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Nesting Behavior and Interaction of Minnows in Tenderfoot Creek, Michigan

BIOS 569 - Practicum in Aquatic Biology

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Nesting Interactions of Minnows

Abstract

The construction of fish nests and the spawning of minnows in riffle areas of small streams are a common type of natural disturbance. Observations of spawning activity and measurements of physical, chemical, and biological parameters of nesting substrates were used to examine the hypothesis that fish nests were more prevalent in the upper reaches of riffle areas than in lower reaches.

During the study temporal changes in water temperature and discharge due to rainfall, also served as abiotic disturbances to the stream substrate. Minnows were less common in the riffle during cold temperatures and showed distribution patterns dependent on water level. High water levels provided access to all the nesting substrates, thus enhancing spawning activity, reducing insect densities and increasing concentrations of chlorophyll *a* .

Nesting Interactions of Minnows

Introduction

Disturbance can be defined as anything that disrupts the existing conditions of a habitat, and can result from various natural or anthropogenic sources. Although pollution can be a severe human caused disturbance, floods, storms, and droughts are natural disturbances that can have positive or negative effects on the pre-existing state. In many freshwater streams, the construction of fish nests is a common source of natural disturbance. During spawning periods in the northern United States (May through July) (Becker, 1983), many fish species build and maintain nests in riffle areas of streams. Riffle areas typically have high current velocities and are well-oxygenated (Hynes, 1970). Typical nesting habitats for many species are sand or gravel bottom streams with little silt and low turbidity (Trautman, 1981).

Segregation of breeding periods and the behavioral pattern associated with fish nest formation are successful mechanisms allowing habitat partitioning (Gorman, 1988). Gorman (1988) recognized six microhabitat categories that allow fish to partition stream habitats and thereby minimize niche overlap. These categories are depth, lateral, vertical, and longitudinal positioning, current velocity, and substrate size. During breeding seasons; however, stream fishes often show flexible and opportunistic habitat use. Species interact by sharing and guarding nests, and by hybridizing (Trautman, 1981). For example, the nests of Nocomis biguttatus (hornyhead chub) are used as spawning substrates for other species such as Luxilus cornutus (common shiner), Notropis heterolepis (blacknose shiner), and Semotilus atromaculatus (creek chub) (Vives et al., 1990).

Nesting of N. biguttatus begins in late May or early June (Vives et al., 1990). The nests occur in the stream riffle where the current velocity is faster, but the deeper waters of the riffle are preferred. Nests are built in close proximity to other nests and the majority are built in open areas. A male hornyhead chub begins by digging a pit about 5-10 cm deep in, or close to, an old nest. Stones are then carried by mouth to the pit to create a surface that is approximately level with the stream bottom. The male then removes some of the stones to form the spawning cup that receives the eggs from the females. The cup is further shaped by action of the chub's ventral surface and anal fins. After spawning, the male chub places more stones in and around the cup. As a result of multiple spawnings the nests eventually take the shape of mounds. Nests average 50 cm wide and 40 cm long and the mounds rise above the substrate about 6.4 cm.

The majority of nests are located in the upstream area of the riffle. In fact, 85% of the nests in a northern Michigan stream are in the upper 10% of the riffle area (M. Berg, pers. comm.). The importance of this positioning is proposed to be associated with the effects of upwelling and downwelling between the surface water and the hyporheic (sub-surface) water (Valett et al., 1990). In the upper regions of riffles, surface water infiltrates the sediments forming areas of downwelling. In these areas important to the survival of fish eggs, highly oxygenated water is delivered to the sediments. In downstream sections of the riffle, areas of upwelling bring nutrients from the hyporheic zone to the surface. These patterns may have a great influence on the nesting and feeding habits of stream minnows.

The nests built by _N_. _biguttatus_ are used by other species of fish. Five species of fish gave been observed to spawn at one nest. A commensal association exists with _Luxilus_ _cornutus_, the common shiner (Becker, 1983). The shiner shares the spawning cup with the chub and provides protection against other shiners while the chub is preparing the nest (Vives et al., 1990). _Nocomis_ _rubellus_, the rosyface shiner, engages in aggressive interactions with the chub by gathering above a nest in such abundance that they hamper the movement of the chub around the nest. The chub will charge the group of shiners and the cup (Vives et al., 1990).

Nest building by _N_. _biguttatus_ and other species is a natural disturbance in riffle areas of many streams. Their presence at breeding times results in a breakdown of Gorman's (1988) habitat categories resulting in increased interactions between fish species. Nocomis biguttatus and Luxilus cornutus take turns defending and maintaining the nest from other spawning species such as Nocomis heterolepis and Semotilus atromaculatus.

The purpose of this study was to characterize the related nesting behaviors of Nocomis biguttatus and Luxilus cornutus and other potentially competing species. In addition, environmental factors such as water temperature, dissolved oxygen, and chlorophyll a were examined in, and around, the nests. Fish nests are hypothesized to be positioned in the upper regions of riffle habitats due to the favorable conditions created by downwelling.

Several questions on fish behavior in and around the fish nests were considered. How do the species interact with one another? Which species assume the role of guarding and maintaining nests? Do the fish break from spawning activities to feed or rest? Do fish preferentially construct and use nests at the upper or lower end of the riffle? If so, what factors contribute to their use?

Methods and Materials

The longitudinal profile of the riffle study area in Tenderfoot Creek was sketched and measured along its length and width. As fish nests appeared on the substrate, they were marked with forestry flagging suspended from metal rods (placed downstream to minimize disturbance) and the location was marked on the map. Each nest was measured for its width, length, height, and distance to the nearest neighbor.

Control (artificial) nests, including spawning cup formation, were constructed close to natural nests in the upper and lower ends of the riffle. Control nests were created by a waving movement of a diver's hand, which was intended to mimic the movement of a fish's caudal fin as it cleared the stream bottom of debris. Stones of similar size to those used in natural nests were arranged to form a flat oval on the substrate. As in natural nests, the width of the nests were constructed to be greater than the length. A few stones were removed from the center of the nest and a diver's hand were used to mold a spawning cup.

Three environmental parameters were measured. Water temperature and dissolved oxygen were measured twice weekly using a YSI dissolved oxygen meter and thermistor. The amount of chlorophyll _a_ on nesting and non-nesting substrates was measured by taking replicate rock samples from areas in the upper, middle, and lower riffle at the beginning and end of the study. Epilithic algae were scraped from the rocks and was then filtered and kept frozen in the dark in film canisters. The surface area of the rocks was determined by wrapping them in aluminum foil, determining the weight of the foil, and then converting weight into square centimeters. The algae were extracted with 25 ml of methanol for twenty-four hours before being analyzed with a gas chromatograph at absorbance wavelengths of 750, 664 (chlorophyll _a_), and 665 (pheophytin). Discrepancies in the acidification process of chlorophyll _a_ yielded errors in calculations. Thus, the optical density (OD) was calculated by subtracting the absorbance at 750 nm from 664 nm. The amount of chlorophyll _a_ was determined by the following equation: Chlorophyll _a_ = 11.85(OD 664) mg/sq. cm.

Invertebrate samples also were collected by replicate rock samples from nesting and non-nesting substrates in the upper, middle, and lower riffle areas at the beginning and end of the study. Because differences in chlorophyll _a_, an indicator of algal biomass may be due to nutrient differences in nesting and non-nesting substrates, it was thought that invertebrate densities also would reflect differences in algal biomass. If fish excretion leads to enhanced algal populations, then one might expect concomitant differences in insect populations.

Results

Observations on the minnow species in Tenderfoot Creek were consistent with those made by Vives (1990).

Nesting Interactions of Minnows

Male N. biguttatus constructed nests by using their mouths to pick up stones the size of gravel. The stones were placed to form a flat oval with a depressed spawning cup. The nests became mounded after multiple spawnings in which stones were piled on top of the spawned cup and a new cup was formed beside the original one. The male hornyhead chub would frequently leave the nest to search for stones, while one L. cornutus remained to guard the nest. Other common shiners of comparable size would compete for the guard position. When another shiner came too close to the nest, the guard would aggressively approach the other and swim parallel with it until it was beyond a certain distance. The shiner maintained its role by swimming side to side and circling. If a diver's hand was placed just over the nest, the shiner and/or the chub would hit the hand with their anterior end. Abundant, smaller-sized species, between thirty and forty, waited just downstream of the nest. Some of their dorsal surfaces had open wounds behind the dorsal fin, an example of the aggressive nature that can occur in the competition for nests.

Occasionally, the guarding shiner appeared to allow some female chubs to enter the nesting area. Five or six fish from the periphery would proceed head first into the spawning cup and immediately retreat. This action was either: 1) the actual spawning, 2) a mechanism for rearranging the already laid eggs, or 3) the forming of a better spawning cup. It was observed; however, that the guarding shiners continually rubbed their ventral surfaces over the spawning cup to enhance cup formation.

Spawning activity began in the mid morning and continued throughout the day until dusk. During the early morning and late evening, minnows were observed to be feeding off algae found on rocks from the non-nesting substrates, woody debris, and macrophytes. During the night, fish activity was minimal. Many of the minnows rested quietly near the bottom just upstream of a rock or in a crevice between a rock or woody debris and the bottom. The minnows tended to rest on the sides of the riffle away from the strongest currents.

Nesting Interactions of Minnows

The first fish nest was observed on May 29 and increasingly more nests appeared as the season progressed. One week after the appearance of the first nest, fifteen newly constructed nests were discovered in the upper and middle riffle areas. By the middle of week 3, the nests had become so numerous (Fig. 1.) in all areas of the riffle that some were only tallied, and not marked or observed regularly. Discrepancies in the number of nests counted may be attributed to the fact that an individual nest will have multiple spawnings and thus expand. Often two or more nests will combine to form one large, spawned, nested area.

In the fifth week of the study, the minnows left the riffle and spawning activity ceased. The water level had dropped substantially from late May, exposing the tops of nests in the 5 cm deep areas of the lower riffle. Areas at the upper end of the riffle and downstream of the lower end however, had become more suitable spawning areas and spawning activity resumed. Spawning activities also were observed far downstream of the riffle area as indicated by the presence of fish nests. The few fish that remained in the shallower upstream riffle were smaller in size compared to the larger shiners and chubs found downstream in the newly extended riffle areas.

In the beginning of July, water levels in Tenderfoot Creek increased as a result of late June precipitation. Water levels were similar to those in the Spring. As a result, the minnows again were absent from the riffle and spawning had ceased a second time. Within a week, fish had returned in high numbers to all areas of the riffle and spawning activities continued. The number of spawning hornyhead chubs; however, decreased and was replaced by <u>S</u>. <u>atromaculatus</u>.

Of the fifteen artificial nests in which construction had begun, all were eventually used by stream fishes in some manner. Twelve of the artificial nests were completed by the natural spawning activities of fish. One nest was created using the stones from an artificially-begun nest, but were carried upstream approximately 30 cm. Later, however, another nest was built in the area that had initially been cleared. Similarly, stones from two artificial nests at the pool downstream of the riffle were transported laterally approximately 30 cm where the natural nests appeared at the end of the study.

