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Dragraking Impact on Irish Moss (*Chondrus crispus*) Frond Size Structure

By

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ABSTRACT

Chrondrus crispus Stackhouse has been intensively cropped by dragrakes off western Prince Edward Island for 20 yr. Here we attempt to assess the impact of this harvest on frond class (based on frond dichotomy number) size structure by comparing samples from dragraked and non-dragraked Marine Plant Harvesting Districts (MPHD). Frond size class frequency distribution in the former district was biomodal, with peaks in abundance at Classes 0 (no dichotomies) and 6 (six dichotomies). This distribution was unimodal in the latter district with peaks at about Class 7. The means for frond weight (dry), frond length, and frond size in the harvested and non-harvested beds were respectively 0.14 g, 8.0 cm and 5 and 0.40 g, 11.0 cm and 8. It was concluded that intense to moderate dragraking has altered the frond class structure. Resource management measures, however, must await further analysis.

Résumé

Depuis 20 ans, l'algue rouge *Chondrus crispus* (Stackhouse) a été récoltée de manière intensive par râtelage mécanique sur la côte ouest de l'Île-du-Prince-Édouard. Dans le but d'évaluer l'impact de la récolte sur la structure des classes de tailles de frondes (les classes ont été déterminées par le nombre de ramifications dichotomiques), nous avons comparé des échantillons de deux districts de récolte des plantes marines (DRPM) : un district où la récolte se fait au râteau mécanique et un autre où l'on n'utilise pas le râteau. Dans le premier cas, on a observé une distribution de fréquence des classes de tailles de frondes de type bimodal comportant des pics pour la classe 0 (aucune ramification) et la classe 6 (6 ramifications). La distribution de fréquence, dans les districts où le râteau n'est pas utilisé, était de type unimodal, le pic étant observé dans le cas de la classe 7. Les valeurs moyennes en ce qui concerne le poids sec, la longueur et le nombre de ramifications des frondes étaient de 0,14 g, 8,0 cm et 5 respectivement dans le cas des districts râtelés et de 0,40 g, 11,0 cm et 8 respectivement dans celui des districts non râtelés. Nous en avons conclu que la récolte au râteau mécanique, utilisée de manière modérée à intensive, modifiait la structure des classes de frondes. Toutefois, les décisions en matière de gestion des ressources devront être précédées d'une analyse plus poussée.

INTRODUCTION

Chondrus crispus Stackhouse (Irish moss) has been cropped annually, by dragraking, in Marine Plant Harvesting District (MPHD) 1 (lat. 46°52'47"N; long. 65°14'3"W) since the mid-1950's. The fishery was fully developed by the late 1960's (Pringle and Mathieson 1986) when the mean annual landing was 12 000 t (1966-1971). Between 1972-1979 this yield declined to 8 000 t. During this period annual landings oscillated markedly. Evidence was presented (Pringle 1981) that this interannual variance was due to fluctuations in standing crop.

Resource management methods for this fishery include: limited entry, fishing season, and gear control. The fishery, like most inshore fisheries, is overcapitalized (Pringle 1981). Pringle and Semple (1984) demonstrated that harvest intensity per unit area of bed is high. Pringle (1979) found 25% and 50% of the cropped fronds in 1975 respectively to be attached to holdfasts (holdfasts are important for vegetative reproduction, hence, recruitment) and small in size. The overall mean frond dry weight for the 1979 season was small, suggesting that the stock was growth overharvested (Pringle et al. 1987). The aims of the present study are threefold: first, to describe frond characteristics in commerical dragraked and non-dragraked beds; secondly, to determine if these characteristics are significantly different between these beds; and thirdly, to attempt to discern if these differences are implicated with intense dragraking.

MATERIALS AND METHODS

Irish moss is harvested by dragraking (see Pringle and Mathieson 1986 for resumé of the technique) in MPHD's 1, 2, 8, and 9; the beds are heavily raked, moderately raked, and lightly raked in Districts 1 and 2, 8, and 9 respectively (Fig. 1).

