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**Pre-fishing surveys of kina (*Evechinus chloroticus*) in Dusky Sound,
southwest New Zealand**

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This series documents the scientific basis for stock assessments and fisheries management advice in New Zealand. It addresses the issues of the day in the current legislative context and in the time frames required. The documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

1. INTRODUCTION

There are few fisheries that progress with direct information on the population structure of the unfished stock. More often than not, population trajectories of exploited stocks are reconstructed from a time series of catch data. This approach is so common that it is enshrined in standard fisheries texts (e.g., Beverton & Holt 1957, Ricker 1975). However, this strategy seldom allows sources of variation in, for instance, stock abundance to be identified. Observed or estimated changes in population structure of any fished stock may be due to other factors operating concurrently with fishing. For example, annual recruitment can vary by orders of magnitude particularly for invertebrate species (Cushing 1988).

Compensatory changes in growth and survival form the basis of surplus production theory which is fundamental to fisheries science (Beverton & Holt 1957). Although this paradigm has a sound theoretical basis, it has an equivocal empirical basis for many exploitable species. This is hardly surprising; many fishstocks are mobile and occur in hostile or inaccessible habitat which preclude experimental manipulation. In the present study, the impact of fishing can be measured directly. In considering this impact in relation to similar unfished stocks, effects solely due to fishing may be isolated from other factors causing variation in the population structure (Underwood 1992). Thus, any hypothetical change in growth, survival, or yield predicted from standard fisheries models can be tested.

Sedentary species from shallow waters are especially suited to this approach. For these species, the abundance of a population or stock can often be estimated *in situ* with reasonable precision and accuracy. Moreover, stocks can be defined within certain geographical boundaries and changes over time measured over a range of spatial scales. Populations with the same general biological characteristics of growth, survival and recruitment can be compared on the basis of the response of these parameters to fishing.

The size of the food gathering apparatus (hereafter termed "jaws") of several species of sea urchin correlated with the density of conspecifics and food availability (Ebert 1980, Black *et al.* 1982, 1984, Levitan 1991, Edwards & Ebert 1991). The relative length of jaws of urchins has been used, albeit crudely, to indicate fishing intensity (Levitan 1992) and could also be used to indicate compensatory effects associated with reduced density accompanying experimental fishing, as proposed for the present study.

Sea urchins have been shown to play a structuring role in subtidal benthic communities. Some species of sea urchin can, by grazing, have profound effects on algal assemblages by keeping areas free of large seaweeds (Lawrence 1975, Schiel & Foster 1986, Andrew 1988). The apparent association of sea urchins with "barren" habitat is reinforced by manipulative experiments which showed that macroalgae can reestablish in such habitat after removal of sea urchins (Choat & Andrew 1986, Andrew 1988).

The experimental studies that established the importance of herbivory in structuring sublittoral algal assemblages were mainly conducted over small areas. Fishing generally takes place over large areas (square kilometres rather than square metres) and all

available sea urchins may not be removed. Predictions of the effects of fishing for sea urchins based on small scale experimental studies may therefore be unreliable (Andrew 1988). In the present study we consider the effects of a reduction in the density of sea urchins by fishing on the sublittoral algal assemblages.

Evechinus chloroticus, the subject of the present study, is endemic to New Zealand, may be considered sedentary, and is common on shallow subtidal reefs (Andrew 1988): interest in developing a commercial fishery is high (McShane *et al.* 1992). A preliminary survey revealed abundant and ubiquitous populations in Dusky Sound (McShane & Naylor 1991). Estimates of standing stock were necessarily crude because of the difficulty in accurately estimating the surface area of the sub-tidal reefs inhabited by *E. chloroticus*. In the absence of productivity information on *E. chloroticus* stocks, or indeed on any other species of sea urchin, likely yields from any fishery can only be speculative.

We present the results of four population surveys of *E. chloroticus* conducted over 18 months before fishing. Data are presented on the distribution and abundance of *E. chloroticus*, together with information on their size composition, morphometrics, and reproductive state. The relationship of jaw length with diameter of *E. chloroticus* is also presented with a view to using it as a measure of compensatory changes in fished populations. Information on the floristic composition of subtidal reefs in Dusky Sound is presented. Finally, we describe how a number of hypotheses relating to the effects of fishing on the population biology of *E. chloroticus* and the community ecology of subtidal reefs can be tested.

2. MATERIALS AND METHODS

Surveys of about 10 days duration were conducted in Dusky Sound on four occasions: November 1991; October 1992, and January and April 1993. The methods for the November 1991 survey have already been described by McShane & Naylor (1991). Information from preceding surveys was used to improve the design and conduct of later surveys. The following represent changes to the methods described by McShane & Naylor (1991).

In October 1992 the available habitat was further stratified to include deep (9 - 20 m) habitat and the area available to fishing ("fishdown") was expanded to include all waters surrounding Anchor Island (Figure 1). For random sites in both deep (> 9 m) and shallow habitat (0 - 9 m), two divers each sampled from a prearranged random depth in a prearranged random direction. Thus, a 1 m² quadrat was overturned sequentially so that replicate random strips 25 x 1 m were sampled for *E. chloroticus* and other dominant epifauna.

In January 1993 the fishdown area was further stratified to take into account the differential variability of *E. chloroticus* between areas and the likely development of an experimental fishery which would be concentrated in the sheltered waters of Anchor Island (stratum 1, Figure 1). Random sample sites were allocated accordingly (Figure 1). An estimate of the mean density (no per m²) of the population in the fishdown area (A_{st}) was given by:

$$A_{st} = \sum N_h a_h / N$$

where N_h is the total number of sample sites in the h th stratum, a_h is the sample mean in the h th stratum and $N = \sum N_h$ is the total sample size.

The standard error of the sample mean (A_{st}) was given by:

$$s(A_{st}) = \sqrt{\sum W_h^2 s_h^2 / N_h}$$

where the relative weight attached to each stratum $W_h = N_h/N$ and s_h^2 is the sample variance in the h th stratum.

Within each of the three main areas of Dusky Sound (fishdown area; Parrot/Pigeon Islands; Indian Island and surrounding waters) sites were chosen at random for examination of morphometric characteristics of *E. chloroticus* (McShane & Naylor 1991). At these sites, a subsample covering the size range of *E. chloroticus* was chosen from the random sample of urchins normally gathered during population sampling (all individuals collected were measured for test diameter to the nearest millimeter). Gonad colour was assessed according to a five point scale (Table 1; colour photographs showing the different levels are shown in McShane *et al.* 1992) and the Aristotle's lanterns of individuals removed (*see* Black *et al.* 1984). The lanterns were stored individually with records of individual test diameter (to the nearest millimeter) and whole wet weight (to the nearest gram). The gonad volume was measured (McShane & Naylor 1991).

Aristotle's lanterns were bleached (5% sodium hypochlorite) to remove any organic material. After bleaching (at least 48 h), the skeletal elements of the lantern were rinsed in freshwater before being drained and air-dried. The lengths of three jaws from each lantern were measured to the nearest 0.1 mm as shown in Levitan (1992). Jaw length was expressed as a function of test diameter - about 20 individuals were examined from each stratum. Analysis of variance was used to test for homogeneity of the slopes of jaw size versus test diameter between sites and for sites nested within areas (control versus fished).

Floristic composition was assessed by sampling in 10 randomly allocated sites each in strata 1,2,3,7 and 8. Density or percent cover was estimated for two replicate subsites at each site. We used a randomly placed and directed 1m² quadrat as described for the assessment of kina density. A flexible cord with five irregularly spaced knots was sequentially stretched across the diagonal of the quadrat and hits of the knots scored separately for encrusting, turfing, and canopy-forming macroalgae to the lowest identifiable taxon. Thus, up to 125 points were scored for each taxon. Where a canopy-forming macroalga was encountered, for example *Ecklonia radiata*, it was scored then placed aside so that the understory of either encrusting or turfing species could also be scored (Foster *et al.* 1991). We also recorded bare space (rock, sand, or gravel) and epibiota such as sponge, bryozoa, and ascidians. In each of the 25 contiguous quadrats sampled by each diver at a site, we also recorded the large brown macroalgae (*Ecklonia radiata* and *Carpophyllum flexuosum*) and depth to the nearest metre. Floristic composition was therefore described for each stratum in terms of

percent cover by taxon and density of large brown macroalgae for comparison between strata by analysis of variance (sites nested within strata).

