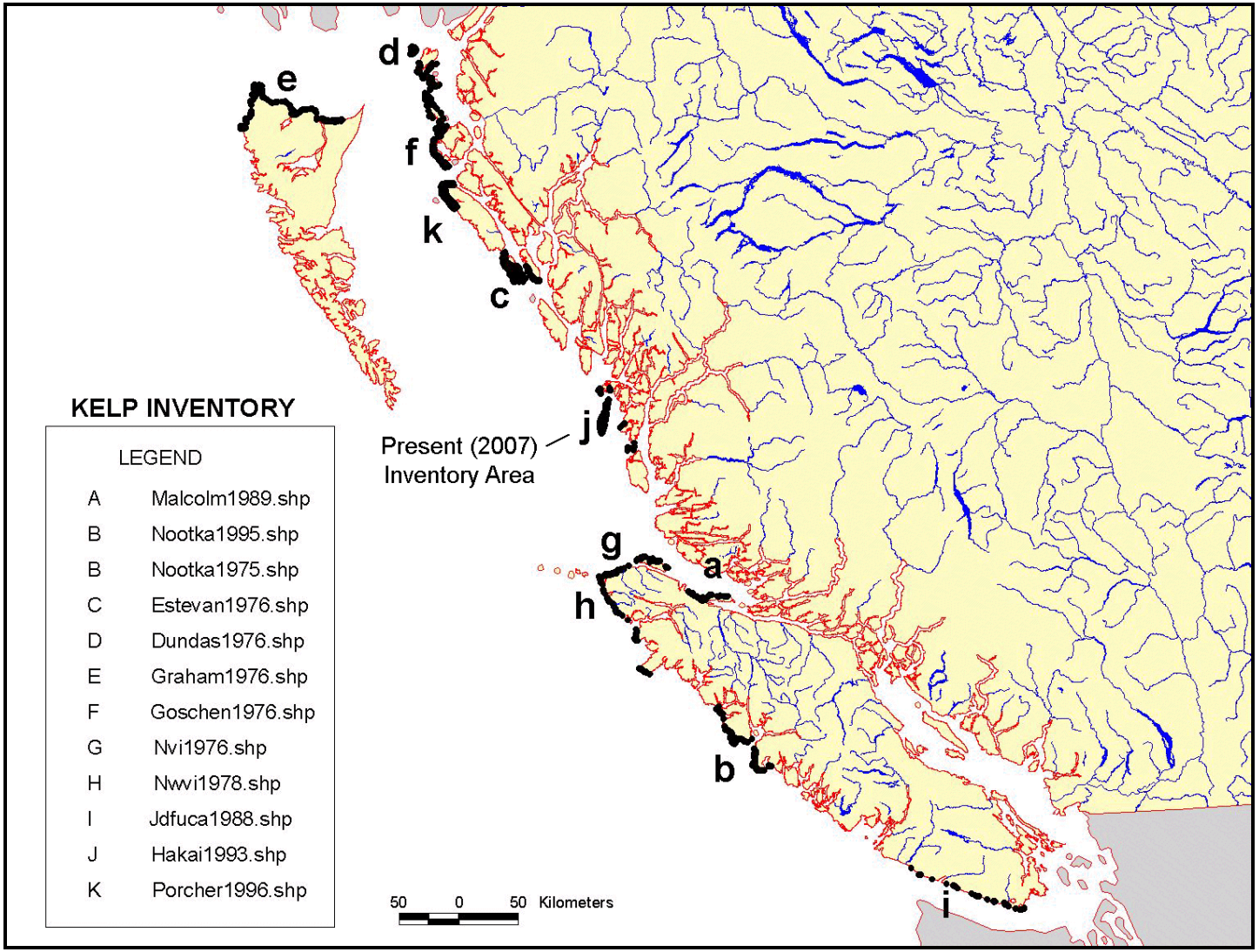

Figure 1. Map of the British Columbia coast showing locations of kelp inventories undertaken between 1975 and 2007. The legend indicates files of the inventory available through the Ministry of Environment website at http://www.agf.gov.bc.ca/fisheries/commercial/Historical_Kelp_Inventory.htm#REPORTS

MATERIALS AND 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 fieldwork component as well as to take advantage of new technologies such as digital photography and mapping. Modifications of this method as stated by Coon *et al* (1976), Field (1996), Field *et al* (1977), Field (1996) and Sutherland (1989, 1990 and 1996) were used in this study. In the 2007 inventory, colour infrared photography and digital mapping of kelp polygons directly from georeferenced digital images have been incorporated for the first time.

Aerial Photography and Mapping

Previously, the KIM-1 technique involved obtaining 24 cm format, 1:7,200 scale, black and white, infrared aerial photography of the kelp bed and shoreline in the desired region. Charts of the coastline and the offshore kelp beds were made by tracing on to Mylar film directly from the black and white IR negatives. For the present inventory, colour infrared aerial photography was undertaken of the area by Hauts-Monts Inc. under contract to Oceans and Marine Fisheries Branch in August and September, 2007 at the same scale. The images were scanned to digital form, georeferenced and kelp beds were traced using geographic information system (GIS) software directly from the digitized aerial photographs (for details of methods used in digital aerial photo interpretation, kelp bed mapping and *Nereocystis* density evaluation see Appendix I).

With initial assistance in air photo interpretation of the kelp beds and methodologies from IEC Collaborative Marine Research and Development Ltd. (IEC) under contract, OMFB staff continued with the interpretation, developed methods to integrate the digital photography and map kelp bed polygons, placed the statistical kilometer blocks, calculated the areas of kelp bed polygons, obtained *Nereocystis* densities from the photography and produced digital data files and maps of the inventory areas (see Appendix I for methods). The Ministry provided the field data and the maps and data derived from the aerial photographs to IEC who completed the data analysis for the inventory and produced the present report.

The kelp bed maps produced from the photographs are divided to sections, or blocks, that are 1 kilometer in width along the shore for statistical purposes. Kelp bed surface area data for each statistical kilometer block is derived from these maps for 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 (10 or greater plants or fronds per 10 square meters).

Nereocystis Density

Density for *Nereocystis* for the tide level at the time of photography (ideally at a tide height of Mean Water Level $\pm$ 0.6 meters for the KIM-1 method and as was the case for the present inventory) was determined from the aerial photographs by the KIM-1 point intercept method (Foreman, 1975) adapted for digital techniques (see Appendix I). *Nereocystis* beds are made up of plants of varying lengths and so the density of *Nereocystis* plants visible on the surface at the time of photography varies with tide height. In order to relate density data from the photos to other levels a conversion factor based on the vertical distribution of plants in field samples has been used. This data was not available for the present Inventory and an average conversion factor was used as employed in the 1993 inventory for the area (Field, 1996; the average was calculated from field data from previous inventories ranging from Vancouver Island to the Queen Charlotte Islands as shown in Table 1). The conversion factor was used as follows:

Total (bottom) Density = Density at Mean Water Level x 1.13

Table 1. *Nereocystis* density conversion factors from previous inventory work in northern British Columbia and the average value calculated and used in the present report to convert density at MWL to total or bottom density.

Inventory Area and Source	Conversion Factor
Northern Vancouver Island (Coon et al., 1981)	1.05
NE Vancouver Island and Malcolm Island (Sutherland, 1990)	1.12
Estevan Group and Campania Island (Field et al., 1977)	1.27
Goschen Is. to Tree Nob Group (exposed; Coon et al., 1980)	1.15
Goschen Is. to Tree Nob Group (sheltered; Coon et al., 1980)	1.11
Dundas Group (exposed; Field et al., 1978)	1.15
North and West Graham Island, QCI (Coon et al., 1981)	1.04
	1.13

Field Sampling

Near the time of year that the beds were photographed, 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.* Under contract to the Heiltsuk Tribal Council and the Hakai Lúxvbálís Conservancy Area and at the direction of T. Norgard field data was collected in August, 2007 by, K. Cripps, D. Paltzat, R. Wilson and S. Humchitt (see Appendix II for field survey report including methods). The field sampling records of the locations of sample stations and species sampled are invaluable as an aid in identification or confirmation of the species during later interpretation of aerial photography.

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.

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. The average *Macrocystis* density value determined from field transects was 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.

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	=	0.42	X	Mean biomass per ha. of low or high *Nereocystis*	+	0.58	X	Mean biomass per ha. of *Macrocystis*

The 0.42 and 0.58 values in the equation are derived from the ratio found to occur in samples used in development of the KIM-1 method (Foreman, 1975). Low or high density is not considered for the *Macrocystis* portion of the calculation.

Data obtained from the aerial photography is combined with field sampling data to produce biomass estimates. Kelp biomass was determined by multiplying the mean weight per plant or frond values by the plant or frond densities at the sea bottom and multiplying this product by the observed bed areas. All biomass estimates in this report are of total standing crop.

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 12:50 and 15:20 on August 22, 2007 and between 13:31 and 14:18 on September 8, 2007 (Pacific Standard Time). Approximately half of the photography was found to be within the desired 10:00 to 14:00 range that provides proper sun angles for best IR picture quality and to minimize reflected glare. (Roll: 30BCF07060; Base Map Online Store at Province of British Columbia website http://openmaps.gov.bc.ca/imfows13/imf.jsp?site=idt). Some glare from waves was noted in the photography but by using non-glare areas of images, interpretation was possible (comm. with MOE staff). Port Hardy weather (Port Hardy is 120 km south of the inventory area) showed clear/ cloud/ fog with light winds on August 22, 2007 and mainly clear with moderate winds on September 8, 2007 (Environment Canada website historical data http://www.climate.weatheroffice.ec.gc.ca/climateData/canada_e.html).

Observed water levels from the tidal gauges at Bella Bella, the nearest port from the Integrated Science Data Management, DFO, were corrected to the inventory areas using the secondary port of Gosling Island (http://www-sci.pac.dfo-mpo.gc.ca/charts/tides/owl_e.htm). Tidal height at the time of photography was found to be within the MWL $\pm$0.6 meter KIM-1 tidal range.

Inventory Areas and Statistical Block Locations

Figure 2 indicates the locations of statistical blocks in the inventory area. Placement of the kilometer wide blocks has been kept the same as the 1993 inventory layout to aid in comparison but block numbers have been given a letter prefix (a to f) to more easily indicate the geographic area. As in 1993, the inventory area has been divided to six geographic areas. Disposition of kelp beds within the areas is illustrated on 9 maps which can be found in Appendix III. The six geographic areas and map layout are as follows:

a) Hakai Passage and Stirling Island: Waters along the north side of Hakai Passage off southern Nalau and Stirling Islands; Eastern Stirling Island; around Underhill Island including Edward and Ward Channels; and Turnbull Inlet; 2 maps: one covers the

eastern portion (Hakai Passage map) and one covers the western portion (Stirling Island map).

b) Cultus Sound: Waters along both shores of Cultus Sound from Superstition Ledge to the mouth of Kinsmen Inlet; 1 map covers the area.

c) Goose Group: Waters surrounding The Goose Group from Currie Islet in the south to Weyburn Rock in the north; 2 maps: one covers the northern portion (Goose Group North map) and one covers the southern portion (Goose Group South map).

d) McMullin Group: Waters within the McMullin Group and northwards almost to Tuft Islands; 1 map covers the area.

e) Thompson Bay: Waters from the Tuft Islands off Stryker Island in the south, north along the east side of Thompson Bay to mid Gale Passage; 2 maps: one covers the northern portion (Thompson Bay North) and one covers the southern portion (Thompson Bay South).

f) Bardswell Group: Waters off the Southwest end of Athlone Island and surrounding Wurtele Island from Godfrey Rock to Townsend Point; 1 map covers the area.

Note that in the 1993 inventory (Field, 1996), certain statistical blocks on the Cultus Sound and Thompson Bay maps were given temporary numbers, shown in brackets. The areas covered in the 2007 inventory are very similar to the 1993 inventory, these blocks have retained the temporary numbers in the present inventory but a letter prefix has been added to indicate the location for 2007. It is anticipated that inventories in the future, if they include waters beyond the limits of the current inventories, will assign suitable permanent numbers to these blocks. Differences in coverage did occur between inventories; the 1993 inventory included 136 statistical kilometer blocks and the 2007 inventory includes 130. The 2007 inventory is missing 7 statistical blocks (a6, c16, e4, e6, e7, e20 and f23) and a small portion of one block (e19) that were covered in 1993, and includes one block that was absent in 1993 (e(3); note that the 2007 labeling scheme is used). There are 128 statistical blocks that are common to both reports.

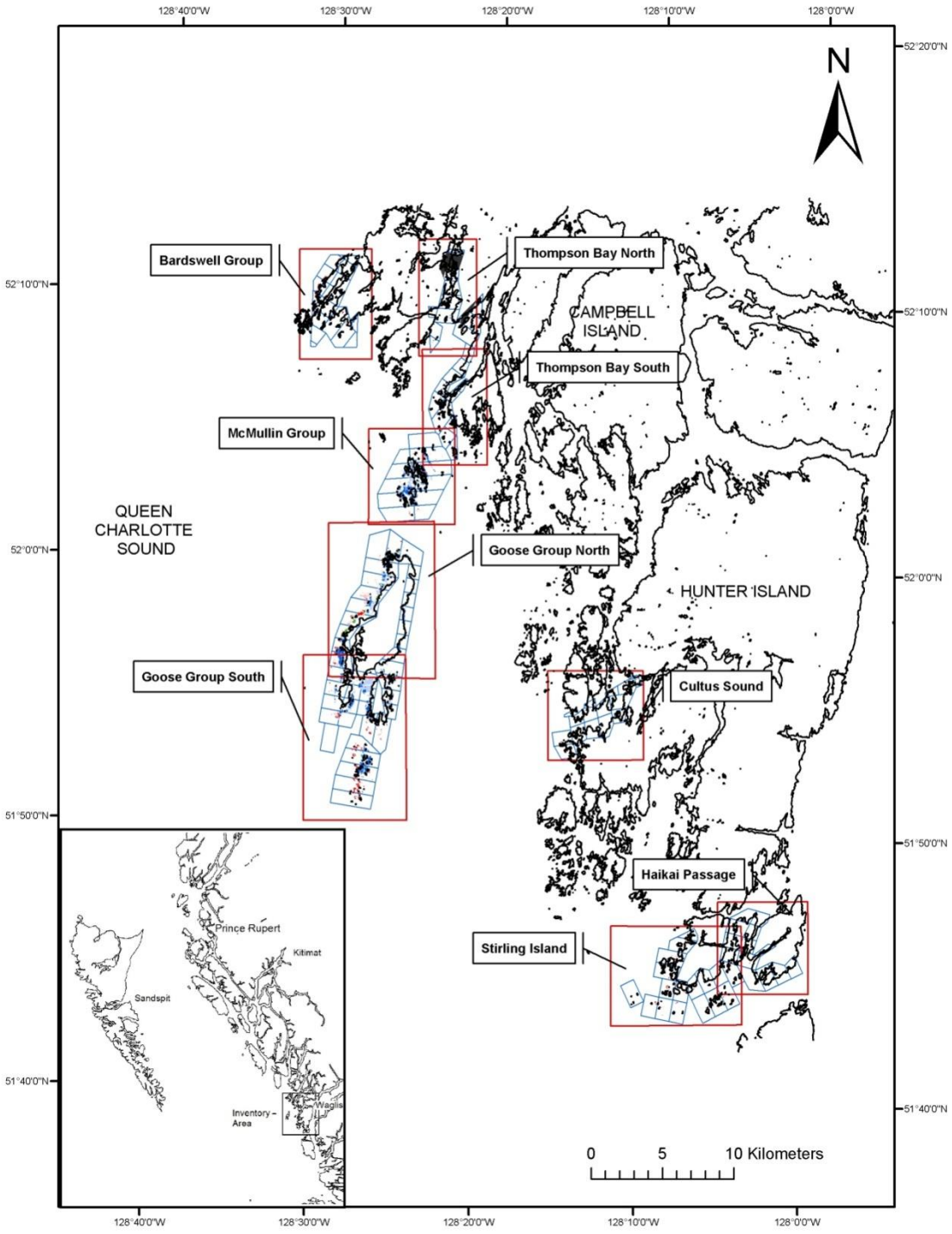

Figure 2. Map of the Hakai Passage to Bardswell Group areas inventoried for floating kelp resources in 2007 showing the layout of statistical blocks and map sheets.

Mean Biomass per Plant or Frond and Density

Sample station locations are shown in Appendix II (Figure 1 of Appendix II). All stations were used in calculations as being representative of the region although a number were not directly within the inventory area. Table 2 presents the field-determined mean biomass per plant and frond estimates obtained from means of 29 *Nereocystis* and 39 *Macrocystis* sampling station means.

Table 2. *Nereocystis* mean biomass per plant and *Macrocystis* mean biomass per frond values (total wet weight) derived from August, 2007 field samples.

Nereocystis mean biomass/plant (n=29 stations):	1.98 kg.	SD = 1.16	396 plants sampled
Macrocystis mean biomass/frond (n=39 stations):	0.79 kg.	SD = 0.34	822 fronds sampled

Table 3. Field determined *Macrocystis* bed density value derived from August, 2007 counts along underwater transects.

Mean no. of fronds/ sq. m. (n=39 stations):	4.45/ sq. m.	SD = 2.88	3,120 sq. m. counted

A total of 396 *Nereocystis* plants and 882 *Macrocystis* fronds were sampled at these stations from August 22 to 30, 2007. Considerable variability exists between stations. Maximum and minimum station mean biomass values were 4.95 kg. (at south Goose Island) and 0.54 kg. (at Stryker Island between Hakai Passage and Cultus Sound) per *Nereocystis* plant and 1.45 kg. (at west Goose Island) and 0.16 kg. (in the Breadner Group between Hakai Passage and Cultus Sound areas) per *Macrocystis* frond. The highest *Nereocystis* mean plant weights were found around Goose Island, the Bardswell Group and McMullin Island; the highest *Macrocystis* mean plant weights were found around Goose Island, McNaughton Group (just North of Cultus Sound) and Thompson Bay.