The crop in MPHD's 3 and 4 is gathered as beached "storm toss" only, active dragraking last occurred here about 1971. Fronds were handpicked by SCUBA-equipped personnel from haphazardly chosen 0.25 m^2 quadrats (sample unit) from the inner, middle, and outer regions of the most important commercial bed in each District. The sample units from each bed were pooled and transported on ice to the Miminegash field station. The sample was mixed and preserved by freezing. Prior to sorting, the sample was thawed overnight. Small handfuls of fronds (haphazardly chosen) were removed from the sample. Each frond chosen (the number of fronds assessed per bed is given in Fig. 2) was classified, based on the number of dichotomies (Class 0, no dichotomies; Class 9, nine dichotomies), and its length recorded. Each frond class was segregated, the total were dry weighted using standard procedures, and the average dry weight per frond size class was calculated by dividing the total dry weight by the number of fronds. The samples were collected in 1978 in early June in MPHD 1, and in mid to late June in the remaining districts.

The length data were tested for a normal distribution by using the Kolmogorov-Smirnov goodness-of-fit test (SPSS, Section 7, Hull and Nie 1981). If the data were not normal (i.e. did not have a Z value <1.96, $P\leq0.05$), they were transformed to the log (10). The transformed data with a normal distribution were then tested with the one-way ANOVA and Tukey range test (SPSS, Section 22, Nie et al. 1975).

Relationship between frond weights and size classes were assessed with a simple regression and correlation analysis (SPSS Section 18.4, Nie et al. 1975).

C. crispus frond length increases with dichotomy number to about frond size Class 9 (Pringle et al. 1987). Mean length ranges from 2.0 cm (Class 0) to 10 cm (Class 9). Samplers wore thin, five-finger gloves and removed all fronds ≥Class 1. The samples included only those Class 0 fronds that were easily removed by gloved samplers. This class can be numerous and small, e.g. in MPHD 1; hence, time did not permit their total removal. To estimate sampling error, four 0.25 m^2 quadrats were haphazardly chosen in early June 1978 on sandstone ledge in the middle of the Pleasant View bed (MPHD 1). SCUBA-equipped personnel carefully removed all C. crispus holdfasts, and their respective fronds, with a thin, flexible metal scraper. The areal coverage of each holdfast was measured, and each attached frond size-classified.

RESULTS

Frequency Distribution

The district size class frequencies for the handpicked samples are presented in Figure 2. The moderate to heavily dragraked districts (MPHD's 1 and 8) have a bimodal distribution with peaks at Classes 0 and 5-6 (Fig. 2A, B, and C). There was a difference in frequency of Class 0 fronds between moderately and heavily dragraked beds; these values were 8% and 22% respectively. The real frequencies were likely somewhat higher given the results of the scraped sample from MPHD 1 (Fig. 3). When all Class 0 fronds are included for MPHD 1, the overall frond frequency pattern is unimodal, with Class 0 fronds being the most frequent. The incidence of these fronds in the scraped sample was greater than those in the handpicked by a factor of ~2.5.

The non-dragraked and lightly dragraked districts yielded a unimodal frond size-frequency distribution (Fig. 2D, E, and F); however, the pattern was somewhat different to that of the more heavily dragraked districts. The classes with the most abundant fronds were Classes 6 (MPHD 3), 7 (MPHD 9), and 8 (MPHD 4). Class 0 fronds were rare in District 3 and absent in Districts 4 and 9. Classes 1 and 2 also were absent in District 4. The absence of these frond size classes is surprising. There is little doubt that these classes were on the beds and that they were included in the samples. Their densities may have been so low that they were missed when the sample was subsampled prior to sorting. The method was, however, sufficiently sensitive to detect all frond size classes in MPHD 3, a non-dragraked district.

Frond Characteristics

The district average for each measured frond characteristic reflects these frequency distributions (Fig. 4A-C). Mean frond length was shortest

(~7 cm) in the heavily dragraked district and longer (10-12 cm) in the non-dragraked/lightly dragraked districts (Fig. 4A). The same pattern persisted for both district mean frond dichotomy number and district mean frond dry weight (Fig. 4B, C). Mean frond dichotomy number and mean frond dry weight in the non-dragraked/lightly dragraked districts, were greater by a factor of 2, or more, over the respective values in the moderately/heavily dragraked districts.

The relationship between frond length and dichotomy number was not linear (r values ranged from 0.29 to 0.51) in any of the districts (Fig. 5). Fronds, up to Class 11 from District 9, tended to be the longest, significantly ($P \leq 0.05$) longer than fronds from all other districts (Fig. 6). Districts 1 and 3 fronds, up to Class 12, tended to be the shortest, significantly ($P \leq 0.05$) shorter than fronds from all other districts. Fronds of Class 12 from all districts were of equal length ($P=0.05$).

