FINAL REPORT

CM 167

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Final work product

"IMPOUNDMENT MANAGEMENT" AND "EFFECTS OF NUTRIENTS ON SEAGRASSES"

CM 167

FINAL REPORT

CONTENTS

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CM 167

"FISH, MACROCRUSTACEAN, AND HYDROLOGICAL STUDIES"

"EFFECTS OF NUTRIENTS ON SEAGRASS

"VEGETATION PRODUCTION STUDIES"

and

"MOSQUITO SAMPLING"

Enclosed are the final reports of the four principal investigators for CM 167. All reports this year are extremely tentative in their recommendations, for several reasons. The most important factors influencing field work were the anomalous low spring and summer tides and rainfall. This made it difficult to study the impacts of seasonal water levels on vegetation litter production, and to see the water transport effects of the different culvert sizes. For the same reason, it was difficult to determine the effect on mosquito production after installation of the additional 30" culvert.

Both rainfall and tides increased somewhat toward the very end of the study period, but analysis of these factors could not be included in these reports. Further complicating the field vegetation study were the unusually high winter temperatures, which probably contributed to unusual growth patterns for the majority of the study period. However, the PIs have indicated they are going to continue to gather water-level related data through this fall's high tides, and will incorporate these findings in their publications.

Despite these difficulties, Dr. Gilmore was able to determine a significant preference by migrating fish for the 30" culvert over the 18" culvert ; and to obtain preliminary figures on water transport between impoundment and estuary under differing culvert configurations. It is interesting to note, though, that the preliminary work was not able to show that the larger culverts had a significant impact on dissolved oxygen levels, and we are not able to claim that larger numbers of fish entered or left the impoundment because of the increased culvert volume.

The laboratory-based seagrass study was relatively narrow in scope, and has produced expected results, indicating that increased nutrients induce increased algal and phytoplankton growth, which in turn limit the amount of sunlight reaching the seagrasses. However, the PIs did not complete detailed statistical analysis of the data by the conclusion of the study period. Alan Curtis, who was a PI for statistical analysis on the previous CZM contract (CM-122), has reviewed the seagrass data. He reports it is sufficiently complete and rigorous to allow a variety of statistical tests. He has transferred their data to the IBM-AT purchased via the previous contract, and begun working with the PIs to complete this portion of their project. Finally, readers of this section of the final report should note that this study is based on the effects of extremely high nutrient levels, and cannot necessarily be extrapolated to cover nutrient levels naturally found in the estuary or introduced via typical run-off conditions.

Recommendations:

From the initial Final Report for CM-47 in the series of Coastal Management Projects relating to the management of impounded marshes, the researchers have identified the inside perimeter ditch as the most important and difficult physical feature. In fact, the perimeter ditch apparently outweighs even the impact of the dike itself, since the dike can be breached with culverts which have proved to be highly efficient in allowing fish to move between impounded marsh and estuary.

The perimeter ditch changes the distribution patterns of fish in the impoundment in a manner that may well be detrimental to maximizing fish production; it substantially affects water quality in and outside of the impoundment, and may be an important element in causing estuarine fish kills during otherwise desirable early September openings of managed impoundments; in this year's study, Dr. Rey hypothesizes that the perimeter ditch is important in transporting organic matter from impoundment to estuary; and one of Dr. Gilmore's conclusions is that installation of additional culverts in an impoundment may diminish the reproductive abilities of marsh resident fishes by rapid de-watering the upland-edge of the marsh, which in turn increases the relative impact of the perimeter ditch on impoundment fish production. His report concludes by reminding us that there are over 403 km of perimeter ditch habitat along the east coast of Florida.

As an agency charged with managing thirty impoundment groups, we are increasingly frustrated by our ignorance of the exact mechanisms at work in the perimeter ditch; and of ways of determining impacts of the management strategies on it and areas it affects. Thus, our major conclusion after reading this year's final reports is that future research must concentrate on this man-made feature. The fish mortality study being undertaken by Mr. Gilmore on the upcoming CM-196 contract pertains directly to this need. Further, we are encouraging this study's PIs to develop a comprehensive proposal relating to modeling and modifying the perimeter ditch to enhance water quality, fish utilization of the entire marsh, and appropriate bio-mass transport.

CM 167

IMPOUNDMENT MANAGEMENT

FISH, MACROCRUSTACEAN AND HYDROLOGICAL STUDIES OF AN IMPOUNDED SUBTROPICAL HIGH MARSH

FINAL REPORT

OCTOBER 1, 1987

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INTRODUCTION

The primary objectives of our research program were to examine the hydrological and biological effects of two 30 in. (76.2 cm) diameter culvert installations at Indian River County Impoundment No. 12. These culverts were to be compared with two 18 in. (45.7 cm) diameter culverts originally installed approximately 1.0 mile (1.61 km) apart. A single 30 in. culvert was installed adjacent to each of the 18 in. culverts to allow hydrological and biological comparisons to be made at the same location.

Our original NULL hypotheses were to be examined in a one year study. They were as follows:

(1) Water level dynamics do not differ significantly in the same impoundment fitted with two 18" diameter culverts versus two 30" diameter culverts.

(2) Organism transport does not differ significantly in the same impoundment fitted with two 18" diameter culverts versus two 30" diameter culverts.

(3) Dissolved oxygen levels in the perimeter ditch do not differ significantly in the same impoundment fitted with two 18" diameter culverts versus two 30" diameter culverts.

These hypotheses were to be tested with the use of 18" and 30" diameter culverts with various scenarios of water level and current flow rate measurements in addition to simultaneous biological samples to be taken within each culvert.

Several natural phenomena and personnel activities have not permitted the objectives of this grant program to be realized to the extent expected. First, the hydrological dynamics of the study year left the majority of the marsh unflooded for much of September, October, January through early March and from late March to mid-late August. Low water precluded adequate perimeter ditch dissolved oxygen transect data collection. Therefore, the third hypotheses was never tested as only D.O. transect data was taken for the 18" culvert system. Low water also precluded adequate water flow comparisons through the northern 18" culvert. This latter culvert was not at the same low elevation at which the adjacent 30" was set and, therefore, adequate hydrological comparisons could not be made at this site unless very high tides were experienced. In addition to these difficulties, most regrettably, the principal research assistant on this research grant was replaced no less than twice as the first two individuals obtained permanent positions elsewhere. This was certainly fortunate for them considering that salary funding has ended in this program, but this loss of experienced personnel set back the data analysis phase of this program considerably and, therefore, the timely production of this report.

METHODOLOGY

Continuous water level recordings were made as in all previous CM funded studies (i.e. CM -47,73,93 and 122). Water flow rates were determined using a General Oceanics flow meter (Model 2031H), with a Model 2035 MK III flowmeter readout mated to a Cole Parmer Model 8377-15 mini-recorder. Dates for water flow records are given in Table 1.

Dissolved oxygen levels were determined with each biological collection as were salinities, water temperature and pH using the same equipment utilized in all previous annual research programs (Table 2). In addition, dissolved oxygen levels were routinely monitored for 24 hours on the day of biological collections for a total of 48 recordings (Table 2). Dissolved oxygen transects were made from the culvert site at 5, 10 and 50 m intervals up to a distance of 100 m north of the south pull net bridge north of the south 18" culvert. Nine transects were made during January and February 1987 (Table 3).

Biological samples were taken with culvert traps set in both or either culvert simultaneously at the north and south culvert sites for three hours each on the flood, then on an ebb tide during the day, and again on a flood tide at night. Pull nets collections were made during the AM day and at night after sunset at both the north and south sites. Heart traps were set overnight at two sites on upper marsh <u>Batis</u> flats as were box nets in tidal ditches were set in the north marsh study area (Figure 1, Table 4). These techniques are not quantitative but could be used to compare captures of similar gear in historical studies within the impoundment.

Seven hundred and fifty-one meter square throw net samples were also made as were 141 gill net sets, however, these samples were taken for objectives other than those provided in the initial proposal. The throw net transects provided an accurate fish density and biomass estimate for large portions of the upper marsh while gill nets set outside of the culverts and within the perimeter ditch were used to assess the movement of larger fish not typically captured with the variety of other techniques used at this site over the past ten years. As these were the last quantitative samples to be made at this marsh site after ten years of intensive study every effort was made to obtain as comprehensive treatment as possible. All study sites utilized from CM-43 to present are presented on Figure 1 and Table 4.

RESULTS

<u>Hydrological Studies: Water Level Dynamics</u>. Figure 2 reveals a major difference between the 18" and 30" culverts in replication of estuarine tidal amplitudes within the impoundment. In early February the impoundment was drained with two 18" culverts. As estuarine tides approached spring tide levels around th 7-11th of February, impoundment water levels remained quite high and did not recede when estuarine levels did and the tidal amplitude changes, particularly low tides, in the impoundment did not replicate those observed in the adjacent estuary.

However, in late February, after the installation of 30" culverts and closure of the 18" culverts impoundment, water level dynamics followed the estuary closely even though estuarine tidal amplitudes, and thus impoundment flooding was much higher than in early February. The only major difference observed between estuarine and impoundment tidal amplitudes with 30" culverts is that the maximum height of the estuarine tide surpasses that of the impoundment considerably at tidal amplitudes over 25.0 cm. At a water level of 25.0 cm over 90% of the marsh surface is flooded and prevents rapid water movement through the culvert. Therefore, estuarine high tides reach their peak and begin to fall well before the high tide is reached in the impoundment. This phenomena also occurred with 18" culverts when estuarine high tides exceeded 25.0 cm but the lag time between estuarine high tides and impoundment highs was much greater than with the 30" culvert, at times over a tidal cycle apart (i.e. the estuarine high occurred simultaneous with impoundment low tides). This means that with 30" culverts the upper marsh will not remain flooded as long during spring tide events and although tides will reach a higher amplitude, periodic exposure will occur more often.

Whether this new tidal pattern is positive or negative is debatable. It certainly increases water movement in the perimeter ditch which should improve water quality (not determined). However, under natural conditions much of the marsh would have held water that passed over the natural berm around the perimeter of the marsh at the estuarine edge. Therefore, rapid exposure of the marsh was unlikely a natural condition during exceptionally high tidal periods. The majority of the marsh is upper marsh and will now be exposed between tides more often during spring tide events. This will reduce spawning and feeding area and time for upper marsh aquatic residents, such as sheepshead minnows, sailfin mollies and mosquitofish. Their populations should, therefore, be reduced below the numbers observed in previous years, not only through loss of habitat, but through increased predation by both birds and fishes when they concentrate in lower marsh ponds and the perimeter ditch during the more frequent marsh exposure periods. The most positive aspect of the installation of larger diameter culverts is their affect on the perimeter ditch. With the artificial construction of a perimeter ditch system landward of the natural berm, an additional water body with significantly differing water quality and dynamics was created. The perimeter ditch resembles a tidal creek and is therefore enhanced with increased water flow. The most significant improvement made with 30" culvert installation is, therefore, to the hydrology of the perimeter ditch. The perimeter ditch system has been demonstrated to act as a significant habitat of great biological importance in impoundment and fisheries management.

<u>Water Flow Rates</u>.- Water flow rate data taken for 18" diameter culverts from 21 April to 17 November 1986 and compared to the same measurements taken for 30" culverts taken from 21 to 30 April 1987 did not present a definitive comparison (Table 1). There was considerable overlap in maximum flow rates. However, when simultaneous records were taken for 1.7 hours on 28 September 1987 there was a major difference between water flow rates in adjacent culverts (Figure 3). The maximum flow in the 30" culvert was 1.0

m/s during the record comparison while the 18" culvert only reached 0.3 m/s or one-third the velocity. As the 30" culvert will carry approximately 2.78 times the volume at 3 times the speed per second, 8.3 times more water is transported by the 30" culvert at peak tidal velocity. This represents a significant improvement in water flow rate and volume, particularly when the 30" culvert is set low enough to be nearly completely submerged through those periods of the year in which it is functioning.

Water Quality.- It was hypothesized (null) that there would be no change in water quality as measured by dissolved oxygen levels in the perimeter ditch with the transition from 18" to 30" culverts. To test this hypothesis a dissolved oxygen transect was was set up linearly from the culvert to be tested. Dissolved oxygen transects taken at varying distances down the perimeter ditch from the 18" culvert, 19 January to 5 February 1987, prior to the installation of the 30" culvert did not reveal major changes in dissolved oxygen, even as one approached 100 m from the culvert (Table 3). As these transects were made during the winter months when water temperatures are at their lowest and dissolved oxygen levels are typically stable in shallow open marshes such as Impoundment 12, there was no gradient of dissolved oxygen from the estuary. Thus the present data verifies the null hypothesis in that there is not a major loss in water quality (based on dissolved oxygen measurements) when an 18" culvert is used to transport water from the estuary to the impoundment perimeter ditch.

In order to realistically compare water quality effects of the 18" culvert to the 30" culvert dissolved oxygen transects should be made for both culverts alternately on consecutive days (under similar hydrological conditions) and on the same tidal cycle during periods when water quality and dissolved oxygen levels are considered to be the lowest. This means the warmer periods of the year, particularly when the late summer months B.O.D. reaches a seasonal maximum. These transects were not made during the early summer due to low water conditions in the perimeter ditch, and will have to be conducted during October. They will be appended to this report. We anticipate that several transects will be made on consecutive days with alternate opening of the 30" and 18" culverts to tidal flow. Only after these transects are made will the null hypothesis be considered.

Biological Data: Culvert Comparisons. - From 24 June to 27 August 1987 four culvert traps were set simultaneously in the 18" and 30" culverts for 15 trials. The results were quite definitive. The 30" culverts produced 16 species of fishes and macrocrustaceans and 8,269 individuals during this period, while the 18" culverts produced 8 species and 142 individuals (Table 5). With an order of magnitude difference between the culverts there is little question that the 30" culvert is significantly superior to the 18" culvert in transporting organisms to and from the marsh.

These data also demonstrated that there was an obvious community difference between the culvert sites (Table 5). The south culverts produced 7,436 individuals and 13 species while the north culverts produced 975 individuals and 11 species. Eight resident species (7,385 individuals) were captured at the south site while only three (949 individuals) were captured at the north site. Qualitative differences in resident individuals captured were also significant as 99.6% of the north site residents were palaemonid shrimp, many of which may not have been residents, while 97% of the resident individuals captured at the south site were cyprinodontid and poeciliid fishes. More transient species were captured at the north site, i.e., eight, while five were captured at the south site. Transients made up a greater percentage of the total catch at the north site (2.6%) versus the south site (0.7%). Although with such a low catch of transient fishes it is difficult to place weight on the trends observed, 69% of transients captured at the north site were either gray snapper, _Lutjanus griseus_, sheepshead, _Archosargus probatocephalus_, or irish pompanos, _Diapterus auratus_. These species are all known to associate with mangrove prop root fouling communities and could have been actively associated with the fouling organism community within the culverts. However, it is more likely that as they are transients from the open estuary they would be more likely to contact the more accessible north culverts before the south culverts. In contrast, 82% of the transients from the south site were mugiliids, striped and white mullet, _Mugil cephalus_ and _M. curema_. Blue crabs, _Callinectes sapidus_ were also more numerous at the south site.

DISCUSSION AND SUMMARY

Two of the three null hypotheses have been tested sufficiently enough to come to a conclusion regarding water dynamics and biological transport differences between 18" and 30" diameter culverts. There is in fact, a significant difference between water level changes and flow rates operating with 18" versus 30" culverts. Tidal exposure of the marsh increases and marsh submergence periods decrease with the increased flow volume of 30" over 18" culverts. Flow rates may improve by a factor of 3 during the maximum water flow periods with the installation of a 30" culvert. Total volume exchange rates at maximum flow is improved by a factor of eight with the use of 30" culverts. It is anticipated that these improvements in water movement will also improve water quality parameters within the perimeter ditch once the necessary studies are complete.

Even beyond the obvious increase in water volume exchange is a factorial improvement in biological exchange. Fish and crustaceans moved through the 30" culvert in such large numbers when compared to the 18" culvert it appears that some rheotaxic phenomenon may be attracting them to the larger culvert. As most specimens were small and are typically transported passively through the culvert it is possible that entrainment may account for many of the captures in addition to rheotaxic behaviors. Therefore, the greater flow through the 30" culvert could entrain significantly more passively swimming organisms.

As has been demonstrated in earlier studies (CM-47,73, 93, and 122) the microhabitat in which the culvert is placed can greatly effect its importance as a faunal access point to the marsh. We observed in this study a major biological difference between the north and south 30" culverts which further verifies this phenomenon. As in CM-93, the south culvert site produced more resident fishes, but typically fewer transient species, than the north culvert site. The latter location is more proximate to open estuarine waters and is, therefore, more accessible to estuarine species which periodically migrate into the marsh (e.g. snook, mullet, ladyfish). This demonstrates that the site for the marsh access is just as important as the size of the culvert installed as only an 18" culvert was utilized to allow fish access to the marsh during CM-93. The same species were transported in approximately the same relative numbers with either 18" diameter (1984-85) or 30" diameter culverts (1987) and yet the same microhabitat bias was observed.

This study, therefore, documents conclusively the hydrological and biological benefits of the increase in culvert diameter. The only negative biological effects may be the reduced upper marsh submergence periods under natural flood conditions which will result in a reduction of breeding and feeding area for marsh residents. As these fishes are so adaptive to a wide variety of environmental conditions and characteristically produce large numbers of progeny during a single year, it is doubtful that this reduction in habitat will be a significant factor to consider in marsh management. During summer RIM flood periods reproduction in these species will be enhanced through increased spawning and feeding habitat availability which should more than offset the reduction in habitat during open tidal periods.

This study has focused on estuarine impoundment access structures and how they might improve water exchange, and therefore, water quality and organism exchange between impoundment perimeter ditch habitats and the open estuary. Other studies have examined the optimum distance between culverts for effective water and transient organism exchange. All of these studies have produced positive recommendations for effective structural settings. However, we still have a series of basic questions to answer. What is causing the water quality problem in the perimeter ditch to begin with? Is it detrital accumulation, a natural microbial phenomena, or a geochemical phenomena? How, when and why does the perimeter ditch water column exceed the physiological limits of the very organisms we seek to access this habitat? What are the causes of fish mortality? Are some fish preadapted to survive this environment while others are not? Can fish be conditioned to survive the most physiologically challenging periods induced by impoundment management? There are over 403 km of perimeter ditch habitat along the east coast of Florida most of which offers both an optimum habitat and liability to the fishery resources which are capable of using it. For this reason the understanding and effective management of this habitat is quite important to the coastal zone of east-central Florida.

PRESENTATIONS AND PUBLICATIONS

Three professional presentations were made during the past year utilizing the results of the research programs funded by Indian River Mosquito Control District and the Florida Department of Environmental Regulation. These presentations were as follows:

National Meetings of the Am. Soc. of Ichthyologists and Herpetologists, Albany, N.Y. , 21 - 26 June 1987.

Gilmore, R.G. Dynamics of microhabitat selection in fishes inhabiting subtropical herbaceous marsh and mangrove swamp ecosystems.

Hood, P.H. Utilization of east-central Florida salt marsh habitats by snook, *Centropomus undecimalis*, ladyfish, *Elops saurus*, and tarpon, *Megalops atlanticus*.

Invited presentation at Research Station, Everglades National Park, U.S. Dept. of Interior. July, 1987.

Gilmore, R.G. Dynamics of microhabitat selection in fishes inhabiting subtropical herbaceous marsh and mangrove swamp ecosystems.

A single publication resulted from earlier studies although another is in press.

Gilmore, R.G. Fish, macrocrustacean and avian population dynamics and cohabitation in tidally influenced impounded subtropical wetlands. In: Proceedings of the Symposium on Waterfowl and Wetland Management Zone of the Atlantic Flyway.

TABLE 1. Flow rate data schedule.

DATE	MEAN M/S MAX. FLOW	MAX. RATE RANGE M/S	MAX. RATE STAND. DEVIA.	RECORDING TIME HR.
18" CULVERT				
21/22 Apr.'86	1.0	0.9 - 1.2	0.14	9.6
23/24 Apr.'86	0.8	0.5 - 1.2	0.35	18.2
30 Apr.'86	1.0	0.9 - 1.1	0.14	9.4
5/6 Nov.'86	1.0	0.3 - 1.4	0.50	25.9
16/17 Nov.'86	1.1	0.5 - 1.4	0.36	25.7
30" CULVERT				
21/22 Apr.'87	1.1	1.1	-	2.8
29/30 Apr.'87	1.1	1.0 - 1.2	0.12	22.8
30 Apr.'87	0.8	0.5 - 1.2	0.23	20.2
SIMULTANEOUS 18" AND 30" CULVERT FLOW COMPARISON				
28/29 Sept.'87				
18"	0.3	0.3	-	1.7
30"	0.8	0.5 - 1.2	0.33	20.9

TABLE 2.CZM 167 DATA COLLECTIONS 1986-87

DATA	DATES	N
I. PHYSICAL DATA		
A. Water level records, continuous inside/outside	9/86-9/87	
B. Water flow rates		
1. 15" culvert without 30" culvert	9/86-2/87	2
2. 30" culvert without 15" culvert	2/87-6/87	3
3. 15"/30" culvert combo	6/87-9/87	1
C. Dissolved oxygen		
1. 24 hr DO recordings, ea. coll. period	9/86-9/87	48
2. Spot DO's with ea. coll.	9/86-9/87	288
3. D.O. transects, S & N culvert sites	1/87-2/87	9
D. Salinity/Temperature/pH, w. ea. coll.	9/86-9/87	288
II. BIOLOGICAL DATA		
A. Culvert traps		
1. Tidal samples, 3 sets per day		
a. 15" culvert only	9/86-2/87	60
b. 30" culvert only	2/87-6/87	54
c. 15/30" culvert combo	6/87-9/87	60
B. Pull nets, 2 coll.'s day/night		
C. Throw nets		
1. Sites 54 & 55	9/86-4/87	300
2. 3 up. marsh transects, 10 throws ea.	9/86-4/87	450
D. Gill nets, set time 1700-0800 hrs.	9/86-9/87	141
E. Heart traps, two	9/86-3/87	30
F. Box traps, two	9/86-9/87	46

Table 3. Impoundment 12: dissolved oxygen transects taken along perimeter ditch

Date:	870119		870120		870122		870123		870126		870127		870203		870204		870205	
Time:	1335		1445		1505		1433		1545		1205		1605		1440		1515	
Weather:	SU		RN		RN		SU		SU:W		SU:W		CL		PC		CL	
Air T(F)	84		73		70		65		70		50		70		73		70	
Station	60		60		60		60		60		60		72		72		60	
	T	DO	T	DO	T	DO	T	DO	T	DO	T	DO	T	DO	T	DO	T	DO
D (m)																		
-4	26	6.4	22	2.8	21	4.6	17	8.0	21	0.6	14	7.8	20	5.4	20	5.4	21	6.3
culvert	26	6.4	22	2.8	21	5.8	17	8.3	21	4.9	14	7.4	20	5.9	20	5.6	21	6.2
5	25	6.4	22	2.8	21	5.9	18	10.1	21	3.8	14	7.4	20	5.5	20	5.4	22	17.8*
10	25	6.4	22	3.1	21	5.9	17	8.7	21	3.6	15	7.8	20	5.3	22	5.4	21	6.4
15	25	6.4	23	3.2	20	5.7	18	7.9	21	3.6	15	7.8	21	5.0	21	5.4	21	6.2
20	25	6.2	22	3.8	20	5.8	18	7.9	21	3.8	15	7.5	21	4.8	21	5.3	21	5.9
30	25	6.2	22	2.9	20	5.9	18	8.0	21	3.7	15	7.4	21	5.5	21	5.4	21	6.1
40	26	6.2	22	2.8	20	5.7	18	8.0	21	3.4	15	7.5	21	5.7	21	5.4	21	5.8
50	26	6.0	22	2.8	21	5.6	18	7.6	21	3.4	15	7.5	20	5.7	21	5.4	21	6.4
100	26	6.0	22	2.3	20	5.4	19	7.3	21	3.4	15	6.9	20	6.2	23	6.7	21	5.8

