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Canadian Atlantic Fisheries Scientific Advisory Committee

CAFSAC Research Document 80/72

FISHING POWER AND ECOLOGICAL IMPACT ON GULF CHONDRUS (IRISH MOSS) OF MODIFIED CHONDRUS DRAGRAKES

by

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ABSTRACT

The harvest of the traditional dragrake, employed in the southern Gulf of St. Lawrence to harvest *Chondrus crispus* Stackhouse (Irish moss), consists of between 24% and 35% (by number) fronds with holdfasts attached and between 50% and 66% (by number) prerecruits (immature fronds). It was hypothesized that minor modifications to rake characteristics such as tine extension, tine height off bottom, and tine spacing would have a significant ($P < 0.05$) effect on ecological impact. Trials were carried out with 16 prototypes towed behind both haulers and winchers in Marine Plant Harvesting Districts 1 and 2 (western Prince Edward Island). The winching technique had a significantly higher yield (20.1 ± 9.8 kg h^{-1}) than the hauling technique (12.8 ± 8.0 kg h^{-1}) in both districts; and in District 2, haulers (1133.1 ± 436.0) removed significantly ($P < 0.05$) more immature fronds per 3,000 fronds than winchers (987.4 ± 451.7) and significantly more holdfasts; 1261.0 ± 577.4 and 1105.0 ± 573.6 respectively. There were significantly more immature fronds per 3,000 fronds in the total harvest from District 2 (1043.6 ± 450.7) than from District 1 (880.9 ± 383.6) but no significant difference in the number of fronds attached to holdfasts. The position of individual dragrakes on a wincher influenced fishing power; the middle port position had a significantly lower yield (18.6 ± 6.7 kg h^{-1}) than the outer starboard position (30.9 ± 5.3 kg h^{-1}), but position did not significantly influence ecological impact. Similarly, dragrake position influenced fishing power behind haulers; rake 1 removed 11.2 $\pm$

6.6 kg h^{-1}, whereas rake 3 removed 7.3 ± 4.8 kg h^{-1}. Dragrake 4 removed significantly fewer fronds with holdfasts attached.

The grand mean (a combination of all trials) yield per prototype varied significantly, ranging from 8.3 ± 6.2 kg h^{-1} to 20.4 ± 10.3 kg h^{-1}. Prototypes with narrow (6.5 mm) tine spacings or narrow and elevated (6.5 mm or 11.0 mm) tines had significantly greater fishing success than those with broad (8.0 mm or 11.0 mm) tine spacings or broad and elevated. Significantly fewer immature fronds and fronds attached to holdfasts were observed in the harvest of dragrakes with narrow tine spacings which were either unelevated or elevated. The findings were similar for the number of fronds attached to holdfasts. Dragrakes with longer tines (5 cm longer than traditional tines) employed in District 1 removed significantly fewer fronds attached to holdfasts than traditional dragrakes, but fishing success was significantly reduced. Vertically thicker tines increased ecological impact. Fishing power of flat-riding dragrakes was not significantly higher than the traditional dragrake, nor was adverse ecological impact reduced. Fishing power of dragrakes with narrow (5.0 mm) tine spacings was not significantly higher, nor was the adverse ecological impact significantly reduced.

RÉSUMÉ

La drague à râteau traditionnelle utilisée dans le sud du golfe du Saint-Laurent pour l'exploitation de *Chondrus crispus* Stackhouse (mousse d'Irlande) récolte entre 24 et 35% de frondes immatures. Nous avons cru que le fait de modifier quelque peu les caractéristiques du râteau, dents plus longues, plus hautes au-dessus du fond et différemment espacées, aurait un impact écologique significatif ($P < 0,05$). Nous avons donc mené des essais avec 16 prototypes traînés par bateaux utilisant des monte-trappe et d'autres utilisant des treuils dans les districts 1 et 2 de récolte de plantes marines (ouest de l'Île-du-Prince-Édouard). La méthode du treuil est nettement plus productive (20,1 ± 9,8 kg h^{-1}) que celle des monte-trappe (12,8 ± 8,0 kg h^{-1}) dans les deux districts; dans le district 2, les monte-trappe prélèvent des quantités significativement ($P < 0,05$) plus grandes (1 133,1 ± 436,0) de frondes immatures par 3 000 frondes que les treuils (987,4 ± 451,7) et nettement plus de crampons : 1 261,0 ± 577,4 et 1 105,0 ± 573,6 respectivement. La récolte totale du district 2 contient plus de frondes immatures par 3 000 frondes (1 043,6 ± 450,7) que celle du district 1, mais le nombre des frondes fixées à des crampons ne diffère pas de façon appréciable. La position des dragues à râteau sur un bateau utilisant un treuil influe sur le potentiel de capture; la position à babord centre est

nettement moins productive (18,6 ± 6,7 kg h^{-1}) que celle hors tribord (30,9 ± 5,3 kg h^{-1}). Par contre, la position n'influe pas beaucoup sur l'impact écologique. De même, la position de la drague influence le potentiel de capture des utilisateurs du monte-trappe; la drague 1 prélève 11,2 ± 6,6 kg h^{-1}, alors que la drague 3 prélève 7,3 ± 4,8 kg h^{-1}. La drague 4 remonte nettement moins de frondes fixées à des crampons.

Le taux de capture moyen général (tous les essais combinés) par prototype varie de façon significative, de 8,3 ± 6,2 kg h^{-1} à 20,4 ± 10,3 kg h^{-1}. Les prototypes à dents rapprochées (6,5 mm) ou à dents rapprochées et surélevées (6,5 mm ou 11,0 mm) ont une production nettement plus forte que ceux à dents plus espacées (8,00 mm ou 11,0 mm) ou à dents espacées et surélevées. Nettement moins de frondes immatures et de frondes fixées à des crampons ont été observées dans la récolte des dragues à râteau avec dents rapprochées, surélevées ou non. Les observations sont les mêmes quant au nombre de frondes fixées à des crampons. Les dragues avec longues dents (15 cm de plus que les dents traditionnelles) employées dans le district 1 prélèvent moins de frondes fixées aux crampons que les dragues traditionnelles, mais le potentiel de capture est significativement moindre. Des dents verticalement plus épaisses accentuent l'impact écologique. Le potentiel de capture de dragues à râteau râtelant à plat n'est pas appréciablement plus élevé que celui de la drague traditionnelle, et l'impact écologique n'est pas diminué. Le potentiel de capture de dragues à dents rapprochées (5,0 mm) n'est pas appréciablement plus élevé, et l'impact écologique adverse n'est pas non plus réduit pour la peine.

INTRODUCTION

The mean annual harvest of Chondrus crispus Stackhouse for the past 14 years (1967 to 1979) in the Maritimes is approximately 35 000 MT (wet). The bulk of this is cropped by various raking methods. It has been pointed out (MacFarlane, 1956 and Taylor et al., 1975) that the Chondrus holdfast is perennial and a source of recruitment; thus, it should not be removed during harvesting operations (Figure 1).

Chondrus has been harvested by dragrakes towed behind inshore fishing boats (for details, see Scarratt, 1972 and Pringle, 1979) since the early 60's. Pringle (1979), during 1975 and 1976, assessed the ecological impact on Chondrus beds of traditional harvesting techniques. Observers went aboard Chondrus harvesting boats throughout the season. It was shown that between 24% and 35% (depending on the harvest method) of the fronds removed were attached to holdfasts and between 50% and 66% of the fronds were suboptimal in size (for harvesting). One technique, the basket-dragrake, was shown to have a greater adverse ecological impact on both lobsters and Chondrus than the dragrake and was banned from use (Pringle et al., 1979).

Chondrus dragrake shape and size evolved over the years. The original Chondrus dragrake was merely a handrake head tied with rope to the stern of a boat. Harvesters then manufactured bigger dragrakes from car frames; teeth were cut in the frame with hacksaws. The present dragrake evolved from the latter (Figure 2) and is manufactured by the buyers. The rake tines were originally placed on top of the bar, but in about 1972 the harvesters of Marine Plant Harvesting Districts 1 and 2 found fishing success (CPUE-Ricker, 1975) increased when placed below. As far as is known, that is the only design change that has taken place since this dragrake was first manufactured.

Various attempts have been made to develop mechanized harvesters that have a greater fishing success with a reduced ecological impact than the traditional dragrake, but these have failed (Anonymous, 1974; Nicholson, 1971; Pringle and Semple, 1976).

When the large number of holdfasts and immature fronds (prerecruits) were originally observed in the harvest of dragrakes off both Districts 1 and 2 (Pringle, 1979), it was decided to determine if minor modifications to the dragrake would lessen the ecological impact on Chondrus populations. A study was initiated in 1978 to test the hypothesis that minor modifications to the traditional dragrake would have significant effects on both ecological impact and fishing success. Presented below are data from studies carried out during 1978 and 1979.

METHODS AND MATERIALS

The concept of modifying the traditional dragrake in minor ways to lessen its ecological impact was presented by the first author to the Gulf Marine Plants Advisory Committee in 1978; it was accepted as a potential study. A subcommittee was struck, consisting of Mr. Terry Ball[1] (Chairman), Captain Jamie Ellsworth[2], and the authors. It was decided that three basic modifications would be assessed: tine spacing, height of tines off the ocean bottom (hereafter referred to as tine elevation), and length of tines. Eleven prototypes plus the traditional design were employed during the 1978 *Chondrus* harvesting season (Table 1). The 13 m long, 4 m beam "Centennial Pride" (Figure 3), owned and operated by Captain Leo Gallant, was chartered out of Miminegash, Prince Edward Island. It was powered by 100 hp gasoline engine. The boat was rigged with steel booms and winches employed in the wincher method and a lobster trap hauler used in the hauler method for attaching the single dragrakes to the boat (Pringle et al., 1979).

The dragrakes are hooked in triplicate on each side of a boat rigged for winching; each attached to a common tow bar in front but unattached laterally (Figures 2 and 4). This permits independent upward and downward movement of each rake. Cable runs from the tow bar to a winch secured to the mid deck of the boat. During the harvesting operation, the boat moves continuously with one set of dragrakes cropping, while the other is being cleaned (Figure 2).

The arrangement of dragrakes (in this study dragrake, rake and prototype are synonymous) behind a hauler is shown in Figure 4. Each dragrake is attached to the boat with rope, independent of the other rakes. The boat pulls all dragrakes over the bottom simultaneously, stopping to permit retrieval of dragrakes and removal of crop.

There are six distinct positions each dragrake could be placed (Figure 4) in relation to the other dragrakes, when the wincher method is employed; with the hauler method there are as many positions as rakes employed. Four prototypes per hour were used in this study. The effect of rake position on both fishing success and ecological impact were unknown, thus to avoid bias, each prototype was assessed in each position behind wincher and hauler (Tables 2-5). Dragrake X (traditional) was assessed five times in each position on winchers and haulers; prototypes A to H were assessed three times in each position; prototypes I, J, and K were employed twice in each position. Each trial took one hour.

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[2]Captain Jamie Ellsworth, *Chondrus* harvester, Miminegash, P.E.I.

The study began on Tignish beds (Figure 5), June 29 and moved August 8 to various Miminegash beds. The trials took place on those beds where the bulk of the fleet were operating (Figure 5). It ended October 5.

The harvest from each hourly trial was placed into garbage bags and at the end of the day weighed on spring scales (Toledo, Ottawa, Canada) at the Marine Plants Field Station, Miminegash. The yield per prototype was then emptied and 2000 g/45 kg of harvest were haphazardly removed; this was one sample unit. Each immature and mature frond and the number of fronds attached to holdfasts per sample unit were enumerated. The data were placed on computer tape and analyzed with various SPSS packaged programs (Nie et al., 1975). All data per dragrake type per harvesting method per district were pooled. The mean number of immature fronds per 3,000 fronds, mean number of fronds attached to holdfasts per 3,000 fronds, and mean yield per hour of harvesting were determined along with standard deviations and standard error of the means. Duncan's New Multiple Range Test (Nie et al., 1975) was used to determine if differences between means were significant ($P < 0.05$).

The results of this study were assessed and it was decided in 1979 to test five different prototypes; the dimensions are shown in Table 6 and their deployment schedule in Table 7. Each prototype and the traditional dragrake were assessed 16 times in each starboard position and eight times in each port position for a total of 72 trials per rake type. The wincher method only was employed.

It was noted that heavily used dragrakes had most wear on the curved portion of the runner. This was a result of the dragrake riding flat over the ocean bottom at an angle of approximately 11°. It was hypothesized that a flat-riding rake may remove fewer holdfasts. Experiments were carried out with different systems of maintaining a flat-riding dragrake. The method adopted employed the mounting of a foil on the dragrake back, above the tines. The foil was employed on all prototypes plus the traditional dragrake.

The study was carried out in District 1 only on a 300 hp wincher, the 13 m x 4 m "Sherry M.G.", owned and operated by Captain Stevie Gallant of Miminegash. The general location of the beds raked are shown in Figure 5. The study began October 2 and finished November 1. Sample unit size and their analysis were as in 1978.

RESULTS

1978 STUDY

Winchers

The mean yield (catch by weight - Ricker, 1975) (Figure 6) for the prototypes towed with a wincher off Miminegash ranged between 5.9 $\pm$ 2.3 kg h^{-1} (rake E) and 22.1 $\pm$ 9.4 kg h^{-1} (rake X); differences were significant ($P \leq 0.05$). The rakes with the greatest fishing power (the relative vulnerability of the stock to different boats or gear - see Ricker, 1975) had the narrowest tine spacing (6.5 mm), but yield was independent of tine height off the bottom (e.g., C and F) unless combined with broad tine spacings (e.g., B, D, E, and G) which reduced fishing success significantly. Similarly, tines on the bottom, but with broad spacing, had significantly less yield (compare B and X). The number of immature fronds per 3,000 fronds ranged between 623.4 $\pm$ 260.2 (rake C) and 1,114.0 $\pm$ 331.8 (rake B); differences were significant (Figure 7A). The number of fronds attached to holdfasts (Figure 7B) per 3,000 fronds ranged between 631.1 $\pm$ 304.9 (rake I) and 1,691.8 $\pm$ 498.3 (rake B). The rakes with a significantly lower ecological impact were those with the narrowest tine spacing (X, C, F, I, J, K); height off the bottom did not have a significant effect when tines were narrow. However, those rakes with broad tine spacings (rake B) or with both broad tine spacings and elevated tines (rakes E and H) had a significantly greater ecological impact. Those rakes that had long tines on the bottom (rakes J and K) did not have a significantly reduced ecological impact over the traditional rake (rake X).

The mean yield (Figure 8) for each prototype towed with a wincher off Tignish ranged between 12.3 $\pm$ 6.2 kg h^{-1} (rake E) and 25.8 $\pm$ 11.2 kg h^{-1} (rake X); a significant difference The basic pattern of fishing power per rake type was similar to that observed in District 1 for winchers, with the exception that rakes with elevated, broad-spaced tines had higher fishing success (rakes G and H). Conversely, the rakes with longer tines (rakes I and K) had less fishing success. The number of immature fronds per 3,000 fronds (Figure 9A) ranged between 863.2 $\pm$ 360.0 (rake C) and 1,275 $\pm$ 426.1 (rake H); these were the only two significantly different means. The number of fronds attached to holdfasts per 3,000 fronds (Figure 9B) ranged between 847.1 $\pm$ 474.9 (rake K) and 1,502.5 $\pm$ 574.5 (rake H); these were the only two means that were significantly different.

Haulers

The mean yield (Figure 10) for the prototypes towed with a hauler off Miminegash ranged between 3.9 $\pm$ 1.5 kg h^{-1} (rake B) and 14.5 $\pm$ 4.6 kg h^{-1} (rake C) - a significant difference. The rakes with the broadest tine spacings (rake B) or broad tine spacings and elevated tines (rakes E, G, H) had the lowest fishing success. The number of immature fronds per 3,000 fronds ranged between 511.8 $\pm$ 253.9 (rake K) and 1,297.0 $\pm$ 414.0 (rake B); a significant difference (Figure 11). The rakes with the narrowest tine spacing (rakes C, F, J, K, and X) but with long tines (rakes J and K) or elevated tines (rakes C and F) removed fewest immature fronds. The number of fronds attached to holdfasts per 3,000 fronds ranged between 367.1 $\pm$ 282.5 (rake K) and 1,824.4 $\pm$ 569.0 (rake B); a significant difference (Figure 11B). The pattern in holdfast removal per rake type was similar to that of immature plant removal.

The mean yield (Figure 12) for the prototypes towed with a hauler off Tignish ranged between 8.8 $\pm$ 9.3 kg h^{-1} (rake E) and 18.1 $\pm$ 8.4 kg h^{-1} (rake X). This was the only significant difference in fishing success. The number of immature fronds per 3,000 fronds ranged between 1,012.9 $\pm$ 426.2 (rake D) and 1,417.1 $\pm$ 583.9 (rake E); the differences were not significant (Figure 13A). The number of fronds attached to holdfasts per 3,000 fronds ranged between 1,056.6 $\pm$ 535.7 (rake K) and 1,785.9 $\pm$ 775.5 (rake E); this was the only significant difference (Figure 13B). The K rake was unelevated and had longer tines and narrower tine spacings than the E rake.

District 1

The data for each prototype per wincher and hauler assessed off Miminegash were pooled (Figures 14 and 15A, B). Mean yield ranged between 5.5 $\pm$ 2.8 kg h^{-1} (rake E) and 18.2 $\pm$ 9.5 kg h^{-1} (rake X); certain differences were significant. Fishing success was significantly higher for those prototypes with the narrowest tine spacings (rakes C, F, I, and X) or with narrow tine spacings and long tines (rakes I and K). Those with broad tine spacings (rake B) or with broad tine spacings and elevated tines had reduced fishing power. The mean number of immature fronds per 3,000 fronds ranged between 599.4 $\pm$ 237.6 (rake K) and 1,195.0 $\pm$ 360.8 (rake B); significant differences were observed (Figure 15A). The rakes with the narrowest tine spacings and elevated tines (rakes C and F) and narrow tine spacings with long tines (rakes K and J) removed significantly fewer immature fronds than those with broad tine spacings (rakes A and B) or broad tine spacings and elevated tines (rakes E and H). A similar pattern was observed in the number of fronds attached to holdfasts per 3,000 fronds (Figure 15B).

District 2

The data for each prototype per wincher and hauler assessed off Tignish were pooled (Figures 16 and 17A, B). Mean yield ranged between 11.2 $\pm$ 7.4 kg h^{-1} (rake E) and

22.5 ± 10.7 kg h^{-1} (rake X); certain differences were significant. The pattern per prototype was similar to that for the same techniques off District 1 except that rakes A and G had a greater fishing power than rakes J and K, longer tines reduced fishing success. The mean number of immature fronds per 3,000 fronds ranged between 954.2 ± 382.0 (rake F) and 1,237.3 ± 489.2 (rake H); the differences were not significant. The mean number of fronds attached to holdfasts per 3,000 fronds ranged between 956.1 ± 508.2 (rake K) and 1,483.8 ± 663.6 (rake H). The rake with narrow tine spacings (rake X), the rakes with narrow tine spacings and elevated tines (rakes F and C), or those with narrow tine spacings and long tines (rake K) removed significantly fewer holdfasts than those with broad tine spacings and elevated tines (rakes E and H).

Winchers and haulers - Districts 1 and 2

All the data were pooled (Figures 18 and 19A, B). The grand mean yield for each prototype ranged between 8.3 ± 6.2 kg h^{-1} (rake E) and 20.4 ± 10.3 kg h^{-1} (rake X); certain differences were significant. Those rakes with the narrowest tine spacings (rake X) or with narrowest tine spacings and elevated tines (rakes C and F) had significantly higher fishing success than all other prototypes. The prototype with the greatest adverse ecological impact and lowest mean hourly yield had broad tine spacings (11.0 mm), which were elevated 6.5 mm off the bottom (rake E). There was little significant difference in fishing power between the rest of the prototypes.

The grand mean number of immature fronds (Figures 19A,B) removed per 3,000 fronds ranged between 787.2 ± 380.2 (rake C) and 1,135.8 ± 449.8 (rake H); certain differences were significant (Figures 19A,B). Those prototypes with lesser ecological impact had narrow tine spacings (rakes C, F, J, K, and X) which were either elevated (rakes C and F) or longer than traditional tines (rakes J and K).

