# Potential ecological impacts of harvesting kina (*Evechinus chloroticus*) in Fiordland

Eduardo Villouta
Science and Research Unit
Department of Conservation
PO Box 10-420
Wellington
New Zealand

Published by
Department of Conservation
Head Office, PO Box 10-420
Wellington, New Zealand

This report was commissioned by Southland Conservancy.

ISSN 1171-9834



Reference to material in this report should be cited thus:

Villouta, E., 2000.
Potential ecological impacts of harvesting kina (*Evechinus chloroticus*) in Fiordland. *Conservation Advisory Science Notes No. 286*, Department of Conservation, Wellington.

Keywords: kina, sea urchin, *Evechinus chloroticus*, macroalgae, fishing impacts, Fiordland.

# Summary

High densities of *Evechinus chloroticus* are common in the rocky subtidal of outer Dusky Sound, Fiordland. Within this area, organisms are zonated into three habitats. These habitats are a shallow fucoid fringe; a mid-depth barren zone dominated by crustose forms (algae and sessile invertebrates) and devoid of most large algae; a deeper algal meadow where smaller herbaceous and turfing algae predominate. In many sites, a fourth (deeper) zone dominated by a dense *Ecklonia radiata* forest is found. *Evechinus* is most abundant in the two shallowest zones and its abundance decreases noticeably thereafter.

In a large two-year experimental study, sea urchins were removed, causing the community structure to change dramatically by allowing large algal habitat-forming species to form a more homogeneous, taller, algal canopy. However, two years of continual sea urchin removal was not enough time for the community to reach a stable structure.

During the experimental period, there was no evidence that diversity of taxa smaller than large brown algae varied when sea urchins were removed. However, the loss of the so-called `barren habitat' (middle zone) due to the large community structure changes can be considered as a reduction in habitat diversity. The implications of the loss of the barren habitat for the whole community (sessile and mobile species) are not known.

Longer-term predictions (longer than two years), for at least two important taxa, *Carpophyllum* spp., and *Ecklonia*, were possible using additional information from a comprehensive observational study. In the upper zone (range 0 - 3.5 m), it appears that the changes detected for *Carpophyllum* density in the short term (2 years) do not last longer. *Ecklonia* could increase its density up to 0.6 plant/m$^2$ if urchins were removed below a threshold of 2 individuals/m$^2$. In the middle zone (range 3.5 - 6.5 m), as for the upper zone, it appears that the short-term *Carpophyllum* density increases do not last longer. *Ecklonia* increases its density up to 1 plant/m$^2$ when sea urchins are removed below the sea urchin threshold of 2 individuals/m$^2$. In the lower zone (range 6.5 - 11.5 m), as for the shallower depth zones, the available evidence shows that we cannot expect significant differences in *Carpophyllum* densities between areas with and without sea urchins in the longer term. *Ecklonia* could increase its mean density to 1.55 plants/m$^2$ when sea urchins are removed below threshold levels.

# 1. Introduction

In order to address a conservation management issue arising from the proposal to establish a large sea urchin fishery in Fiordland, Southland Conservancy sought technical advice from Science and Research Unit, Department of Conservation (hereafter SRU). The specific questions asked were:

- How would *Evechinus* harvesting affect the algal communities in Dusky Sound?
- At what point in any decline in *Evechinus* density will algal populations show a significant response or change?
- What are the short- and long-term changes expected to occur on the benthic community after harvesting *Evechinus?*
- Is *Evechinus* harvesting expected to make changes in biodiversity?

To address these questions, two sources of information were consulted. The first was a study carried out by SRU. A second study was carried out by the Ministry of Agriculture and Fisheries (MAF).

*SRU's Study*. During October 1992 and April 1995, SRU conducted a large sea urchin removal experiment (8 removal and 8 control sites) in Dusky Sound aimed at detecting possible ecological changes in the benthic community. All visible sea urchins were removed every three months at eight sites including a buffer zone around each of them (another eight sites were selected as controls). At this removal rate sea urchin re-invasion was maintained between 8.3 and 2.6 %.

*MAF's Study*. During the same period of time (April 1993 to January 1994), MAF-Fisheries (today NIWA) conducted four surveys. A total of 168 site/date samples constituted the full dataset (not all the initially sampled sites were sampled in each occasion). This large dataset was later handed to DOC (in the form of raw field sheets) for DOC's use and publication.The methodology followed by MAF consisted in sampling in 10 randomly selected sites from each of five different geographic locations into which the outer Dusky Sound had been partitioned. The densities of two large brown algae (*Carpophyllum, Ecklonia*) were sampled at each site/date combination in a randomly located 25 x 1 mZ strip quadrat (McShane et al. 1993).The sampling design assumed that detection of any possible impact would have been possible by randomly re-sampling the outer sound after successive sea urchin harvesting seasons. The 130 t *Evechinus* that were harvested in Dusky Sound within the three-year period of experimental fishing (4.3 % of the combined three-year quota) were insufficient to cause any measurable change in the sea urchin population or in the algal composition (McShane et al. 1994, McShane 1997).

# 2. Results

## 2.1 GENERAL FINDINGS

High densities of *Evecbinus* are common in the outer Dusky Sound, and they occur mainly above 9 m depth. In areas where sea urchins densely aggregate, a very well defined algal zonation was present. The zonation included four habitats or zones: a shallow fucoid fringe (hereafter upper zone), a mid-depth barren zone (hereafter middle zone) dominated by crustose forms (algae and sessile invertebrates) and devoid of most large algae, a deeper algal meadow where smaller herbaceous and turfing algae predominate (hereafter lower zone). In many sites, a fourth (deeper) zone dominated by a dense *Ecklonia radiata* (hereafter *Ecklonia*) forest was found. *Evecbinus* occurs mostly in the upper and middle zones (Figure 1).

