Long-term Effects of Mechanical Harvesting on Eurasian watermilfoil

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Management Perspective

Eurasian watermilfoil is a nuisance aquatic plant which has invaded many lakes and rivers in Canada. Mechanical harvesting is generally agreed to be the most ecologically sound control method but is criticized because multiple harvests may be required each growing season and no long-term effect on regrowth may be apparent. Environment Canada's research has examined the short and long-term effects of mechanical harvesting.

A previous NWRI report (#85-36) outlined the observed response of milfoil to 19 different harvesting strategies. The most effective cutting scenario was a June/September double cut. A four year long-term harvesting experiment using the June/September double cut strategy was initiated in 1981.

Milfoil biomass, shoot weight and plant density were reduced over the four years; however, plant height was maintained at the water's surface in the last year. The effect on biomass but not plant height was also observed in the earlier report. Smaller root masses were observed in the harvested area. A linear relationship was determined between shoot weight and root weight, suggesting that harvesting of shoot material would result in some root die-back.

The reason for the reduction of biomass in the harvested plot was unclear. Tissue phosphorus and carbohydrates and sediment phosphorus were affected by harvesting but the changes could not explain the biomass reduction.

The purpose of harvesting milfoil is to improve the recreational potential of the lake. Recreational potential is determined to a great extent by boating access. Since the milfoil managed to maintain a plant canopy at the water's surface in the fourth year of the study, boating access would still be restricted, although somewhat easier due to the decreased milfoil density and plant weight.

Perspective-gestion

Le myriophylle de l'Eurasie est une plante aquatique nuisible qui a envahi de nombreux lacs et rivières au Canada. On admet en général que sur le plan écologique, la récolte mécanique est la méthode de lutte contre cette plante la plus appropriée mais elle est critiquée parce que plusieurs récoltes peuvent être nécessaires au cours de chaque saison de croissance et qu'il est possible qu'aucun effet à long terme ne soit évident sur la repousse. Dans le cadre des travaux de recherche d'Environnement Canada, on s'est penché sur les effets à court terme et à long terme de la récolte mécanique.

Dans un précédent rapport de l'INRE (85-36), les auteurs ont examiné la réaction du myriophylle à 19 méthodes différentes de récolte. Le scénario de coupe le plus efficace a été celui d'une double coupe effectuée en juin et en septembre. En 1981, on a entrepris une expérience de récolte à long terme d'une durée de quatre ans au cours de laquelle on a utilisé la méthode de la double coupe en juin et en septembre.

La biomasse du myriophylle, le poids des pousses et la densité végétale ont été réduits au cours des quatre années; toutefois, la dernière année, la hauteur de la plante demeurait au niveau de la surface de l'eau. Dans le rapport précédent on avait également observé l'effet sur la biomasse mais non sur la hauteur de la plante. Des masses radiculaires plus petites ont été observées dans la zone récoltée. Un rapport linéaire a été établi entre le poids des pousses et la poids des racines, ce qui porte à croire que la récolte de pousses entraînerait un certain dépérissement des racines.

La réduction de la biomasse dans la parcelle récoltée n'a pu être expliquée clairement. La teneur en phosphore et en hydrates de carbone des tissus et la teneur en phosphore des sédiments ont été touchées par la récolte mais les modifications n'expliquent pas la réduction de la biomasse.

La récolte de cette plante a pour but d'améliorer le potentiel récréatif du lac. Ce potentiel est établi en grande partie par l'accès à la navigation de plaisance. Étant donné que cette plante a maintenu une couverture végétale à la surface de l'eau au cours de la quatrième année de l'étude, l'accès à la navigation sera encore limitée, même si elle est un peu plus facile à cause de la baisse de densité de la plante et de son poids.

Abstract

The long-term efficacy of mechanical harvesting of Eurasian watermilfoil was examined over a four year period. The harvesting strategy chosen was a double cut performed in June and September of each year. Milfoil biomass, shoot weight and plant density were reduced; however, plant height was maintained at the water's surface in the fourth year of the study. Smaller root masses were observed in the harvested area. A linear relationship between shoot weight and root weight was determined suggesting that harvesting of shoot material would result in some root die-back.

Tissue concentrations of phosphorus and total non-structural carbohydrates increased and decreased, respectively. Tissue phosphorus concentrations were above growth-limiting levels, nor were any trends discernible that would explain the impact of harvesting on milfoil biomass. Carbohydrate concentrations were reduced particularily in the fall and subsequent spring, but any differences between harvested plants and control plants were eliminated by mid-summer. The effect of harvesting on biomass did not appear to be related to shoot or root carbohydrate concentration trends.

Sediment biologically-available phosphorus concentrations were reduced in the last two years of the study; however, since tissue concentrations were not limiting, the effect of harvesting would not appear to be related to changes in sediment phosphorus.

Résumé

L'efficacité à long terme de la récolte mécanique du myriophylle de l'Eurasie a été étudiée pendant une période de quatre ans. On a choisi comme méthode de récolte la double coupe effectuée chaque année en juin et en septembre. La biomasse de la plante, le poids des pousses et la densité végétale ont été réduits; toutefois, la hauteur de la plante demeurait au niveau de la surface de l'eau au cours de la quatrième année. On a observé des masses radiculaires plus faibles dans la zone récoltée. On a établi une relation linéaire entre le poids des pousses et le poids des racines, ce qui porte à croire que la récolte des pousses entraînerait un certain dépérissement des racines.

La teneur des tissus en phosphore et la teneur en hydrates de carbone totaux non structuraux ont respectivement augmenté et diminué. La teneur en phosphore des tissus dépassait la teneur limitant la croissance, et aucune tendance discernable n'a pu expliquer les répercussions de la récolte sur la biomasse de cette plante. La concentration en hydrates de carbone a été abaissée surtout à l'automne et au printemps suivant, mais toute différence entre les plantes récoltées et les plantes témoins avait disparu avant le milieu de l'été. L'effet de la récolte sur la biomasse ne semblait pas être lié aux tendances de la teneur en hydrates de carbone des pousses ou des racines.