Table 1: Classification of the relative colour and volume of the gonad of *Evechimus chloroticus*.

Index	Colour	Volume
1	Dark brown, black or grey	coarse grain, low volume
2	Dark to light brown	coarse grain, low to medium volume
3	Light brown to dull orange	coarse grain, any volume
4	Orange to yellow, bright colour	medium grain, any volume
5	Bright orange or yellow	fine grain, high volume

3. RESULTS

3.1. Density

Four pre-fishing surveys have been completed in Dusky Sound (November 1991, October 1992, January and April 1993). The results confirm that *E. chloroticus* are abundant and ubiquitous in Dusky Sound: they were found at all sites at all times. In April 1993, immediately prior to fishing, the mean density of *E. chloroticus* (\pm SE) in the fishdown area was $1.6 \pm 0.1 \text{ m}^{-2}$. The density of *E. chloroticus* varied between the three areas and over time (Figure 2; ANOVA revealed a significant area x time interaction, $F_{2,308} = 4.14$, $P = 0.017$). Surveys in October 1992 revealed that less than 10% of the estimated total *E. chloroticus* were in depths greater than 9 m. Further surveys were restricted to depths of 9 m or less. It was noted that *E. chloroticus* were more prevalent in deep water at exposed sites than at sheltered sites. However, although *E. chloroticus* were found to 20 m at exposed sites, they were always more abundant in shallow waters (< 9m).

3.2 Size composition

The size composition of *E. chloroticus* varied between the three areas and over time (Figure 3). In November 1991, the population was apparently unimodal for all areas (McShane & Naylor 1991), but in October 1992 there was evidence of a newly recruited cohort of 40 - 60 mm, particularly in stratum 8 (Figure 3). This suggests that recruitment was not uniform between strata: recruitment was evidently strong in strata 3 and 8 compared with other strata. For latter strata, modes of increasing test diameter could be followed through time (Figure 3).

3.3 Growth

We derived a preliminary estimate of the growth rate of *E. chloroticus* from a sequential analysis of the size composition data (Figure 4). The estimated growth was $25.8 (\pm 3.6) \text{ mm. yr}^{-1}$ (\pm S.E.) assuming a linear increase in test diameter with time. In April 1993, the 0+ cohort was identified in strata 3 and 8 (Figure 3). Before April, individuals were presumably too small or cryptic to sample.

3.4 Reproduction and morphometrics

The gonad index (percent gonad volume/whole weight) varied spatially and temporally (Figure 5) but in general, the gonad indices were highest in January 1993. A decrease in the gonad index indicative of spawning occurred in February (Figure 6). Spawning individuals were frequently observed during February. The colour index of *E. chloroticus* remained similar with time for each stratum (Figure 5).

The relationship of jaw length to test diameter was highly significant in all strata. More than 80% of the variation in lantern (jaw) length was explained by variation in test diameter for any one stratum. However, analysis of variance comparing the three areas (Fishdown, Control 1, and Control 2) revealed that the slopes of the relationship were heterogeneous ($P < 0.01$). Further examination of the data showed that the heterogeneity of slopes was due to stratum 4. The slopes of all other strata were homogeneous ($F_{2,193} = 0.37, P = 0.69$). Analysis of covariance revealed that adjusted Y 's were similar between the three areas ($F_{2,192} = 0.96, P = 0.38$). Thus a single relationship between jaw length (Y) and test diameter (X) can be used to represent *E. chloroticus* in Dusky Sound ($Y = 0.16 X + 1.74$; Figure 7) except stratum 4 ($Y = 0.11 X + 7.4$).

Analysis of covariance showed that the weight of test and spines of *E. chloroticus* was greater in exposed than in sheltered habitats ($F_{1,115} = 15.5, P < 0.001$) (Figure 8). However, exposure did not significantly influence the relationship of gonad weight to whole weight (by analysis of covariance; $F_{1,109} = 2.7; P > 0.1$) (Figure 9).

3.5. Other subtidal epibiota

We used 14 taxa, out of 35 taxa identified, in our assessment of the spatial variability in subtidal epibiotic communities in Dusky Sound - the remaining taxa were rare (< 1% cover) (Table 2). It was generally not possible to identify taxa to species level. For the macroalgae, identification was accorded to physiognomic groups such as crustose coralline, articulate coralline, flat reds, and filamentous reds. Voucher specimens of all taxa encountered have been preserved in a herbarium (MAF Fisheries, Greta Point: J.R. Naylor, curator). For epifauna, taxa were grouped as bryozoa, ascidians, and sponges. Table 2 indicates that for many taxa there was insufficient power to make valid comparisons between strata. Some taxa, for example *Ecklonia radiata*, were uniformly distributed between strata (Table 2).

The epibiota were arbitrarily divided into canopy forming and turfing macroalgae and encrusting biota. The results are presented as the proportion of the total for canopy and turfing macroalgae (Figure 10) and as percent cover for encrusting biota (Figure 11). The encrusting biota included unidentified taxa (Other) which included the stipes and holdfasts of brown macroalgae and a complex of hydroids, coralline algae, and ascidians that could not be attributed to any one taxon. There was obvious variation between strata involving *Carpophyllum flexuosum*, *Caulerpa* spp, filamentous reds, and flat reds. Analysis of variance (arcsin transformed data) and *a posteriori* tests (Tukey's HSD test) confirmed differences between strata for crustose corallines, filamentous reds and flat reds (Figure 13). The *a posteriori* tests revealed that strata 3 and 8 were similar, but different from the other strata examined (1, 2 and 7).

Similarly the density of *C. flexuosum* varied between strata (by ANOVA $F_{4,94} = 3.3$, $P < 0.01$) with strata 3 and 8 different from the other strata examined (Figure 14). However, analyses of variance showed that the density of *Ecklonia radiata* and juveniles of both species were similar between strata ($P > 0.3$) (Figure 14). Juvenile brown macroalgae were abundant in Dusky Sound, but they could not be reliably identified to species level. Densities of *C. flexuosum* and *E. radiata* were negatively ($r = -0.22$, $P = 0.03$) and positively ($r = 0.21$, $P = 0.03$) correlated with depth, respectively. *E. radiata* was most common in waters deeper than 6 m (Figure 15).

Crustose coralline was correlated with the density of kina ($r = 0.56$, $P < 0.01$) and *C. flexuosum* ($r = 0.66$, $P < 0.01$).

Other dominant epifauna on the subtidal reefs of Dusky Sound were the sea cucumber *Stichopus mollis* and the turbinid snail *Turbo smaragdus*. The presence of these species was not correlated with kina: censuses in January 1993 revealed that the densities (no/m²) of each species were similar between strata in Dusky Sound (*S. mollis* density (\pm 95% confidence limits) = 0.27 (0.04); *T. smaragdus* = 0.24 (.10)).

4. DISCUSSION

The results of four pre-fishing surveys of *Evechinus chloroticus* in Dusky Sound show that there is natural spatial and temporal variation in density, recruitment, and gonad condition. The latter is clearly influenced by season but at any time there is variation from place to place. Such variation will influence the development of a fishery for *E. chloroticus* in Dusky Sound which would aim to provide high quality product ("roe") to export markets (McShane *et al.* 1992). However, natural variation in any parameter will confound the interpretation of a fishing-induced change in that parameter.

In designing the experimental fishery for *E. chloroticus* it was assumed that any change in a parameter could be attributed to the effects of fishing by comparison with adjacent non-fished areas and by comparing parameters from the fishdown area before and after fishing (McShane & Naylor 1991). Parameters under consideration are the density of *E. chloroticus*, the relative gonad condition (volume relative to total weight), the relative gonad quality (colour and volume), the relative jaw length, recruitment, growth rate, survival rate, and floristic composition.

The growth rate of *E. chloroticus* derived from preliminary surveys is similar to estimates given by Dix (1972). Dix showed that the early growth of *E. chloroticus* was linear, as we assumed in the present study, but slowed in later years (presumably accompanying maturity). Our preliminary data, though limited, showed no evidence of differential growth between strata. Estimates of growth and mortality will become more robust with further surveys and with the results of direct measurement methods, such as tag-recapture.