Dragrake position - wincher

The data for the traditional dragrake (rake X) behind winchers in both Districts 1 and 2 were pooled (Figures 20A, B, C). The production ranged between 18.6 ± 6.7 kg h^{-1} (middle port side) and 30.9 ± 5.3 kg h^{-1} (outer starboard side); the difference was significant. However, there was no significant difference in ecological impact between the various positions.

Dragrake position - hauler

The fishing success of all prototypes tested off Miminegash plus the traditional dragrake were pooled (Figure 21) for each position behind a hauler. The grand mean yield per position ranged between 7.3 $\pm$ 4.8 kg h^{-1} and 11.2 $\pm$ 6.6 kg h^{-1}. Dragrakes in position 1 showed significantly higher fishing power than in positions 2 and 3. There was no significant difference in number of immature fronds removed (Figure 22A), but dragrakes in position 4 removed significantly fewer holdfasts than dragrakes in other positions (Figure 22B).

1979 STUDY

The mean yield for each of the five prototypes plus the traditional dragrake without foils ranged between 4.3 $\pm$ 2.9 kg h^{-1} (rake C) and 22.3 $\pm$ 9.0 kg h^{-1} (rake D) (Figure 23). The mean yield for each of the rakes tested with foils ranged between 5.3 $\pm$ 5.0 kg h^{-1} (rake B) and 18.0 $\pm$ 7.7 kg h^{-1} significant differences were observed (Figure 23). There was no significant difference either in fishing power or ecological impact (Figures 24 and 25) between the prototypes with and without foils; consequently, the data were pooled to obtain a larger sample size (Figure 26). There was no significant difference in fishing power between the traditional dragrake (A) and the two prototypes D and E. The fishing success of F was significantly less than A; F differed in design from the latter in having tines thicker on the vertical by 6.25 mm. The two prototypes (B and C) with longer, vertically-thicker and horizontally-thinner tines than the traditional dragrake gave significantly lower yields (Figure 26).

The mean number of immature fronds per 3,000 fronds per prototype with and without foils did not vary significantly (Figure 24); consequently, the data were pooled for each prototype (Figure 27). The mean number of immature fronds per 3,000 fronds ranged between 248.4 $\pm$ 228.0 (rake C) and 387.9 $\pm$ 234.9 (rake E); differences between means were significant. The prototypes that removed the lowest number of immature fronds were C and D; C differed from the traditional rake in a number of features (Table 6) and D in one only - narrower tines. Prototypes with thicker tines (F), longer tines (B), or elevated tines removed significantly more immature fronds.

The mean number of fronds with holdfasts per 3,000 fronds per prototype with and without a foil did not vary significantly (Figure 25); consequently, the data for each prototype with and without foils were pooled. The mean number of fronds with holdfasts per rake ranged between 272.5 $\pm$ 178.2 (rake D) and 530.6 $\pm$ 327.6 (rake E); significant differences in means were observed (Figure 28). The prototypes with the narrowest tine spacings (D) or the longest tines (C) had fewest fronds with holdfasts attached, but they were not significantly lower than the traditional dragrake (A). Increased tine height off the bottom by 25 mm (rake E) caused a significant increase in the number of fronds attached to holdfasts as did vertically-thickened and horizontally-narrower tines (rake F).

DISCUSSION

It can be seen from this study that the location of harvesting within the Gulf of St. Lawrence (between Districts 1 and 2), the method of harvesting, the position of each dragrake, and the type of dragrake can have significant effects on both fishing success and ecological impact. Although in the southern Gulf of St. Lawrence there are seven districts where dragraking for *Chondrus* takes place, trials were carried out in Districts 1 and 2 only, as approximately 75% of the dragraked harvest comes from these districts. The grand mean yield in District 1 (the fishing success per prototype was pooled for all trials) was 12.8 ± 8.0 kg h^{-1}, significantly lower than in District 2 (17.3 ± 9.8 kg h^{-1}) (Figure 29). This was likely due to the trials between districts. The trials were initiated well into the season in District 1; in District 2 the study began on opening day. The removal of fronds with holdfasts attached was not significantly greater in District 2 (Figure 29), however, the removal of immature fronds was significantly greater by a factor of 1.2. This is in spite of the trials taking place in the middle and end of the season in District 1 and in the early portion of District 2's season. The rougher, more boulder-strewn bottom of District 2 may permit the dragrakes greater access to smaller plants.

When the data for all prototypes plus the traditional dragrake per harvesting method per district were pooled (Figures 30A, B, C), the winchers had greater fishing power than haulers. This is probably related to the wincher's ability to crop continuously, whereas the haulers must stop cropping when cleaning the harvest from the dragrakes.

It has been the belief of many in the industry that winchers would have a greater adverse ecological impact than haulers because of the larger heavier rakes and faster towing speeds. It appears this is incorrect; and the converse may be the case in District 2. The number of immature fronds and fronds attached to holdfasts between the harvest of haulers and winchers was not significantly different in District 1 (Figures 30A, B); in District 2 haulers removed significantly more of both. The path of hauler dragrakes in positions 2-4 (Figure 24) tend to overlap the track of the preceding dragrake. This may permit a closer cropping of the plants and hence the removal of more immature fronds. However, no significant difference in the number of immature fronds was observed between the dragrake positions of haulers (Figure 22).

The study has shown that the hypothesis to be tested was correct; that minor modifications to dragrake design can cause significant differences in both fishing success and ecological impact. Of all the modifications made to dragrakes in this study, it appears tine spacing has the most influence. Dragrakes with the narrowest tine spacings (J, C, F, and X) had significantly greater fishing power than those with broad tine spacings (E, B, and H) (Figure 18). This may be due to the fronds being more tightly bound between the tines and other fronds, which would cause a higher removal rate for fronds in contact with the inter-tine space. Also, once the frond was cropped, because it may be more tightly bound than in a dragrake with wider tine spacings, there would be less chance of it being lost. It was hypothesized prior to the study that prototypes with elevated tines would have a reduced fishing power; this was not always the case (Figure 18). The prototypes with both narrow tine spacings and elevated tines (C and F) did not have a significantly reduced fishing power over the traditional dragrake (X). The prototype with the lowest fishing success was E, which had both wide tine spacings (11.0 mm) and elevated tines (6.5 mm). Surprisingly, its fishing success was significantly less than H which had the same tine spacing but with greater tine elevation (12.5 mm).

It was also hypothesized that both fishing success and adverse ecological impact would be significantly reduced with dragrakes with wide tine spacings. The reason for testing them was that the over the long term prerecruit density might be increased. These hypotheses are rejected.

To determine which variable, tine spacing or tine elevation, caused greater ecological impact, the data for each characteristic were pooled and the results are shown in Figures 31 and 32. There was no significant difference in either fishing power or number of fronds attached to holdfasts in the harvest if tine elevation were increased but tine spacing remained narrow (6.5 mm) (Figures 31A, C). However, if tine elevation remains constant but tine spacing is allowed to vary, then significant differences in both fishing power and ecological impact occur (Figures 32A-I). For example, if the tines are not elevated but tine spacing is increased by 4.5 mm, fishing power decreases significantly (Figure 32A) and adverse ecological impact increases (Figure 32C). The difference is even more marked when tines are elevated by 6.5 mm, a 1.5 mm increase in tine spacing caused a significant decrease in fishing power (Figure 32D) and a significantly greater number of fronds attached to holdfasts (Figure 32F). Similar observations were made when tine elevation was 12.5 mm (Figures 32G-I).

Although tine spacing appeared to be the most important variable, tine elevation did have significant effect on ecological impact (Figure 31B). Prototype C (6.5 mm tine spacing; 6.5 mm tine elevation) cropped significantly fewer immature fronds than the traditional dragrake (rake X). This was not due to an increase in holdfast removal by the latter (Figure 31C). The reasons for this effect are not clear, particularly when the prototype with tines elevated 12.5 mm did not have significantly fewer immature fronds than the traditional dragrake. It should be noted, however, that there appears to be a critical height in tine elevation somewhere between 12.5 mm and 25.0 mm; dragrakes with tines spaced 6.5 mm apart but raised to the latter level had a significantly greater adverse impact than the traditional dragrake (Figures 27 and 28).

The study carried out in 1979 was an extension of the 1978 study. Because narrow tine spacings (6.5 mm) increased fishing success and were less deleterious ecologically, a prototype with 5.0 mm tine spacings was tested, as was one with a higher tine elevation (25.0 mm). Prototypes with longer, vertically thicker and horizontally thinner tines were tested, as the K prototype (longer tines) removed significantly fewer holdfasts than did the traditional dragrake (Figure 19B); but its fishing power was significantly reduced as well (Figure 18) particularly in District 2 (Figure 12). The second author felt the reduced fishing power was due to the "down time" required to straighten bent tines (it is likely this was a greater problem off District 2 than District 1 due to the greater density of boulders in the *Chondrus* beds [Pringle, unpublished data]).

The most promising prototype tested was that with tine spacings 1.5 mm narrower (rake D - Figures 23 to 25) than the traditional dragrake. It consistently had the highest mean fishing success and the lowest mean number of immature fronds and fronds attached to holdfasts in the harvest; the means were not significantly different from the traditional dragrake; however, it was originally hypothesized that dragrakes with narrow tine spacings would have a higher fishing power but that they would remove significantly more immature fronds. The latter part of the hypothesis is rejected. The reduced holdfast number in the harvest, less than the traditional dragrake by a factor of 0.3, is promising and its use should be encouraged. Further study with prototypes with narrow spaced tines is recommended.

It is obvious the authors do not completely understand the mechanism by which dragrakes crop *Chondrus* plants, given the rejection of many of the above hypotheses. Dragrakes with broader tine spacings (Figure 32C) may remove more holdfasts than those with narrower tine spacings because the tines are catching more fronds per holdfast and thus exerting more pressure on the holdfast. A dragrake with narrower tines would catch fewer fronds per holdfast, thus exerting less pressure on the holdfast.

It was originally hypothesized, following the 1978 study, that the rocking action of the dragrakes caused excess pressure to be exerted on the holdfast and assisted in their removal. This was shown to be false, given the results of those prototypes tested with the foil which kept the dragrake flatter on the ocean bottom.

Although minor modifications to the traditional dragrake can have significant effects on both fishing success, harvest yield and ecological impact, there was only one prototype (rake C - 1978 study) that had combined both the fishing power of the traditional rake and a significantly reduced ecological impact (Figures 15A and 31B). The introduction of this rake to the fishery should take place. Studies with rakes with narrow (5 mm - rake D, 1979) tine spacings should continue.

The prospect of developing a dragrake that will have important consequences in maximum sustained yield seem unlikely. Thus, it is recommended that attempts be made to develop a MSY harvesting model that takes into consideration this loss in both harvest yield and a portion of the holdfast standing crop (a source of recruitment).

SUMMARY

Chondrus (Irish moss) is a benthic macroalga consisting of a concentric, basal disk (holdfast) which increases in diameter on an annual basis and supports upright fronds (up to 100 or more) which, when harvestably mature, are approximately 12 cm in height and extensively branched. Generally, only a few of the fronds on a single plant are harvestably mature. Harvesting of *Chondrus* with dragrakes is conducted throughout nearshore southern Gulf of St. Lawrence waters by approximately 400 inshore boats. The typical dragrake has 40 tines, 20 cm long, with cross-sectional dimensions of 12.5 mm x 12.5 mm and a distance between the tines of 6.5 mm. Two basic methods of harvesting are employed. The "wincher" method uses winches, steel booms, and cable and the dragrakes are rigged in triplicate. The "hauler" method uses the lobster trap hauler and single rakes, rigged with rope. Approximately 20 000 MT of *Chondrus* *in toto* are harvested annually with these techniques. Studies carried out in 1975/76 showed that up to 60% of the harvest by number consisted of immature fronds, and 25% to 35% of the fronds by number were attached to holdfasts. It was hypothesized that minor modifications to the dragrake such as modified tine spacings, elevated tines, and length and thickness of tines might reduce adverse ecological impact while improving fishing success.

It was shown that minor modifications to the Chondrus dragrake can significantly effect both fishing power and ecological impact. Broader tine spacings and vertically thicker tines reduced harvesting efficiency significantly ($P < 0.05$) and significantly increased the adverse ecological impact. Increased tine elevation did not significantly decrease harvesting efficiency; but off District 1, there was a significant increase in harvest yield with a prototye with 6.5 mm tine elevation. Two prototypes with tines 25 cm in length were tested, one (J) with cross-sectional dimensions of 12.7 mm x 12.7 mm, the other (K) 12.7 mm (horizontal) x 9.5 mm (vertical). The difference in fishing power between them in District 1 was not significant; however, harvest yield significantly increased compared with the traditional dragrake. As well, both K and J removed significantly fewer fronds with holdfasts attached.

During 1979, five prototypes were constructed and tested, based on the above results. They were assessed with and without foils; the latter reduced the rocking motion of the traditional dragrake (this did not have a significant [$P < 0.05$] effect on fishing success or ecological impact). The prototype with vertically-thick, short tines were significantly less efficient than the traditional dragrake; and significantly more fronds attached to the holdfasts were observed in its harvest. The dragrakes with vertically thick (25 mm), long (25 cm) tines were significantly less productive than the traditional dragrake but ecological impact was greater. One promising prototype (D) tested had tine spacings of 5.0 mm - narrower than the traditional dragrake by 1.5 mm. Mean yield of this prototype was 20.2 ± 8.5 kg h^{-1} compared to 17.1 ± 7.9 kg h^{-1} for the traditional dragrake; the difference was not significant ($P < 0.05$). Similarly, although the mean number of immature fronds and fronds attached to holdfasts in the harvest of prototype D was less than the traditional dragrake, the differences were not significant ($P < 0.05$). Further work is required on dragrakes with narrow tine spacings. The possible synergistic effect between narrow tine spacings and both tine elevation and tine length should be investigated.

Winchers in both districts studied had a significantly greater fishing power than haulers. There were no significant differences in ecological impact between the two methods in District 1; however, haulers in District 2 had a significantly greater ecological impact.

CONCLUSIONS

1. Minor modifications to the Chondrus dragrake can significantly affect both fishing success, harvest yield and ecological impact.

2. Fishing power of winchers is significantly greater than haulers.

3. Harvest yield and ecological impact is not significantly different between winchers and haulers in Districts 1 and 2.

4. Harvest yield of haulers in District 2 is significantly less and there are more fronds attached to holdfasts in their harvest than winchers.

5. Of the four variables assessed in this study, tine spacing had the greatest influence on fishing success, harvest yield and ecological impact.

6. Dragrakes equipped with tines spaced 6.5 mm apart and unelevated or elevated either 6.5 mm or 12.5 mm above the bottom, have a greater fishing power than dragrakes with broad tine spacings and tines unelevated or elevated 6.5 mm or 12.5 mm above the bottom.

7. Dragrakes with tines spaced 6.5 mm apart and unelevated or elevated either 6.5 mm or 12.5 mm off the bottom have a significantly greater harvest yield than dragrakes with tines spaced 11.0 mm apart and unelevated or elevated either 6.5 mm or 12.5 mm off the bottom.

8. Dragrakes with tines spaced 6.5 mm apart and unelevated or elevated either 6.5 mm or 12.5 mm off the bottom have significantly fewer fronds attached to holdfasts in the harvest than dragrakes with tines spaced 8.0 mm or 11.0 mm apart and unelevated or elevated either 6.5 mm or 12.5 mm off the bottom.

9. Increasing the tine elevation by 6.5 mm or 12.5 mm in dragrakes with 6.5 mm tine spacing does not significantly affect fishing power.

10. Dragrakes with tines spaced 6.5 mm apart and with tines elevated 6.5 mm off the bottom have a significantly greater harvest yield than dragrakes with unelevated tines of the same tine spacing.

11. Flat-riding dragrakes (those with foils) do not significantly enhance fishing power or reduce ecological impact.

12. Fishing power is not increased significantly in dragrakes with tines elevated 25.0 mm but the adverse ecological impacts significantly greater.

13. Dragrakes equipped with cross-sectional tines with dimensions of 18.8 mm x 6.3 mm have a significantly

reduced fishing power and a significantly higher number of fronds attached to holdfasts than dragrakes equipped with traditional tines (12.5 mm x 9.4 mm).

14. Increasing the length of traditional dragrake tines by 5.0 mm and 10.0 mm and by increasing traditional tine cross-sectional dimensions by 12.5 mm on the vertical and reducing it 3.0 mm on the horizontal reduces catchability significantly.

RECOMMENDATIONS

1. That dragrakes with tine spacings broader than 6.5 mm not be permitted.

2. That the use of dragrakes with tine spacings between 5.0 mm and 6.5 mm be encouraged.

3. That the use of dragrakes with tines elevated 6.3 mm be encouraged.

4. That the use of winchers over haulers be encouraged in District 2.

5. That a study be undertaken to assess the effects of narrow tine (5.0 mm) spacing on both fishing power and ecological impact in Districts 1, 2, 6, and 7.

6. That a study be undertaken to assess the synergistic effects of narrow tine spacing (4.0 mm to 6.3 mm), tine length (20.0 cm to 25.0 cm), and tine height (3.0 mm to 25.0 mm) on fishing power and ecological impact in Districts 1, 2, 6, and 7.

ACKNOWLEDGEMENTS

The authors thank the following for their able assistance in this study: the captains of the charter vessels - Messrs. Leo and Stevie Gallant and their crew members - Messrs. Joe Pitre and Ronnie Gallant; the sorters - Ms. Pam Hanic and Colleen Murphy and Mr. Carl Doucette who assisted on board the "Centennial Pride"; the managers of the *Chondrus*-buying companies that donated the experimental dragrakes during 1978 - Messrs. Ronnie Costain, Wendell Stewart, Terry Ball, and Harald Norve; Messrs. Jamie Ellsworth and Terry Ball, Subcommittee members; Mr. Bob Semple who analyzed the data; and CAFSAC Subcommittee members who gave constructive criticism on the manuscript. The manuscript has benefited from a review by Glyn Sharp and Tissa Amaratunga.

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Table 1. The dimensions of the traditional dragrake (x) and the prototypes tested during 1978.

Dragrake	Tine Dimensions (x-section)		Tine length	Tine space	Tine height off bottom
	Vertical (mm)	Horizontal (mm)	(cm)	(mm)	(mm)
X	12.5	12.5	20.0	6.5	Nil
A	12.5	12.5	20.0	8.0	Nil
B	12.5	12.5	20.0	11.0	Nil
C	12.5	12.5	20.0	6.5	6.5
D	12.5	12.5	20.0	8.0	6.5
E	12.5	12.5	20.0	11.0	6.5
F	12.5	12.5	20.0	6.5	12.5
G	12.5	12.5	20.0	8.0	12.5
H	12.5	12.5	20.0	11.0	12.5
I	12.5	9.5	20.0	6.5	Nil
J	12.5	12.5	25.0	6.5	Nil
K	9.5	12.5	25.0	6.5	Nil

Table 2. The sequence in which the traditional dragrake (x) and the prototypes were tested on winchers during 1978.

Hour	1	2	3	4	5	6	7	8	9	10
	imo	imo	imo	imo	imo	imo	imo	imo	imo	imo
Port	XAB	CDE	FGH	BXA	ECD	HFG	ABX	DEC	GHF	XAB
Starboard	CDE	HFG	ABX	FGH	GHF	XAB	ECD	GHF	BXA	FGH

Hour	11	12	13	14	15	16	17	18	19	20
	imo	imo	imo	imo	imo	imo	imo	imo	imo	imo
Port	CDE	FGH	BXA	ECD	HFG	ABX	DEC	GHF	XAB	CDE
Starboard	GHF	CDE	ECD	FGH	BXA	HFG	XAB	ABX	ECD	ABX

Hour	21	22	23	24	25	26	27
	imo	imo	imo	imo	imo	imo	imo
Port	FGH	BXA	ECD	HFG	ABX	DEC	GHF
Starboard	DEC	CDE	HFG	DEC	DEC	BXA	XAB

i = inner
m = middle
o = outer

Table 3. The sequence in which the traditional dragrake (x) and the prototypes were tested on the hauler during 1978.