The experimental removal of *Evecbinus* from subtidal habitats in Dusky Sound resulted in conspicuous changes in algal communities at all depth zones examined (Villouta et al. unpubl. data). A pictorial representation of these changes is presented in Figures 1 and 2.

DOC's experimental data showed a causal non-linear relationship between the abundance of sea urchins and the abundance of *Ecklonia, Carpophyllum* spp., *Sargassum* spp., *Landsburgia quercifolia*, *Cystopbora* spp. (Figure 3). The non-linear relationship between sea urchin density and *Carpophyllum* and *Ecklonia* was confirmed using MAF's observational study (Figure 4). Hence the two datasets were combined for better representation of the outer Dusky Sound (Figure 5). Decreasing *Evechinus* density below 2 individuals/m$^2$ causes *Ecklonia* density to increase dramatically. In the same manner, densities below 3 individuals/m$^2$ of *Evecbinus* cause an increase in *Carpophyllum*. The relationship between *Carpophyllum* and *Evechinus* follows the same pattern as for *Ecklonia,* though weaker.

This means that the high densities of *Evechinus* commonly found in Dusky Sound maintain in a community structure generally comprising small herbaceous and turfing algae, sessile invertebrates and crustose algae, and where large brown algal populations are suppressed. When sea urchins are removed down to the threshold density (see above), the community structure changes dramatically, allowing large habitat-forming species to take over and form a more homogeneous, taller algal canopy (Figure 2).

## 2.2 CHANGES PREDICTED IN THE SHORT TERM (FIRST TWO YEARS)

The changes in plant density shown by fucoid species after removing all sea urchins for 25 months occurred in the shallower habitats (upper and middle zones), where most *Evechinus* occur (Villouta et al. unpubl. data).

*Upper zone (mean depth 2 m; range 0 - 3.5 m*). The significant changes in plant density observed for *Carpophyllum*, *Cystophora* and *Sargassum* resulted in their predominance in the upper zone. Although more variable, these density changes were of a similar magnitude to that recorded in the middle depth zone. *Carpophyllum* and *Cystophora* contributed most, although significant colonisation was also recorded for *Sargassum* (Figure 6). This altered what had been predominantly a two-species stand to one of three species. No real changes in coverage of herbaceous, turfing or crustose algae were apparent after 25 months of urchin exclusion (Figure 7).

*Middle zone* (*mean depth* 5 *m; range 3.5 - 65 m*). The greatest changes occurred in the middle zone, where coralline crust-dominated areas were generally replaced by a mixed stand of fucoids numerically dominated by *Sargassum*, *Cystophora* and *Carpophyllum* (Figure 6). Smaller increases of *Landsburgia* and *Ecklonia* also occurred (Figures 6,7). There were also significant increases in the sub-canopy of herbaceous algae, principally bushy and leafy reds, most noticeable soon after urchin removal (Figure 7).

*Lower zone (mean depth 9 m; range 65 - 11.5 m)*. Here the changes were smaller than those recorded above, although still statistically significant. The lower zone prior to urchin removal was dominated by a cover of small algae (herbaceous and turfing) (Figure 7), while adult large brown algae, particularly *Carpophyllum* and *Ecklonia*, were uncommon (Figure 6). After urchin removal, densities of *Ecklonia* and *Carpophyllum* increased. Colonisation by *Landsburgia* and *Cystophora* also occurred but at densities much lower than the former taxa (Figures 6 and 7). At the end of the experiment, large brown algal abundance was still patchy, and herbaceous and turfing algae were still the dominant plant cover.

## 2.3 CHANGES PREDICTED OVER LONGER PERIODS (LONGER THAN TWO YEARS)

The large number of MAF's sites, including the full range of *Evechinus* densities, is considered here to represent the longer-term picture, where the community structure sampled is assumed had been modified by the sea urchins for long periods of time. MAF's study included information only on the density of *Ecklonia* and *Carpophyllum*, hence predictions for only these two taxa could be done, and no longer-term predictions can be done for the other fucoid species, at any of the three zones.

*Upper zone.* MAF's study shows the naturally occurring *Carpophyllum* densities as opposed to densities obtained by DOC's experimental manipulation. MAF's study shows that there is no significant difference in density of *Carpophyllum* between sites with the full range of sea urchin density and sites with sea urchin density below the estimated threshold (3 individuals/ $m^2$) (Figure 8). Likewise, DOC's results shows that *Carpophyllum* density does not differ between sea urchin removal sites and control sites in three of the four surveys in which the density was monitored (Figure 6). This suggests that the weaker relationship between *Carpophyllum* and *Evechinus* (Figure 5) could be strongly influenced by other factors, thus introducing 'noise' and obscuring the relationship (it is suspected that exposure to water movement could be one such factor). The mean density of 4 plants/$m^2$ shown in MAF's study (Figure 8) is lower that the 5 - 6 plants/$m^2$ reached after removing sea urchins in DOC's study (Figure 6). The difference is probably due to the fact that in DOC's study sea urchins were completely removed.

MAF's study, of the naturally occurring *Carpophyllum* densities as opposed to densities obtained by DOC's experimental manipulation, shows that there is no significant difference in density of *Carpophyllum* between sites with the full range of sea urchin density and sites with sea urchin density below the estimated threshold (3 individuals/$m^2$) (Figure 8).