Les teneurs en phosphore biologiquement actif dans les sédiments ont été réduites au cours des deux dernières années de l'étude; toutefois, puisque la teneur dans les tissus ne constituait pas un facteur limitatif, l'effet de la récolte ne semblerait pas lié aux modifications de la teneur en phosphore des sédiments.

Introduction

Mechanical harvesting is commonly employed to control the nuisance aquatic plant, Eurasian watermilfoil (Myriophyllum spicatum). The ability of harvesting to achieve long-term control is desirable but questionable. Perkins and Sytsma (1982) reported that no long-term control of biomass was achieved in their harvesting experiments in Union Bay, Lake Washington. Kimbel and Carpenter (1979) reviewed several research harvesting projects and observed that harvesting had an impact on regrowth in the second year in 12 of 13 reported projects. Painter and Waltho (1985) observed that if a fall harvest was conducted then the biomass was significantly affected in the second year but plant height was not.

Tissue chemistry, particularily total non-structural carbohydrates (TNC), has been examined in an attempt to explain the effects of harvesting on regrowth. Harvesting would remove photosynthetic tissues which would otherwise be producing storage carbohydrates possibly necessary for over-winter survival. Harvesting would also remove tissue nutrients and further growth and uptake of nutrients from the sediment could possibly deplete the sediment nutrient pool if the harvesting program was maintained over a long period. Both Perkins and Sytsma (1982) and Painter and Waltho (1985) observed declines in tissue carbohydrates as a result of harvesting. Painter and Waltho (1985) also observed minor effects on tissue phosphorus, nitrogen and carbon. The effect of harvesting was most pronounced on root TNC which was reduced 36.3% in the harvested plants. Lower root TNC was observed in 18 of 19 harvested plots in June of the subsequent year.

The possibility of long-term control of Eurasian watermilfoil was examined by harvesting a 2 hectare plot in Buckhorn Lake for 4 years. A harvesting scenario was chosen that Painter and Waltho (1985) had observed would have the most impact on the subsequent year's biomass and tissue chemistry.

Methods

One experimental and one control plot were located in 1.5 to 2.5 meters of water on the west side of Nichol Island in Buckhorn Lake, Ontario. The 2 hectare plots were created by dividing a bay in half length-wise. Painter and Waltho (1985) had previously used the bay to examine the short-term impact of 19 harvesting strategies, therefore, two years of pre-treatment data were available for most of the parameters sampled. Eurasian watermilfoil was the dominant aquatic plant present in the area and its biomass was extremely dense and uniform. A single cut was performed in the fall of 1980 and June and September cuts were performed from 1981 to 1984. The harvesting was contracted to a local contractor. The milfoil was cut at approximately 50 cm from the sediment surface. Sampling of both the control and harvested areas was conducted monthly from April to November of each year.

Milfoil shoot weight was determined by obtaining 25 random samples of milfoil plants from each area and weighing the shoot material. Plant density was determined using the Point-Centered

Quarter Method as described in Mueller-Dombois and Ellenberg (1974). The closest individual method and the Point-Centered Quarter method were tested with two samplers and compared with actual density measurements and the Point-Centered Quarter method was determined to be accurate (+/- 1 plant/m^2) for density measurements of Eurasian watermilfoil. A plotless, non-destructive sampling method was chosen to minimize the damage to the plots. Biomass was determined from shoot weight and plant density.

Shoot and root samples were analyzed for % water, % organic content, total non-structural carbohydrates, and total phosphorus. Sediment samples were obtained by Ekman grab and were analyzed for biologically available phosphorus and spring sediment samples were analyzed for CDB and NaOH-extractible phosphorus, Apatite phosphorus, total inorganic and total phosphorus. Total phosphorus of the plant material and the various sediment phosphorus fractions were determined as described in Mayer and Williams (1981). Biologically-available phosphorus was determined on the sediments using a 0.1 N NaOH extraction (Williams et al. 1980).

Plant material was dried for 16 hours at 75 C for determination of dry weight. Loss on ignition (% organic content) was determined on dried plant material which was ignited in a muffle furnace at 550 C for two hours. Total non-structural carbohydrates were determined by enzymatic extraction with amyloglucosidase for conversion of starches to glucose and glucose analysis using the phenol-sulphuric acid colorimetric method (J. Burton, pers. comm.). The loss on ignition values were used to correct the chemical analyses, initially expressed on a dry weight basis (DW), to an ash-free dry weight basis (AFDW).

Results and Discussion

The biomass of Eurasian watermilfoil was reduced by the double harvesting treatments performed (Fig 1). The milfoil biomass in the control plot fluctuated during the six years sampled. The cause for the dramatic drop in the biomass in 1982 in the control plot cannot be ascribed to climatic conditions in either the previous winter or that growing season and remains unknown. Shoot weight of the harvested plants was also reduced compared to the control plants (Fig 2). Plant density in the harvested area dropped while in the control area the density increased (Table 1). The density increase in the control area in 1983 was probably a response to the drop in shoot weight in 1982. In 1982, the shoot weight and size was much smaller than the previous year, therefore, allowing more light penetration to the sediment surface and increased chances for shoot fragments to root and establish. The shoot weight in the harvested area naturally decreased as a result of the harvesting but the plant density decreased rather than increased as would have been expected. Since plant density increased in the control area when shoot weight decreased, the observed decrease in plant density in the harvested area is significant. One possible hypothesis is that the harvesting affected the sediment chemistry in such a way as to thwart shoot fragment establishment.

Plant height was not measured rigorously but visual observations were recorded. The biomass in the harvested area in 1983 had been affected to such an extent that harvesting throughout the season would not have been necessary to maintain boating access. In 1984, however, the milfoil shoot weight and biomass had increased very slightly, but plant height had increased, so that the stems were reaching the water's surface and restricting access. The plant density and shoot weight were affected by the harvesting, but the milfoil stems were capable of reaching the water's surface in 1.5-2.5 meters of water after four years of harvesting. Boating access was easier in the harvested area than the control area, but frequent stops to clean the propeller were still necessary. Painter and Waltho (1985) also observed in an earlier study on short-term harvesting effects that milfoil biomass was affected in the year following harvesting but that plant height was not.