In designing surveys to detect fishing-induced change in any factor against a background of natural spatial and temporal variation, the relative size of the experimental areas should be taken into account. Relative to the two control areas, the fishdown area is large. Spatial variability in any one parameter could, therefore, be greater in the fishdown area than in the control areas, thus confounding analysis of

variance of that parameter between fished and non-fished areas. Which areas are fished will be influenced by the abundance and potential yield of *E. chloroticus*, and by practical considerations such as access and relative shelter. We expect relatively infrequent fishing in strata 4 and 6 because of exposure. These strata are exposed to the often heavy seas characteristic of Fiordland. Stratum 5 typically has sheer sided steep reefs in very deep water (> 100m). In contrast, stratum 1 offers shelter in the lee of the many islands in the area and has abundant accessible shallow habitat for *E. chloroticus*.

Both the density and potential yield of *E. chloroticus* are high in stratum 1 compared with other areas, and strata 2 and 3 also support high densities. Thus the fishery may be expected to develop first in stratum 1 and progress to strata 2 and 3 when stocks are depleted. The greatest impact of fishing on the population of *E. chloroticus*, or on the subtidal community of which the population is a part, is therefore likely to be in stratum 1.

There are clear differences between the strata examined in Dusky Sound. Stratum 8 has a lower density of *E. chloroticus*, lower gonad yield, and differs in floristic composition from all strata except stratum 3. The floristic composition of stratum 3 and stratum 8 is similar. These strata adjoin and approach the inner limits of the open water habitat in Dusky Sound and, as such, are periodically exposed to fresh water and support a more typically "Fiord" type biota dominated by sponges and bryozoa. These two strata also supported higher recruitment of *E. chloroticus* compared to the other strata. Recruitment of *E. chloroticus* in Dusky Sound is apparently local rather than regional. Stratum 8 differs in most respects from the other strata, and it is therefore inappropriate to use this stratum as a "control" area as originally proposed (McShane & Naylor 1991). If there is differential fishing intensity between strata, with stratum 1 receiving most fishing effort as we expect, then a comparison between stratum 1 and the other strata would be more appropriate.

The assessment of any impact of removal of *E. chloroticus* will therefore be based on a comparison of strata 2, 3, 5, and 7 with stratum 1. This provides for a balanced design in the analysis of variance of the factors under consideration. Presumably there will be a decrease in the abundance of *E. chloroticus* in fished strata associated with a permitted harvest of 1000 t. The size of the measured decrease will depend on the size of the standing stock and the power of any survey to detect a difference. Preliminary estimates of the variance of density in the fishdown area suggest power of around 0.8 to detect a 20% decrease in the mean density in two consecutive surveys. The precision of surveys has been further improved by the present stratification of the fishdown area. It follows that if a significant decrease in the density of *E. chloroticus* is measured during the first year of fishing, then the initial standing stock would have been less than 5000 t; confirming the initial estimate of McShane & Naylor (1991).

The results of our studies of the relationship of jaw length to test diameter suggested that exposure is a significant source of variation. Variation in this relationship may also be due to food availability and the density of conspecifics (Black *et al.* 1982, 1984). We seek to use the relative size of the jaws to detect compensatory morphometric changes associated with fishing. The relative weight of the test and spines was greater in exposed than in sheltered habitats of Dusky Sound confirming results of other

studies (e.g., Edwards & Ebert 1991) which show that sea urchins preferentially allocate resources to body maintenance in exposed habitats. The cost of such resource allocation may explain the observed difference in relative jaw length of *E. chloroticus* from exposed versus sheltered habitats.

The results of the surveys of *E. chloroticus* in Dusky Sound provide a sound basis from which to assess the impact of a large annual harvest for this species in one area of Dusky Sound. We have described spatial and temporal variation in a range of parameters. This now forms the basis for hypothesis testing. We predict that the following will occur in fished strata relative to pre-fishing estimates and in comparison with unfished or lightly fished strata:

1. A decrease in the density of *E. chloroticus*
2. An increase in the growth of remaining *E. chloroticus*
3. A decrease in the relative jaw length of *E. chloroticus*
4. An increase in the relative gonad yield of remaining *E. chloroticus*
5. A decrease in the percent cover of crustose coralline algae due to colonisation by other algae.
6. An increase in the density and canopy cover of *Ecklonia radiata* and *Carpophyllum flexuosum*.

The preliminary estimates of precision for the level of replication applied in regular surveys indicates that there is sufficient power (> 0.8) to detect a relatively small ($< 20\%$) change sufficient to adequately test the above hypotheses. This is an exciting opportunity to test hitherto untested paradigms of the structuring role of sea urchins over large spatial and temporal scales.

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Taxon	Physiognomic affinity	Power
Crustose coralline	red encrusting	0.85 *
Articulate coralline	red encrusting	0.4
<i>Carpophyllum flexuosum</i>	canopy forming brown	0.6 *
<i>Ecklonia radiata</i>	canopy forming brown	P > 0.5 *
Juveniles of <i>C. flexuosum</i> and <i>E. radiata</i>	turfing browns	0.4
<i>Caulerpa</i> spp.	turfing green	0.6 *
<i>Codium</i> spp.	turfing green	< 0.3
	filamentous reds	0.8 *
	flat reds	0.8 *
Sponge	encrusting	0.6 *
Bryozoan	encrusting	< 0.3
Ascidian	encrusting	P > 0.5 *
<i>Asparagopsis armata</i>	filamentous red (annual)	P > 0.5
<i>Spatoglossum chapmani</i>	turfing brown (annual)	< 0.3
<i>Ulva lactuca</i>	turfing green (annual)	< 0.3
<i>Landsburgia quercifolia</i>	canopy forming brown	< 0.3
<i>Sargassum undulatum</i>	canopy forming brown	P > 0.5
<i>Sargassum verticillatum</i>	canopy forming brown	P > 0.5
<i>Lessonia variegata</i>	canopy forming brown	< 0.3
<i>Xiphora</i> sp.	canopy forming brown	< 0.3
<i>Macrocystis pyrifera</i>	canopy forming brown	P > 0.5
<i>Cystophora</i> spp.	canopy forming brown	< 0.3
<i>Margaritella</i> sp.	canopy forming brown	< 0.3
<i>Durvillea antarcticum</i>	canopy forming brown	< 0.3
<i>Glossophora kaurihii</i>	canopy forming brown	0.4
<i>Zonaria turneriana</i>	turfing brown	< 0.3
<i>Haliopteris congesta</i>	turfing brown	< 0.3
<i>Haliopteris junicularis</i>	turfing brown	< 0.3
<i>Colpomenia</i> sp.	encrusting brown	P > 0.5
<i>Cladophora</i> sp.	turfing green	P > 0.5
<i>Splachnidium rugosum</i>	turfing brown	P > 0.5
<i>Diclyota papenfussi</i>	turfing brown	< 0.3
<i>Diclyota</i> sp.	turfing brown	< 0.3
<i>Demarestia ligulata</i>	turfing brown	< 0.3
<i>Sporochnus</i> sp.	turfing brown	< 0.3
<i>Carpomitra costata</i>	turfing brown	< 0.3
<i>Aporhiza lyalli</i>	turfing red	< 0.3
<i>Anorticium crinitum</i>	filamentous red	< 0.3
<i>Lophurella hookeriana</i>	turfing red	< 0.3
<i>Euphloia formosissima</i>	filamentous red	< 0.3
<i>Dasya collabens</i>	filamentous red	< 0.3
<i>Polysiphonia rhododactyla</i>	filamentous red	< 0.3
<i>Gymnogongrus furcatus</i>	filamentous red	< 0.3
<i>Plocamium costatum</i>	filamentous red	< 0.3
<i>Plocamium leptophyllum</i>	filamentous red	< 0.3
<i>Delisea elegans</i>	filamentous red	< 0.3
<i>Stenogramme interrupta</i>	flat red	< 0.3
<i>Hymenena palmata</i>	flat red	< 0.3
<i>Grateloupia intestinalis</i>	flat red	< 0.3
<i>Rhodophyllus gunnii</i>	flat red	< 0.3
<i>Ptilonia willana</i>	flat red	< 0.3
<i>Epymania</i> sp.	flat red	< 0.3

Table 2: Taxa encountered in surveys of sublittoral reefs in Dusky Sound in April 1993 and their physiognomic affinity. Power is indicated for one way analysis of variance of taxa between strata (P < 0.05). Where there was clearly no difference in the abundance of the taxon, the probability value is indicated. Where no estimate of power is given, the taxon is too rare to be included in the analysis of variance. All data were analysed as percent cover (arcsin transformed) except for *Carpophyllum flexuosum* and *Ecklonia radiata* which were assessed as density. Asterisks indicate the taxa that may be used for comparison between fished and unfished strata, i.e., those taxa where abundance is estimated sufficiently precisely to detect differences over natural variation between strata.