The *Macrocystis* mean density value (see Table 3) was derived from transect counts performed at the same locations as the *Macrocystis* biomass samples were taken. The standard error value of 0.46 fronds per square meter represents 10% of the mean and falls within the 20% criterion established for the method (Sutherland, 1990). 13,895 *Macrocystis* fronds were counted on 3,120 square meters of bottom over the 39 stations. Maximum and minimum mean station densities from *Macrocystis* transects

were 11.95 (at Spider Island between Hakai Passage and Cultus Sound) and 0 fronds per square meter (in Cultus Sound; it was noted that *Macrocystis* was present but wrapped in *Nereocystis* plants at the station). North Goose Island and Thompson Bay also had frond densities of over 10 per square meter.

Densities of Bull kelp beds were obtained using the standard KIM-1 point-intercept count method using aerial photography (Foreman, 1975; with supplementary regression developed by Foreman and Cabot in 1979) as adapted for use with digital methods (see Appendix I). As has been standard in application of the KIM-1 method to areas with little *Nereocystis* or with small beds of the species, it was often necessary to combine counts for adjacent or nearby blocks in order to obtain a minimum acceptable number of 10 counts for each *Nereocystis* density category (low or high).

In the 1993 inventory there were few counts possible in areas other than the Goose and McMullin Groups and low and high *Nereocystis* densities were calculated from combined Goose Group and McMullin Group data and applied to other areas. In 2007, fewer counts of *Nereocystis* density were possible than in 1993 in the McMullin Group and the Goose Group counts alone were used in the same manner for areas with too few counts. Calculations used the method described in Field (1996; for each of low and high *Nereocystis* categories, the total biomass in tonnes was divided by the total bed area in hectares, then divided by the mean biomass per plant in kg and multiplied by 1,000 to produce the overall mean bottom density per hectare). For 2007, this method was applied to all other areas than the Goose Group for low density *Nereocystis*; and to Cultus Sound, McMullin Group and Thompson Bay for high density *Nereocystis*.

Tables 4 through 9 present estimates of kelp bed density, area and biomass for bed types within each block of the six geographic inventory areas as follows:

Table 4: Hakai Passage and Stirling Island;

Table 5: Cultus Sound;

Table 6: Goose Group;

Table 7: McMullin Group;

Table 8: Thompson Bay; and

Table 9: Bardswell Group.

Table 10 summarizes the biomass and kelp bed area estimates for each geographic area by kelp species/density category and for the entire 2007 inventory area. Table 11 summarizes the bed area and biomass estimates for *Nereocystis*, *Macrocystis* and Mixed beds and each geographic area. Percent composition of low and high density

Nereocystis, *Macrocystis*, mixed and total bed surface area and biomass are shown in Table 12 and 13, respectively, for each geographic area.

The entire inventory area had an estimated standing stock of 37,289.2 tonnes of kelp in 1,147.69 hectares over its 130 statistical kilometer blocks. Of this, 7,082.0 tonnes (19% of biomass) was pure *Nereocystis* in 278.92 hectares (24% of beds), 27,694.5 tonnes (74%) was pure *Macrocystis* in 786.78 hectares (69% of beds) and 2,512.7 tonnes (7%) in 81.99 hectares (7%) was in mixed beds. *Macrocystis* made up most of the kelp bed area and biomass within each inventory area except the Hakai Passage/Stirling Island area where there was little of the species noted. The distribution of kelp varied considerably both between and within the inventory areas:

The **Hakai Passage/Stirling Island** inventory area had an estimated standing stock of 1,996.9 tonnes of kelp in 69.22 hectares over its 29 statistical kilometer blocks. The kelp was approximately 98% *Nereocystis* by bed area, spread in fringing beds running along shore or reefs, mainly along the south and western shores of the area. *Macrocystis* and mixed kelp were in small beds mainly near the west shore of Stirling Island.

The **Cultus Sound** survey area had an estimated standing stock of 1,385.5 tonnes of kelp in 43.15 hectares over its 16 statistical kilometer blocks. In the area, small fringing beds, mainly less than one hectare in size were approximately 74% *Macrocystis* by bed area. *Nereocystis* was found mainly in the western reaches of the survey area while *Macrocystis* and a small amount of mixed kelp were in the more sheltered areas within the Sound.

The **Goose Group** was the largest area surveyed and had more kelp than the other areas combined, with an estimated standing stock of 21,095.8 tonnes of kelp in 646.57 hectares over its 40 statistical kilometer blocks. Kelp was found in extensive beds in the Goose Group, mainly on the western and southern portions of the survey area, with up to 44 hectares within one statistical kilometer block. Smaller, fringing beds were found on the eastern shore of Goose Island. Approximately 22% of the kelp bed area was *Nereocystis*, 69% was *Macrocystis* and 9% was mixed kelp; *Nereocystis* was found mainly in outer regions along the west and south portions of the area.

The **McMullin Group** survey area had an estimated standing stock of 7,573.0 tonnes of kelp in 221.49 hectares over its 11 statistical kilometer blocks. Kelp was found in extensive beds in the McMullin Group with up to over 50 hectares within one statistical kilometer block. Approximately 88% of the kelp bed area in the McMullin Group was

Macrocystis; small beds of *Nereocystis* (approximately 8% by bed area) were found in outer parts of the survey area.

The **Thompson Bay** survey area had an estimated standing stock of 3,042.6 tonnes of kelp in 91.27 hectares over its 20 statistical kilometer blocks. Fringing beds of mainly *Macrocystis* (approximately 82% of bed area) extended through the survey area. Several statistical blocks in Thompson Bay that were covered by the 1993 survey were not available in the 2007 photography.

The **Bardswell Group** survey area had an estimated standing stock of 2,195.4 tonnes of kelp in 75.99 hectares over its 14 statistical kilometer blocks. Kelp beds were moderate in size and spread along the outer portions of the survey area. Beds were generally not found in the surveyed portions of the channel behind Wurtele Island. Approximately 43% of the kelp bed area was *Nereocystis*, 51% was *Macrocystis* and 6% was mixed kelp. Although both species were spread through the area, *Macrocystis* was found largely in the southern and southwestern portions.

Table 4: Estimates of kelp bed area and biomass by statistical block and species/density category in the Hakai Passage and Stirling Island inventory area for August 22, 2007. B = Biomass (metric tonnes) ha = hectare d=density D = Density (number of plants or fronds/hectare)

	Nereocystis - Low Density					*Nereocystis* - High Density					*Macrocystis*						Mixed - Low Density			Mixed - High Density			Total	Total
												Low d	High d	Total										
Stat.	Photo.	Bottom	Area	Mean		Photo.	Bottom	Area	Mean		Bottom	Area	Area	Area	Mean		Area	Mean		Area	Mean		Area	B
Block	D	D	(ha)	B/ha	B	D	D	(ha)	B/ha	B	D	(ha)	(ha)	(ha)	B/ha	B	(ha)	B/ha	B	(ha)	B/ha	B	(ha)	(tonnes)
a1	6,600	7,500	0.19	14.9	2.8	15,100	17,100	0.69	33.9	23.4										0.05	34.6	1.7	0.93	27.9
a2	6,600	7,500	0.36	14.9	5.3	15,100	17,100	0.50	33.9	16.9													0.86	22.2
a3	6,600	7,500	0.29	14.9	4.3	15,100	17,100	0.94	33.9	31.8	44,500	0.03	0.00	0.03	35.2	1.1							1.26	37.2
a4	6,600	7,500	0.25	14.9	3.7	15,100	17,100	0.37	33.9	12.5													0.62	16.2
a5	6,600	7,500	0.09	14.9	1.3	15,100	17,100	1.17	33.9	39.6	44,500	0.00	0.03	0.03	35.2	1.1							1.29	42.0
a7	6,600	7,500	0.01	14.9	0.1																		0.01	0.1
a8	6,600	7,500	0.02	14.9	0.3																		0.02	0.3
a9	6,600	7,500	0.05	14.9	0.7																		0.05	0.7
a10	6,600	7,500	0.05	14.9	0.7																		0.05	0.7
a11	6,600	7,500	0.11	14.9	1.6	15,100	17,100	0.05	33.9	1.7													0.16	3.3
a12	6,600	7,500	0.18	14.9	2.7																		0.18	2.7
a13	6,600	7,500	0.88	14.9	13.1	15,100	17,100	1.17	33.9	39.6													2.05	52.7
a14	6,600	7,500	1.14	14.9	16.9	15,100	17,100	4.61	33.9	156.1													5.75	173.0
a15	6,600	7,500	0.29	14.9	4.3	15,100	17,100	3.40	33.9	115.1	44,500	0.00	0.03	0.03	35.2	1.1							3.72	120.5
a16	6,600	7,500	2.87	14.9	42.6	15,100	17,100	3.74	33.9	126.6													6.61	169.2
a17	6,600	7,500	0.72	14.9	10.7	15,100	17,100	0.95	33.9	32.2													1.67	42.9
a18	6,600	7,500	0.19	14.9	2.8	15,100	17,100	0.45	33.9	15.2													0.64	18.0
a19	6,600	7,500	0.69	14.9	10.2	15,100	17,100	1.86	33.9	63.0													2.55	73.2
a20	6,600	7,500	0.11	14.9	1.6	15,100	17,100	2.53	33.9	85.7													2.64	87.3
a21	6,600	7,500	1.01	14.9	15.0	15,100	17,100	3.84	33.9	130.0										0.14	34.6	4.8	4.99	149.8
a22	6,600	7,500	0.76	14.9	11.3	15,100	17,100	4.44	33.9	150.3													5.20	161.6
a23	6,600	7,500	0.20	14.9	3.0	15,100	17,100	1.34	33.9	45.4													1.54	48.4
a24	6,600	7,500	0.17	14.9	2.5	15,100	17,100	1.06	33.9	35.9													1.23	38.4
a25	6,600	7,500	0.38	14.9	5.6	15,100	17,100	1.30	33.9	44.0													1.68	49.6
a26	6,600	7,500	0.54	14.9	8.0	15,100	17,100	0.38	33.9	12.9													0.92	20.9
a27	6,600	7,500	2.43	14.9	36.1	15,100	17,100	7.36	33.9	249.2							0.07	26.7	1.9	0.37	34.6	12.8	10.23	300.0
a28	6,600	7,500	1.73	14.9	25.7	15,100	17,100	3.84	33.9	130.0	44,500	0.03	0.10	0.13	35.2	4.6							5.70	160.3
a29	6,600	7,500	1.85	14.9	27.5	15,100	17,100	2.91	33.9	98.5	44,500	0.00	0.13	0.13	35.2	4.6							4.89	130.6
a30	6,600	7,500	0.70	14.9	10.4	15,100	17,100	0.73	33.9	24.7	44,500	0.33	0.00	0.33	35.2	11.6							1.78	47.2
Totals:			18.26		270.8			49.63		1,680.3		0.39	0.29	0.68		24.1	0.09		2.4	0.56		19.3	69.22	1,996.9

Table 5: Estimates of kelp bed area and biomass by statistical block and species/density category in the Cultus Sound inventory area for August 22, 2007. B = Biomass (metric tonnes) ha = hectare d=density D = Density (number of plants or fronds/hectare)

	Nereocystis - Low Density					*Nereocystis* - High Density					*Macrocystis*						Mixed - Low Density			Mixed - High Density			Total	Total
Stat. Block	Photo. D	Bottom D	Area (ha)	Mean B/ha	B	Photo. D	Bottom D	Area (ha)	Mean B/ha	B	Bottom D	Low d Area (ha)	High d Area (ha)	Total Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	B (tonnes)
b(1)	6,600	7,500	0.59	14.9	8.8	14,800	16,700	1.16	33.1	38.4	44,500	0.08	0.01	0.09	35.2	3.2							1.84	50.4
b(2)	6,600	7,500	2.13	14.9	31.6	14,800	16,700	1.47	33.1	48.6													3.60	80.2
b(3)	6,600	7,500	0.08	14.9	1.2	14,800	16,700	0.53	33.1	17.5													0.61	18.7
b1	6,600	7,500	0.69	14.9	10.2	14,800	16,700	0.35	33.1	11.6	44,500	1.87	0.54	2.41	35.2	84.8	0.25	26.7	6.7				3.70	113.3
b2	6,600	7,500	0.04	14.9	0.6	14,800	16,700	0.04	33.1	1.3	44,500	0.45	1.05	1.50	35.2	52.8	0.20	26.7	5.3				1.78	60.0
b3						14,800	16,700	0.05	33.1	1.7	44,500	2.82	0.37	3.19	35.2	112.3							3.24	114.0
b4											44,500	0.93	4.20	5.13	35.2	180.6							5.13	180.6
b5											44,500	0.82	2.53	3.35	35.2	117.9							3.35	117.9
b6	6,600	7,500	0.02	14.9	0.3						44,500	3.78	1.22	5.00	35.2	176.0	0.02	26.7	0.5				5.04	176.8
b7	6,600	7,500	0.11	14.9	1.6						44,500	0.30	0.38	0.68	35.2	23.9	0.15	26.7	4.0				0.94	29.5
b16											44,500	0.14	0.00	0.14	35.2	4.9							0.14	4.9
b20	6,600	7,500	0.05	14.9	0.7						44,500	1.81	0.25	2.06	35.2	72.5							2.11	73.2
b21	6,600	7,500	0.17	14.9	2.5						44,500	2.37	1.72	4.09	35.2	144.0				0.34	34.3	11.7	4.60	158.2
b22	6,600	7,500	1.04	14.9	15.4						44,500	2.09	0.18	2.27	35.2	79.9							3.31	95.3
b23											44,500	2.11	0.00	2.11	35.2	74.3							2.11	74.3
b27	6,600	7,500	0.90	14.9	13.4	14,800	16,700	0.75	33.1	24.8										0.00	34.3	0.0	1.65	38.2
Totals:			5.82		86.3			4.35		143.9		19.57	12.45	32.02		1,127.1	0.62		16.5	0.34		11.7	43.15	1,385.5

Table 6: Estimates of kelp bed area and biomass by statistical block and species/density category in the Goose Group inventory area for August 22 and September 8, 2007. B = Biomass (metric tonnes) ha = hectare d=density D = Density (number of plants or fronds/hectare)