The mean dimensions (length, width, and height) of the nests in the upper, middle, and lower areas of the riffle were statistically similar according to the Kruskal-Wallis test (Table 1.). The probability failed to reject the null hypothesis of equal mean lengths. The null hypotheses for equal mean widths and equal mean heights also were failed to be rejected.

Analysis of the distribution of fish nests (Fig. 2.) shows that a greater number of nests occurred in the upper regions of the riffle. The distance from one nest to their nearest neighbor was used to determine whether the nests were clumped or spaced randomly. This was determined by calculating a coefficient of dispersion (CD) where CD= variance/mean. A CD of <1 indicates that the nests were spaced randomly; whereas, a CD of >1 indicates that the nests were clumped. The CD for nests in Tenderfoot Creek was 563.935 and indicates that nests were clumped in the riffle. This is consistent with observations that nests tend to be built on or around other nests.

Levels of dissolved oxygen varied throughout the study. There were slight differences in dissolved oxygen concentrations between the upper, middle, and lower riffle areas (Fig. 3.). At the beginning of the summer, the dissolved oxygen levels were highest in the upper riffle where water was turbulent. Slight decreases in dissolved oxygen were detected near the margins of the creek where the water was less turbulent. Dissolved oxygen levels also decreased at sites further downstream. These differences; however, were not statistically significant.

Chlorophyll a concentrations on spawned areas before the period of high water were significantly less than those found after high water (Mann-Whitney; Fig. 4.). The amount of chlorophyll a in unspawned areas before and after the high water period, however, did not differ statistically (Fig. 5.). There were slight, but insignificant differences in chlorophyll a between spawned and unspawned areas (Fig. 6, Fig. 7).

Numbers of insects collected before the high water event were greater from those sampled after high water (Fig. 8). More specifically, numbers of insects from spawned areas differed before and after the high water (Fig. 9) and numbers from unspawned areas also differed before and after the high water (Fig. 10). Thus, the null hypothesis was rejected and there were significant differences between the numbers of insects in each of the two types of areas before and after the high water. There also was a significant difference in the numbers of insects in spawned and unspawned areas before the high water period (Fig. 11) and for the numbers of insects sampled from spawned and unspawned areas after high water (Fig. 12). Both before and after high water, spawned areas had fewer insects than unspawned areas.

The relationship between chlorophyll a and insects was quite variable. It can be inferred from the results that whether the substrate was a nesting or non-nesting area had no effect on the amount of chlorophyll a and the numbers of insects (Fig. 13, Fig. 14). On both nesting (Fig. 15) and non-nesting (Fig. 16) substrates after the flood, however, there was a decrease in numbers of insects and reflects an increase in the amount of chlorophyll a.

Discussion

The spawning activity of minnows in Tenderfoot Creek and the appearance of their nests, is largely dependent on weather conditions. The first two weeks of the study were characterized by very warm conditions and coincided with the commencement of the spawning period. The greatest number of nests appeared within the first three weeks of the study and probably was a result of the unseasonably warm weather. With the onset of several weeks of colder weather, the minnows left the riffle area and apparently ceased to spawn. Spawning activities subsequently resumed with the return of warmer weather.

High water levels from spring slowly dropped during the course of the summer eventually revealing the tops of nests in the lower riffle and extending more suitable nesting substrates beyond the original lower and upper ends of the riffle. Larger minnows were found in the newly extended riffle and likely are suited better to these deeper waters than smaller minnows that utilize shallow riffles. Because of their body size, it is possible that smaller minnows were forced to spawn in the suboptimal shallow riffle areas.

The high water event that occurred on July 2 raised the water level to spring conditions with a concomitant increase in current velocity. Faster current and cooler temperatures may explain the minnows movement out of the riffle area. Upon returning to spawn, minnows continued spawning activities in all areas of the riffle due to the deeper water.

Interestingly, nests were found several hundred meters downstream of the riffle area in the vicinity of a bridge crossing. When minnows left the riffle area during adverse weather, it appears as if they did continue to spawn outside of the riffle. The reason as to why this area was a desirable spot to spawn during the cold weather with fluctuations in the water level is unclear.

Nests were initially hypothesized to be more abundant at the upper end of the riffle. Although results from the present study support this hypothesis (Fig. 2), dissolved oxygen concentrations in the upper riffle areas where downwelling was hypothesized to occur did not differ from those further downstream. Dissolved oxygen levels were high at the beginning of the study due to cooler water temperatures and the high spring water levels. Insignificant differences in dissolved oxygen levels between the upper, middle, and lower riffle areas showed that upper regions of the riffle had slightly more dissolved oxygen. With the decreased water level, the lower riffle areas eventually had higher dissolved oxygen levels. Concomitant with increased flow due to a rain event, dissolved oxygen was higher in the upper riffle area. According to Stanley and Valett (1988), dissolved oxygen decreases as a stream undergoes drying. At upwelling and stationary sites, hydraulic changes associated with drying reversed flow such that surface water entered the hyporheic zone. Sites of downwelling remained until surface flow was lost. Stanley and

Valett (1988) observed periods of reverse flow as long as 70 days for riffle areas and as short as a few days in sandy regions. An increase in hyporheic dissolved oxygen was shown to follow small floods; a finding consistent with what occurred in Tenderfoot Creek.

Insect abundance also was affected by high water and was likely due to dislodgment of invertebrates. Nests, because they are raised above the streambed, had fewer insects compared to the unspawned substrates that were relatively undisturbed by the increased current velocity. Unspawned areas also may have more insects because most of the fish activity occurred downstream of the nests. As a result, algal food resources would increase in unspawned areas due to nitrogen and phosphorus release by minnows.

Concentrations of chlorophyll a also were affected by the high water. The increased water level and stronger currents that dislodged insects indirectly reduced algal loss to grazers. The non-significant chlorophyll a differences between spawned and unspawned substrates before and after the high water questions the relationship that links fish nutrient release with increased algal biomass and increased insect numbers. The non-nesting areas adjacent to nesting areas were hypothesized to have higher chlorophyll a levels than the nested areas because the substrate is less disturbed by the current and nest building and maintenance activities. In addition, non-nested areas would still receive nitrogen and phosphorus inputs from minnows on the periphery of nesting areas.

Conclusions

Climate changes in temperature and rainfall greatly influenced the nesting activity of minnows in Tenderfoot Creek. Warm temperatures were associated with increased spawning activity; whereas, colder temperatures reduced spawning activity. The lack of rain decreased dissolved oxygen concentrations in the upper end of the riffle. However, lower water levels uncovered some rocks and resulted in water velocity to increase and an extension of the riffle area. High water from rain events delayed spawning because of strong currents. High water also dislodges insects and indirectly enhanced algal growth.

Just as high water and environmental changes can be disturbances to substrates, the formation of fish nests also is considered a disturbance to the substrate. The movement of stones to construct nests disrupts the natural fauna, dislodging insects and algae. The nests are situated to expose the developing eggs to high levels of dissolved oxygen. As a result, this subjects the insects and algae to a new environment that is higher in the water column with a faster current velocity.

Acknowledgements

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Table 1. Mean Dimensions of Nests

	Length (cm.)	Width (cm.)	Height (cm.)
Upper Riffle	29.292 n=33	39.103 n=33	9.192 n=33
Middle Riffle	33.325 n=25	46.726 n=25	8.911 n=11
Lower Riffle	27.858 n=45	33.810 n=45	7.601 n=53

* Degrees of Freedom = 2

Table 2. Kruskal-Wallis Tests

	Length	Width	Height
K-W H Statistic	2.613	3.399	4.863
K-W X^2 Probability	0.271	0.183	0.088

Table 3. Mann-Whitney Tests: Chlorophyll *a*

	M-h T Statistic	Conclusion
Nests before high water v. nests after high water	22	Reject
Non-nesting substrates before high water v. nesting substrates after high water	27	Fail to reject
Nests before high water v. non-nesting substrates before high water	40	Fail to reject
Nests after high water v. non-nesting substrates after high water	45	Fail to reject

* Sample size n=6
* Critical values= 26,52

Table 4. Mann-Whitney Tests: Insect Densities

	M-W T Statistic	Conclusion
Nests before high water v. nests after high water	57	Reject
Non-nesting substrates before high water v. non-nesting substrates after high water	57	Reject
Nests before high water v. non-nesting substrates before high water	25.5	Reject
Nests after high water v. non-nesting substrates after high water	25	Reject

* Sample size n=6
* Critical values= 26,52

Fig. 1.