*seaweed mat

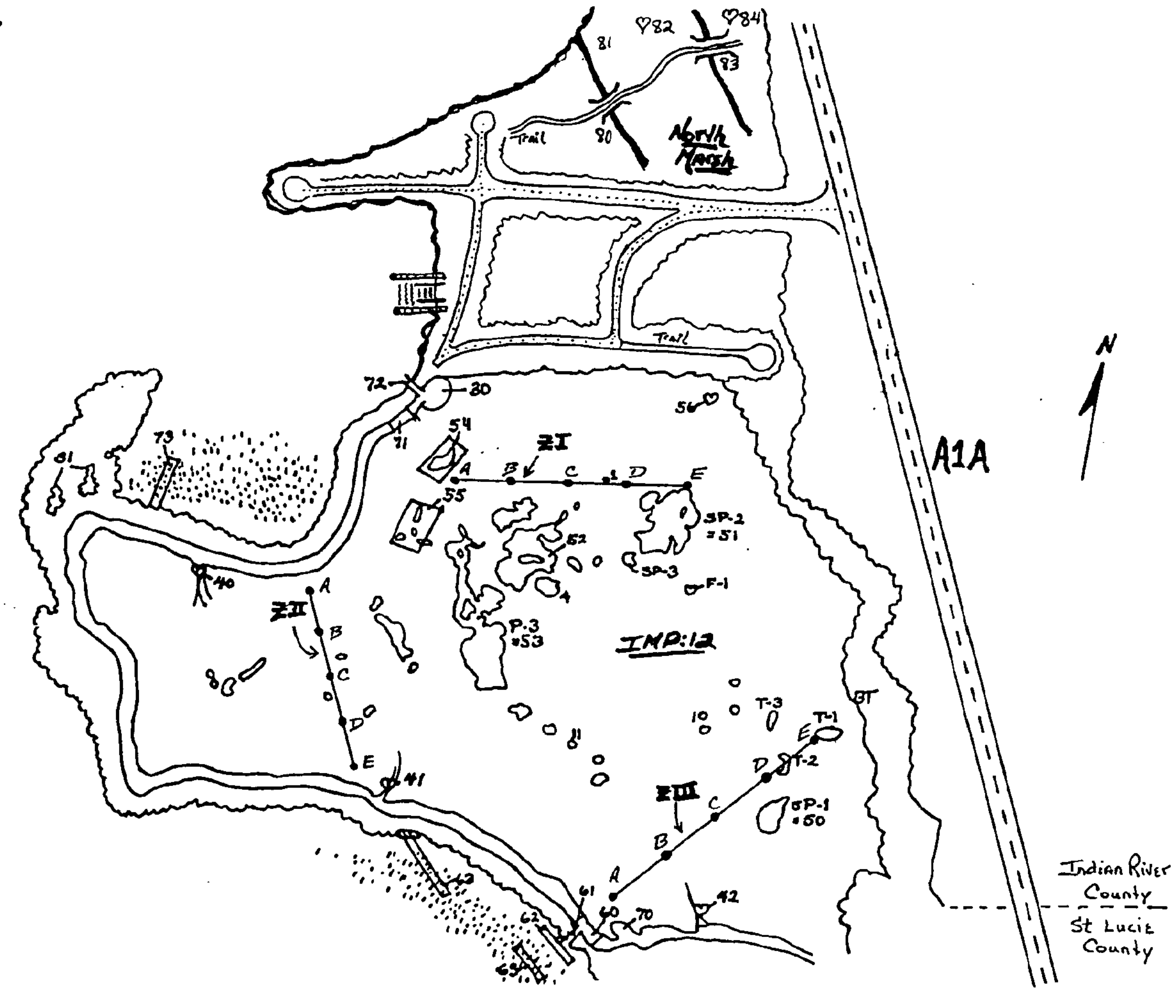
TABLE 4 CZM 167 COLLECTION STATIONS 1986-87

Station #	Station Location	Gear Type	Gear Number
	Impounded Marsh Site		
72	North culvert	Culvert trap	80/81
75	North culvert	Culvert trap	80/81
61	South culvert	Culvert trap	80/81
64	South culvert	Culvert trap	80/81
71	North perimeter ditch	Pull net	007
60	South perimeter ditch	Pull net	007
30	Mole hole	Cast net	003
56	Rain guage	Heart trap	004
55	High breed	Throw trap	005
54	Low breed	Throw trap	005
90	North perimeter ditch	Gill net	001
91	North culvert (out)	Gill net	001
92	South perimeter ditch	Gill net	001
93	South culvert (out)	Gill net	001
94	North upper marsh	Gill net	001
95	South upper marsh	Gill net	001
96	Central upper marsh	Gill net	001
411	North transect 1	Throw net	005
412	North transect 2	Throw net	005
413	North transect 3	Throw net	005
414	North transect 4	Throw net	005
415	North transect 5	Throw net	005
421	Central transect 1	Throw net	005
422	Central transect 2	Throw net	005
423	Central transect 3	Throw net	005
424	Central transect 4	Throw net	005
425	Central transect 5	Throw net	005
431	South transect 1	Throw net	005
432	South transect 2	Throw net	005
433	South transect 3	Throw net	005
434	South transect 4	Throw net	005
435	South transect 5	Throw net	005
	North Marsh Site		
080	West tidal creek (out)	Box trap	011
081	West tidal creek (in)	Box trap	011
082	Pneumatophore bed	Heart trap	004
083	East tidal creek (out)	Box trap	011
084	East tidal creek (in)	Box trap	011
085	West batis bed	Heart trap	004
086	East batis bed	Heart trap	004

Table 5. Fish and crustacean captures within 18" and 30" culverts at north and south sites during fifteen simultaneous culvert trap sets from 24 June to 27 August 1987.

	NORTH SITE CULVERT DIAMETER			SOUTH SITE CULVERT DIAMETER		
SPECIES	30"	18"	TOTAL	30"	18"	TOTAL
RESIDENTS						
Poeciliids						
G. affinis				112	4	116
P. latipinna	2		2	6,459	71	6,530
Cyprinodonts						
C. variegatus	2		2	502	26	528
F. confluentus				3		3
F. grandis				3		3
L. parva					1	1
Atherinids						
M. beryllina				1		1
TRANSIENTS						
Elopids						
E. saurus				1		1
Belonids						
S. notata	2		2			
Centropomids						
C. undecimalis	2		2	1		1
Gerriids						
D. auratus	6		6			
Sparids						
A. probatoceph.	3		3			
Lutjanids						
L. griseus	3	6	9			
Mugilids						
M. cephalus		2	2	41		41
M. curema	1		1	1		1
CRUSTACEANS						
C. sapidus	1		1	7		7
Palaemonetes	945		945	203		203
TOTALS	965	10	975	7,304	132	7,436
SPECIES	9	4	11	12	6	13

FIGURE 1. IMPOUNDMENT 12.



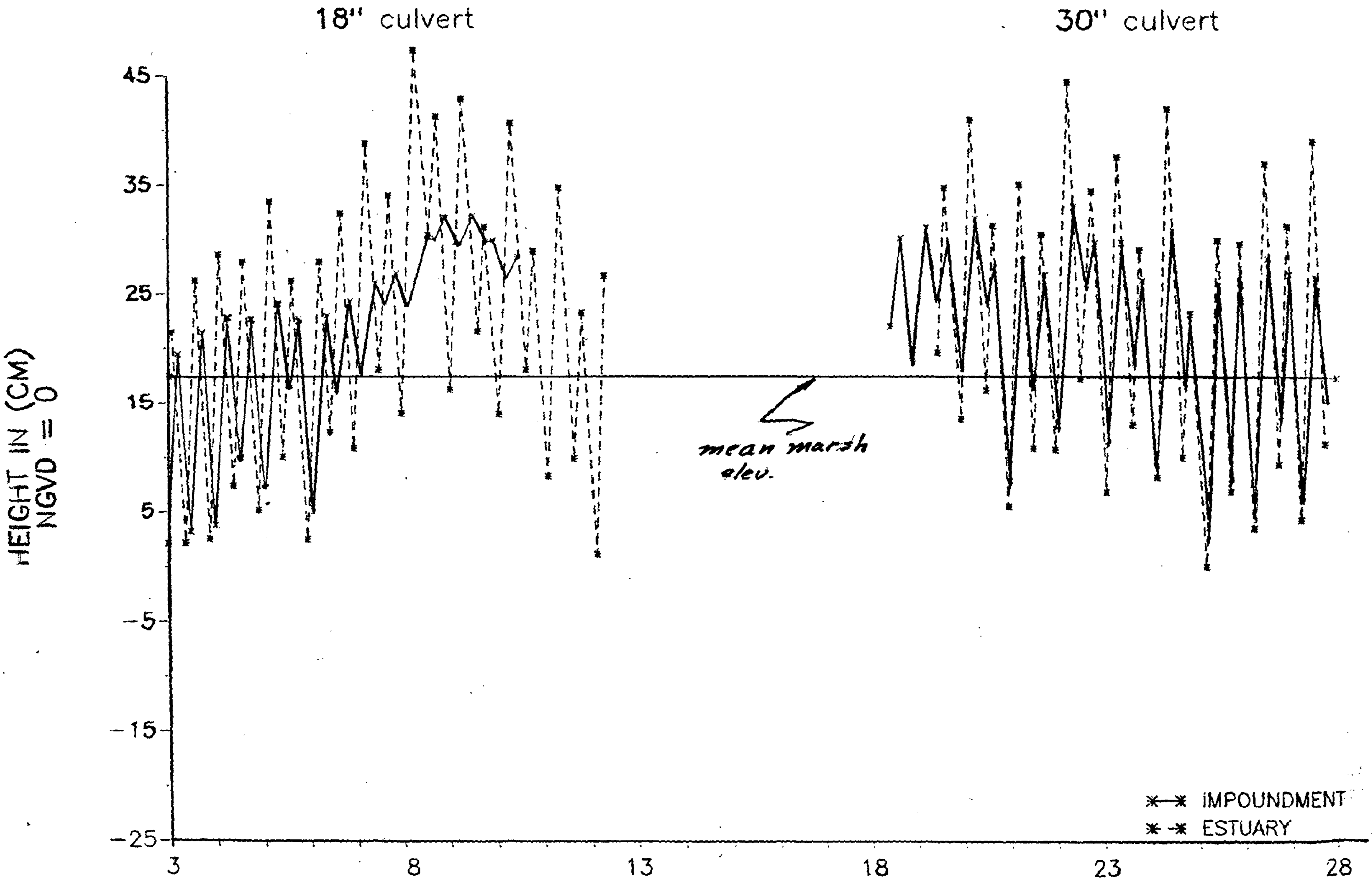
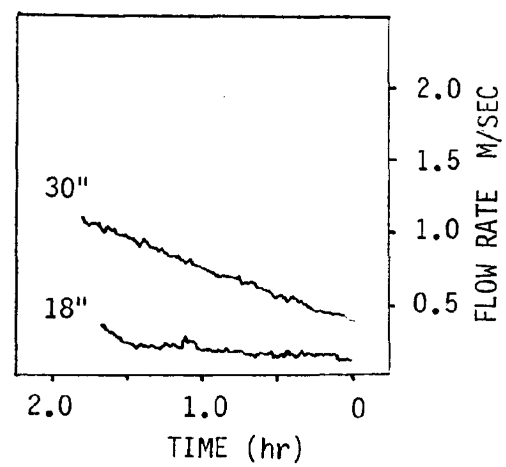
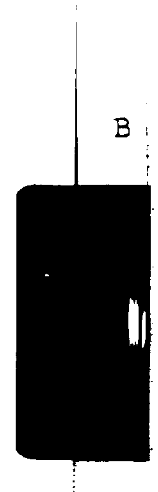


FIGURE 2

3-February to 28-February 1987

FIGURE **3.** SIMULTANEOUS WATER FLOW RATE COMPARISON BETWEEN 18" AND 30" CULVERTS IN IMPOUNDMENT 12, 28 SEPTEMBER 1987.




B

CM-167 FINAL REPORT

VEGETATION PRODUCTION STUDIES

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INTRODUCTION

Below we present data obtained from October 1986 to July 1987 on salt marsh halophyte production in impounded and open marshes along the Indian River lagoon in East central Florida. This study represents a first attempt at quantifying the effects of impoundments upon salt marsh halophyte production, litter decomposition, and litter transport, as well as the interactions between these effects and other environmental variables. The results presented here include only 9 months of a two-year study, therefore, patterns identified here should be considered only preliminary

METHODS

Study Area

Three marshes were chosen for this study (Fig 1): IRC #12; a marsh on the barrier island side of the lagoon which is presently impounded for mosquito control. The original vegetation of the marsh (prior to impounding in 1965) consisted of *Batis*-*Salicornia* meadows, with many black mangroves (*Avicennia germinans*) and a few white mangroves (*Laguncularia racemosa*) interspersed throughout the marsh (Harrington & Harrington 1961). Most of the marsh vegetation was killed when management of the impounded marsh was abandoned at the request of the property owner. Subsequent opening of the culverts connecting the marsh with the lagoon resulted in a rapid recovery of the ground vegetation in certain portions of the marsh. Other portions, however, still remain devoid of vegetation, and there has been almost no recovery of the mangrove cover. Since the initial recovery, there has been an increase in density of Batis and Salicornia in the revegetated patches, but very little change in coverage (Rey et al, in prep.). Study sites were established near the perimeter ditch (PD), and in the North end of the marsh near the uplands (RG).

North Marsh; this is an open marsh directly north of IRC #12. Vegetation is typical of high marshes in the area, consisting of a ground cover of Batis and Salicornia, with a black and white mangrove canopy. A study site was established within a large Batis - Salicornia stand with no mangrove cover.

Oslo Road Marsh; another open marsh on the mainland side of the lagoon, almost directly across from the other two sites. Vegetation is almost exclusively Batis and Salicornia, with no mangrove cover.

Production

Vegetation production at each site was estimated using the clip-quadrat method. During each monthly sampling all of the above-ground vegetation falling within five 1/4m ^{2} "quadrats" was clipped and placed in plastic bags for transport to the laboratory. All of the ground litter within each quadrat was also collected and placed in separate plastic bags. In the laboratory, the standing vegetation was separated into live (standing live) and dead (standing dead) fractions. The standing live vegetation was futher separated into species. Each fraction was then placed in a drying cabinet where it was stored for 3 - 5 days prior to grinding with a Wiley mill. Thereafter, the samples were dried to constant weight at 104°C. After the dry weights were recorded, the samples were inserted into a furnace at 550^{o}C for ashing and the ash-free dry weights were calculated and recorded.

Litter Losses.

To estimate the amount of litter lost from each station during a sampling interval, we placed two rows of 13 litter bags each at each station. The individual bags were made from 2 mm square mesh netting and contained approximately 20 g of dry vegetation. During each sampling we collected 8 bags (one bag from each row at each site), and transported them to the laboratory where their contents were dried and weighed as above. The rates of weight loss during the interval were then estimated from the differences in weight. A further row of 6 bags was placed at each station on March 18, 1987 to investigate seasonal effects on rates of litter loss and decomposition. Thereafter, one bag from this extra row was also collected each month for a total of 12 bags per month.

We decided to use dry instead of fresh vegetation during the first year because we had observed a great deal of standing dead vegetation in the study sites, indicating that a large portion of the litter reaches the ground in that condition. Use of fresh vegetation would necessitate estimation of the dry weight in each bag from dry:wet weight ratios, and would also underestimate the rate of litter removal if the majority of the litter reaches the ground in a dry or semi-dry state. On the other hand, use of dry vegetation overestimates the rate of removal of that fraction of the vegetation that reaches the ground fresh, but the above observation on the amounts of standing dead vegetation indicates that this source of error is very likely to be smaller than those introduced by using wet vegetation and estimating actual dry weight through ratios. We intend to use fresh vegetation in the bags during the coming year to compare the two methods.

Sample Weights.

Originally, each weighing for each sample (tare weights, litter bags, quadrats) was repeated three times (two for the ash weights). The procedure involved drying (or ashing) the item, placing it in a desicator for 1/2 hour, weighing the item, returning to the oven for at least 1 hour, and then repeating the above procedure two other times. The recorded weight for each time was then taken as the mean of the three measurements. Examination of the resultant data however, indicated that the variability between the three weights was so small that it did not warrant the extra time (over 100 hrs per month) required to obtain the triplicate weights (Table 1). Therefore only one weight is presently taken fro each item.

Physical Variables.

Recording thermographs were installed at the Perimeter Ditch, North Marsh, and Oslo Road sites with the sensors at the marsh surface. In addition, water temperature, salinity, pH and D.O. were measured at each site during each sampling when water was present on the marsh. Precipitation is being measured by the Indian River Mosquito Control District at the RG site.

The number of tidal submergences is an important variable, particularly with respect to the rates of litter disappearance. The unusually low water levels recorded in the lagoon during the past year did not allow us to measure the flooding elevations for each site until August 1987, at which time the flooding elevations for the PD and RG sites were determined. Flooding elevations for the NM site will be determined as soon as sufficiently high tides reach the area. Once all of these elevations are determined, the number of days per month that each site received a flooding tide will be calculated from the tidal records obtained from gauges maintained by the Harbor Branch Oceanographic Institute near the study sites. Since the Oslo Marsh is located in the mainland side of the lagoon, tidal records from the barrier island gauges may not be applicable; To determine the number of days per month that the Oslo Marsh was flooded we installed a max-min water level gauge at this site and calibrated it with the flooding elevation of the marsh. Daily inspection of the gauge reveals whether or not the marsh was flooded during the previous day. Elevations of each site were determined by Doug Carlson of the Indian River Mosquito Control District.

Soils.

During 1987, soil samples were collected at depths of 0 to 10 and 11 to 20 cm from the marsh surface. Samples were collected at various locations throughout the study marshes, including NM, PD, and OR. In our laboratory, the samples were cleaned of rocks and large pieces of debris, dried, broken down into fine particles, and subsamples of each were sent to the Soil Analysis Laboratory and to the Soil Characterization Laboratory of the Institute of Food and Agricultural Sciences, University of Florida, Gainesville for analysis. The following analyses were performed for each of the samples: Particle size distribution, organic carbon, pH, soluble salts, phosphorus, sodium, NH_4, NO_3, Cl, and organic carbon.

DATA ANALYSIS

Since the data collected to date does not include a complete yearly cycle, only partial analyses have been performed.

Production.

As is customary in vegetation production studies, several different methods were used to calculate production at each site (Kirby and Gosselink 1976, Turner 1976, Linthurst and Reimold, 1978) and are briefly described below:

Peak Biomass - This method simply takes the highest observed standing biomass as an estimate of the total production during the year. This method is also known as the "End of Season Biomass" method (EOSB, Turner 1976).

Max - Min - Estimates total production as the difference between the highest and lowest standing biomass recorded during the year (Milner and Hughes 1968).

Smalley - Production is calculated by computing the changes in standing crop between successive sampling intervals (months) and recording the monthly production as this difference (or zero if the difference is negative). Total production is then computed as the algebraic sum of the individual monthly production estimates (Smalley 1959).

Wiegert and Evans - This method is similar to the above except that it accounts for all vegetation losses (except by herbivory) from the study plots during sampling intervals. An instantaneous loss rate is computed from litter bag losses for each sampling interval (see below) and is then multiplied by the average ground litter biomass (GLB) recorded in each plot during the sampling interval; this quantity estimates the amount of vegetation lost between successive samples. For each month, this amount is added to the dead biomass, and live biomass to reach a total above-ground biomass (TAGB) estimate. Total production is then calculated as the sum of the differences in total biomass between successive samples as indicated above (Wiegert and Evans 1964, Kirby 1972).

Different methods, or modifications of the above, have been used by various authors such as Williams and Murdoch (1969), Odum and Fanning (1973), Hatcher and Mann (1975), and others to fit their particular circumstances.

Two production estimates were calculated with each of the above methods, one using the actual field data and the other using values from third degree polynomial curves fitted to the actual data. In addition, max - min and peak biomass estimates were obtained using live standing biomass (SLB) only, as well as live + dead standing biomass (SDB). Since data for only nine months are included in this report, yearly values were computed by extrapolating the nine-month results to a 12-month period.

Litter Loss Rates

Monthly loss rates from the litterbags were calculated as follows: The loss rate during a particular interval (in g/g/unit area) is calculated as (initial wt. - final wt.)/initial wt. To calculate the initial weight for each interval one must substract from each bag the amount of weight loss during preceeding intervals. This is done by multiplying the weight of each bag at the start of the interval by the loss rate computed for the previous month and substracting this amount from the starting weight. The resultant value then represents the starting weight for the following month. This procedure is then repeated each month for each bag remaining in the marsh. Due to the preliminary nature of the data, estimates of loss rates were only calculated using the actual data, but in the future both actual and "curve-fit" data will be used to estimate these rates.

RESULTS

Soil.

The data resulting from analysis of the marsh soils is presented in Table 2. The Oslo marsh soils contain a greater proportion of silt and a lesser proportion of sand than the other stations, whereas the North Marsh soils appear to contain lesser concentrations of phosphorus. Chloride content was highest at PD, followed by OR and NM, whereas organic carbon content was highest at OR, followed by PD and NM.

Physical Variables.

Figure 2 shows the mean monthly surface temperatures recorded at PD and NM. The Oslo Marsh thermograph was not installed until March 1987, malfunctioned in April, and was not returned from the manufacturer until June; thus only three months of data were available for this report. It is evident from Figure 2 that some very high temperatures were recorded at NM and PD during the summer, with those at PD tending to be higher than at North Marsh.

Because of the unusually low water levels observed during the past year the marsh floor remained dry at all three sites during most of the time covered by this report. As a result, our water quality records are scant and patchy and will not be presented at this time.

Standing Biomass

The patterns of dead (SDB) and live (SLB) standing biomass at the open sites were the opposite of those at the impoundment sites. Whereas in the open sites SLB was generally greater than SDB, the opposite was true at the impoundment sites (Figures 3 & 4). At NM & OR, the live:dead ratios increased from January to May, whereas at PD and RG they remained very low (less than 1) during the same interval and only increased between June and July (Figure 4).

Litter

As expected from the above, the impoundment sites usually had greater amounts of ground litter than the open sites (Table 3). Inspection of the loss rate data of Table 3 does not indicate any major difference in rates between the sites (no statistical comparisons have been performed on these data yet), but more litter was lost from the impoundment sites as a result of the greater amount of ground litter at those sites (Figure 5).

The seasonal patterns of litter loss were similar at the four sites, with minima during the winter and maxima in the summer (Figure 6). The high values observed during November 1986 are a result of the unavoidable initial loss of litter from the bags during transport and placement on the field.

Total Biomass.

The seasonal patterns of total above ground biomass (TAGB) at PD and RG were similar, showing a decreasing trend from November to January, increases from February to April, and decreases again from May to July (Figure 7). TAGB at NM decreased from November to December of 1986, increased from December 1986 to May 1987, and decreased from June to July. Oslo Marsh exhibited a monotonic increase from November 1986 to April 1987, and a monotonic decrease thereafter (Figure 7). Note that the overestimation of litter loss rates during the first month of this study may be a contributing factor in the decreases observed from November to December at PD, RG, and NM.