	Nereocystis - Low Density					*Nereocystis* - High Density					*Macrocystis*						Mixed - Low Density			Mixed - High Density			Total	Total
Stat. Block	Photo. D	Bottom D	Area (ha)	Mean B/ha	B	Photo. D	Bottom D	Area (ha)	Mean B/ha	B	Bottom D	Low d Area (ha)	High d Area (ha)	Total Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	B (tonnes)
c1	5,400	6,100	1.14	12.1	13.8	16,700	18,900	0.41	37.4	15.3	44,500	7.45	2.04	9.49	35.2	334.0	0.28	25.5	7.1	1.40	36.1	50.6	12.72	420.8
c2	5,400	6,100	1.94	12.1	23.4	16,700	18,900	1.44	37.4	53.9	44,500	6.20	15.07	21.27	35.2	748.7				3.26	36.1	117.8	27.91	943.8
c3	5,400	6,100	2.89	12.1	34.9															0.47	36.1	17.0	3.36	51.9
c4	5,200	5,900	2.35	11.7	27.5	16,700	18,900	0.18	37.4	6.7	44,500	4.91	6.05	10.96	35.2	385.8	0.49	25.3	12.4	0.19	36.1	6.9	14.17	439.3
c5	5,200	5,900	2.95	11.7	34.5	16,700	18,900	0.26	37.4	9.7	44,500	15.08	9.81	24.89	35.2	876.1	1.02	25.3	25.8				29.12	946.1
c6	5,200	5,900	13.22	11.7	154.4	16,700	18,900	0.75	37.4	28.1	44,500	8.05	4.57	12.62	35.2	444.2	2.54	25.3	64.3	2.59	36.1	93.6	31.72	784.6
c7	5,900	6,700	3.23	13.3	42.8	16,700	18,900	5.46	37.4	204.3	44,500	18.47	7.83	26.30	35.2	925.8	5.16	26.0	134.1				40.15	1,307.0
c8	6,500	7,300	0.92	14.5	13.3	16,700	18,900	7.42	37.4	277.7	44,500	1.46	0.34	1.80	35.2	63.4	1.28	26.5	33.9	3.47	36.1	125.4	14.89	513.7
c9	7,700	8,700	0.95	17.2	16.4	16,700	18,900	0.46	37.4	17.2	44,500	0.23	0.86	1.09	35.2	38.4	0.97	27.7	26.8	6.11	36.1	220.8	9.58	319.6
c10	7,700	8,700	1.17	17.2	20.2	16,700	18,900	4.49	37.4	168.0	44,500	3.15	13.46	16.61	35.2	584.7				0.78	36.1	28.2	23.05	801.1
c11	7,700	8,700	5.14	17.2	88.5	17,300	19,500	3.04	38.6	117.4	44,500	3.43	32.70	36.13	35.2	1,271.8							44.31	1,477.7
c12	7,200	8,100	1.06	16.0	17.0	13,600	15,400	0.48	30.5	14.6	44,500	3.49	9.38	12.87	35.2	453.0	1.78	27.2	48.3				16.19	532.9
c13	7,300	8,200	1.71	16.2	27.8	13,600	15,400	0.64	30.5	19.5	44,500	2.90	3.72	6.62	35.2	233.0	0.25	27.2	6.8				9.22	287.1
c14	7,100	8,000	0.05	15.8	0.8	13,600	15,400	0.11	30.5	3.4	44,500	0.14	1.41	1.55	35.2	54.6							1.71	58.8
c15	7,400	8,400	3.22	16.6	53.6	13,600	15,400	6.16	30.5	187.8	44,500	0.01	0.23	0.24	35.2	8.4							9.62	249.8
c17	7,500	8,500	0.68	16.8	11.4	12,200	13,800	1.69	27.3	46.2	44,500	0.79	1.39	2.18	35.2	76.7	0.97	27.5	26.7				5.52	161.0
c18											44,500	6.91	15.11	22.02	35.2	775.1	0.18	27.5	4.9				22.20	780.0
c19											44,500	4.39	5.91	10.30	35.2	362.6							10.30	362.6
c20											44,500	3.88	2.24	6.12	35.2	215.4							6.12	215.4
c21											44,500	35.43	0.00	35.43	35.2	1,247.1							35.43	1,247.1
c22											44,500	24.18	7.91	32.09	35.2	1,129.6							32.09	1,129.6
c23	7,500	8,500	0.20	16.8	3.4						44,500	3.14	10.43	13.57	35.2	477.7							13.77	481.1
c24	7,500	8,500	2.88	16.8	48.5	13,800	15,600	4.30	30.9	132.8	44,500	2.05	5.65	7.70	35.2	271.0	0.48	27.5	13.2	0.43	33.4	14.4	15.79	479.9
c25	7,500	8,500	0.51	16.8	8.6	13,800	15,600	6.68	30.9	206.3	44,500	0.16	4.78	4.94	35.2	173.9	0.22	27.5	6.0				12.35	394.8
c26	8,100	9,200	1.67	18.2	30.4	13,800	15,600	5.05	30.9	156.0	44,500	2.05	27.87	29.92	35.2	1,053.2	4.55	28.1	127.7				41.19	1,367.3
c27	8,300	9,400	2.24	18.6	41.7	13,800	15,600	5.57	30.9	172.0	44,500	3.53	23.56	27.09	35.2	953.6	2.60	28.2	73.4	0.34	33.4	11.4	37.84	1,252.1
c28	8,300	9,400	3.24	18.6	60.3	14,200	16,000	17.28	31.7	547.4	44,500	0.19	0.00	0.19	35.2	6.7							20.71	614.4
c29	8,300	9,400	1.97	18.6	36.7	14,200	16,000	6.78	31.7	214.8													8.75	251.5
c30	8,300	9,400	0.60	18.6	11.2	14,200	16,000	2.84	31.7	90.0	44,500	4.60	0.44	5.04	35.2	177.4	0.69	28.2	19.5				9.17	298.1
c31	8,300	9,400	1.22	18.6	22.7						44,500	5.44	0.00	5.44	35.2	191.5	3.31	28.2	93.5				9.97	307.7
c32	8,300	9,400	0.01	18.6	0.2						44,500	9.87	0.82	10.69	35.2	376.3	0.91	28.2	25.7				11.61	402.2
c33	8,300	9,400	0.73	18.6	13.6						44,500	15.33	0.00	15.33	35.2	539.6	1.59	28.2	44.9				17.65	598.1
c34	8,300	9,400	0.37	18.6	6.9						44,500	8.24	3.69	11.93	35.2	419.9	3.17	28.2	89.5				15.47	516.3
c35	8,300	9,400	0.13	18.6	2.4						44,500	2.87	2.78	5.65	35.2	198.9	0.29	28.2	8.2				6.07	209.5
c36	8,300	9,400	0.36	18.6	6.7	14,200	16,000	0.21	31.7	6.7	44,500	2.00	3.41	5.41	35.2	190.4	1.32	28.2	37.3				7.30	241.1
c37											44,500	0.00	1.47	1.47	35.2	51.7	1.47	28.2	41.5	1.00	33.7	33.7	3.94	126.9
c38											44,500	1.95	3.98	5.93	35.2	208.7							5.93	208.7
c39											44,500	0.87	0.00	0.87	35.2	30.6	2.85	28.2	80.5				3.72	111.1
c40	8,300	9,400	0.02	18.6	0.4						44,500	1.77	0.00	1.77	35.2	62.3							1.79	62.7
c41	8,300	9,400	0.05	18.6	0.9						44,500	1.77	0.00	1.77	35.2	62.3				2.35	33.7	79.2	4.17	142.4
Totals:			58.82		874.9			81.70		2,695.8		216.38	228.91	445.29		15,674.1	38.37		1,052.0	22.39		799.0	646.57	21,095.8

Table 7: Estimates of kelp bed area and biomass by statistical block and species/density category in the McMullin Group inventory area for August 22 and September 8, 2007. B = Biomass (metric tonnes) ha = hectare d=density D = Density (number of plants or fronds/hectare)

	Nereocystis - Low Density					*Nereocystis* - High Density					*Macrocystis*						Mixed - Low Density			Mixed - High Density			Total	Total
Stat. Block	Photo. D	Bottom D	Area (ha)	Mean B/ha	B	Photo. D	Bottom D	Area (ha)	Mean B/ha	B	Bottom D	Low d Area (ha)	High d Area (ha)	Total Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	B (tonnes)
d43	6,600	7,500	0.86	14.9	12.8	14,800	16,700	0.98	33.1	32.4	44,500	0.08	0.00	0.08	35.2	2.8							1.92	48.0
d44	6,600	7,500	0.83	14.9	12.3	14,800	16,700	1.70	33.1	56.2	44,500	8.44	23.68	32.12	35.2	1,130.6	0.08	26.7	2.1	6.21	34.3	213.0	40.94	1,414.2
d45	6,600	7,500	1.89	14.9	28.1	14,800	16,700	2.57	33.1	85.0	44,500	28.56	20.53	49.09	35.2	1,728.0							53.55	1,841.1
d46	6,600	7,500	0.94	14.9	14.0	14,800	16,700	1.02	33.1	33.7	44,500	19.82	4.64	24.46	35.2	861.0							26.42	908.7
d47	6,600	7,500	0.03	14.9	0.4	14,800	16,700	0.45	33.1	14.9													0.48	15.3
d49	6,600	7,500	0.69	14.9	10.2	14,800	16,700	0.53	33.1	17.5	44,500	0.04	0.10	0.14	35.2	4.9	0.01	26.7	0.3				1.37	32.9
d50	6,600	7,500	0.26	14.9	3.9	14,800	16,700	0.06	33.1	2.0	44,500	9.35	6.14	15.49	35.2	545.2	0.00	26.7	0.0	0.08	34.3	2.7	15.89	553.8
d51	6,600	7,500	0.19	14.9	2.8						44,500	6.76	22.89	29.65	35.2	1,043.7	0.03	26.7	0.8				29.87	1,047.3
d52	6,600	7,500	0.83	14.9	12.3	14,800	16,700	1.40	33.1	46.3	44,500	8.43	13.02	21.45	35.2	755.0	0.48	26.7	12.8	0.42	34.3	14.4	24.58	840.8
d53	6,600	7,500	2.62	14.9	38.9	14,800	16,700	0.76	33.1	25.1	44,500	4.26	16.96	21.22	35.2	746.9	0.68	26.7	18.1				25.28	829.0
d54											44,500	0.91	0.28	1.19	35.2	41.9							1.19	41.9
Totals:			9.14		135.7			9.47		313.1		86.65	108.24	194.89		6,860.0	1.28		34.1	6.71		230.1	221.49	7,573.0

Table 8: Estimates of kelp bed area and biomass by statistical block and species/density category in the Thompson Bay inventory area for August 22 and September 8, 2007. B = Biomass (metric tonnes) ha = hectare d=density D = Density (number of plants or fronds/hectare)

	Nereocystis - Low Density					*Nereocystis* - High Density					*Macrocystis*						Mixed - Low Density			Mixed - High Density			Total	Total
Stat. Block	Photo. D	Bottom D	Area (ha)	Mean B/ha	B	Photo. D	Bottom D	Area (ha)	Mean B/ha	B	Bottom D	Low d Area (ha)	High d Area (ha)	Total Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	B (tonnes)
e(3)						14,800	16,700	0.04	33.1	1.3													0.04	1.3
e(4)	6,600	7,500	0.10	14.9	1.5						44,500	0.04	1.11	1.15	35.2	40.5							1.25	42.0
e(5)	6,600	7,500	0.26	14.9	3.9	14,800	16,700	0.28	33.1	9.3	44,500	1.07	8.93	10.00	35.2	352.0	0.13	26.7	3.5				10.67	368.7
e(6)	6,600	7,500	0.75	14.9	11.1	14,800	16,700	0.74	33.1	24.5	44,500	0.03	3.26	3.29	35.2	115.8				1.03	34.3	35.3	5.81	186.7
e(7)	6,600	7,500	1.59	14.9	23.6	14,800	16,700	0.36	33.1	11.9	44,500	3.45	6.79	10.24	35.2	360.4	0.50	26.7	13.3	0.90	34.3	30.9	13.59	440.1
e(8)	6,600	7,500	1.38	14.9	20.5	14,800	16,700	1.02	33.1	33.7	44,500	0.70	5.37	6.07	35.2	213.7							8.47	267.9
e(9)											44,500	1.07	0.43	1.50	35.2	52.8							1.50	52.8
e(10)											44,500	0.01	0.22	0.23	35.2	8.1							0.23	8.1
e1	6,600	7,500	0.13	14.9	1.9	14,800	16,700	0.14	33.1	4.6	44,500	2.80	5.87	8.67	35.2	305.2				1.44	34.3	49.4	10.38	361.1
e2											44,500	2.11	0.00	2.11	35.2	74.3				0.16	34.3	5.5	2.27	79.8
e3											44,500	0.85	0.00	0.85	35.2	29.9							0.85	29.9
e5											44,500	0.34	0.17	0.51	35.2	18.0							0.51	18.0
e13											44,500	1.49	0.44	1.93	35.2	67.9	0.06	26.7	1.6				1.99	69.5
e14	6,600	7,500	0.19	14.9	2.8						44,500	1.86	0.00	1.86	35.2	65.5	2.33	26.7	62.1				4.38	130.4
e15											44,500	0.73	0.00	0.73	35.2	25.7							0.73	25.7
e16	6,600	7,500	1.06	14.9	15.7						44,500	2.38	3.51	5.89	35.2	207.3	0.67	26.7	17.9				7.62	240.9
e17	6,600	7,500	0.83	14.9	12.3						44,500	6.12	3.48	9.60	35.2	337.9	0.21	26.7	5.6				10.64	355.8
e18											44,500	1.61	2.16	3.77	35.2	132.7							3.77	132.7
e19											44,500	2.14	4.33	6.47	35.2	227.7							6.47	227.7
e21											44,500	0.02	0.08	0.10	35.2	3.5							0.10	3.5
Totals:			6.29		93.3			2.58		85.3		28.82	46.15	74.97		2,638.9	3.90		104.0	3.53		121.1	91.27	3,042.6

Table 9: Estimates of kelp bed area and biomass by statistical block and species/density category in the Bardswell Group inventory area for August 22 and September 8, 2007. B = Biomass (metric tonnes) ha = hectare d=density D = Density (number of plants or fronds/hectare)

	Nereocystis - Low Density					*Nereocystis* - High Density					*Macrocystis*						Mixed - Low Density			Mixed - High Density			Total	Total
Stat. Block	Photo. D	Bottom D	Area (ha)	Mean B/ha	B	Photo. D	Bottom D	Area (ha)	Mean B/ha	B	Bottom D	Low d Area (ha)	High d Area (ha)	Total Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	Mean B/ha	B	Area (ha)	B (tonnes)
f18	6,600	7,500	0.05	14.9	0.7						44,500	2.70	4.39	7.09	35.2	249.6							7.14	250.3
f19						12,200	13,800	0.10	27.3	2.7													0.10	2.7
f20	6,600	7,500	3.47	14.9	51.5	12,200	13,800	1.91	27.3	52.2	44,500	0.54	1.95	2.49	35.2	87.6	0.78	26.7	20.8				8.65	212.1
f21	6,600	7,500	2.84	14.9	42.2	12,200	13,800	3.64	27.3	99.5	44,500	5.38	3.25	8.63	35.2	303.8	0.29	26.7	7.7	1.48	31.9	47.2	16.88	500.4
f22											44,500	0.05	0.00	0.05	35.2	1.8							0.05	1.8
f24	6,600	7,500	0.01	14.9	0.1																		0.01	0.1
f25	6,600	7,500	0.01	14.9	0.1	12,200	13,800	0.02	27.3	0.5	44,500	0.83	0.00	0.83	35.2	29.2	0.09	26.7	2.4				0.95	32.2
f26	6,600	7,500	0.15	14.9	2.2	12,200	13,800	0.39	27.3	10.7	44,500	7.09	4.13	11.22	35.2	394.9				0.22	31.9	7.0	11.98	414.8
f27	6,600	7,500	0.03	14.9	0.4						44,500	0.19	0.00	0.19	35.2	6.7							0.22	7.1
f33	6,600	7,500	1.03	14.9	15.3	12,200	13,800	3.46	27.3	94.5	44,500	0.47	3.31	3.78	35.2	133.1	0.57	26.7	15.2				8.84	258.1
f34	6,600	7,500	1.99	14.9	29.6	12,200	13,800	3.30	27.3	90.2	44,500	0.00	3.47	3.47	35.2	122.1	0.21	26.7	5.6				8.97	247.5
f35	6,600	7,500	2.33	14.9	34.6	12,200	13,800	1.89	27.3	51.6	44,500	0.04	0.00	0.04	35.2	1.4	0.23	26.7	6.1				4.49	93.7
f36	6,600	7,500	1.86	14.9	27.6	12,200	13,800	2.51	27.3	68.6	44,500	0.71	0.00	0.71	35.2	25.0				0.31	31.9	9.9	5.39	131.1
f37	6,600	7,500	1.87	14.9	27.8						44,500	0.00	0.43	0.43	35.2	15.1				0.02	31.9	0.6	2.32	43.5
Totals:			15.64		232.1			17.22		470.5		18.00	20.93	38.93		1,370.3	2.17		57.8	2.03		64.7	75.99	2,195.4

Table 10: Summary of total kelp bed area and standing crop kelp biomass estimates for each geographic area summarized by kelp species for the 2007 inventory area.

	Geographic area	Area (hectares)	Biomass (metric tonnes)
	Low Density *Nereocystis*		
a)	Hakai Passage and Stirling Island	18.26	270.8
b)	Cultus Sound	5.82	86.3
c)	Goose Group	58.82	874.9
d)	McMullin Group	9.14	135.7
e)	Thompson Bay	6.29	93.3
f)	Bardswell Group	15.64	232.1
	High Density *Nereocystis*		
a)	Hakai Passage and Stirling Island	49.63	1,680.3
b)	Cultus Sound	4.35	143.9
c)	Goose Group	81.70	2,695.8
d)	McMullin Group	9.47	313.1
e)	Thompson Bay	2.58	85.3
f)	Bardswell Group	17.22	470.5
	Low and High Density *Macrocystis*		
a)	Hakai Passage and Stirling Island	0.68	24.1
b)	Cultus Sound	32.02	1,127.1
c)	Goose Group	445.29	15,674.1
d)	McMullin Group	194.89	6,860.0
e)	Thompson Bay	74.97	2,638.9
f)	Bardswell Group	38.93	1,370.3
	Low Density Mixed		
a)	Hakai Passage and Stirling Island	0.09	2.4
b)	Cultus Sound	0.62	16.5
c)	Goose Group	38.37	1,052.0
d)	McMullin Group	1.28	34.1
e)	Thompson Bay	3.90	104.0
f)	Bardswell Group	2.17	57.8
	High Density Mixed		
a)	Hakai Passage and Stirling Island	0.56	19.3
b)	Cultus Sound	0.34	11.7
c)	Goose Group	22.39	799.0
d)	McMullin Group	6.71	230.1
e)	Thompson Bay	3.53	121.1
f)	Bardswell Group	2.03	64.7
	Total of all species for entire inventory area:	1,147.69	37,289.2

Table 11. Kelp bed area and total biomass estimates for *Nereocystis*, *Macrocystis* and Mixed beds and for each geographic area.

			Area (hectares)	Biomass (metric tonnes)
Totals by species:		*Nereocystis*	278.92	7,082.0
		Macrocystis	786.78	27,694.5
		Mixed	81.99	2,512.7
Totals by geographic area:	a)	Hakai Pass. and Stirling	69.22	1,996.9
	b)	Cultus Sound	43.15	1,385.5
	c)	Goose Group	646.57	21,095.8
	d)	McMullin Group	221.49	7,573.0
	e)	Thompson Bay	91.27	3,042.6
	f)	Bardswell Group	75.99	2,195.4
Total of all species for entire inventory area:			1,147.69	37,289.2

Table 12. Percent composition of low and high density *Nereocystis, Macrocystis* and mixed bed surface area in each geographic area. The last column gives percent composition of the kelp bed surface area for the entire 2007 inventory area.

Area:	a	b	c	d	e	f	Combined
Percent Bed Area							
Nereocystis							
-low density	26.4%	13.5%	9.1%	4.1%	6.9%	20.6%	9.9%
-high density	71.7%	10.1%	12.6%	4.3%	2.8%	22.7%	14.4%
Macrocystis							
-high and low	1.0%	74.2%	68.9%	88.0%	82.1%	51.2%	68.6%
Mixed							
-low density	0.1%	1.4%	5.9%	0.6%	4.3%	2.9%	4.0%
-high density	0.8%	0.8%	3.5%	3.0%	3.9%	2.7%	3.1%

Table 13. Percent composition of *Macrocystis* and low and high density *Nereocystis* and mixed bed total biomass in each geographic area. The last column gives percent composition of the total biomass for the entire 2007 inventory area.

Area:	a	b	c	d	e	f	Combined
Percent Biomass							
Nereocystis							
-low density	13.6%	6.2%	4.1%	1.8%	3.1%	10.6%	4.5%
-high density	84.1%	10.4%	12.8%	4.1%	2.8%	21.4%	14.5%
Macrocystis							
-high and low	1.2%	81.3%	74.3%	90.6%	86.7%	62.4%	74.3%
Mixed							
-low density	0.1%	1.2%	5.0%	0.5%	3.4%	2.6%	3.4%
-high density	1.0%	0.8%	3.8%	3.0%	4.0%	2.9%	3.3%

Comparison with 1993 Kelp Inventory

Kelp inventory estimates rely on field sampling and on the results of aerial photography and its interpretation; changes in these aspects between inventories will affect the subsequent estimates.

