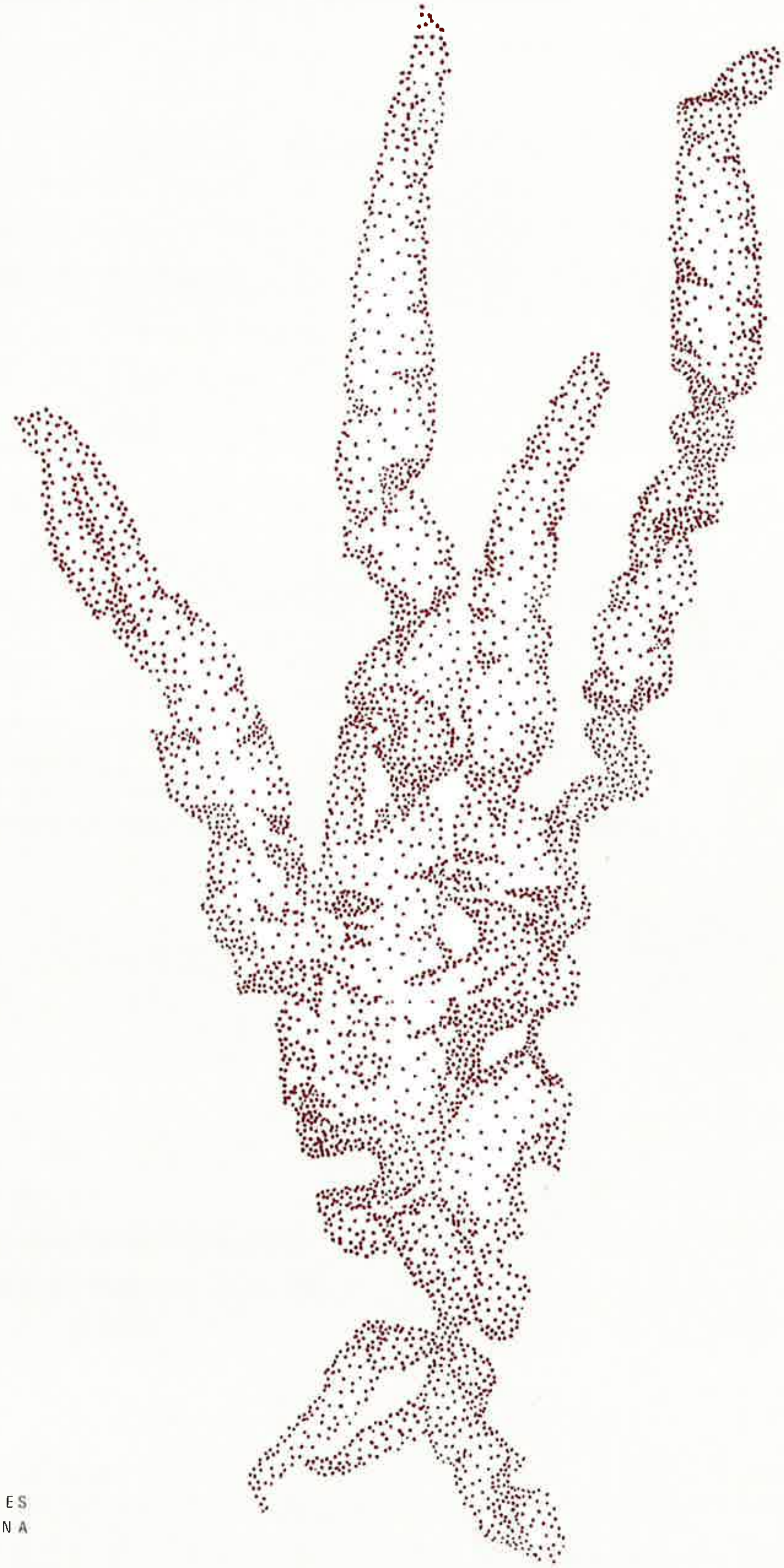
Phenology of the red seaweed Porphyra (karengo) at Kaikoura, South Island, New Zealand



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Phenology of the red seaweed *Porphyra* (karengo) at Kaikoura, South Island, New Zealand

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Cover: *Porphyra* mature plant. (Drawn by A. M. Conroy)

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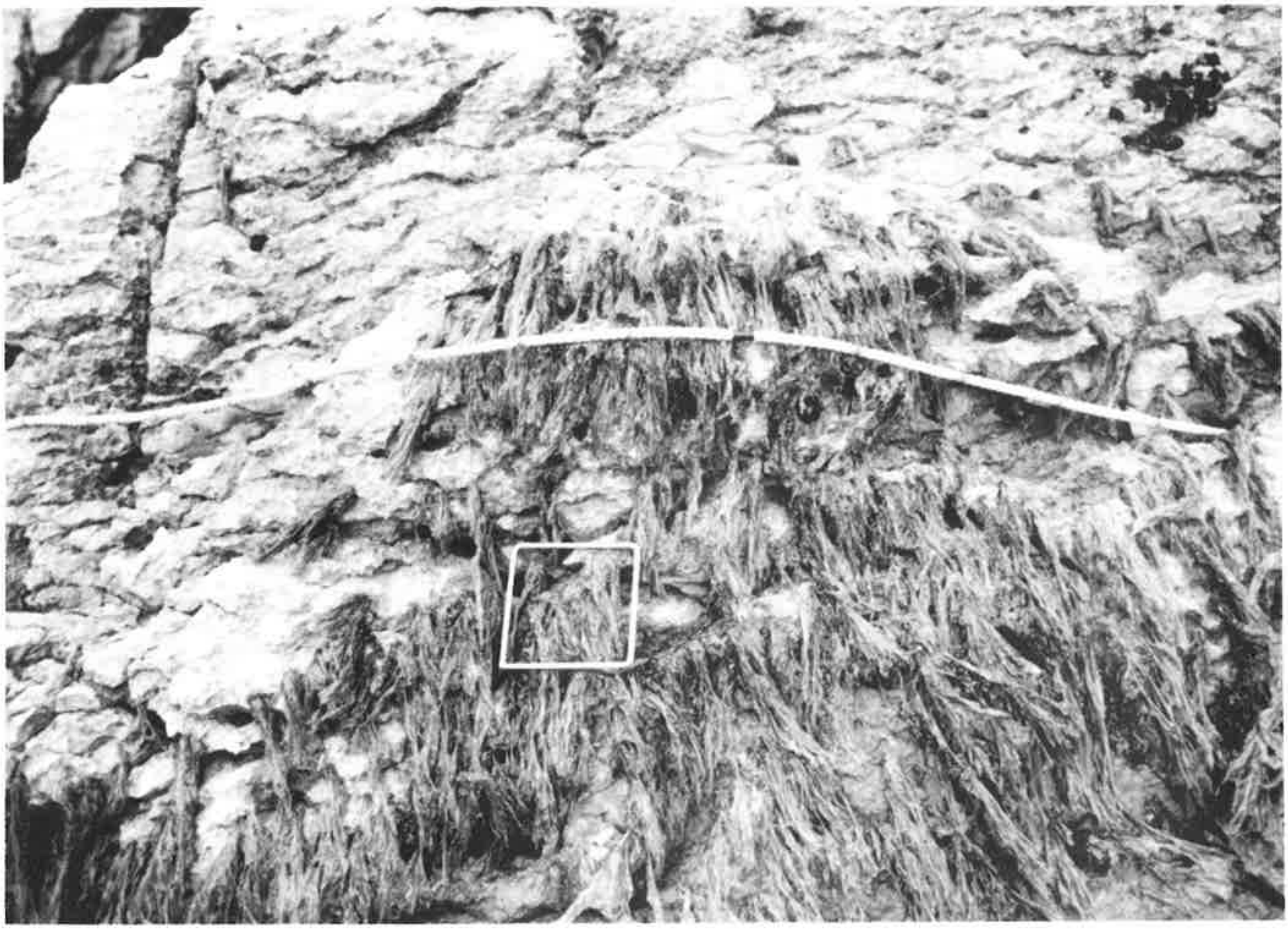

Frontispiece: An example of the *Porphyra* population at South Bay, Kaikoura showing a transect line and a quadrat (10 x 10 cm).

Abstract

Nelson, W. A., O'Halloran, S. M. L., Conroy, A. M., and Jorgensen, M.A. 1990: Phenology of the red seaweed *Porphyra* (karengo) at Kaikoura, South Island, New Zealand. *N.Z. Fisheries Technical Report No. 20*. 23p.

Commercial interest in New Zealand's *Porphyra* resource highlighted the need to obtain information about the phenology and impact of harvest on this red seaweed. Systematic field observations were carried out between August 1985 and October 1986 on *Porphyra* populations on the Kaikoura coast (east coast of the South Island), the site of most of the commercial interest. The three study areas (Waipapa Bay, Point Kean, and South Bay) were chosen so that the 14 sample sites covered the full tidal range of *Porphyra* distribution and included different aspects, substrate types, textures, and slopes. Monthly phenology observations made it possible to assess changes in population density and variability, as well as mean plant size (length). The mowing trial executed on 45 sets of four 10 x 10 cm quadrats showed that quadrats left unharvested during July gave significantly greater yields than those harvested in July and one, or both, subsequent months. This study also showed that there were several species of *Porphyra* at Kaikoura, rather than one, as previously thought.