Production.

Yearly total above-ground production (TAGP) estimates are shown in Table 4. It is apparent from this table that some of the estimates using the different methods and actual vs fitted data are very close, but others are widely different. The biggest discrepancy occurred between the Wiegert and Evans method with fitted data for PD and RG and the other estimates for these sites. Figures 8A and 8B are graphic representations of these data.

The seasonal patterns of production are similar for all four sites with peak production taking place during the late winter and spring (Figure 8). The shape of the (Wiegert and Evans) production curves for the impoundment sites are very similar, with production peaks displaced about one month (Figure 8A). Likewise, the shapes of the curves for the two open sites are similar, but in this case the Oslo Road marsh had a much higher peak than North Marsh (Figure 8B).

DISCUSSION

Although we have only inspected data for 8 months, several interesting patterns are beginning to emerge and merit some discussion.

The differences in production estimates obtained from using different calculation methods are the rule in studies such as this (Kirby and Gosselink 1976, Turner 1976, Linthurst and Reimold 1978). Polynomial curve fitting is a standard technique used for calculation of production since this procedure tends to smooth out stochastic variation inherent in the sampling methodology. Unfortunately, this method also smooths out real peaks and valleys thus introducing error in the calculation of production. The MAX-MIN and Peak biomass methods tend to underestimate actual production since they do not take into account vegetation removed from the study plots between sampling intervals. In addition, these methods are more suitable for measurements of production of annuals, where there is no "residual" AGB from year to year. The Wiegert and Evans method has a built-in bias towards exageration of actual production because apparent negative production is ignored, but it is still the most realistic estimate of the real yearly production. In cases such as this one where there are many production peaks and valleys throughout the year, the fitted data is best used to identify seasonal trends, and the field data to compute actual production. Figures 9 - 11 illustrate the production estimates resulting from application of the different methods.

It is interesting to note the similarity in the shapes of the production curves of the two open sites and the two impoundment sites. It is difficult, however, to speculate on the possible causes of this phenomenon without access to the monthly submergence data and the rainfall data for each site. The production peaks observed this year appeared somewhat earlier than expected, but the past year was unusual in that the winter was mild, with no major freezes reported for the area, and with extremely low water levels in the lagoon.

As expected, significant differences are apparent between the impoundment sites and the open sites (i.e. seasonal production patterns, relative importance of SDB vs SLB, magnitude and pattern of litter loss, etc.). "Normal" water management of the impounded sites and a more complete data base will allow us to investigate these differences during the coming year.

So far we have not detected any consistent difference between impounded and unimpounded sites in their total yearly production. Although the highest production (Wiegert and Evans - actual data) was recorded at an open site (OR) and the lowest at an impoundment site (PD), the RG site had higher production than NM. Various factors may be responsible for this pattern. In particular, the RG site is close to edge of the uplands, which may mean that it has better drainage, higher runoff and lower soil salinities than the other sites. These factors have been shown to be important in the production dynamics of other areas (Zedler 1984, Zedler <u>et</u> <u>al</u>. 1980), and may be affecting production here as well. The total yearly production estimates calculated for these marshes compare favorably with those reported from other _Batis_ - _Salicornia_ marshes elsewhere (Table 5). This result is not surprising since the data available at this time are mostly from California hypersaline marshes which receive very little precipitation during the year, and whose production is expected to be lower than that of marshes with less saline soils and higher precipitation regimes (Zedler 1963, 1984.)

There are differences in the relative proportions of the different components of TAGB (SLB, SDB, GLB) at the different sites. At the open sites, SLB is by far the greatest contributor to TAGB, but at the impounded sites the dead fraction (SD + GLB) predominates, with SD being the major contributor. The high amount of dead biomass at the impounded sites is partially due to the greater amounts of standing dead vegetation at these sites at the start of the study, which in turn may be a consequence of the significant amount of vegetation damage observed during last year's pump-flood cycle (Rey _et al._, in prep.). Other factors may also be responsible for the observed pattern: The removal rates of litter from the different sites are not very different, but it is likely that the rate of production of dead vegetation may be quicker at the impounded sites (i.e. vegetation stays alive for a shorter period of time) than at the open sites.

We can not assume that all of the ground litter observed at a given site was produced _in situ_. Therefore it is possible that within-marsh transport of litter may contribute to the L:D patterns observed. This may be particularly important at the perimeter ditch site were litter from higher areas of the marsh may accumulate before being washed into the ditch. Variations in ground litter at PD are greater than at the other sites; GLB is either high (>200 g/m^2) or 0, whereas at RG the GLB remains fairly constant (at > 200 g/m^2) and at the open sites the levels remain much lower throughout the year.

CONCLUSIONS

Even with the limited amounts of data available as of this report, several intriguing patterns are already evident. One result that we need to follow closely during the coming months is the greater proportions of ground litter and standing dead vegetation found in the impounded sites. If this pattern holds, it may mean that the litter dynamics of impounded areas are quantitatively (but not necessarily qualitatively) different than those of open marshes. This observation, however, does not mean that litter is being accumulated at the impounded sites (although PD and RG tend to have more ground litter than NM and OR at any one time) since the ground litter levels have fluctuated throughout the year (see above). Therefore, an important question that needs to be investigated is the fate of the litter washed from the marsh floor. A likely scenario is that some of that litter decomposes in situ and is converted into dissolved organic matter, while the rest makes its way to the perimeter ditch as particulate organic matter. The nutrient dynamics in perimeter ditches is another important factor in need of investigation since it is here that some of the more visible results of impounding are manifested. Abnormal accumulation of organic materials in the perimeter ditches may be partially responsible for the poor water quality observed at these sites during parts of the year, and may be result in for reduced input of marsh-generated nutrients into the lagoon. If this is the case, alternative management strategies for these areas may be called for. This study will provide a foundation for further investigation of these problems.

Although no clear hierarchy in total production has been established between sites yet, we have evidence that at least quantitative differences exist between impounded and unimpounded marshes. Of particular interest with rerspect to this observation is the effect of the proximity of RG to the uplands upon that site's production. Time permitting, we will try to add observations to next year's sampling protocol that will be pertinent to this question.

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FIGURE LEGENDS

Figure 1. General location of the study sites.

Figure 2. Mean temperatures recorded at the PD and NM sites.

Figure 3. Patterns of standing live biomass (dry weight) at the four sites.

Figure 4. Live:Dead biomass ratios at the impoundment sites (A) and at the open sites (B).

Figure 5. Dry weights of ground litter collected at the four sites.

Figure 6. Litter losses throughout the year at the impoundment sites (A) and at the open sites (B), and third degree polynomial curves fitted to the data.

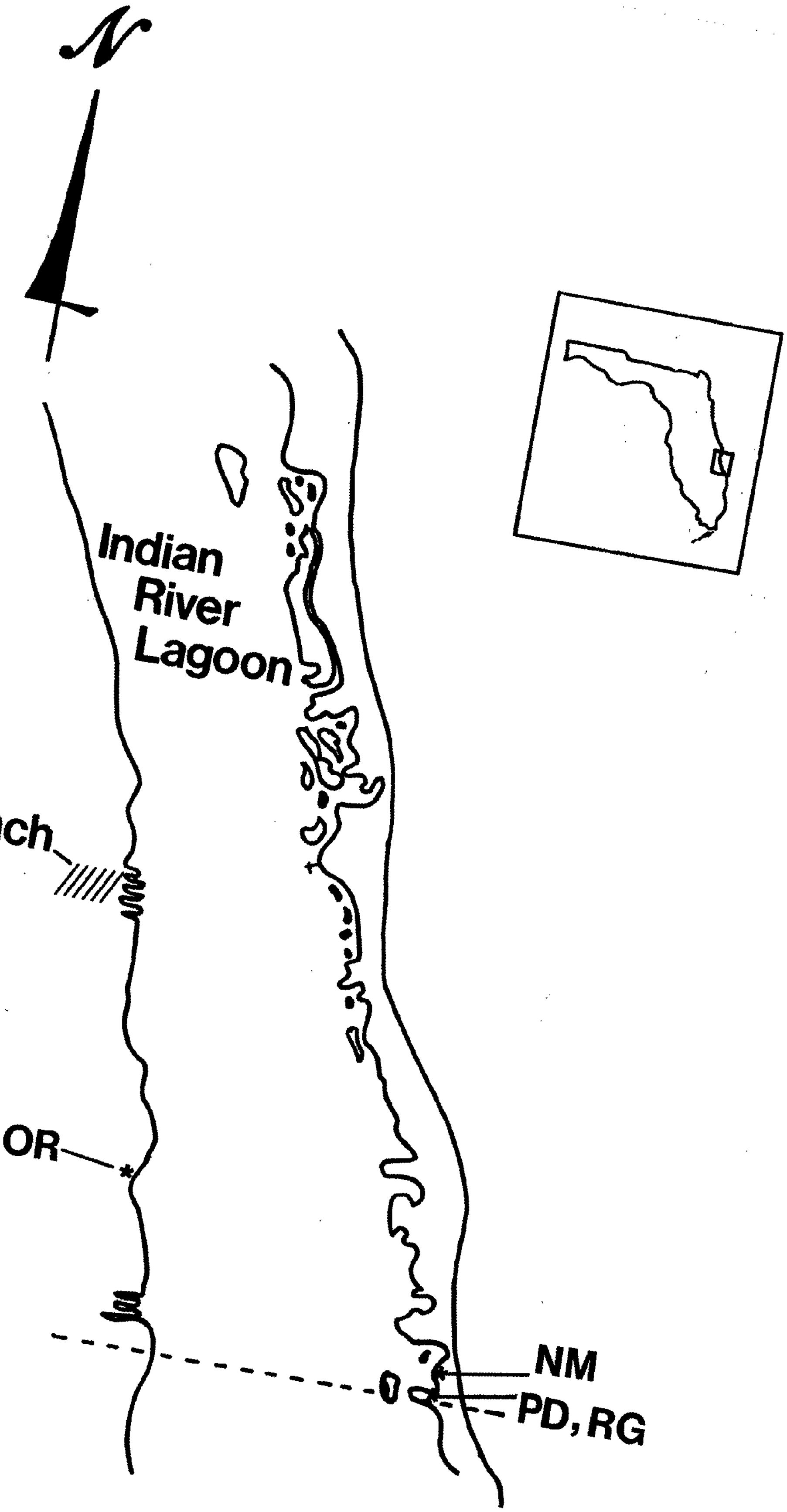
Figure 7. Patterns of total above ground biomass (dry weight) resulting from third-degree polynomial fits to the field data.

Figure 8. Total above-ground production (dry weight) at the impoundment sites (A) and at the open sites (B).

Figure 9. Total above-ground production estimates computed with the Max-min, Peak Biomass, and Wiegert and Evans methods using the actual field data.

Figure 10. Total above-ground production estimates computed with the Max-min, Peak Biomass, and Wiegert and Evans methods using polynomial fit data.

Figure 11. Total above-ground production estimates computed with the Max-min (M-M) and Peak Biomass (MAX) methods using standing live only and standing live + standing dead biomass.



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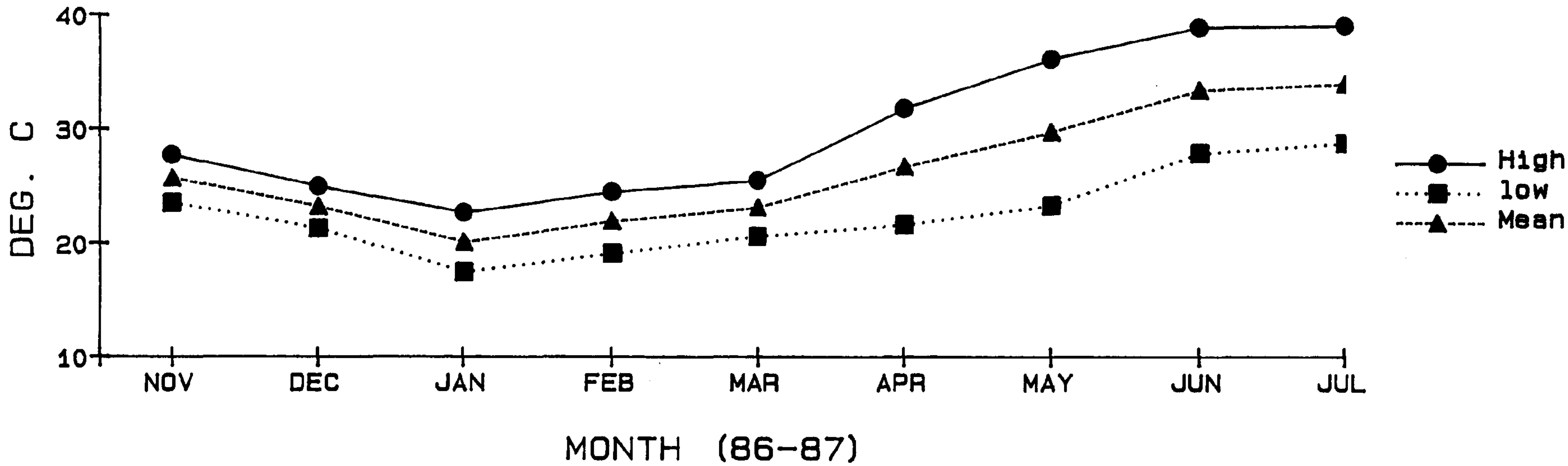
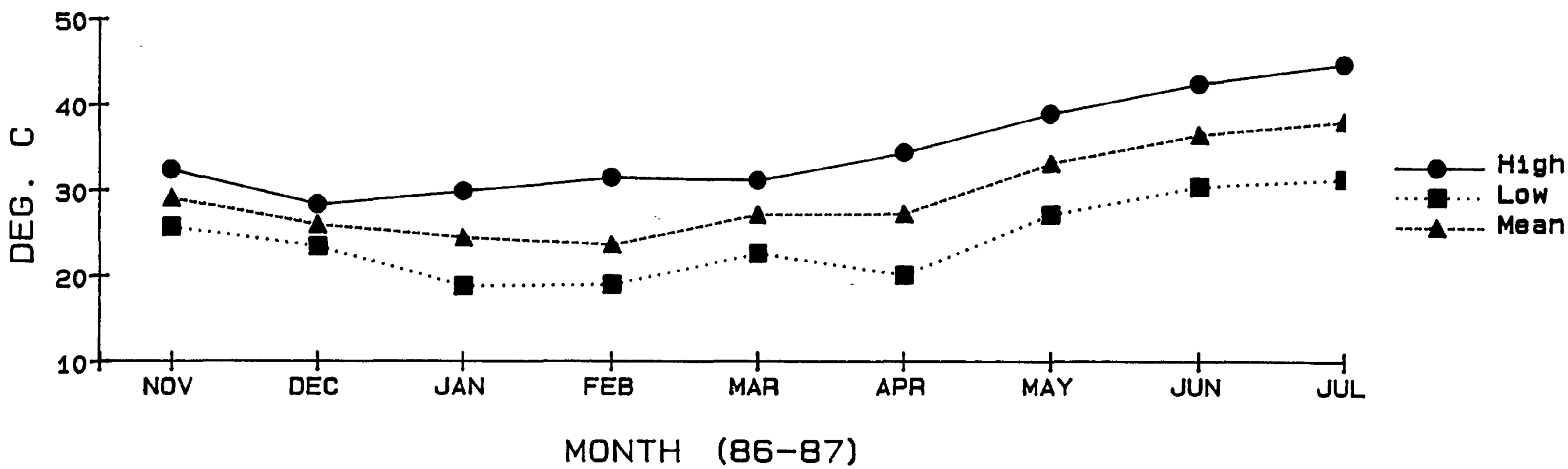


MEAN TEMPERATURES - PD



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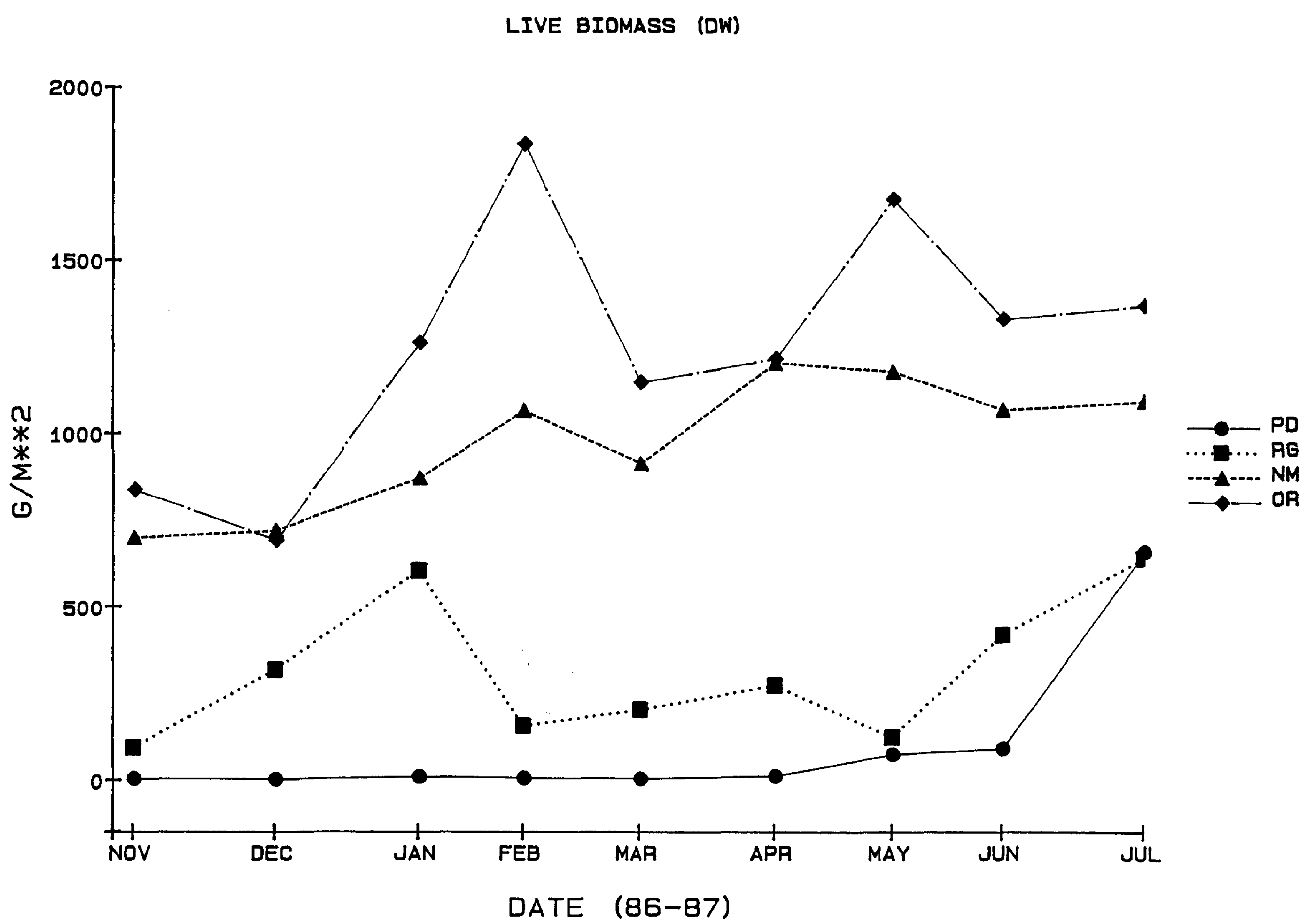

LIVE BIOMASS (DW)
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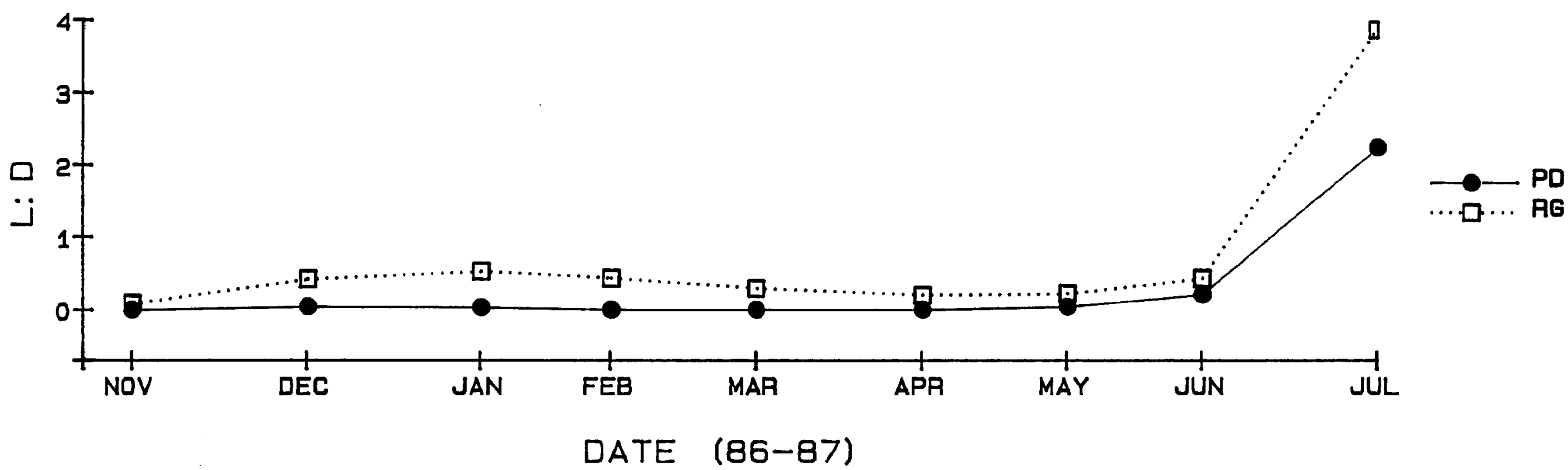
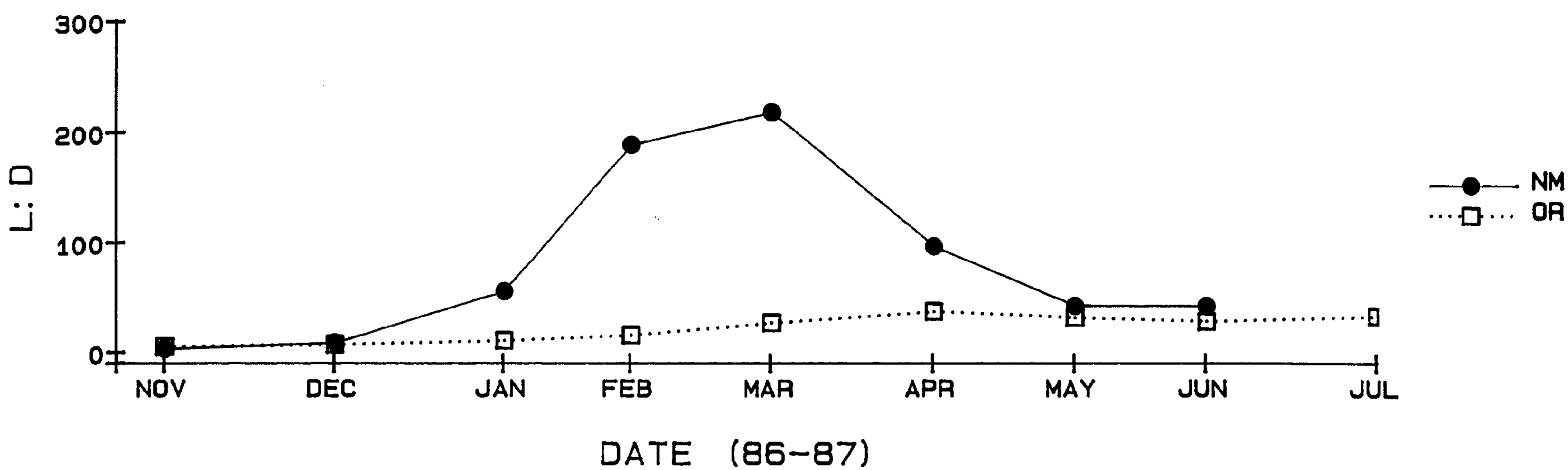
NM
OR