Field work provides data on mean biomass per *Nereocystis* plant or *Macrocystis* frond and also *Macrocystis* density. Field methods used in 1993 and 2007 field work were generally similar. As shown in Table 14, mean biomass per *Nereocystis* plant has decreased between the inventories by 31%, mean biomass per *Macrocystis* frond values increased by 8%, and the *Macrocystis* density decreased by 10%.

Table 14. The mean total biomass per *Nereocystis* plant and *Macrocystis* frond and mean *Macrocystis* density for both the 1993 and 2007 inventories. (1993 data from Field, 1996)

	Mean Biomass/ plant or frond (kg)		Mean # fronds/sq.m.
Inventory Date	*Nereocystis*	*Macrocystis*	*Macrocystis*
1993	2.85	0.73	4.93
2007	1.98	0.79	4.45

Briefly, the aerial photography is used to determine species present, kelp bed area and *Nereocystis* density. 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 the tide height increases, lesser amounts of kelp are able to reach the water surface to be seen in aerial photographs. For this reason, tide can be a critical factor, however, both the 1993 and 2007 aerial photography was taken at MWL +/- 0.6 meters as is optimal for KIM-1 (Foreman, 1975).

The 1993 aerial photography used black and white infrared film as the KIM-1 method was designed to use and beds were traced directly from the negatives; the 2007 photography used colour infrared film which was digitized and beds were outlined digitally. In the black and white negatives, the kelp is dark against a light ocean, standing out fairly clearly. In the colour infrared photographs the kelp is coloured light reddish against a dark ocean. In correspondence with British Columbia's Integrated Land Management Bureau (A. Calarco, Manager, Air Photo and Digital Imagery) it was noted that while it is expected that: "black and white IR (BIR) film is still available, it hasn't been used by the Province in some time and is not as responsive as colour IR (CIR) media. The BIR film is commonly called near-infrared film since it is only sensitive in the 0.7 to 0.9 micron range while CIR is substantially more sensitive (0.5 to 0.9 microns). A big advantage to CIR is that you not only get a wider range of IR data but also capture the red and green colour bands." And, "typically the preference is to go with CIR film for the reasons mentioned above."

.Some photography of both the 1993 and 2007 inventories was taken outside the 10:00 to 14:00 hours optimum times, a condition that could increase glare, especially in waves, possibly obscuring some kelp in portions of the images; in 2007, almost half of the images were outside the optimum.

As noted above, area coverage available from aerial photography is very similar in the 1993 and 2007 kelp inventories but with some differences. While the 1993 inventory included 136 statistical kilometer blocks and the 2007 inventory includes 130, there are 128 statistical blocks that are common to both reports. The following discusses these common blocks using results of the 2007 inventory and data taken from the report by Field (1996) for 1993.

Table 15 presents the kelp bed area and total standing crop biomass estimates for 1993 and 2007 in the common blocks by bed type. Figure 5 presents the kelp bed area information graphically by species for each survey area; Figures 6 and 7 present the information for bed area and biomass, respectively, for the area as a whole. When all bed types are included for this area, the 2007 bed area and biomass estimates are roughly 75% and 68%, respectively, of the 1993 estimates, indicating an overall decline in stocks.

In the 1993 inventory of the overlap area, *Macrocystis* made up 23% of the bed area and biomass; in 2007 the species reached 68% of the bed area and 74% of the biomass biomass (Table 15; Figure 5). The estimated *Macrocystis* bed area in 2007 was found to be more than 2.25 times the

1993 area (Figure 6). The average biomass per hectare for the species in 2007 of 35.2 tonnes/ha. was only slightly less than the 1993 value of 36.0 tonnes/ha (Figure 7). The *Macrocystis* biomass estimate for 2007 was approximately 2.21 times the 1993 estimate.

Nereocystis bed area and biomass estimates declined over the 14 years and by 2007 are 26% and 19%, respectively, of the 1993 estimates (Table 15, Figure 5). In the 1993 inventory estimate, 70% of the bed area and biomass in the area in common was made up of *Nereocystis*; this had declined to 24% of the bed area and 19% of the biomass in 2007 (Figure 6 and 7).

Mixed beds are not extensive in the region of overlap, estimated at 7 to 8% of the bed area and biomass in 1993 and 2007, respectively.

Table 15. Kelp bed area and total standing crop biomass estimates for the 128 statistical block region of overlap in 1993 and 2007 inventories area by bed type and summarized by species. (1993 data adapted from Field, 1996); high and low denote density; N = *Nereocystis*; M = *Macrocystis*; Mix = mixed beds.

Total Kelp Bed Area (hectares) of common blocks

	Low	High	Low	High	High & Low M	Low	High	Tota
199	583.5	478.3	229.9	115.66	345.5	91.7	23.7	
200	113.9	164.9	367.6	412.64	780.3	46.4	35.5	1,141.1

	N	M	Mi	Tota
199	1061.8	345.5	115.4	1522.9
200	278.8	780.3	81.9	1141.1

Total Biomass (tonnes) of common blocks

	Low	High		High & Low M	Low	High	Tota
199	12,634.	25,524.		12,440.	2,730.	1,028.	54,358.
200	1,693.	5,387.		27,466.	1,265.	1,245.	37,059.

	N	M	Mi	Tota
199	38,158.6	1244	3759.	54,358.0
200	7,080.7	27,466.8	2511.	37,059.0

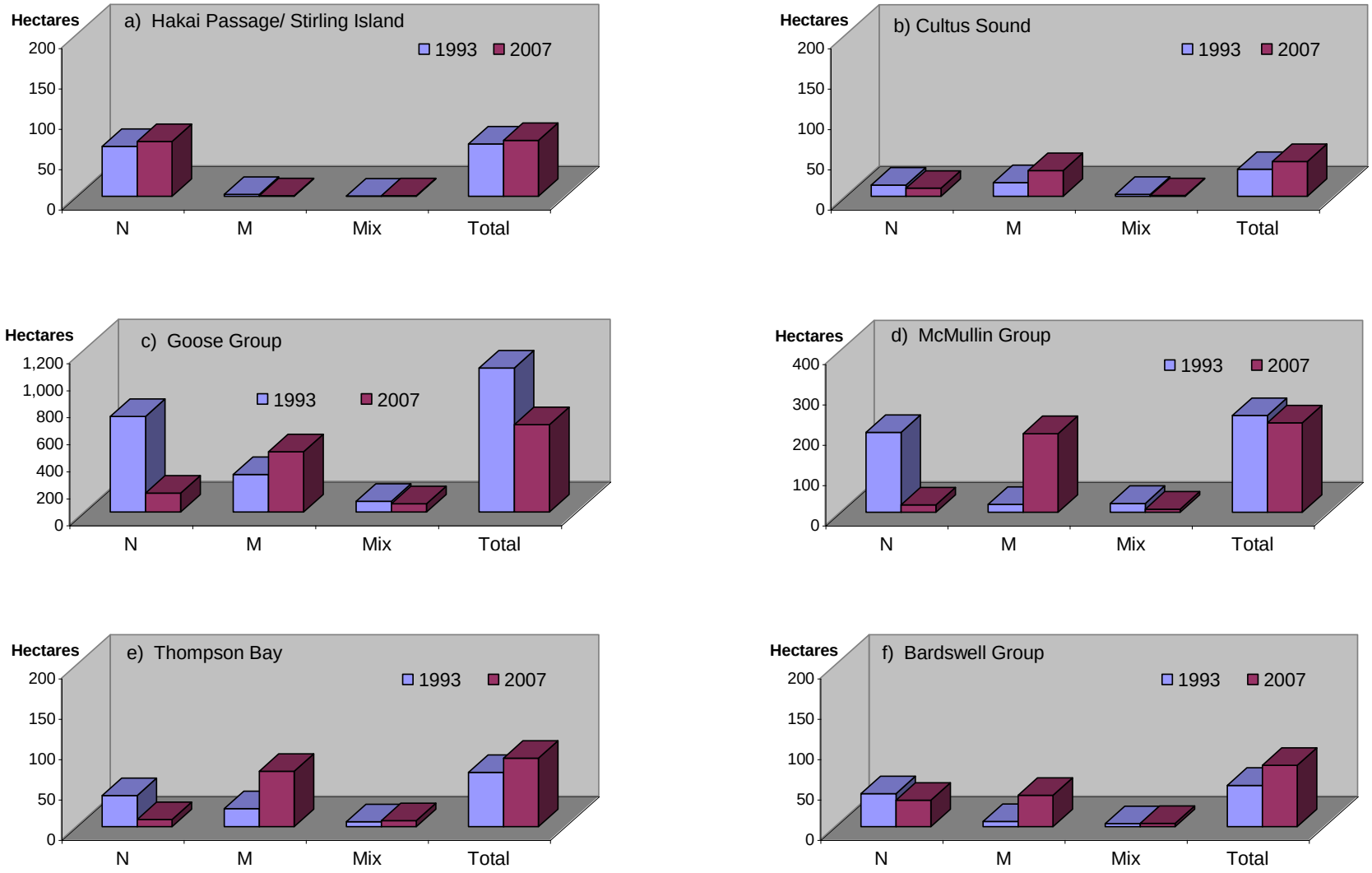

Figure 5. Graphs showing estimated changes in kelp bed area in hectares by species for the statistical blocks that are covered by both the 1993 and 2007 inventories for each geographic inventory area. Note that the scale changes between charts. N = *Nereocystis*; M = *Macrocystis*; Mix = mixed beds

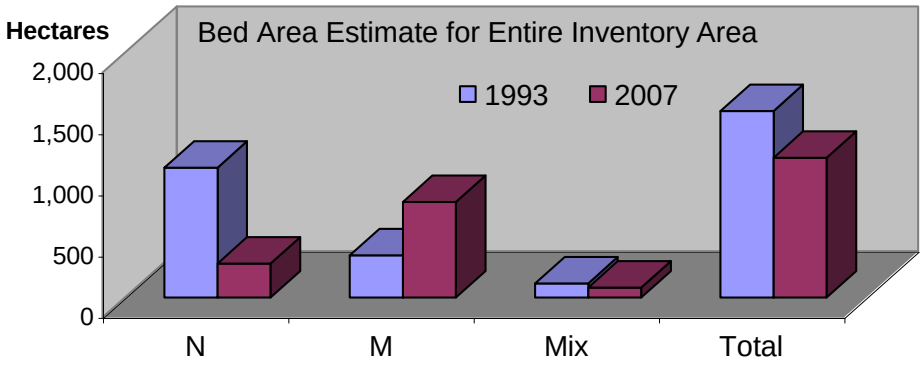

Figure 6. Graphs showing estimated changes in kelp bed area in hectares by species for the 128 statistical blocks over the inventory area that are covered by both the 1993 and 2007 inventories. N = *Nereocystis*; M = *Macrocystis*; Mix = mixed beds.

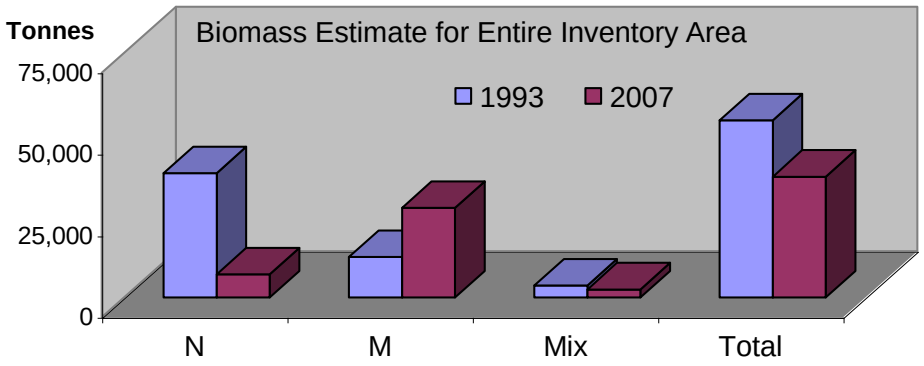

Figure 7. Graphs showing estimated changes in kelp bed biomass in tonnes by species for the 128 statistical blocks over the inventory area that are covered by both the 1993 and 2007 inventories. N = *Nereocystis*; M = *Macrocystis*; Mix = mixed beds.

Nereocystis density in both years was derived using the point intercept method and calculations used the same conversion factor to total density. In 1993, adequate *Nereocystis* beds to allow counts of density were available in the Goose and McMullin Groups. The overall mean bottom densities for low and high density *Nereocystis* were calculated by Field (1996) for these areas, combined, for use in areas with too few counts; similar figures were calculated for the Goose Group alone in 2007 for the same purpose. For a limited comparison of *Nereocystis* density between surveys the overall

mean bottom densities for the Goose Group were calculated for 1993 and 2007 and presented in Table 16.

Table 16. Overall mean bottom densities (plants per hectare) for high and low density *Nereocystis* for the Goose Group calculated for 1993 and 2007 using the equation shown below where D/ha= bottom density per hectare and A = kelp bed area (hectares).

	Low *Nereocystis*	High *Nereocystis*
1993	7,700/ ha	17,900/ ha
2007	7,500/ ha	16,700/ ha

$$\text{Mean bottom density per hectare for area} = \frac{\sum(D/ha * A)}{\sum(A)}$$

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 fieldwork. Modifications to the method for *Nereocystis* have appeared 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). Updating technology through the use in the present inventory of colour infrared photography and digital mapping of kelp polygons directly from georeferenced digital images are the most recent changes to methods. The resulting accuracy of the latest version of KIM-1, with the changes made over the years, has not yet been tested by harvesting an inventoried area.

A significant section made up of 128 statistical kilometer blocks of the Hakai Passage to Bardswell Group area was inventoried in 1993 and again in 2007. Estimates showed an overall decline over the fourteen year period to approximately 75% of the 1993 bed area and 68% of the biomass. *Macrocystis* beds increased during the period while *Nereocystis* beds declined. Mixed kelp made up 8% of bed area in 1993 and 7% in 2007.

Over the entire inventory area, in 2007 most *Nereocystis* beds were found in the Goose Group, Hakai Passage/Stirling Island and the McMullin Group, the largest quantity being in the Goose Group. Inventory estimates showed a decrease in *Nereocystis* stands by 2007 to 26% of 1993 bed area and 19% of biomass estimates. The greatest decline was in the McMullin Group where the 2007 estimate of bed area declined to 9% of the 1993 estimate and biomass to 6%.

The focus of the present report was to inventory *Macrocystis* stocks. The major concentrations of the species were in the Goose and McMullin Groups but significant bed areas of the species were found in all areas except the Hakai Passage/Stirling Island area where less than a hectare of the species in pure stands was found. Inventory estimates indicate an increase between 1993 and 2007 of 2.25 times in *Macrocystis* bed area and 2.21 times in biomass.

Provided sea surface conditions, tide height, currents and flight conditions are right, kelp bed area is usually considered to be the most reliable estimate made in the kelp inventories. Changes, both large and small, in kelp bed area, over a period of years, have been noted in a few past kelp inventories where there were small areas of overlap with previous inventories (Sutherland, 1990, 1998, 1999). Often, a decline in *Nereocystis* was noted along with an increase in *Macrocystis* as in the present inventory. The reasons for the changes are not known although a large settlement of sea urchins was suggested anecdotally to have contributed to one past *Nereocystis* decline.

In 2007 the Goose and McMullin Groups together were estimated to hold 76% of kelp bed area and 77% of the biomass, however, all inventory areas held significant stocks of kelp. Cultus Sound was estimated to hold the least, with 43 hectares of mainly *Macrocystis*.

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Barron Carswell
Manager of Operations
Oceans and Marine Fisheries Branch
B.C. Ministry of Environment, 2008

APPENDIX I

Methods used in digital aerial photo interpretation, kelp bed mapping and *Nereocystis* density evaluation.

Courtesy of M. Mamoser and V. Karpouzi, B.C. Ministry of Environment

Methods

The methods used to obtain kelp bed maps and estimates of area coverage and biomass in this inventory follow those outlined by Field (1996).

Information on kelp distribution and biomass was encoded in a spatial database for both Bull [*Nereocystis luetkeana* (K. Mertens) Postels & Ruprecht 1840] and Giant kelp (*Macrocystis integrifolia* Bory de Saint-Vincent 1826). Both species occur along the Central Coast of B.C. The areas included in the inventory are the Hakai Passage, Bardswell, McMullin and Goose Groups, Thompson Bay, Cultus Sound and Stirling Island. Each kelp bed was represented as a polygon with a unique identification number. For each polygon, information on the kelp species, area coverage (in m^2), species density and biomass was also recorded.

Aerial Photography

High quality infrared (IR) aerial photographs were taken on August 22 and September 8, 2007. The photos were taken at a 1:7200 scale (KIM-1 was developed and statistically evaluated for this scale), using a 1443 Kodak Aerochrome III IR film and a 305 mm lens. Forward overlap was 20%. Aerial photography occurred between 1250 and 1520 PST, over calm seas, at sea level equal or less than 0.6 meter of the Mean Water Level (MWL). Tide level readings for Bella Bella (the nearest recording station to the inventory area) were obtained from the Canadian Hydrographic Service. The data were converted to levels at Gosling Island, using information from Volume 6 of the Canadian Tide and Current Tables. Thus, it was determined that all aerial photography was done during the optimal for KIM-1 tide level range (i.e., MWL ± 0.6 m; range from 2.32 m to 2.84 m).