Introduction

The red seaweed *Porphyra* is eaten throughout the world where the genus is found. It is a highly regarded seafood in Asia, particularly in Japan, where it is very important commercially and has a retail value of over US$1 billion and where there are over 20 000 people employed in the cultivation of *Porphyra* or *nori* (Mumford and Miura 1989). In New Zealand *Porphyra* is known as karengo and is a highly prized seasonal food of the Maori. Commercial interest in the *Porphyra* resource has raised questions about the biology and distribution of this seaweed in New Zealand and has also generated considerable concern about the impact of harvesting on the sustainable growth of karengo populations.

The Kaikoura region, on the east coast of the South Island, has been the centre of most commercial interest in karengo. There has been one fishing permit holder operating a small harvest in the area for about 10 y. The Kaikoura Tribal Council has expressed concern about the potential impact of commercial harvesting on the traditional use of the karengo populations.

There are no published accounts of the ecology of *Porphyra* in New Zealand, though Rasmussen (1965) made brief comments about the size of the *Porphyra* population at Kaikoura, and Bradstock and Kissling (1980) used aerial infra-red photography to attempt estimates of the biomass of *Porphyra* available for harvest on the Kaikoura coast.

The aim of this study was to gather background information on the seasonal cycle of *Porphyra* at Kaikoura. A programme of systematic observations was established in August 1985, and data were collected from September 1985 until October 1986. A second phase of the work began in June 1986 with an experimental trial designed to examine the impact of harvesting on different parts of the population. An outcome of this preliminary field experimentation was a further experimental programme (May-September 1987) to examine the impact of harvest method and timing on regeneration and yield of *Porphyra* (Nelson and Conroy in press).

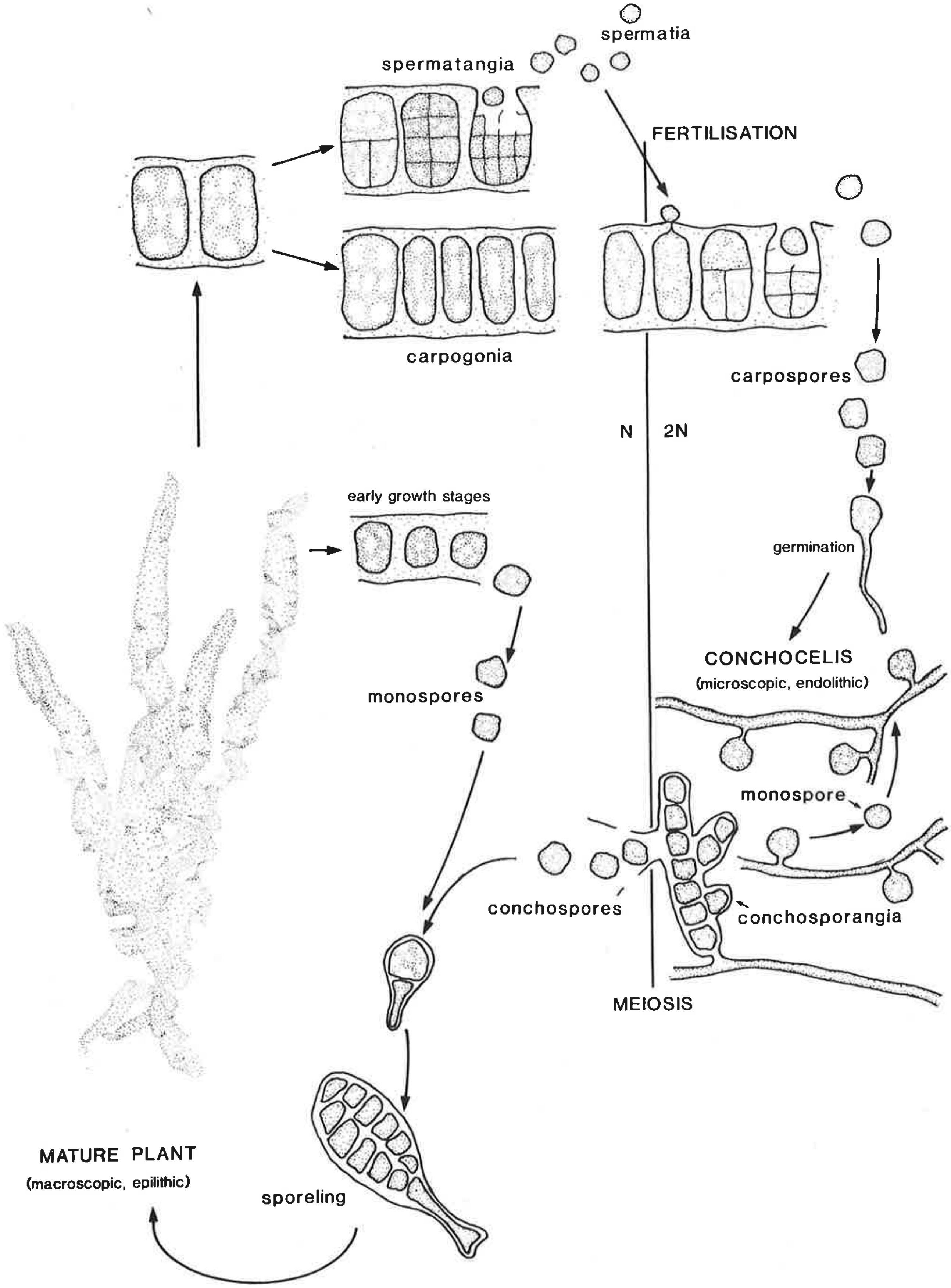

Figure 1: Life history of *Porphyra* species showing the alternation of macroscopic and microscopic generations.

Porphyra taxonomy and life history

At present one name is used for all *Porphyra* found growing on rocks in mainland New Zealand: *Porphyra columbina* Montagne (Levring 1955, Chapman 1969). A taxonomic study of the genus in New Zealand is in progress (Nelson, National Museum), and it is now clear that there are several undescribed epilithic species in New Zealand. In this study samples were taken for herbarium reference, and these are contributing to the development of new species concepts. Because the taxonomic situation was not clear when the field programme began, we tried to sample the greatest range of material growing on the shore and thereby cover all species of *Porphyra* occurring in the area. Sites were selected to cover as many habitats of *Porphyra* as possible.

Porphyra has a complex life history in which the sheet or ribbon-like seaweed seen growing on the shore for part of the year alternates with a microscopic phase which grows in mollusc and barnacle shells for the rest of the year (Figure 1). This generalised life history was unravelled for a species of *Porphyra* by Drew (1949) who showed that the filamentous conchocelis phase grew from spores produced by *Porphyra*. Subsequent life history studies of many species of *Porphyra* in other parts of the world have found that the plants are sensitive to levels of light, temperature, and nutrients and that the production of spores is triggered by seasonal changes in these environmental factors. There are no published accounts of culture studies of epilithic *Porphyra* in New Zealand. Conchocelis filaments were recently observed for the first time in New Zealand within calcareous shells, some of which came from Kaikoura (Nielsen 1987).

Methods

Study areas

On the Kaikoura coast three localities with varied aspect and topography and substantial *Porphyra* populations of commercial interest were selected: Waipapa Bay, Point Kean, and South Bay (Figure 2). Within these localities 14 sample sites were selected to span the full tidal range of *Porphyra* distribution. The sites were permanently marked by small coloured plastic markers set in an epoxy-based cement (1 : 1 mixture by volume of Epiglass ER270 and EH310, Consolidated Chemicals, Auckland, New Zealand) on the rock.

Waipapa Bay

Greywacke bedrock and crags form the predominant bedrock with large smooth boulders dominating the upper intertidal zone. There was evidence of sand abrasion from beaches to the north and there was also considerable transport of gravel and cobbles in the upper intertidal. Six sites were chosen: two upper intertidal, two mid intertidal, and two lower intertidal. The sites were open to the prevailing winds from the south.

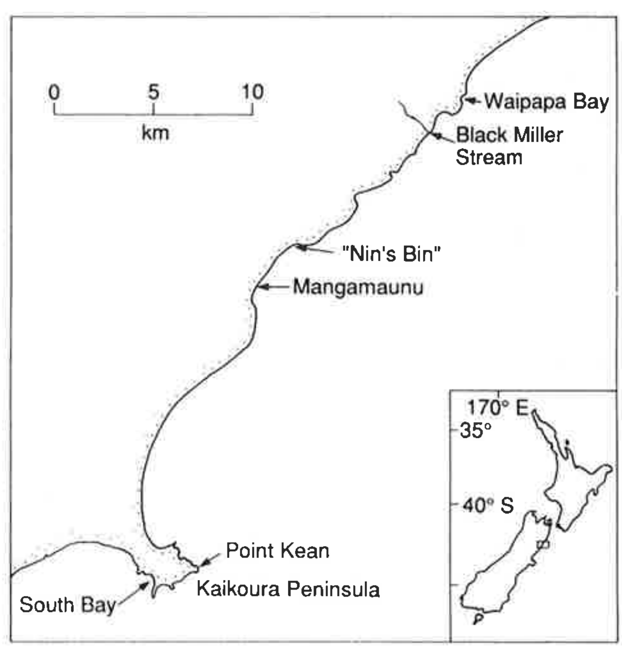

Figure 2: Study areas on the Kaikoura coast.