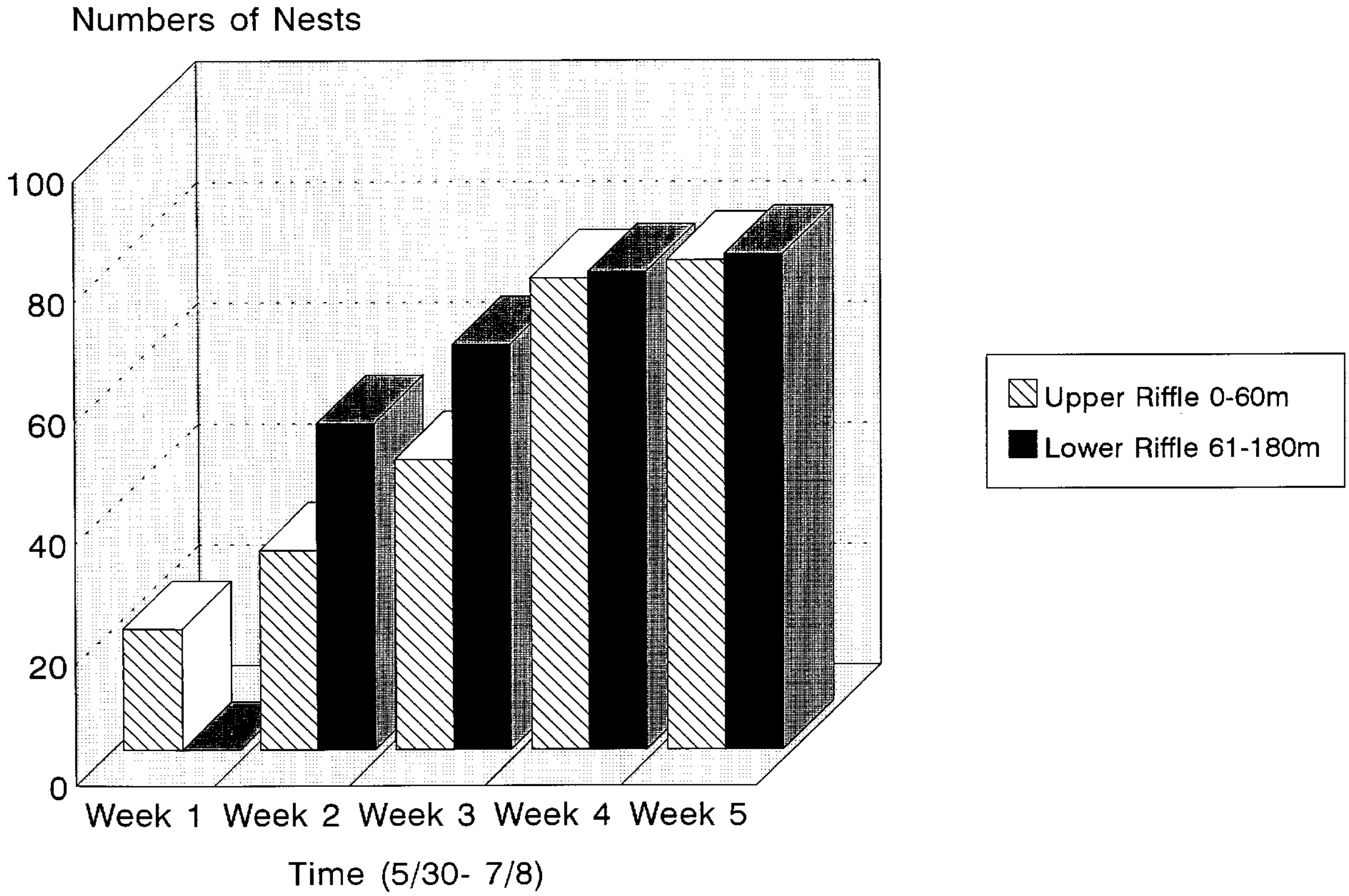

Numbers of Nests
100
80
60
40
20
0
Week 1
Week 2
Week 3
Week 4
Week 5
Time (5/30- 7/8)
▨ Upper Riffle 0-60m
■ Lower Riffle 61-180m

Fig. 2.

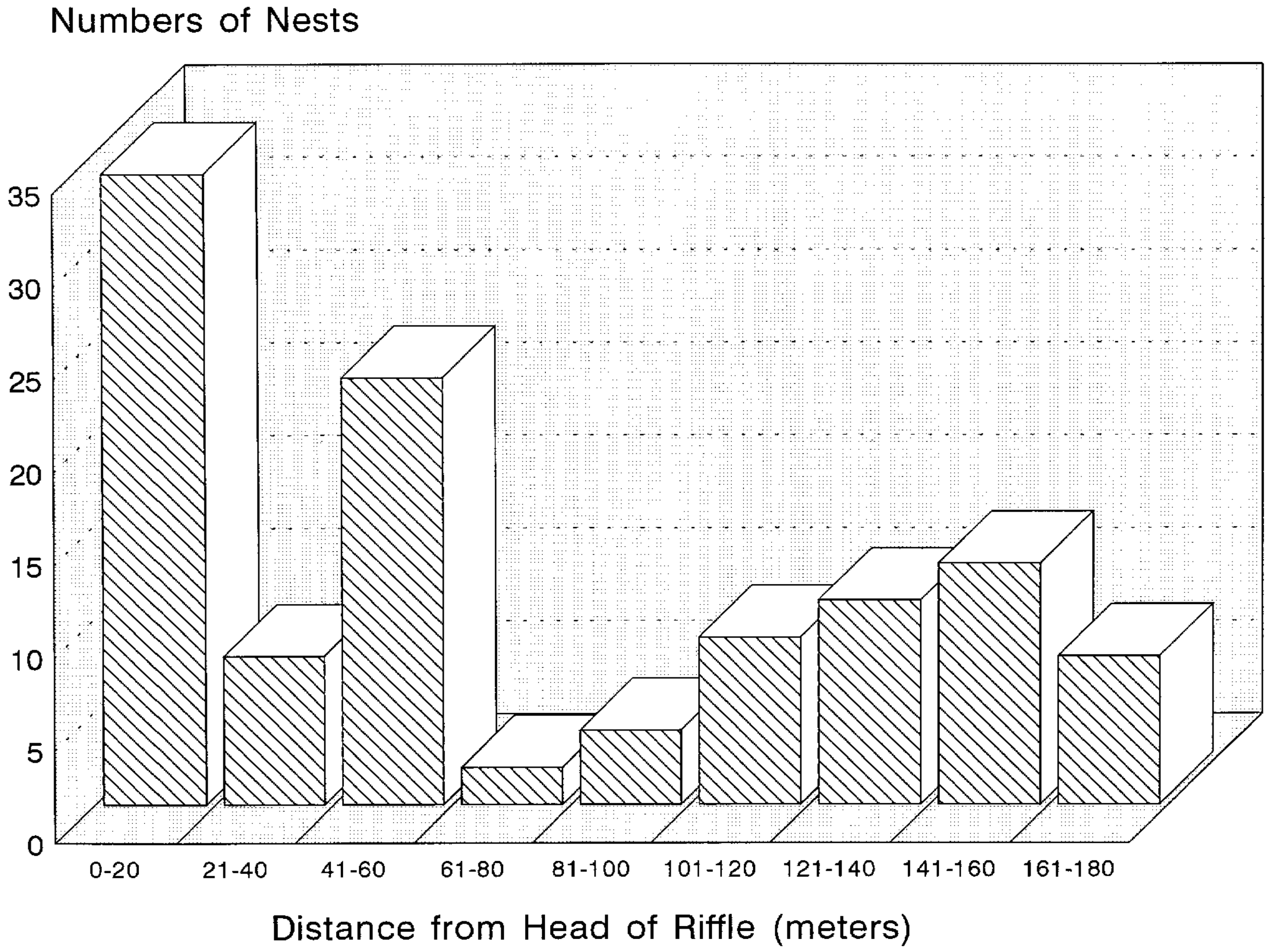

Numbers of Nests
35
30
25
20
15
10
5
0
0-20
21-40
41-60
61-80
81-100
101-120
121-140
141-160
161-180
Distance from Head of Riffle (meters)

Fig. 3.

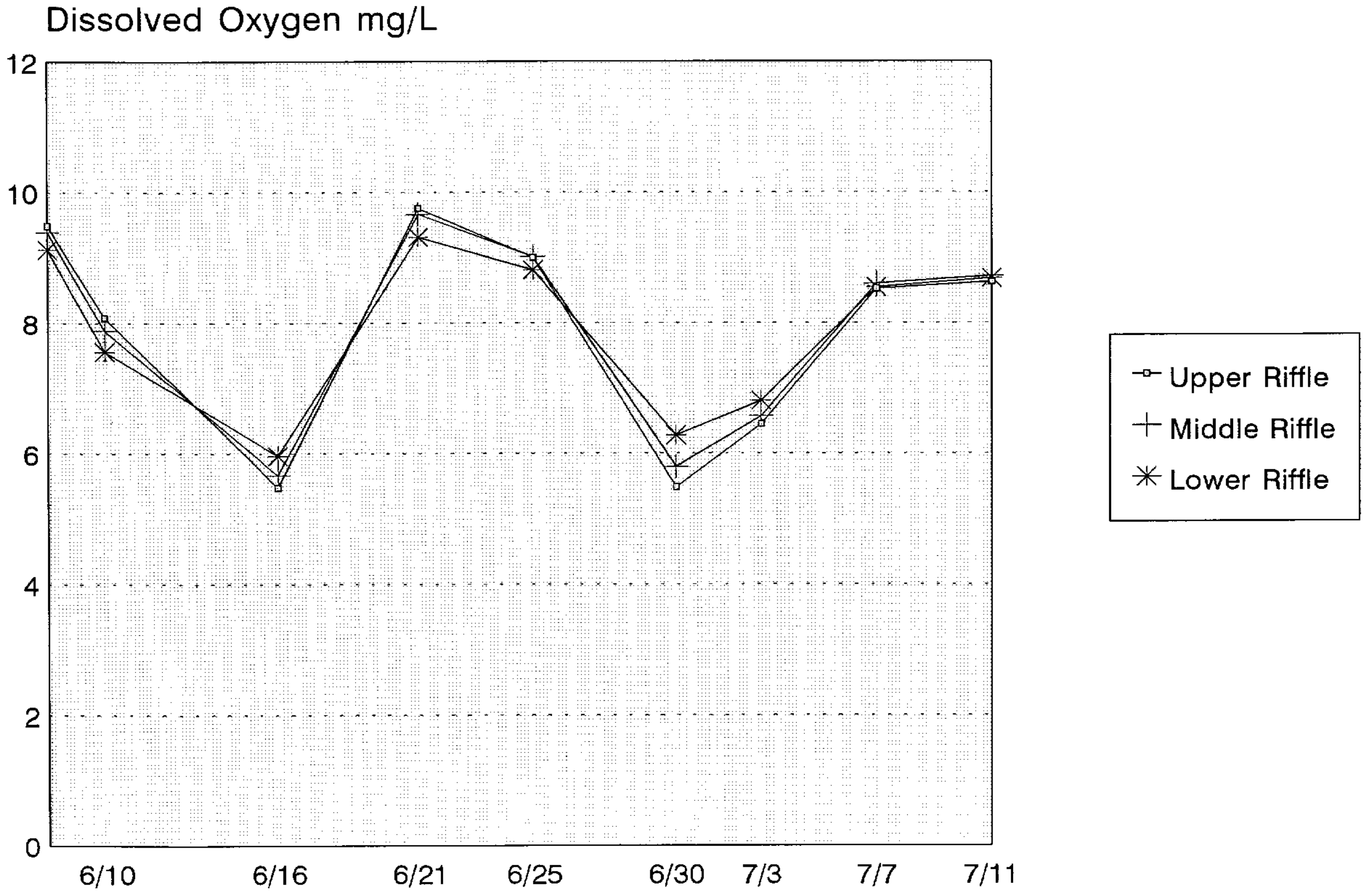

Dissolved Oxygen mg/L
12
10
8
6
4
2
0
6/10
6/16
6/21
6/25
6/30
7/3
7/7
7/11
Upper Riffle
Middle Riffle
Lower Riffle

Fig. 4.