A significant increase in density of *Ecklonia* (from c. 0.4 to 0.6 plants/$m^2$) was obtained when comparing sites with the full range of sea urchin density against sites with sea urchin density below the estimated threshold (2 individuals/$m^2$) using the MAF's dataset (Figure 8). A much lower *Ecklonia* density value (0.2 plant/$m^2$) was obtained from sea urchin removal sites in DOC's study. This suggests that for this study, time was insufficient to reach the *Ecklonia* densities higher than 0.6 plants/$m^2$ expected under the condition of complete absence of sea urchin (Figure 7).

*Middle zone.* MAF's study did not show significant differences in *Carpophyllum* density between sites with the full range of sea urchin density and sites with sea urchin density below the estimated threshold (3 individuals/$m^2$) (Figure 8). Numerically, *Carpophyllum*, became the dominant species reaching a peak of c. 8 plants/$m^2$ under continued urchin removal (Figure 6) in DOC's study. However, this density was declining after the first year of experimental sea urchin removal (Figure 6). This downward trend could have continued (if DOC's experiment had run for longer) until leveling off at the assumed longer-term density observed in MAF's study (c. 3 plants/$m^2$) for sites above and below the threshold (Figure 8).

MAF's dataset shows that *Ecklonia* density could increase its mean from 0.8 up to 1 plant/$m^2$ in sites with sea urchin densities below the estimated threshold (2 individuals/$m^2$) (Figure 8). The lower but upward trend shown in DOC's experiment suggests that *Ecklonia* density could have continued to rise until it reached at least that observed in MAF's example, because of the higher level of sea urchins removal (total removal) (Figure 6).

Thus, harvesting sea urchins to the threshold level could turn the middle zone into one dominated by *Ecklonia*, and *Carpophyllum*, as well as by *Cystophora* and *Landsburgia*, which also increased notably their density in two years of sea urchin removal (Figure 6).

*Lower zone.* According to MAF's results, for *Carpophyllum* there is no difference in density between sites with the full range of sea urchin density and sites with sea urchin density below the estimated threshold (3 individuals/ m'). Assuming that the density of 0.8 plants/$m^2$ observed in MAF's study represent longer-term density (Figure 8), then the differences with the density of 2.6 plants/$m^2$ observed in DOC's study is likely due to that in the latter sea urchins were totally.

According to MAF's study, a change in *Ecklonia* density from 1.4 up to 1.55 plants/m$^2$ could be expected if sea urchin density is reduced below the threshold of 2 individuals/m$^2$ (Figure 9). The higher *Ecklonia* density reached in DOC's sea urchin removal experiment (1.9 plants/m$^2$), suggests a stronger effect at total sea urchin removal.

## 2.4 BIODIVERSITY AND HABITAT CHANGES

Within DOC's experiment we did not monitor species diversity, although we monitored a fixed number of taxa and physiognomic groups. Twenty-two species and groups were monitored as percentage cover. Figure 10 shows the number of these taxa at the start and at the end of the two-year removal experiment, at the three zone depths studied. In the upper zone (2 m), there is no difference in diversity with or without urchins (both lines lay together). In the middle and lower zones (5 m, 9 m), the number of taxa increased when urchins were removed, but the differences at the end of the experiment were not significant.

By removing all sea urchins, the mid-depth barren habitat (middle zone) undergoes important changes that can result in the establishment of a tall algal canopy. The community structure under the canopy might change and the barren habitat be lost completely. Partial removal of sea urchins was not done so predictions are difficult.

# 3. Discussion

Kina is an efficient grazer and its important role in structuring community is well known in northern New Zealand (Choat & Schiel 1982, Schiel 1990, Schiel & Foster 1986). The high densities of *Evechinus* commonly found in Dusky Sound maintain a community structure which generally comprises small herbaceous and turfing algae, sessile invertebrates and crustose algae, and large brown algal populations are suppressed. Total sea urchin removal causes the community structure to change dramatically, allowing large habitat-forming species to take over and form a more homogeneous, taller algal canopy. Changes on sessile invertebrates in the under-canopy have also been found (Villouta et al. unpubl. data). The magnitude of the sea urchin effect in Dusky Sound is comparable to that exerted to the benthic communities in the northern part of the country.

Grazing effects at various sea urchin densities on large brown algae is not linear. This was observed for *Ecklonia*; *Carpophyllum*; *Sargassum*; *Landsburgia*; and *Cystophora*. There are sea urchin density thresholds, below which further sea urchin removals cause a large change in algal density. Such urchin density thresholds vary according to the algal species. It was estimated that they are 2 and 3 sea urchins/m$^2$ for *Ecklonia* and *Carpophyllum* respectively. The threshold effect is much more pronounced for *Ecklonia* than for *Carpopbyllum*. This suggests that the loosely non-linear relationship estimated for *Carpopbyllum* and sea urchins (hence the estimated threshold) might be obscured by other factors such as exposure. Further analyses to test the importance of this physical factor are needed.

Long-term predictions suggest the type of changes the benthic community structure in the outer Dusky Sound could undergo when sea urchin are removed below threshold densities. The long-term changes described for *Ecklonia* exemplify the changes expected. Total sea urchin removal will cause a greater change in the community structure.

Sea urchin grazing in Dusky Sound varies in the different depth related habitats. These changes affect mostly the mid-depth barren zone, where a shift to a tall canopy of *Ecklonia, Cystopbora,* and *Landsburgta* is expected.