The relationship between frond dry weight and dichotomy number was linear in all districts (Fig. 7). Fronds, under Class 8, from the higher intensity dragraked districts (1 and 8) were lightest; those from the lightly dragraked district (9) were heaviest. Beyond Class 8, fronds from Districts 1 and 8 were heaviest. Fronds from the non-dragraked districts tended to be of moderate weight per size class.

DISCUSSION

The study was designed to discern the impact of intense *C. crispus* dragraking on frond size class frequencies, frond gross morphological characteristics, and biomass yield. The ideal experimental design would be to vary harvest intensity in an experimental bed, where at least gross environmental factors would be similar. The year this study was undertaken, the bulk of the harvesters had agreed to set aside a bed for experimental purposes (Pringle 1985). Inadequate enforcement permitted uncooperative (<10% of the harvesters) harvesters to ruin experiments begun in 1979. The responsibility for research was transferred to the Gulf Region in 1980 and no further data are available for a discussion of the relationship between dragraking and frond size structures (Pringle et al. 1987).

It is important to determine whether the above observed differences between MPHD's was due to varying environmental factors between the districts or dragraking intensity. Marine plants in general (see Mathieson et al. 1981 for a review), and *C. crispus* in particular (Mathieson and Prince 1973), are thought to have considerable phenotypic plasticity. The definitive experiments have yet to be reported, however, for *C. crispus*. As well, there is good evidence that there are different genetic strains of *C. crispus* within eastern Canada. Chen and Taylor (1980a) described two morphotypes: a narrow, thick form from the southeastern Gulf of St. Lawrence; and a broad, thin form from Bay of Fundy, north. Laboratory experiments (Chen and Taylor 1980b) provided good evidence that these were indeed genecotypes and possibly different biological species (rudimentry crossing experiments failed to show interfertility).

Do these findings have implications on the present study? First, the concept of biological populations has not been formally applied to C. crispus. Little is known about spore dispersal. However, the differences observed here in C. crispus frond morphology from different parts of the southern Gulf of St. Lawrence are not beyond the morphological repetoire expected of a single genotype based on experimental work from other species (Mathieson et al. 1981; Pringle 1975).

Fronds from MPHD 9 were most dissimilar (Fig. 4 to 6) to those from the other districts. These plants are likely only phenecotypes as the ecology of St. George's Bay is somewhat different from that of the remainder of the study area. First, the substrate tends to have considerably more granite and less sandstone, which tends to produce less-turbid water. The shores are more steeply sloped in MPHD 9; hence, the mean water depth over the beds is deeper. Also, C. crispus is an understory species in MPHD 9; it is associated with large (1-2 m in length) Fucus serratus L. plants. C. crispus under these conditions tends to produce larger, less-branched forms (Chen and Taylor 1980a; Mathieson and Prince 1973).

The bulk of the differences observed, between districts, in frond characteristics can be accounted for by the differences in frond size frequency distribution. For example, decreases in mean frond length, mean frond dichotomy number; and mean frond weight (Fig. 4A, B, and C) can all be attributed to an increase in the incidence of smaller fronds (≤7 dichotomies). This incidence occurred in three of the six beds studied; two of the beds were in the heavily dragraked district (MPHD 1); the other bed was in the moderately dragraked district (MPHD 8).

Of interest is that these two districts are not contiguous, but separated by considerable distance (Fig. 1). Thus, there is less likelihood these similarities are due to similar environmental conditions or closely linked genotypes. As well, it has been frequently noted that intense fishing of commercial finfish species reduces the mean size of the stock (Cushing 1981). Consequently, we conclude that moderate to heavy dragraking of C. crispus increases the frequency of the smaller (≤7 dichotomies) frond size classes (~95% of the fronds in the heavily dragraked beds were ≤7 dichotomies, versus ~60% in the non-dragraked districts), thus decreasing the mean frond weight by up to a factor of 3.

What impact has this had on the fishery in MPHD 1? Unfortunately, information on annual catch per unit effort (CPUE) or biomass yield is not available for the mid to late 1960's, the peak harvest period. We do know the crop's mean frond size was small for 1979 (0.149 g), and this was a reasonably good harvest year. The mean frond dichotomy number was 5.5 (see Pringle 1987). Preharvest scraped samples yielded fronds with a mean dichotomy number of 4.6 and a mean dry weight of 0.09 g. If the mean frond size of the biomass could be increased to seven dichotomies, the harvest yield would nearly double to 0.28 g (Fig. 8).