During the last year of the experiment, the root masses of the harvested plants appeared to be much smaller than those of the control plants. For several months the root weights of the 25 plant samples from both the harvested and control areas were also measured. Root weight in the harvested area was smaller. The root to shoot percents for both areas were similar so the observed smaller root mass in the harvested area was due to the smaller shoot size. Root weight was linearly related to shoot weight ($RW= 0.778 + 0.194*SW$, $r=0.69$, $df=123$, $p<0.001$). Therefore, root/shoot percents were inversely related to shoot weight. For mature plants which had the stems removed by harvesting, the root/shoot percent approached 100% and for large uncut plants the root/shoot percent approached 20%. Harvesting resulted in smaller shoot weights which then resulted in some root death, since the remaining milfoil shoots could not support the total root mass.

Shoot and root phosphorus concentrations generally increased after harvesting as was previously observed by Painter and Waltho (1985). Tissue concentrations would appear to be high enough not to limit growth (Figures 3 &4). Schmitt and Adams (1981) determined that photosynthesis would approach maximum rates at tissue phosphorus concentrations of 0.3% or 3000 ug/g DW (approx. 3333 ug/g AFDW). No trends in the shoot or root phosphorus concentrations were discernible over the four years of the harvesting experiment that would explain the drop in biomass as a result of harvesting or the poor growth in 1982.

Shoot and root total non-structural carbohydrate concentrations (Figures 5 &6) were similar or higher than previously reported observations (Perkins and Sytsma, 1982; Titus and Adams, 1979). Harvesting resulted in a reduction in the TNC concentrations in the roots after both harvests. The spring root TNC concentrations were also reduced. The TNC concentrations in the shoots appeared to be affected only in the fall and the effect carried over until the spring. A reduction in the spring TNC concentration as a result of a fall harvest has been previously reported (Painter and Waltho, 1985). The spring differences in shoot and root TNC concentrations between control and harvested plants were eliminated by mid-summer. The effect of harvesting on biomass did not appear to be related to shoot or root TNC trends during the four years.

Sediment biologically-available phosphorus concentrations were reduced in the spring in the last two years in the harvested area compared to the control area (Figure 7). Phosphorus fractionation analysis of the surficial sediment from the spring period during the six years confirmed that the BAP and total inorganic phosphorus concentrations were reduced in the last two years and the CDB phosphorus fraction was reduced in the last year in the harvested area (Table 2). The total phosphorus concentration averaged 1373 ug P/g over the six year period. This concentration was twice as high as was observed in L. Wingra (Prentki, 1979) but was similar to the Great Lakes (Mayer and Williams, 1981). Prentki reported that L. Wingra sediments were roughly 50 % organic and 50% inorganic phosphorus, whereas, Buckhorn Lake sediments are roughly 70% organic and 30% inorganic phosphorus. The total inorganic phosphorus concentrations in the two lakes were similar (400 ug P/g) but in L. Wingra more than half of the inorganic phosphorus was residual (apatite) phosphorus. In Buckhorn Lake only 25% of the inorganic phosphorus was residual, leaving 75% as potentially available for uptake. The shoot and root tissue phosphorus concentrations would suggest that phosphorus in the sediments was not limiting growth. Harvesting appears to have had an effect on the readily available sediment phosphorus fractions in the last two years of the four year harvesting experiment but the reduction in sediment phosphorus did not appear to translate into a reduction in tissue phosphorus concentrations. Therefore, the reduction in the sediment phosphorus fractions cannot explain the impact of harvesting on the biomass of milfoil.

Conclusions

A double harvesting program carried out over a four year period reduced Eurasian watermilfoil biomass and plant density. In the third year of the program, the milfoil biomass and plant height had been affected sufficiently so that harvesting would not have been necessary to maintain boating access. The second year of the program, however, was a poor year for milfoil growth in the control area and presumably in the harvested area as well. The milfoil in the control area recovered in the third and fourth years, but the harvested milfoil biomass continued to be reduced. The milfoil in the harvested area managed to reach the water's surface in the fourth year, even though plant weight and plant density were still reduced. Root weight and shoot weight were related linearly which meant that harvesting shoot material also resulted in some die-back of root material.

Tissue concentrations of phosphorus and total non-structural carbohydrates were affected as has been previously observed (Painter and Waltho, 1985). Tissue phosphorus concentrations increased after harvesting and the levels were above growth limiting levels. No trend in tissue phosphorus concentration was discernible over the four years that would explain the drop in biomass as a result of harvesting. Carbohydrate concentrations were reduced particularily in the fall and subsequent spring, but the differences between the harvested plants and the control plants were eliminated by mid-summer. The effect of harvesting on biomass did not appear to be related to shoot or root TNC trends.

Sediment biologically-available phosphorus concentrations were reduced in the last two years in the harvested area but since the tissue concentrations were not limiting, the effect of harvesting would appear not to be related to sediment phosphorus. Nevertheless, harvesting did affect the milfoil growth by decreasing the shoot weight, decreasing the plant density and limiting the establishment of milfoil fragments. Some other chemical within the sediment would appear to have been affected. Recently, Anderson and Kalff (1985) reported that nitrogen enrichment of the sediment resulted in a 30-40% increase in milfoil biomass compared to no response for phosphorus or potassium enrichment.

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Figure Legends

Figure 1: Eurasian watermilfoil biomass (gDW/m^2) in the control and harvested areas from 1979 to 1984.

Figure 2: Eurasian watermilfoil shoot weight (g) in the control and harvested areas from 1981 to 1984.