Point Kean

In this area of the eastern Kaikoura peninsula there are extensive siltstone platforms. Three sites (upper, mid, and lower range) were located here. The upper site was on a smooth gently sloping platform, and the mid and lower sites covered an area of platform and boulders, the lower reaches of which were occasionally affected by gravel and cobble movement. The sites faced north.

South Bay

Five sites were set up at this locality on the southern coast of the peninsula. The two upper sites were on craggy rocks, and the one mid range and two lower range sites were on undulating boulders. The sites faced west. In addition to these localities, collections of *Porphyra* were made at other places along the coast, particularly Black Miller Stream, Mangamaunu, "Nin's Bin", and around the Kaikoura Peninsula.

Phenology observations 1985-86

Each site was visited at monthly intervals to coincide with spring low tides. At each visit a rope, which was permanently marked at 0.5 m intervals, was laid on the substrate within the area marked for each site. Two measurements were recorded at each 0.5 m interval:

1. the distance to the nearest *Porphyra* plant; if there were no plants within 0.5 m, "> 0.5 m" was recorded;
2. the length of the plant to the nearest millimetre; for recognisable plants under 0.5 mm in length, "< 0.5 mm" was recorded.

The following summary statistics were calculated from the nearest neighbour data: density index and an interquartile range to give an indication of variability and mean plant length and its standard error (*see* Appendix 1).

Colour slides were taken at each visit from the same vantage point for each site. A metre rule and a 10 x 10 cm quadrat were placed within the sample area to serve as reference scales. The slides enabled us to follow beach building or substrate erosion and boulder movements over time, and they provided a visual record of the phenological sequence.

Porphyra within the quadrat was scraped from the substrate, placed in a labelled plastic bag, dried at 60 °C, and weighed to give a single monthly dry weight for each site.

From each locality samples of *Porphyra* were collected and preserved in formalin for later study as reference herbarium specimens. Additional material from other localities was similarly preserved for further study.

Mowing trial 1986

At Waipapa Bay 45 sets of four 10 x 10 cm quadrats were established by use of plastic markers set in the epoxy-based cement. The quartets of quadrats were arranged in one of two patterns (Figure 3); a particular pattern was chosen so that the quadrats shared the same aspect and substrate type as closely as possible.

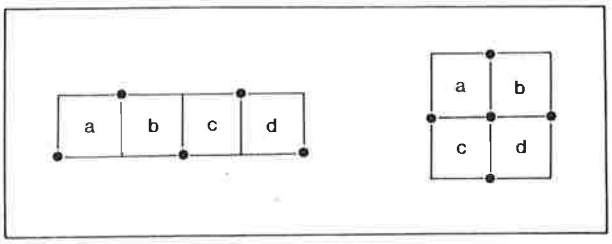

Figure 3: Arrangements of quartets of quadrats used in the 1986 mowing trial (spots represent plastic markers set on rock).

The quadrat sets were located in an area where there had been good *Porphyra* growth in the previous season. As wide a range of surfaces was used as possible. Each quadrat set was classified by factors which were hypothesised to affect yield: degree of slope, aspect, surface, texture, and the presence of crevices and barnacles. These factors are not necessarily independent. The distribution of plots in the various classes is presented in Appendix 2. Practical field considerations prevented randomisation of the harvesting design, so the treatments 1-4 were assigned to quadrats a-d respectively.

The harvest treatment for quadrat sets is given in Table 1. The harvests were separated by 30 day intervals and timed to coincide with spring low tides. Harvesting consisted of removing all macroscopic *Porphyra* plants within the quadrat frame by use of a putty-knife scraper and placing the plants in a labelled plastic bag. These samples were kept cool and transported to the laboratory where they were weighed (wet weight), dried at 60 °C, and reweighed (dry weight). A standard procedure was used to minimise weighing errors. The bags were rinsed with sea water to remove all fragments of plants: plants sat in sea water for 2 min, were drained into a sieve, transferred to a paper towel, then placed in an aluminium weighing dish, weighed, then transferred to the oven. The dishes stayed in the oven at 60 °C overnight and were taken out and weighed when they had cooled (about 10 min later).

Table 1: Mowing trial harvest treatment for quadrat sets

Visit date	Harvest treatment			
	1	2	3	4
Jul	–*	–	+†	+
Aug	–	+	+	–
Sep	+	+	+	+

* No harvest.
† Harvest.

Results

Phenology observations 1985-86

Porphyra populations in Kaikoura show distinct seasonal growth patterns. Results from the nearest neighbour sampling programme are given in Appendix 3. The population trends were summarised most clearly by the density index data and the mean plant length data. The dry weight samples provided some information, but because each site was represented by only one sample per visit there was no measure of variability.

Porphyra plants at Kaikoura began to appear in late autumn to early winter (April-May). The populations declined from October, so that by the summer (December-January) most quadrats contained no *Porphyra*, and only a very rare basal stub of *Porphyra* (less than 5 mm) was found. The colour slides recorded this cycle very clearly, and they also showed that from October most *Porphyra* plants looked unhealthy (greenish rather than black-red and often bleached and pale). The precise timing of this seasonal cycle varied from site to site.

The plants in the *Porphyra* populations reached their maximum density by June-July in most sites. (At two sites the peak was slightly earlier and in three sites slightly later.) At Waipapa Bay and Point Kean the density of plants was greater in upper and mid intertidal sites than in the lower intertidal sites.

At all sites the plants were not at their largest size when the number of plants was greatest. As plant density declined from June-July the mean plant size increased to a peak in September-October at all sites. Plant density and plant size varied greatly both within and between sites. The largest plants were found at the mid or lower intertidal sites. Mean plant length of the upper intertidal samples was much less than at the mid or lower intertidal sites, particularly at South Bay and Point Kean.

The herbarium samples collected at the main field sites and supplemented by collections from other Kaikoura locations have shown that there are several species of *Porphyra* on this coast. The commercial and amateur harvest of karengo appears to focus primarily on two species which are at present unnamed. These species grow in similar parts of the intertidal and are difficult to distinguish in the field, though there are obvious differences when they are examined in the laboratory. In addition, another two species occur in the upper intertidal at some localities, and there are also some very small, apparently monosporic, plants which occur at some sites and may belong to a further undescribed species or may be juvenile or monosporic plants of a species known primarily in its larger or fertile form.

Mowing trial 1986

Time of harvest

The wet weight of *Porphyra* harvested from all quadrats was very low; the average was under 1 g wet weight per quadrat, and there were many zero yields. The distribution of total yields is shown in Table 2.

There was considerable variability in the weight distributions between the quadrats in each treatment. At least one-third of the quadrats in all treatments yielded less than 0.04 g. In treatments 1 and 2, where there was no July harvest, a higher proportion of the quadrats yielded greater than 0.16 g.

The mean yields for the harvest treatments are shown in Table 3. Because of the zero yields and the asymmetric distribution, statistical analysis was carried out by nonparametric methods (Kolmogorov-Smirnov and ranking, Siegel 1956).

Treatments 1 and 2, which were left uncut in July, gave higher yields overall than the two which had an early harvest. Although treatment 2, which was first cut in August, gave a lower total yield than treatment 1 (cut only in September), this difference could have been due to chance as could the difference between treatments 3 and 4.

Table 2: Distribution of the total yields (wet weight)

	Weight (g)	*n*
Treatment 1 (Sep)	0.00–0.04	17
	0.04–0.16	4
	0.16–0.64	5
	0.64–1.28	5
	>1.28	14
Treatment 2 (Aug and Sep)	0.00–0.04	16
	0.04–0.16	5
	0.16–0.64	9
	0.64–1.28	3
	>1.28	12
Treatment 3 (Jul, Aug and Sep)	0.00–0.04	19
	0.04–0.16	18
	0.16–0.64	5
	0.64–1.28	2
	>1.28	1
Treatment 4 (Jul and Sep)	0.00–0.04	19
	0.04–0.16	17
	0.16–0.64	7
	0.64–1.28	0
	>1.28	2

Table 3: Mean yields (wet weight in grams per 100 cm² of the mowing trial harvests

Visit date	Harvest treatment			
	1	2	3	4
Jul	–*	–	0.090	0.104
Aug	–	0.56	0.004	–
Sep	3.82	0.73	0.250	0.075
Total	3.82†	1.29†	0.344‡	0.179‡

* No harvest.
† Weights do not differ significantly.
‡ Weights do not differ significantly.