SUMMARY

Background

1. The mean annual yield from the MPHD 1 beds decreased by 33% from the period 1966-1971 to the period 1972-1979. This decrease was due to a decrease in harvestable biomass.

2. The crop removed by a traditional dragrake in MPHD 1 in the mid 1970's consisted of fronds, 25% of which were attached to holdfasts (an important source of recruitment), and 50% of which were classed as harvestably immature.

Current study

3. The frond size class frequency distribution in handpicked samples removed from non-dragraked/lightly dragraked beds was unimodal with the peak at ~Class 7. The average frond weight (dry), the mean frond length, and the average frond size class (dichotomy number) were respectively ~0.40 g, ~11 cm, and ~8.

4. The frond size class frequency distribution in handpicked samples removed, just before season opening, from moderate/heavily dragraked beds was biomodal, with peaks at Classes 0 and 6. The average frond weight (dry), the mean frond length, and the average frond size class were respectively ~0.14 g, ~8 cm, and ~5.

5. MPHD frond lengths differed significantly ($P \leq 0.05$) at specific size classes (3, 5, 7, 9, and 11): fronds from MPHD's 1 (heavily dragraked) and 3 (non-dragraked) were significantly shorter than those from all other districts; fronds from MPHD 9 (lightly dragraked) were usually significantly ($P \leq 0.05$) longer; and there was no significant ($P=0.05$) difference in the length of Class 12 fronds from all MPHD's.

6. The somewhat different morphology of fronds from MPHD 9 (somewhat longer, with fewer dichotomies) could be attributed to a somewhat different habitat (deeper water coverage, less-turbid water, and having a canopy of *Fucus serratus*).

7. There was a direct relationship between frond dry weight and dichotomy number for each MPHD. The relationship varied between MPHD's; however, the difference could not be attributed to the presence of dragrakes.

CONCLUSIONS

1. Twenty years of intense dragraking has not influenced either the weight or length of *C. crispus* fronds within specific size classes.

2. Twenty years of intense dragraking in MPHD 1 has markedly altered frond size class structure by substantially increasing the frequency of smaller (≤7 dichotomies) size-class fronds (particularly Classes 0 and 1) which in turn reduced the mean individual frond biomass by a factor of 3. This has resulted in a small crop mean frond size.

3. Harvest strategy for increasing mean frond size in the crop is not straightforward. The obvious solution of moving the opening dates back to about July 1 to take advantage of peak growing conditions is confounded by the possible loss in production, through canopy shading, of the smaller fronds.

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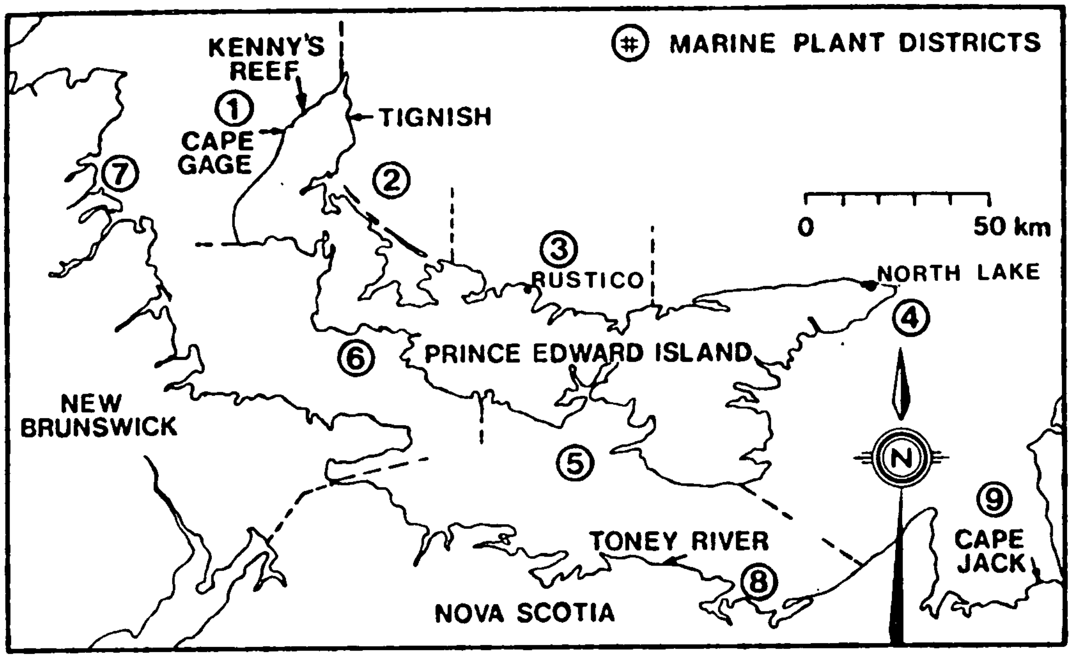