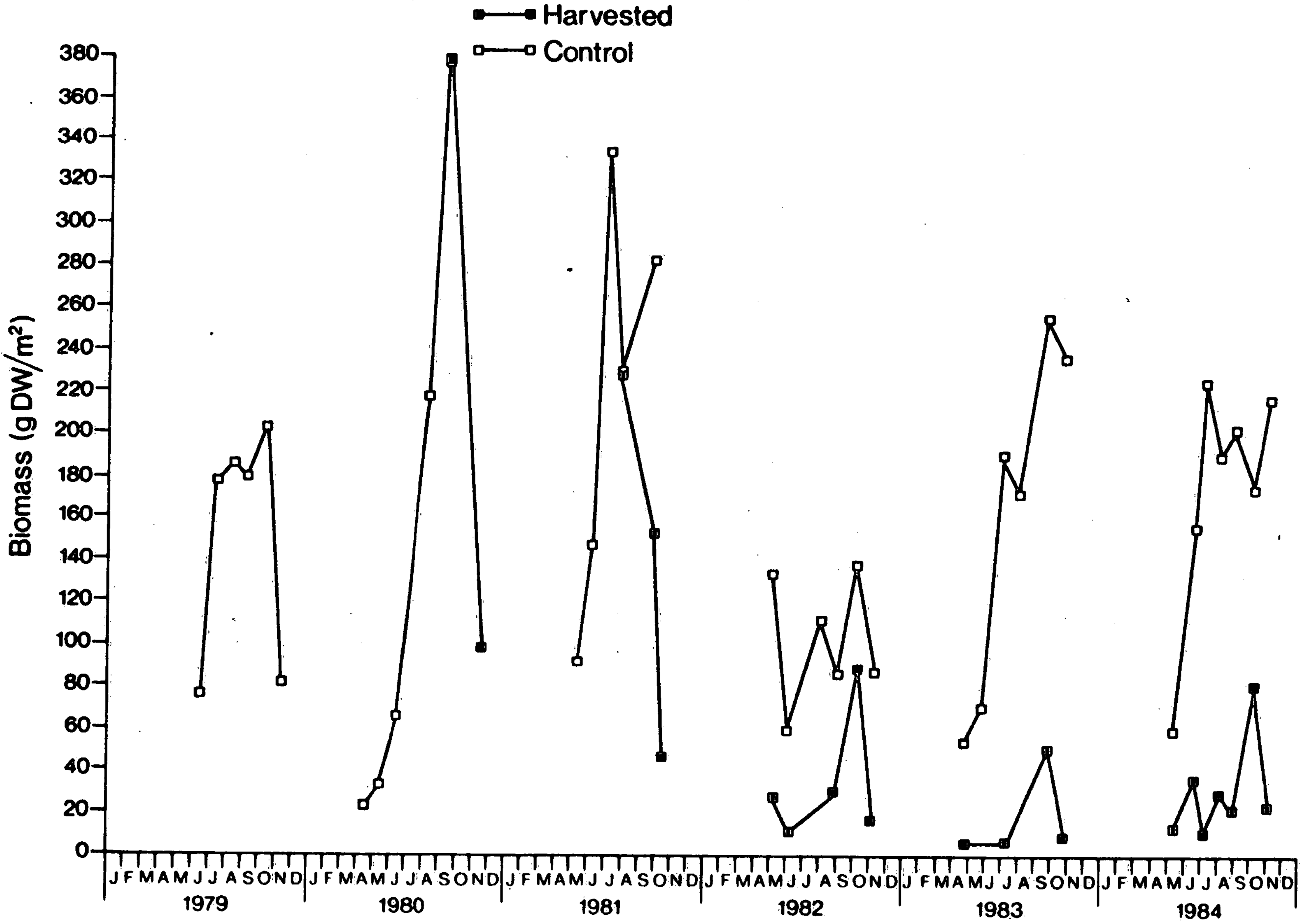
Figure 3: Eurasian watermilfoil shoot phosphorus (ug P/gAFDW) in the control and harvested areas from 1979 to 1984.

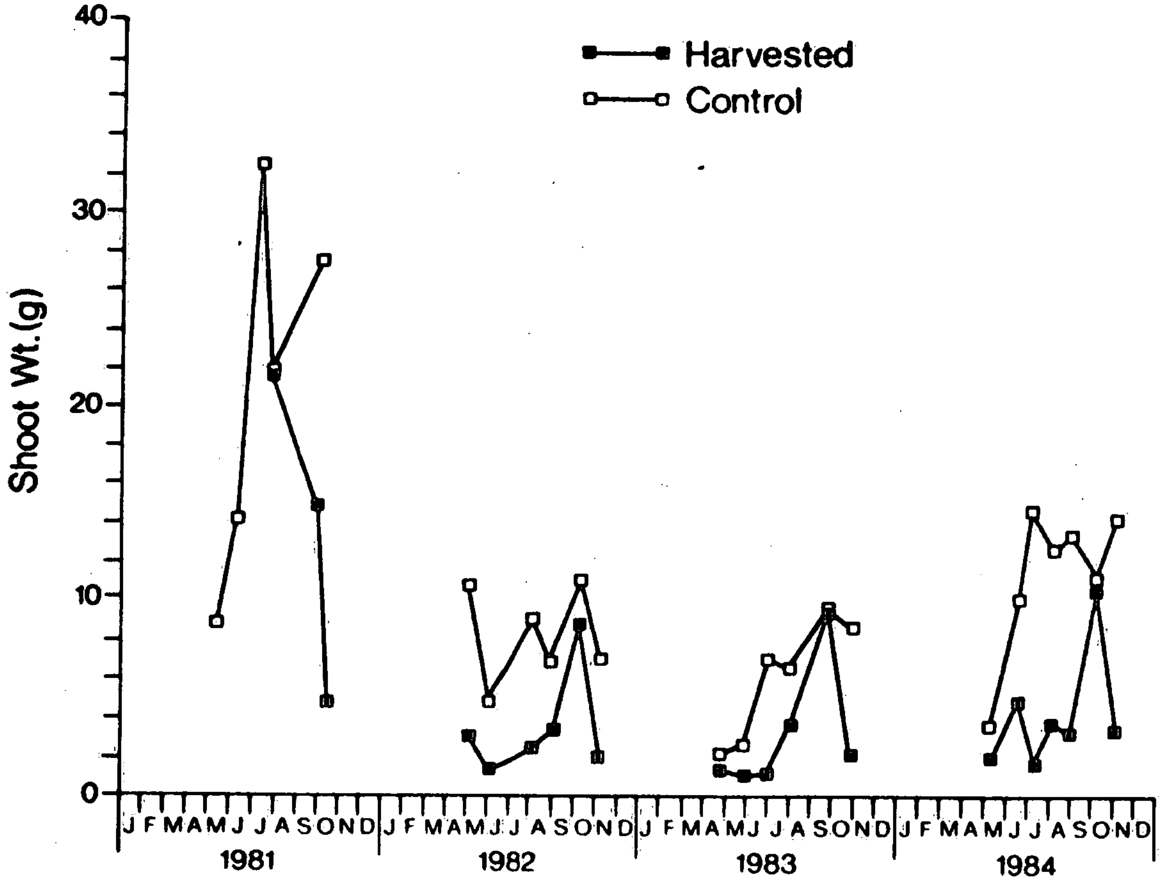
Figure 4: Eurasian watermilfoil root phosphorus (ug P/gAFDW) in the control and harvested areas from 1979 to 1984.