MAF's dataset does not include information on the density of *Cystophora* and *Sargassum* that can be used to make longer-term predictions. Percentage cover of *Cystopbora* and *Landsburgta* was sampled by MAE This different type of information could also be used for further predictions, but data have not as yet been analysed.

Species diversity changes were not properly addressed in the studies summarised here. Some evidence of diversity change of a selected group of species is apparent in the middle and lower zones, but these should be treated cautiously since they were not significant.

Total sea urchin removal caused loss of the mid-depth barren habitat (middle zone). However, predictions over habitat losses with partial removal are only speculative.

# 4. Acknowledgements

The Ministry of Agriculture and Fisheries (MAF-Fisheries, today NIWA) and the Department of Conservation, New Zealand, jointly funded the studies used in this paper. Permission to use MAF-Fisheries data set is appreciated.

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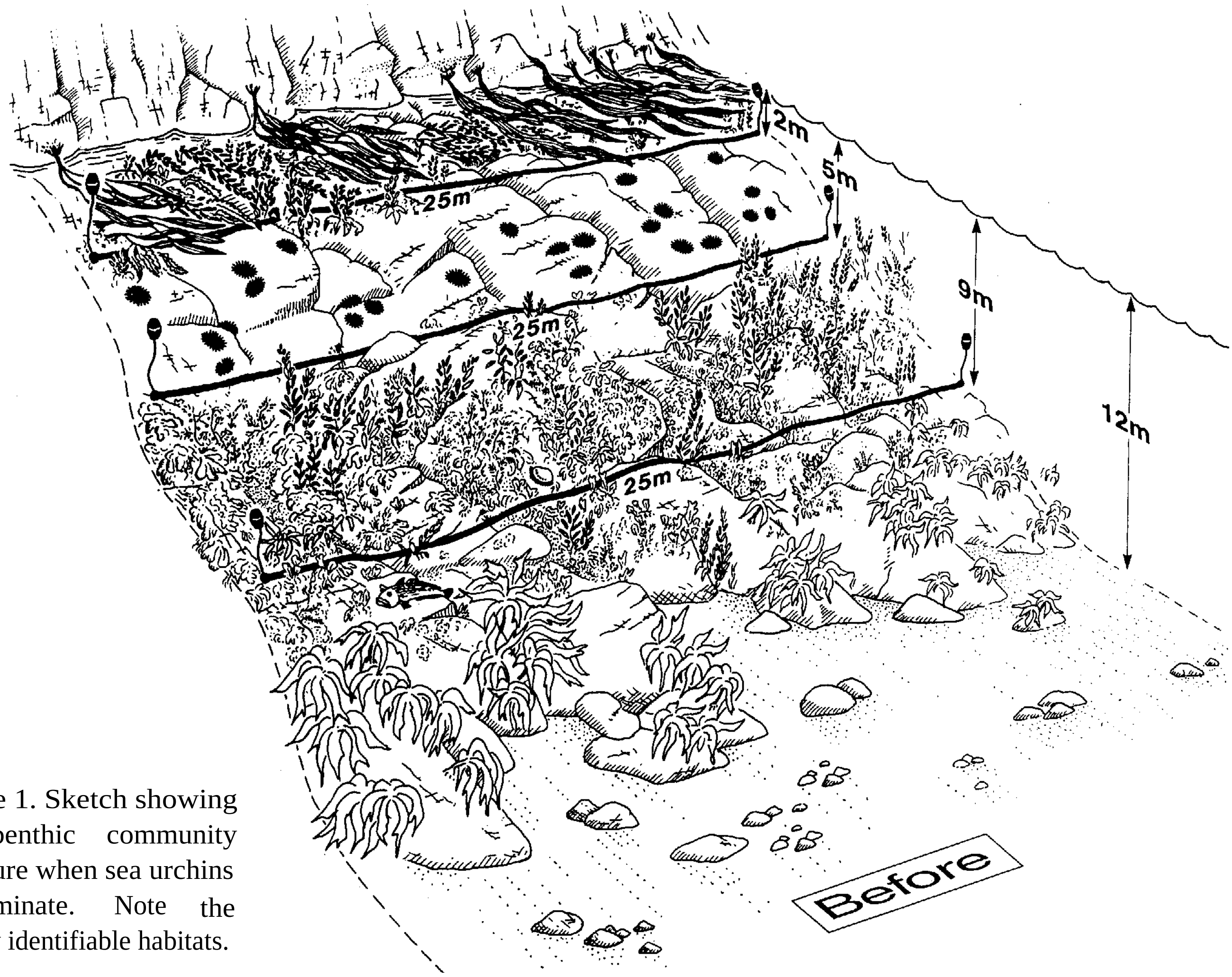


Figure 1. Sketch showing the benthic community structure when sea urchins predominate. Note the clearly identifiable habitats.