L: D RATIOS



L: D RATIOS



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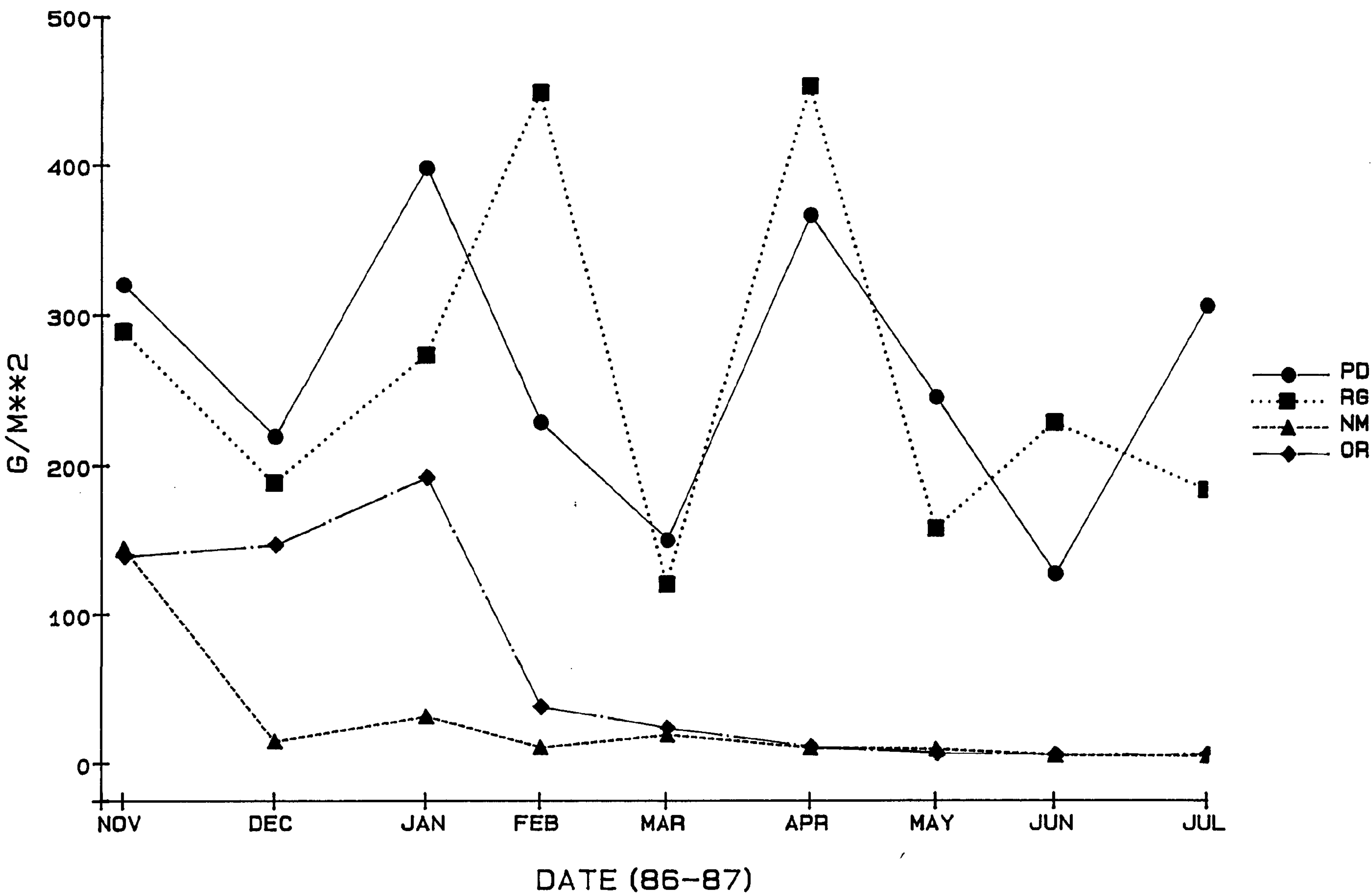
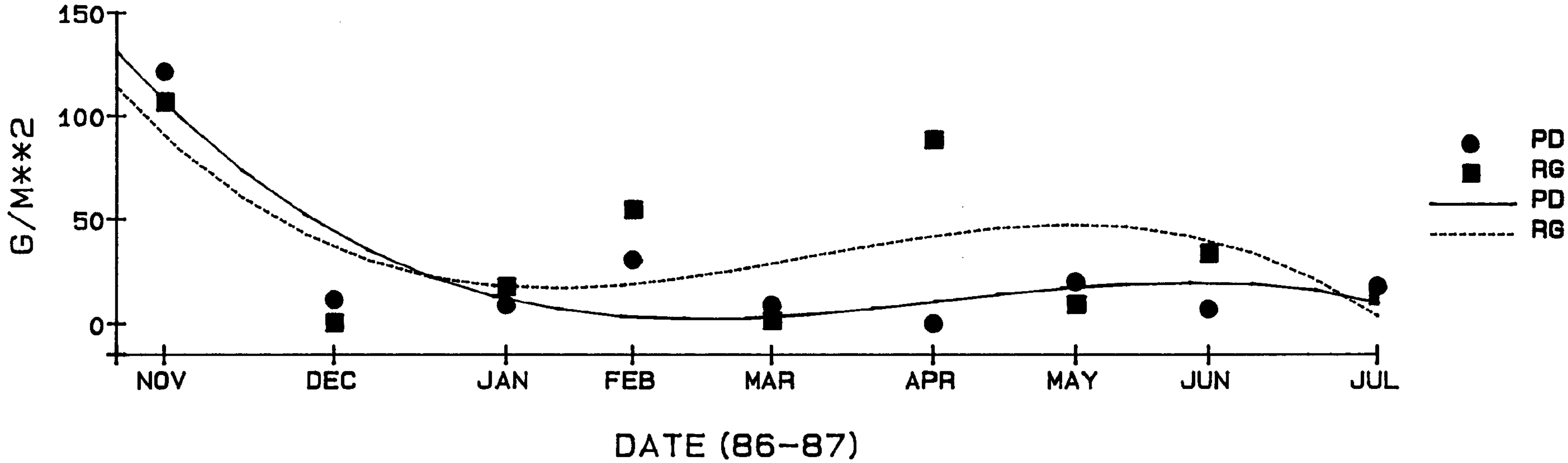
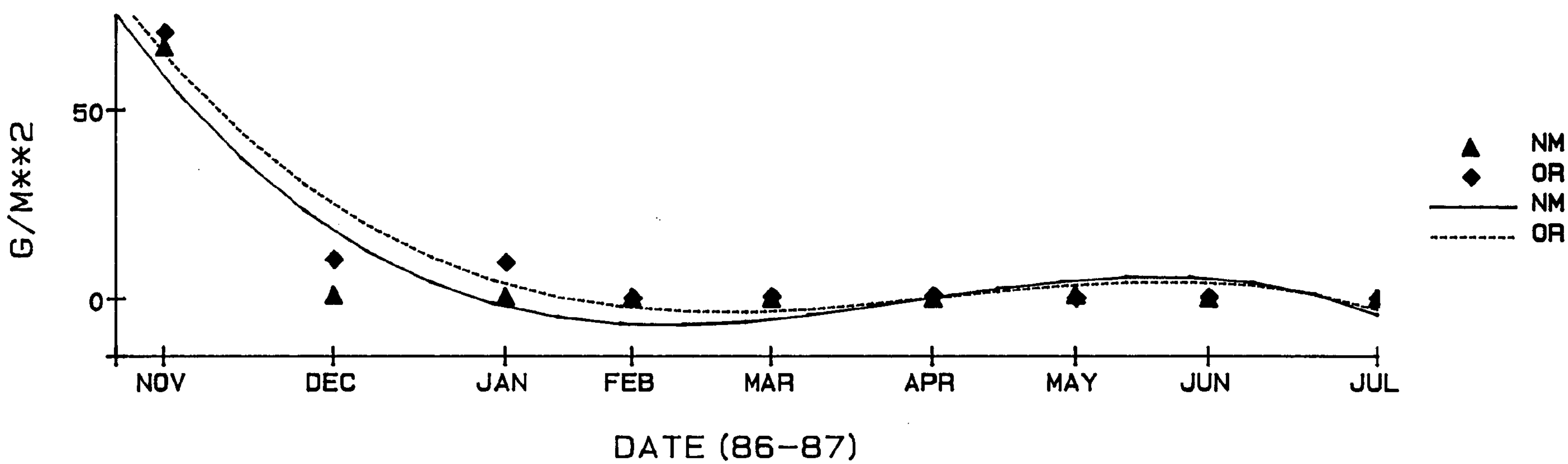
GROUND LITTER



LITTER LOSSES



LITTER LOSSES



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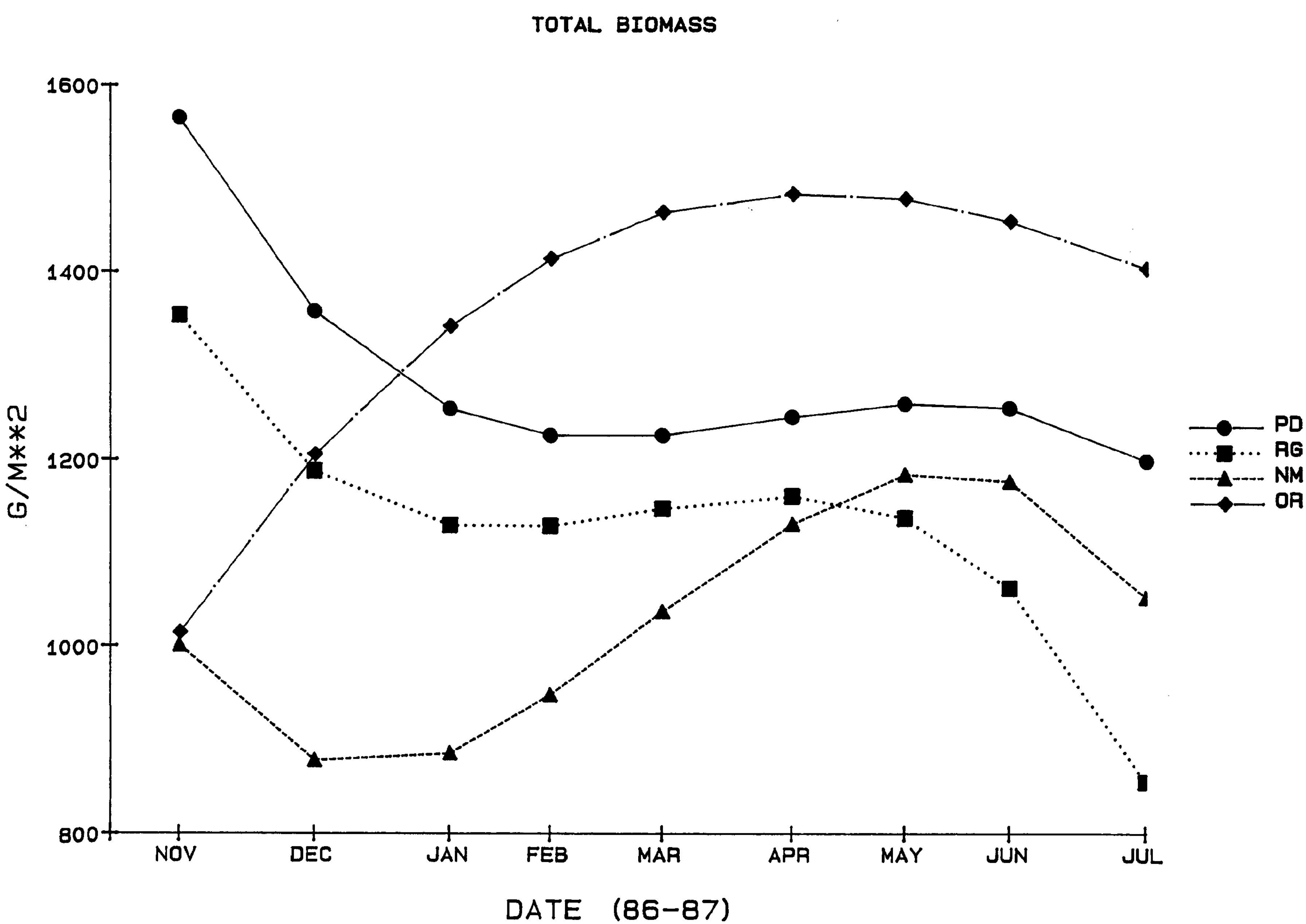
TOTAL BIOMASS
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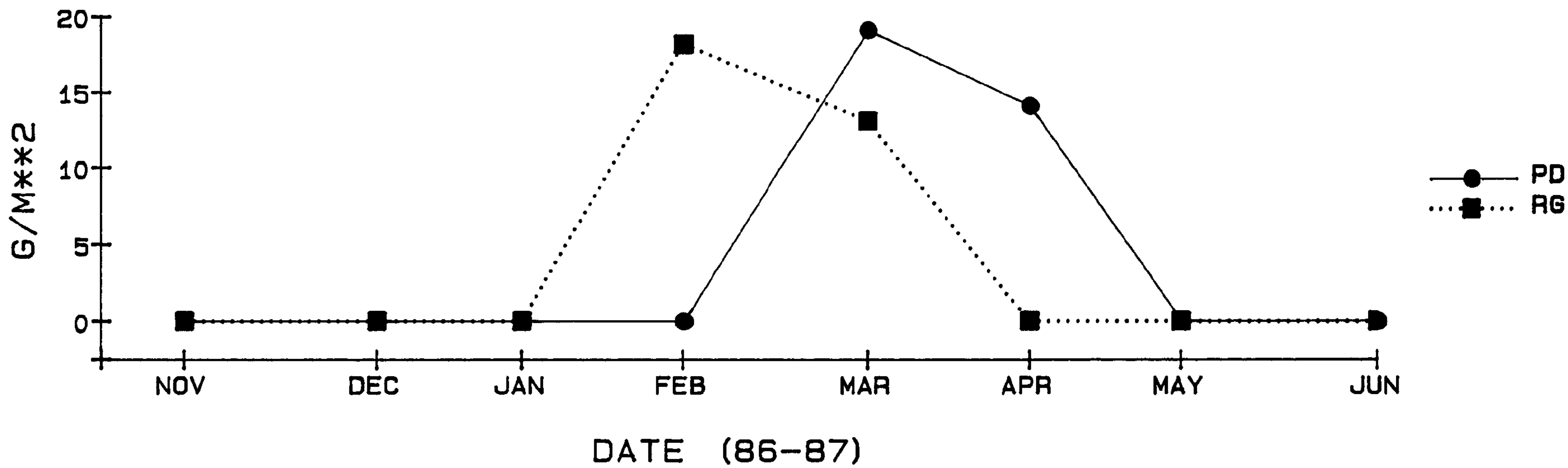
A.G. PRODUCTION



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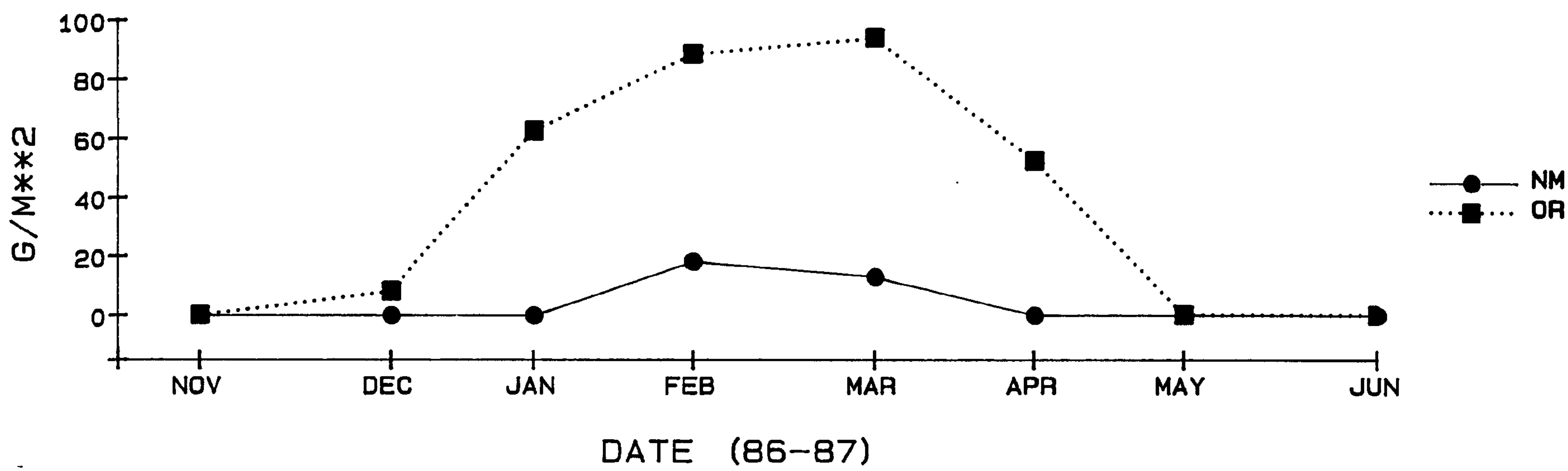
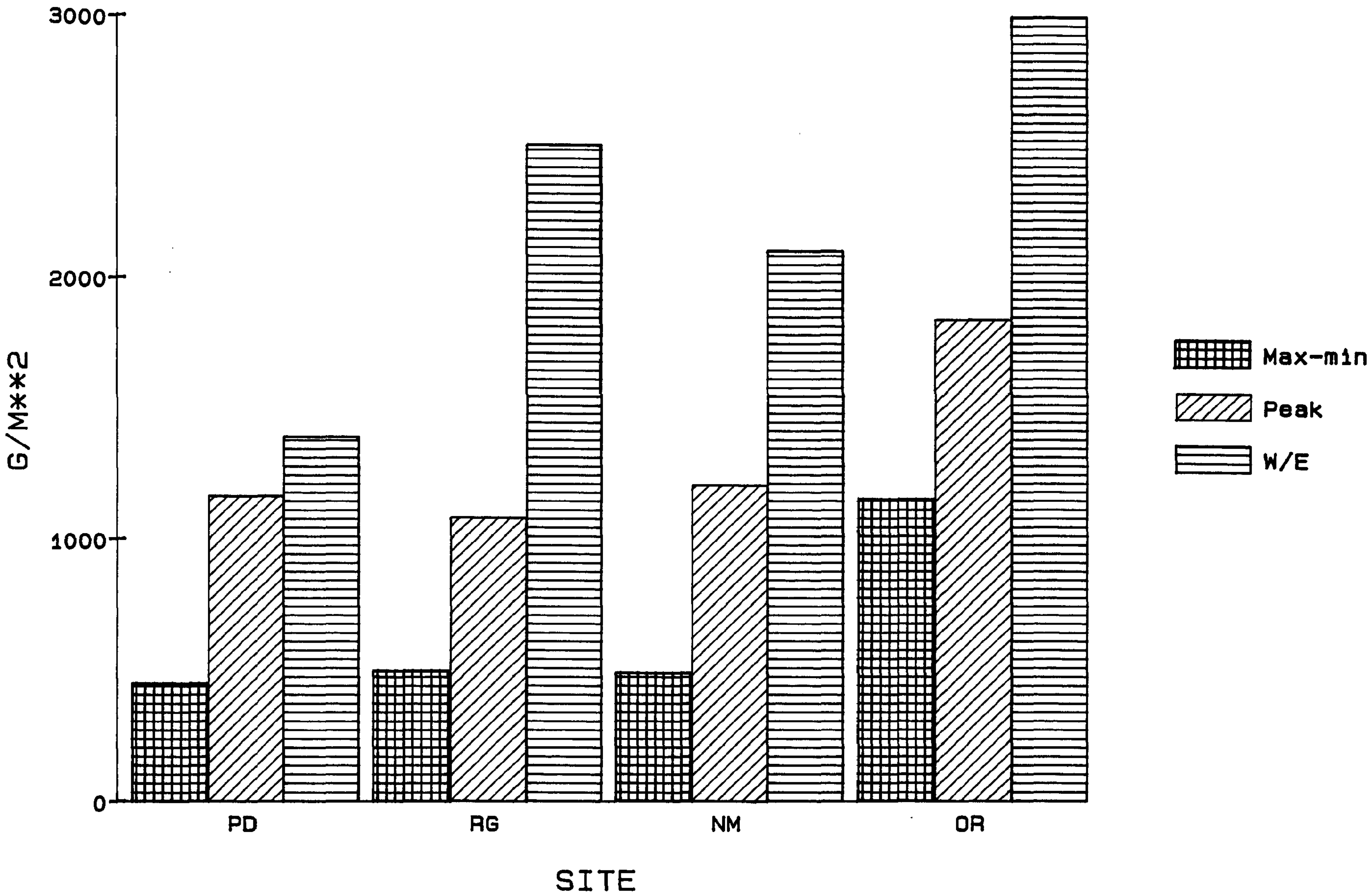
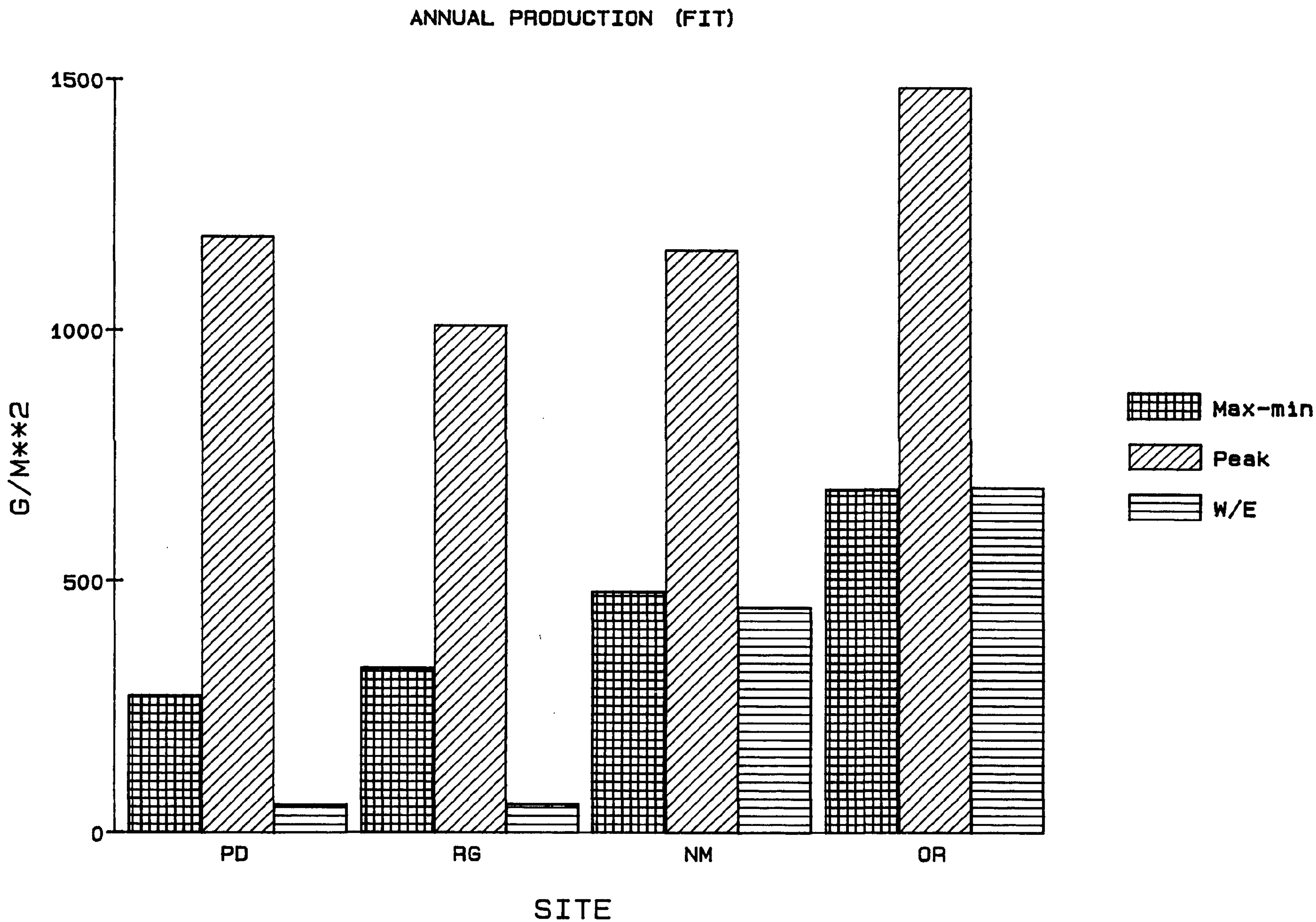