Hour	1	2	3	4	5	6	7	8	9
(Position)	123	123	123	123	123	123	123	123	123
Rake	XAB	CDE	FGH	BXA	ECD	HFG	ABX	DEC	GHF

Table 4. The sequence in which the traditional dragrake (x) and certain prototypes (I, J, and K) were tested on the wincher during 1978.

Hour	1	2	3	4	5	6	7	8	9	10	11	12
Port	XI	JK	IK	IJ	JX	XK	IK	JK	IX	IJ	XJ	KX
Starboard	IJ	XJ	XK	KJ	KI	IX	JI	XK	XJ	IX	KJ	KI

Table 5. The sequence in which the traditional dragrake (x) and certain prototypes (I, J, and K) were tested on the hauler during 1978.

Hour	1	2	3	4
Position	1234	1234	1234	1234
	XIJK	IJKX	JKXI	KXIJ

Table 6. The dimensions of the traditional dragrake (A) and the prototypes tested during 1978.

Dragrake Designation		Tine Dimensions (x-section)		Tine length	Tine space	Tine height off bottom
No Foils	Foils	Vertical (mm)	Horizontal (mm)	(cm)	(mm)	(mm)
A	A'	12.5	9.4	20.0	6.3	Nil
B	B'	25.0	6.3	25.0	6.3	Nil
C	C'	25.0	6.3	30.0	6.3	Nil
D	D'	12.5	9.4	20.0	5.0	Nil
E	E'	12.5	9.4	20.0	6.3	25.0
F	F'	18.75	6.3	20.0	6.3	Nil

Table 7. The sequence in which the traditional dragrake (A) and the prototypes were tested during 1979.

Session	1		2		3		4		5		6		7		8		9		10		11		12	
Hour	1 imo*	2 imo	3 imo	4 imo	5 imo	6 imo	7 imo	8 imo	9 imo	10 imo	11	12	13 imo	14 imo	15 imo	16	17	18	19	20	21	22	23	24
Starboard	A B C	D E F	A'A B	C D E	B'A'A	B C D	C'B'A'	A B C	D'C'B'	A'A B	E'D'C	B'A'A	F'E'D'	C'B'A'	F F'E'	D'C'B'	E F F'	E'D'C'	D E F	F'E'D'	C D E	F F'E'	B C D	E F F'
Port	A'B'C'	D'E'F'	B'C'D'	E'F'F	C'D'E	F'F E	D'E'F'	F E D	E'F'F	E D C	F'F E	D C B	F E D	C B A	E D C	B A A'	D C B	A A'B'	C B A	A'B'C'	B A A'	B'C'D'	A A'B'	C'D'E'

i = inner
m = middle
o = outer

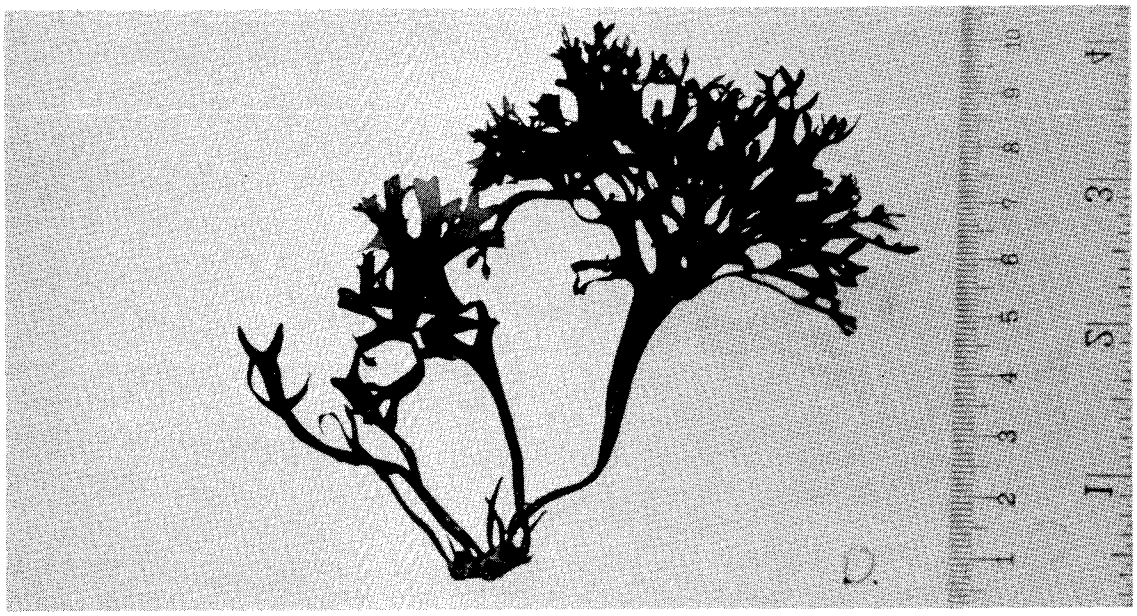

Figure 1. <u>Chondrus</u> plant showing the basal holdfast and upright fronds. The largest frond is harvestably mature.

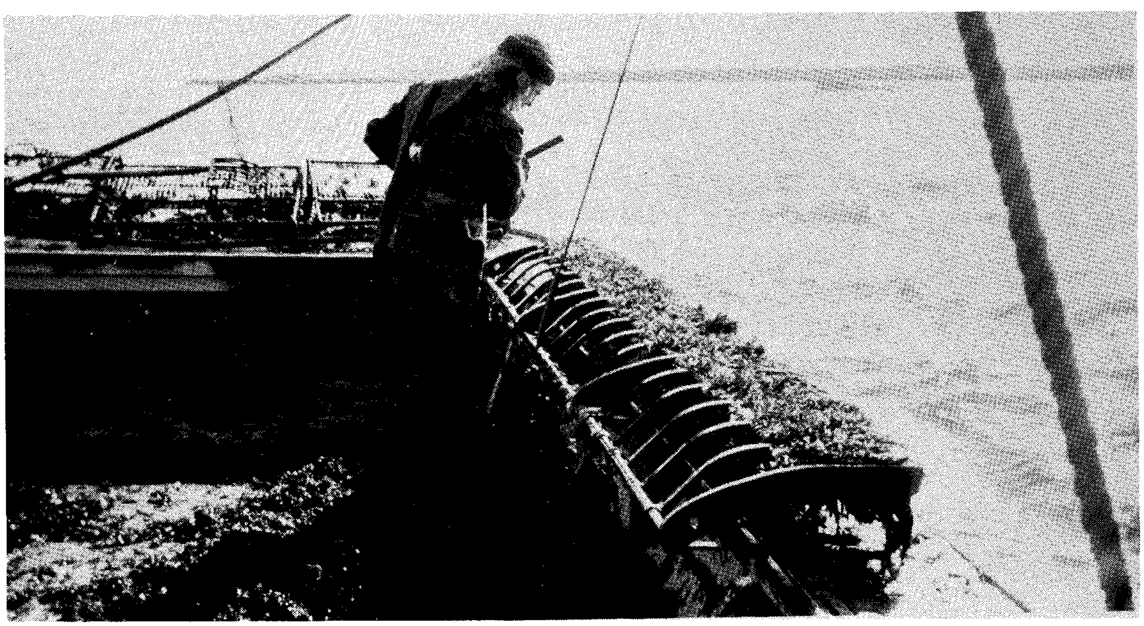

Figure 2. <u>Chondrus</u> dragrakes rigged in triplicate for use on a wincher. The deckhand is striking the tines with a steel rod to loosen the crop prior to removal by hand.

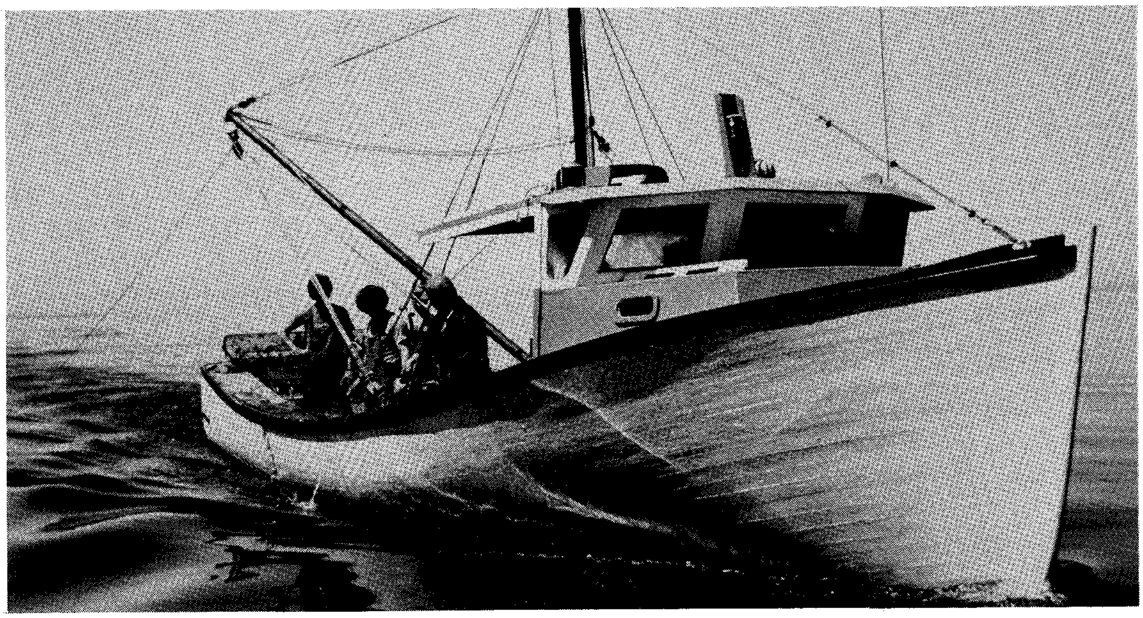

Figure 3. The charter boat, Centennial Pride, employed during the 1978 study. Note steel boom visible on the starboard side rigged with cable.

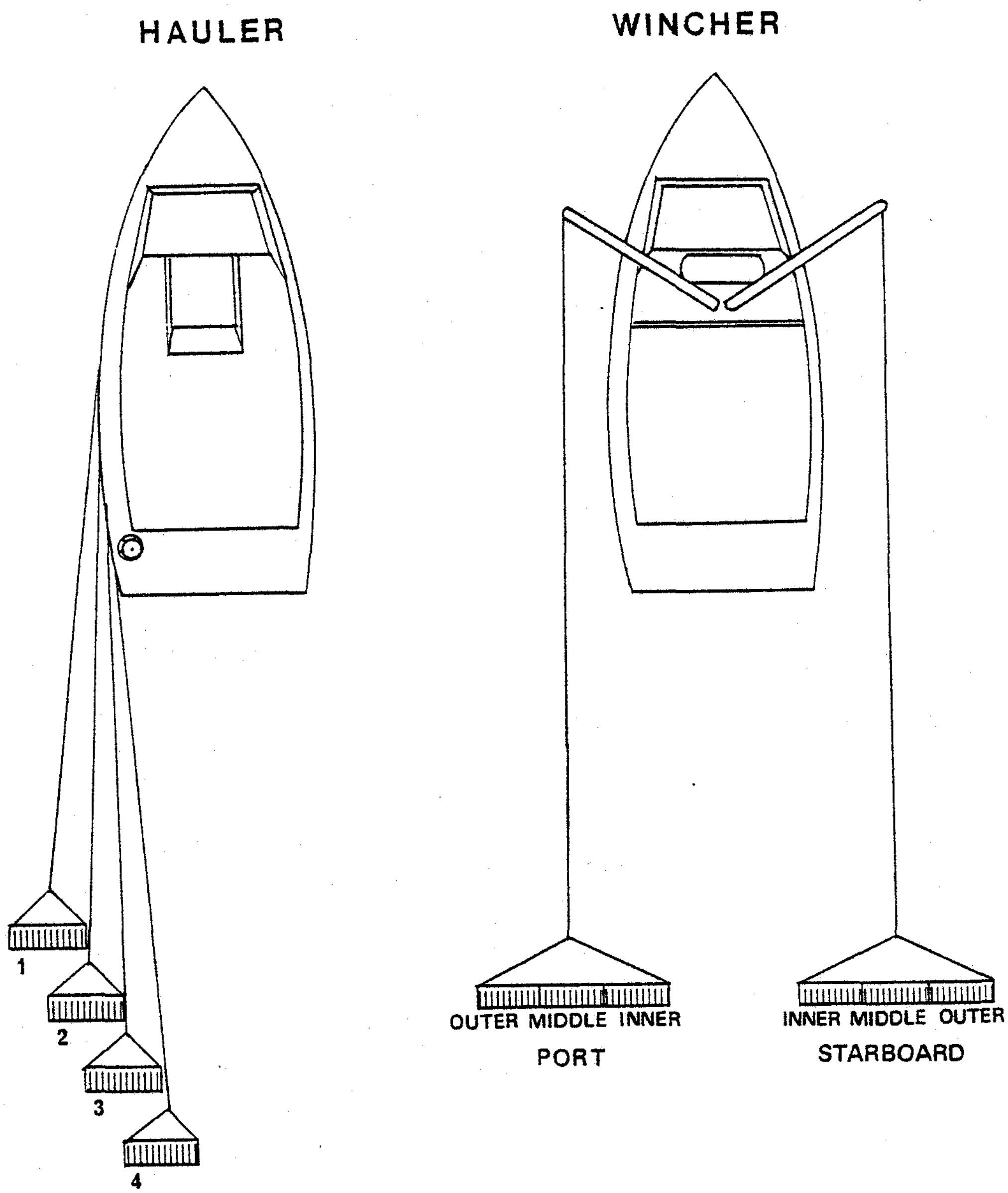

Figure 4. Aerial view of a hauler and a wincher, showing the positioning of dragrakes.

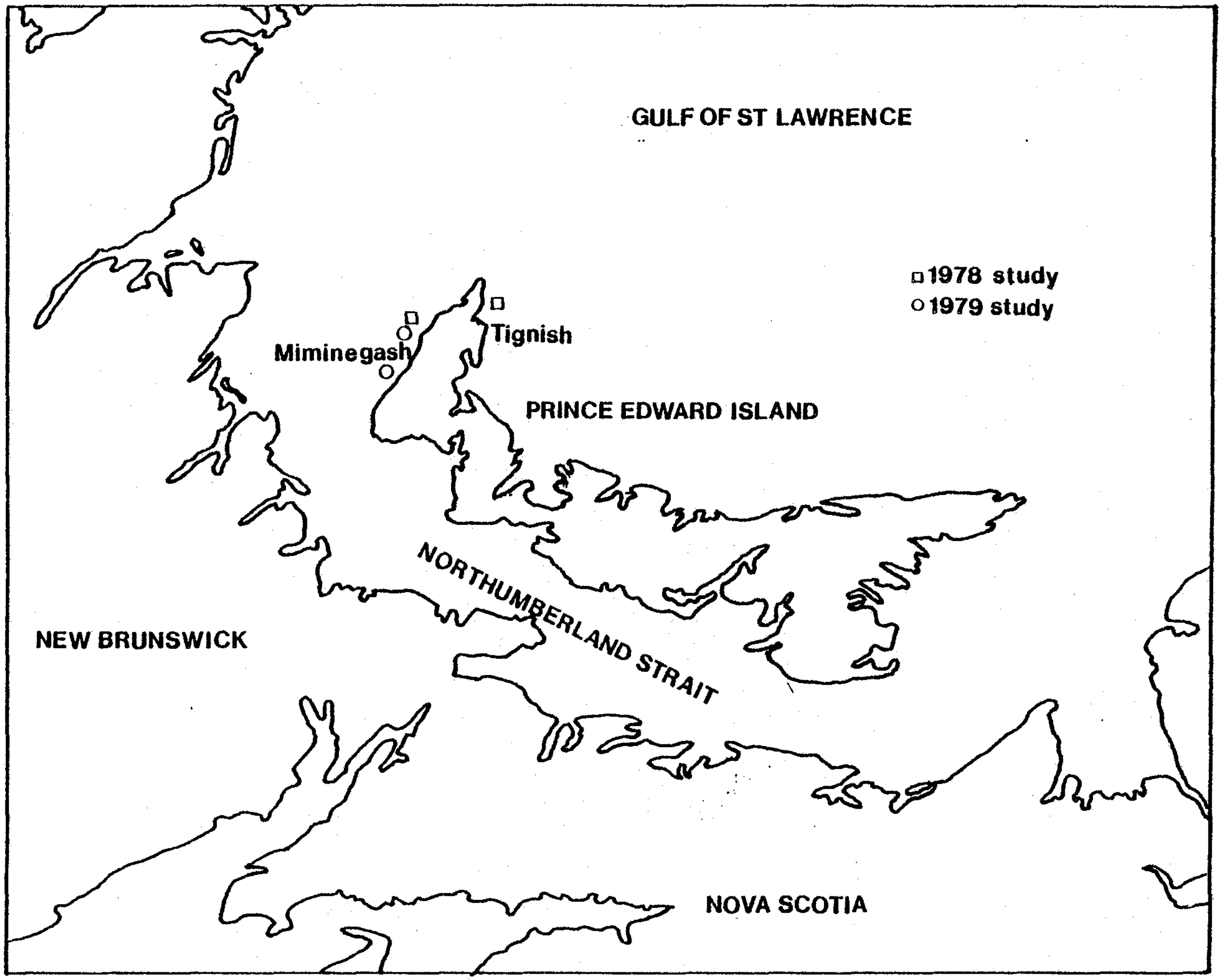

Figure 5. Southern Gulf of St. Lawrence, showing the approximate location of the harvesting trials. Miminegash is in District 1; Tignish is in District 2.

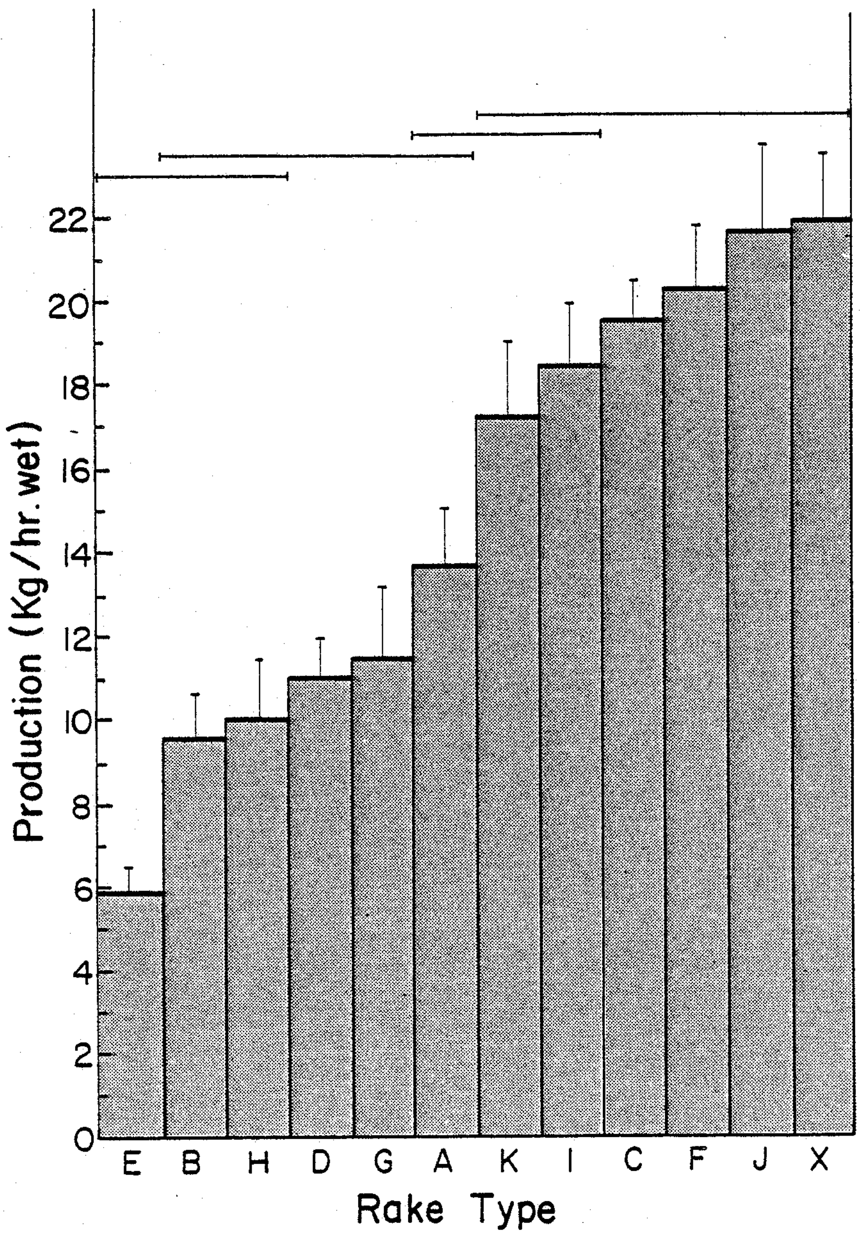

Figure 6. Fishing success of the traditional dragrake (x) and the prototypes tested behind winchers off Miminegash in 1978. [Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

The figure should be used in conjunction with Table 1.