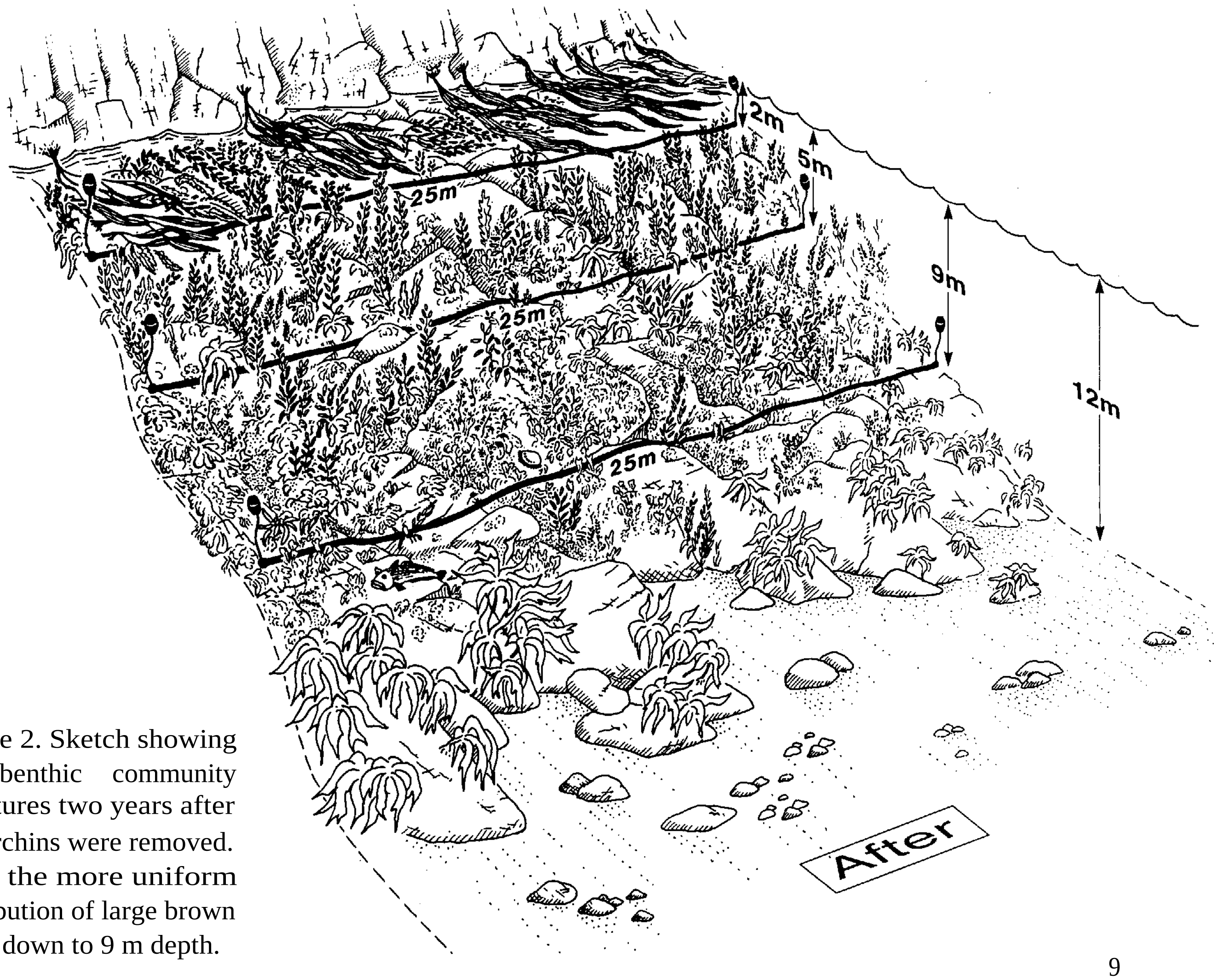


Figure 2. Sketch showing the benthic community structures two years after sea urchins were removed. Note the more uniform distribution of large brown algae down to 9 m depth.