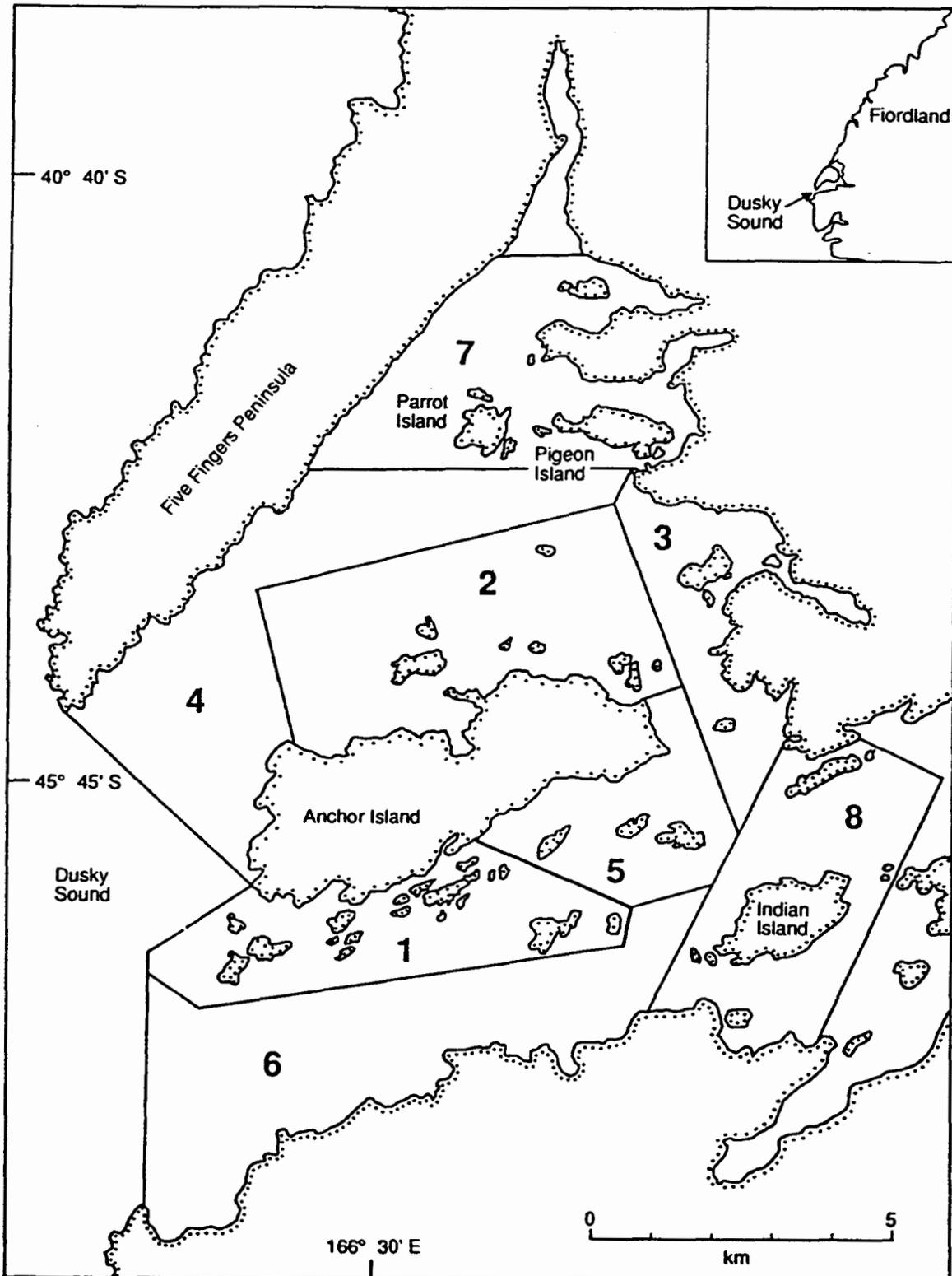


Figure 1. Sample strata used in surveys of *Evechimus chloroticus* dominated communities of Dusky Sound.

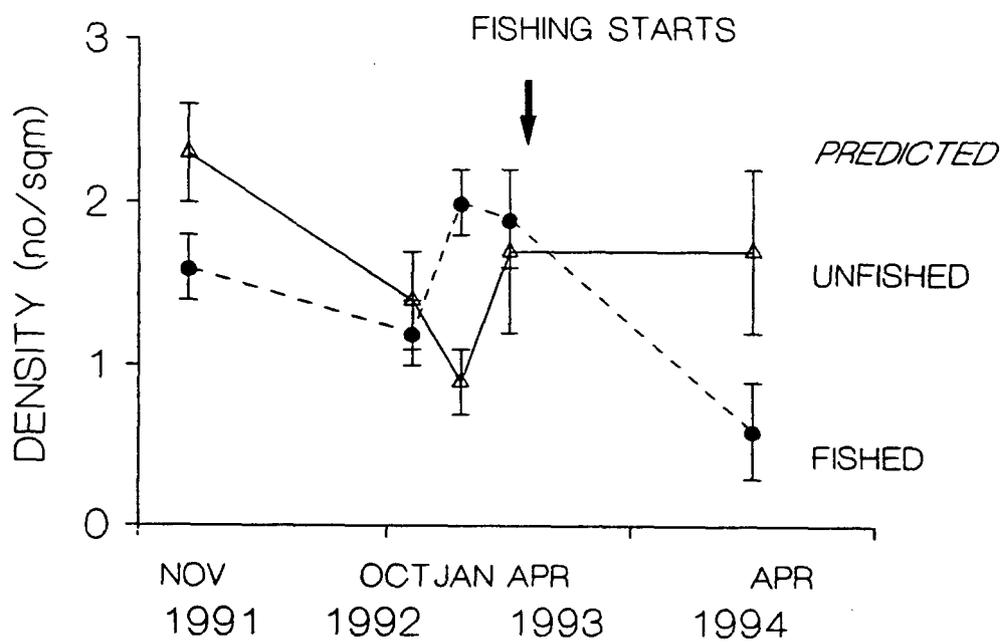


Figure 2. Temporal variation in the density of *Evechimus chloroticus* in stratum 1 (solid dots) and stratum 7 (open triangles). The change in density predicted from an annual harvest of 1000 t from stratum 1 is indicated. Data are means with SE.