ANNUAL PRODUCTION (FIELD)




ANNUAL PRODUCTION (FIT)
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1000
500
0
G/M**2
PD
RG
NM
OR
SITE
Max-min
Peak
W/E

PRODUCTION (STANDING)

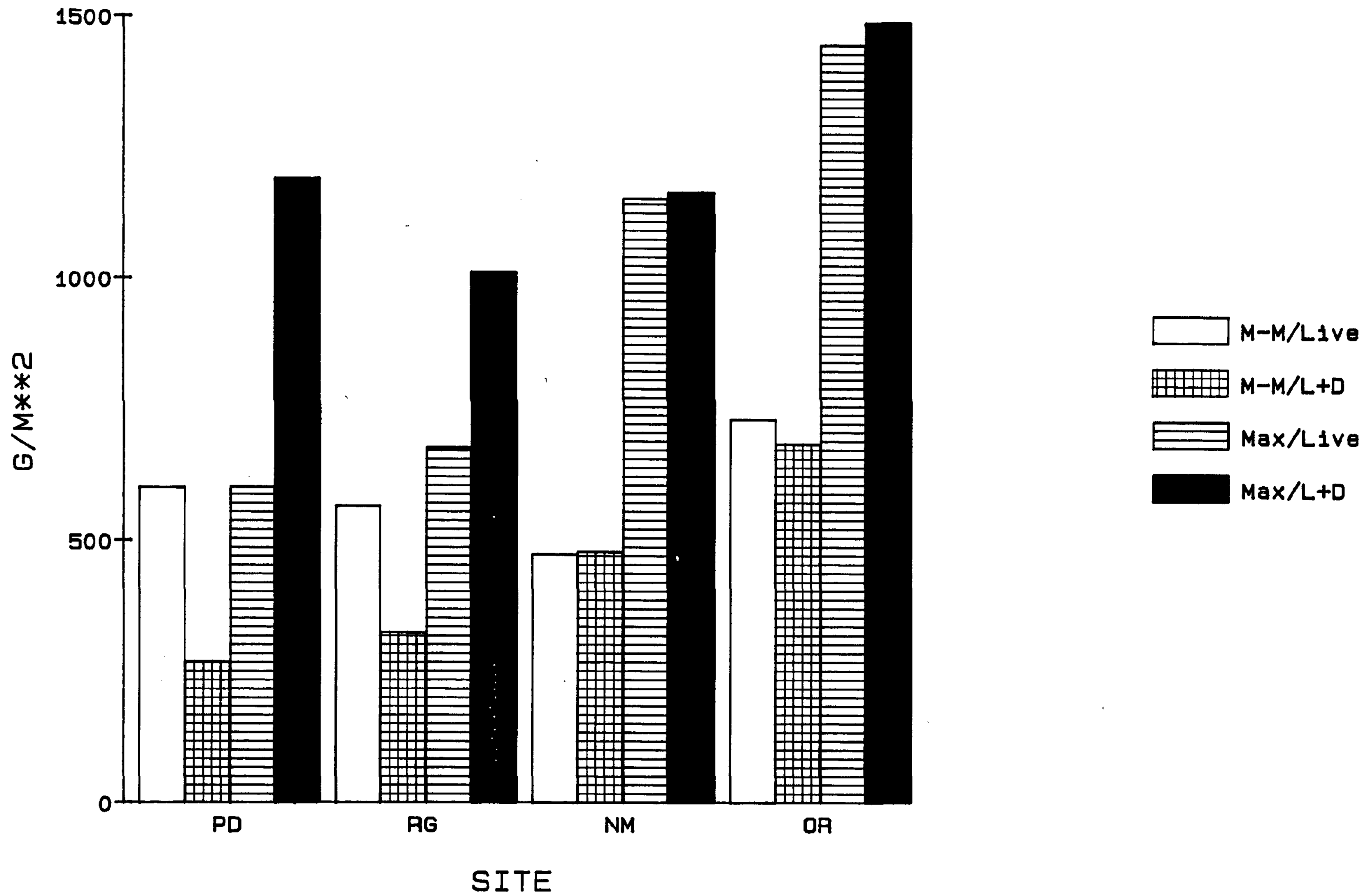

Table 1. Examples of repeated weights obtained from 20 of the samples during May 1986. (DW = dry weight, AW = ash weight).

Sample	DW1	DW2	DW3	AW1	AW2
1	33.8646	33.8933	33.8781	28.7818	28.7814
2	32.2082	32.2254	31.8850	28.5006	28.4997
3	34.5406	34.5643	34.5013	27.9705	27.9644
4	33.3515	33.3734	33.3076	26.7754	26.7747
5	36.5976	36.6029	36.5295	29.5386	29.5378
6	33.6752	33.6830	33.6790	28.3695	28.3689
7	37.5609	37.5784	37.4905	30.4963	30.4959
8	29.6410	29.6493	29.6045	24.4717	24.4710
9	33.7226	33.7297	33.6877	28.1252	28.1230
10	32.9465	32.9596	32.9127	28.0621	28.0614
11	30.8150	30.8224	30.7990	28.7071	28.7060
12	35.3915	35.4047	35.3522	28.4370	28.4351
13	32.7392	32.7488	32.7065	27.2912	27.2885
14	33.7780	33.7861	33.7821	28.3092	28.3077
15	34.8918	34.9021	34.8398	28.3092	28.3077
16	34.2955	34.3080	34.2536	26.4608	26.9576
17	26.7138	26.7202	26.6941	24.1127	24.1117
18	35.2525	35.2630	35.1958	28.3922	28.3904
19	35.1085	35.1175	35.0606	28.0340	28.0320
20	38.2425	38.2759	38.2252	33.1565	33.1586

Table 2. Marsh Soil Analysis. For each site, the top figure is the percent composition from 0-10 cm deep, the bottom figure from 11 to 20cm. (a) = mg/kg

	SAND							
SITE	VC	C	M	F	VF	TOTAL	SILT	CLAY
NM/T	0.0	0.0	0.6	22.4	29.2	52.2	21.5	26.3
NM/B	0.0	0.0	0.4	11.8	17.6	29.8	30.1	40.1
PD/T	0.0	0.2	0.6	20.4	24.2	45.4	24.0	30.6
PD/B	0.0	0.1	0.6	29.0	22.7	52.4	17.9	29.7
OR/T	0.0	0.2	1.8	9.8	15.6	27.4	43.3	29.3
OR/B	0.0	0.2	1.2	7.4	11.6	20.4	33.3	46.4

SITE	P (a)	Na (a)	pH	S.Salt ppm	NH4 ppm	NO3 ppm	Cl ppm	OC %
NM/T	3.2	6080	8.4	18480	4.2	0.8	2000	2.11
NM/B	2.8	5280	8.2	17640	3.0	0.6	2000	2.11
PD/T	32.4	7640	8.0	25200	7.6	0.6	12000	5.28
PD/B	24.8	8800	7.8	27160	6.6	0.2	12000	2.90
OR/T	45.2	8800	6.5	21700	8.0	2.0	6000	8.19
OR/B	43.6	800	6.6	22680	5.8	2.8	4000	6.34

VC = 2-1mm, C = 1-0.5mm, M = 0.5-0.25mm, F = 0.25-0.1mm, VF =0.1-0.05mm.

Table 3. Loss rates from bags and estimated litter losses from each site. All values are per 1/4 square meter.

DAYS	RATE (g/g/mo)	LITTER (grams)	LOSS (grams)
P.D.			
28	0.379	80.096	30.346
63	0.052	54.766	2.872
98	0.023	99.626	2.263
124	0.133	57.082	7.613
153	0.060	37.436	2.257
186	0.000	91.730	0.000
215	0.082	61.300	5.004
242	0.054	31.848	1.715
277	0.058	76.416	4.445
R.G.			
28	0.367	72.304	26.550
63	0.000	47.054	0.000
98	0.064	68.252	4.380
124	0.120	112.380	13.534
153	0.009	30.012	0.261
186	0.194	113.402	22.001
215	0.058	39.346	2.264
242	0.147	56.992	8.384
277	0.070	45.862	3.231
N.M.			
28	0.461	36.122	16.638
63	0.061	3.572	0.217
98	0.012	7.806	0.095
124	0.034	2.594	0.087
153	0.002	4.716	0.009
186	0.000	2.432	0.000
215	0.112	2.170	0.243
242	0.000	1.162	0.000
277	0.000	1.052	0.000
O.R.			
28	0.508	34.730	17.649
63	0.070	36.650	2.566
98	0.049	467.986	2.341
124	0.000	9.498	0.000
153	0.021	5.882	0.123
186	0.068	2.722	0.184
215	0.021	1.668	0.036
242	0.051	1.282	0.066
277	0.000	1.390	0.000

Table 4. Yearly above-ground production estimated with different methods and using actual data as well as data resulting from third degree polynomial equations of curves fitted to the field data. All production estimates are in g(dw)/square meter/year. "Live" indicates that only standing live biomass was used for the estimates, "L+D" indicates that live and dead standing vegetation were used.

SITE	METHOD	PRODUCTION FITTED	PRODUCTION ACTUAL
Perimeter Ditch	Max - Min Live	601.35	601.35
	Peak Live	601.35	163.65
	Max - Min L+D	269.40	443.20
	Peak L+D	1187.77	1162.35
	Wieg.-Evans	55.97	1388.46
Rain Gauge	Max - Min	565.27	135.75
	Peak Live	676.62	158.91
	Max - Min L+D	325.24	492.55
	Peak L+D	1010.61	1079.78
	Wieg.-Evans	56.22	2502.66
North Marsh	Max - Min Live	474.36	126.47
	Peak Live	1150.82	300.67
	Max - Min L+D	477.02	458.22
	Peak L+D	1161.77	1202.78
	Wieg.-Evans	446.42	2099.88
Oslo Rd. Marsh	Max - Min Live	730.64	286.46
	Peak Live	1443.68	459.03
	Max - Min L+D	682.42	1145.83
	Peak L+D	1484.32	1836.14
	Wieg.-Evans	686.78	2986.73

Table 5. Comparison of various poroduction estimates for *Batis - Salicornia* marshes. All production figures are in g/square meter/year.

LOCATION	PRODUCTION	SOURCE
Tijuana Estuary	700 - 900	Winfield 1980
Sweetwater Marsh	1300	Zedler *et al*. 1980
San Diego Marshes	600	"
Newport Bay	600	"
Indian River	1300-2900	This report.

FINAL REPORT

for CM-167

"EFFECTS OF NUTRIENTS ON SEAGRASS"

by

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ABSTRACT

Seagrass beds provide several critical functions for coastal ecosystems, but are often stressed by low light levels. Excess dissolved nutrients are often a major culprit. By adding various levels of dissolved nutrients to Halodule seagrass microcosms, we tested the relationship between dissolved nutrients, epiphytic algae, and seagrass growth and survival. Some results were obvious after 2-3 weeks. In all of the control tanks (no nutrient addition), the water remained clear, the sediment surface looked sandy, and most of the seagrass blades were green and looked "healthy." In contrast, in the high nutrient addition tanks, the water became turbid, and the tank walls and seagrass blades were covered with a thick film of algae. Many of the seagrass blades were black, and in all of the pots all of the shoots had died by week 9. Differences between treatments in seagrass productivity and standing stock were large and rapid. For example, order-of-magnitude differences in growth rate occurred within 3-4 weeeks. Compared to the controls, treatment tanks had increased epiphyte loads and declines in: number of shoots, canopy height, growth rate, and total production. The control of nutrient inputs and the relationship of these inputs to seagrass health demand attention. Management decisions must consider that any addition of nutrients result in some decline in seagrass.

INTRODUCTION

Seagrasses provide several important functions of high primary and secondary productivity, sediment stability, and the provision of food and habitat for dense and diverse assemblages of animals. Perhaps most important is this provision of food and refuge, which provides the basis for a major food web. Without the presence of seagrass, this food web would not exist.

Seagrass beds are important in Indian River lagoon, but in many areas throughout the state are severely stressed (Virnstein and Cairns, 1986). Penetration of light to seagrass leaves is **the** single most important factor determining survival of seagrass beds (DER Seagrass Task Force, unpublished report). Decreases in light can have several causes.

In many coastal areas, one of the major causes of stress (besides suspended sediment) is caused by excess dissolved nutrients in the water column. These nutrients can be a problem by (1) increasing growth of phytoplankton, thus shading the underlying seagrass and (2) increasing growth of epiphytic algae on seagrass blades, again shading the blades. Either of these processes would decrease the productivity of the underlying seagrass and might result in its ultimate demise.

Because dissolved nutrients are more readily and rapidly taken up by algae than by seagrass, any increase in dissolved nutrients favors the growth of algae. Because these algae shade seagrass, any increase in algal growth would result in a decline in light penetration and thus a decline in seagrass growth. What level of nutrients results in what level of seagrass decline? This question is important when management decisions must be made regarding allowable levels of nutrients in coastal waters. We sought to experimentally evaluate this nutrient/algae/seagrass relationship.

METHODS

Our basic approach was to dose seagrass with various levels of nutrients and then to follow the response of the seagrass over time. Because of severe time and money/funding constraints, experiments were carried out only in laboratory culture over a period of a few months.

We used a completely-randomized experimental design. Results were analyzable by a two-way analysis of variance (ANOVA). The two factors analyzed were treatment and time. We went to some pains to have true replication of treatments and to avoid pseudoreplication (a common malady of subsampling one treatment and then considering those subsamples as replicates). Four replicates of each of four treatments were randomly allocated to separate tanks. In each tank there were three pots, each initially containing more than 100 shoots of the seagrass *Halodule wrightii*. In each pot, we measured growth rates of three randomly selected seagrass shoots every 2 weeks. Although we kept track of individual pots, the combined measurement for the nine measured shoots in each tank constituted one replicate measurement.

We selected Cuban shoal grass (*Halodule wrightii*) as our test species. *Halodule* has the widest distribution range of seagrasses in Florida, is compact in form, is easy to transplant and culture in tanks (Short, 1985), does not have a large storage rhizome, and grows fast (Virnstein, 1982). Thus *Halodule* should respond rapidly to stress.

Plugs of *Halodule* were collected in April and May 1987 from a shallow (0.3 m deep) site 500 m south of Link Port in Indian River lagoon. A 19-cm diameter cylinder was pushed into the sediment to a depth of 10 cm [and retrieved by pushing a flat-bladed shovel under the cylinder]. Each seagrass-plus-sediment plug was transferred to a 19-cm diameter plastic pot. Plugs were kept covered and wet and transported back to the lab within 2 hr.

Seagrass plugs were transferred to sinks within outdoor tanks supplied with running ocean seawater at the Indian River Marine Science Research Center belonging to the Florida Institute of Technology. Three pots were put in each of 16 plastic sinks 50 x 50 cm and 30 cm deep which were filled with filtered ocean seawater. Sinks were 90% immersed in a water bath in insulated 0.8 x 0.6 x 2.2-m concrete vaults supplied with flow-through seawater to moderate water temperatures. Each sink was supplied with air through an airstone to keep the water stirred and oxygenated, and the walls of each sink were lined with removable sheets of black plastic film.

One half the water in each sink was exchanged weekly with fresh filtered ocean water to simulate flushing in the interior of the Indian River lagoon. Freshwater was added as needed to maintain salinity at 30-36^{o}/oo. All sinks were covered with shade screens allowing 30% of sunlight transmission, simulating low-light conditions typical of the turbid waters of the lagoon.

After a 3-6-week acclimation period, we began our experimental treatments on 22 May 1987. There were four experimental treatments: (0) control (zero nutrient addition), (1) low (1/4 of high level), (2) medium ($\frac{1}{2}$ of high level), and (3) high. The "high" level of nutrient addition was chosen to simulate eutrophic conditions in Indian River lagoon, such as occurs near Vero Beach (Mahoney and Gibson, 1983), with a nitrogen to phosphorus ratio of 5:1. We used a commercial soluble fertilizer with a composition of 30% nitrogen and 10% phosphorus. Due to an unfortunate calculation error, however, our concentrations were 25x higher than intended. These nutrients were added in a dissolved form once each week. Realized concentrations were:

	Concentration (mM)	
Treatment	Nitrogen	Phosphorus
Control	0	0
Low	1.1	0.17
Medium	2.2	0.34
High	4.4	0.67

After 3 weeks, all sinks were re-innoculated with epiphytic algae in order to provide the same opportunities for algal recruitment. Epiphytes were scraped from aproximately 30 field-collected *Halodule* blades and three blades from each sink and mixed with lagoon water and water from each sink. Equal amounts of this "broth" were added to each sink.

We periodically measured temperature, salinity, dissolved nutrient levels, number of seagrass shoots, canopy height, blade growth rate, epiphyte load, and rate of blade loss. Schedules for these various measurements varied. Lost (cast off) blades were collected from each sink and weighed (dry wt) three times a week. Number of seagrass shoots and canopy height were measured every 3 weeks. Blade growth rate and epiphyte load were measured every 2 weeks. The experiment was terminated after 10 weeks, on 31 July 1987. At this time, all live shoots were counted, and seagrass in all pots was washed free of sediment, separated into three fractions: (1) leaves (above the sheath), (2) shoots, and (3) roots and rhizomes, then dried and weighed.

To measure growth rates of the seagrass blades, we marked shoots by placing a colored plastic stick next to the shoot. The youngest blade in the shoot was clipped at an angle just above the plant sheath to mark that individual blade. The top of the stick was set at the height of the tip of this cut blade. One week later, all blades in this shoot were clipped at the level of the top of the stick. Blades were separated into new growth and old growth, based on the marks. Epiphytic algae were scraped off the old blades with microscope slide covers and dried and weighed. Lengths of both new and old blades were measured, and blades were dried and weighed. Marking was done every other week, with harvesting on alternate weeks.

One problem was controlling populations of amphipod crustaceans in the tanks. Although these amphipods normally eat epiphytic algae, they can consume seagrass. Because their predators were not present in these microcosms, the amphipod populations were not held in check. Unfortunately, the severe cut in funding did not allow us to run our proposed field experiments. In some tanks with few epiphytes, large numbers of green blades were chewed off by the amphipods. We then added 5-6-cm long pinfish (Lagodon rhomboides) to all sinks to prey on these amphipods.

RESULTS

Some results were obvious and did not require measurements or statistical analyses. In all of the control tanks (no nutrient addition), the water remained clear, the sediment surface looked sandy, and most of the seagrass blades were green. Generally, tanks looked "healthy." In contrast, in the high nutrient addition tanks, the water became turbid within 2-3 weeks of nutrient addition, and the tank walls and seagrass blades were covered with a thick film or fuzz of algae. Many of the seagrass blades were black, and in all of these high nutrient pots, all of the shoots had died by week 9. Generally, these tanks looked "sick." Tanks with intermediate levels of added nutrients were variable, but generally had intermediate levels of response.

Environmental parameters

Weather during our experimental period was sunnier than normal (personal observation). Water temperature within the sinks was generally maintained near $30^{\circ}C \pm 2^{\circ}$. Overall range measured by minimum-maximum thermometer was 24-33°C. Salinities were maintained between 28 and 37°/oo.

Shot density

Initial shoot densities were similar in all treatments (mean = 5,146 shoots/m^2). All treatments declined over time, but the three nutrient addition treatmentsdeclined more rapidly. The control had the least decline (to 40% of initial density), and by 6 weeks, control shoot density was significantly greater than in the experimental treatments (Figure 1). By week 9, all the shoots had died in the high dosage treatment.

Canopy height

When first measured, after 3 weeks, canopy heights were all similar (mean ≐ 165 mm). The control treatment was the only treatment to increase in canopy height. Final canopy height in the control was only 5% below the initial measurement and above all three nutrient addition treatments. In contrast, in the three nutrient addition treatments, canopy height continually decreased. By 9 weeks, canopy height in the high-dosage treatment declined 80% (Figure 2).

Growth rate

At our first measurement for growth rates (from day 5-12), the control already had a greater growth rate than the other treatments (Figure 3). Changes over time were inconsistent, but the high-dosage treatment declined to zero (all the shoots died).

Old blades

Weight of old blades is a conservative measure of standing stock. In all three nutrient dosage treatments, weight of old blades continually declined with time (Figure 4). After 4 weeks, weight in the control treatment was at least double that in any other treatment. In the control treatment, weight temporarily increased, before gradually declining (Figure 4), reflecting the same pattern demonstrated by canopy height (Figure 2, above).

Lost leaves

Because data were highly variable day-to-day, we plotted a running average (n = 3) by averaging the weight of lost blades on any given collection date with those of the previous and subsequent collection dates. All treatments declined, but after about 4 weeks the control maintained a level of production of blades about 5 times that of other treatments (Figure 5).

Total production

Total production of blades over the 10-week experimental period was calculated as: (sum of loose blades collected, per pot) + (sum of harvested blades, both new and old) + (final collection of blades, on 7/31/87) - (initial standing stock). Initial standing stock of blades was estimated by multiplying the first measurement of weight of blades per shoot (= new + old harvested blades) times the number of shoots. Production in the control treatment was approximately 4 times production in the nutrient addition treatments (Table 1).

Table 1. Total blade production based on the 10-week period.

	Treatment			
	Control	Low	Medium	High
Total production (g/pot/10 wk)	4.0	0.95	1.2	0.97
Productivity (g/m^2/day)	2.0	0.48	0.61	0.49

Weight-to-length ratio

"Robustness" of seagrass blades (a combination of width and thickness) may be measured as weight per unit length. For the newly produced blades, this may be a measure of plant vigor. There was little indication of any pattern, however (Figure 6).

Epiphyte load

We used weight of epiphytes per weight of old blades (as opposed to new recently grown blades) as a standardized measure of epiphyte abundance. After 7 weeks, epiphyte abundance in the high dosage treatment increased 45-fold compared to only 3-fold for the control (Figure 7). The two intermediate doses increased over 20-fold. The relationship of weight of new growth versus the ratio of epiphyte weight:weight of old leaves (Figure 8) shows the relationship between increased epiphyte load and the decrease in new growth. As epiphyte growth increased, the weight of new growth decreased, especially evident in the high nutrient treatment. The increased nutrient loads of the low and medium treatments also indicate that increased epiphytes lead to decreases in new growth.