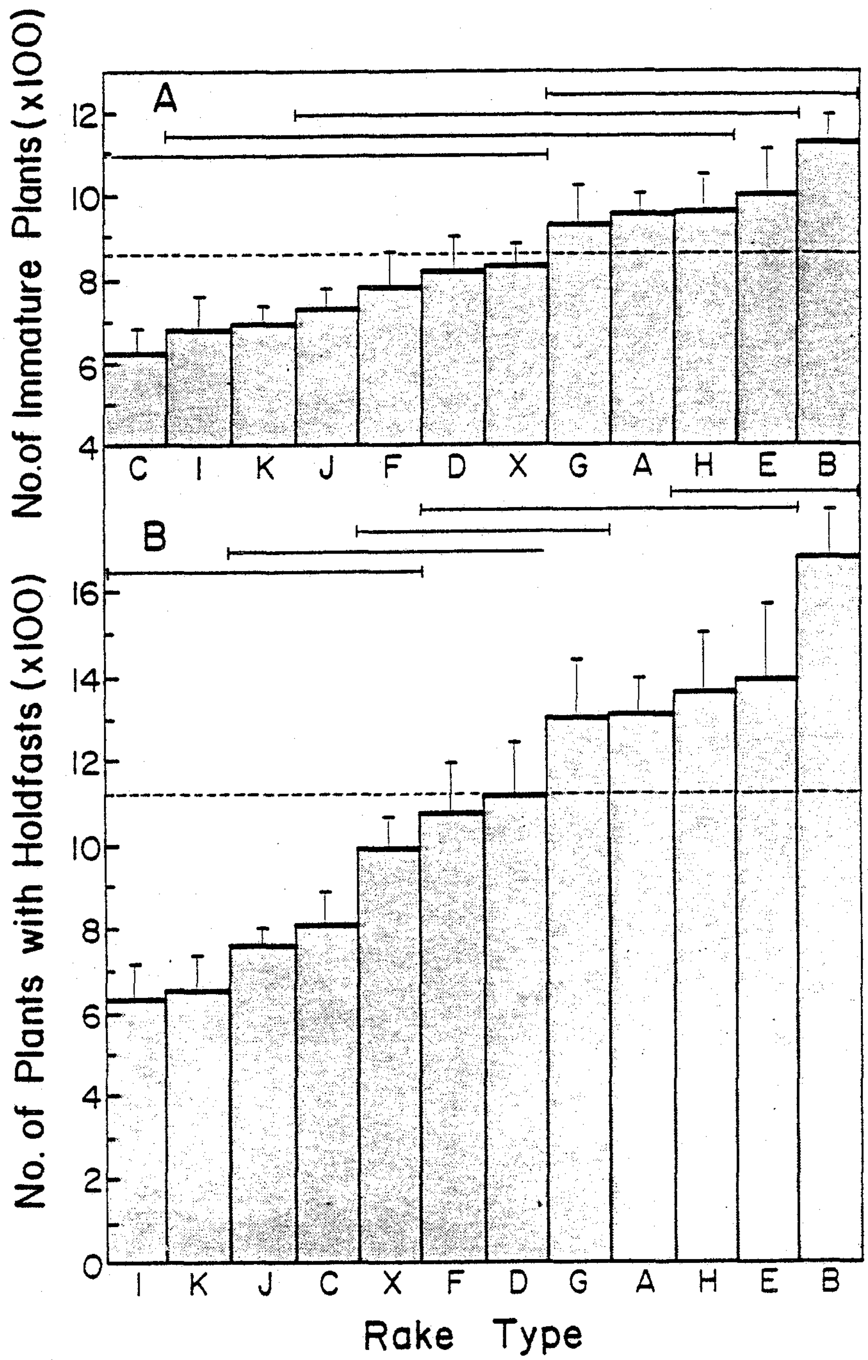

Figure 7. The ecological impact of the traditional dragrake (x) and the prototypes towed behind winchers off Miminegash in 1978.

A. The number of immature fronds/3,000 fronds in the harvest.

B. The number of fronds/3,000 fronds attached to holdfasts in the harvest.

[Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

The figure should be used in conjuction with Table 1.

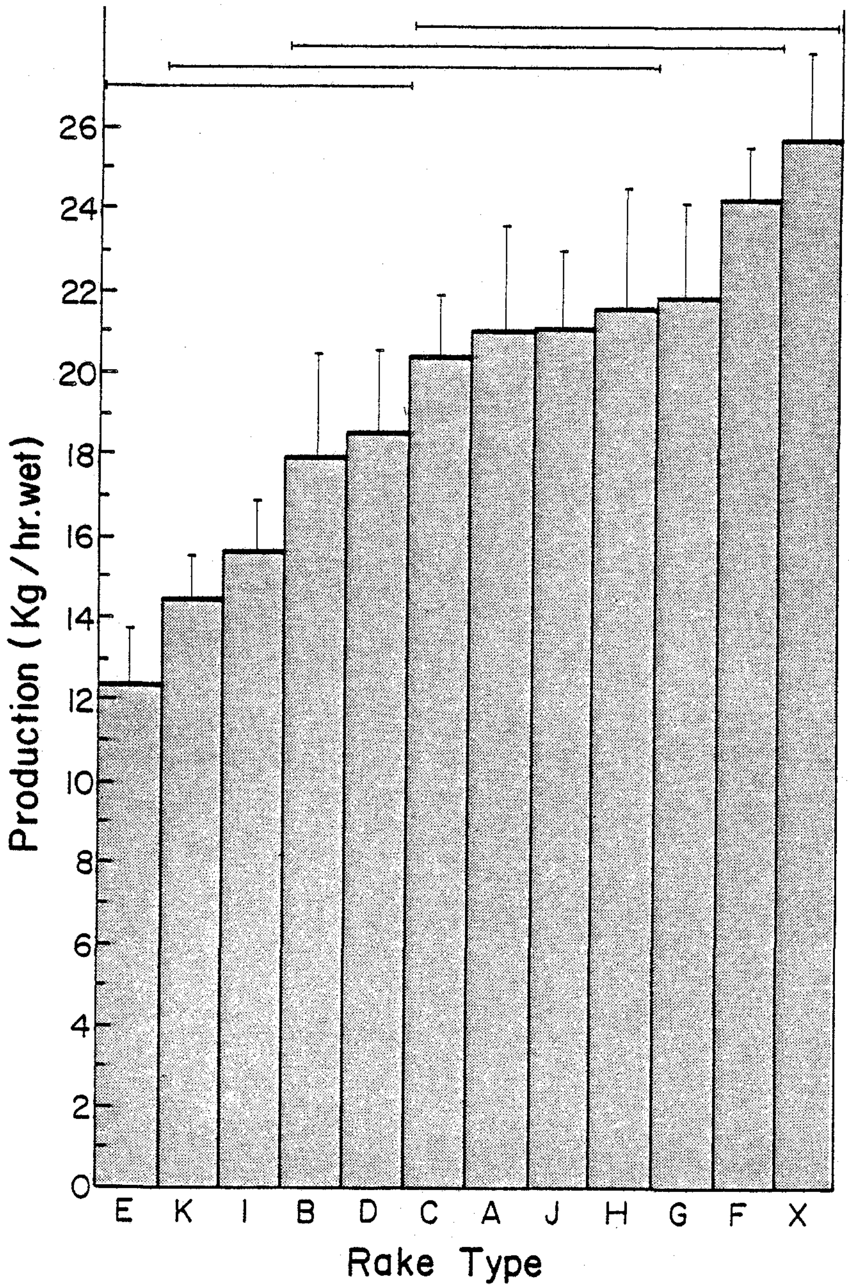

Figure 8. Fishing success of the traditional dragrake (x) and the prototypes tested behind winchers off Tignish during 1978. [Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

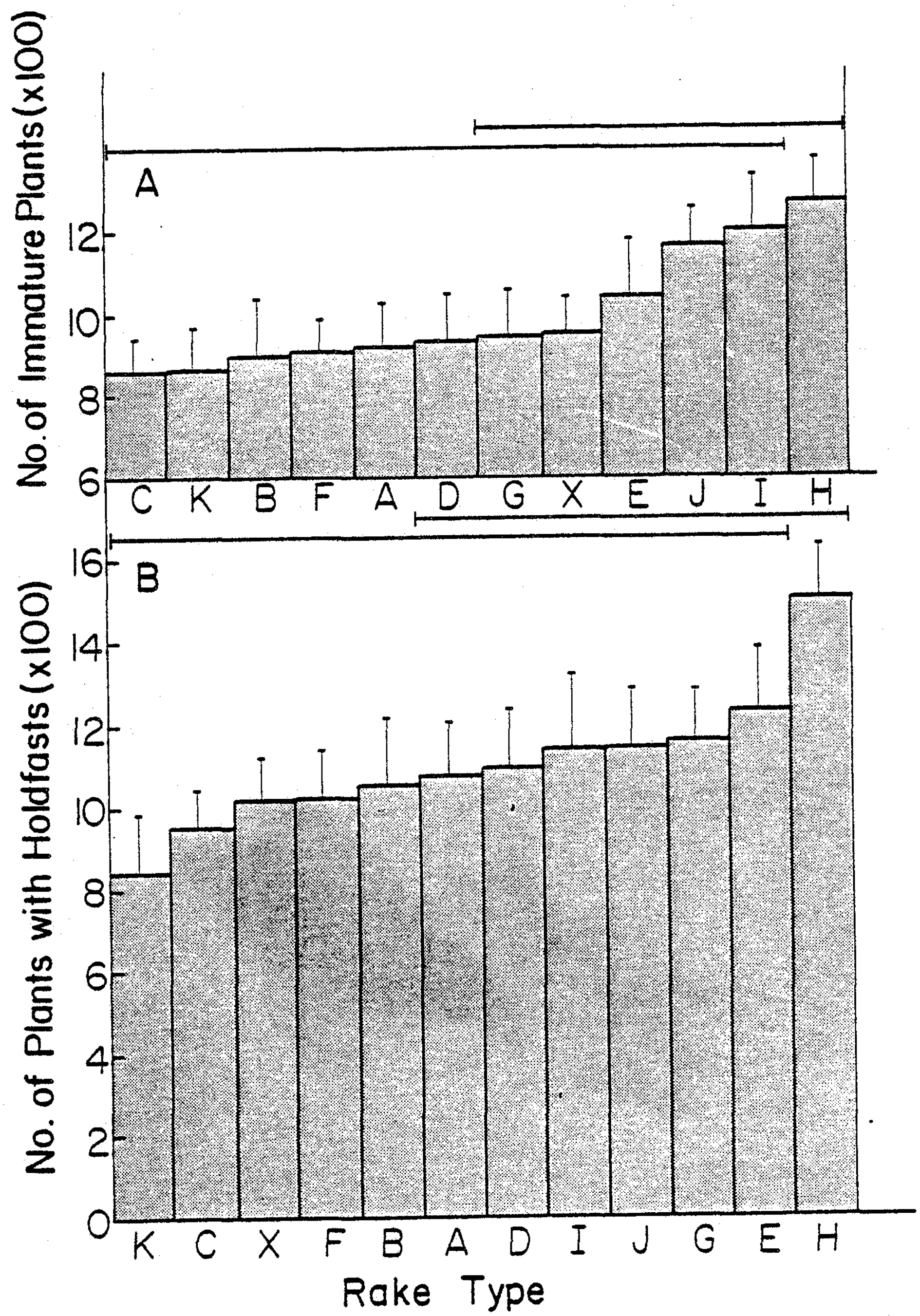

Figure 9. The ecological impact of the traditional dragrake (x) and the prototypes towed behind winchers off Tignish in 1978.

A. The number of immature fronds/3,000 fronds in the harvest.

B. The number of fronds/3,000 fronds attached to holdfasts in the harvest.

[Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

The figure should be used in conjuction with Table 1.

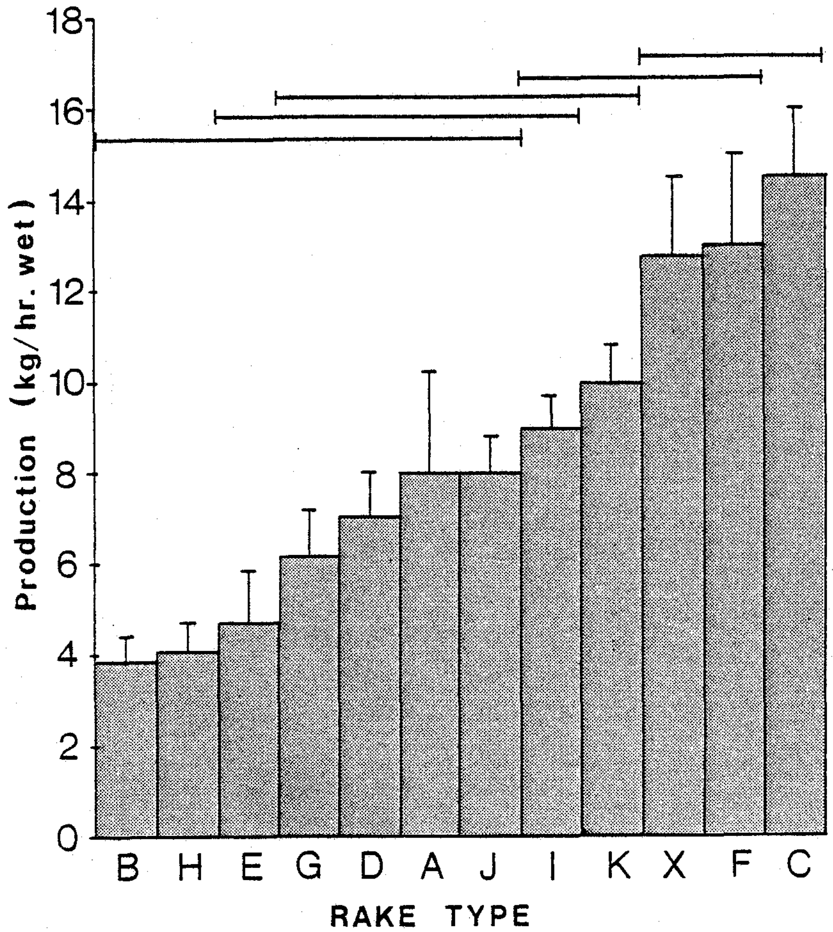

Figure 10. Fishing success of the traditional dragrake (x) and the prototypes tested behind haulers off Miminegash during 1978. [Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

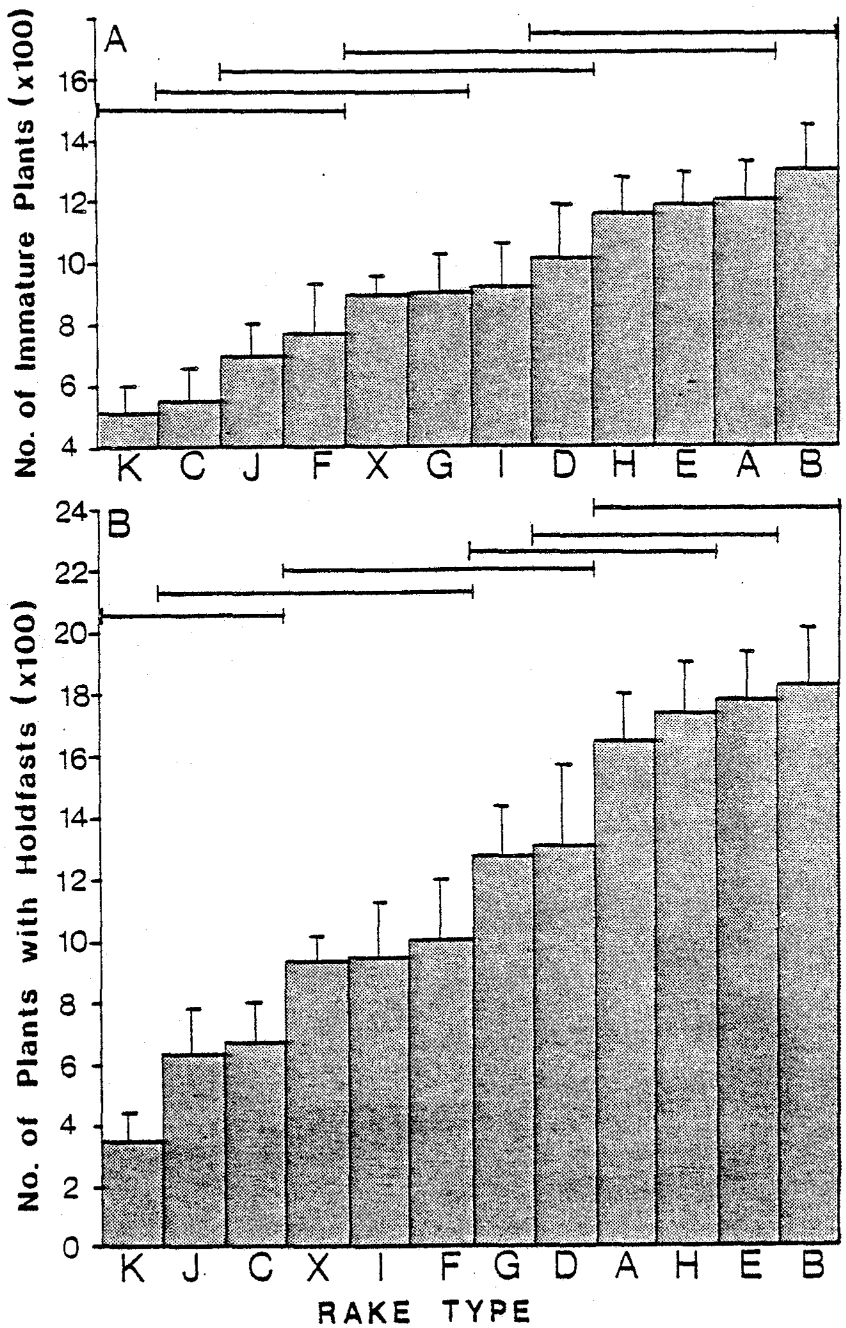

Figure 11. The ecological impact of the traditional dragrake (x) and the prototypes towed behind haulers off Miminegash during 1978.

A. The number of immature fronds/3,000 fronds in the harvest.

B. The number of fronds/3,000 fronds attached to holdfasts in the harvest.

[Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

The figure should be used in conjuction with Table 1.