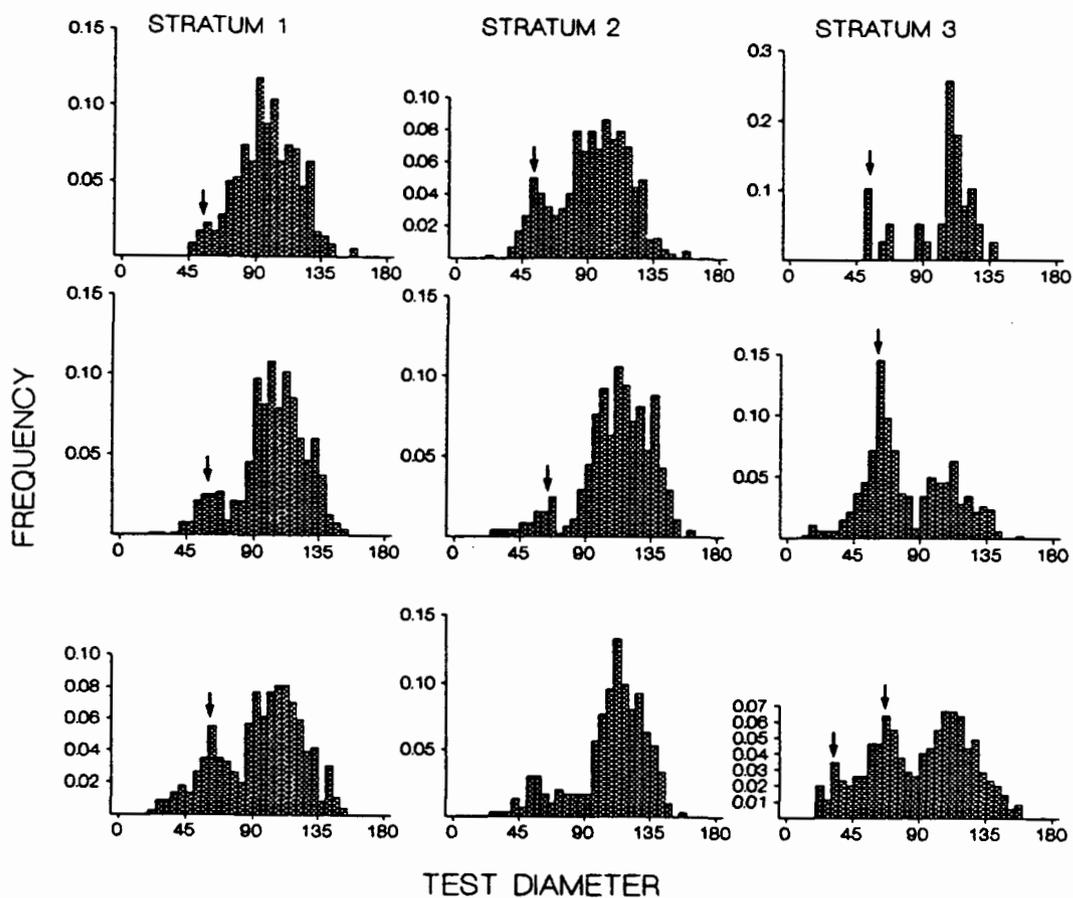


Figure 3. Size frequency of *Evechimus chloroticus* sampled from 5 strata in Dusky Sound on three occasions: October 1992, January 1993, and April 1993 (top to bottom respectively). Median test diameters are indicated (arrows) for estimated year classes.

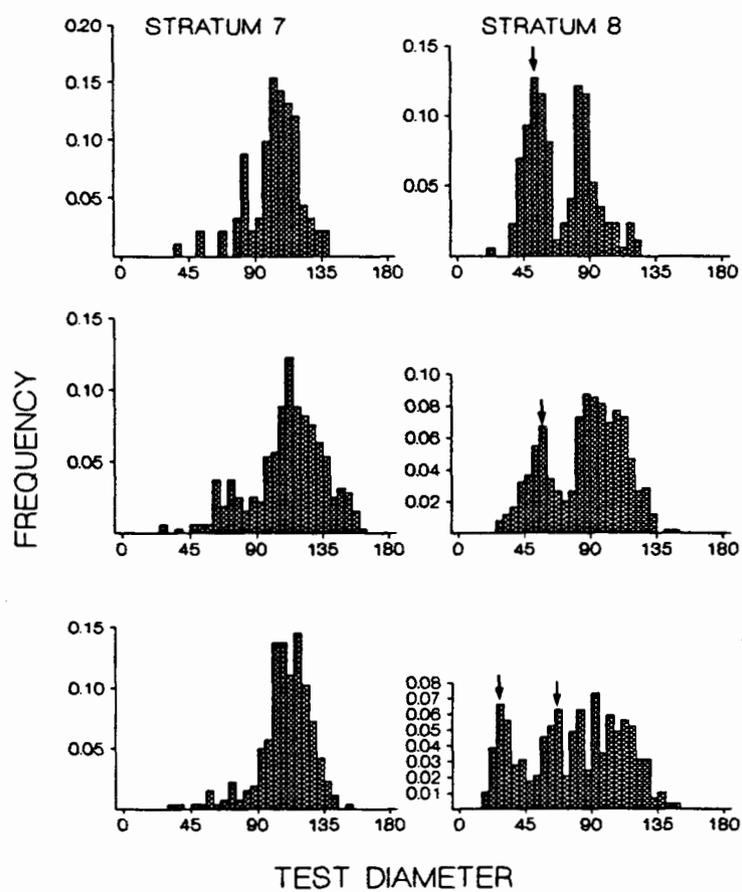


Figure 3. (cont).

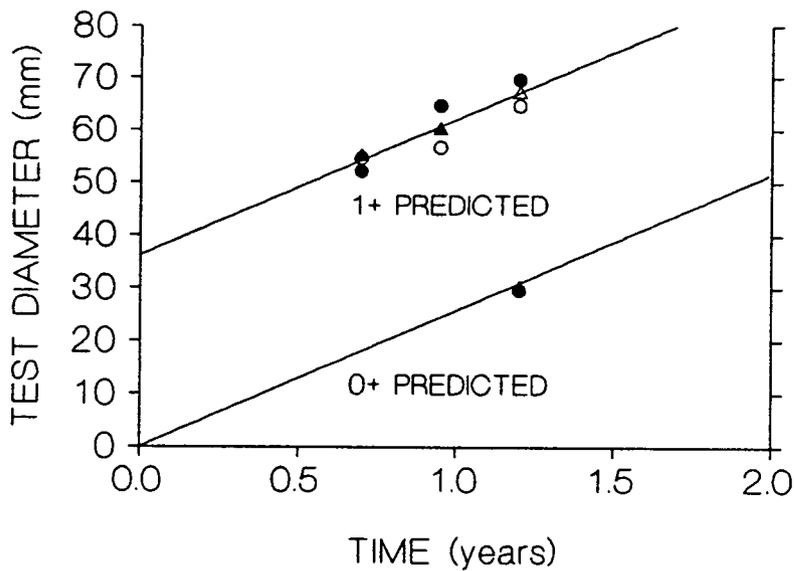


Figure 4. Increase in test diameter of *Evechimus chloroticus* sampled from stratum 1 (open dots), stratum 2 (solid dots), stratum 3 (solid triangles) and stratum 8 (open triangles). Regressions are fitted following sequential analysis of size frequency data (see Figure 3). Year classes were estimated assuming settlement (time = 0 years) during January of any year. Data are shown for predicted growth of two year classes: 0+ and 1+.

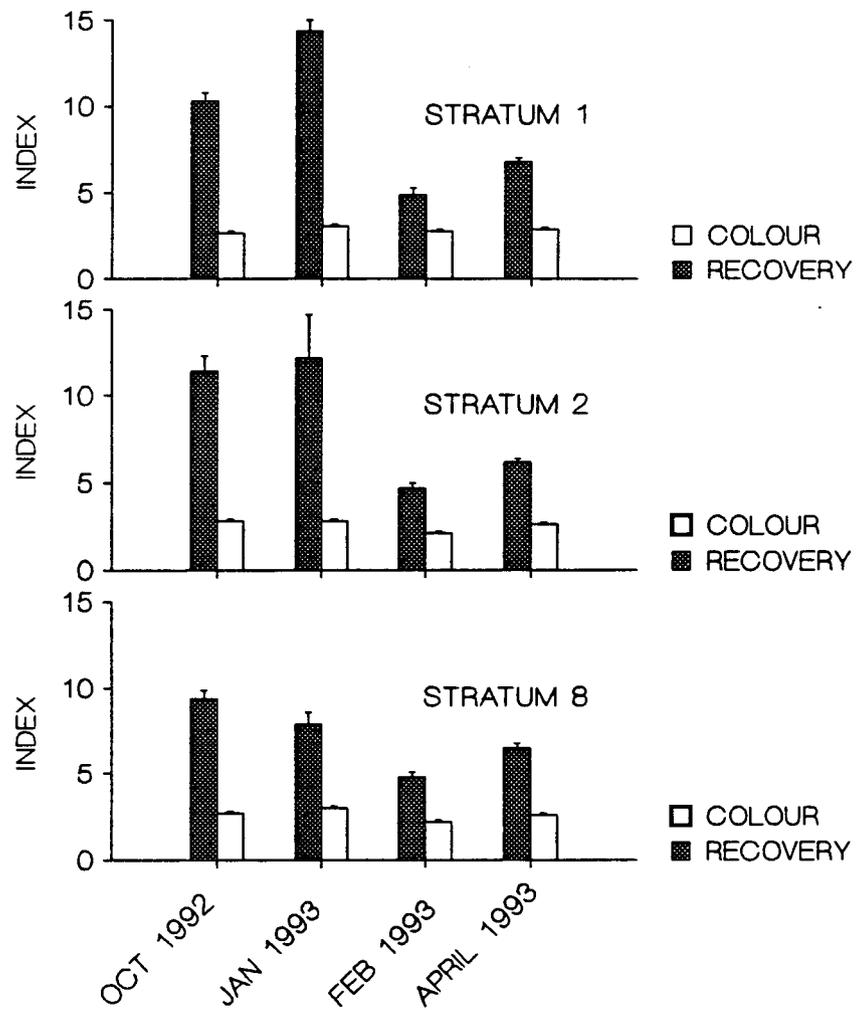


Figure 5. Temporal variation in the recovery (weight of gonad versus whole wet weight) and colour of the gonad of *Evechimus chloroticus* sampled from three strata in Dusky Sound. Data are means with SE.