Aerial triangulation and ortho-rectification (geo-coding) were undertaken for all 2007 infrared aerial photographs with a resolution of 0.12 mm x 0.12 mm cell size. The geo-coded images were made available to the Ministry of Environment in TIF/TFW, Mr.Sid, ECW, and JPEG compressed formats. The projection for the orthophotos was UTM Nad83.

Kelp Bed Mapping

The 1993 kelp inventory for the Central Coast of B.C. is available in a digitized form by the Ministry of Agriculture and Lands. The digitized layers used included:

1. 20k shore;
2. 20k coastline;
3. Statistical block; and,
4. 1993 kelp coverage.

The layers were loaded into ArcGIS 9.2 which was employed to map the kelp beds. The 20k shore and coastline layers functioned as a base map of the

central coast area of interest. The same statistical blocks used for the 1993 inventory were used to make results comparable. The kelp coverage layer from the 1993 inventory was used as a guide to map kelp beds identified on the 2007 digitized aerial photographs.

Kelp bed mapping was done by tracing their outline directly from the digitized aerial photographs. Kelp beds were tabulated by species, *Nereocystis, Macrocystis,* or as mixed, and by density, high or low. Kelp bed polygons occasionally spanned two statistical blocks, in which case they were cut using the statistical block as a guide. This facilitated statistical analysis while maintaining complete coverage.

The two species were distinguished based on clarity, size and location. *Nereocystis* has a linear appearance and, in dense areas, resembles random sticks on the surface of the water. The image is generally quite sharp as most plants are on the surface (See figure X1a). *Macrocystis* has a more clumped appearance and looks somewhat fuzzy. *Nereocystis* are generally smaller than *Macrocystis*, which is perennial, and prefers more exposed areas (See figure X1b). (Foreman, 1975; Abbot and Hollenberg, 1976).

The density separation for a bed was arbitrary based on the percent coverage of plants or fronds. For *Nereocystis* the division was 15% (e.g. Low ≤ 15%; High > 15%) and for *Macrocystis* the division was 40%. See figure X2 for an example of the different density categories.

In order to calculate the kelp bed area (in m^2) represented by polygons, the 'Calculate Areas' command was used from the ArcToolbox menu (Command line path: ArcToolbox ⇨ Spatial Statistics Tools ⇨ Utilities ⇨ Calculate Areas). Overall, the 2007 kelp bed area was 11,476,450 m^2 of that;

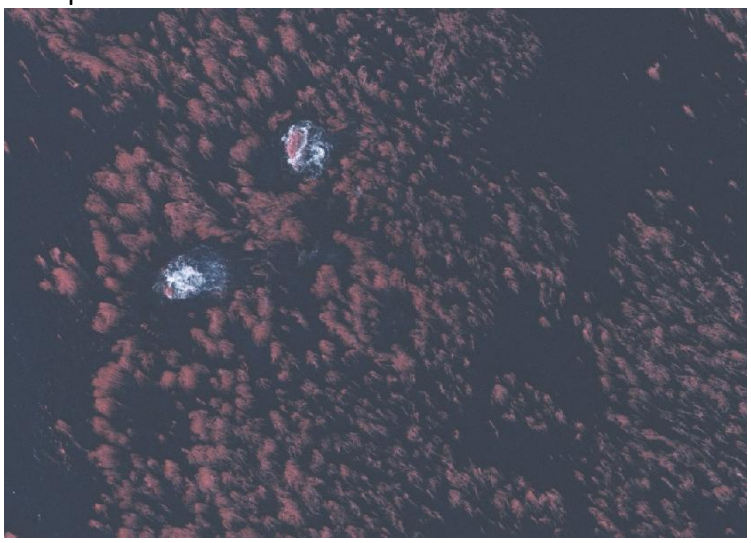
Nereocystis (Bull kelp): 2,789,506.m^2; or 24 %;
Macrocystis (Giant kelp): 7,867,385.24 m^2, or 69%;
Nereocystis/Macrocystis (Mixed beds) 819,558.01 m^2, or 7%

Density Counts

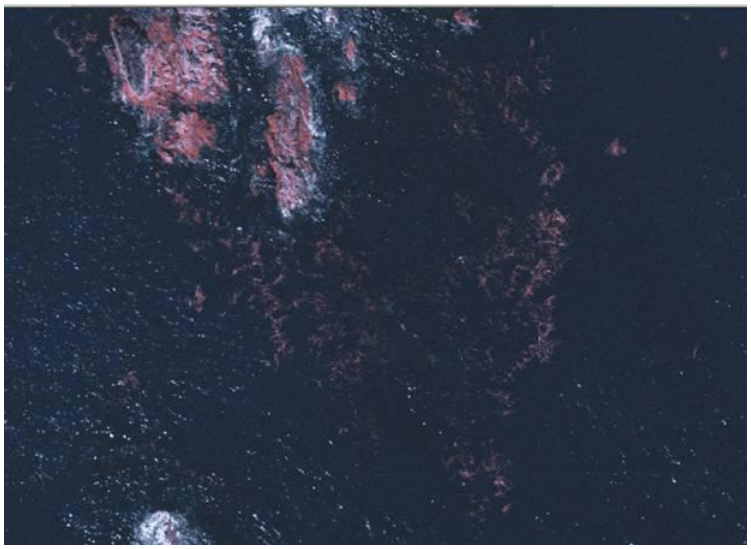
Densities of Bull kelp beds were obtained using the point-intercept count method (Foreman, 1975). In essence, the method samples individual plants via interception of points on a 50 m x 50 m grid superimposed on the IR aerial photograph. For every statistical block, random points were generated using the Random Point-in-Polygon Generation Program (Visual Basic for Applications Macro; Sawada, 2002). Then, random points were used to center the grid at least once on big enough polygons. Overall, only 84 polygons allowed at least one grid count (see Table 1).

Figure X1: Example of different kelp bed types. High resolution images allow better clarity at higher zoom during interpretation.

a) Macrocystis integrifolia



b) Nereocystis luetkeana



c) Mixed

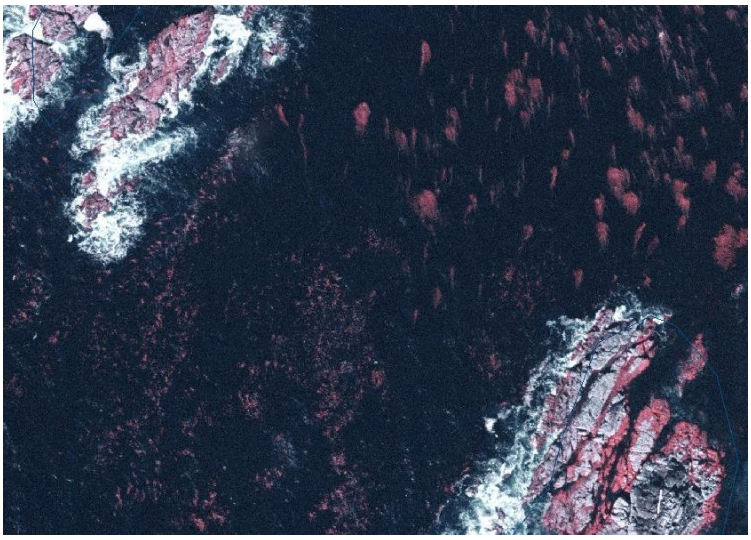


Figure X2: Examples of kelp bed density categories.

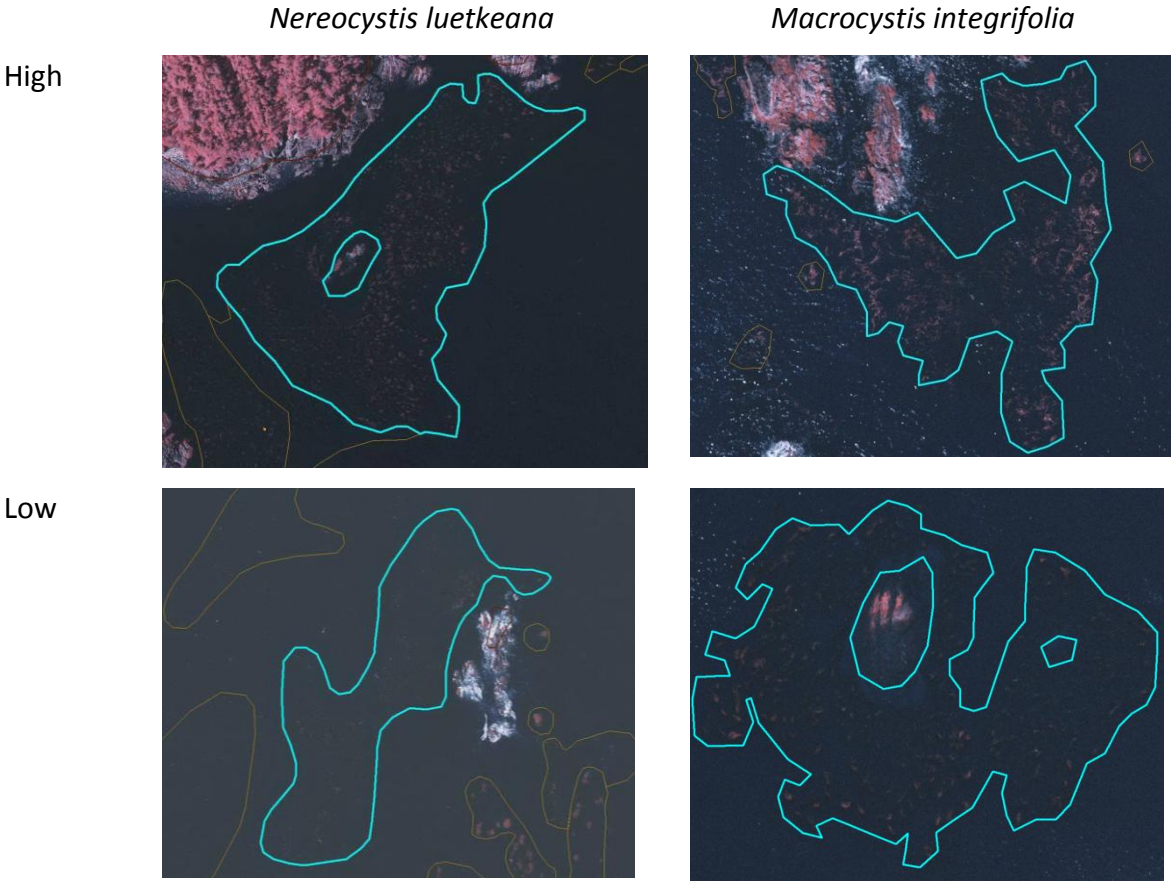


Table 1: Density counts of Bull kelp beds obtained using the point-intercept count method. Block: Statistical block; P_ID: Polygon identification code; Counts:

Number of times the grid was placed in a polygon; #1 – #8: Number of hits of plants on a grid point; Mean: Mean number of hits; D/10 m^2: Density of plants per 10 m^2. [Note that means shown below are illustrative only. As has been standard in application of the KIM-1 method to areas with little *Nereocystis* or with small beds of the species, counts for adjacent or nearby blocks are combined to obtain the minimum acceptable number of 10 counts. IS]

Block	P_ID	Counts	#1	#2	#3	#4	#5	#6	#7	#8	Mean	D/10m^2
a13	1172	1	19								19	12.165
a14	1140	1	19								19	12.165
a15	932	1	32								32	18.091
a15	945	1	18								18	11.709
a17	2042	1	31								31	17.635
a19	1021	1	22								22	13.532
a20	1989	2	35	27							31	17.635
a21	188	1	30								30	17.179
a22	998	1	41								41	22.193
a23	909	1	22								22	13.532
a25	2017	2	14	14							14	9.886
a27	1162	1	28								28	16.267
b(2)	278	1	29								29	16.723
b(2)	265	1	35								35	19.458
b(2)	283	1	58								58	29.942
c2	2815	1	13								13	9.430
c4	2310	1	6								6	6.239
c6	1532	5	0	1	1	0	0				0	3.686
c6	1533	8	1	1	0	4	0	4	2	1	2	4.245
c6	3110	4	15	14	9	5					11	8.404
c6	3111	2	1	1							1	3.960
c6	3112	1	16								16	10.797
c6	3113	2	1	10							6	6.011
c7	1524	7	4	4	2	3	7	6	15		6	6.174
c7	1530	1	5								5	5.783
c7	3098	2	2	2							2	4.416
c8	2133	1	21								21	13.077
c8	2285	8	11	7	5	3	9	6	17	10	9	7.379
c10	1505	1	18								18	11.709
c10	1507	2	16	24							20	12.621
c10	2154	1	57								57	29.487
c10	2168	2	30	49							40	21.509
c10	2169	1	24								24	14.444
c10	2170	1	52								52	27.207
c11	1490	2	29	41							35	19.458
c11	1492	2	8	14							11	8.518
c11	2180	2	18	27							23	13.760
c11	2193	3	2	19	10						10	8.214
c12	2205	1	1								1	3.960
c13	2222	1	32								32	18.091

Contd.

Table 1: *continued*

Block	P_ID	Counts	#1	#2	#3	#4	#5	#6	#7	#8	Mean	D/10m^2
c13	2229	1	14								14	9.886
c15	1362	3	22	25	14						20	12.773
c15	2243	2	7	9							8	7.151
c15	2249	3	3	8	2						4	5.479
c15	2250	3	14	18	16						16	10.797
c17	2251	3	7	21	31						20	12.469
c17	2260	1	13								13	9.430
c24	1318	4	23	16	41	24					26	15.356
c24	2360	1	13								13	9.430
c24	2377	1	15								15	10.342
c25	1311	2	5	15							10	8.062
c25	2408	3	21	6	5						11	8.366
c26	1301	1	39								39	21.282
c26	1303	1	24								24	14.444
c26	2525	2	10	13							12	8.746
c26	2536	1	5								5	5.783
c27	1291	3	24	24	10						19	12.317
c27	2427	1	11								11	8.518
c27	2462	1	22								22	13.532
c28	1261	1	26								26	15.356
c28	1272	3	44	24	27						32	17.939
c28	1274	5	15	27	25	33	15				23	13.988
c28	2471	2	10	6							8	7.151
c28	2474	1	13								13	9.430
c28	2506	5	11	29	35	18	19				22	13.715
c28	2547	1	13								13	9.430
c29	2485	2	9	17							13	9.430
d52	513	1	25								25	14.900
d53	125	1	8								8	7.151
e17	1868	1	10								10	8.062
f20	160	3	0	2	2						1	4.112
f21	3173	2	15	15							15	10.342
f33	1752	1	15								15	10.342
f33	1757	5	12	17	34	30	16				22	13.441
f33	1771	1	11								11	8.518
f34	1773	1	8								8	7.151
f34	2773	1	3								3	4.872
f34	2774	1	8								8	7.151
f35	1794	2	19	31							25	14.900
f35	2779	1	20								20	12.621
f36	1811	1	7								7	6.695
f36	1815	1	17								17	11.253
f36	2753	1	21								21	13.077
f37	2808	1	13								13	9.430

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APPENDIX II

Dive Survey Report
Kelp Inventory 2007

Dive Survey Report
Kelp Inventory, 2007

Areas of British Columbia
Central Coast from Hakai Passage to Bardswell Group

Prepared by
Tammy Norgard
Ken Cripps

Debbie Paltzat

Prepared for
Heiltsuk Tribal Council
and the
Hakai Lúxvbálís Conservancy Area
March 2008

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Introduction

The Kelp Survey Method (KIM-1) developed by Foreman (1975) has been used throughout British Columbia during the 1990's to inventory standing stock of the major bed forming kelps *Nereocystis luetkeana* (bull kelp) and *Macrocystis integrifolia* (giant kelp). This method integrates infrared aerial photography and data from field estimates of mean plant weight to provide species specific biomass estimates.

In 1993 the Heiltsuk Fisheries program undertook an inventory of their Kelp Resources and the results of this survey can be found in the Fisheries Development Report, ISSN 0288-5975; no.37 (Field 1993).

The data reported in this report summarizes the results of the August 2007 kelp dive field survey. This field report will be incorporated into the overall analysis with the infrared aerial photography to gain complete biomass estimates for this area.

The results of the 2007 survey will provide the Heiltsuk Band and the Hakai Luxvbalis Conservancy Area with current kelp biomass estimates. Also this data can be compared with the survey data from the 1993 to assess the changes in kelp biomass over the past 14 years.

Identification of transect locations

The survey was completed from August 22nd to August 30th, 2007.

Transects were randomly identified on nautical charts by placing numbered grid paper over the study area (Figure 1). Random numbers were generated for X and Y intercepts. If the XY intercept fell outside beds identified in previous studies they were excluded. Good weather allowed us to complete more dive transects than were necessary so additional transects were placed in areas that were not part of previous studies. Local knowledge and field observations were used to identify the location and extent of the beds. Transects were then randomly identified in these beds using the same XY intercept approach used to identify transects in previously studied beds. [Ideally, all sample locations should be established at the start of the process to ensure appropriate statistical representation but good weather is too good an opportunity to pass up. IS]

Field Methods

Macrocystis

A 25 foot skiff was used to conduct all field surveys. The skiff was anchored at the randomly selected transect location A compass course was taken on the surface that was roughly parallel to the depth contours. The sampling unit was a 2 meter by 40 meter quadrat. Each of the two divers was responsible for counting all of the fronds

within one meter of their respective side of the transect line. A cannon ball, attached to a 40 meter long lead line, was dropped over the side of the boat to identify the start location for the transect. Diver 1 descended with a goodie bag containing the lead line and swam in the direction of the predetermined compass course. To ensure there was no damage to *Macrocystis* fronds, where *Macrocystis* plants were encounter along the compass bearing the goodie bag containing the leadline was passed through the plant while the diver went around. While Diver 1 was placing the transect line Diver 2 collected a *Macrocystis* plant or plants that were closest to the cannon ball until a minimum of 20 fronds were collected. Depth, substrate, and time were recorded for each biosample. Only plants outside the transect area were collected. Once biosamples were collected Diver 2 retrieved the one meter sticks and clip boards from the skiff and met Diver 1 at the far end of the transect line.