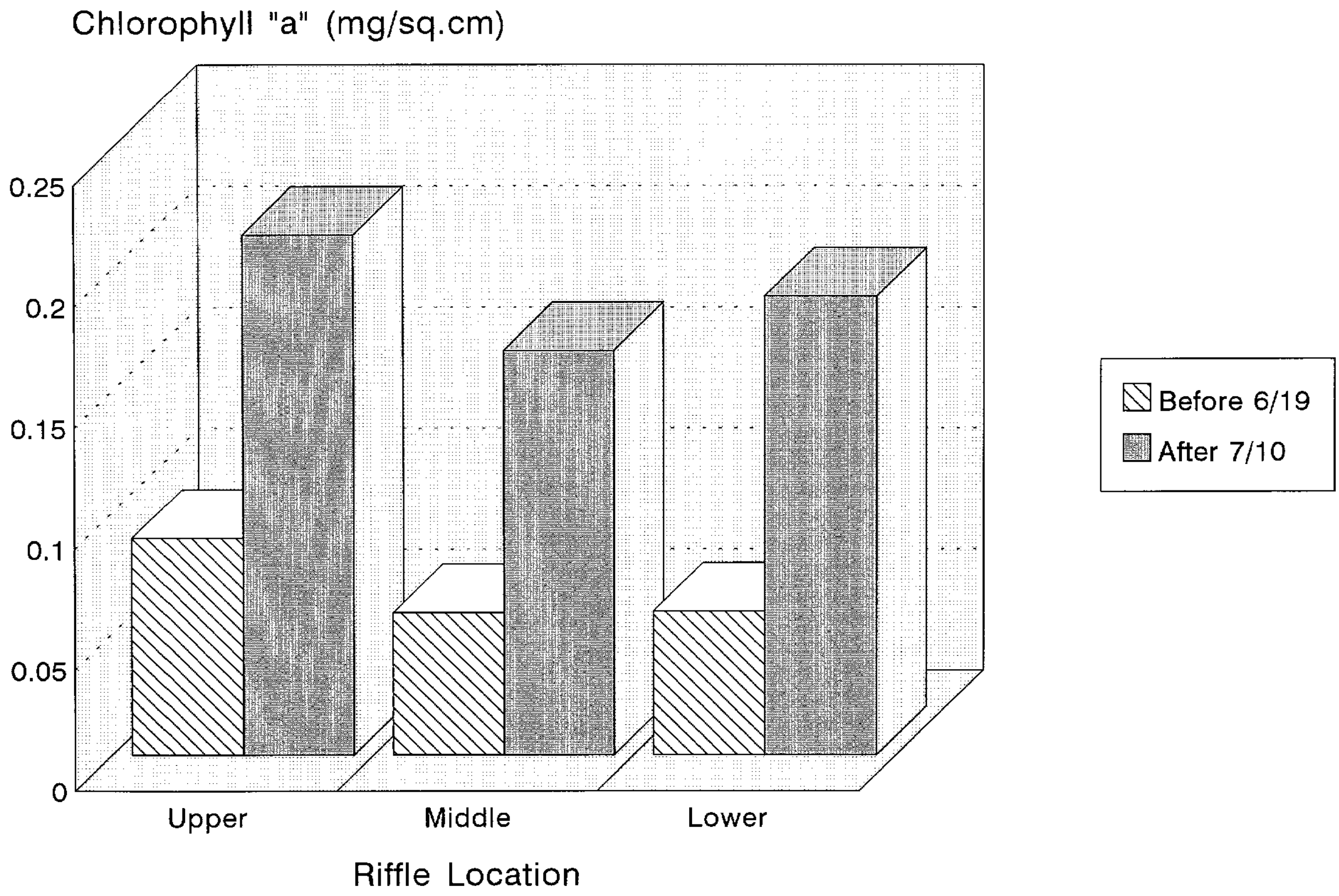

Chlorophyll "a" (mg/sq.cm)
0.25
0.2
0.15
0.1
0.05
0
Upper
Middle
Lower
Riffle Location
▨ Before 6/19
▩ After 7/10

Fig. 5.

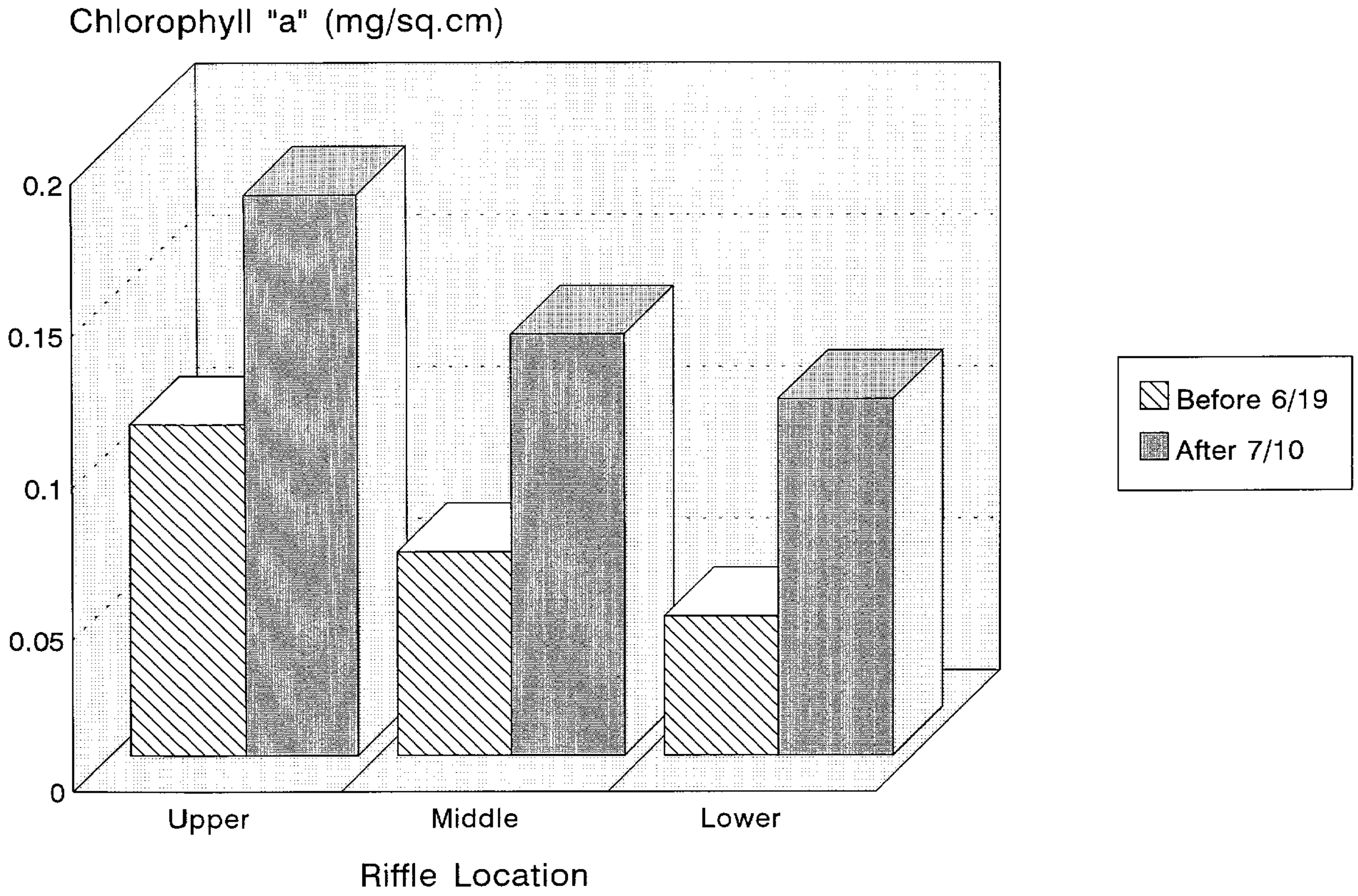

Chlorophyll "a" (mg/sq.cm)
0.2
0.15
0.1
0.05
0
Upper
Middle
Lower
Riffle Location
▨ Before 6/19
▩ After 7/10

Fig. 6.

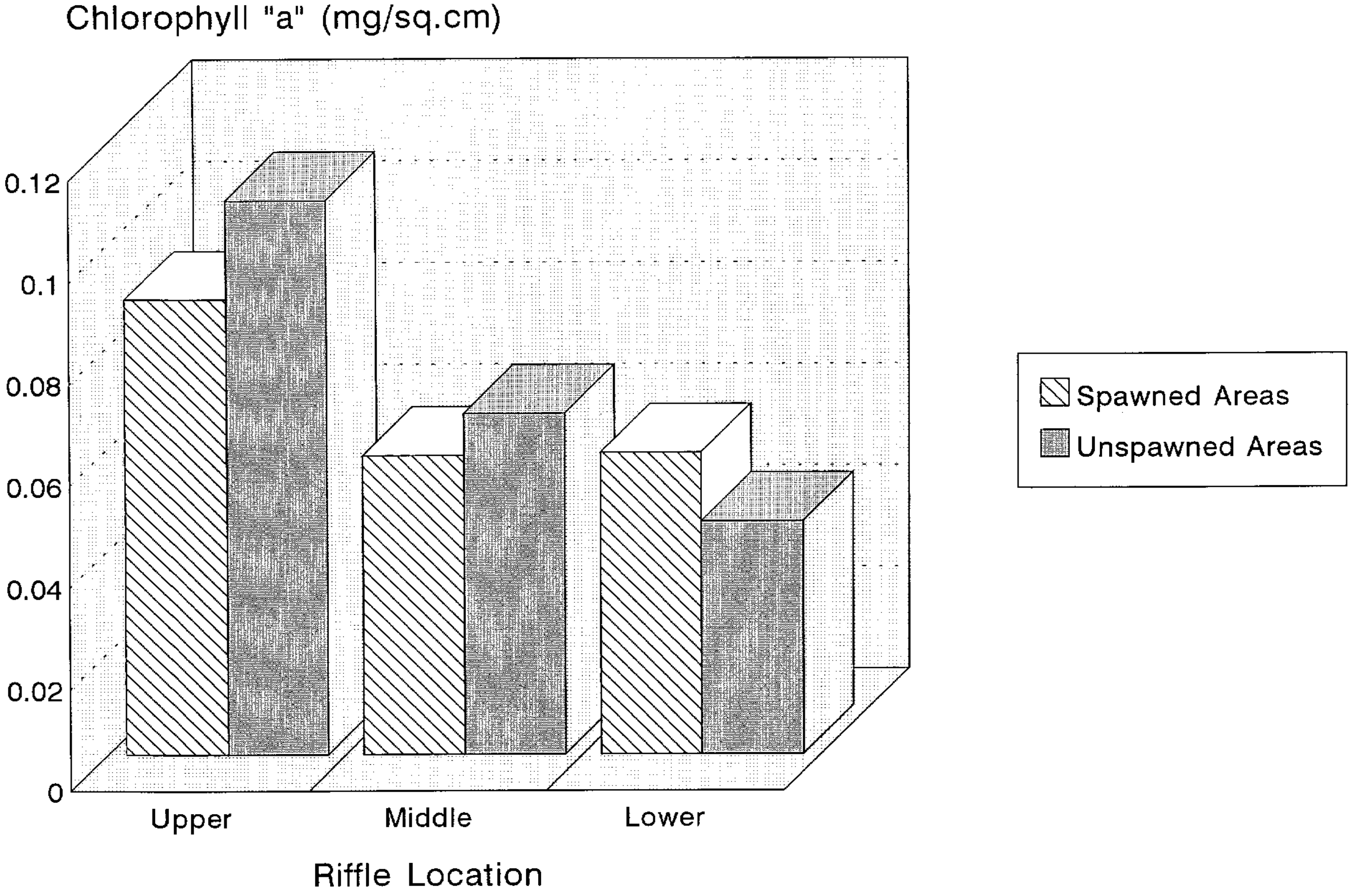

Chlorophyll "a" (mg/sq.cm)
0.12
0.1
0.08
0.06
0.04
0.02
0
Upper
Middle
Lower
Riffle Location
▧ Spawned Areas
▩ Unspawned Areas

Fig. 7.