Fig. 1. The location of the study sites within certain Marine Plant Harvesting Districts in the southern Gulf of St. Lawrence.

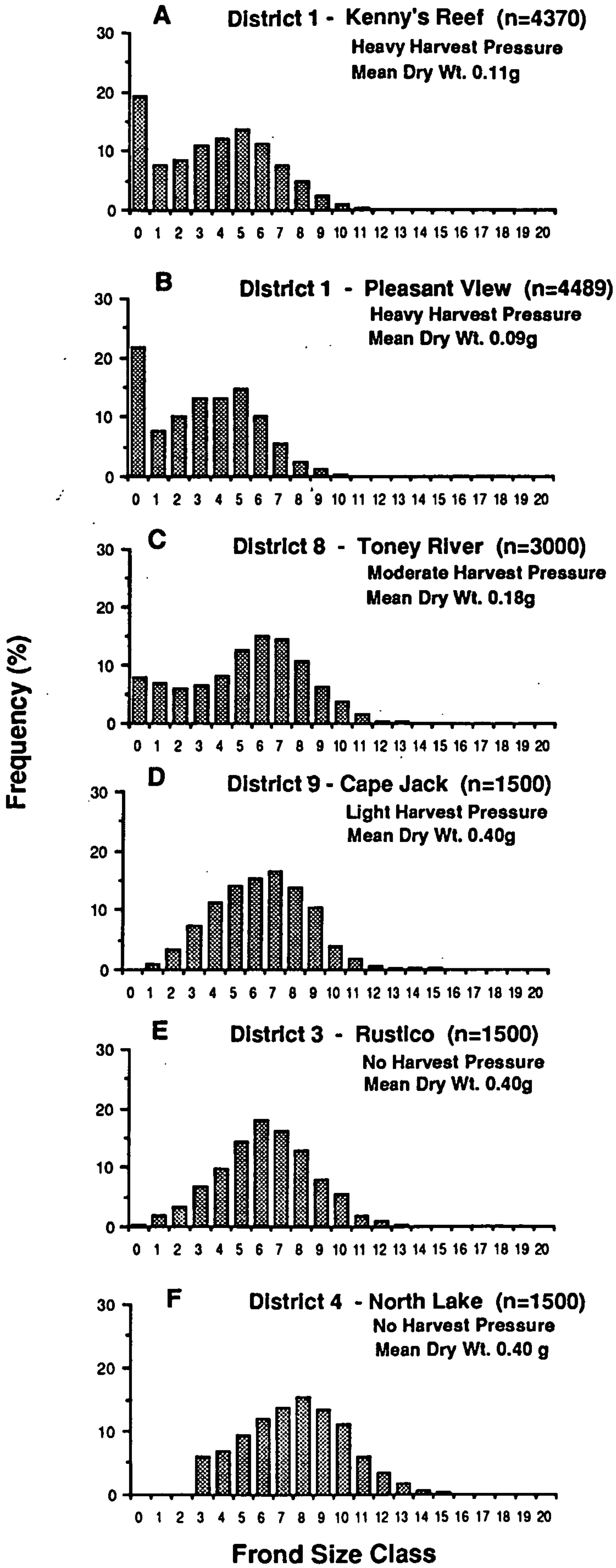

Fig. 2. The frequency of fronds per dichotomy class for each of the six study sites.