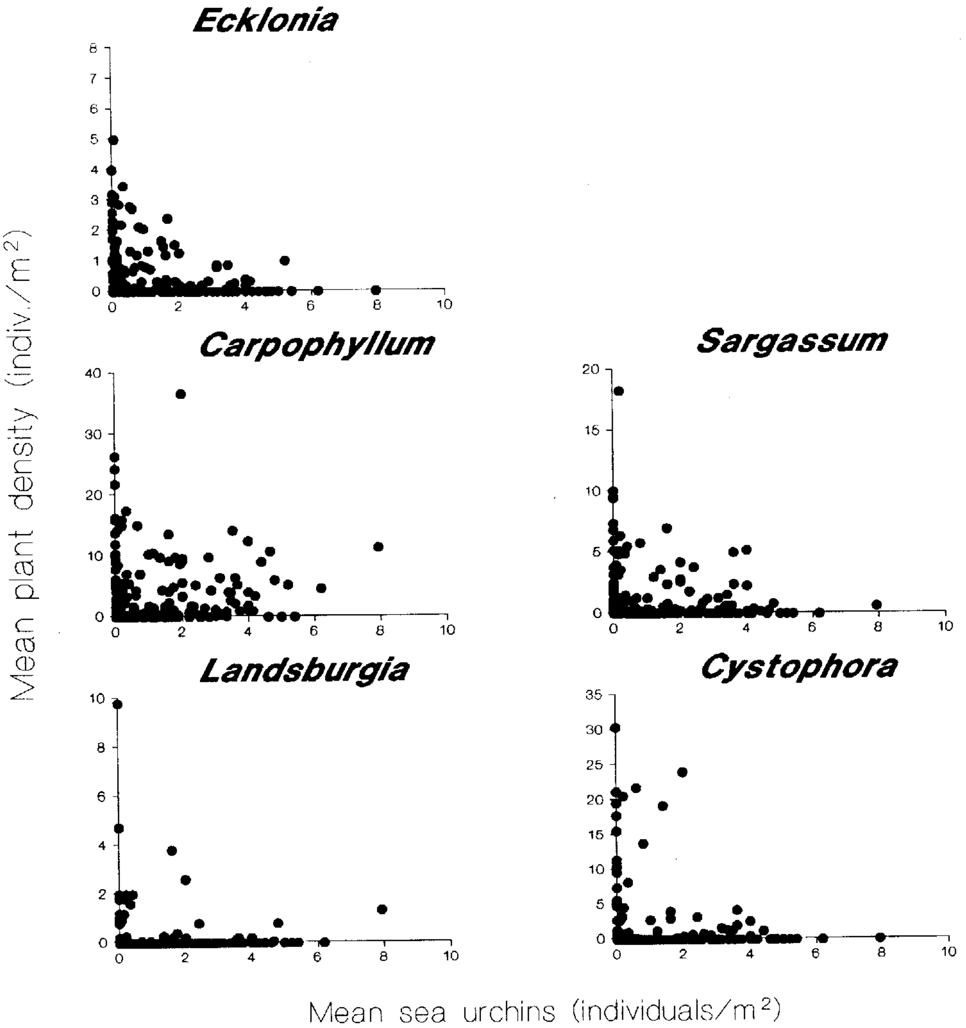


Figure 3. Mean plant density of large brown algal species at different sea urchin mean densities. DOC's data set.

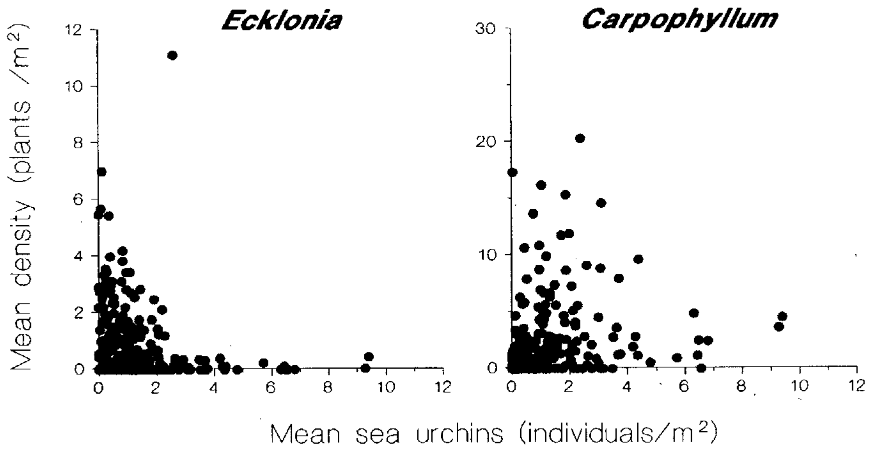


Figure .4. Mean plant density of algal species at different sea urchin mean densities. MAF's data set.

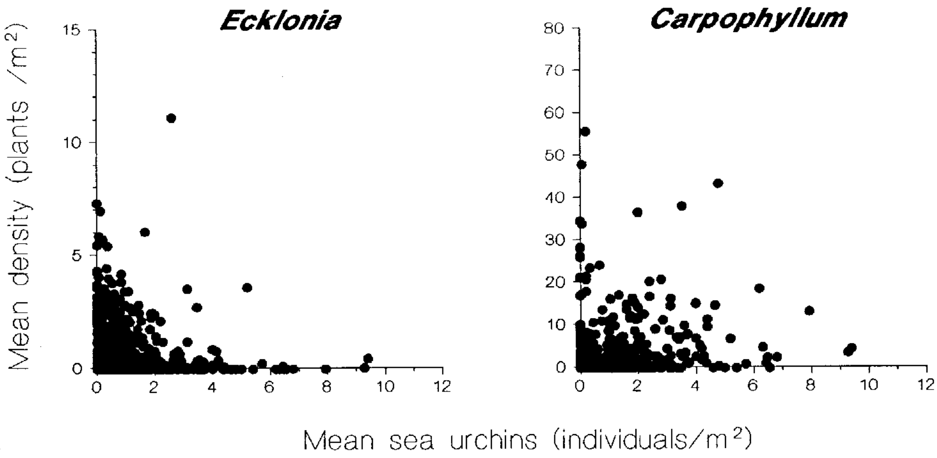


Figure 5. Mean plant density of algal species at different sea urchin mean densities. DOC's and MAF's data sets combined.