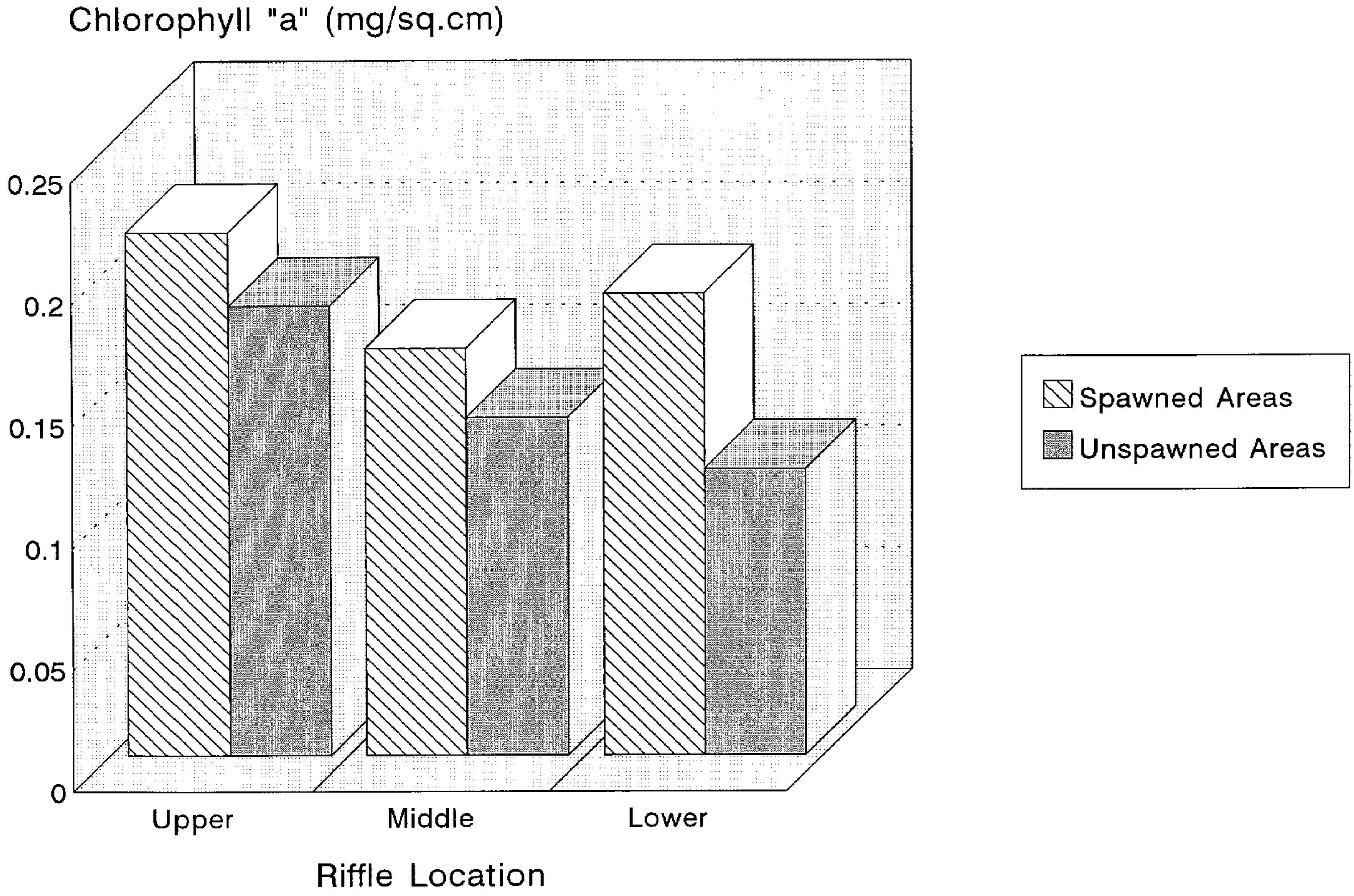

Chlorophyll "a" (mg/sq.cm)
0.25
0.2
0.15
0.1
0.05
0
Upper
Middle
Lower
Riffle Location
Spawned Areas
Unspawned Areas

Fig. 8.

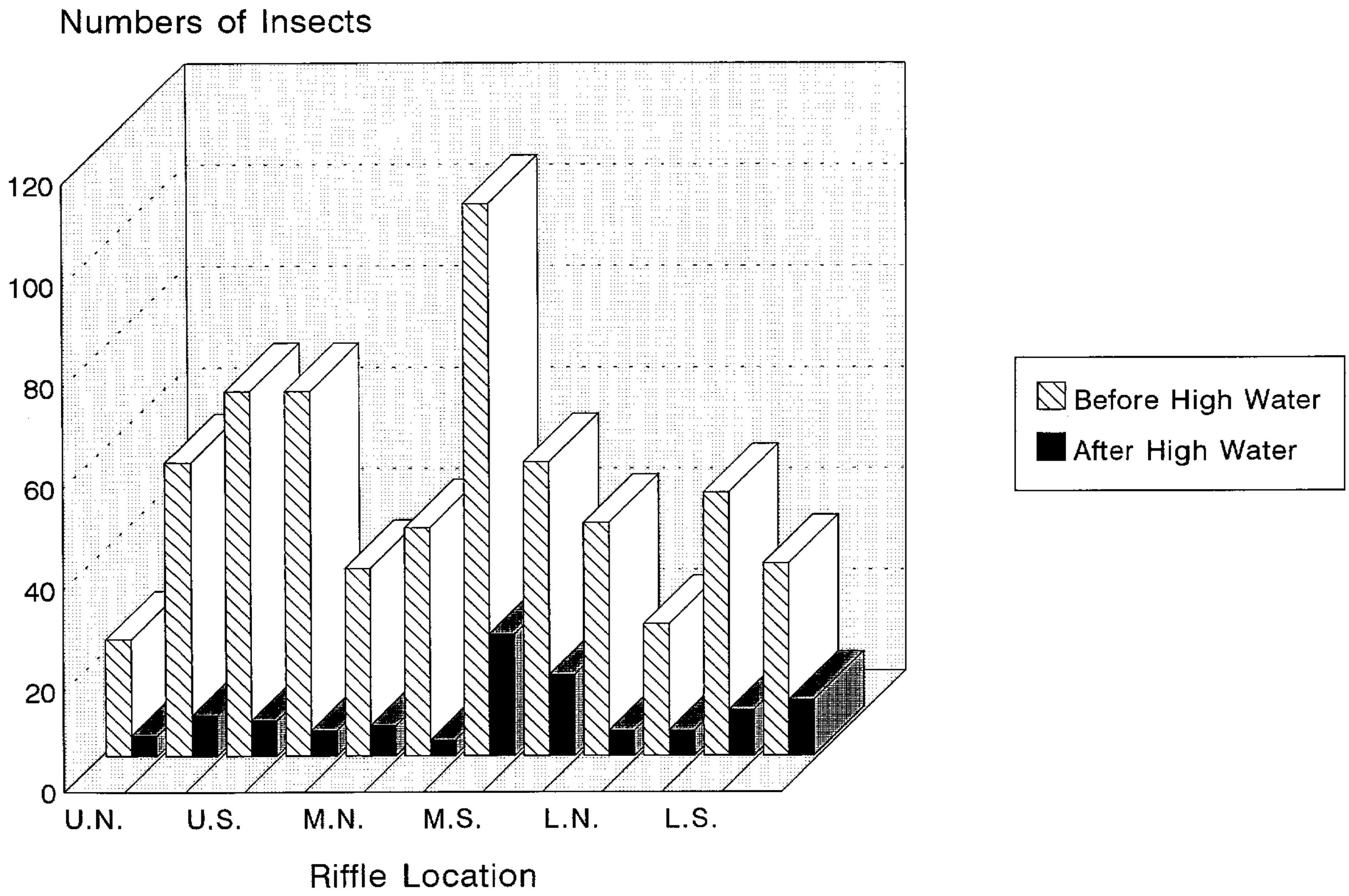
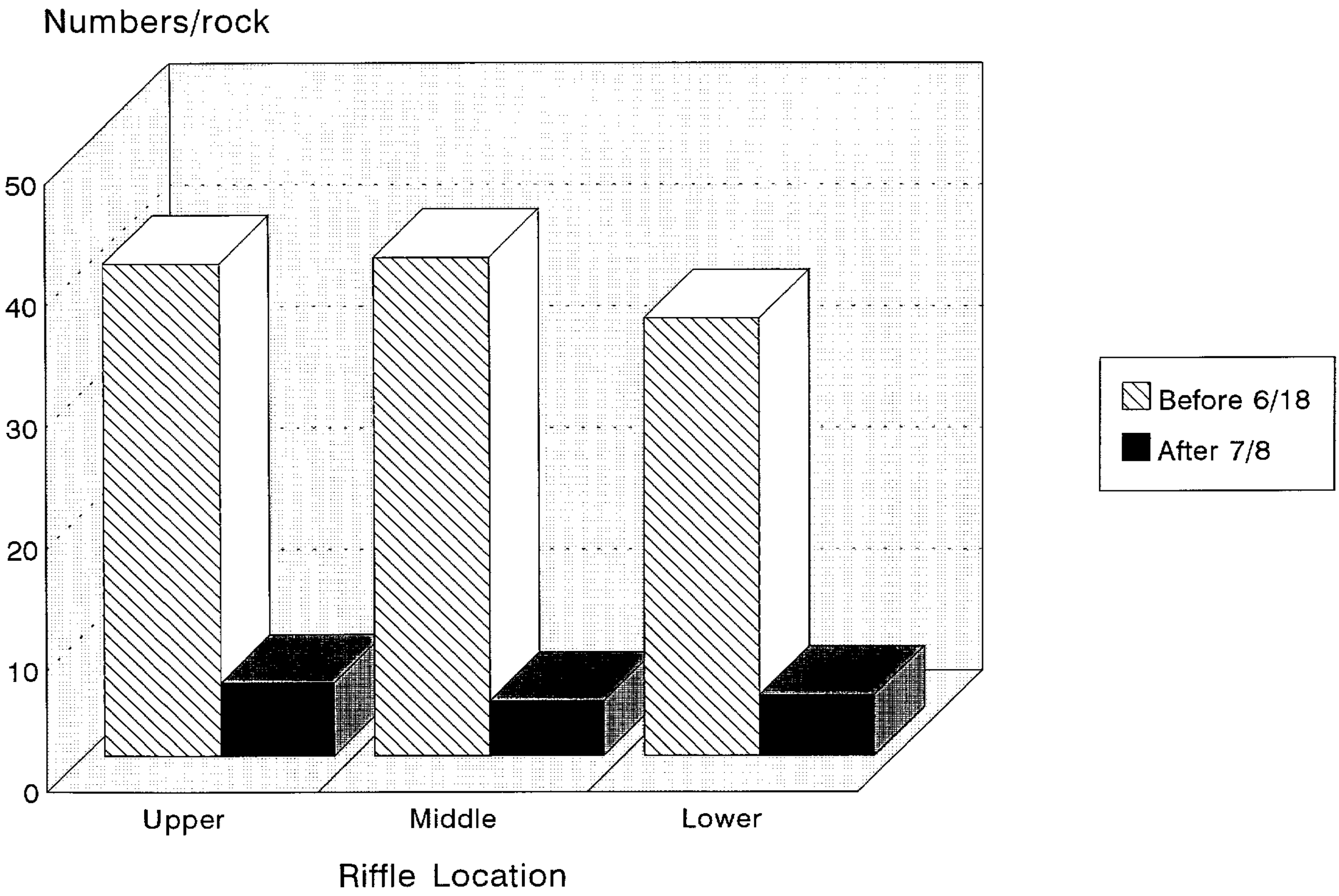

Numbers of Insects
120
100
80
60
40
20
0
U.N.
U.S.
M.N.
M.S.
L.N.
L.S.
Riffle Location
▨ Before High Water
■ After High Water

Fig. 9.