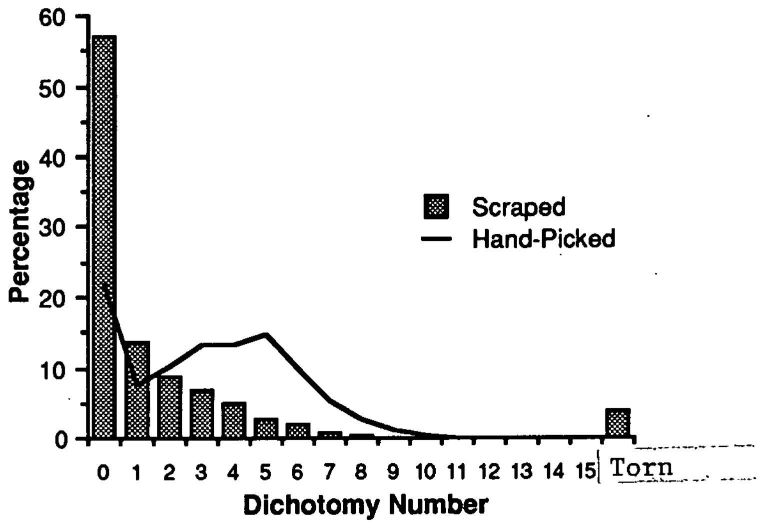

Fig. 3. A comparison of dichotomy class frond frequency in both handpicked and scraped samples from the Pleasant View bed.

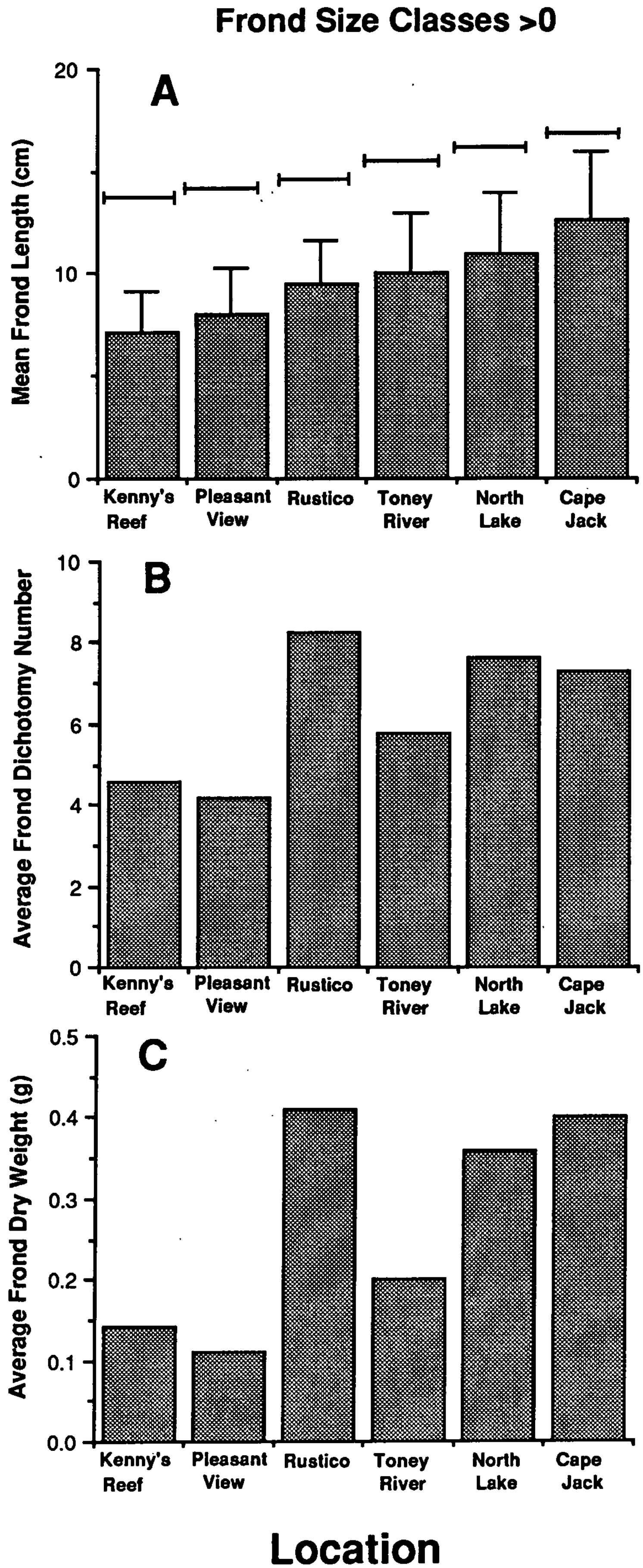

Fig. 4. The mean length, mean dichotomy number, and mean dry weight of fronds ≤Class 1 from each study site. (The data were treated with SPSS [Nie et al. 1975] Program 22.3.3, the vertical lines are standard deviations - those values under a common horizontal line are not significantly different [p=0.05].)