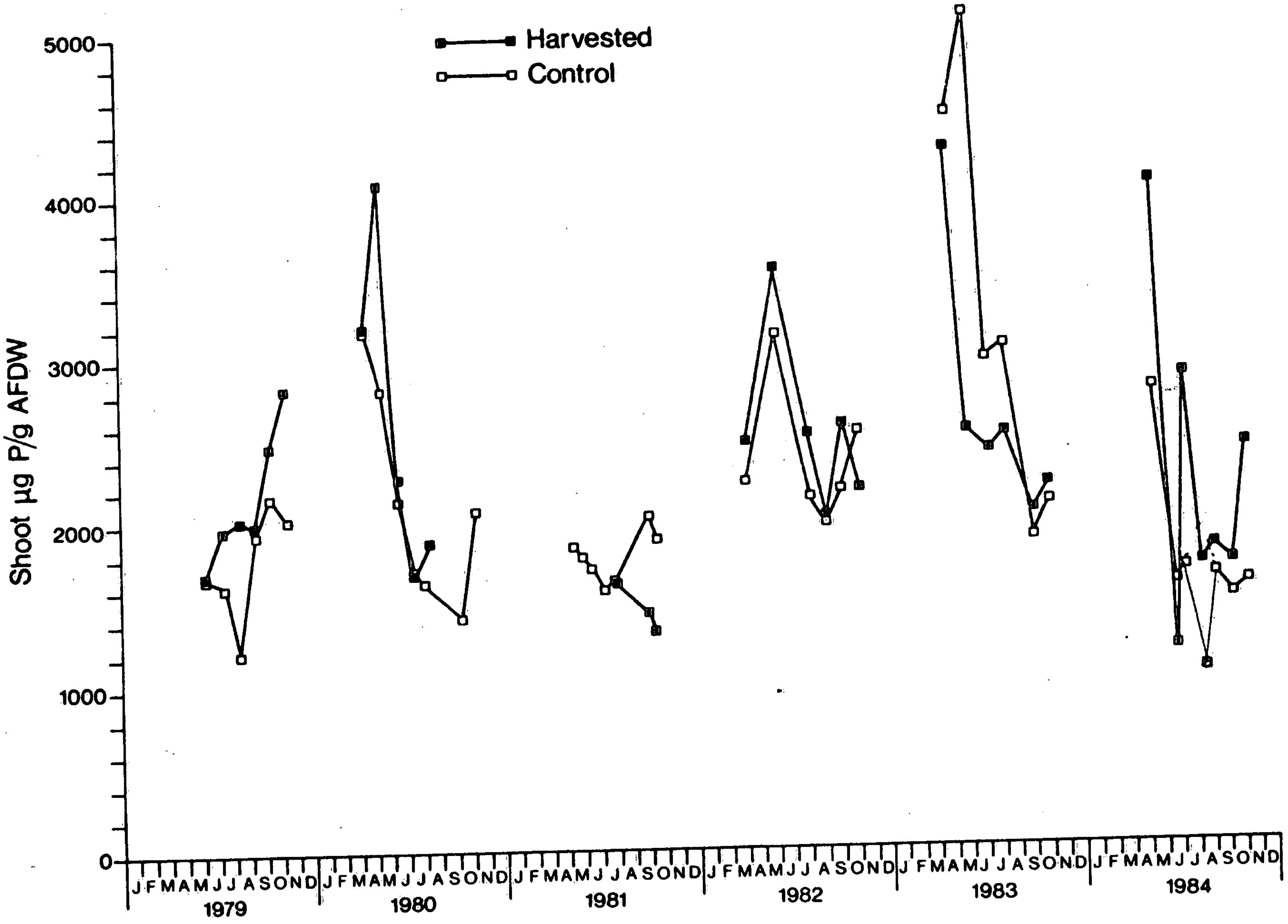
Figure 5: Eurasian watermilfoil shoot total non-structural carbohydrates (mg TNC/gAFDW) in the control and harvested areas from 1979 to 1984.