Numbers/rock
50
40
30
20
10
0
Upper
Middle
Lower
Riffle Location
▨ Before 6/18
■ After 7/8

Fig. 10.

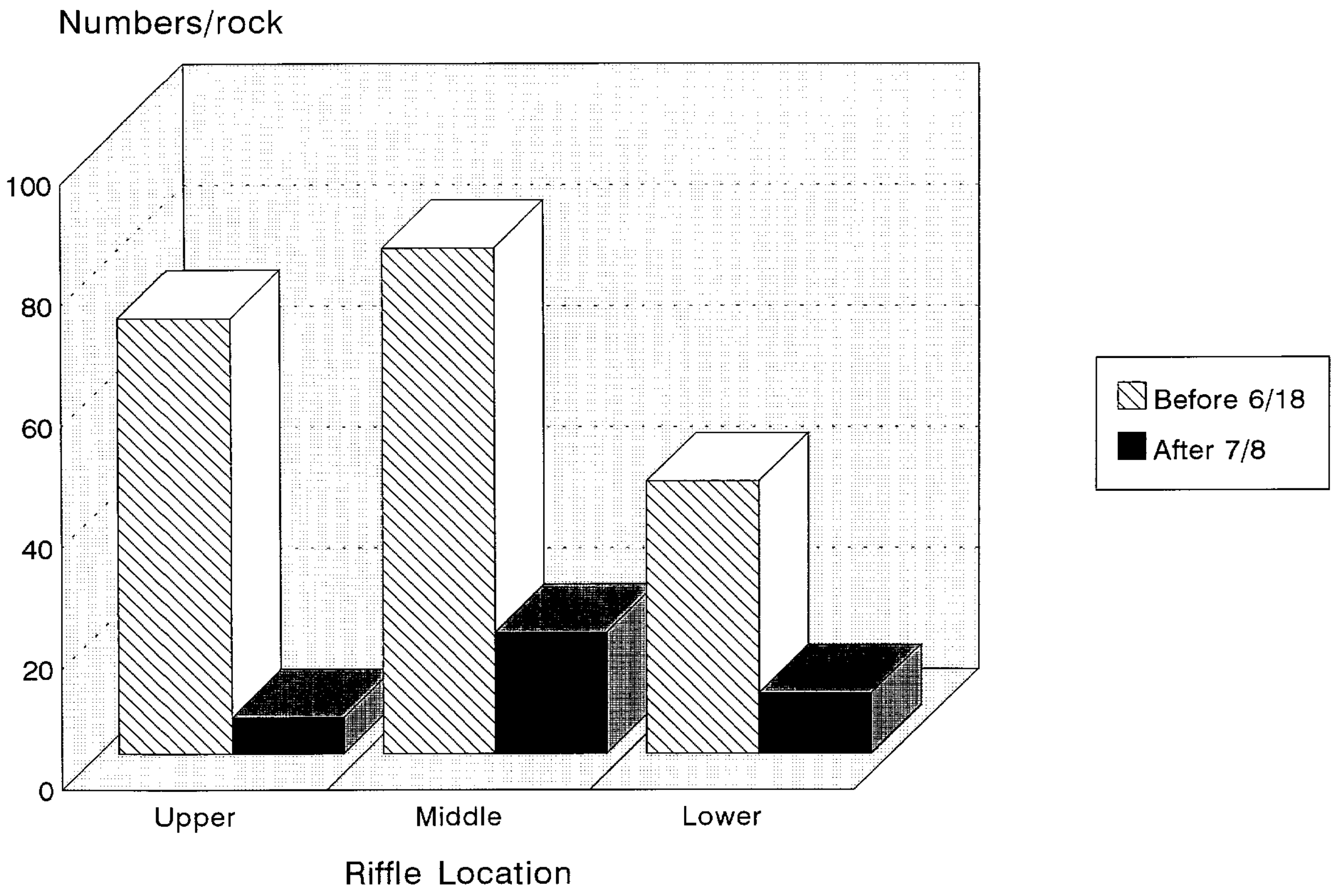

Numbers/rock
100
80
60
40
20
0
Upper
Middle
Lower
Riffle Location
▨ Before 6/18
■ After 7/8

Fig. 11.

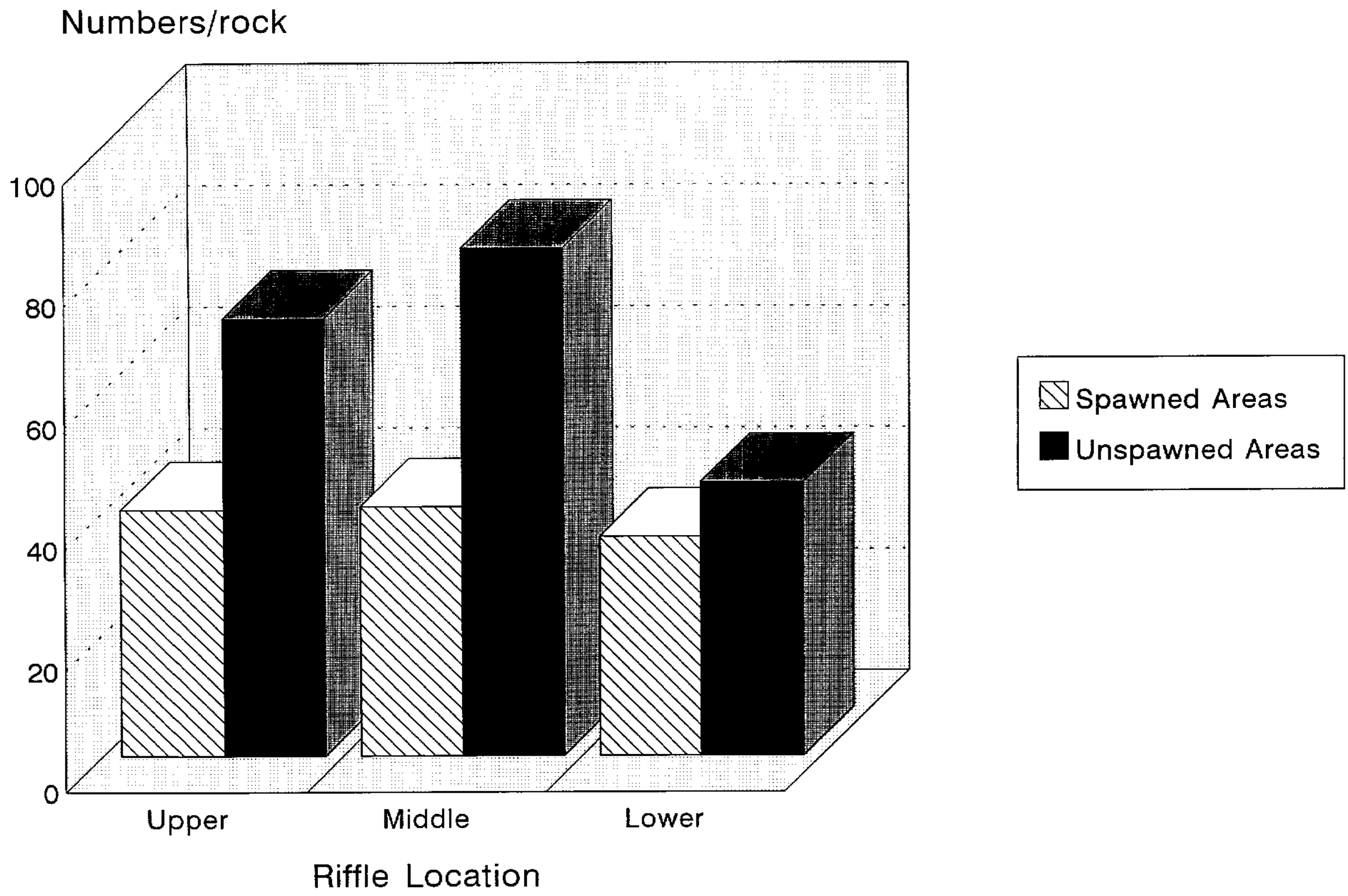

Numbers/rock
100
80
60
40
20
0
Upper
Middle
Lower
Riffle Location
▨ Spawned Areas
■ Unspawned Areas

Fig. 12.