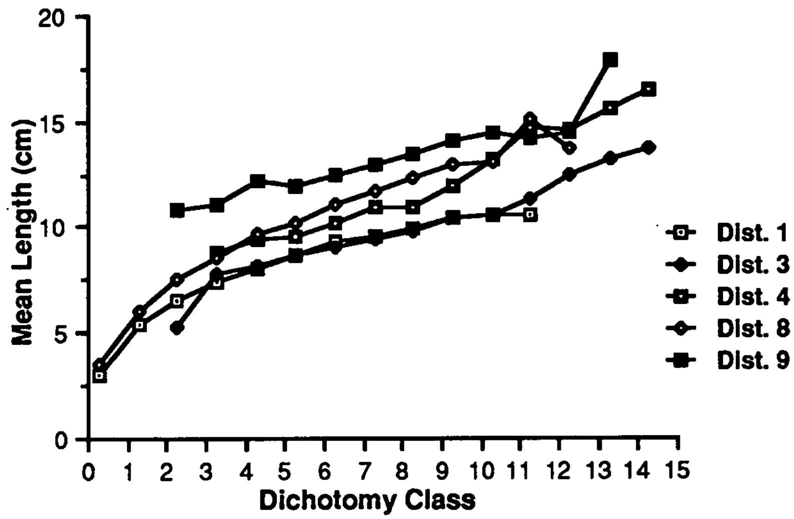

Fig. 5. Comparison of the mean frond length by dichotomy class in each of the study sites.