All fronds, frond initials and senescent fronds greater than 10cm were counted for each holdfast within the quadrat area. To ensure there was no double counting of plants the near shore diver counted all the plants that contacted the transect line plus all of the holdfasts that were completely within the one meter wide quadrat. The other diver did not count any fronds that were in direct contact with the transect line but counted all the holdfasts that were completely within the one meter plus those holdfasts that were partially within the one meter quadrat.

While divers were conducting transect surveys *Macrocystis* biosamples were processed by enumerating and removing the fronds, frond initials, and senescent fronds greater than 10 cm from the holdfast and placing them in a large bucket. A total weight and the number of fronds were recorded for each biosample. Bucket weight was removed from the total weight of the bucket and fronds.

Nereocystis

Only biosamples were required for beds that contained only *Nereocystis*. Biosamples were collected by anchoring the boat at the randomly selected location and sending down a single diver to collect 15 to 20 *Nereocystis* plants that were in close proximity to the anchor. The diver recorded the depth that the biosample was taken. Holdfasts were removed and weight was recorded for each plant.

Field Survey Results

The field survey results will be analyzed with the Ariel survey will be done to complete Biomass estimated for the areas.

The highest *Macrocystis* Frond density of 11.95/m^2 was found at transect 82 in Spider Island (Table 1). Also North Goose and Thompson Bay had Frond densities of over 10/m^2.

The highest *Nereocystis* individual plant weights were found around Goose Island and the Bardwell Group (Table 2).

Summary
Once the dive survey is incorporated with the Arial data we will have a better understanding of the Kelp Biomass in the areas. The preliminary dive survey results show us that there were still high densities of *Macrocystis* throughout the area.

Table 1 Summary of *Macrocystis* Field survey data. The columns were of Total Frond Wt, Mean Frond Wt and Number of Fronds was completed in the Biosampling and the Frond Count was completed in the during the dive. The Frond Density (#/m^2) is the sum of the two diver counts divided by the 80 quadrate (2 meter wide by 40 meter long quadrat).

Transect	Depth(ft)	Date	Time	Location	Latitude	Longitude	Total Frond wt (g)	Tare wt (g)	Mean Frond Wt (g)	Number of Fronds	Frond Count Diver 1	Frond Count Diver 2	Frond Density/ Quadrat (#/m2)
54	18	08/22/07	14:50:00	West Goose Is	51 58.081	128 27.400	17	4.2	0.47	27	329	227	6.95
51	16	08/22/07	13:10:00	N Goose Is	52 00.160	128 26.238	15.4	10.5	0.33	15	568	310	10.98
46	28	08/22/07	9:43:00	E Goose Is	51 58.005	128 05.092	18.7	6.3	0.52	24	183	180	4.54
50	32	08/22/07	12:05:00	N Goose Is	52 00.400	128 26.090	20.8	6.3	0.97	15	116	152	3.35
56	22	08/22/07	15:58:00	West Goose Is	51 56.822	128 28.803	21.3	4.2	1.22	14	221	241	5.78
57	25	08/23/07	13:23:00	West Goose Is	51 56.401	128 28.939	18	2.1	1.45	11	156	222	4.73
39	20	08/23/07	14:23:00	S Goose Is	51 54.965	128 27.263	22.9	8.4	1.12	13	32	87	1.49
42	20	08/23/07	16:08:00	E Goose Is	51 56.120	128 26.292	11.2	2.1	0.51	18	93	132	2.81
37	22	08/23/07	14:53:00	S Goose Is	51 54.068	128 26.312	40.6	6.3	1.43	24	293	219	6.40
43	17	08/23/07	16:35:00	E Goose Is	51 56.320	128 25.830	16.8	2.1	0.67	22	57	117	2.18
27	0	08/24/07	11:39:00	Cultus Sound	51 54.673	128 11.911	7.7	2.1	0.56	10	0	0	0.00
29	18	08/24/07	10:40:00	Cultus Sound	51.55.788	128.10.799	22.4	2.1	0.97	21	112	55	2.09
20	16	08/24/07	13:44:00	Cultus Sound	51 53.578	128 14.218	15.2	2.1	0.66	20	126	99	2.81
25	21	08/24/07	11:52:00	Cultus Sound	51 55.010	128 13.405	22.4	2.1	1.02	20	334	298	7.90
26	12	08/24/07	14:37:00	Cultus Sound	51 54.875	128 12.853	11.5	2.1	0.36	26	179	304	6.04
44	22	08/25/07	10:21:00	E Goose Is	51 57.479	128 25.020	11.4	2.1	0.85	11	80	52	1.65
45	18	08/25/07	9:44:00	E Goose Is	51 57.769	128 25.122	13.9	2.1	0.84	14	335	220	6.94
66	12	08/25/07	13:45:00	Stryker Is	52 05.887	128 22.906	26.2	2.1	1.10	22	134	309	5.54
58	26	08/25/07	11:11:00	Mcmullin	52 02.918	128 24.795	15.7	2.1	0.76	18	100	136	2.95
67	17	08/25/07	14:19:00	Stryker Is	52 06.292	128 22.793	19.4	2.1	0.62	28	159	108	3.34
79	22	08/26/07	15:37:00	Bardswell Grp	52 10.874	128 29.008	7.6	2.1	0.32	17	25	15	0.50
78	18	08/26/07	14:56:00	Bardswell Grp	52 09.385	128 29.570	17.1	2.1	0.71	21	170	88	3.23
76	28	08/26/07	14:03:00	Bardswell Grp	52 08.977	128 28.925	10.3	2.1	0.63	13	214	101	3.94
71	20	08/26/07	11:28:00	Thompson Bay	52 08.841	128 24.035	29.8	2.1	1.32	21	425	436	10.76
72	11	08/26/07	12:52:00	Thompson Bay	52 09.807	128 23.530	6.6	2.1	0.28	16	123	165	3.60
68	18	08/26/07	9:49:00	Thompson Bay	52 07.148	128 22.123	13.8	2.1	0.43	27	85	244	4.11
70	22	08/26/07	10:48:00	Thompson Bay	52 09.113	128 22.693	15.6	2.1	0.75	18	373	393	9.58
19	20	08/28/07	13:12:00	Spider Islands	51 50.508	128 14.008	20.7	2.1	0.93	20	106	230	4.20
81	18	08/28/07	13:51:00	Spider Islands	51 51.425	128 14.454	8.7	2.1	0.55	12	29	67	1.20
82	18	08/28/07	14:22:00	Spider Islands	51 51.377	128 12.941	10.9	2.1	0.38	23	432	524	11.95
18	16	08/28/07	11:22:00	Breadner Grp	51 49.187	128 14.995	6.6	2.1	0.16	28	178	94	3.40
83	19	08/28/07	12:40:00	Kittyhawk Grp	51 49.962	128 11.812	15	2.1	1.17	11	124	105	2.86
16	8	08/28/07	10:15:00	Breadner Grp	51 48.545	128 14.025	18.9	2.1	0.70	24	153	119	3.40
17	25	08/28/07	10:43:00	Breadner Grp	51 49.204	128 13.994	33.1	2.1	1.07	29	287	271	6.98
89	12	08/30/07	14:36:00	Tribal Grp	52 04.453	128 19.244	21.8	2.1	0.62	32	194	148	4.28
88	20	08/30/07	13:28:00	Admiral Grp	52 01.312	128 17.277	38.8	2.1	1.08	34	95	116	2.64
85	18	08/30/07	10:28:00	McNaughton Gr	51 56.886	128 12.568	48.7	4.2	0.87	51	143	103	3.08
84	18	08/30/07	9:45:00	McNaughton Gr	51 57.028	128 14.469	43.7	4.2	1.13	35	219	170	4.86
86	11	08/30/07	10:59:00	McNaughton Gr	51 57.508	128 12.254	24.7	2.1	1.33	17	33	23	0.70

Table 2. Summary *Nereocystis* field data. [Total number of plants: 396. Overall average is shown at bottom (total weight of all plants / total number of plants. StDev shown at bottom is StDev of weight of all plants. IS]

Transect	Depth(ft)	Date	Time	Location	Sum of Plant Wt	Average of Plant Wt	StdDev of Plant Wt
2	11	08/27/07	12:09:00 PM	Hakai Pass	12.70	1.41	0.65
4	22	08/27/07	11:05:00 AM	Hakai Pass	17.00	1.55	1.25
5	22	08/27/07	10:44:00 AM	Hakai Pass	11.80	1.07	0.76
6	11	08/27/07	10:18:00 AM	Hakai Pass	18.80	1.88	0.86
8	21	08/27/07	11:24:00 AM	Hakai Pass	11.00	1.00	0.72
9	18	08/27/07	11:45:00 AM	Hakai Pass	17.80	1.78	1.37
12	33	08/27/07	12:30:00 PM	Hakai Pass	32.40	2.03	1.60
13	35	08/27/07	2:43:00 PM	Hakai Pass	74.10	2.96	1.20
14	18	08/27/07	2:32:00 PM	Hakai Pass	37.50	1.97	0.84
15	19	08/27/07	2:22:00 PM	Hakai Pass	9.00	0.69	0.47
21	26	08/24/07	1:01:00 PM	Cultus Sound	10.80	0.90	0.45
22	22	08/24/07	2:21:00 PM	Cultus Sound	17.80	1.11	0.89
23	26	08/24/07	12:44:00 PM	Cultus Sound	7.00	0.54	0.30
27	13	08/24/07	11:30:00 AM	Cultus Sound	26.40	1.76	1.24
30	24	08/23/07	10:18:00 AM	S Goose Is	63.50	3.74	1.66
33	19	08/23/07	10:53:00 AM	S Goose Is	74.30	4.95	2.97
35	25	08/23/07	11:19:00 AM	S Goose Is	98.40	4.92	2.57
38	24	08/23/07	3:36:00 PM	S Goose Is	17.90	1.12	0.55
40	22	08/23/07	12:52:00 PM	W Goose Is	46.40	3.09	2.39
48	19	08/22/07	11:50:00 AM	North Goose Is	33.40	1.96	1.44
53	24	08/22/07	2:27:00 PM	West Goose Is	34.60	2.16	1.48
59	20	08/25/07	12:02:00 PM	McMullin	28.40	2.03	1.46
61	23	08/25/07	12:46:00 PM	McMullin	25.30	3.16	1.95
63	25	08/25/07	1:03:00 PM	Stryker Is	28.10	2.01	1.61
64	22	08/25/07	1:19:00 PM	Stryker Is	12.00	1.20	0.72
65	12	08/25/07	1:31:00 PM	Stryker Is	14.40	1.11	0.54
69	12	08/26/07	10:25:00 AM	Thompson Bay	8.70	0.87	0.53
75	36	08/26/07	1:34:00 PM	Bardswell Grp	26.50	3.31	1.49
87	12	08/30/07	11:34:00 AM	Prince Group	15.20	1.27	0.68
Total					831.20	2.10	1.82

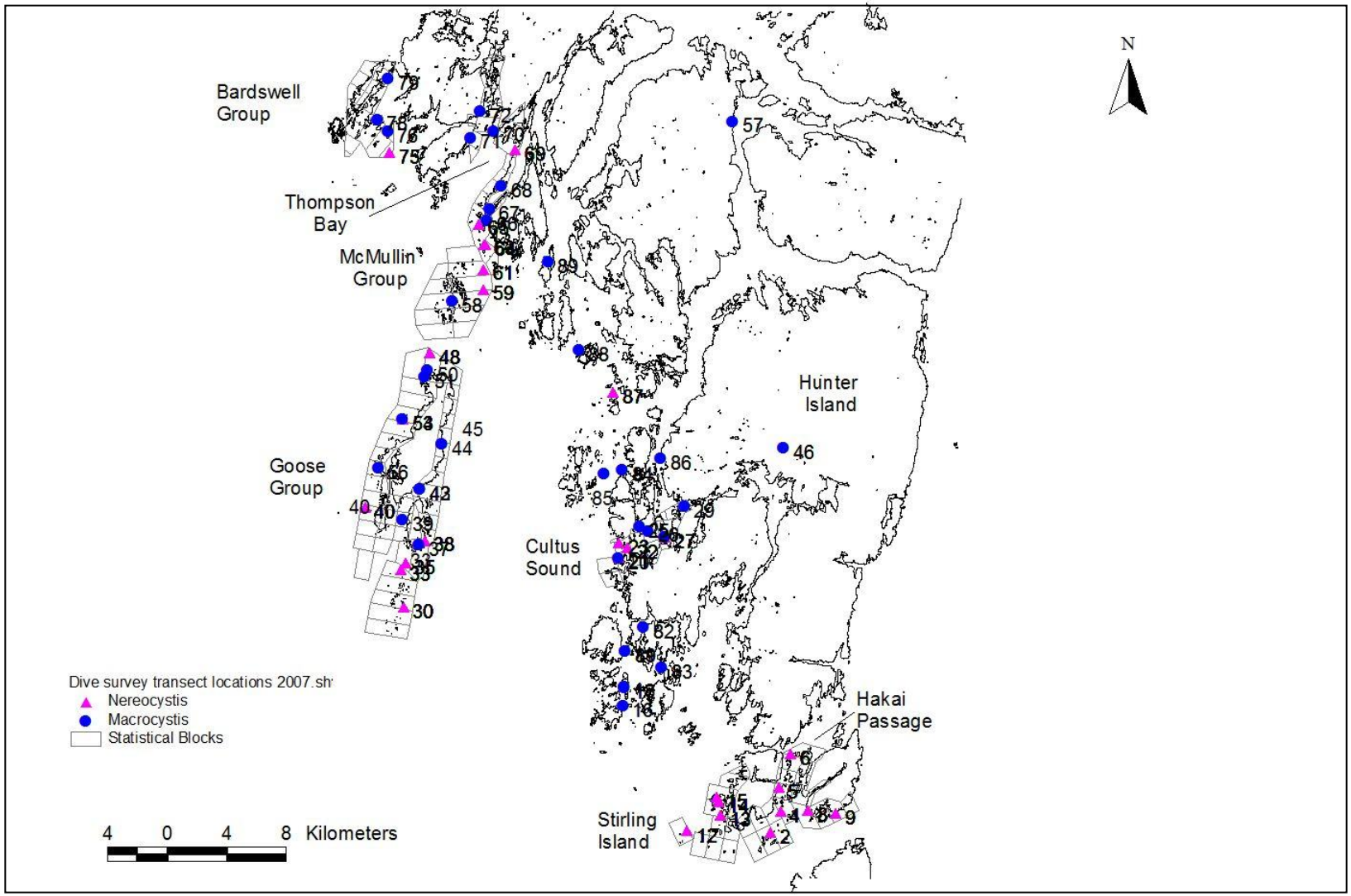

Figure 1. Kelp survey locations, purple triangles are *Nereocystis* transects and blue dots are *Macrocystis* transects