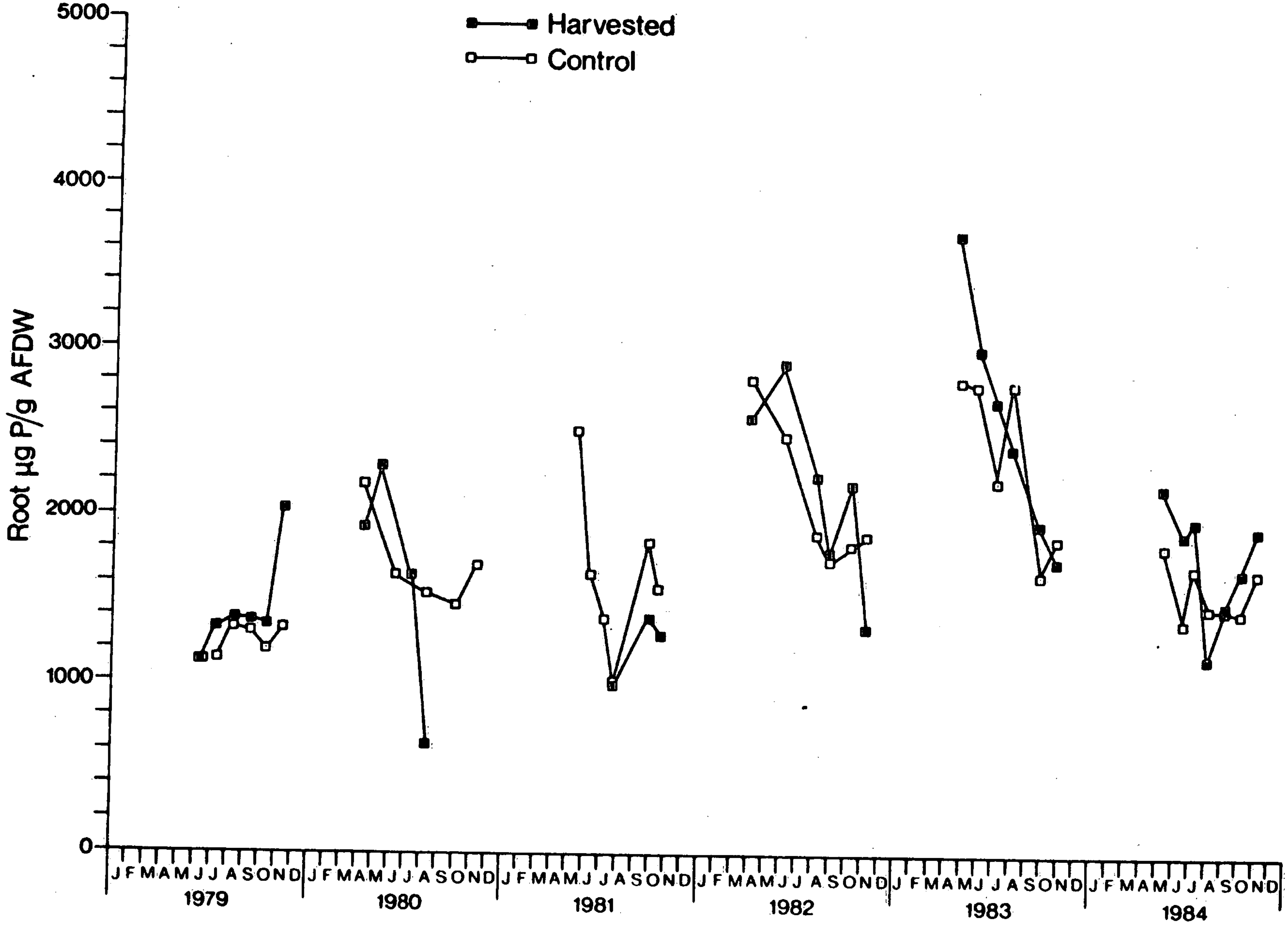
Figure 6: Eurasian watermilfoil root total non-structural carbohydrates (mg TNC/gAFDW) in the control and harvested areas from 1979 to 1984.

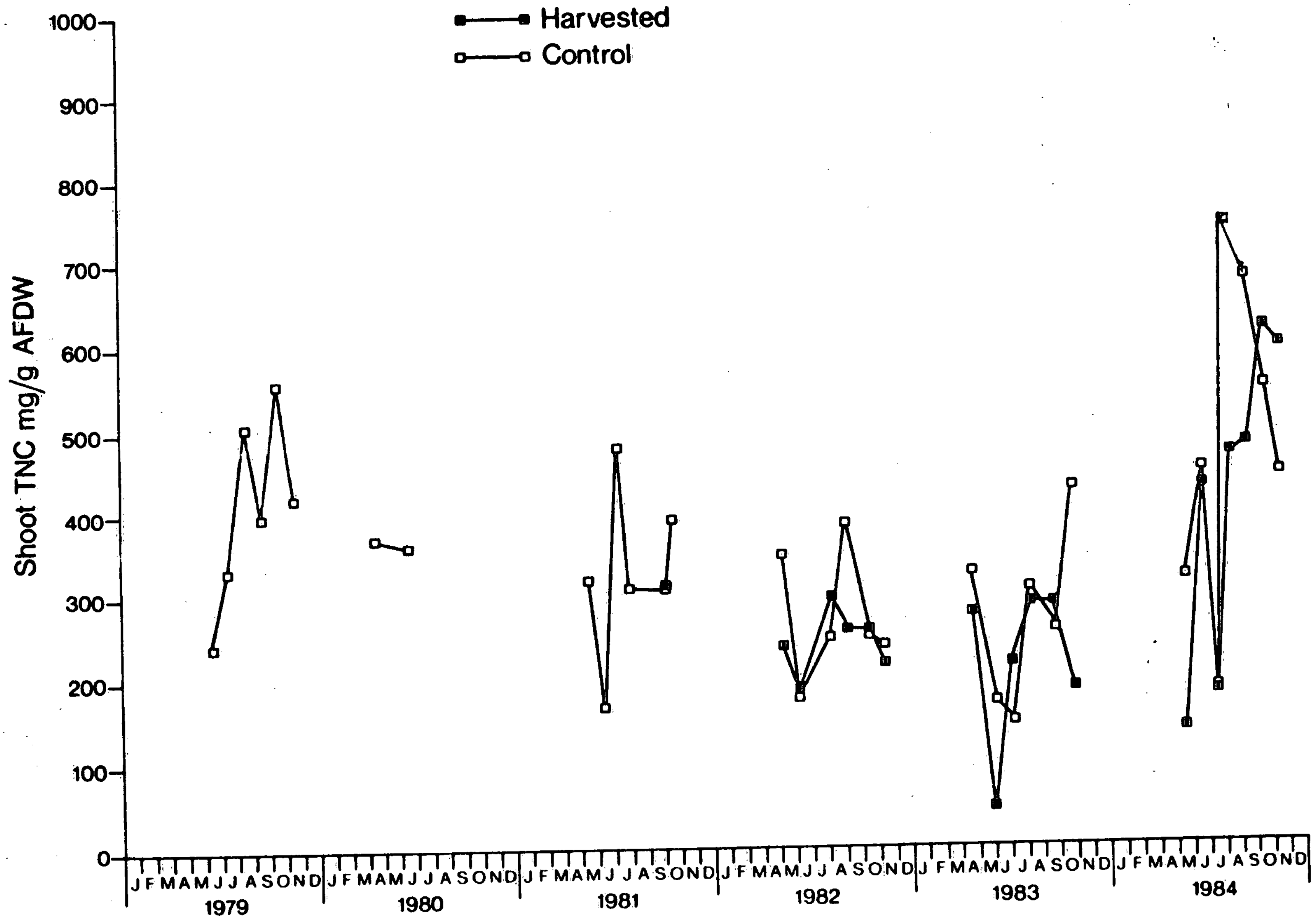
Figure 7: Biologically available phosphorus (ug P/g DW) in the surficial sediment in the control and harvested areas from 1981 to 1984.