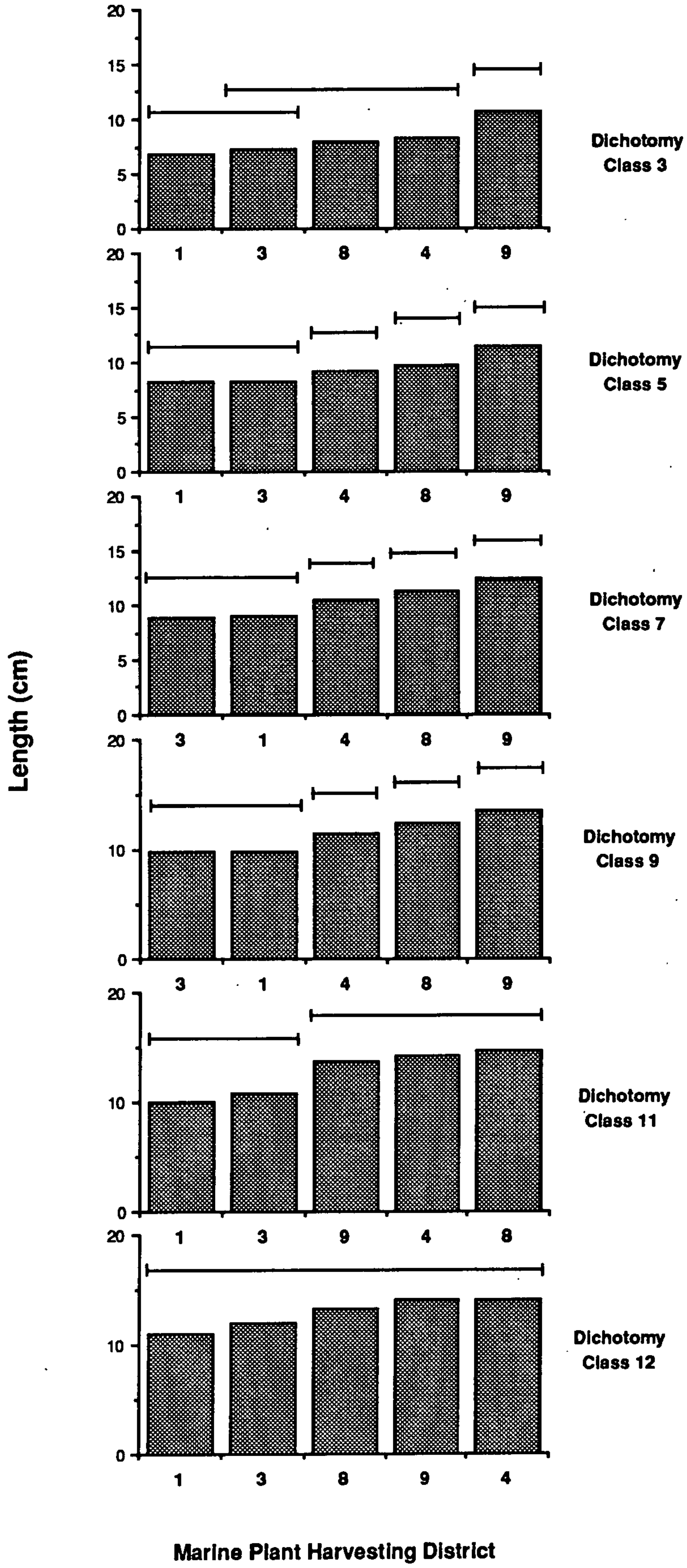

Fig. 6. Comparison of the mean frond length per dichotomy class per study site. The values under a common horizontal line are not significantly different (p=0.05).

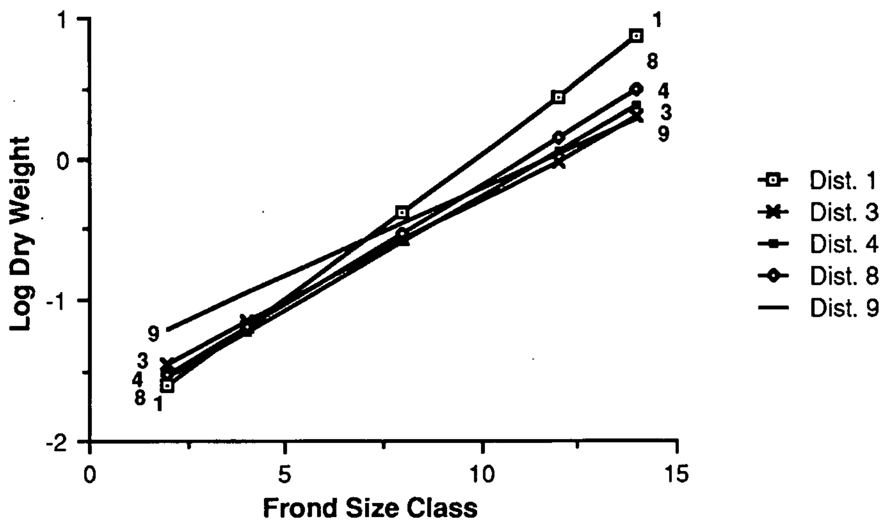

Fig. 7. The relationship between dry weight (log 10) and dichotomy number for all study sites.

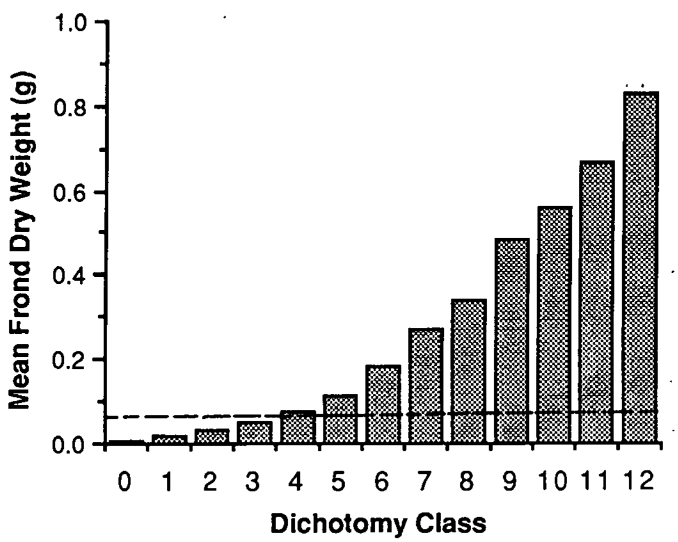

Fig. 8. The relationship between dry weight and dichotomy class. (Samples handpicked from Pleasant View bed, June 1978 [n=4489].)