Final plant biomass

By the end of the experimental period (on 7/31/87), differences in plant biomass for the various treatments were huge (Table 2). For all three plant components, plant biomass in the control was 130 to 430 times that of the high dose treatment.

Table 2. Final plant biomass (mg per pot) on 7/31/87.

	Treatment			
Component	Control	Low	Medium	High
Leaves	142.5	10.2	5.9	0.3
Shoots	178.1	13.6	11.2	0.8
Rhizomes	1943.9	312.2	350.1	14.58

DISCUSSION

Increased nutrients did result in declines in seagrass. These differences in productivity and standing stock were large and rapid. For example, order-of-magnitude differences in growth rate occurred within 3-4 weeks (Figure 3). It was obvious that nutrients directly caused increased abundance of epiphytes heavy enough to shade seagrass. Because of the shallow tanks we used, we largely eliminated the compounding effect that increased nutrients would also cause increased growth of phytoplankton.

The physical setup and the controls that we used apparently provided a reasonable simulation of nature. The control treatments grew and increased, declining only after a few weeks. This delayed decline was likely due to confinement of the seagrass in pots with a limited supply of sediment and nutrients. Our measurements of primary productivity (1-2 $g/m^2/day$) were very similar to field measurements for Halodule (Virnstein, 1982) and other seagrass species (West and Larkum, 1983).

Although our results are reasonable, we did experience some problems. There were a few anomolous responses not directly explainable, such as peaks in growth and epiphytes. Certainly, some of these problems are related to the confinement of the seagrass in pots under laboratory conditions. One problem was that the closed laboratory situation did not allow predators access to prey. Some of these prey (e.g., amphipods) had population explosions resulting in subsequent declines in seagrass. Particularly in the control treatments, with few epiphytes for the amphipods to feed on, abundant amphipods grazed directly on the green seagrass blades. Without this grazing artifact, differences between treatments would have been even greater than we measured.

Despite the unnaturally high levels of added nutrients, we believe the effect was merely to compress the time frame of effects. For lower, more natural levels of nutrients, we believe the effect would be the same, in terms of type and direction, but would simply take a longer time to detect. These longer-term, insidious effects undoubtedly occur but are largely undetected except as an aggregate effect of all stresses.

Our results, despite some problems, clearly demonstrate that controlling inputs of nutrients is necessary for maintaining abundant seagrass beds. Because light is the ultimate key limiting factor for seagrass growth, any decrease in light results in a decrease in seagrass growth. And because epiphytic algae and phytoplankton are controlled largely by nutrient levels, nutrient input must be severely restricted if seagrasses are to survive. Zero discharge should be the goal. Although magnitudes of inputs and impacts are usually not known, two major sources of nutrients are certainly discharges from sewer treatment plants and local land runoff. The relationship of these inputs to seagrass health demand attention.

Changes in nutrient levels will certainly result in changes in the base of primary productivity. Increased levels of dissolved nutrients will result in increased growth of algae, both in the water column and on seagrass blades. Both of these changes would contribute additively to a decline in seagrass and a shift to algae (phytoplankton only, at high nutrient levels) as the base of the food web (Heffernan and Gibson, 1983). To lose seagrasses in coastal and estuarine systems would have a disastrous effect on productivity and fisheries.

RECOMMENDATIONS

The limited availability of time and money did not allow us to test very low levels of nutrients nor to test effects in the field. We can not recommend any "safe" levels of nutrients, nor have we isolated effects of nitrogen and phosphorus. Much remains to be done. At the minimum, we recommend funding field experiments using smaller doses of nutrients and far longer time periods.

Management decisions must consider that <u>any</u> addition of nutrients results in <u>some</u> decline in seagrass. Although it is <u>not</u> known how much harm is caused by a given level of nutrients, any additions of nutrients result in some loss. We should err on the cautious side of protecting fisheries and habitats, not just for their protection <u>per se</u>, but also for the real economic benefits. Since most fisheries species depend on seagrass beds, losses in seagrass beds have huge economic impacts. Fisheries for lagoon-dependent species probably exceed $100 million per year (Yingling, 1987). Such losses can not be tolerated.

Due to the time contraints on this project the final statistical analysis was not completed on all sets of data. Prior to submittal of the final manuscript for publication we intend to do two-way ANOVAs with replicates to determine the time and treatment effects and any interaction effects.

ACKNOWLEDGEMENTS

Kimon Bird, HBOI, graciously allowed us the use of his experimental tanks and elegant plumbing. Allan Curtis, IRMCD, helped with the statistical analyses. Fred Vose, FIT, helped set up the seawater system.

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Figure 1. Mean number of shoots per pot for each of the four nutrient dosage treatments versus time.

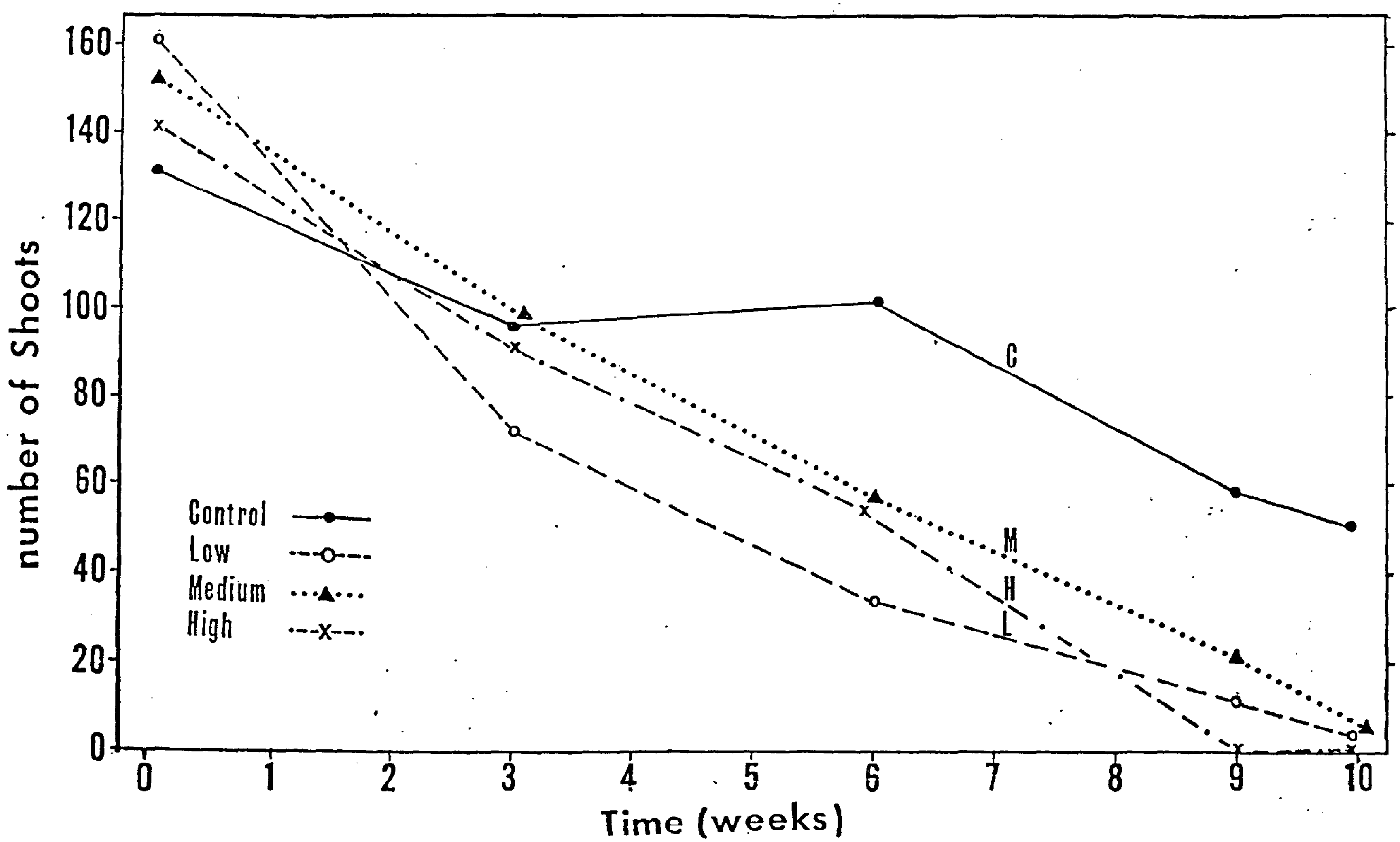


Figure 2. Canopy height for each of the four nutrient dosage treatments versus time.

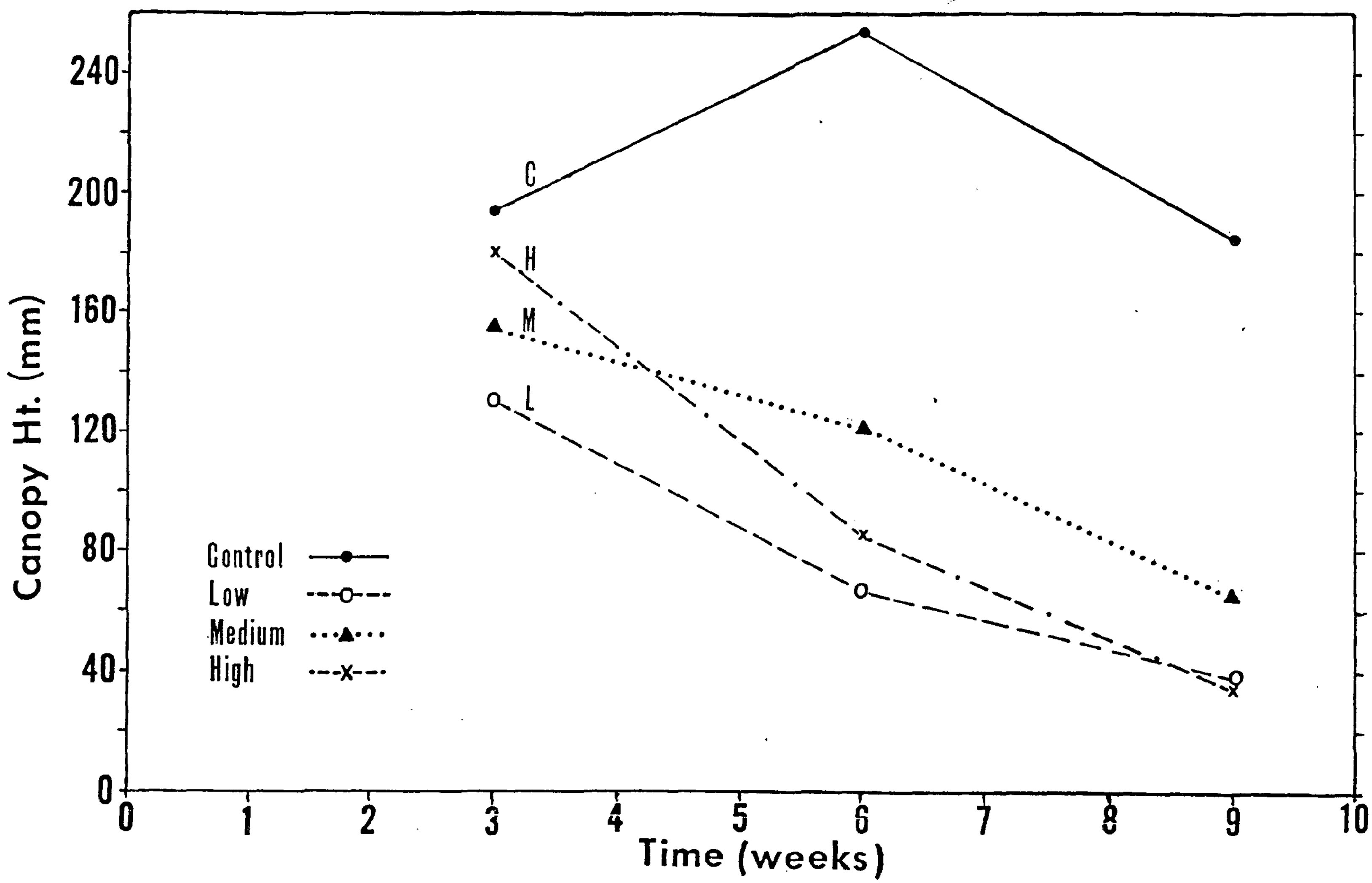


Figure 3. Growth (in weight) of new blades per three shoots over a 1-week period for each of the four nutrient dosage treatments versus time.

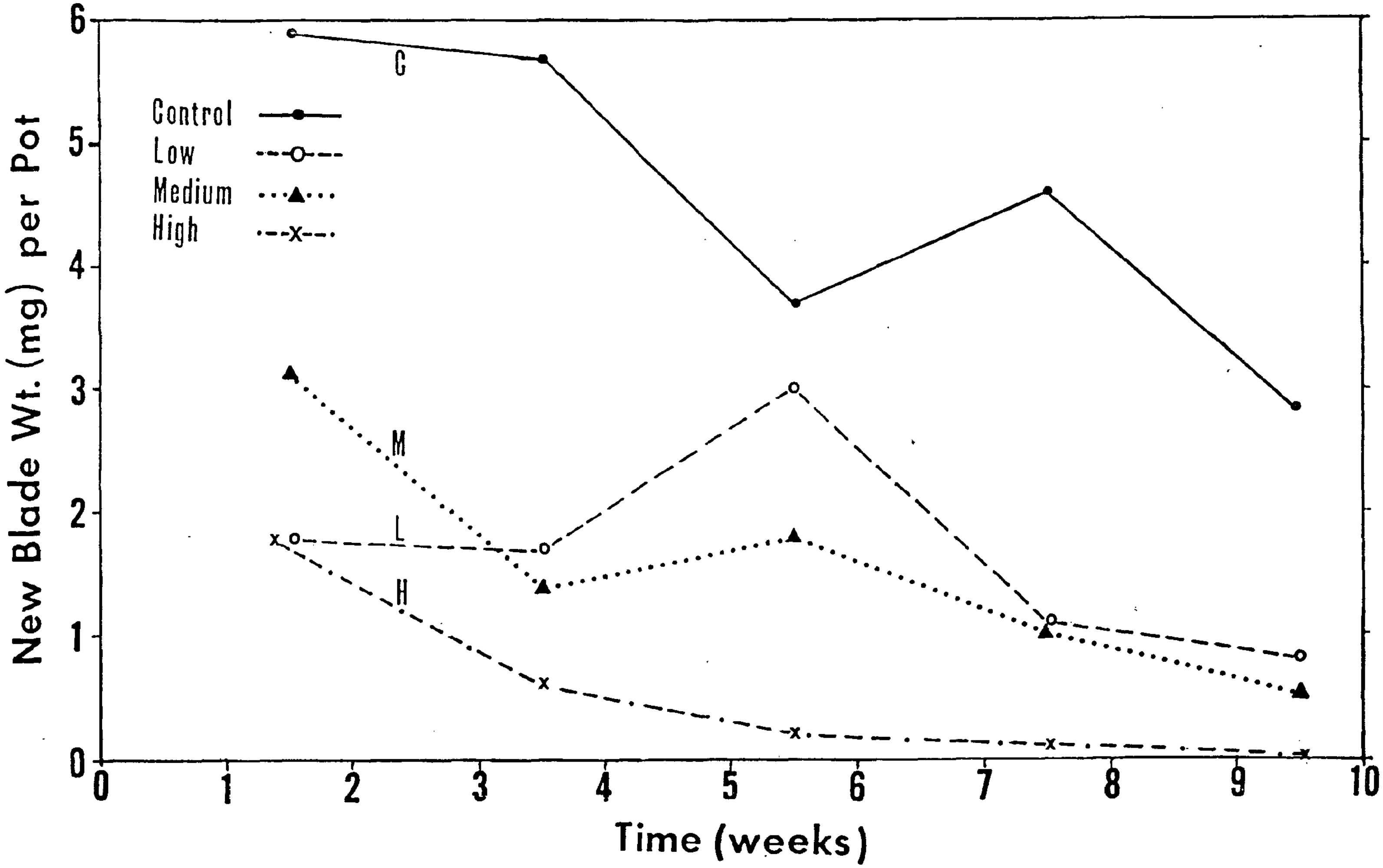


Figure 4. Weight of old blad[illegible] per three shoots for each of the four nutrient dosage treatments versus time.

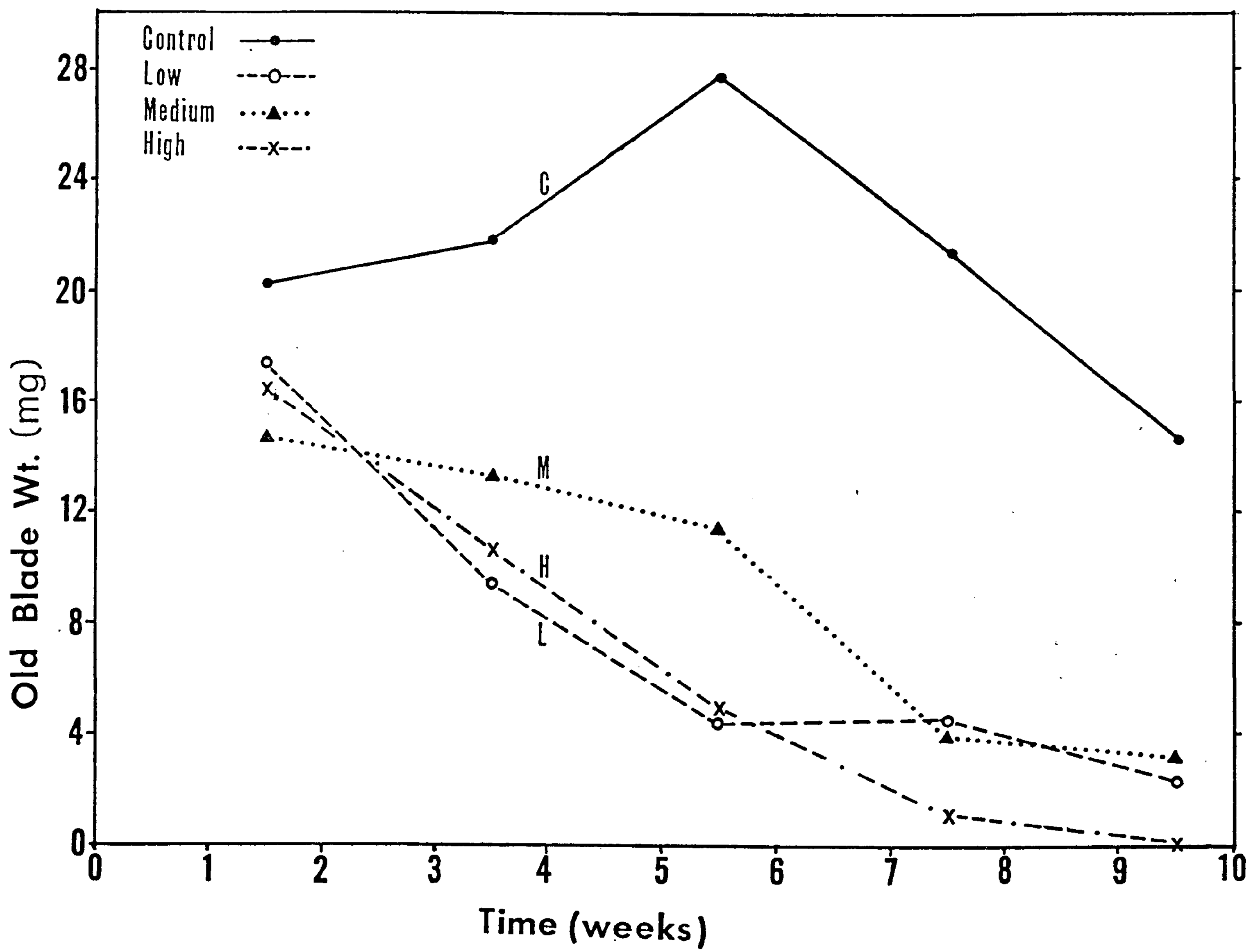


Figure 5. Weight of lost leaves collected for each collection time (three times per week, total N = 29) for each of the four nutrient dosage treatments.

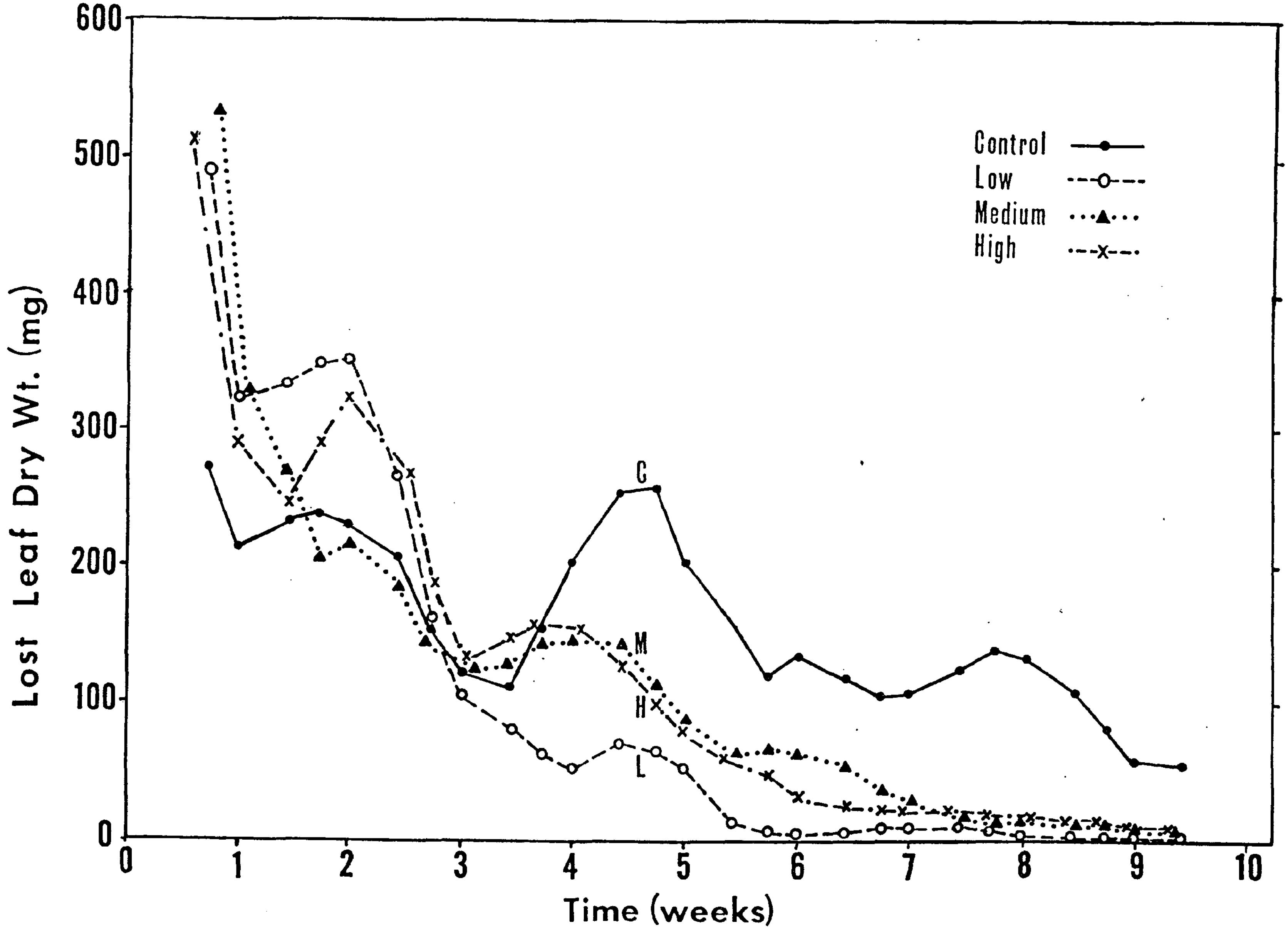


Figure 6. Weight-to-length ratio of new blades for each of the four nutrient dosage treatments versus time. (*Extraneous values from tiny pieces of blade excluded.)