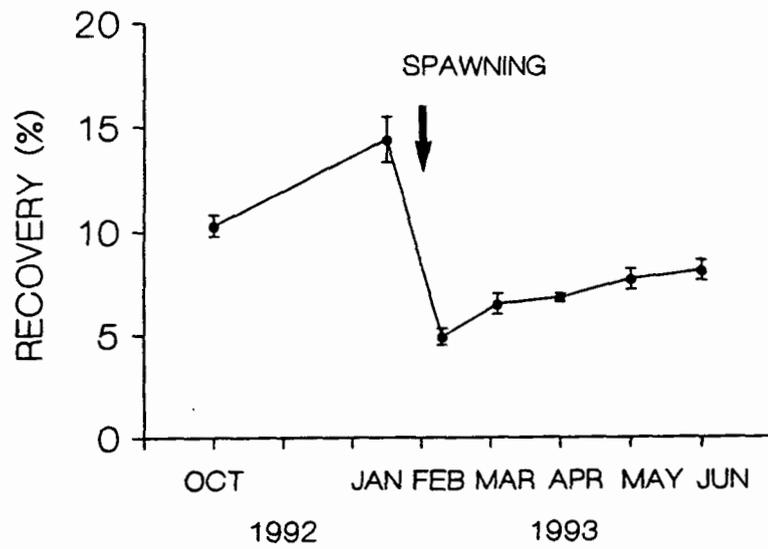


Figure 6. Seasonal variation in the recovery (% gonad weight to total weight) of *Evechimus chloroticus* sampled from stratum 1. Indicated spawning is shown with the arrow.

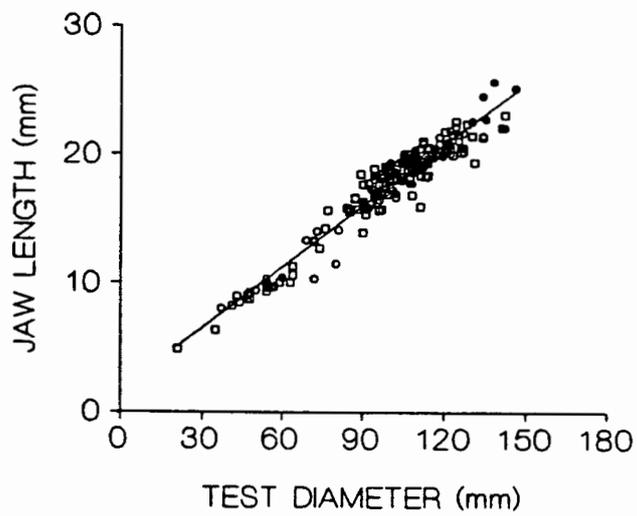


Figure 7. Variation in the jaw length with test diameter of *Evechinus chloroticus* sampled from stratum 1 (solid dots), stratum 2 (open dots) and stratum 7 (squares). Least squares fitted regression is indicated.

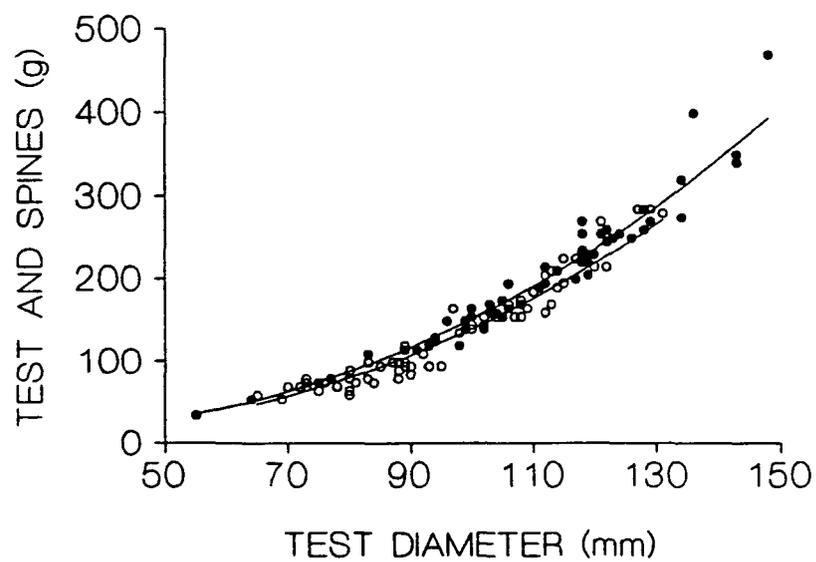


Figure 8. Comparison of the relationship of the weight of test and spines with test diameter for *Evechinus chloroticus* sampled from exposed (solid dots) and sheltered habitats (open dots) of Dusky Sound.

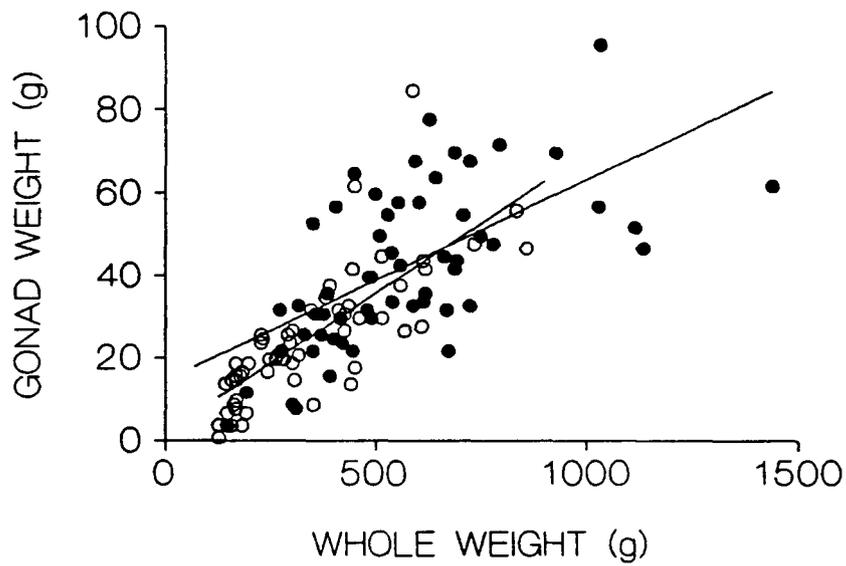


Figure 9. Relationship of gonad weight to whole weight of *Evechinus chloroticus* sampled from exposed (solid dots) and sheltered (open dots) of Dusky Sound. Least squares fitted regressions are indicated in each case but analysis of variance revealed that slopes were homogeneous ($P > 0.1$)