APPENDIX III

Kelp maps on Sheets 2 through 10

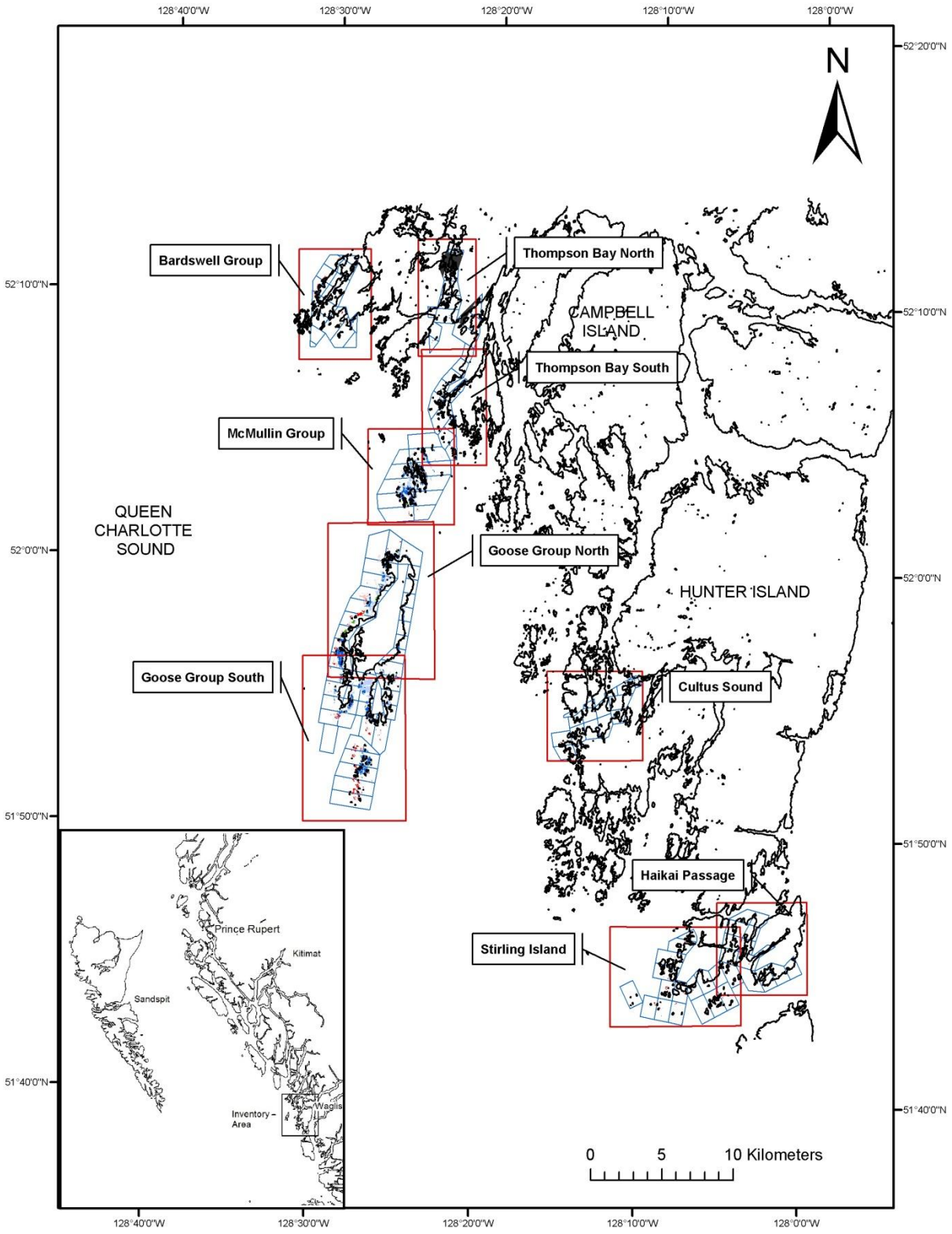

Figure1. Index map of survey areas

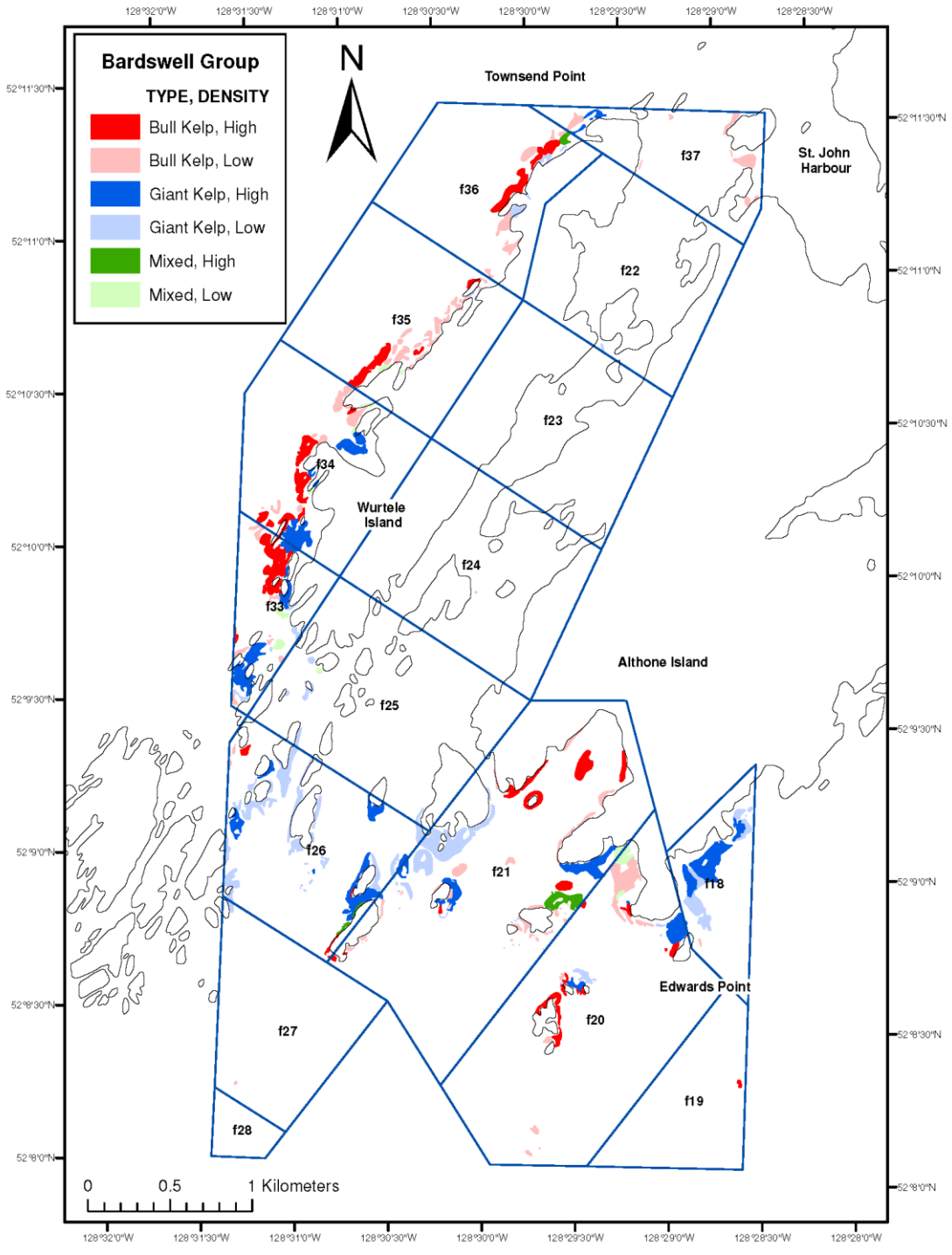

Figure 2. Map of the kelp resources in the Bardswell Group Islands with statistical blocks

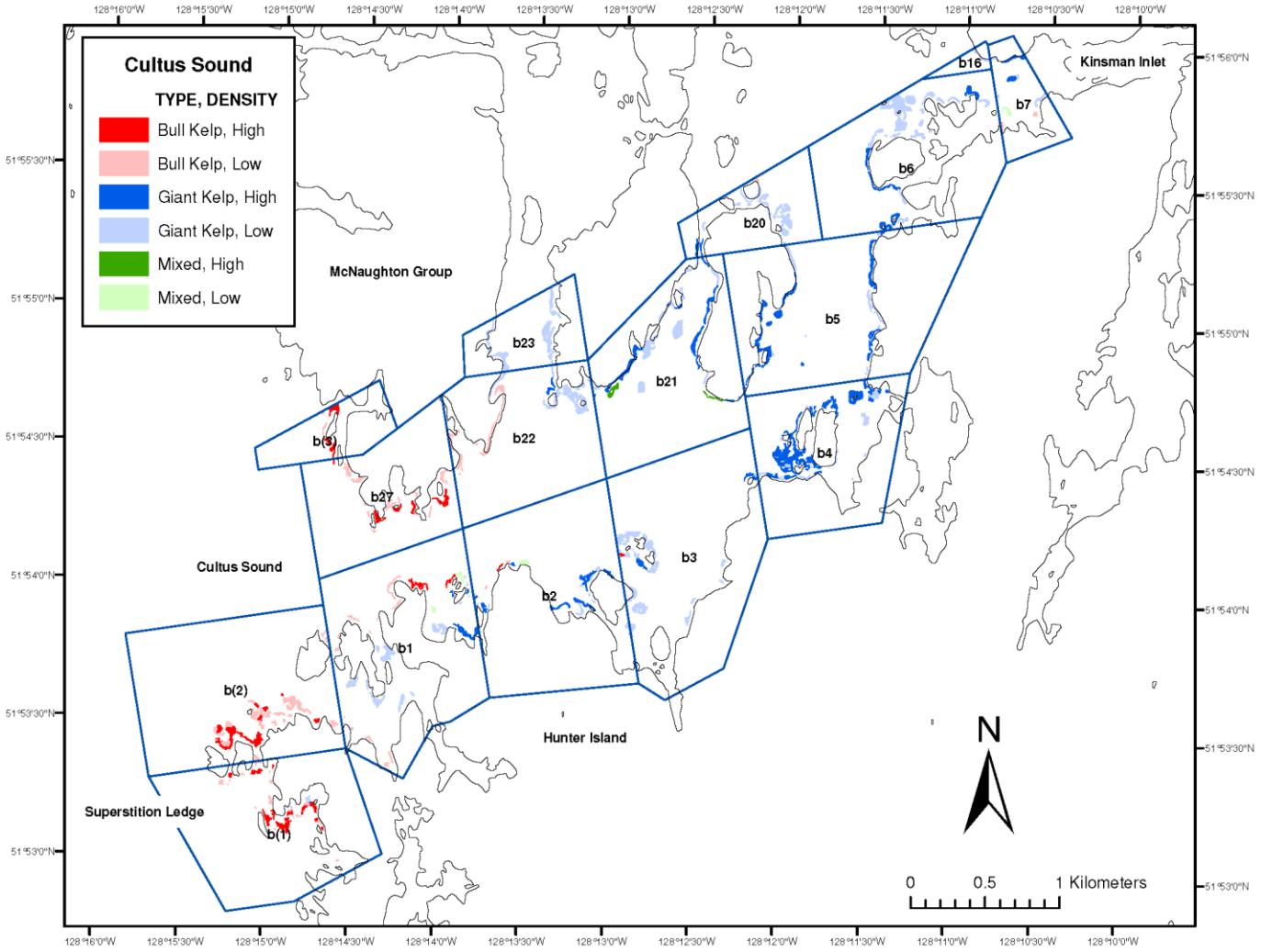

Figure 3. Map of the kelp resources in the Cultus Sound Islands with statistical blocks

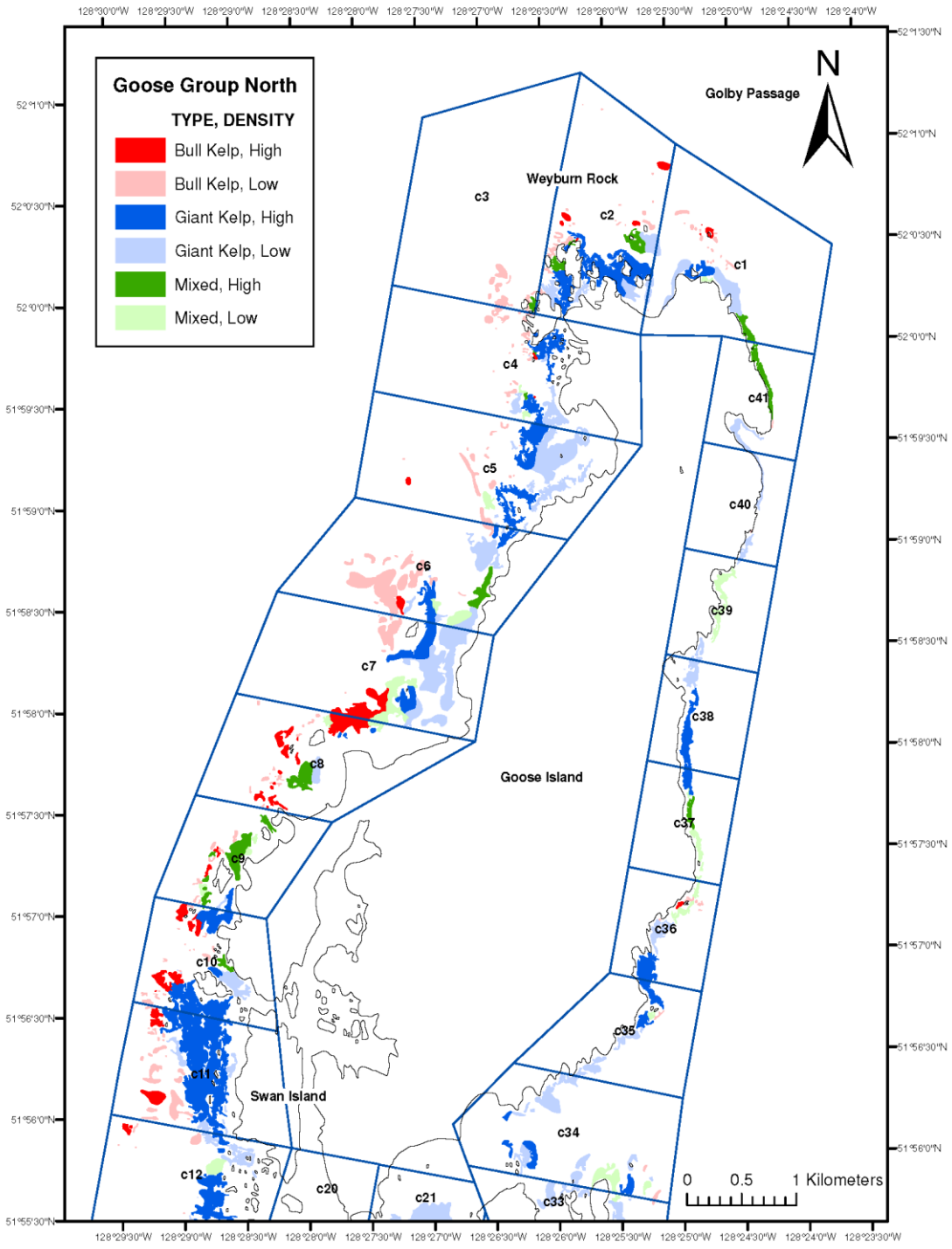

Figure 4. Map of the kelp resources in the northern Goose Group Islands with statistical blocks

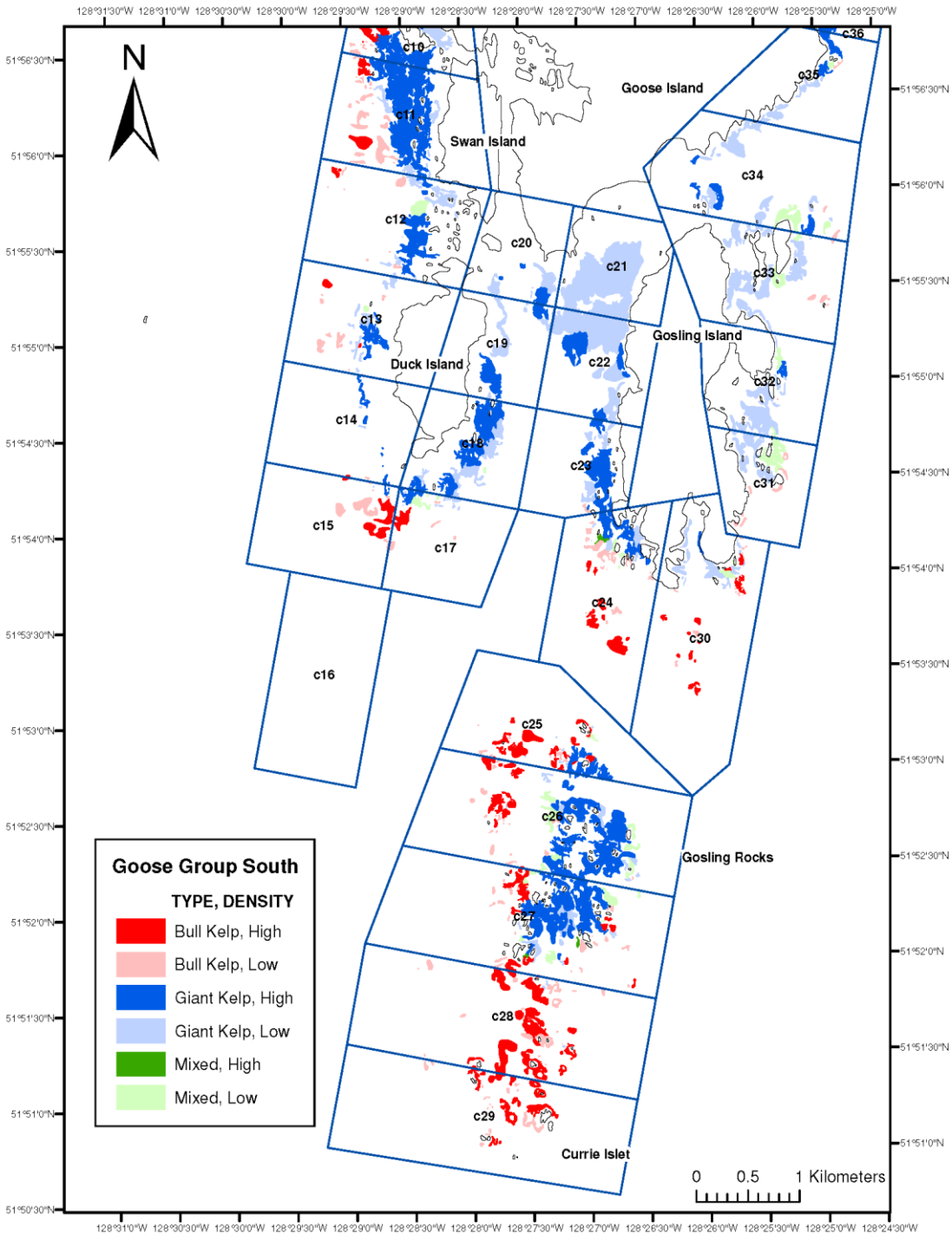

Figure 5. Map of the kelp resources in the southern Goose Group Islands with statistical blocks