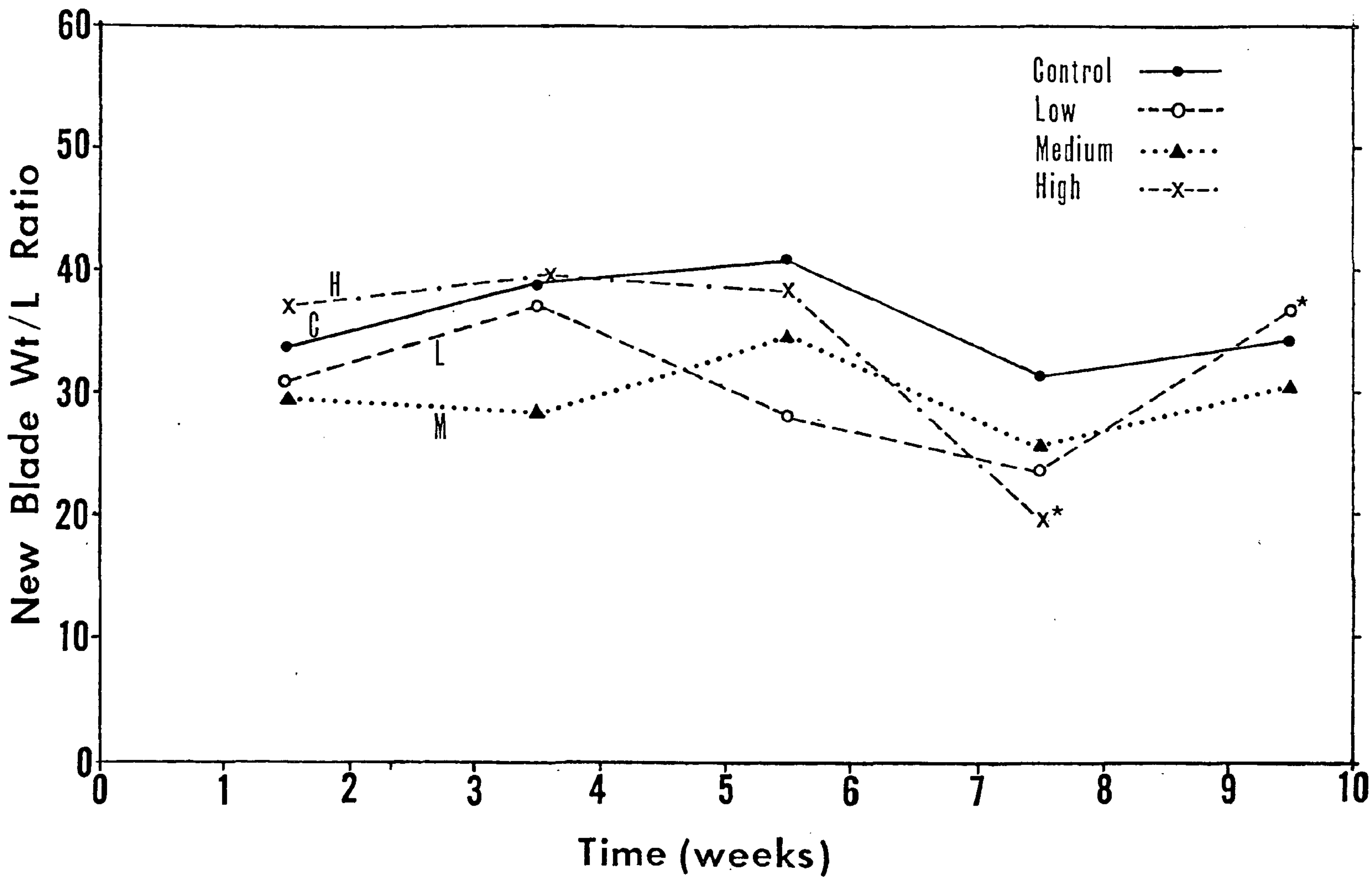


Figure 7. Ratio of epiphyte weight to weight of old blades for each of the four nutrient dosage treatments versus time.

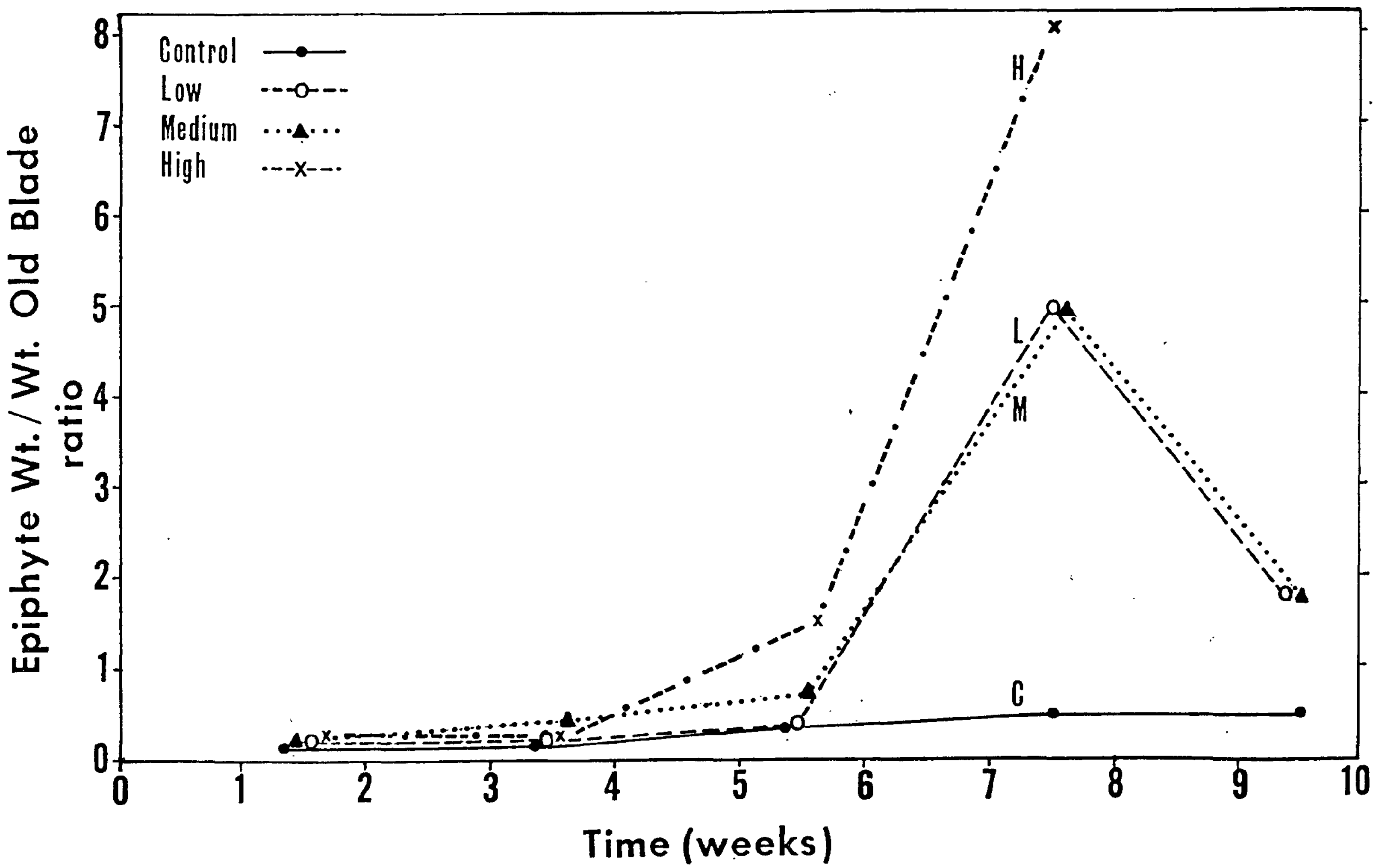
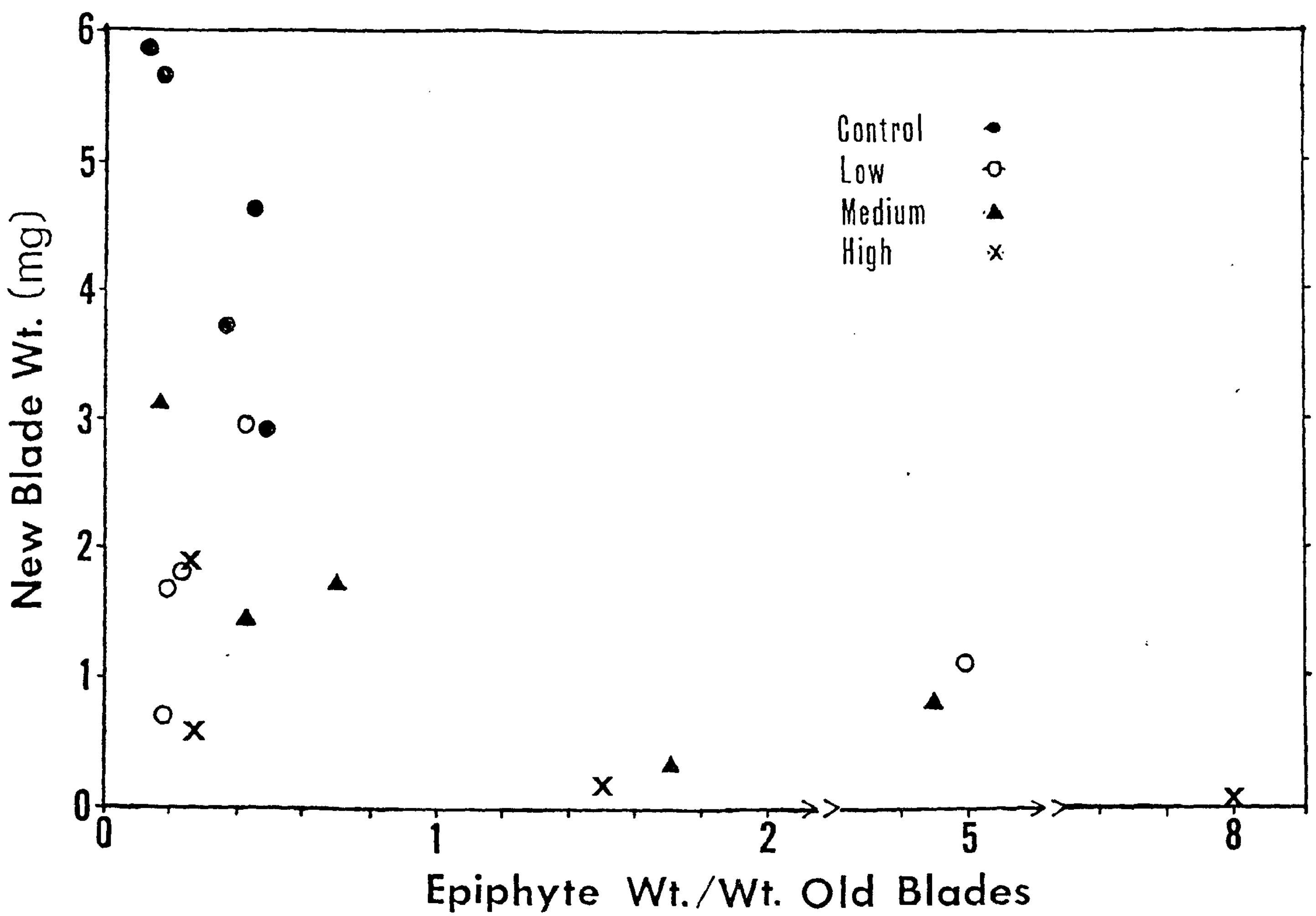


Figure 8. New growth weight (g) versus the ratio of epiphyte weight: weight of old leaves for all four nutrient dosage treatments over the course of the experiment.

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CM 167

IMPOUNDMENT MANAGEMENT

MOSQUITO SAMPLING SECTION

FINAL REPORT

SEPTEMBER 30, 1987

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I. INTRODUCTION

CM 167 is the fifth year of an ongoing impoundment management research project at Indian River Impoundment #12 (County Line). Various management schemes studied have included; open with one 18 in. culvert (CM 47), passive retention of water with flapgate risers (CM 73), open with two 18 in. culverts (CM 93), Rotational Impoundment Management (CM 122), and open with two 30 in. culverts (CM 167). During the first four studies pre-adult mosquitoes were sampled to determine location and relative brood size.

During CM 167, larval sampling was slightly modified to attempt to pinpoint the location of early instar larvae to better identify oviposition sites. Two additional larval sampling sites were selected to coincide with research work being conducted by the other principal investigators in this cooperative project (R.G. Gilmore-Harbor Branch Oceanographic Institution, Inc. (HBOI) and J.R. Rey (Florida Medical Entomology Laboratory (FMEL)). In addition flow rates were measured through the 18 and 30 in. culverts to determine water movement patterns in relation to river and impoundment water levels.

II. MATERIALS AND METHODS

A. STUDY SITES

Indian River Impoundment No. 12 has served as the study site during this entire five year study. Constructed in March 1966 and located on the barrier island at the Indian River-St. Lucie County border, this 20.2 ha (50 acre) impoundment contains a perimeter ditch on 2 1/2 of the 4 dike sides (Fig. 1). The eastern edge does not contain a perimeter ditch and gently slopes into the upland. The marsh surface is primarily vegetated with _Batis maritima_ (saltwort), _Salicornia virginica_ (perennial glasswort), and _Salicornia bigelovii_ (annual glasswort) with scattered black (_Avicennia germinans_), red (_Rhizophora mangle_) and white (_Laguncularia racemosa_) mangroves. There are many open, unvegetated areas and ponds, some of which retain water all year long. During the last four years of this study, the mosquito larvicides Altosid (methoprene) or Florida Formula Oil were applied when needed. Only Florida Formula Oil was necessary during CM 167.

Two additional mosquito sampling sites were studied to coincide with the HBOI and FMEL work. Immediately north of Impoundment #12 ("North Marsh") is an unimpounded but ditched high marsh dominated vegetatively by saltwort (Batis salicornia) and black mangrove (Avicennia germinans). This area is commonly flooded by rainfall and seasonal high tides. Preadult mosquito sampling was conducted in areas near the fish sampling stations set up by the HBOI and near vegetation transects established by the FMEL. Sampling at this "North Marsh" was conducted on the same schedule as Impoundment #12.

The second additional site ("Oslo Road") is located on the mainland, slightly north of Impoundment #12. This marsh is also unimpounded, vegetated predominately by saltwort and black mangrove and flooded by rainfall and high tides. Sampling was conducted near FMEL vegetation transects on the same schedule as our other study sites.

These two additional sites differed from Impoundment #12 in that they have natural tidal creeks or ditches running through or adjacent to them which provide for tidal flooding and allow for the marshes to drain rapidly.

B. MOSQUITO SAMPLING METHODOLOGY

The immature mosquito sampling technique used during the first four years of the study was continued during CM 167 but with a slight modification. The entire marsh was divided into 12 quadrats (Fig. 2). These unequally sized quadrats were designated North A,B,C, West A,B,C, South A,B,C, and East A,B,C. On each sampling visit mosquitoes were sought out in all quadrats. No areas were neglected but through experience those vegetated areas shown to produce mosquitoes were most thoroughly examined. When larvae were found, random sampling with five 350 ml dips were taken per quadrat. In this report, brood size is expressed as mean number per dip and a brood is defined as a group of pre-adult mosquitoes that mature concurrently.

During the last four years mosquito sampling was performed twice weekly. During CM 167 mosquito sampling was based on 'trigger events' (rain or tides) to attempt to locate first instar larvae to better determine ovipositional sites. New maps were drawn (Figs. 3 - 7) showing enlargements of quadrats East C, North A,B,C, and West A in greater detail. Also location codes (Table 1) were developed and each dip positive for first instar larvae was designated by a location code.

C. WATER MANAGEMENT TIMETABLE

The original 18 in. culverts were opened on Tuesday, September 16, 1986 during CM 122. These regimes followed during CM 167:

Tuesday, February 10, 1987
Installation of 30 in. culvert at the south end of the impoundment adjacent to existing 18 in. culvert. Both culverts remained open to river.

Thursday, February 12, 1987
Installation of 30 in. culvert at the north end of the impoundment adjacent to 18 in. culvert. All four culverts open to the river.

Monday, February 16, 1987
18 in. culverts blocked off from river with risers. Impoundment now open only through the two 30 in. culverts.

Thursday, June 18, 1987
Boards removed from 18 in. culverts. Impoundment now open to river through all four culverts.

D. CULVERT FLOW DETERMINATIONS

Culvert flow rates were measured using a General Oceanics flow meter (Model 2031H), flowmeter readout (Model 2035-MK III), and a Cole-Parmer mini-recorder (Model 8377-15). This equipment had been purchased under CM 122 when flow rates for the original 18 in. culverts were determined.

In both the 18 and 30 in. culverts eyebolts were installed in the top and bottom of the culvert. The flowmeter was hooked to the eyebolts using "S-hooks", then the slack was eliminated using turnbuckles. This allowed for the flowmeter to be situated in the center of the culvert to provide an accurate mid-culvert flow rate reading.

The flowmeter was installed for 24 hour periods and Harbor Branch tide meters were reset for 24 hour rates as well to achieve the closest possible relationship between river and impoundment water levels and flow rates.

III. MOSQUITO PRODUCTION

A. PRODUCTION SUMMARY (Table 2).

October 1-15 (rainfall = 0.0 in.) The flooding elevations during this period ranged from 0.13-0.88 ft. NGVD. No mosquito production was observed. Part of the marsh was dry during this period due to an unexplained drop in local tide levels. However upon reflooding, no mosquito production occurred.

October 16-31 (rainfall = 4.6 in.) Flooding elevations ranged from 1.17-1.58 ft. NGVD. River tide levels were reflected more normal historical levels for this time of year keeping the marsh flooded. No mosquito production was observed.

November 1-15 (rainfall = 2.4 in.) Flooding elevations ranged from 0.90-1.31 ft. NGVD. Continued high river levels kept the marsh flooded and no mosquito production occurred.

November 16-30 (rainfall = 0.0 in.) Flooding elevations were from 0.82-0.86 with no mosquito production.

December 1-15 (rainfall = 0.0 in.) Flooding elevations were from 0.79 to 0.94 ft. NGVD with no observed mosquito production.

December 16 - 31 (rainfall = 1.5 in.) Flooding elevations ranged from 0.88 to 1.31 ft. NGVD keeping the marsh flooded with no observed mosquito production.

January 1 - 15 (rainfall = 2.8 in.) Continued high flooding elevations (0.67 to 1.46 ft.NGVD) and rainfall kept the marsh flooded with no observed mosquito production.

January 16 - 31 (rainfall = 0.8 in.) Water levels began to drop over most of the marsh yet lack of significant rainfall resulted in no observed mosquito production. Elevations ranged from 0.25 to 0.75 ft. NGVD.

February 1 - 15 (rainfall = 0.4 in.) Continuing low water levels (0.52 to 0.94 ft. NGVD) with little rainfall resulted in no observed mosquito production.

February 16 - 28 (rainfall = 1.2 in.) Wind induced tides (0.24 to 0.90 ft. NGVD) and some rainfall combined to flood upper portions of the marsh resulting in small broods in North B (X=0.2/dip), East B (X=0.2/dip), and East C (X=11.5/dip).

March 1 - 15 (rainfall = 2.4 in.) Water levels ranged from 0.42 to 1.25 ft. NGVD but a 2.0 in. rainfall resulted in another small brood in East C (X=11.1/dip).

March 16 - 31 (rainfall = 0.3 in.) Overall higher water levels due to tides (0.71 to 1.17 ft. NGVD) resulted in broods being produced in North B (X=1.2/dip), North C (X=2.0/dip), East B (X=1.2/dip), and East C (X=65.8/dip).

April 1 - 15 (rainfall = 0.4 in.) Observed flooding elevations ranged from -0.17 to 0.63 ft. NGVD. The marsh was dry for most of the period but one rainfall produced brood occurred in East C (X = 2.0/dip).

April 16 - 30 (rainfall = 0.0 in.) Flooding elevations ranged from 0.55 to 1.06 ft. NGVD. Wind induced tides flooded most of the marsh and resulted in a brood in East C (X = 23.4/dip). Very scattered larvae in North B (X = 0.2/dip) and North C (X = 0.2/dip) were found.

May 1 - 15 (rainfall = 2.5 in.) Flooding elevations ranged from -0.02 to 0.92 ft. NGVD. A rain produced brood occurred in East C (X = 13.5/dip).

May 16 - 31 (rainfall = 0.3 in.) Observed flooding elevations relatively remained constant at 0.58 ft. NGVD. One tide induced brood was produced in East C (X = 64.0/dip).

June 1 - 15 (rainfall = 1.3 in.) Flooding elevations ranged from -0.21 to 0.33 ft. NGVD keeping most of the marsh surface dry. One rainfall produced brood occurred in East C (X = 1.8/dip).

June 16 - 30 (rainfall = 0.0 in.) Observed flooding elevations ranged from -0.42 to -0.33 ft. NGVD. There was no observed mosquito production.

July 1 - 15 (rainfall = 0.1 in.) Water levels were very low with observed elevations ranging from -0.32 to 0.04 ft. NGVD. There was no observed mosquito production.

July 16 - 31 (rainfall = 1.6 in.) While overall water levels remained low (observed elevations ranged from -0.25 to 0.08 ft. NGVD) moon influenced high tides flooded parts of the West and South quadrats resulting in a brood in West A (X/dip = 15.2). Additionally, rainfall produced a brood in East C (X/dip = 1.4).

August 1 - 15 (rainfall = 1.7 in.) Water levels increased with observed elevations ranging from -0.33 to 0.56 ft. NGVD. Rainfall again produced a brood in East C (X/dip = 15.6).

August 16 - 31 (rainfall = 0.0 in.) Observed water levels ranged from-0.42 to 0.54 ft. NGVD with no observed mosquito production.

September 1 - 15 (rainfall = 0.45 in.) Increased flooding (observed ranges -0.25 to 0.71 ft. NGVD) resulted in tide produced broods in North A (X/dip = 8.6), North B (X/dip = 3.8), and East C (X/dip = 25.8).

B. OVIPOSITIONAL SITES SUMMARY.

One of the goals of CM 167 was to inspect for early instar larvae to better isolate oviposition sites. In addition to the inspection map used during the previous CM studies (Fig. 2) additional inspection maps were developed that gave greater detail of the individual quadrats. Four location codes were also designed to identify whether larvae were found in vegetation, open water, open/vegetation interfaces, or in other areas such as bootprints or tire tracks. Additional vegetation and substrate codes were also used to help describe locations.

Several problems were encountered during the sampling for first instar larvae, the first being the lack of numerous sizable broods. Rainfall totals for June (2.2 in.), July (1.7 in.), and August (1.7 in.) were well below average for the previous six years (5.32, 5.42, and 7.05 in. respectively). This resulted in fewer broods and concentrating of what little water occurred in man-made disturbances such as bootprints. A second problem was the difficulty in finding first instar larvae. As was anticipated prior to undertaking the project, the size and coloration of first instar larvae made for tedious, time-consuming field inspections.