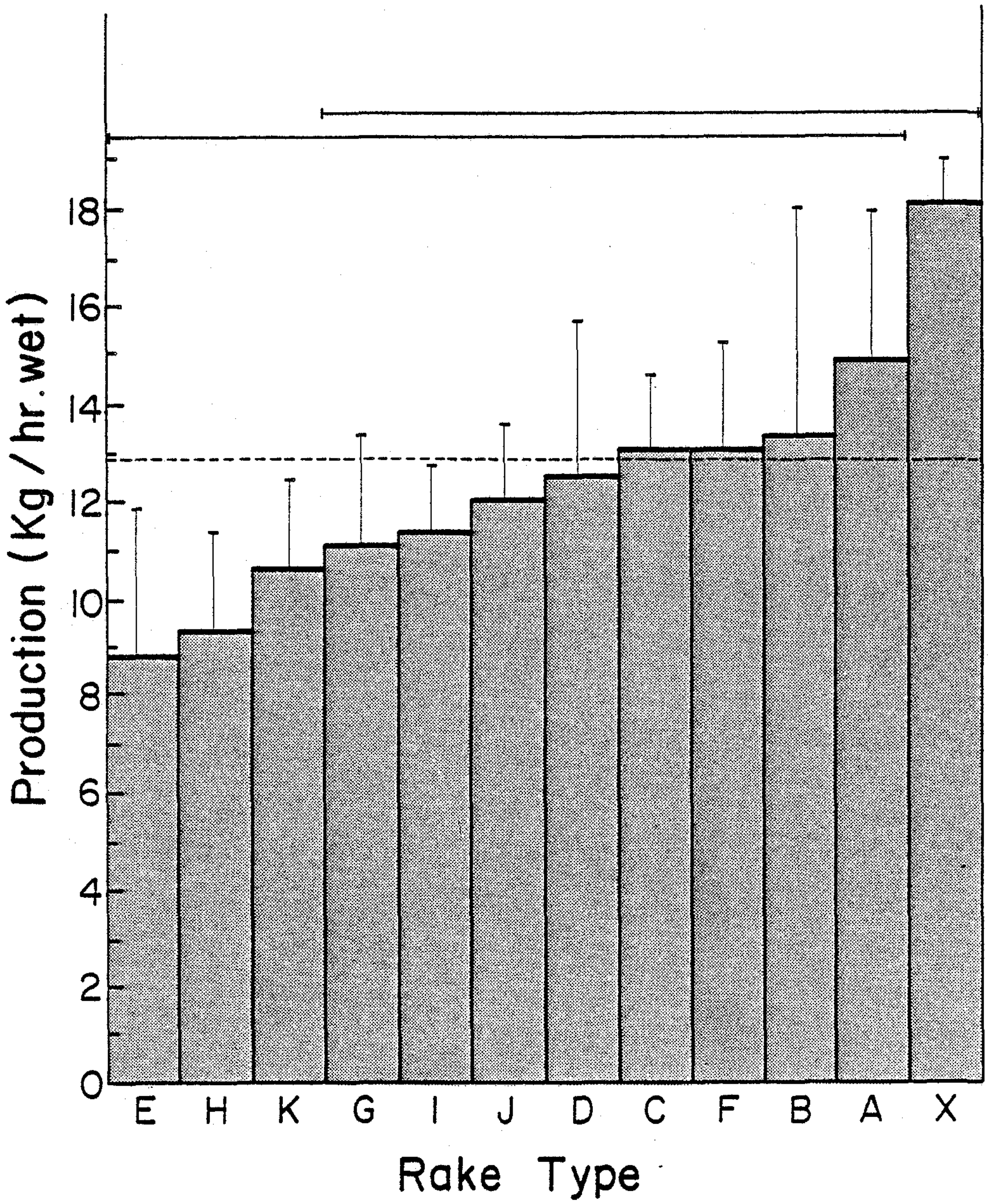

Figure 12. Fishing success of the traditional dragrake (x) and the prototypes tested behind haulers off Tignish during 1978. [Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

The figure should be used in conjunction with Table 1.

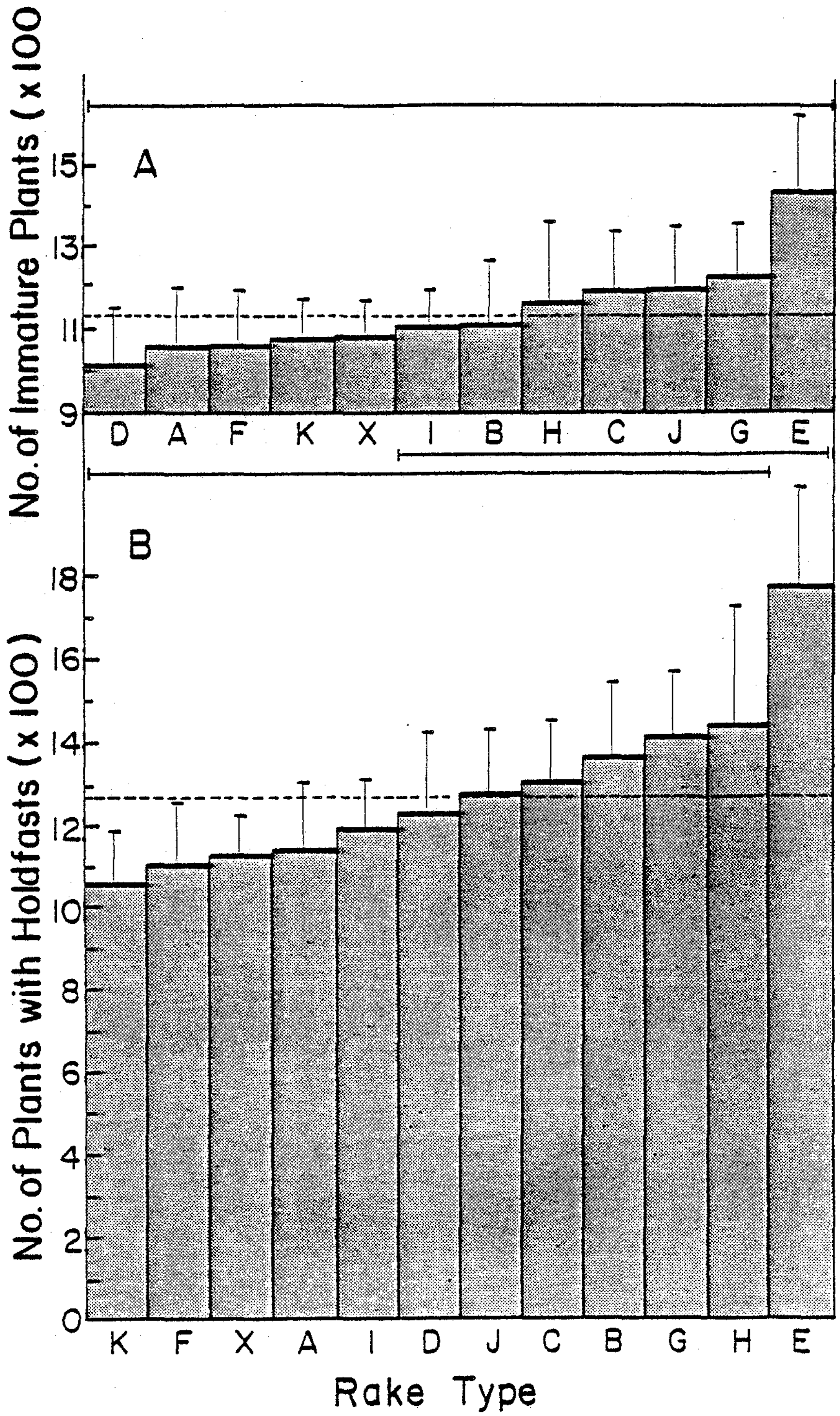

Figure 13. The ecological impact of the traditional dragrake (x) and the prototypes towed behind haulers off Tignish during 1978.

A. The number of immature fronds/3,000 fronds in the harvest.

B. The number of fronds/3,000 fronds attached to holdfasts in the harvest.

[Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

The figure should be used in conjuction with Table 1.

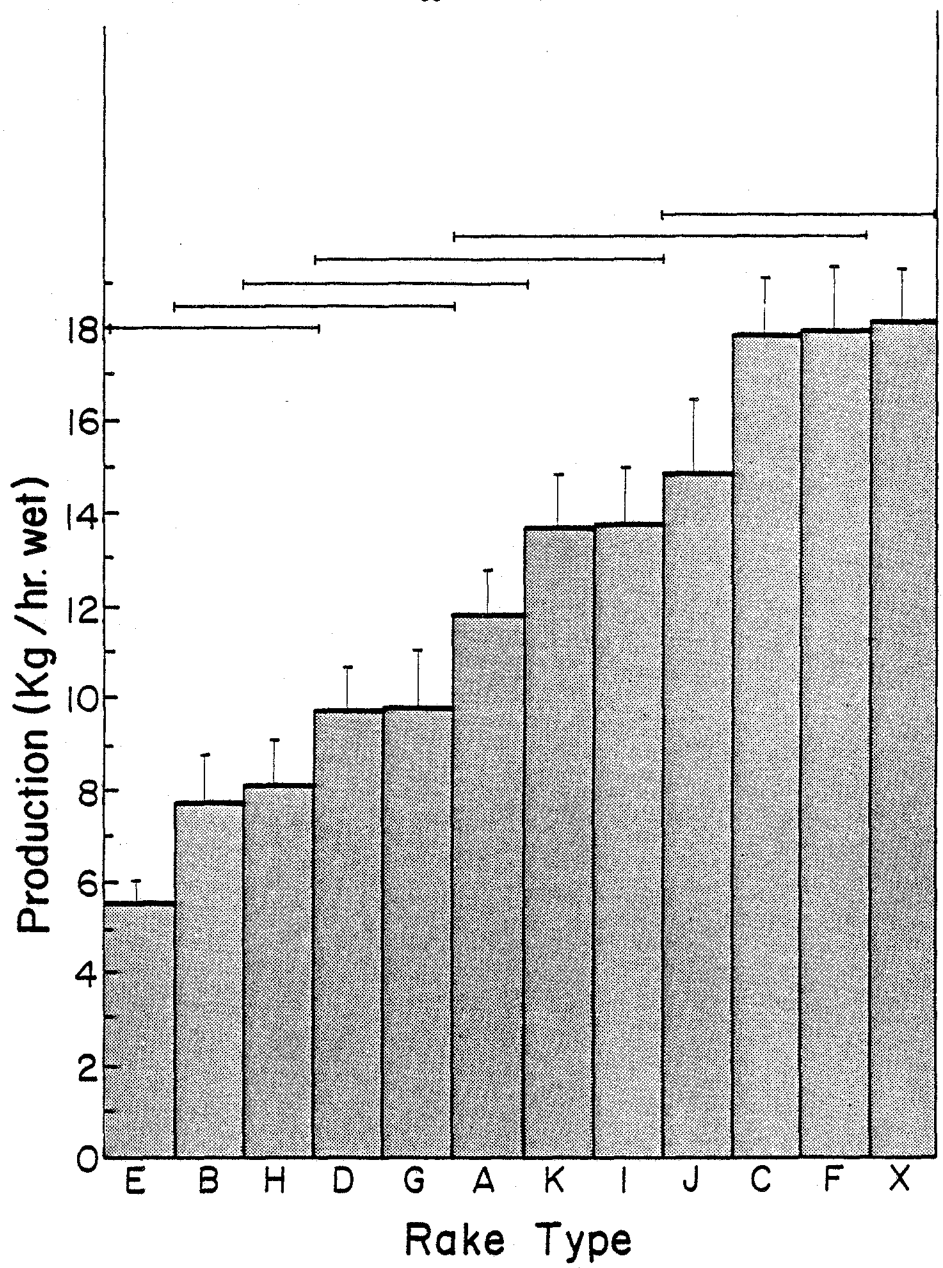

Figure 14. Fishing success of the traditional dragrake (x) and the various prototypes tested behind haulers and winchers off Miminegash in 1978. [Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

The figure should be used in conjunction with Table 1.

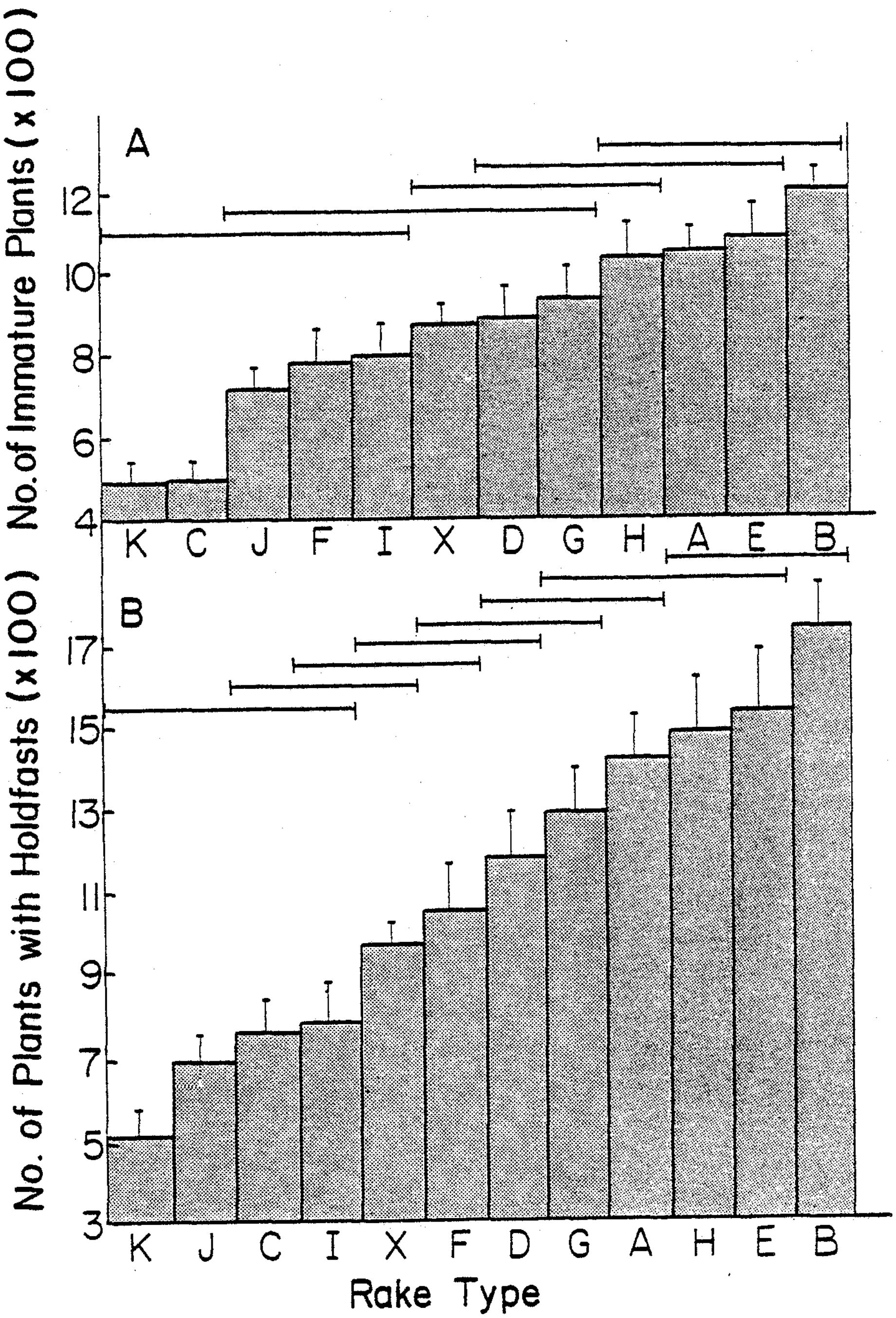

Figure 15. The ecological impact of the traditional dragrake (x) and each prototype towed behind haulers and winchers off Miminegash in 1978.

A. The number of immature fronds/3,000 fronds in the harvest.

B. The number of fronds/3,000 fronds attached to holdfasts in the harvest.

[Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

The figure should be used in conjuction with Table 1.

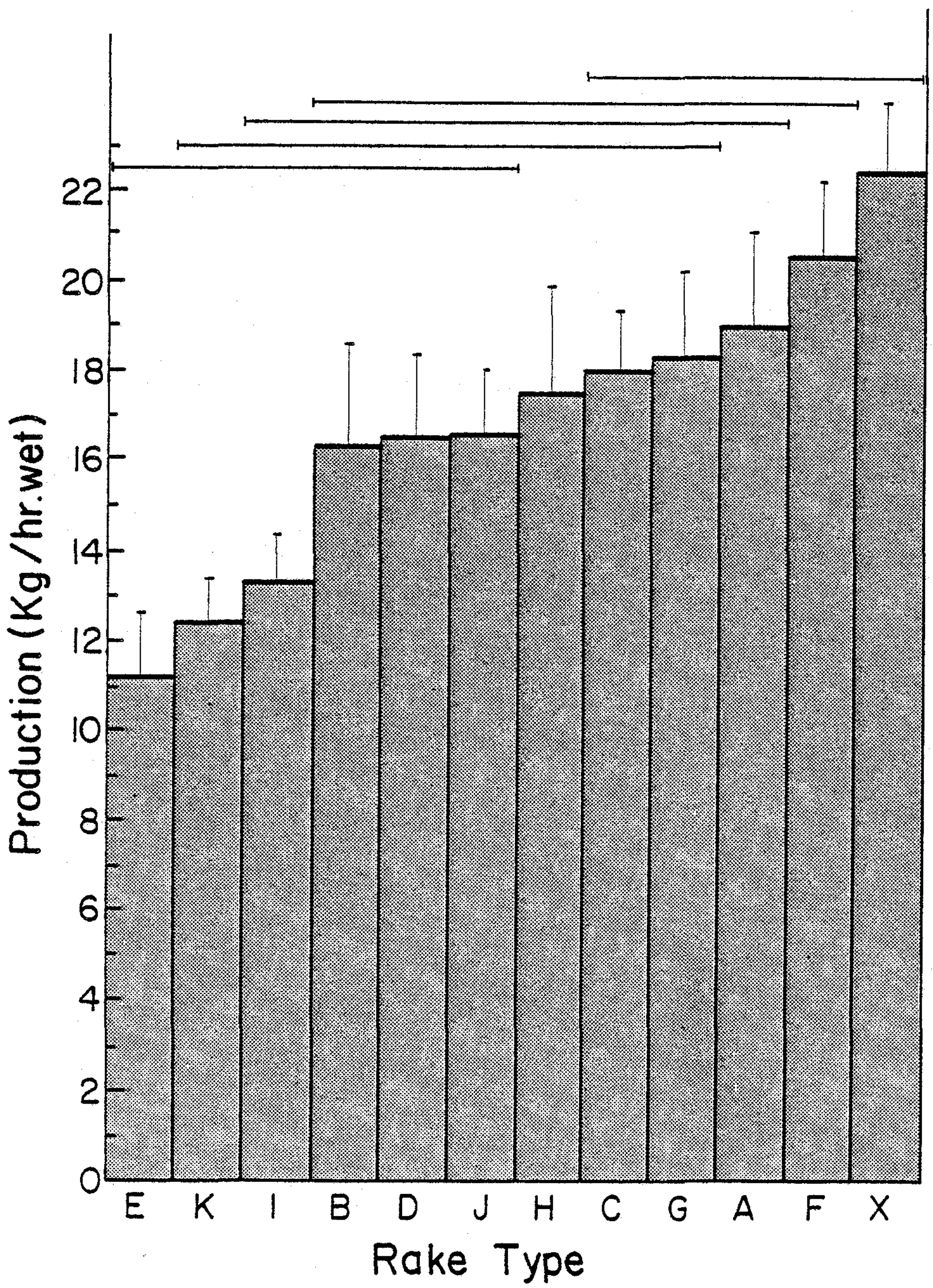

Figure 16. Fishing success of the traditional dragrake (x) and the various prototypes tested behind haulers and winchers off Tignish in 1978. [Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

The figure should be used in conjunction with Table 1.