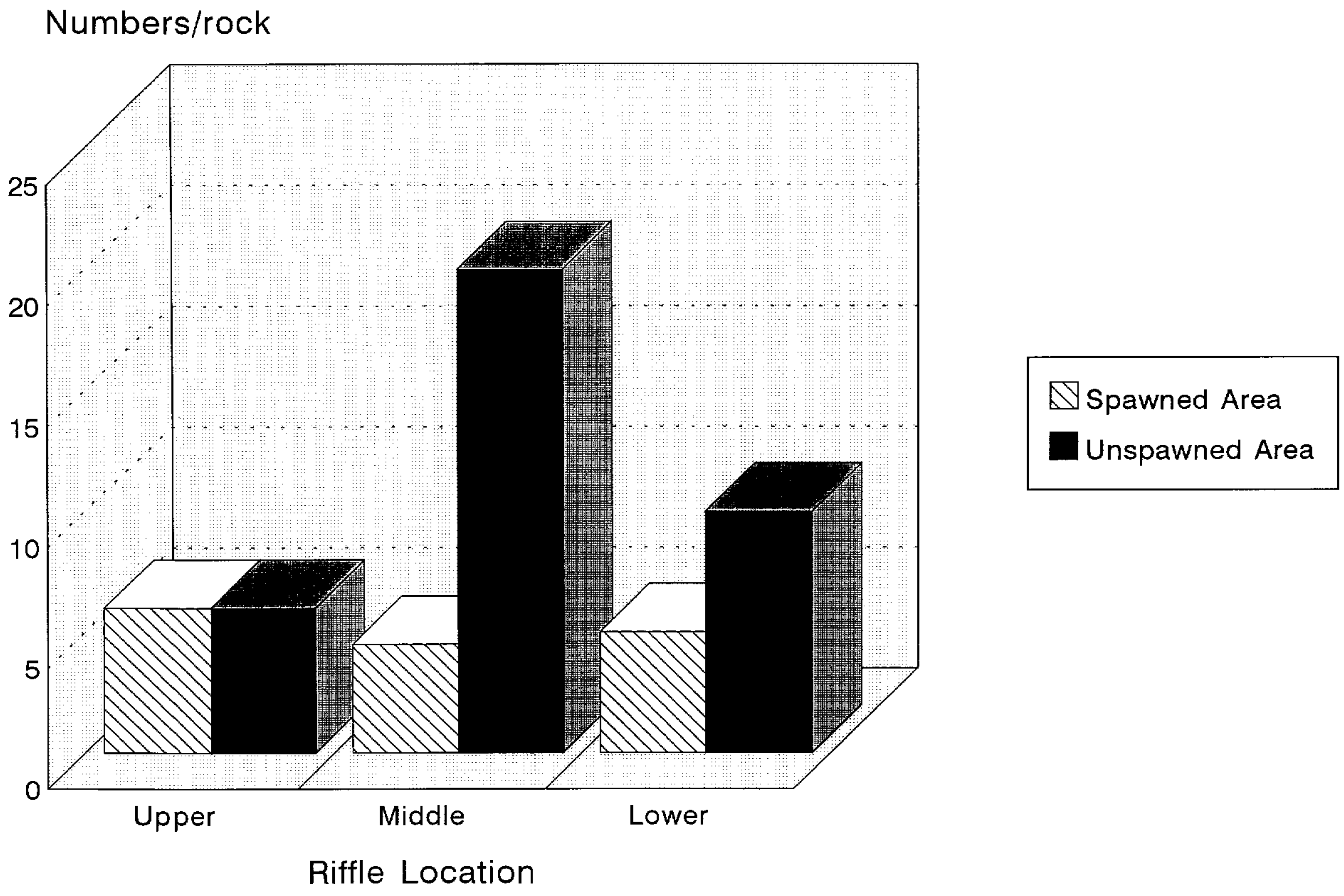

Numbers/rock
25
20
15
10
5
0
Upper
Middle
Lower
Riffle Location
▨ Spawned Area
■ Unspawned Area

Fig. 13.

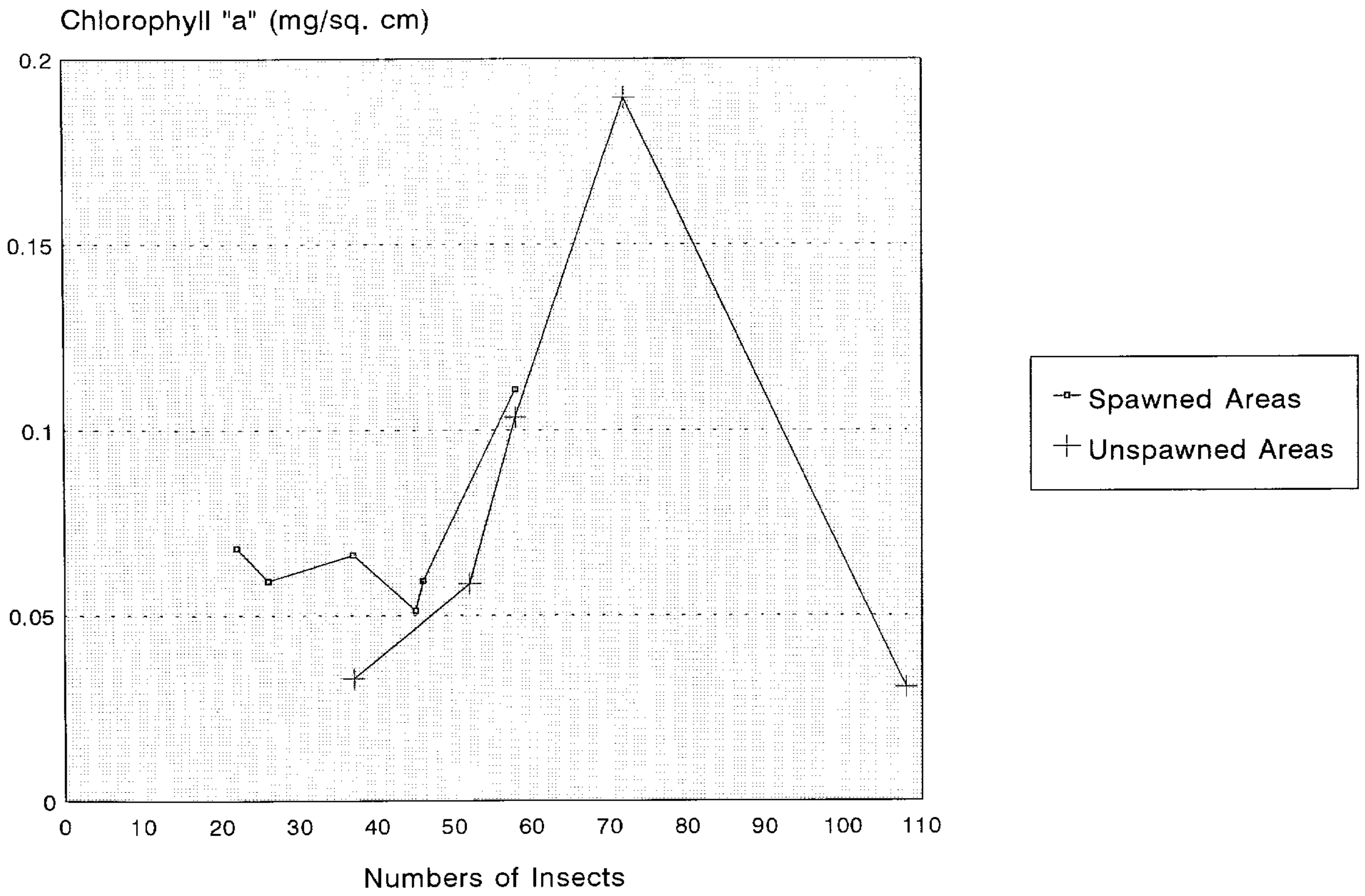

Chlorophyll "a" (mg/sq. cm)
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
60
70
80
90
100
110
Numbers of Insects
Spawned Areas
Unspawned Areas

Fig. 14.

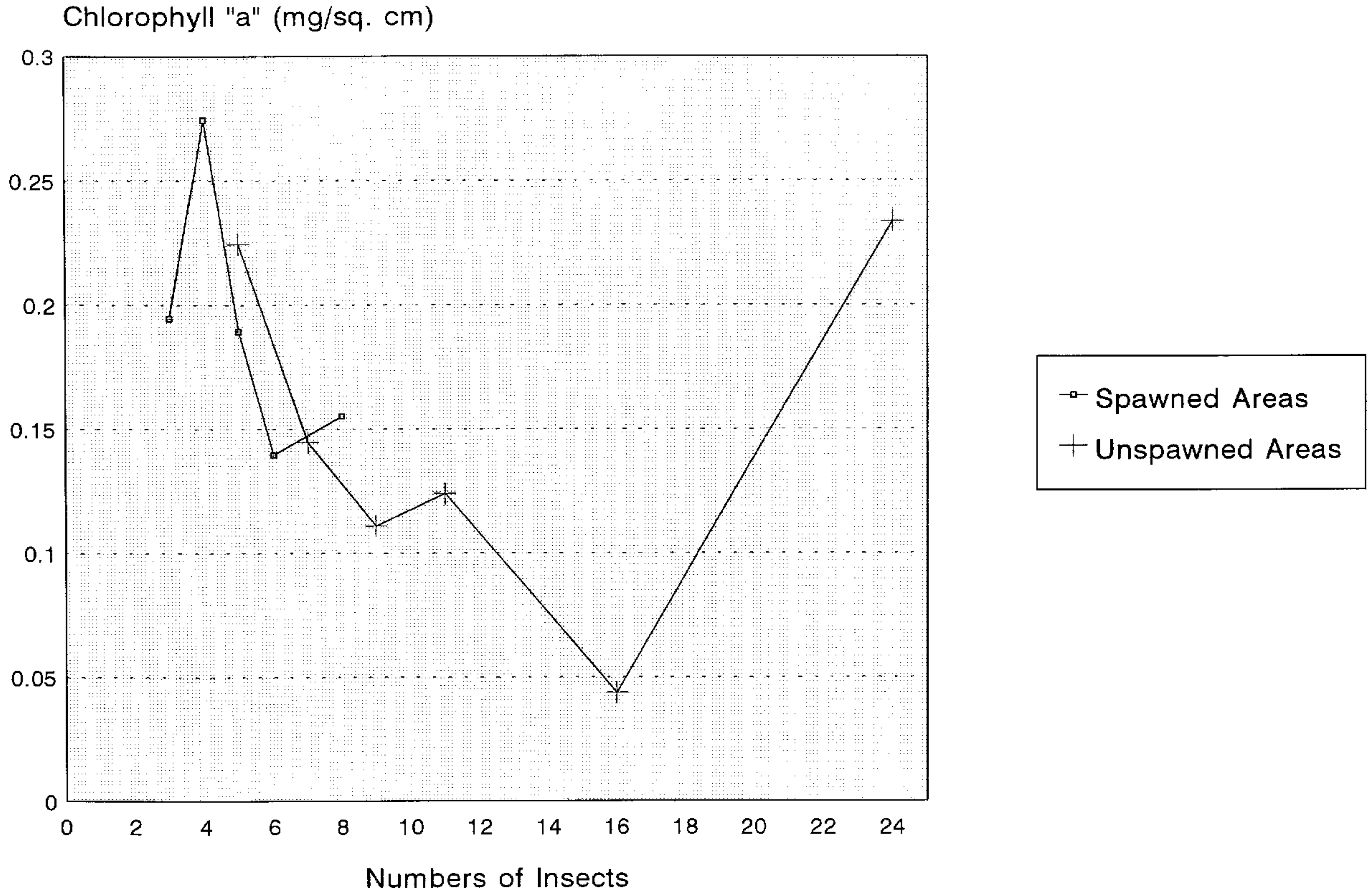
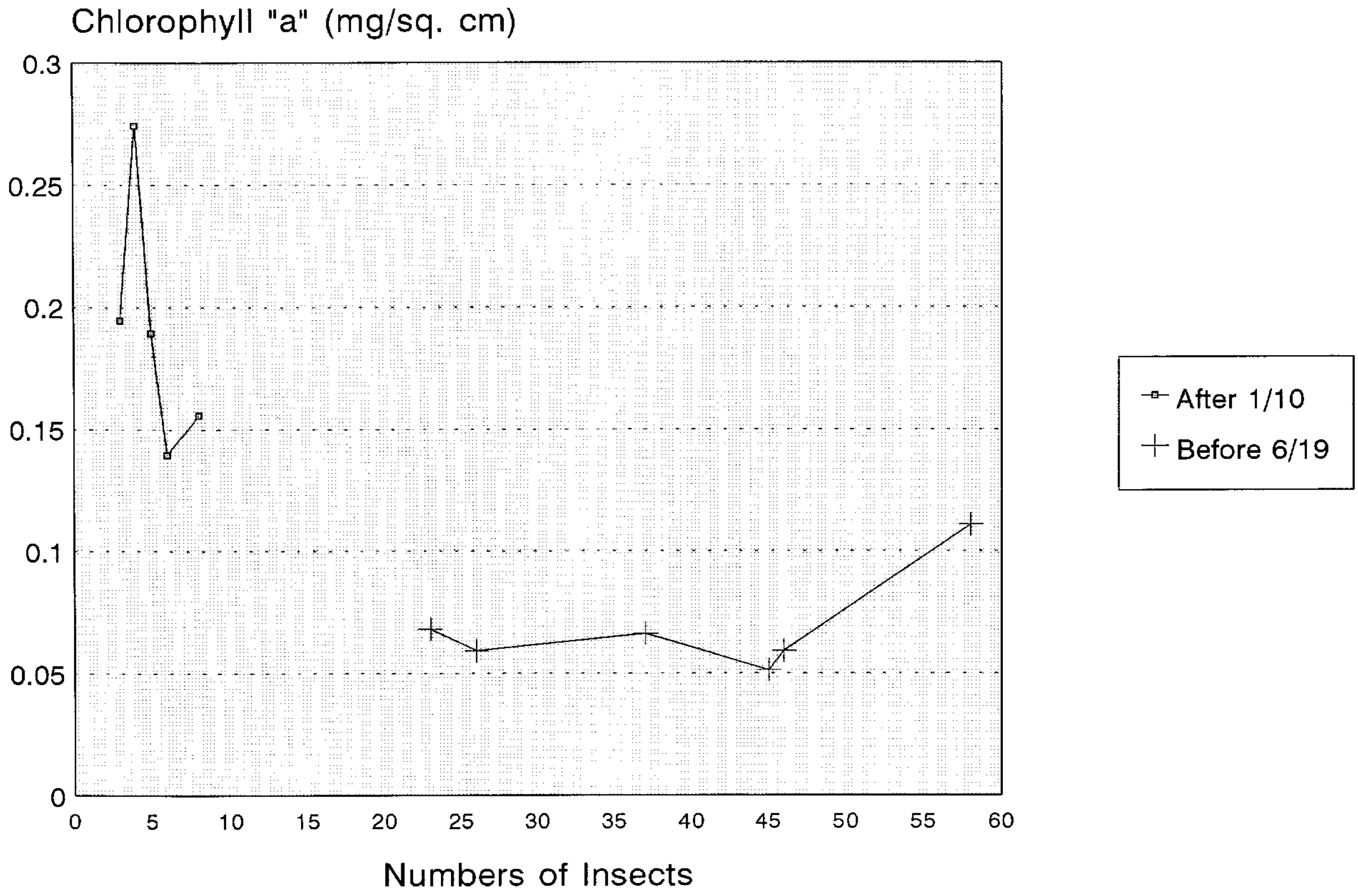