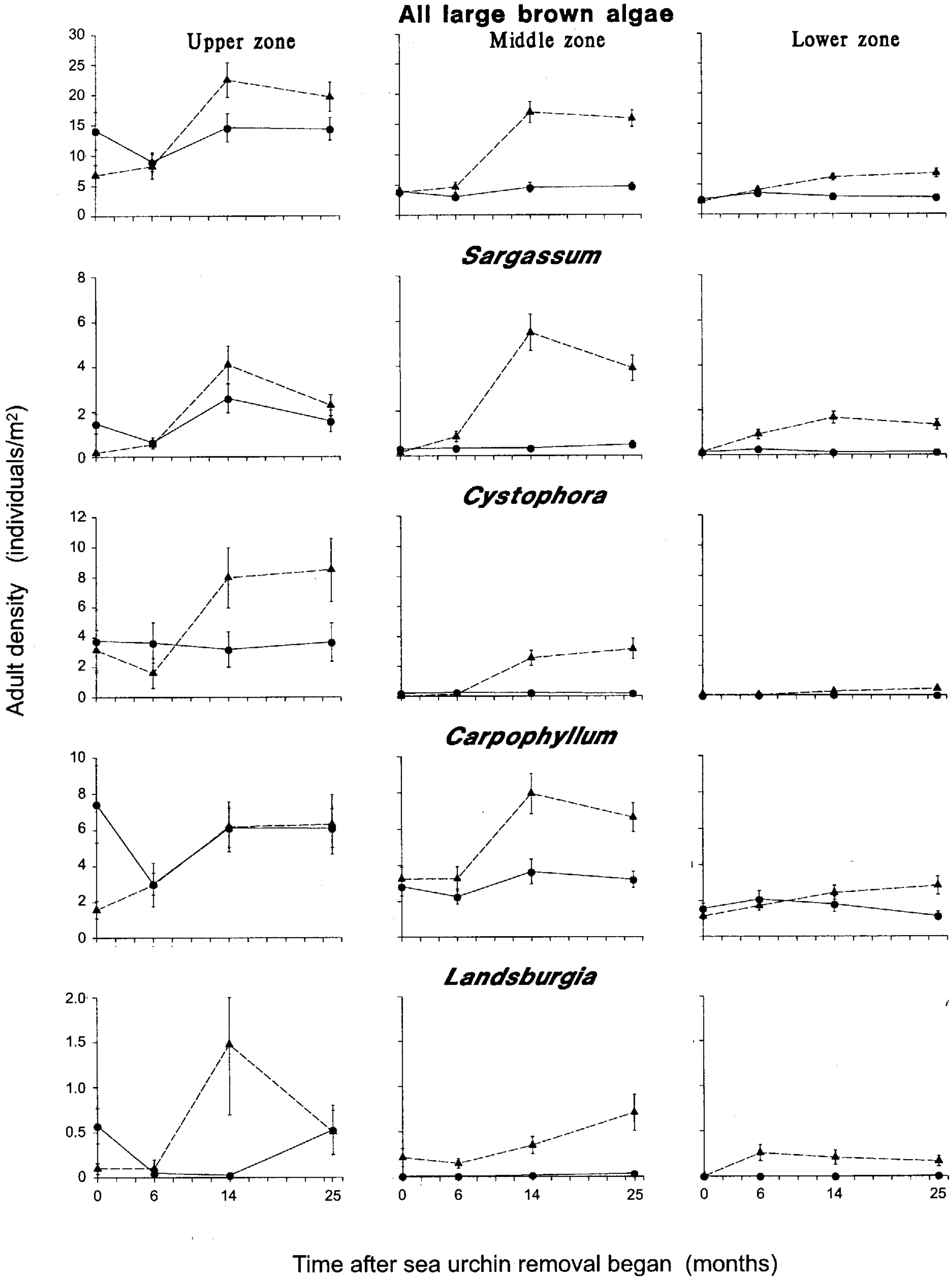


Figure 6. Mean (± SE) adult plant density of brown algae at different times during DOC's urchin removal experiment. Solid line: control sites. Dotted lines: removal sites.