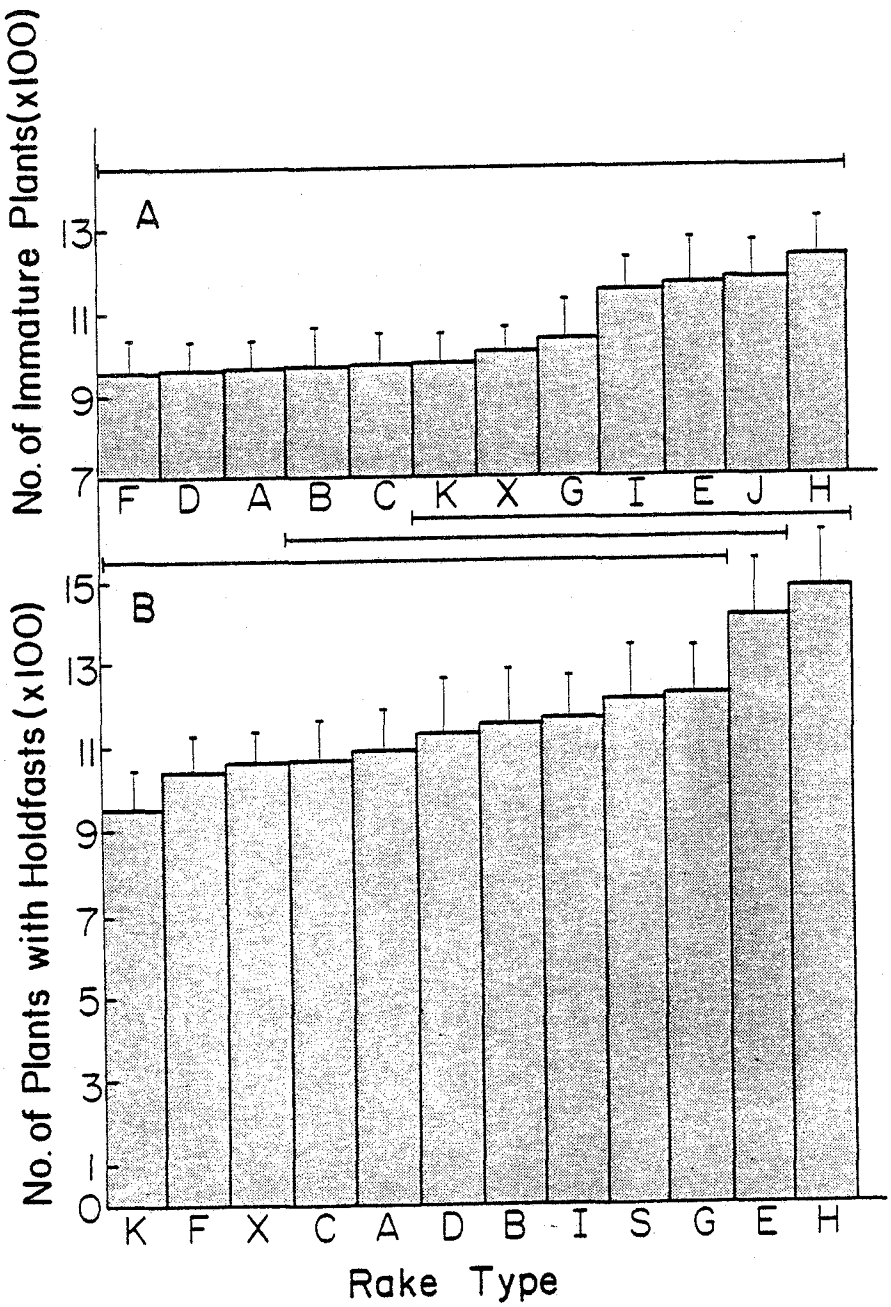

Figure 17. The ecological impact of the traditional dragrake (x) and each prototype towed behind haulers and winchers off Tignish in 1978.

A. The number of immature fronds/3,000 fronds in the harvest.

B. The number of fronds/3,000 fronds attached to holdfasts in the harvest.

[Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

The figure should be used in conjuction with Table 1.

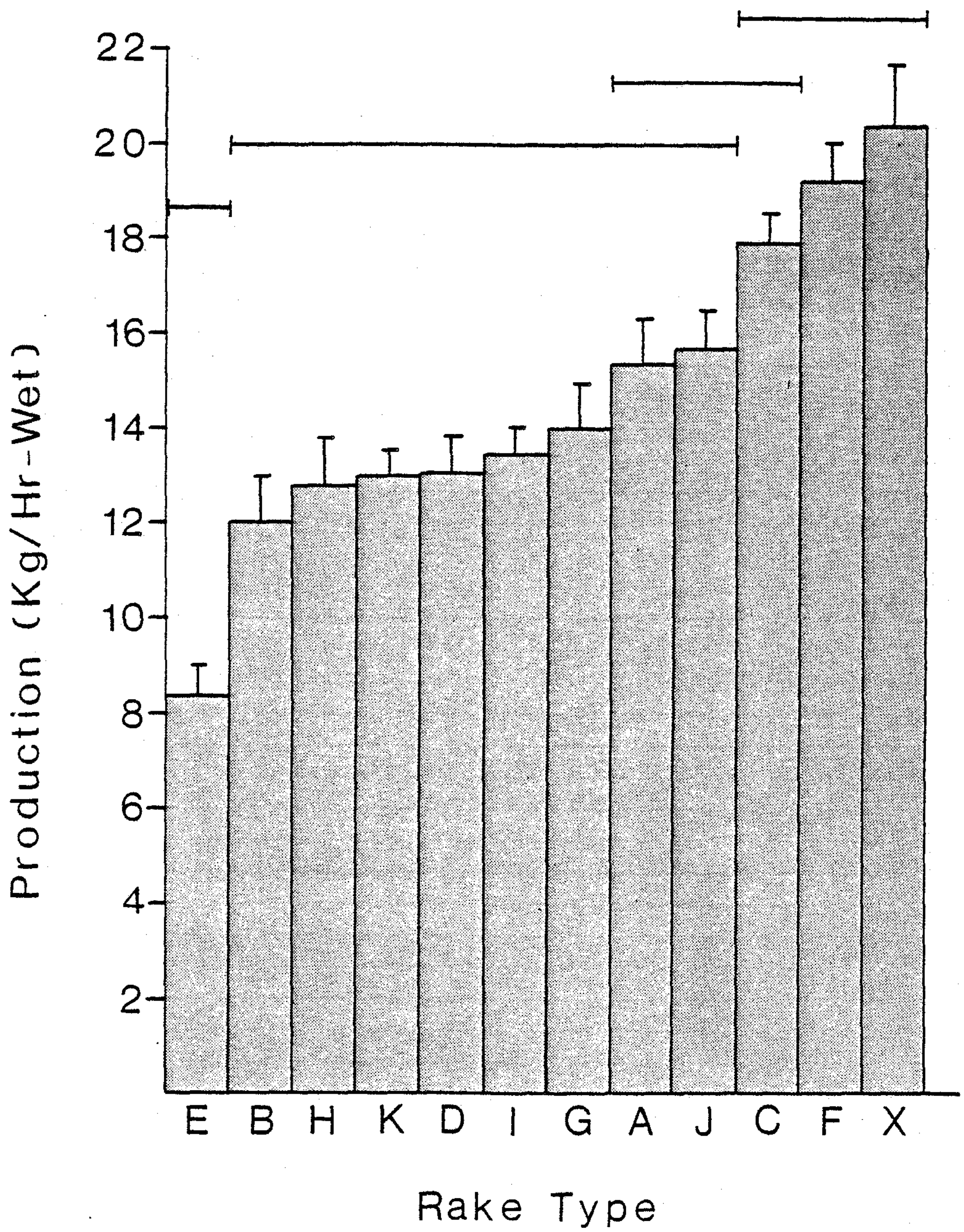

Figure 18. Fishing success of the traditional dragrake (x) and the various prototypes tested behind haulers and winchers off Tignish and Miminegash in 1978. [Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

The figure should be used in conjunction with Table 1.

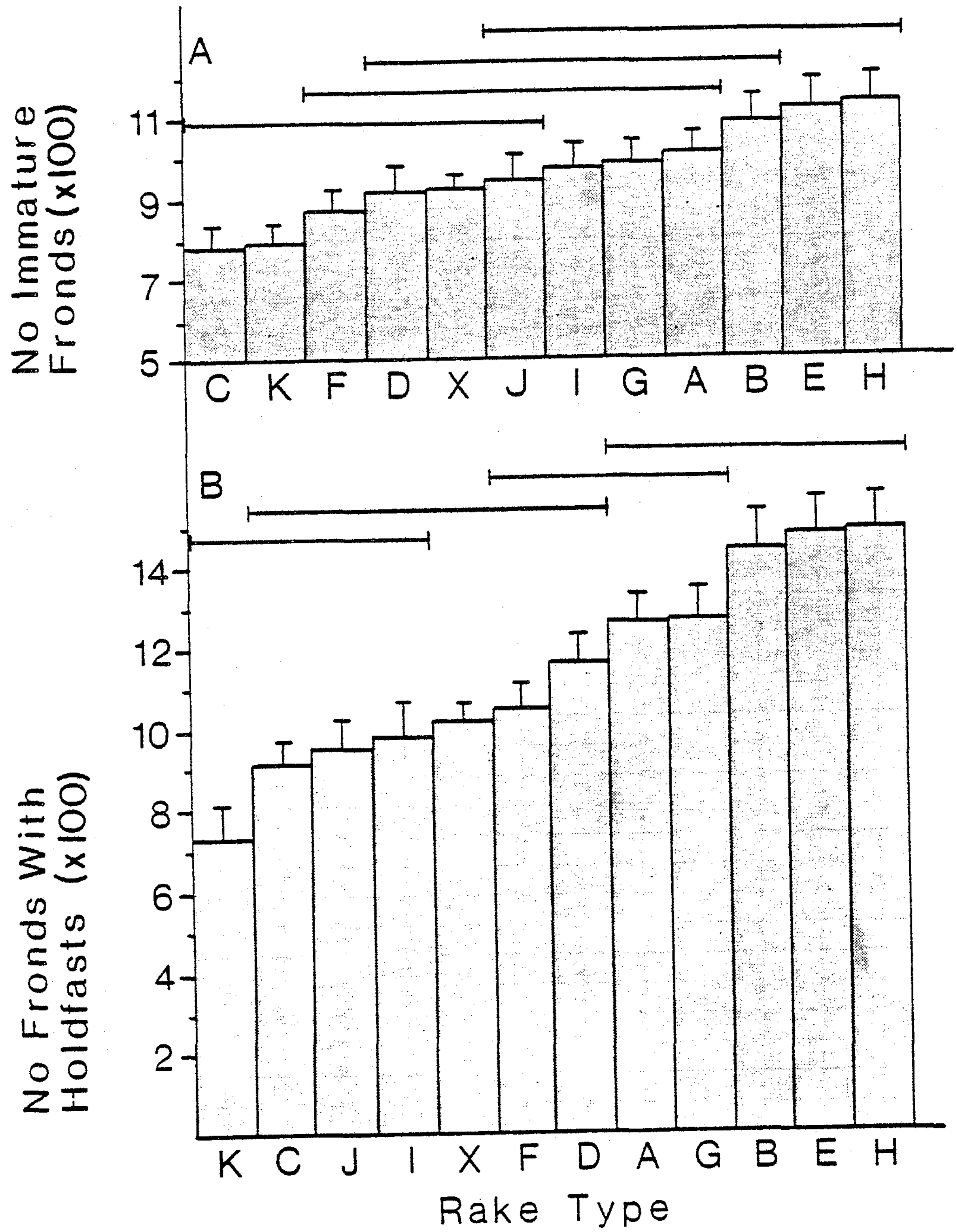

Figure 19. The ecological impact of the traditional dragrake (x) and each prototype towed behind haulers and winchers off Tignish and Miminegash in 1978.

A. The number of immature fronds/3,000 fronds in the harvest.

B. The number of fronds/3,000 fronds attached to holdfasts in the harvest.

[Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

The figure should be used in conjuction with Table 1.

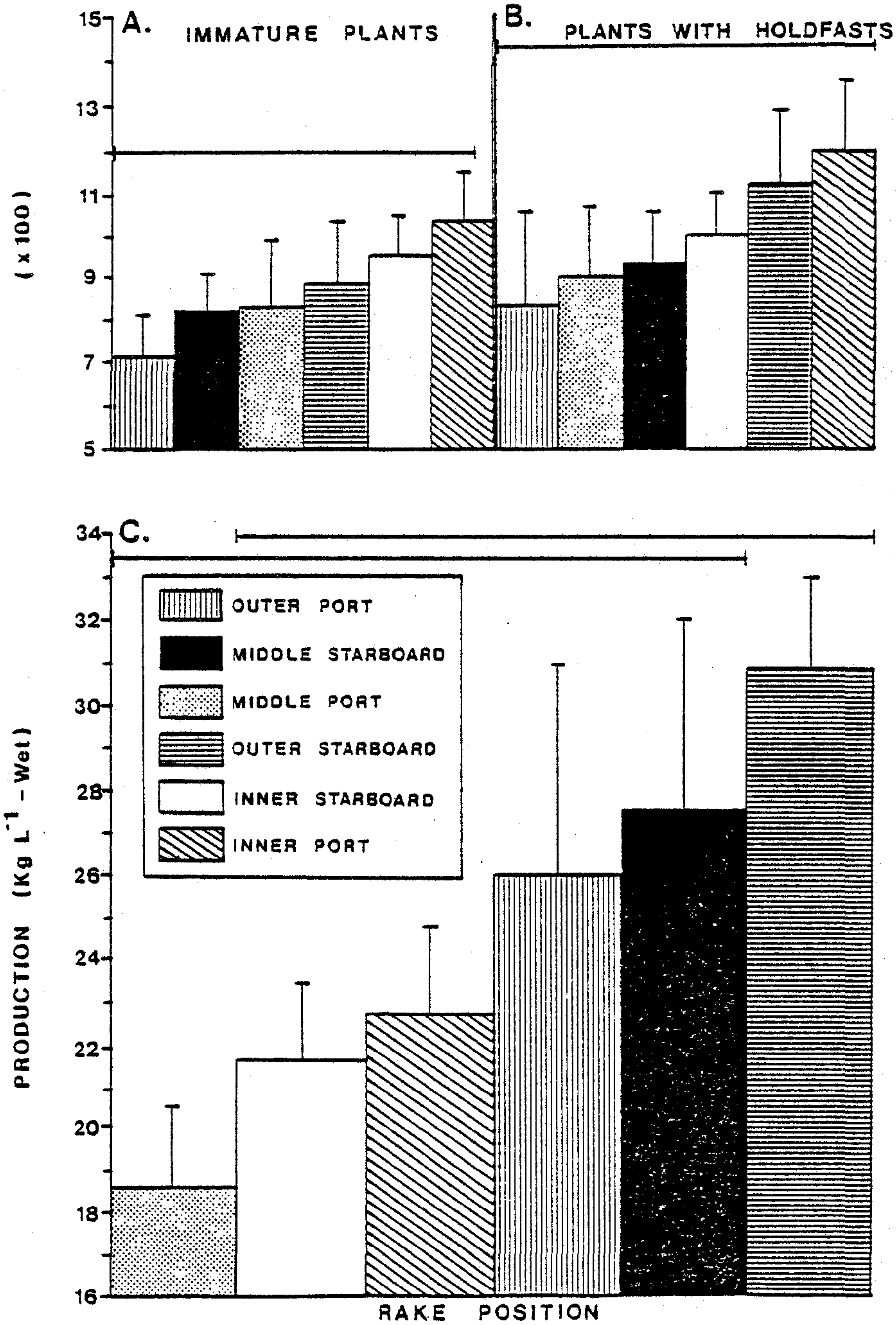

Figure 20. Fishing success (C), number of immature fronds (A), and number of fronds attached to holdfasts (B) in the harvest for each dragrake position behind a wincher. The data were pooled for traditional dragrakes only off Miminegash and Tignish for 1978. [Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significance ($P < 0.05$): the means under a common line are not significantly different.]

The figure should be used in conjuction with Figure 3.

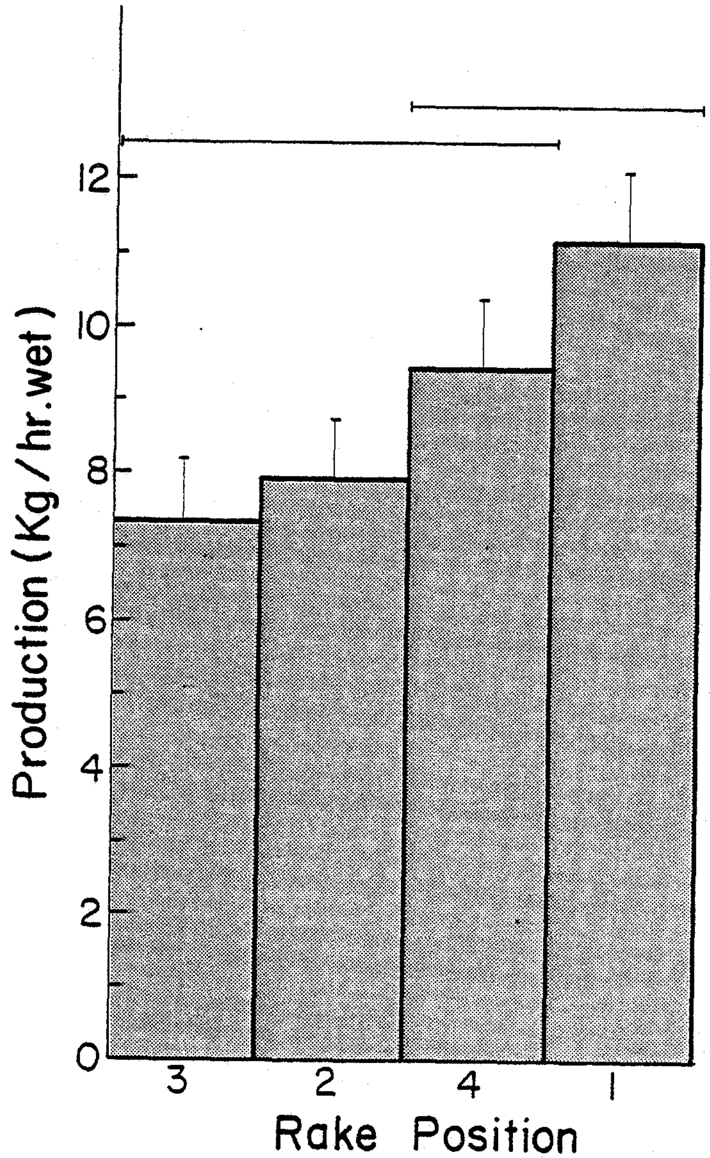

Figure 21. The pooled fishing success of the various prototypes per position tested behind haulers off Miminegash in 1978. [Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

The figure should be used in conjunction with Figure 3.

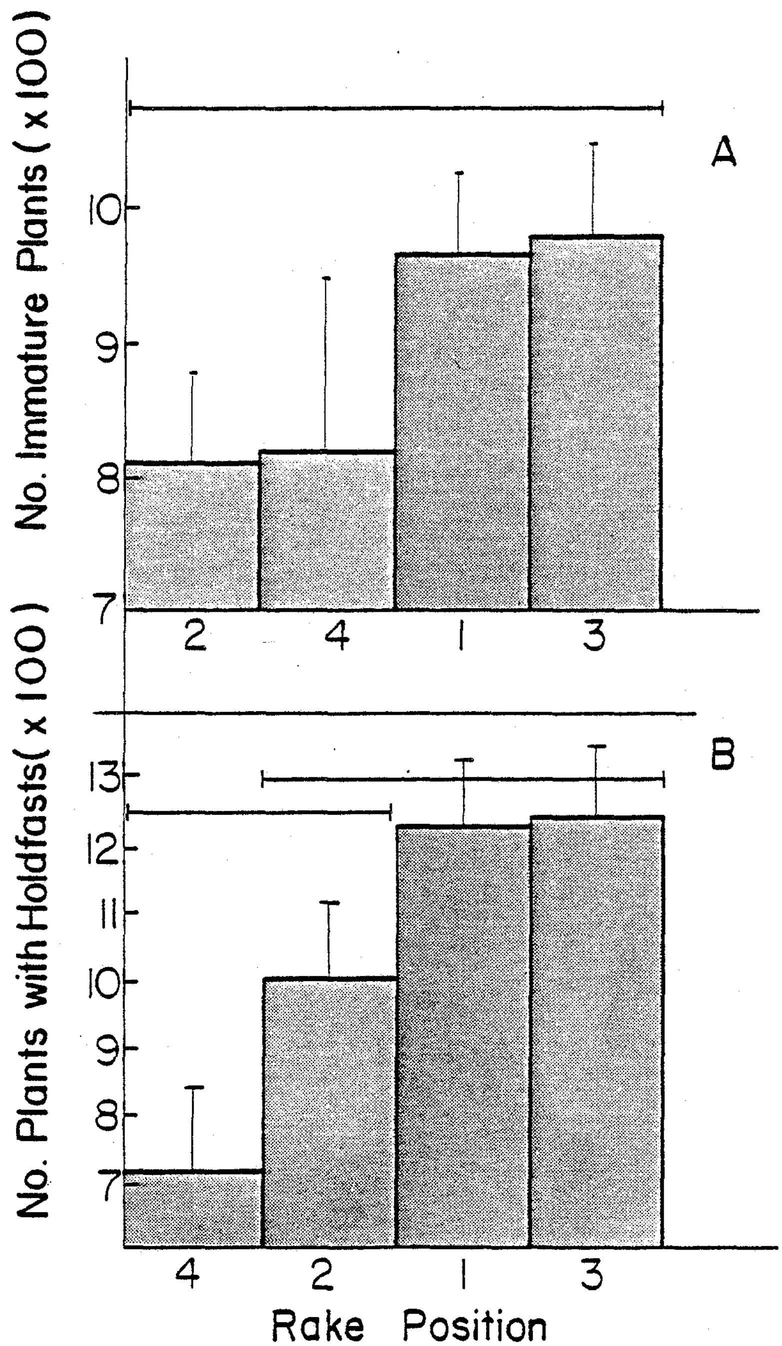

Figure 22. The pooled ecological impact of the various prototypes tested per position behind a hauler off Miminegash.