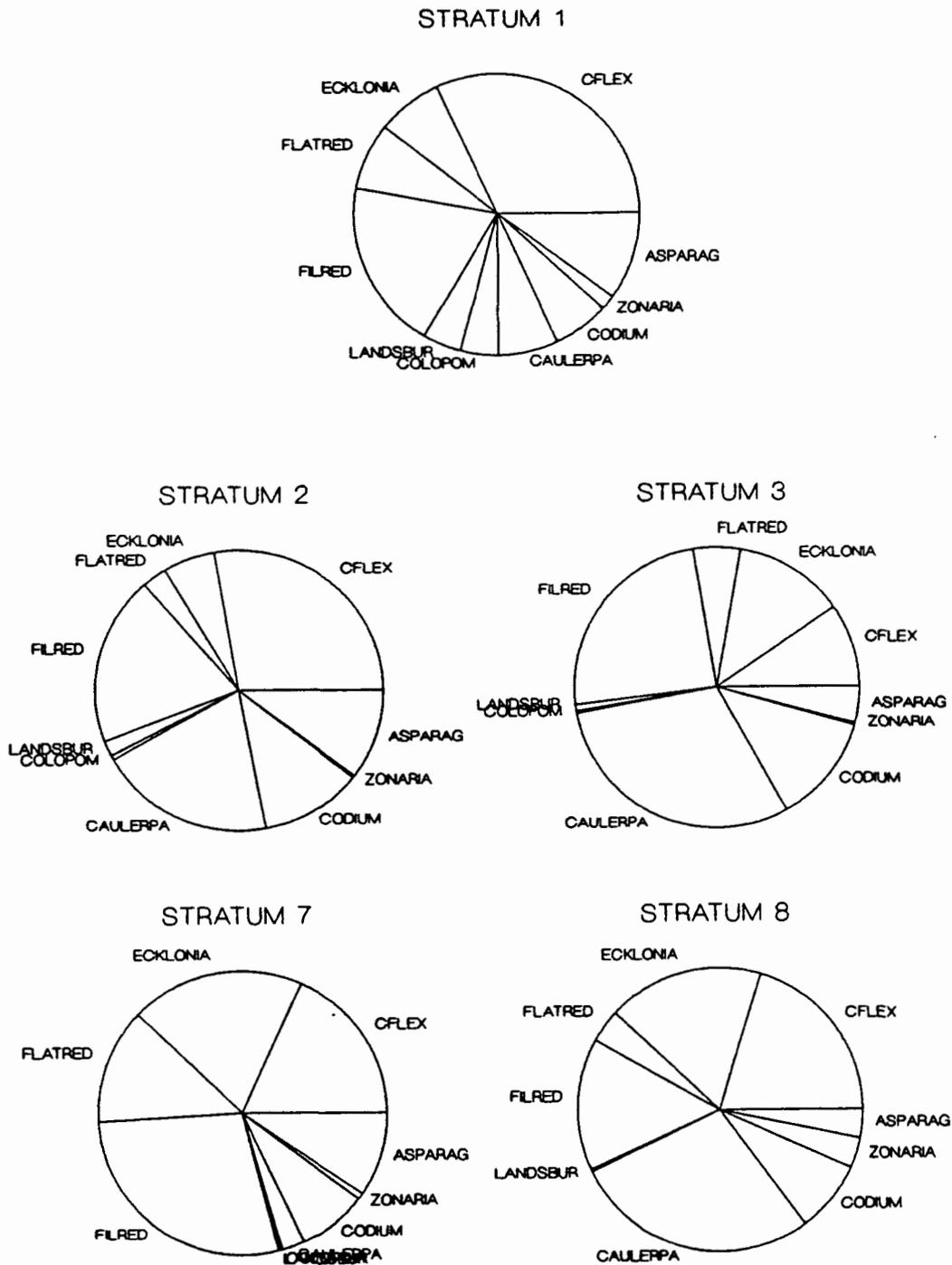


Figure 10. Variation in the relative cover of canopy and turfing macroalgae sampled from strata in Dusky Sound. Data are proportion of the total canopy. ECKLONIA = *Ecklonia radiata*; CLEX = *Carpophyllum flexuosum*; ASPARAG = *Asparagopsis armata*; ZONARIA = *Zonaria turneriana*; CODIUM = *Codium* spp.; CAULERPA = *Caulerpa* spp.; FLATRED = flat red algae; FILRED = filamentous red algae, LANDSBUR = *Landsburgia quercifolia*; COLOPOM = *Colpomenia* sp.

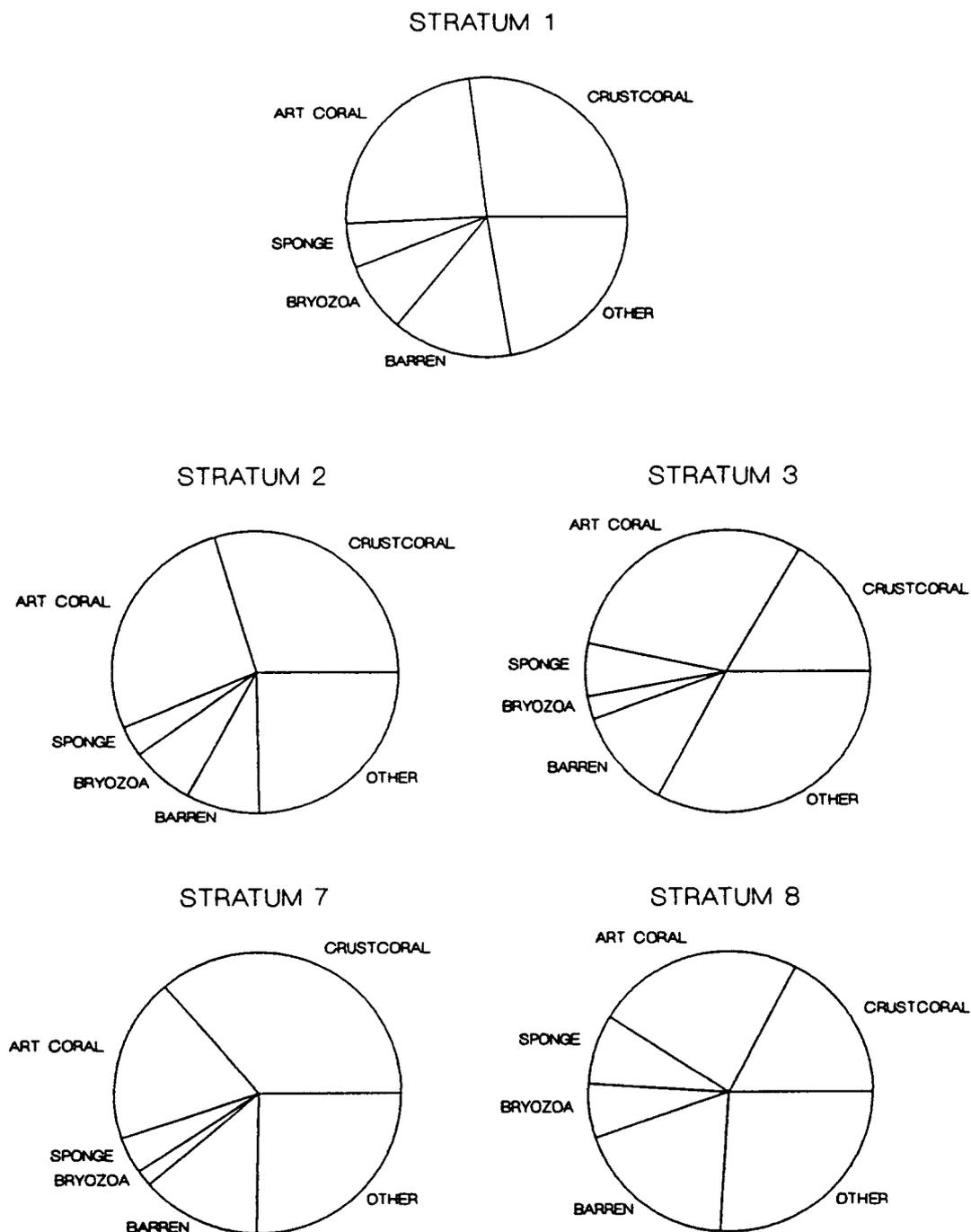


Figure 11. Variation in the percent cover of various encrusting biota sampled from strata in Dusky Sound. ART CORAL = articulated coralline algae; CRUSTCORAL = encrusting coralline algae; BARREN = no biota.