Table 4: Proportions of yielding sets of the factors which affect yield

Factor	Proportion	Statistical significance
Slope		
Level	6/13 = 0.46	Not significantly different, even when data were regrouped
1–20°	5/9 = 0.55	
21–50°	7/16 = 0.44	
51–90°	2/7 = 0.29	
Slope regrouped		
0–50°	18/38 = 0.47	
51–90°	2/7 = 0.29	
Aspect		
Level	6/13 = 0.46	Significantly fewer yielding sets on S or E aspects ($p < 0.01$); probably a true effect because S or E facing sets in the main block of yield sets had no yields, therefore the effect was probably not due to their general location.
S or E	1/12 = 0.08	
N or W	13/20 = 0.65	
Aspect regrouped		
S or E	1/12 = 0.08	
Other	9/33 = 0.56	
Surface		
Flat	13/28 = 0.46	No real difference
Undulating	7/17 = 0.41	
Texture		
Smooth	0/5 = 0.00	Significantly different ($p < 0.05$); tests of textured against rough and smooth against other showed the significant difference was due to the absence of yield in smooth
Textured	10/22 = 0.45	
Rough	10/18 = 0.55	
Crevices		
None	1/7 = 0.14	Not significantly different, even when "none" was compared with "few and many"
Few	16/31 = 0.52	
Many	3/7 = 0.43	
Barnacles		
None	15/37 = 0.41	Not significantly different
Some	5/8 = 0.63	

For the August cut, treatment 2 significantly outyielded the total of July and August cuts of treatment 3. The apparent difference in the September yields of treatments 2 and 3 could be due to chance. No other statistically significant effects were found.

Other factors affecting yield

Most quadrat sets were categorised as 21-50 slope, with few crevices and no barnacles. The quadrat sets were classified by wet weight into two groups: 20 "yielding" sets with large yields (greater than 1 g per 400 cm^2) and 25 with very low yields. Tests were done to check if the factors differed as to the proportions of yielding plots they produced (χ^2, n–2 d.f. for more than two classes, Fisher's exact test for two classes). Flat (plane) and undulating surface sets usually occurred in groups. However, one of the higher yielding areas consisted mainly of flat sets, the other mainly of undulating sets. Data from yielding quadrat sets were used and the results are given in Table 4.

The only significant effects were aspect and texture. These were further examined to try to separate the two effects (Table 5). The apparent effect of aspect is not due to any texture effect; it is likely to be real. The small number of smooth sets made it impossible to establish statistical significance in any further analysis of the texture classes.

Table 5: Proportions of yielding sets of texture and aspect

Texture	Aspect	Proportion	Statistical significance
Smooth	S or E	0/3 = 0.00	Real difference in proportions
Other	S or E	1/9 = 0.11	
Smooth	Other	0/2 = 0.00	
Other	Other	9/31 = 0.61	

Discussion

Porphyra species at Kaikoura undergo a strictly seasonal cycle in which no macroscopic plants can be found for 4-5 months of the year from early spring to autumn. This phenological pattern will be followed every year, though the precise timing of the seasonal events and the maxima for plant density and plant size will vary from year to year with variations in weather patterns and storm activity.

Observations of *Porphyra* populations at Kaikoura over several years have shown substantial yearly variation in the size and precise position of the populations. Rock outcrops that are densely clad with plants in one season may be sparsely covered in the following year.

In Japan the relationship between weather and the size of the *nori* crop has been studied in detail, and it is possible now for *Porphyra* farmers there to accurately predict production levels from weather data (Noda and Iwata 1978).

During this study, examination of freshly gathered field material in the laboratory enabled us to recognise the occurrence of several species of *Porphyra*, most of which are undescribed. However, there are similarities in growth of the various species throughout the sites. Although there were several species (two major species) of *Porphyra* in the sampling areas, we could not determine the precise proportions because of the nondestructive sampling procedure used in the transect study and the destructive (dry weight) procedure used in the harvest trial. Further work is required to understand how these species interact with each other and how they are distributed within the intertidal zone.

In the harvest trial we examined both the impact of harvest timing or frequency on regrowth of *Porphyra* and the distribution of *Porphyra* yields with respect to a range of site characteristics. This experimental trial has provided some useful information; e.g., the demonstration that there is regrowth of *Porphyra* in previously harvested areas within a single season.

This study has shown that the aspect of a site is an important characteristic affecting *Porphyra* growth, and south and east facing rocks give the lowest yields.

The harvest trial work of this study needs to be extended to examine the harvest-site interactions more closely. In addition, the method of harvest (whether plants are completely removed or small portions remain on the rock) needs to be examined to see if it has any effect on resultant regrowth. The characteristics of habitats where *Porphyra* species grow best need to be more clearly understood; it is very likely that the habitat requirements of the individual species will differ. The conclusion that substrate, aspect, and texture affect *Porphyra* growth is likely to apply to all or most species of *Porphyra*, though the settlement success of individual species may be influenced by these characteristics. An extension to this study was carried out in 1987 with an examination of method, timing of harvest, and the regrowth of *Porphyra* after harvest (Nelson and Conroy in press).

Commercial use of *Porphyra*: implications for New Zealand

The international trade in *Porphyra* species centred in Japan, where it is a multimillion dollar industry. Although *nori* is the most important aquaculture product in Japan by tonnage and value, the *nori* industry has faced serious problems, particularly overproduction, slow growth in demand, and a decline in product quality (Kramer, Chin & Mayo, Inc. 1982). *Porphyra* products are subject to strict import quotas by Japan and this seems unlikely to be liberalised in the near future (Kramer, Chin & Mayo, Inc. 1982).

Korea is also a large producer of farmed *Porphyra*, the crop size being about 30-50% that of the Japanese production. Korea also has had erratic production levels, but output has been climbing, and the Koreans believe they can produce at least 50% more *nori*. Historically, the Korean government has protected local industry, and thus it is unlikely that Korea would be interested in importing *Porphyra* products (Kramer, Chin & Mayo, Inc. 1982).

Nori has been cultivated in Japan and other parts of Asia for centuries, and it has become an important part of the Japanese diet. Over this time there has been a selection for strains or varieties with the most pleasing characteristics. *Nori* quality determines the price of the crop. "Quality" is assessed by graders and wholesalers and is based on a range of features, the most important of which are colour, lustre, aroma and flavour, and softness. Substantial effort is expended by the *nori* industry on the improvement of quality characteristics at each step (Noda and Iwata 1978). The major Asian markets are highly discerning of *nori* products as well as strongly protected by government from imports.

The commercial use of New Zealand species of *Porphyra* needs to be considered carefully. There is a domestic market interested in obtaining supplies of karengo as well as a health food market interested in an alternative to buying expensive imported *nori* from Japan or Korea (sometimes via the United States of America). However, these markets are small and finite.

The establishment of wild harvested *Porphyra* products from New Zealand would encounter several barriers and limitations. The use of wild supplies has several disadvantages over farmed product, e.g.,

1. interference with local traditional and amateur harvest of *Porphyra*;
2. yearly variations in crop size, with problems in predicting production levels and therefore problems with continuity of supply;
3. variations in quality of the wild crop, with vulnerability to sunlight, temperature, and wave and wind action resulting in problems of market acceptance of a product of variable quality. It may be difficult to identify markets outside New Zealand which are willing to accept a variable product which does not conform to the grading standards set by the Japanese market.

The establishment of *Porphyra* farming in New Zealand is possible and work on this is being carried out by the Botany Department of the University of Otago. The major barriers to *Porphyra* farming here are the lack of knowledge of the specific life histories of the New Zealand species and how they respond to seasonal environmental cues. We need to know precisely which species we are dealing with. Research is being carried out on the various species of *Porphyra* in New Zealand at the National Museum and Victoria University of Wellington, and life history studies are in progress at Massey University, Palmerston North. Much of the farming technology used in Japan and elsewhere is transferable to New Zealand, but it will require tuning to the New Zealand setting: manipulating and altering techniques to suit sea conditions, weather patterns, and storm activity experienced in the farming site, and discovering which epiphyte and disease problems occur here and how they can be overcome. Obviously, before such farming enterprises are established it is paramount that markets are identified, so that the establishment production costs are justifiable economically.

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Appendix 1

Nearest neighbour experiment statistics 1985–86

Each site visit produced the following data:

Distance (d) (cm)	Plant length (L) (cm)
$d1$	$L1$
$d2$	$L2$
$d3$	$L3$
•	•
•	•
•	•
dN	LN

Let

$Q1$ (d) = lower (1st) quartile of d,

$Q2$ (d) = median (2nd) quartile of d,

$Q3$ (d) = upper (3rd) quartile of d,

then, approximately

$Q1$ $(d)^{-2}$ = upper (3rd) quartile of d^{-2},

$Q2$ $(d)^{-2}$ = median (2nd) quartile of d^{-2},

$Q3$ $(d)^{-2}$ = lower (1st) quartile of d^{-2}.