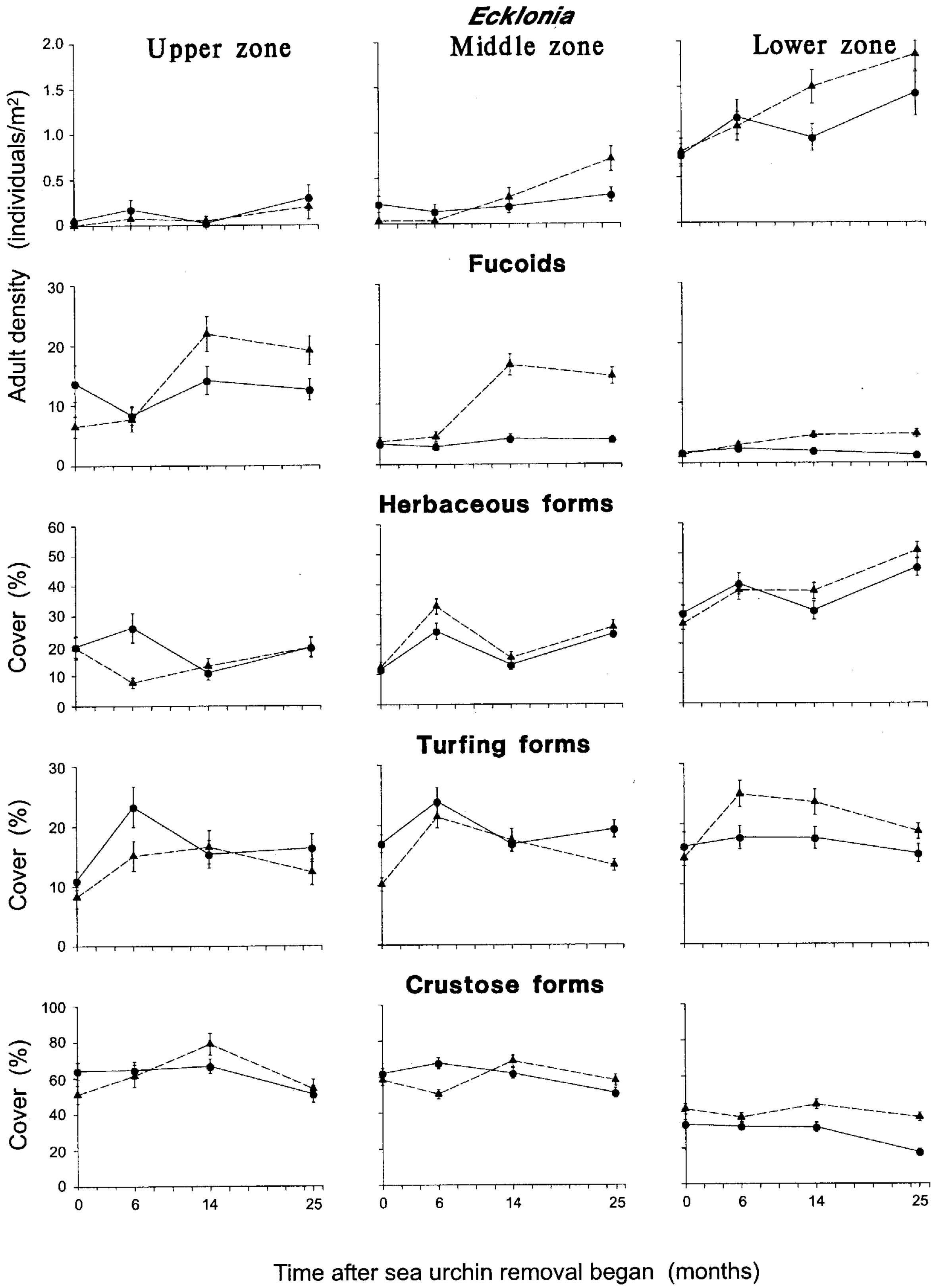


Figure 7. Mean (± SE) adult plant density of *Ecklonia radiata* and other fucoid algal species, and mean percentage cover (± SE) of different algal groups at different times during DOC's urchin removal experiment. Solid line: control sites. Dotted lines: removal sites.

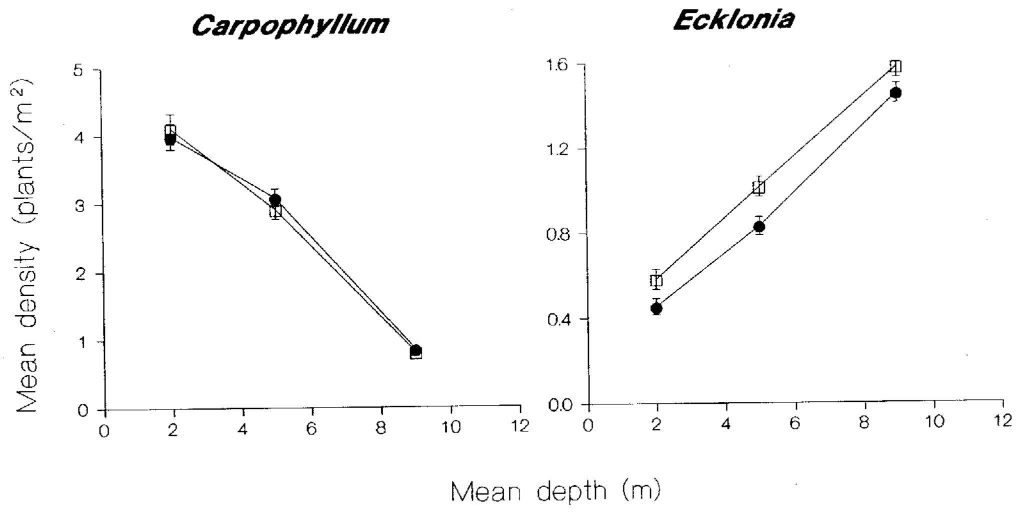


Figure 8. MAF's data set. Mean total density (± SE) of *Ecklonia radiata* and *Carpophyllum* spp by mean depth. For *Ecklonia* squares represent a sub-dataset with sea urchin density < 2 individuals/mz. For *Carpophyllum* spp. squares represent a sub-dataset with sea urchin density < 3 individuals/m2. Dots in both graphs represent densities for both algal species with the whole range of sea urchin density.

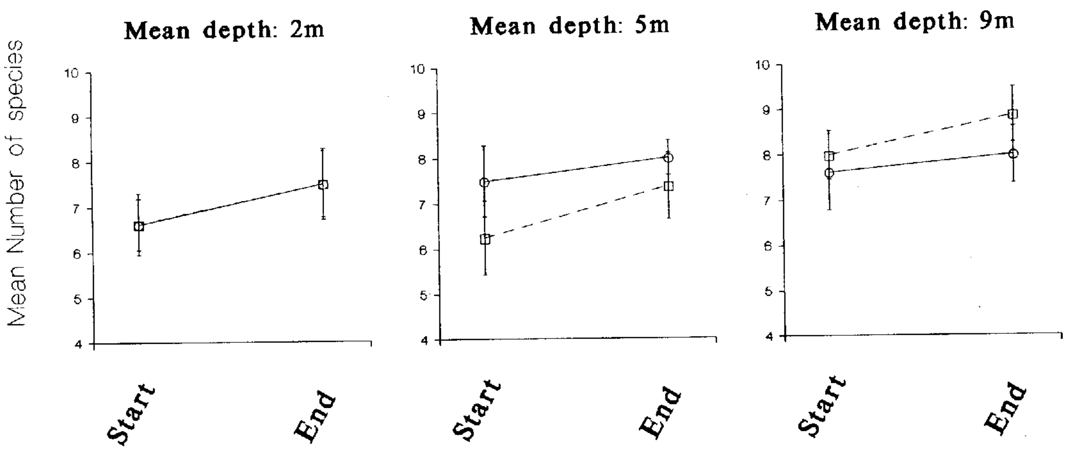


Figure 9. Mean (± SE) number of small sessile physiognomic groups at the start and at the end of DOC's urchin removal experiment, at three depth zones.