A. The number of immature fronds/3,000 fronds in the harvest.

B. The number of fronds/3,000 fronds attached to holdfasts in the harvest.

[Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

The figure should be used in conjuction with Figure 3.

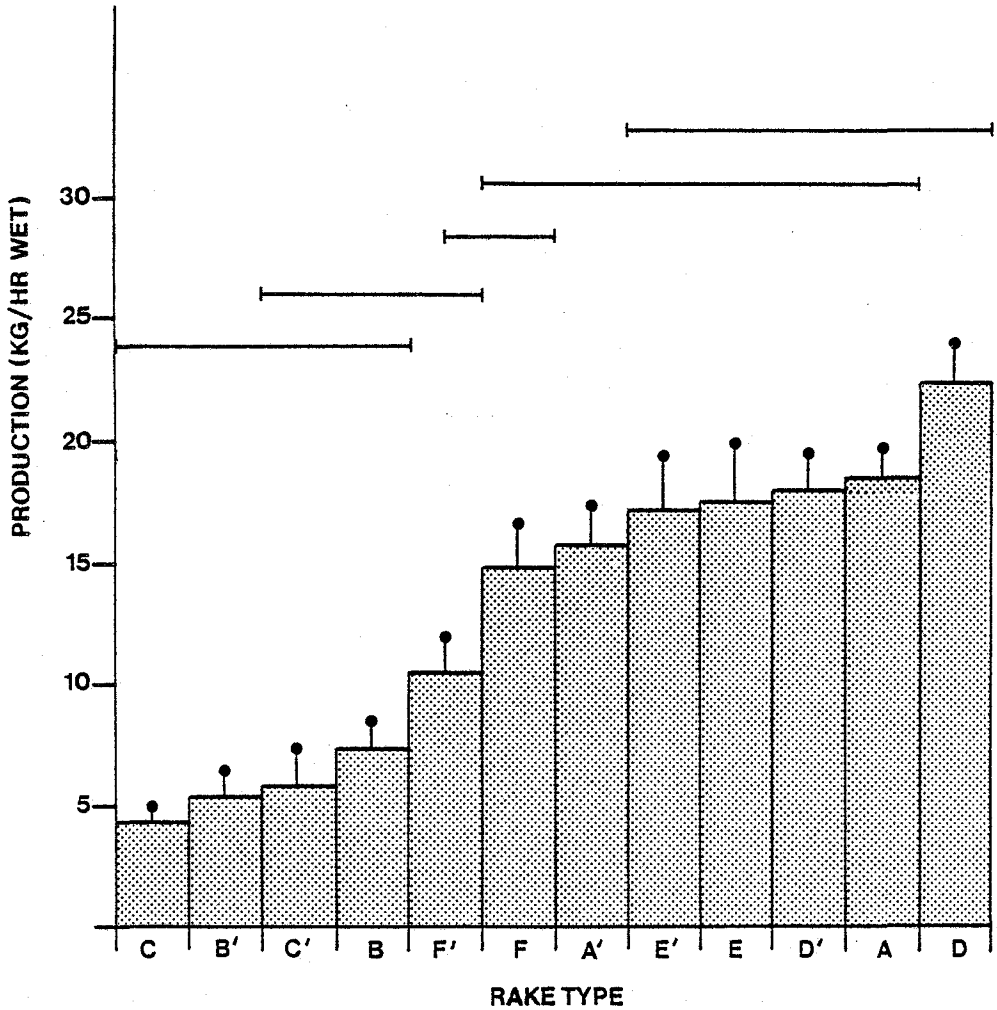

Figure 23. Fishing success of the traditional dragrake (A) and the various prototypes tested behind a wincher off Tignish during 1979. [Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

The figure should be used in conjunction with Table 5.

The rake types designated with a prime (e.g. C') were equipped with foils (flat-riding).

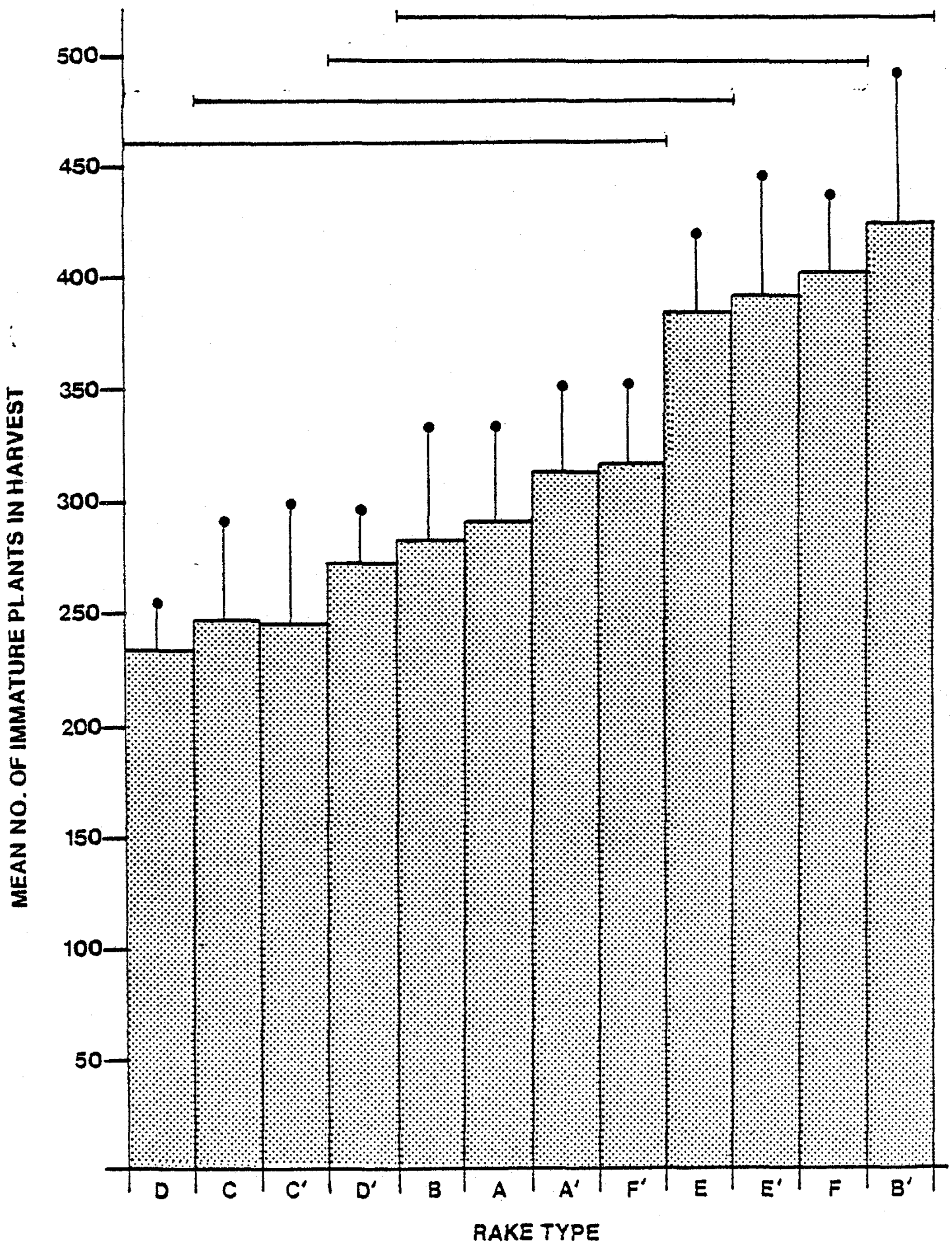

Figure 24. The number of immature fronds/3,000 fronds in the harvest of each prototype towed behind a wincher off Miminegash during 1979.

[Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

The figure should be used in conjuction with Table 5.

The rake types designated with a prime (e.g. C') were equipped with foils (flat-riding).

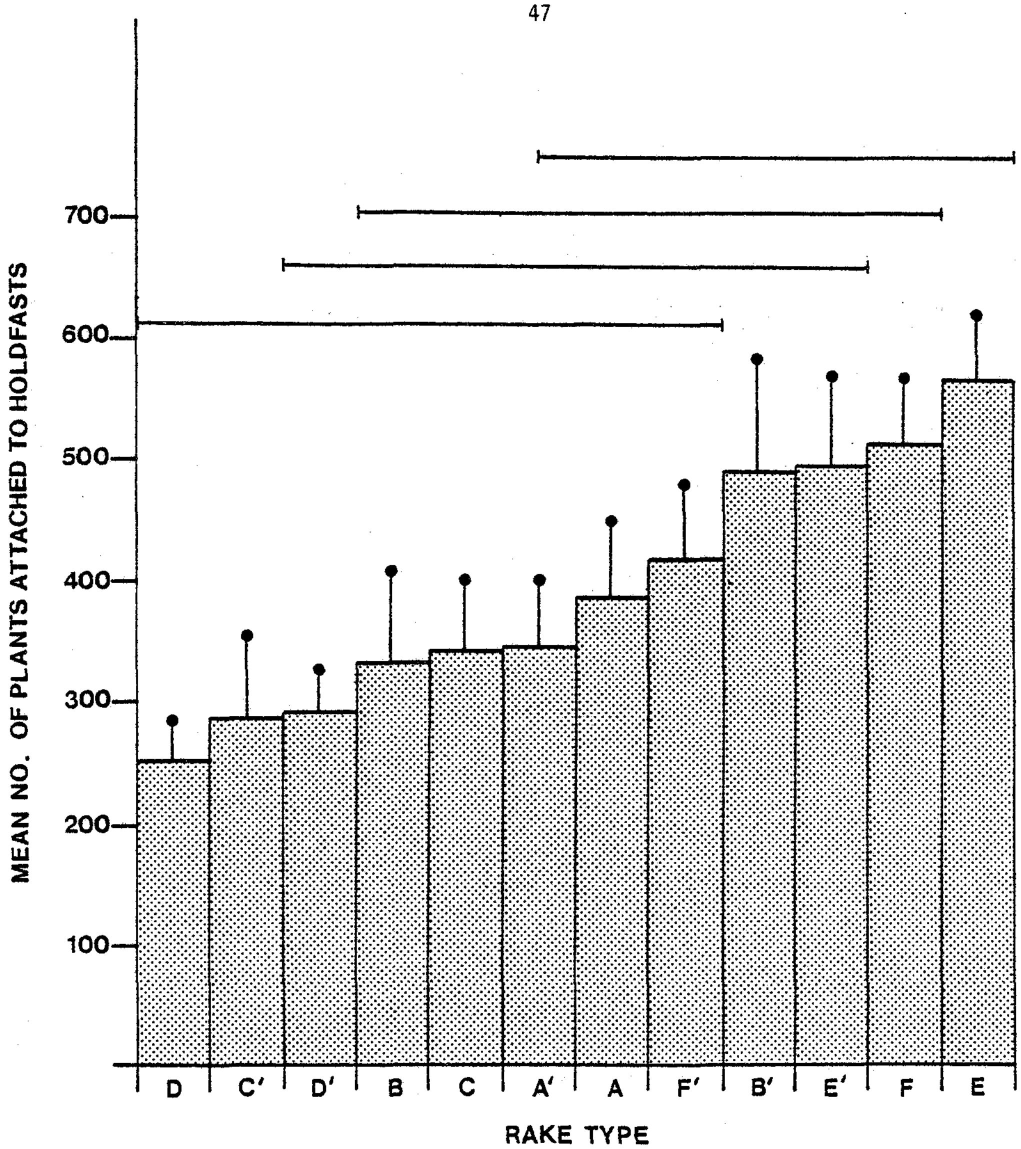

Figure 25. The number of fronds/3,000 fronds attached to holdfasts in the harvest of each prototype towed behind a wincher off Miminegash during 1979. [Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

The figure should be used in conjunction with Table 5.

The rake types designated with prime (e.g. C') were equipped with foils (flat-riding).

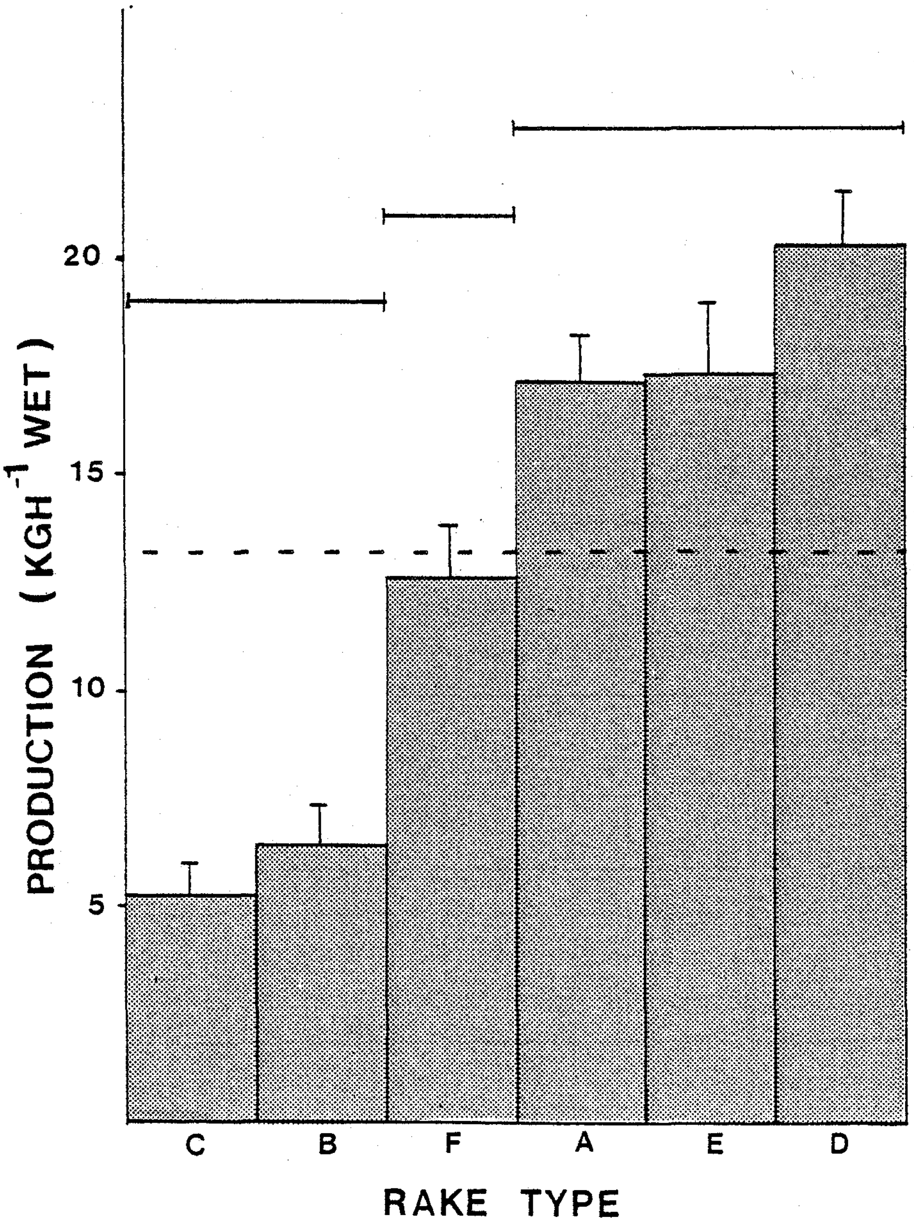

Figure 26. Fishing success of the traditional dragrake (A) and the various prototypes tested behind winchers off Miminegash during 1979. [Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

The figure should be used in conjunction with Table 5.

The means are the result of pooling the prototypes with and without foils.

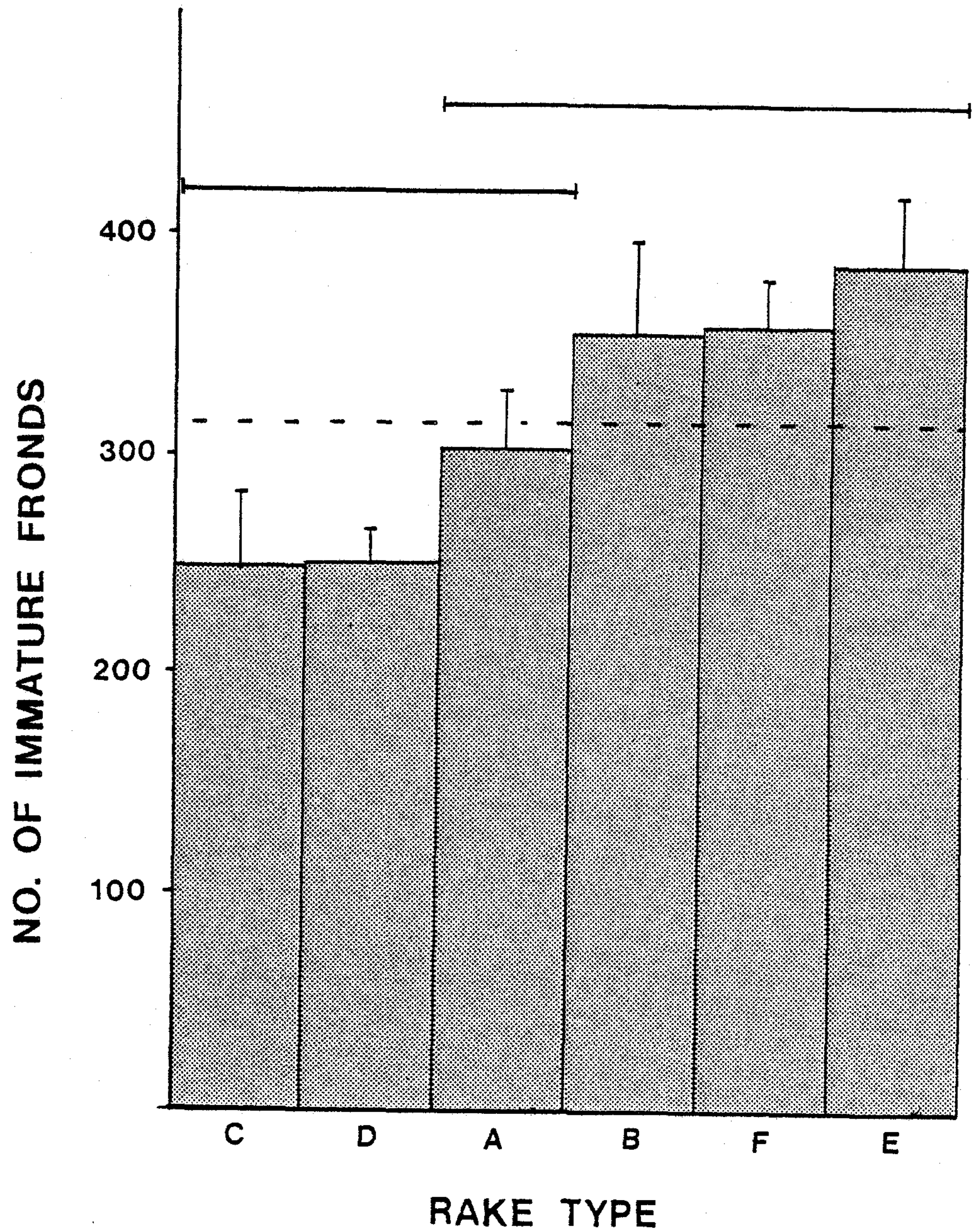

Figure 27. The number of immature fronds/3,000 fronds in the harvest of each prototype towed behind winchers off Miminegash during 1979. [Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different. The dashed line = the grand mean.]