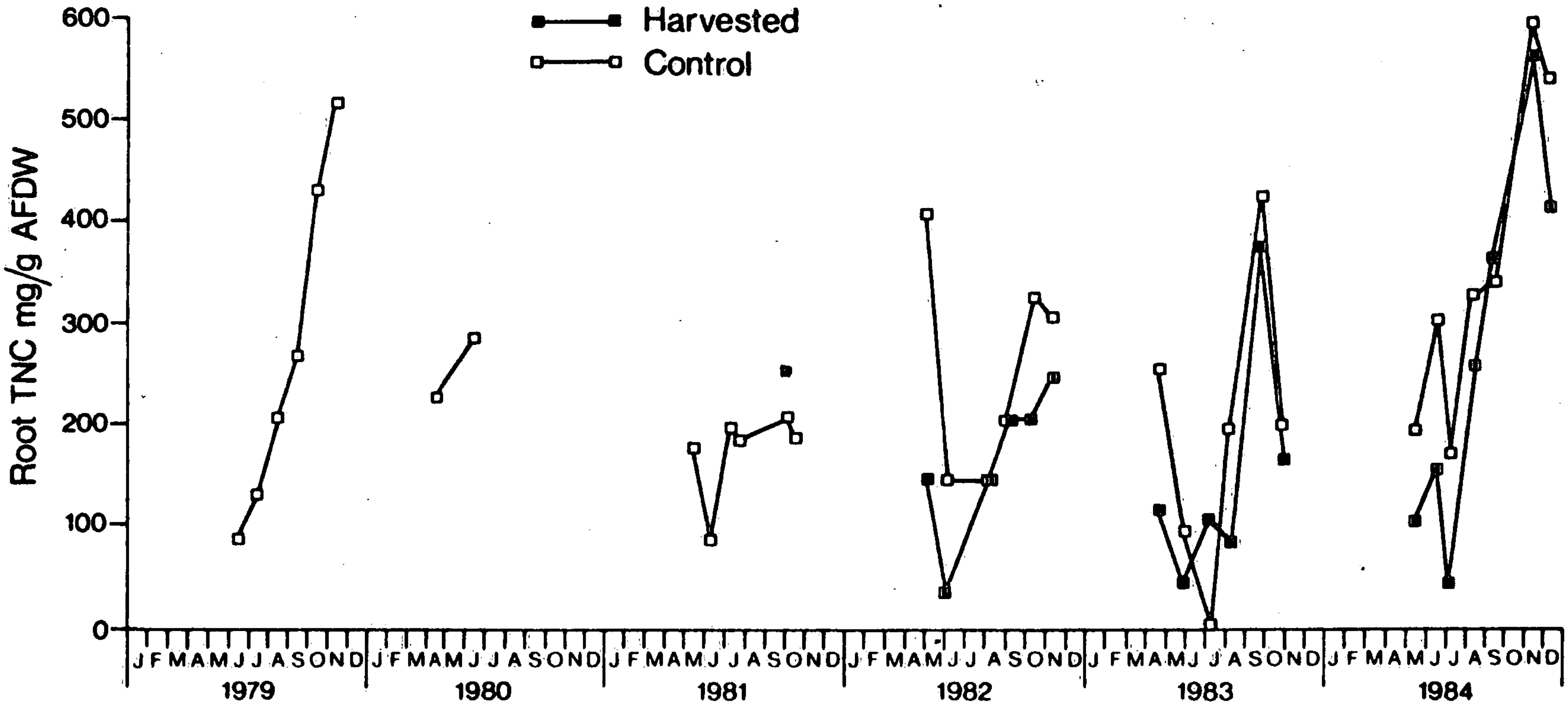

Harvested
Control
Biomass (g DW/m²)
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
J F M A M J J A S O N D
1979
J F M A M J J A S O N D
1980
J F M A M J J A S O N D
1981
J F M A M J J A S O N D
1982
J F M A M J J A S O N D
1983
J F M A M J J A S O N D
1984


Harvested
Control
Shoot Wt.(g)
0
10
20
30
40
J F M A M J J A S O N D
1981
J F M A M J J A S O N D
1982
J F M A M J J A S O N D
1983
J F M A M J J A S O N D
1984


Harvested
Control
Shoot µg P/g AFDW
5000
4000
3000
2000
1000
0
J F M A M J J A S O N D
1979
1980
1981
1982
1983
1984