Therefore, the quartiles of the inverse squares of the distances are the inverse squares of the quartiles of the distances, except that the first and third quartiles swap places in the transformed data. Therefore,

Density Index (DI) = 2206 x $Q2$ (d^{-2})

= 2206 x median (d^{-2})

Interquartile range = $Q1$ (d^{-2}) – $Q3$ (d^{-2})

An indication of the variability of DI is

= 2206 x interquartile range

The basis of the density index is as follows: Pielou (1977) derives the probability distributions for the distance (d) from a point to the nearest member of a randomly dispersed population and also of its square (w). It is not assumed here that the karengo populations studied are actually randomly dispersed, but this assumption is being used to calculate a constant factor that converts distances in centimetres to numbers suggestive of densities in plants per square metre.

The distribution function of w is

$F(w) = 1 - \exp(-\lambda \times w)$

where λ is the expected number of plants in a circle of unit radius. An estimate of λ is obtained by taking w at its median value and equating this expression to 0.5. Therefore,

$\lambda = \log 2/\text{median}(d^2)$

$= \log 2 \times \text{median}(d^{-2})$

This is multiplied by 10 000/π to get the units as plants per square metre and 10 000 x log 2/π is equal to 2206.

Appendix 2

Mowing trial: the distribution of quadrat sets by site characteristics

Aspect

Slope	Level	N or W	S or E	Total
None	13	0	0	13
1–20°	0	7	2	9
21–50°	0	11	5	16
51–90°	0	2	5	7
Total	13	20	12	45

Crevices

Slope	None	Few	Many	Total
Level	2	8	3	13
1–20°	4	5	0	9
21–50°	1	13	2	16
51–90°	0	5	2	7
Total	7	31	7	45

Texture

Slope	Smooth	Textured	Rough	Total
None	2	5	6	13
1–20°	2	5	2	9
21–50°	1	9	6	16
51–90°	0	3	4	7
Total	5	22	18	45

Barnacles

Slope	None	Some	Total
Level	11	2	13
1–20°	9	0	9
21–50°	12	4	16
51–90°	5	2	7
Total	37	8	45

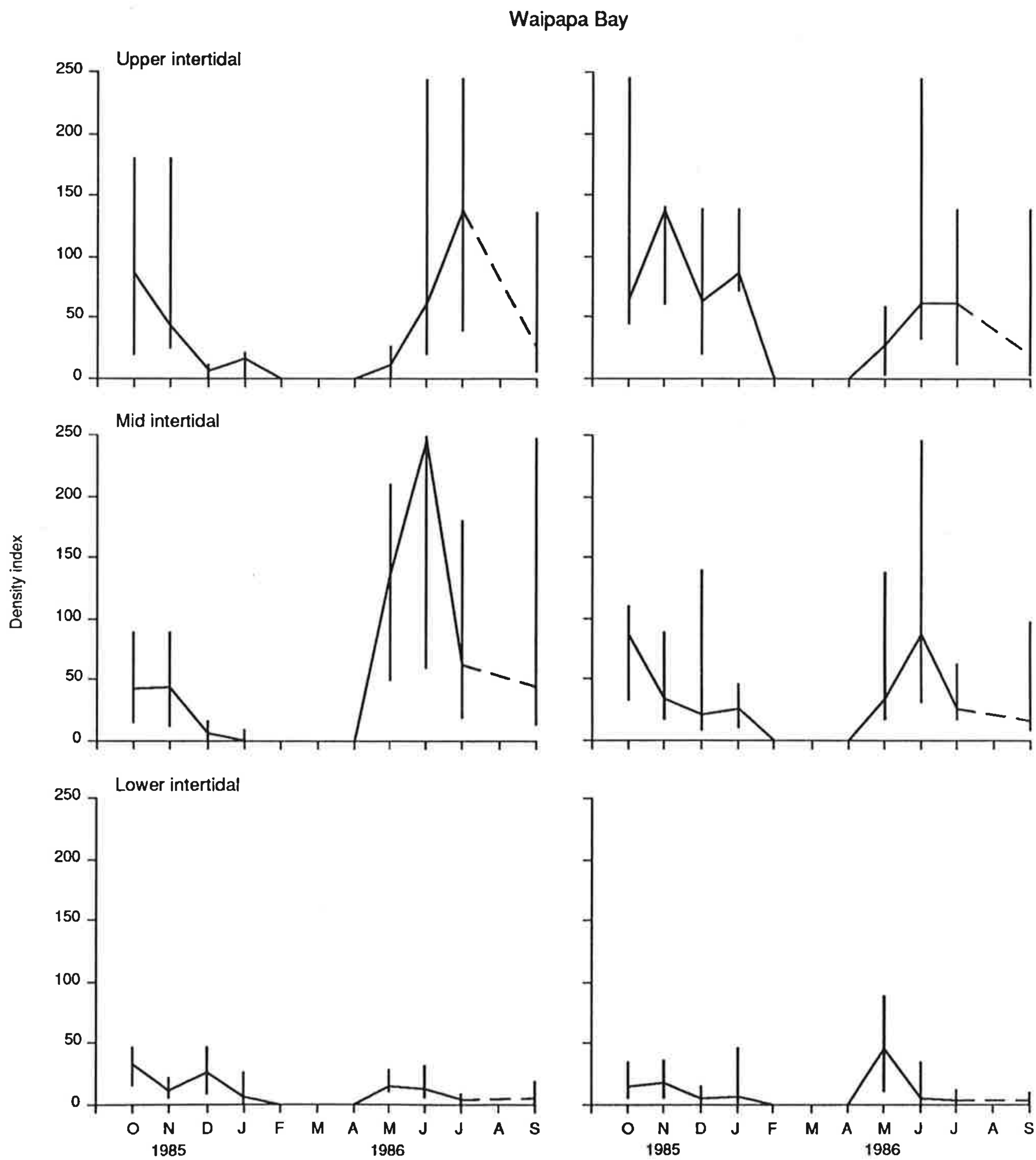
Surface

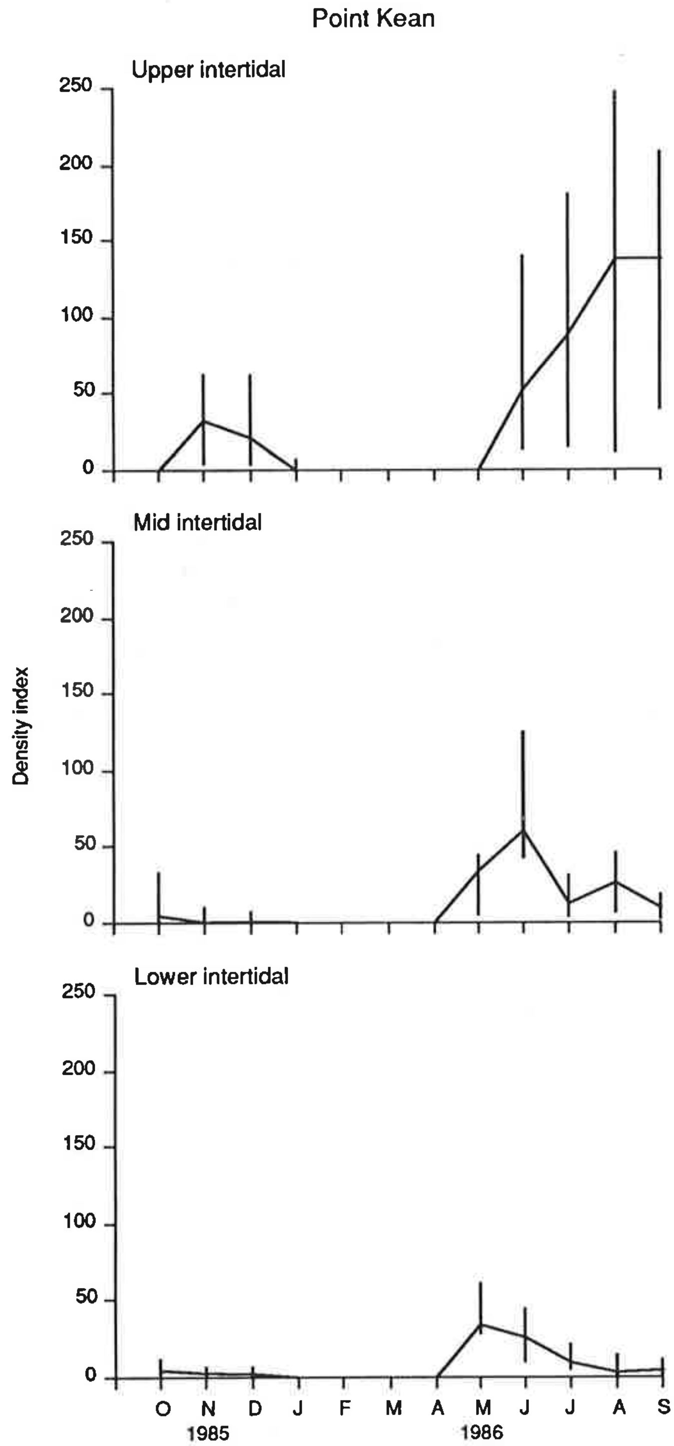
Slope	Flat	Undulating	Total
Level	8	5	13
1–20°	7	2	9
21–50°	9	7	16
51–90°	4	3	7
Total	8	17	45