The figure should be used in conjunction with Table 5.

The means are the result of pooling the prototypes with and without foils.

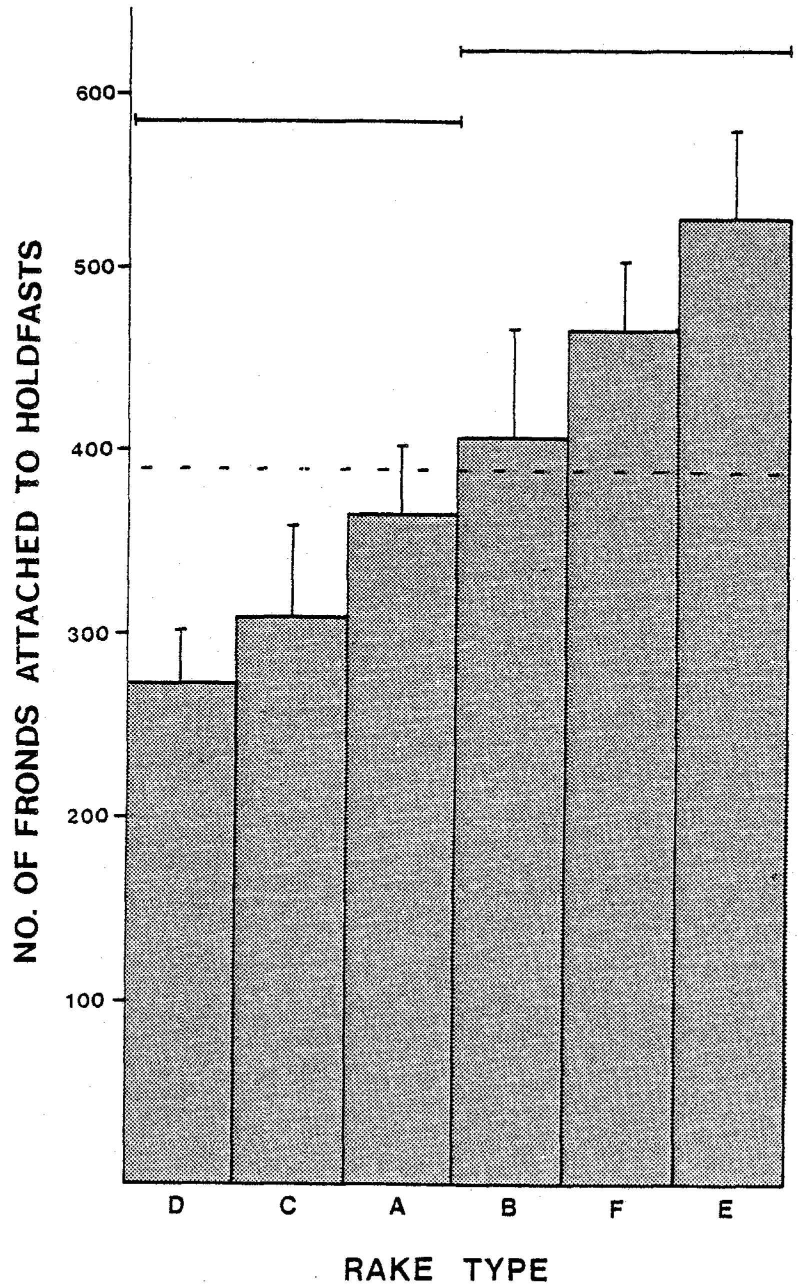

Figure 28. The number of fronds/3,000 fronds attached to holdfasts in the harvest of each prototype towed behind winchers off Miminegash during 1979. [Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different. The dashed line = the grand mean.]

The figure should be used in conjunction with Table 5.

The means are the result of pooling the prototypes with and without foils.

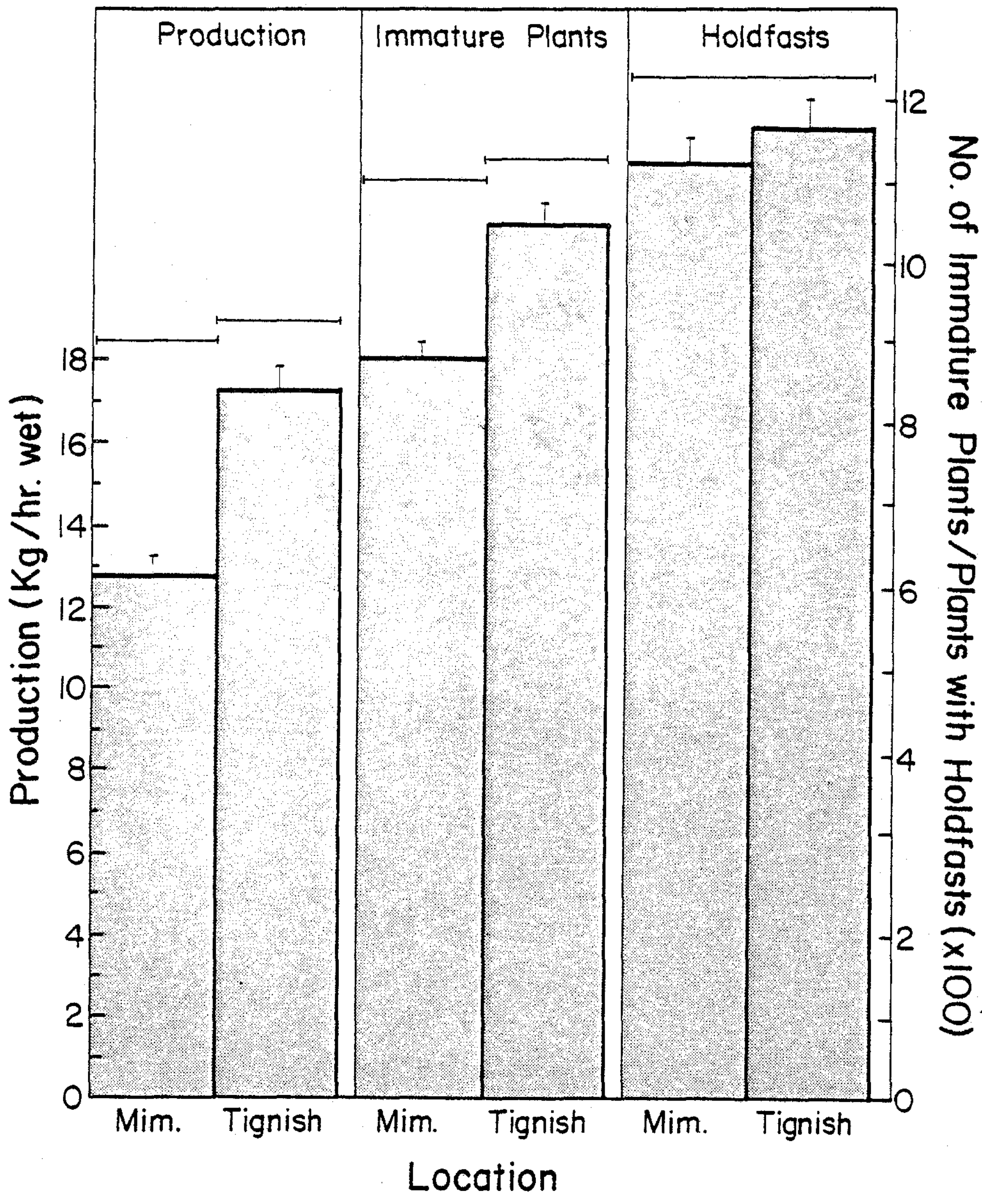

Figure 29. The grand means acquired by pooling all data for each prototype and the traditional dragrake (x) behind both haulers and winchers during 1978 separately for Miminegash and Tignish. Fishing success, number of immature fronds, and number of fronds attached to holdfasts in each harvest are given. [Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant difference ($P < 0.05$): the means under a common line are not significantly different.]

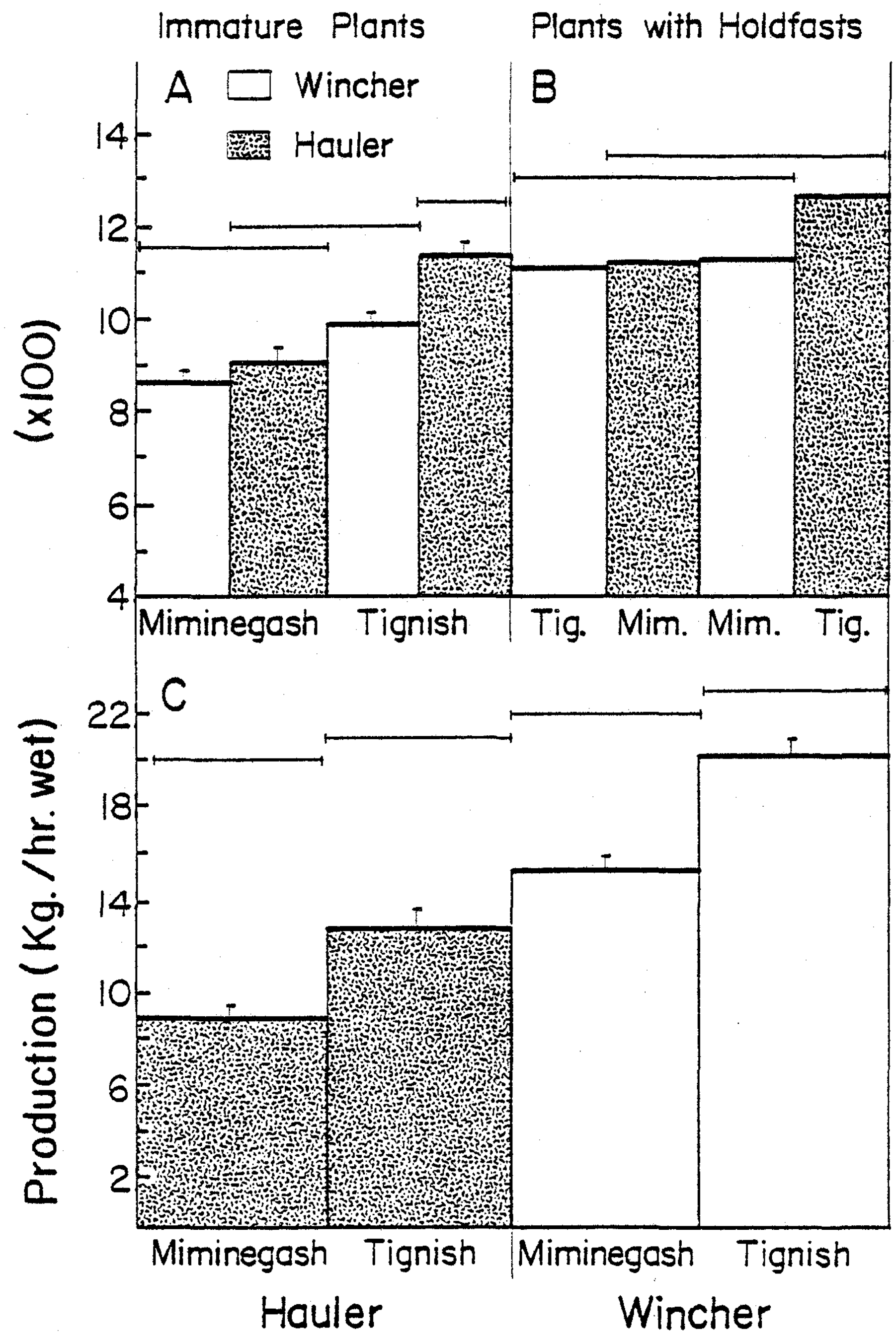

Figure 30. The grand means for all prototypes plus the traditional dragrake (x) pooled separately for winchers and haulers off Miminegash and Tignish during 1978. The number of immature fronds per 3,000 fronds (A), the number of fronds attached to holdfasts per 3,000 fronds (B), and fishing success (C) are given. [Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significant differences ($P < 0.05$): the means under a common line are not significantly different.]

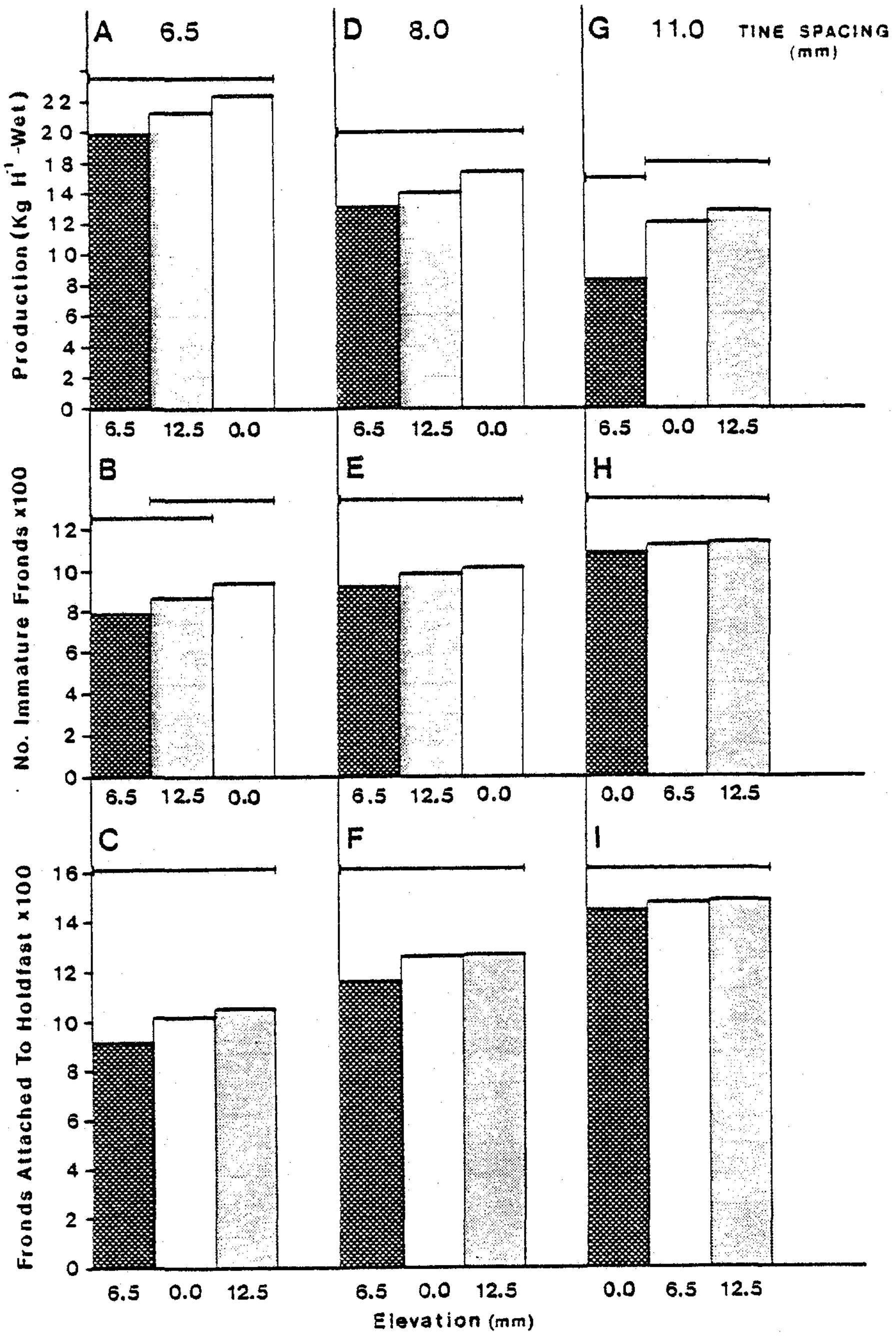

Figure 31. Pooled data for fishing success, number of immature fronds per 3,000 fronds, and number of fronds attached to holdfasts per 3,000 fronds for each prototype towed behind haulers and winchers off both Miminegash and Tignish during 1978.

A,B,C. Pooled data for all rakes with 6.5 mm tine spacing given separately for each tine elevation.

D,E,F. Pooled data for all rakes with 8.0 mm tine spacing given separately for each tine elevation.

G,H,I. Pooled data for all rakes with 11.0 mm tine spacing given separately for each tine elevation.

[Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significance ($P < 0.05$): the means under a common line are not significantly different.]

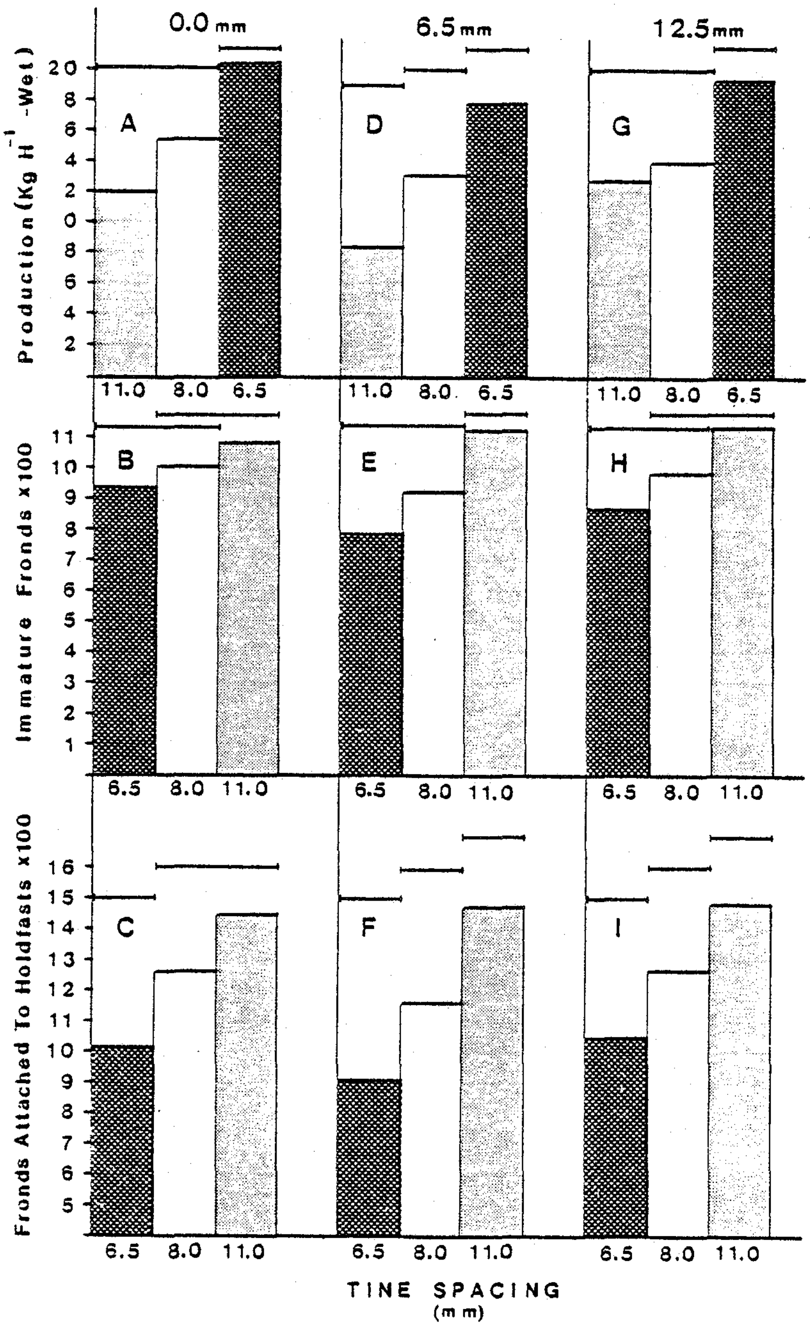

Figure 32. Pooled data for fishing success, number of immature fronds per 3,000 fronds, and number of fronds attached to holdfasts per 3,000 fronds for each prototype towed behind haulers and winchers off both Miminegash and Tignish during 1978.

A,B,C. Pooled data for all rakes with 0.0 mm tine elevation given separately for each tine spacing.

D,E,F. Pooled data for all rakes with 6.5 mm tine elevation given separately for each tine spacing.

G,H,I. Pooled data for all rakes with 12.5 mm tine elevation given separately for each tine spacing.

[Vertical lines above the bars = standard error of the mean; horizontal lines above the bars = levels of significance ($P < 0.05$): the means under a common line are not significantly different.]