Chlorophyll "a" (mg/sq. cm)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Numbers of Insects
Spawned Areas
Unspawned Areas

Fig. 15.



Chlorophyll "a" (mg/sq. cm)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
5
10
15
20
25
30
35
40
45
50
55
60
Numbers of Insects
After 1/10
Before 6/19

Fig 16.

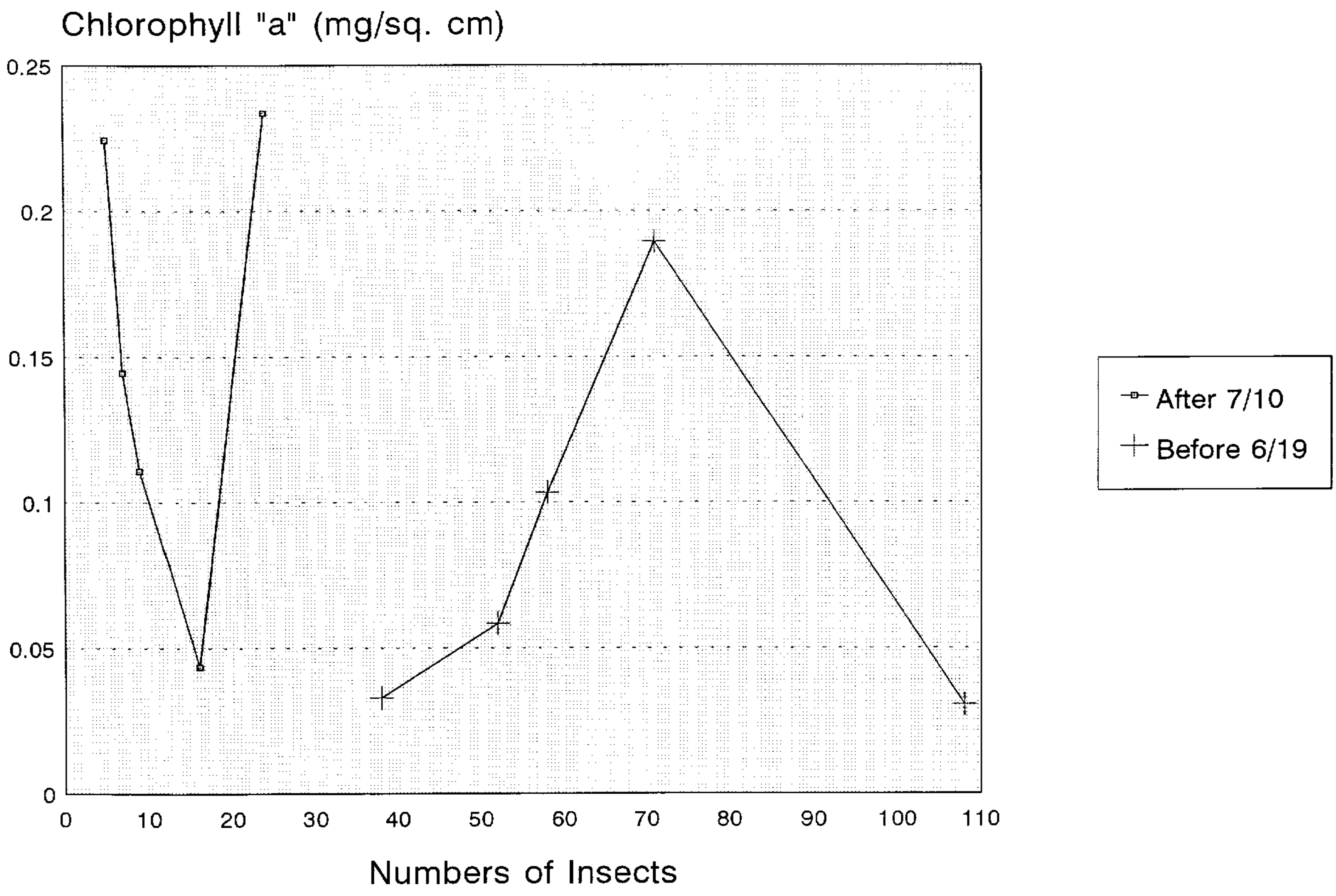

Chlorophyll "a" (mg/sq. cm)
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
60
70
80
90
100
110
Numbers of Insects
After 7/10
Before 6/19

Table of Contents
Diskette 1

File Name	File Extension	Size (bytes)	Format
INSECT	SYS	336	Mystat
INSECT2	SYS	336	Mystat
INSECTS3	SYS	228	Mystat
INSECTS4	SYS	228	Mystat
CHLOR1	SYS	228	Mystat
CHLOR2	SYS	228	Mystat
CHLOR3	SYS	228	Mystat
CHLOR4	SYS	228	Mystat
DOXYGEN	SYS	606	Mystat
DIMENS	SYS	2812	Mystat
NHEIGHT	SYS	1866	Mystat
HG	DIR	1024	Harv Graph
NESTDIST	CH3	7141	Harv Graph
NESTDIS2	CH3	15329	Harv Graph
SPAWNBA	CH3	6353	Harv Graph
USPAWNBA	CH3	6359	Harv Graph
Insects3	CH3		Harv Graph
Insects4	CH3		Harv Graph
CHLOR1	CH3	6570	Harv Graph
CHLOR2	CH3	6403	Harv Graph
CHLOR3	CH3	6394	Harv Graph
CHLOR4	CH3	6236	Harv Graph
DOXYGEN	CH3	12080	Harv Graph
Nspread1	CH3		Harv Graph
Nspread2	CH3		Harv Graph
Chlorin1	CH3		Harv Graph
Chlorin2	CH3		Harv Graph
Chlorin3	CH3		Harv Graph
Chlorin4	CH3		Harv Graph
INSDENS	CH3		Harv Graph
INSECTS	CHT	2013	Harv Graph
CLUMP	WK1	5316	Lotus 123
NSPREAD	WK1	10314	Lotus 123
COMP		17642	Word Perf
CTABLE12		2162	Word Perf
CTABLE34			Word Perf

Figure Captions

Fig. 1. Nest Distribution Over Time
Fig. 2. Nest Distribution Along Tenderfoot Creek
Fig. 3. Changes in Mean Dissolved Oxygen within Areas of Riffle Over Time
Fig. 4. Chlorophyll "a" from Spawned Areas Before and After High Water Event
Fig. 5. Chlorophyll "a" from Unspawned Areas Before and After High Water Event
Fig. 6 Chlorophyll "a" from Spawned and Unspawned Areas Before High Water Event 6/19
Fig. 7. Chlorophyll "a" from Spawned and Unspawned Areas After High Water Event 7/10
Fig. 8. Insect Densities
  X-axis labels:
  U.N. Upper nesting substrate
  U.S. Upper substrate (non-nesting)
  M.N. Middle nesting substrate
  M.S. Middle substrate (non-nesting)
  L.N. Lower nesting substrate
  L.S. Lower substrate (non-nesting)
Fig. 9. Insects Sampled from Spawned Areas Before and After High Water Event
Fig. 10. Insects Sampled from Unspawned Areas Before and After High Water Event
Fig. 11. Insects Sampled from Spawned and Unspawned Areas Before High Water Event 6/18
Fig. 12. Insects Sampled from Spawned and Unspawned Areas After High Water Event 7/8
Fig. 13. Chlorophyll"a" v. Insects of Spawned and Unspawned Areas Before High Water Event 6/19
Fig. 14. Chlorophyll "a" v. Insects of Spawned and Unspawned Areas After High Water Event 7/10
Fig. 15. Chlorophyll "a" v. Insects of Spawned Areas Before and After High Water Event
Fig. 16. Chlorophyll "a" v. Insects of Unspawned Areas Before and After High Water Event