Appendix 3

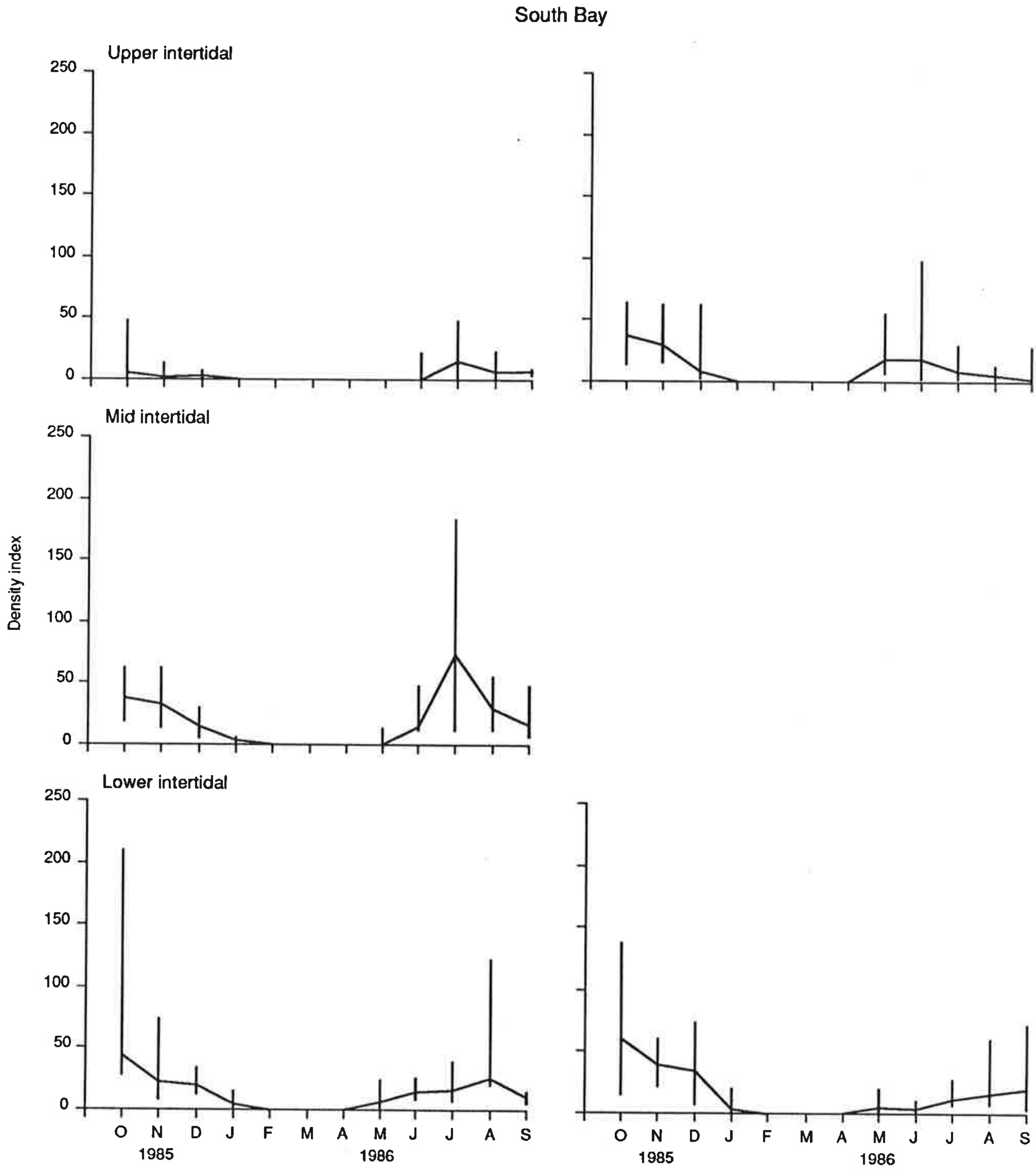
Results of nearest neighbour sampling

(Confidence intervals are the upper and lower quartiles.)

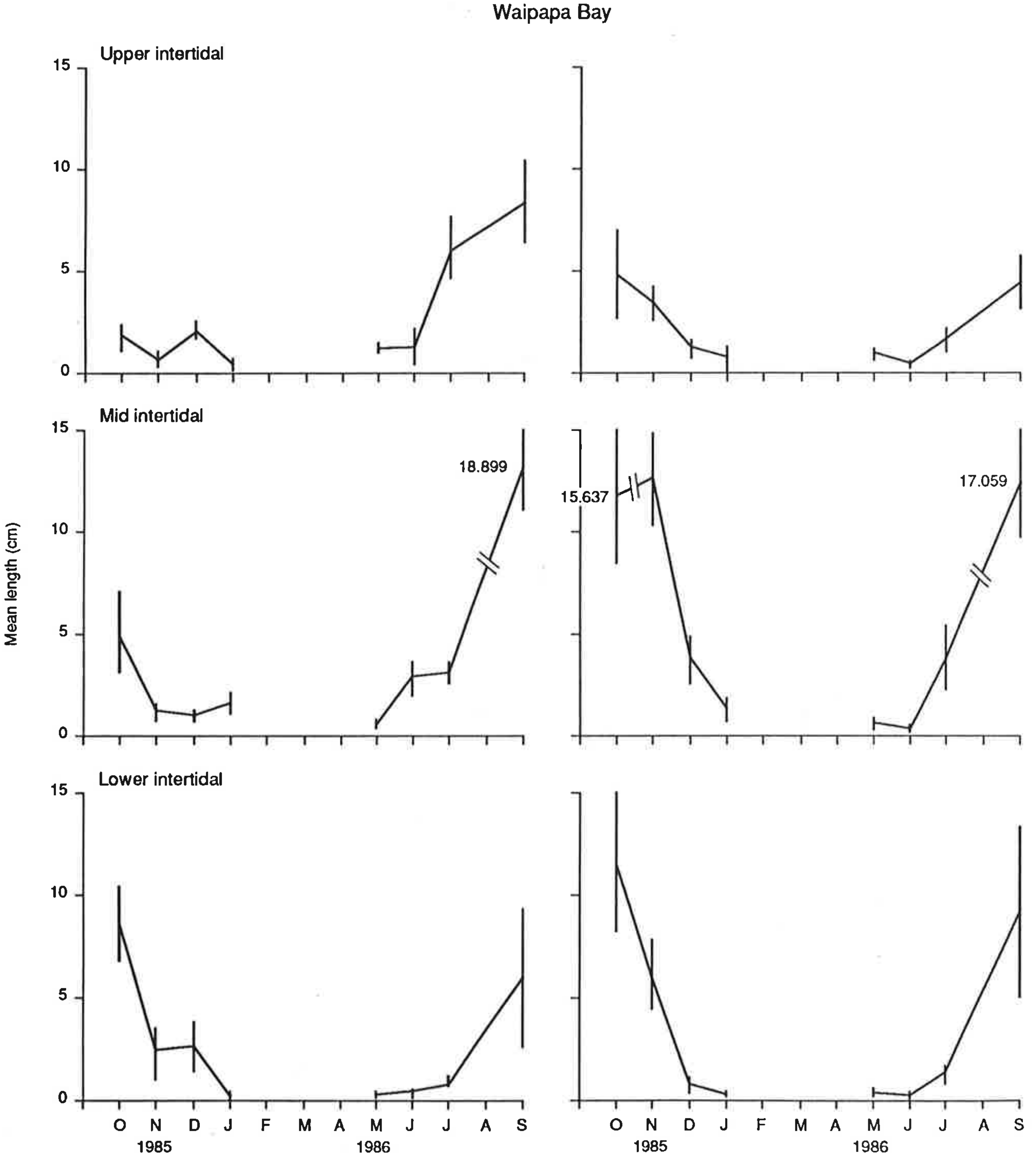



Point Kean
Upper intertidal
Mid intertidal
Lower intertidal
Density index
250
200
150
100
50
0
O
N
D
J
F
M
A
M
J
J
A
S
1985
1986