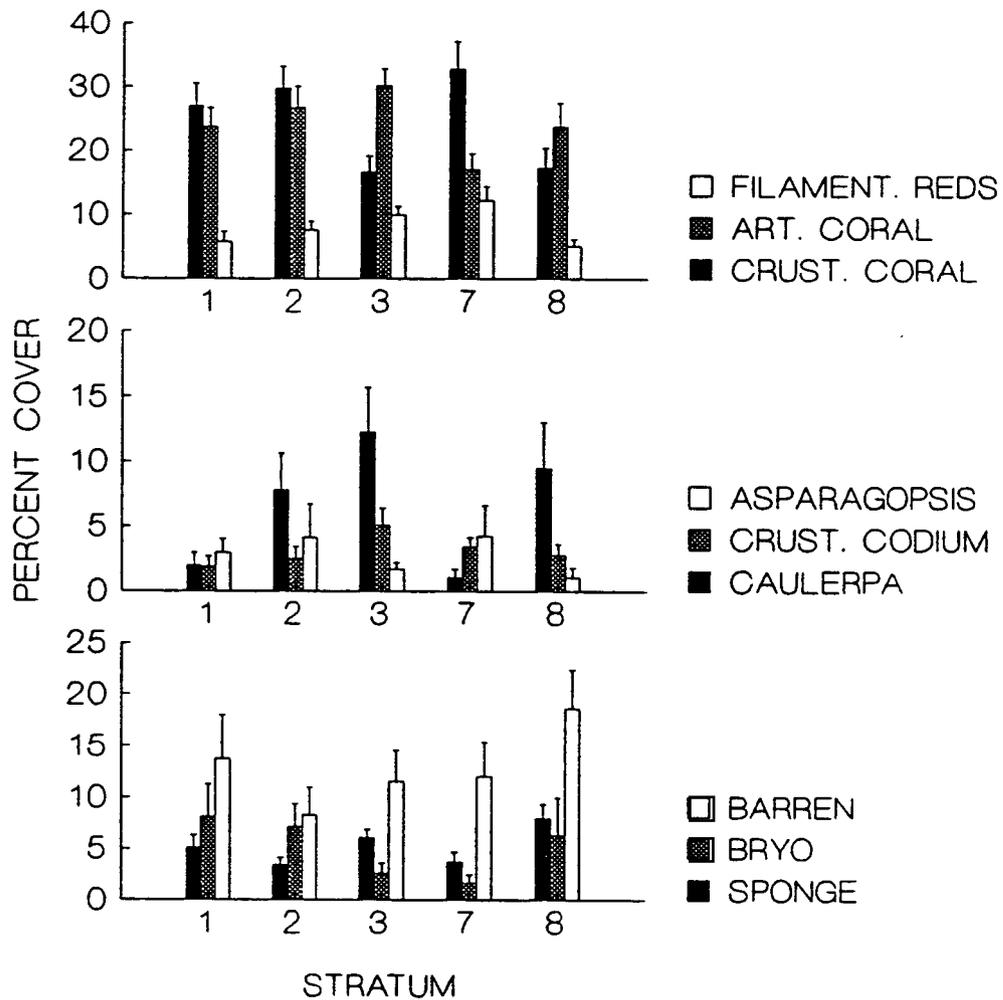


Figure 12. Variation in the percent cover for various taxa sampled from strata in Dusky Sound. Data are means with SE.

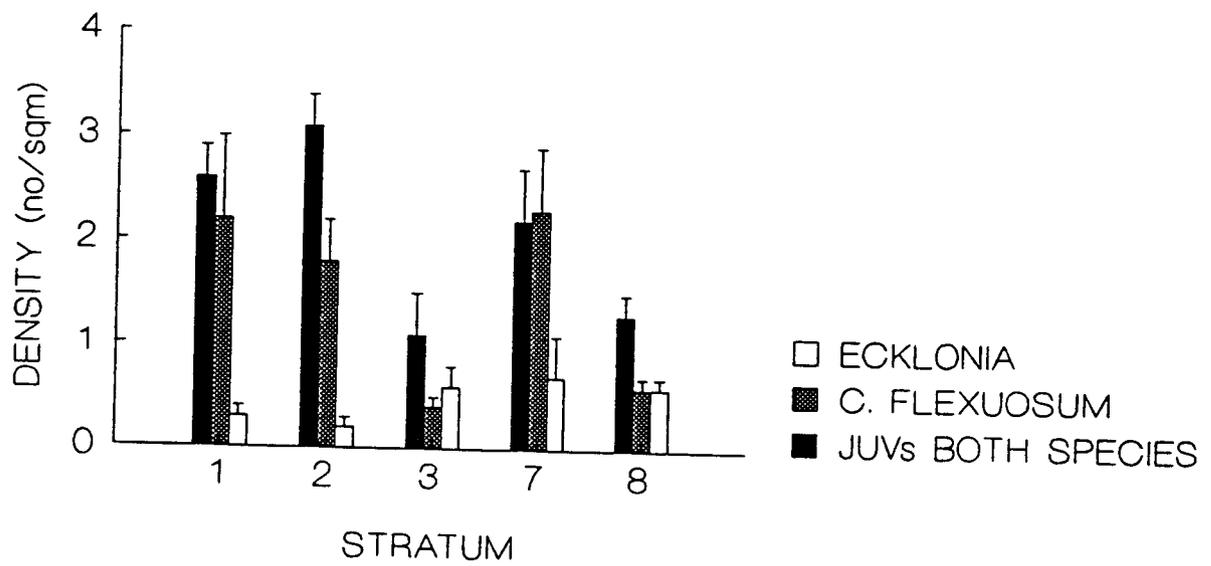


Figure 13. Comparison of the density of *Carpophyllum flexuosum*, *Ecklonia radiata* and juveniles of both species sampled from strata in Dusky Sound. Data are means with SE.

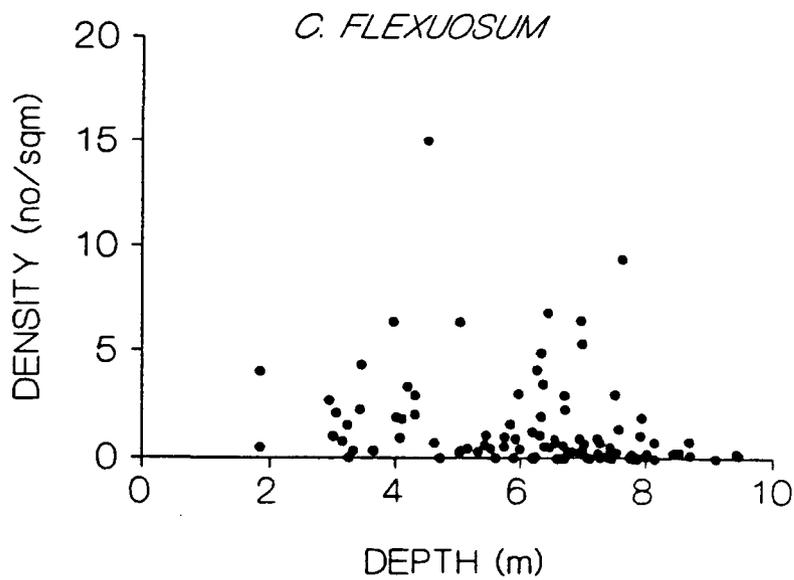
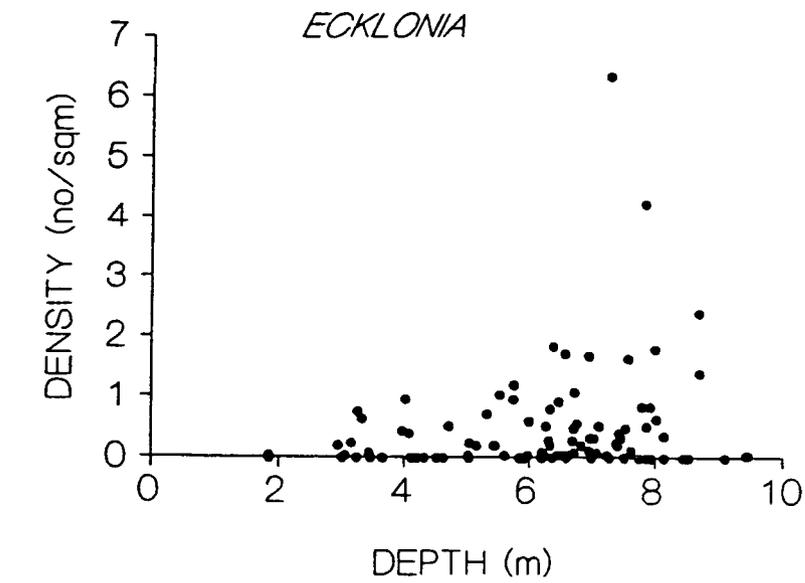


Figure 14. Variation in the density of *Carpophyllum flexuosum* and *Ecklonia radiata* with depth in Dusky Sound.