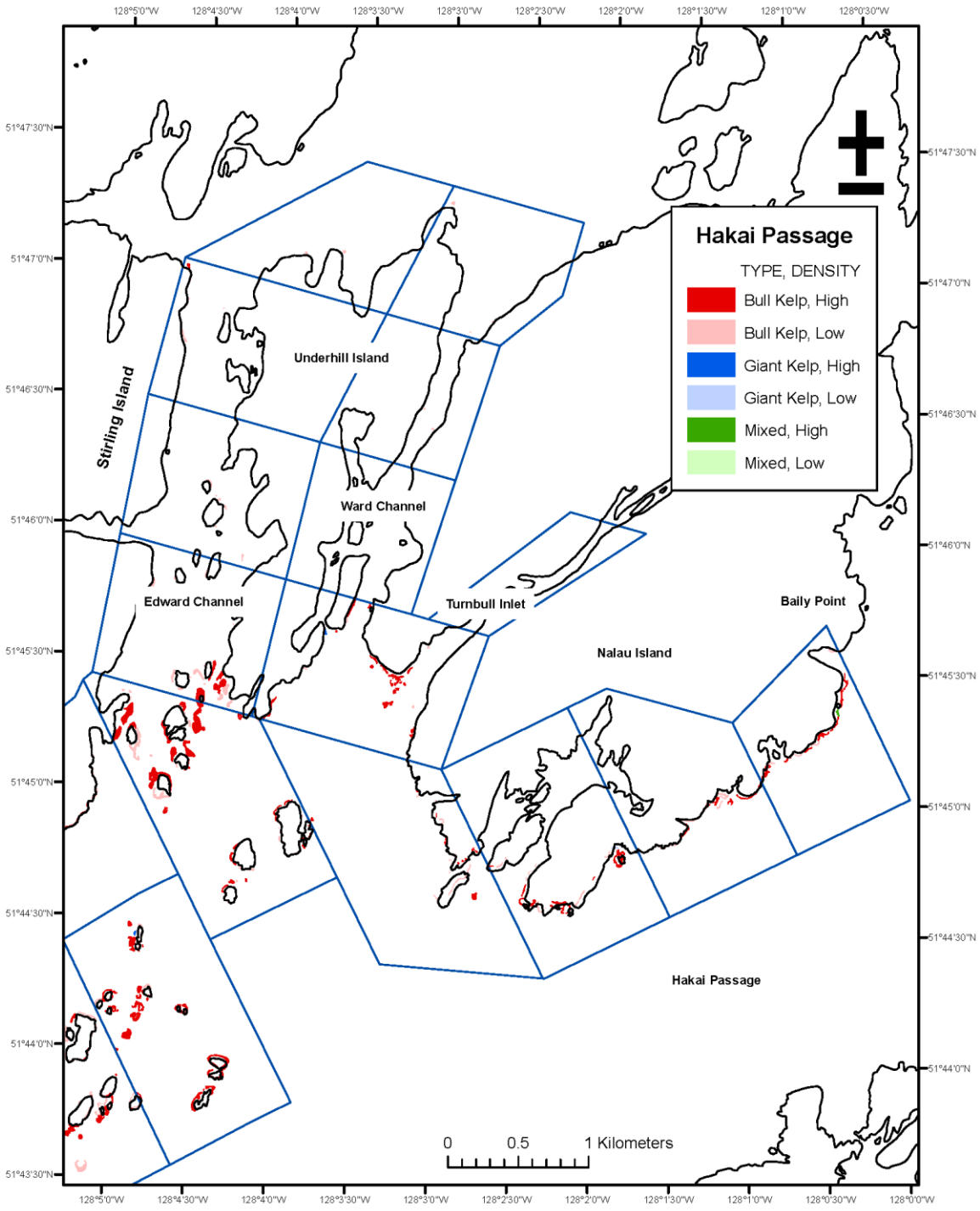

Figure 6. Map of the kelp resources in the Hakai Passage Islands with statistical blocks

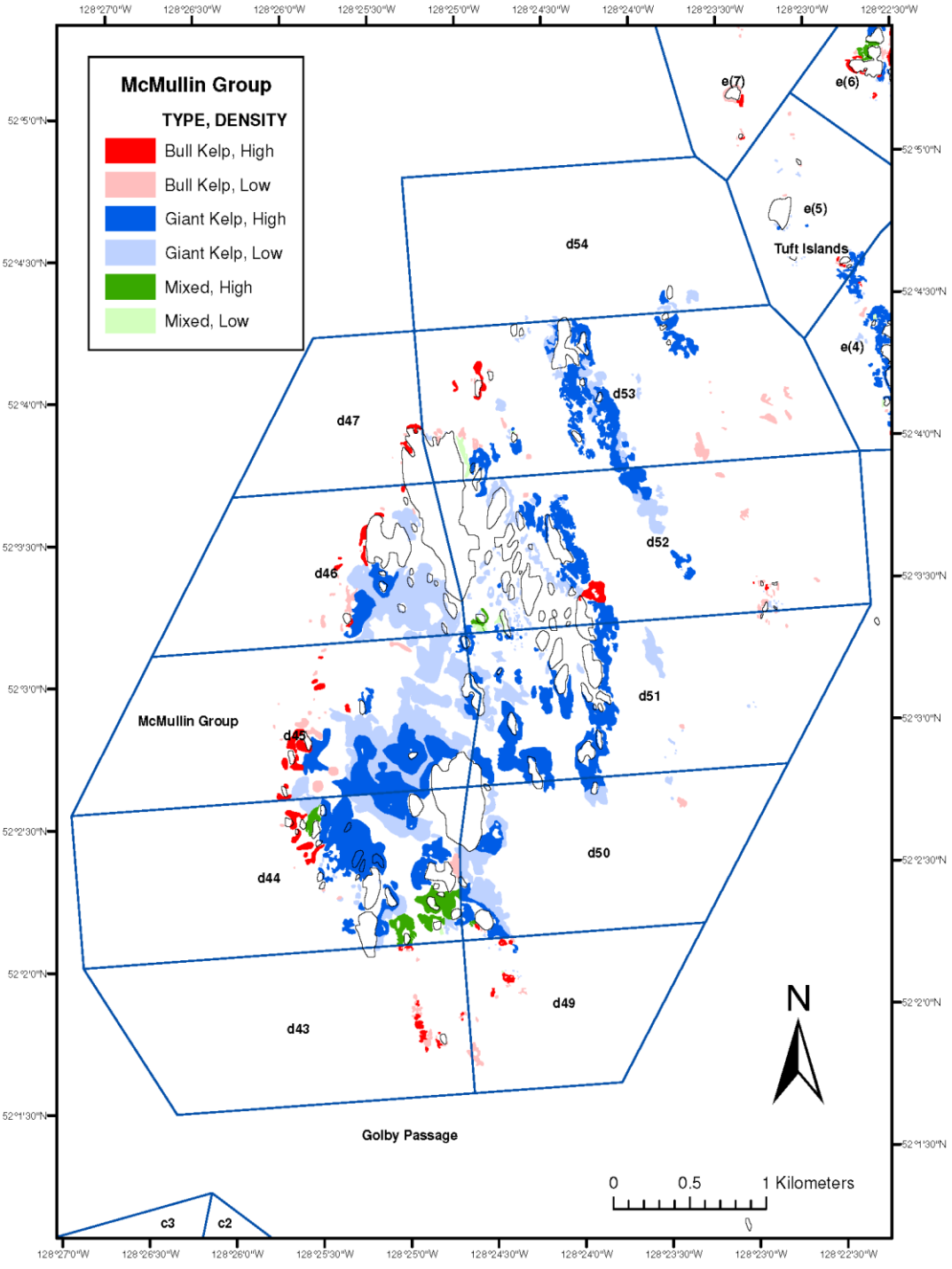

Figure 7. Map of the kelp resources in the McMullin Group Islands with statistical blocks

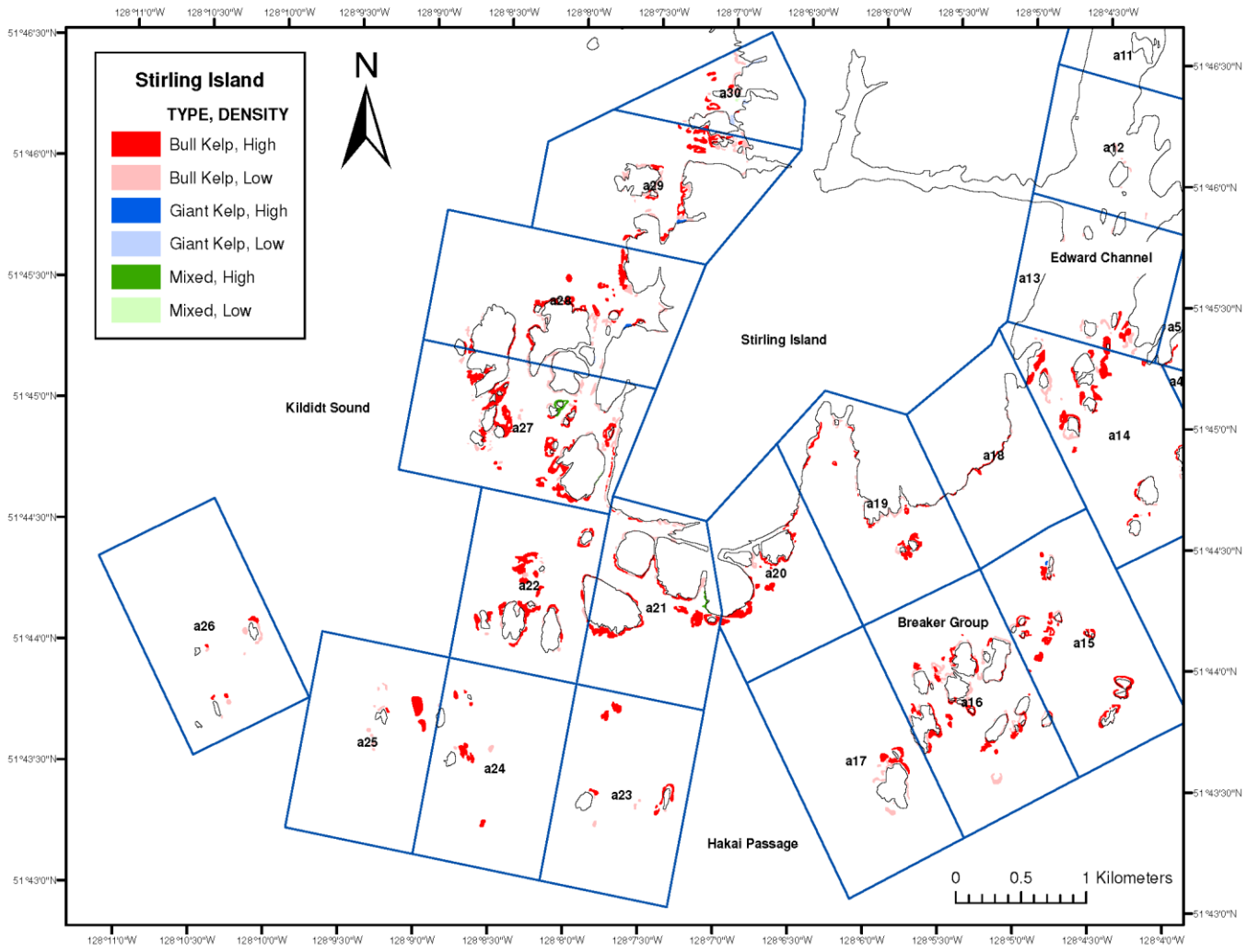

Figure 8. Map of the kelp resources in the Stirling Island area with statistical blocks

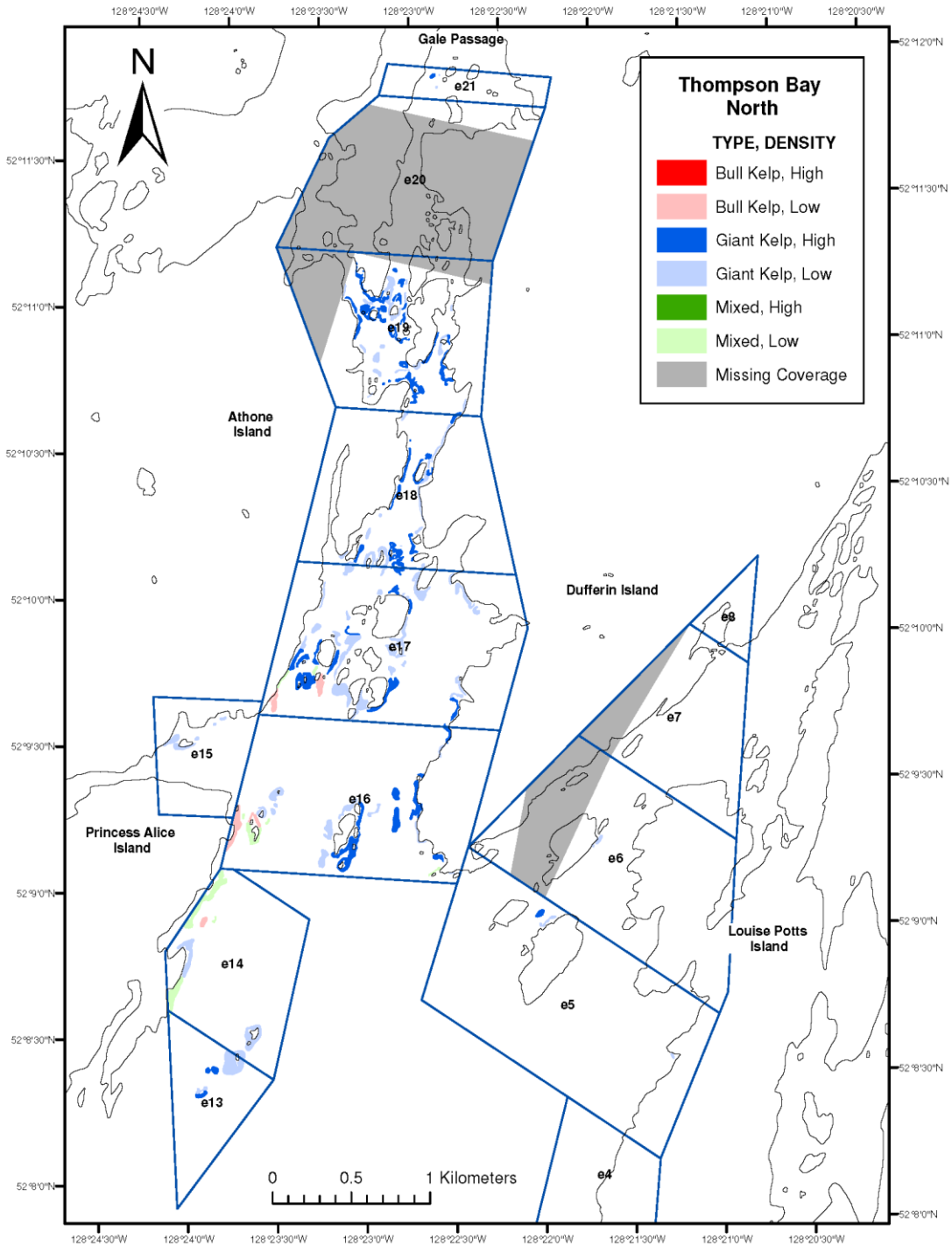

Figure 9. Map of the kelp resources in the northern Thompson Bay area with statistical blocks and showing the missing air photo coverage

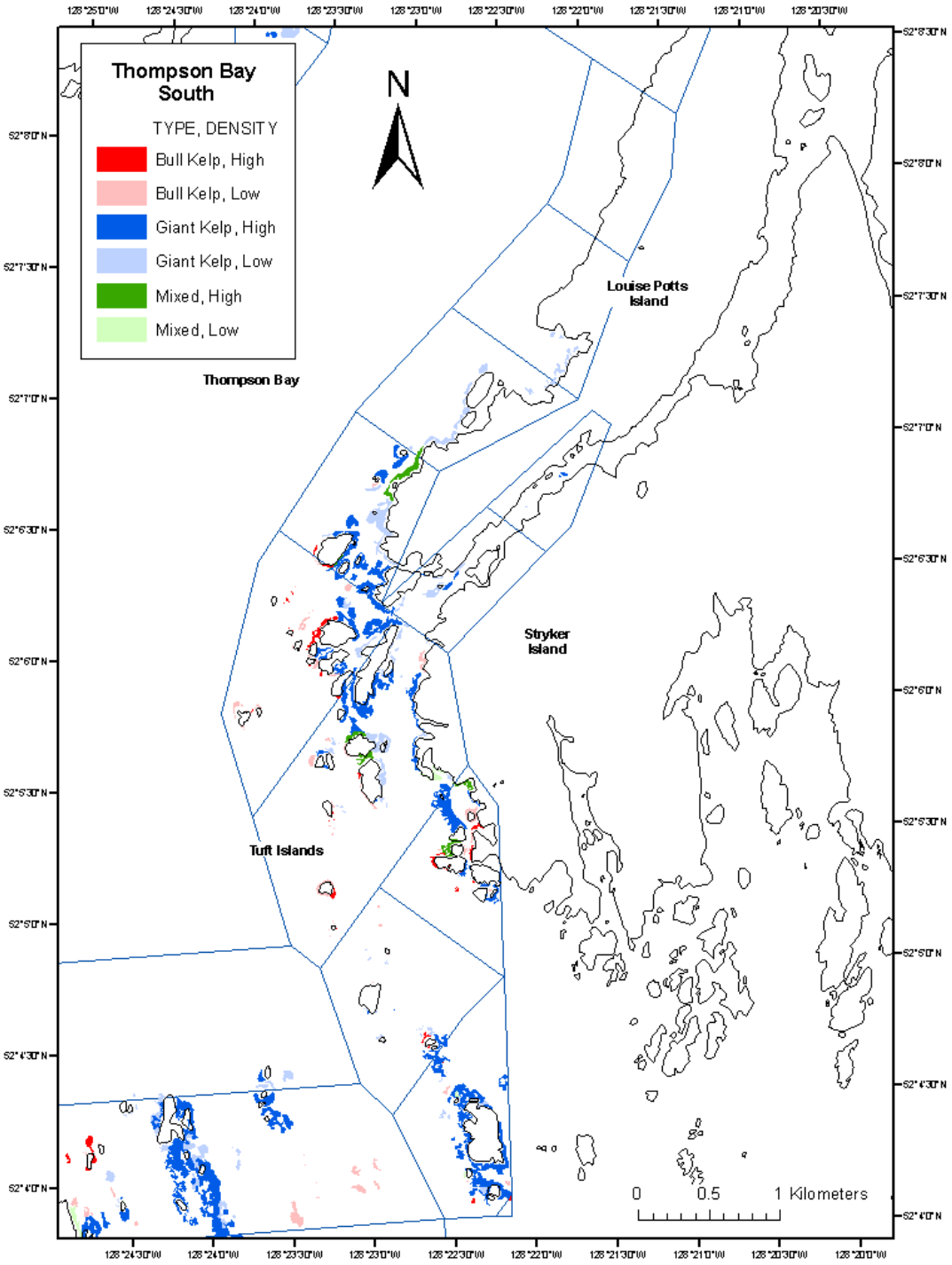

Figure 10. Map of the kelp resources in the southern Thompson Bay area with statistical blocks