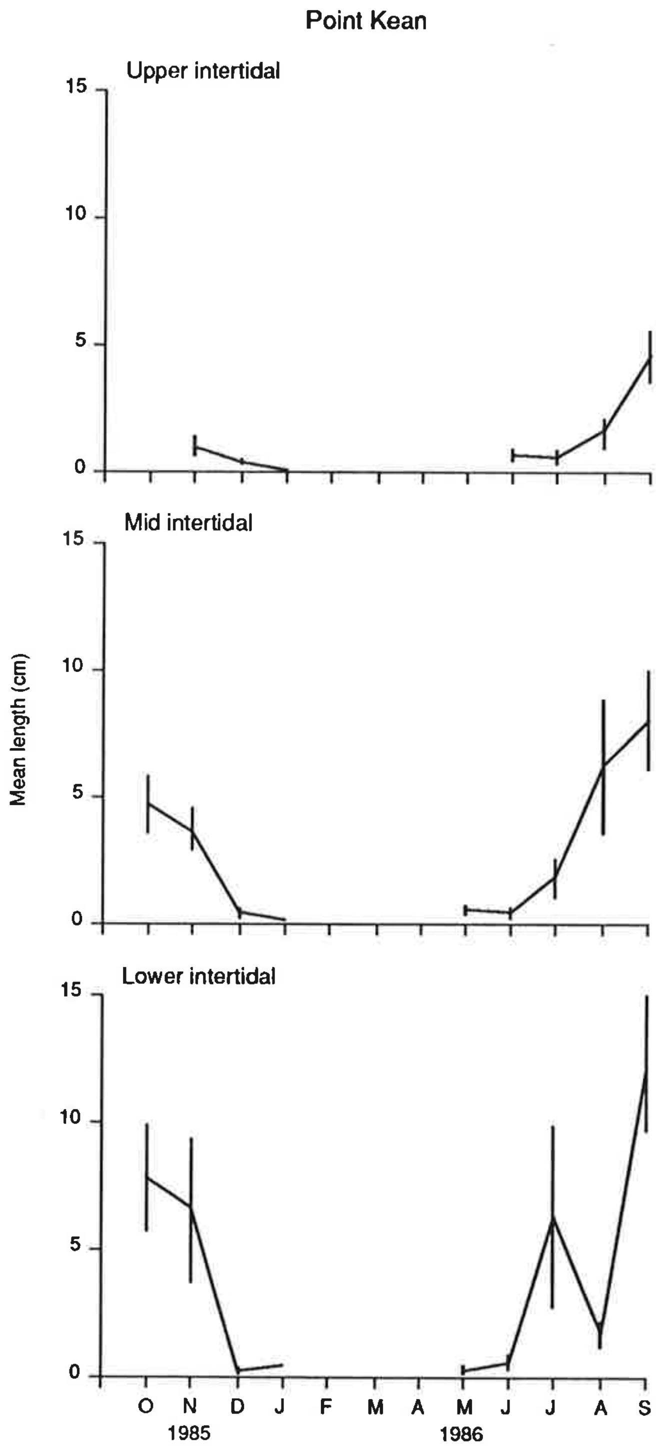
Appendix 3 — *continued*



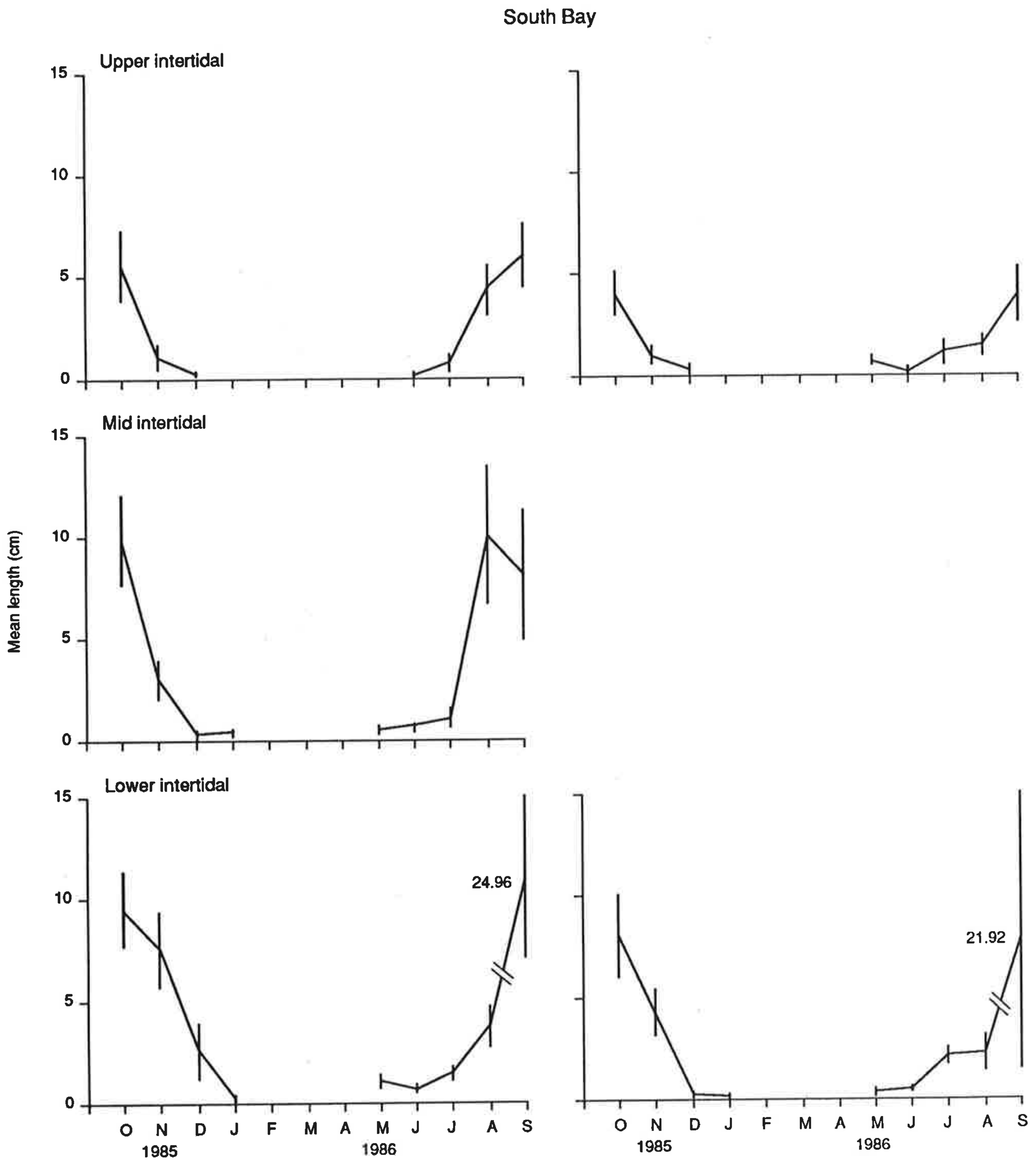
Appendix 3 — *continued*

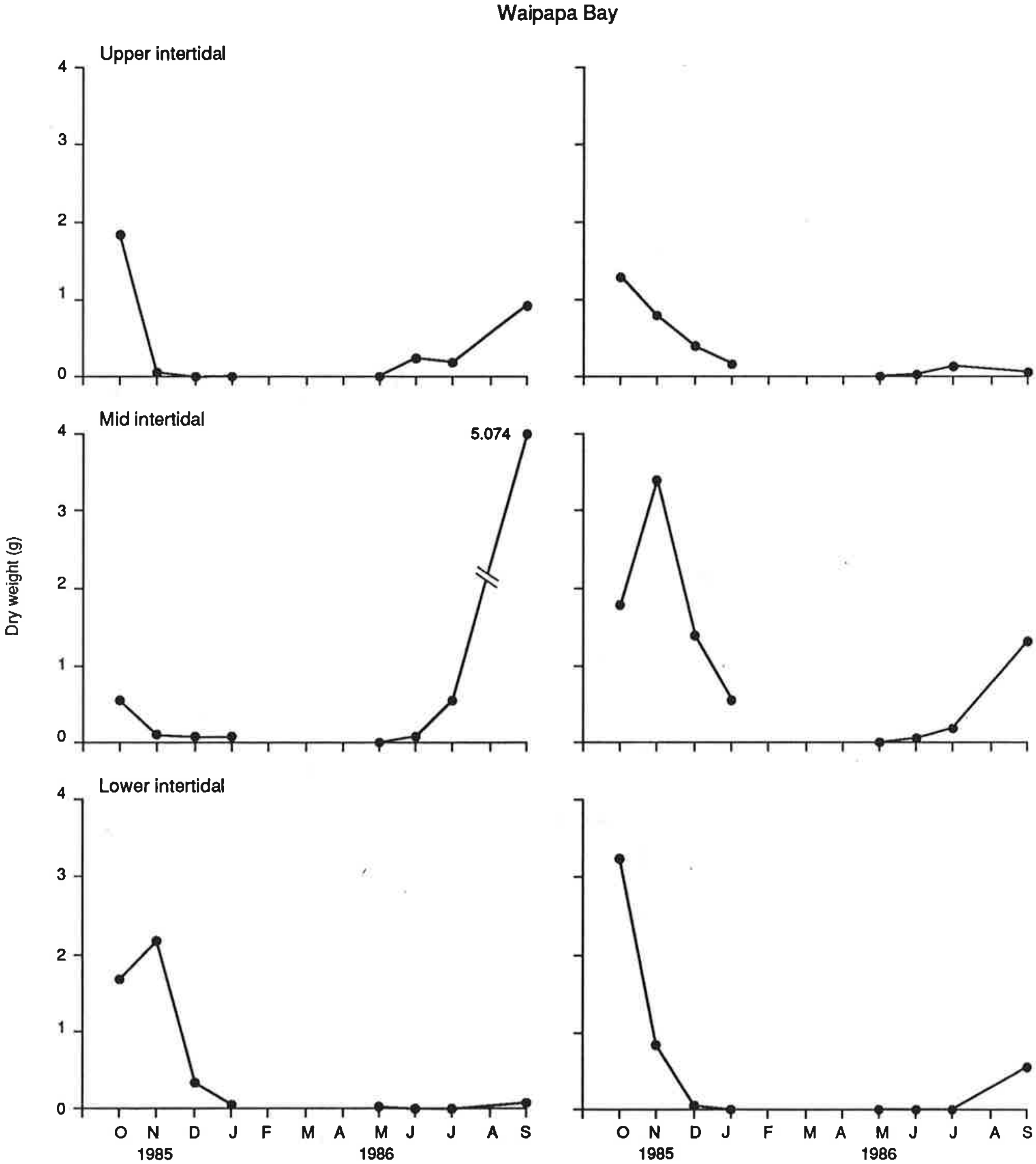


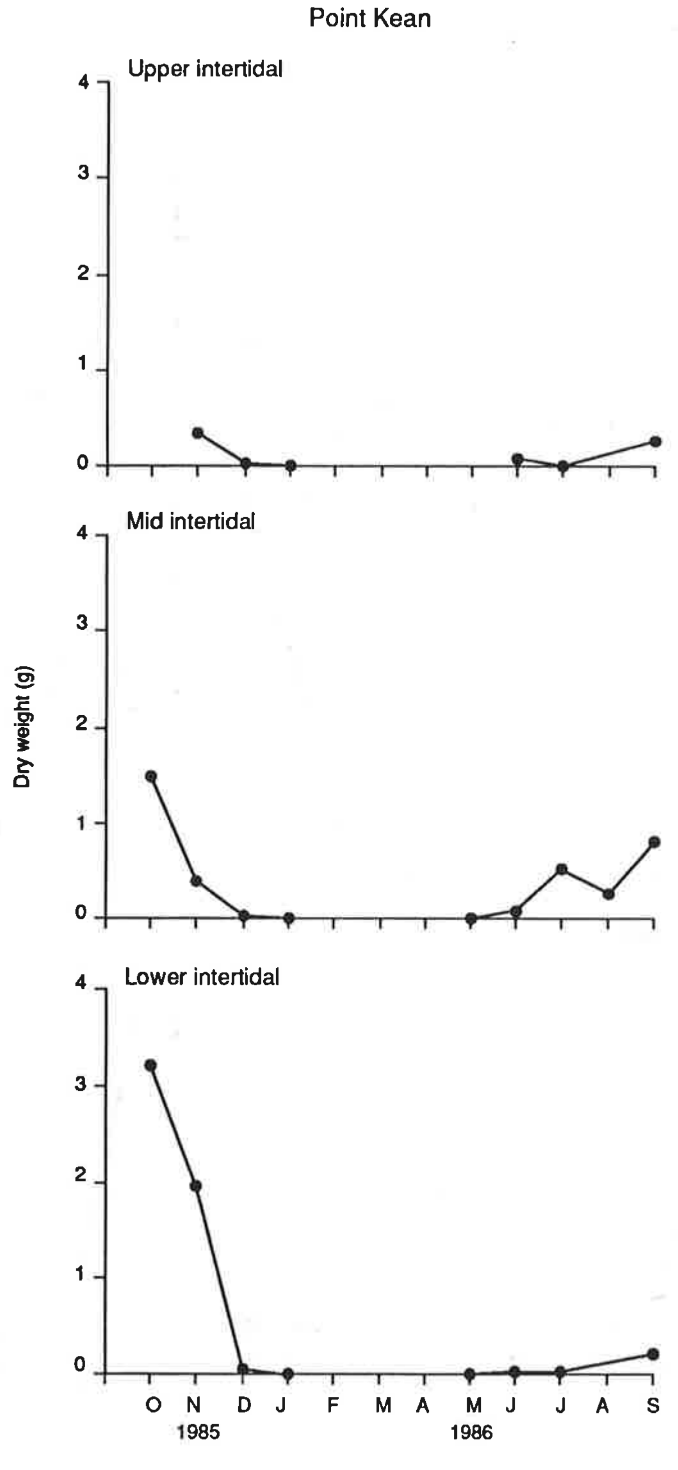
Appendix 3 — *continued*

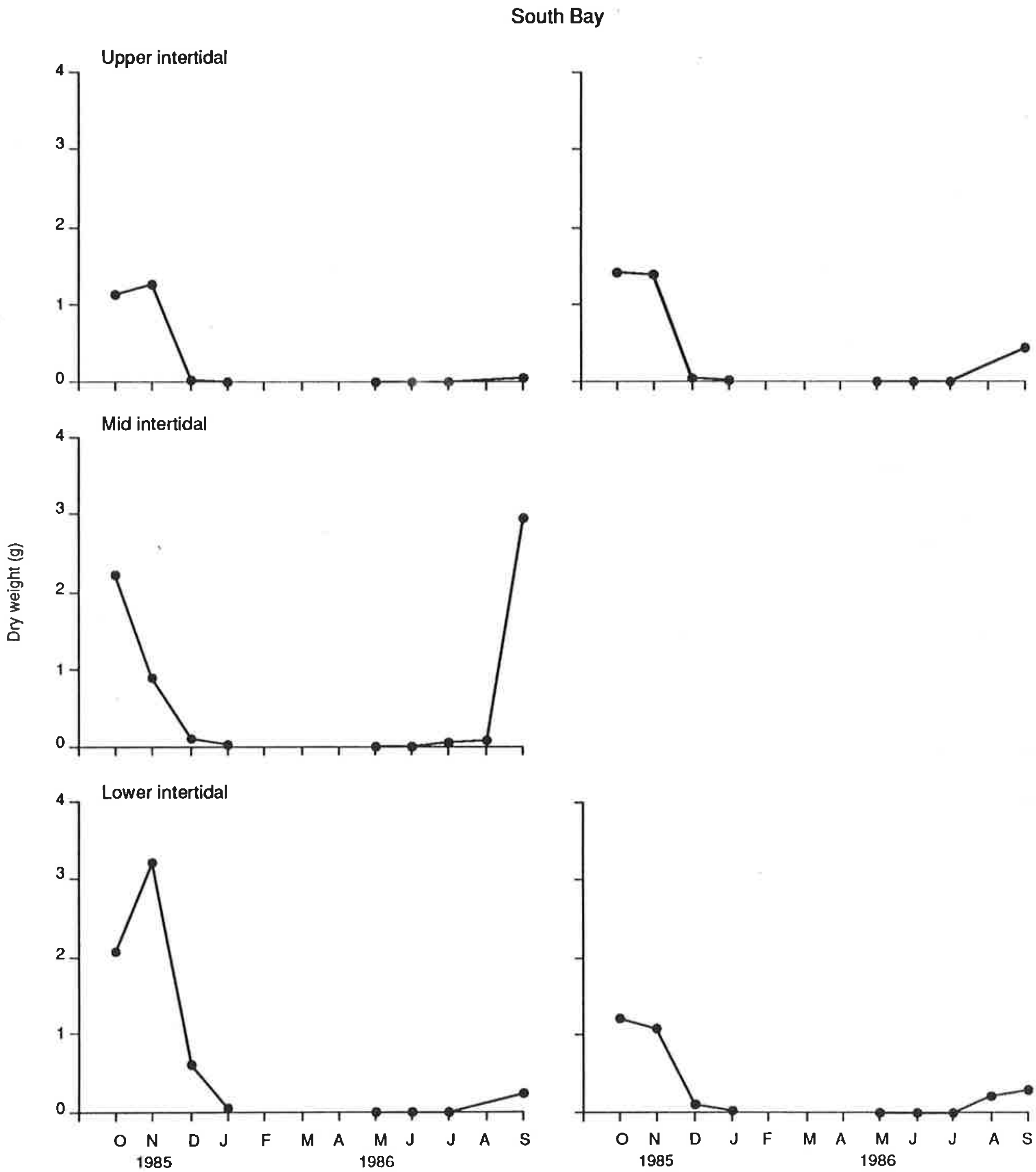


Appendix 3 — *continued*




Waipapa Bay
Upper intertidal
Mid intertidal
Lower intertidal
5.074
Dry weight (g)
0
1
2
3
4
O N D J F M A M J J A S
1985
1986


Point Kean
Upper intertidal
Mid intertidal
Lower intertidal
Dry weight (g)
0
1
2
3
4
O N D J F M A M J J A S
1985
1986


South Bay
Upper intertidal
Mid intertidal
Lower intertidal
Dry weight (g)
0
1
2
3
4
O N D J F M A M J J A S
1985
1986

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