Harvested
Control
Root µg P/g AFDW
5000
4000
3000
2000
1000
0
J F M A M J J A S O N D
1979
1980
1981
1982
1983
1984


■—■ Harvested
□—□ Control
Shoot TNC mg/g AFDW
1000
900
800
700
600
500
400
300
200
100
0
J F M A M J J A S O N D
1979
1980
1981
1982
1983
1984


Harvested
Control
Root TNC mg/g AFDW
600
500
400
300
200
100
0
J F M A M J J A S O N D
1979
1980
1981
1982
1983
1984

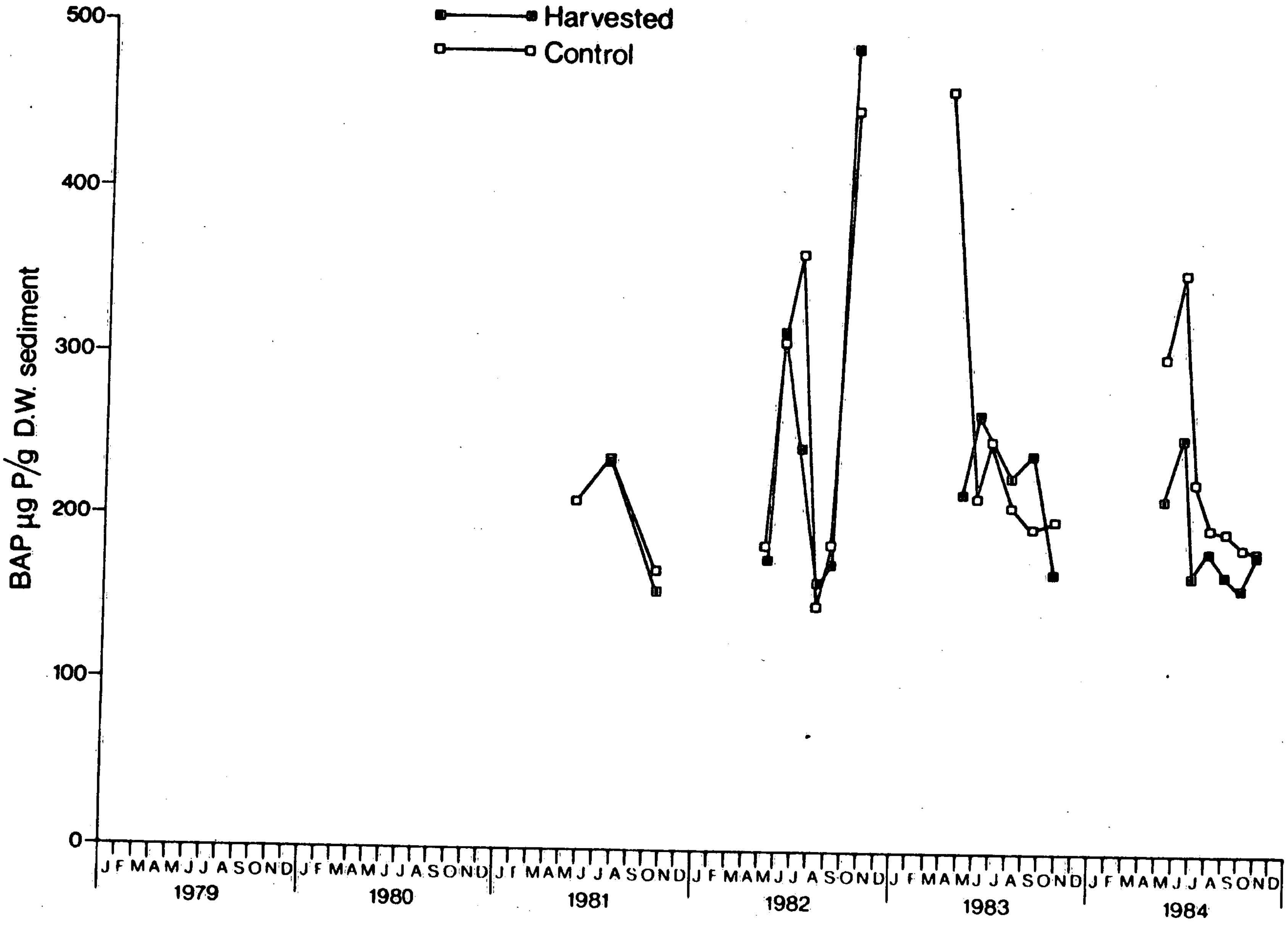

Harvested
Control
BAP µg P/g D.W. sediment
500
400
300
200
100
0
J F M A M J J A S O N D
1979
1980
1981
1982
1983
1984

Table Legends

Table 1: Plant Density (plants/m^2) in the control and harvested areas from 1981 to 1984.

Table 2: Surficial sediment phosphorus fractionation for the control area (C) and harvested area (H) from 1979 to 1984. Phosphorus concentrations are in ug/gDW.

Plant Density
(Plants/m^2)

Date	Control	Harvested
1981	10.3	10.3
1982	12.5	9.4
1983	26.4	5.1
1984	15.0	7.0

Surficial Sediment Phosphorus Fractionation (ug/g)

Year	CDB-P		NaOH-P		Apatite-P		Total P		TIP		BAP	
	C	H	C	H	C	H	C	H	C	H	C	H
79	89.9		23.4		140.3		1113.2		415.5			
80	49.4		77.6		105.0		1175.9		360.8			
81	317.7		84.7		102.9		1581.3		498.9		212.4	
82	176.4	296.1	80.6	60.9	110.1	76.2	1542.6	1528.2	394.9	476.7	182.9	175.0
83	94.7	111.2	73.6	70.5	74.5	91.6	1565.7	1306.7	422.0	289.4	452.5	218.9
84	329.6	181.3	89.5	69.6	105.0	105.0	1262.0	1136.2	430.9	259.5	303.0	215.6