Larvae were found in a variety of micro-habitats but overall showed a pattern of early instars being found in vegetation and then the later instars shifting towards more open habitats. Of 19 dips positive for first instar larvae (Table 3), 13 (68%) were found either in vegetation or at the open/vegetation interface. Dips positive for second and third instar larvae demonstrated 49% (24 of 49) of the 2nds and 51% (20 of 39) of the 3rds in or near vegetation. Of 48 dips positive for fourth instars or pupae, only 17 (35%) were in or near vegetation.

This shift of later instars towards more open habitat is further evidenced by the relative abundance of larvae. In one brood produced in East - C, (April 27, Table 2.), the mean number of larvae/dip for first instars was 4.0, giving the appearance of a small brood. Second instar larvae were present at 8.6 per dip. However, third and fourth instars were found at 57.6 per dip indicating a large brood. This reflects the movement of later instars out of vegetation and into open areas, where they are aggregating and more visible.

These larval habitat findings are similar to those reported by O'Meara et al. (1986) who in a different larval mosquito production study, found larvae in both vegetated and un-vegetated areas but Aedes eggs were only collected in vegetated sites.

No mosquito production was observed at the two additional study sites ("North Marsh" and "Oslo Road"). These sites were probably ovipositionally unattractive because of the rapid draining provided by the natural tidal creeks and ditches running through or adjacent to these marshes.

C. DISCUSSION

Salt marsh mosquitoes are capable of ovipositing year round but in the high salt marshes of central Florida the peak season is during the months of May through September. In comparing the results of CM 167 with the previous management studies, broods produced during this 5 month period will be the basis for comparison.

Carlson and O'Bryan (1987) demonstrated that RIM (flooding the impoundment from May to mid-September and then opening the culverts to allow water exchange with the river) was significantly better in controlling salt marsh mosquito production than the other management techniques examined. Passive retention of rainfall and tidal flooding (CM 73) was the next most successful technique. Leaving the impoundment open with first one 18 in. culvert (CM 47) and then open with two 18 in. culverts (CM 93) were highly unsuccessful in controlling mosquito production.

Table 4 shows mosquito production and rainfall comparisons during the 5 study years. It must be pointed out that rainfall during May through September in 1987 was less than half that in the prior study years. Our past experience is that rainfall is the most important mosquito production trigger during the summer months. This undoubtedly was the key factor in the reduction in broods produced during CM 167 where approximately half the number of broods occurred compared to the regime of open with one (CM 47) or two (CM 93) 18 in. culverts. Overall, both the brood size range and the mean brood size were lower with two 30 in. culverts open to the estuary.

IV. CULVERT FLOW DETERMINATIONS

Culvert flow rates were recorded in the 30 in. culverts concurrently with Harbor Branch tide gauges set to record on a 24 hr. cycle allowing reasonably accurate comparisons. Through regression analysis using a Linear Least Squares Fit test, equations were determined to predict flow rates for given water elevation differences.

Flow rate predictions for 18 in. culverts:

Ebb flow: $Y = 0.135 + (.042 * x)$ p _ 0.01%
Flood flow: $Y = -0.138 + (.076 * x)$ p _ 0.05%

Flow rate predictions for 30 in. culverts:

Ebb flow: $Y = 0.067 + (.159 * x)$ p _ 0.01%
Flood flow: $Y = 0.215 + (.214 * x)$ p _ 0.01%

Where: Y = estimated flow rate (m/sec) and
x = difference in water elevations (cm)

The 30 in. culverts have allowed water levels inside the impoundment to be more reflective of the river water levels. This is indicated by the range in water level elevations between the river and the impoundment. With 18 in. culverts the difference between elevations ranged from 0 to 16.1 cm. The range with 30 in. culverts was 0 to 5.1 cm.

Although it remains unclear if replication of Indian River water levels within an impoundment should be an impoundment management goal, this work indicates that larger culverts are helpful in achieving better replication.

V. MANAGEMENT RECOMMENDATIONS.

The two 30 in. culverts installed during CM 167 allowed for improved flushing and exchange of detrital material between the impoundment and the Indian River Lagoon. However the beneficial aspects of the increased water flow were only apparent in close proximity to the culverts. Sections of the perimeter ditch that are distant from the culverts show large build-ups of detrital material and no influence from increased flushing. Therefore while increased culvert sizing to 30 in. facilitates water exchange, the optimal number of culverts still needs to be determined. It appears that two culverts far apart and at opposite ends of the perimeter ditch is insufficient, but the optimal number may be three, four, five or more. Other investigators, (Grant Gilmore, HBOI) are studying the effects of increased culverts in impoundments located in St. Lucie County. The results of these studies should be considered when making decisions concerning culvert sizing and number.

Rotational Impoundment Management (CM 122) appears to be the better control management plan when compared to leaving the impoundment open to the river through culverts, regardless of culvert size. Low summer river water levels leave most of the marsh surface exposed and the marsh becomes an attractive ovipositional site. Only by flooding the marsh surface during the summer months is optimal control achieved.

Larval sampling for first instars proved to be a time-consuming and relatively unproductive process. This sampling confirmed that most mosquito oviposition occurs in or near vegetation with older instars moving out into the open areas where they congregate. While this work helped confirm ovipositional preferences, larval sampling for first instar would not be a productive aspect of future work.

VI. PRESENTATIONS AND PUBLICATIONS.

A. PRESENTATIONS

Acting as Chairman of the Subcommittee on Managed Marshes, Doug Carlson made a presentation to the Florida Coordinating Council on Mosquito Control on November 18, 1987, in Tallahassee. This presentation was at the request of Dr. John Mulrennan (Coordinating Council Chairman) to update them on progress and issues that the Subcommittee has addressed since its formation in 1983.

Mr. Alan Curtis of IRMCD presented a talk on mosquitoes and mosquito control to the Exchange Club of Vero Beach. In his presentation Mr. Curtis described marsh management practices and used some of the data generated by this series of Coastal Zone Management projects.

Doug Carlson and Peter O'Bryan both attended and made presentations at the annual Florida Anti-Mosquito Association meeting held in Palm Beach, FL during May. Doug Carlson's presentation was "Progress in 1986-87 by the Subcommittee on Managed Marshes in Addressing Florida's Salt Marsh Management Issues" and Peter O'Bryan presented "Salt Marsh Mosquito Production in a Rotationally Managed Impoundment Compared to Two Other Management Techniques". Both of these presentations utilized information gathered during this series of Coastal Zone Management grants.

Doug Carlson and Peter O'Bryan are both scheduled to give a joint presentation to the Pelican Island Audubon Society and also at the Florida Medical Entomology Laboratory Technical Short course. Both presentations will be discussing salt marsh and impoundment management techniques based on data gathered from this series of Coastal Management studies. The presentations will be delivered in October 1987.

B. PUBLICATIONS

During the past year, findings and data collected during this and previous CM studies have been published in one paper. A second publication is undergoing local review.

Carlson, D. B. 1987. Salt marsh impoundment management along Florida's Indian River Lagoon: historical perspectives and current implementation trends. In: Proceedings of the Symposium on Waterfowl and Wetland Management in the Coastal Zone of the Atlantic Flyway, pp. 357-369.

Carlson, D. B., and O'Bryan, P. D. 1987. Salt marsh mosquito production in a rotationally managed impoundment compared to two other management techniques. In local review, to be submitted to the Journal of the American Mosquito Control Association.

VII. REFERENCES

O'Meara, G. F., Julianna, J.E., and Carlson, D. B. 1986. Factors affecting the abundances of Aedes taeniorhynchus and Aedes sollicitans. Unpublished report to the Florida Department of Health and Rehabilitative Services.

Carlson, D. B. and O'Bryan, P. D. 1987. Impoundment management: Mosquito sampling section. Unpublished final report to the Florida Department of Environmental Regulation (CM 122).

FIGURE 1. LOCATION OF STUDY SITE, INDIAN RIVER COUNTY IMPOUNDMENT # 12

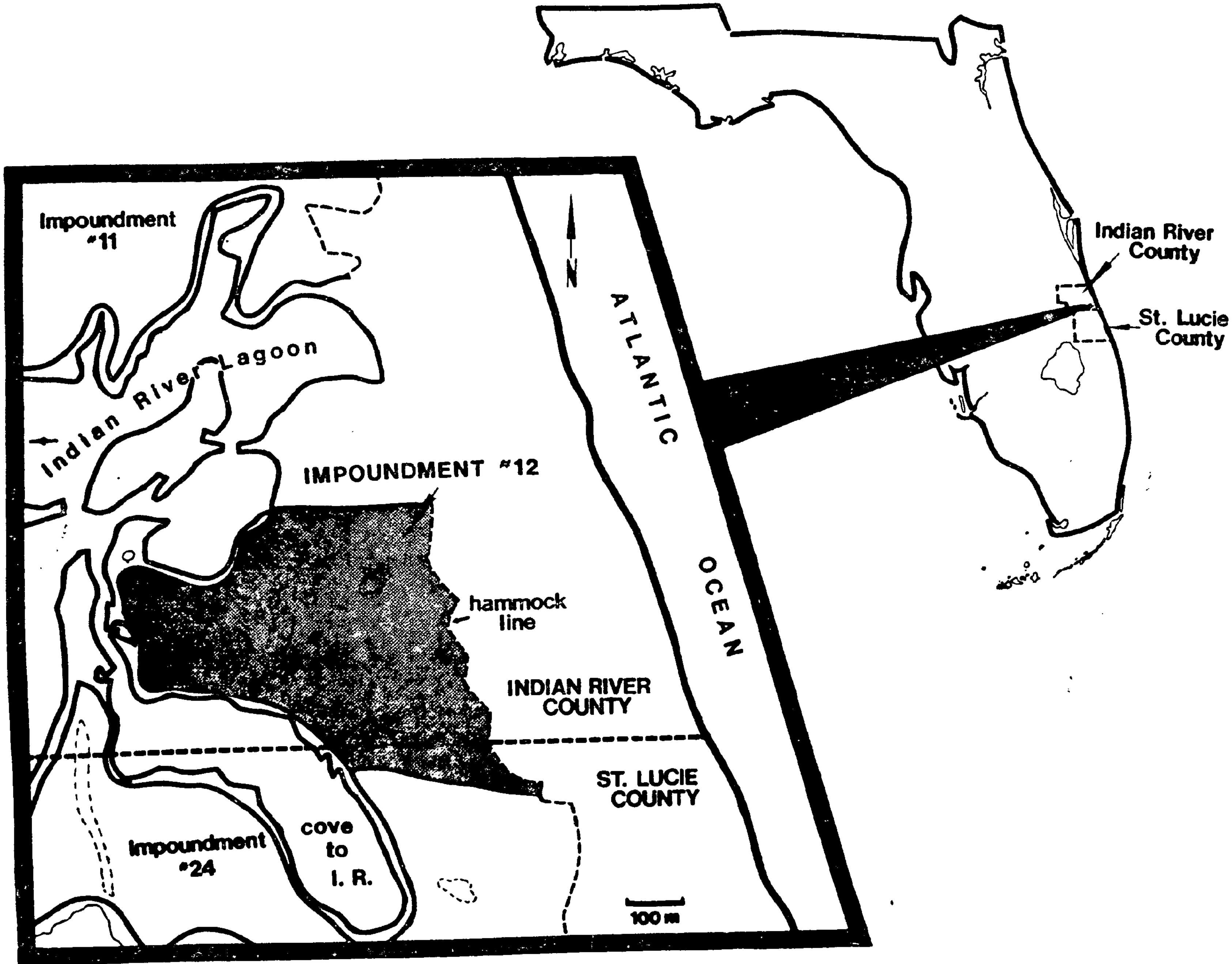

FIGURE 2. IMPOUNDMENT # 12 LARVAL SAMPLING MAP, CM 47, 73, 93, 122, AND 167.

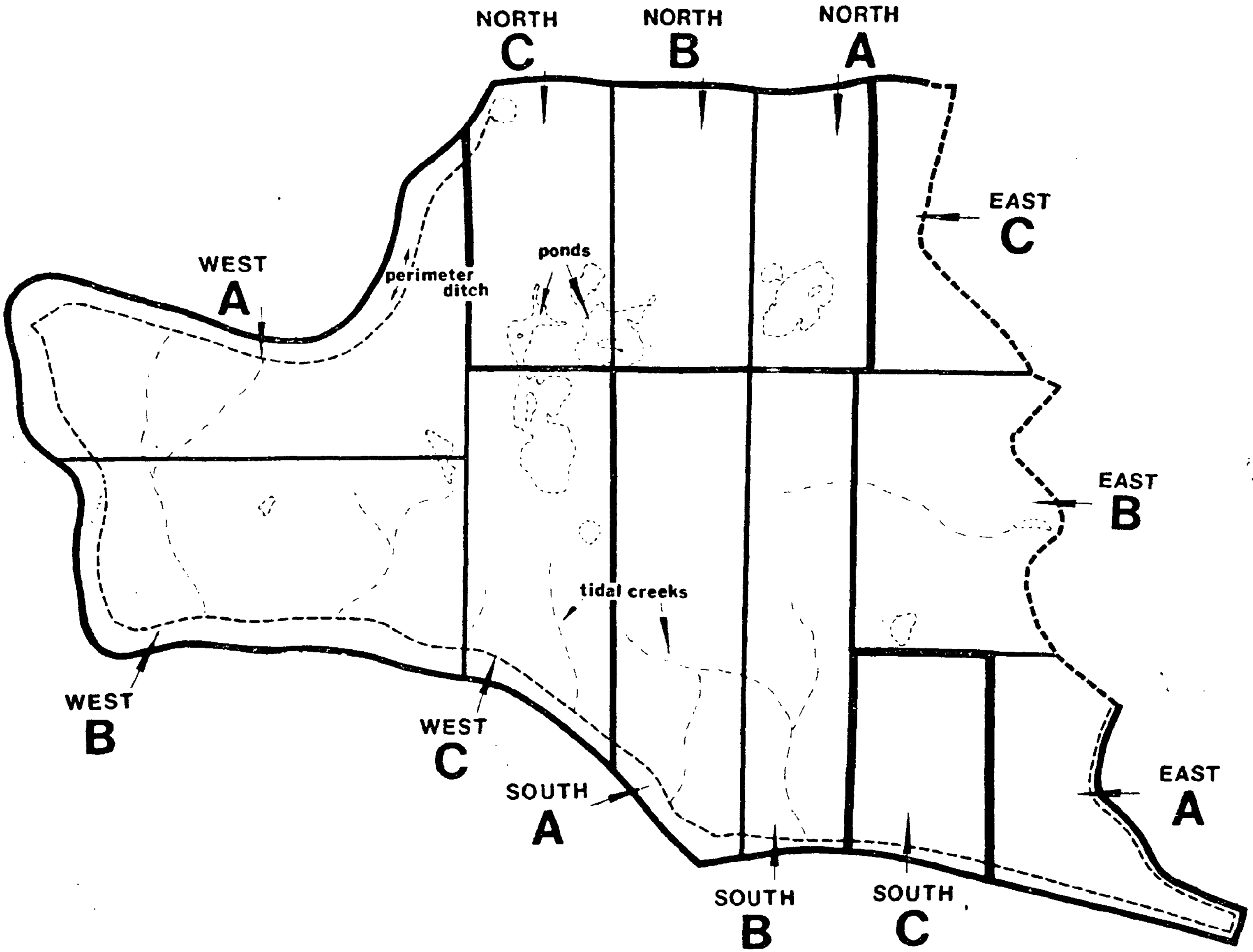

FIGURE 3. MODIFIED LARVAL SAMPLING MAP FOR CM 167, QUADRAT WEST A.

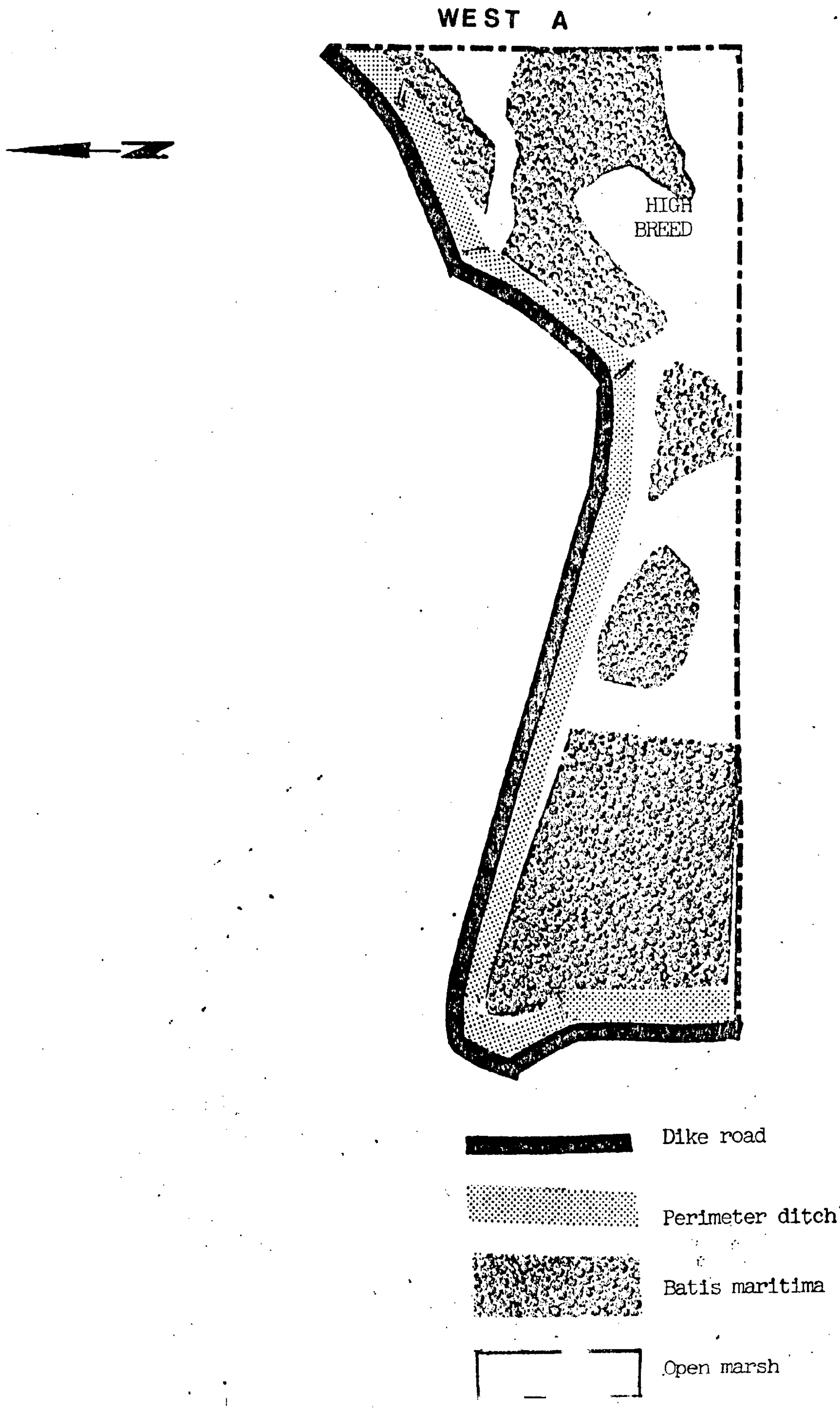

FIGURE 4. MODIFIED LARVAL SAMPLING MAP FOR CM 167, QUADRAT NORTH C.

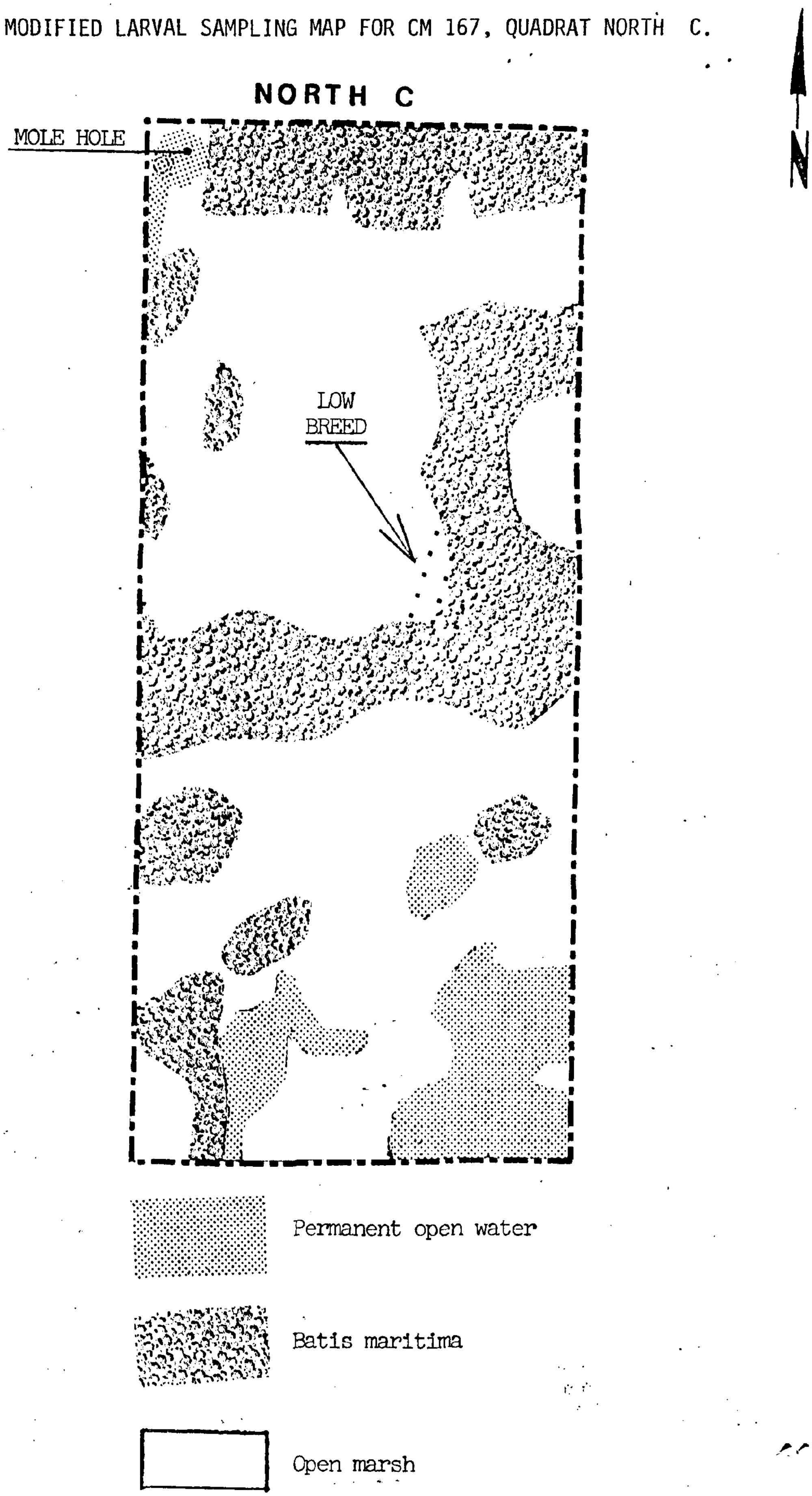

FIGURE 5. MODIFIED LARVAL SAMPLING MAP FOR CM 167, QUADRAT NORTH B.

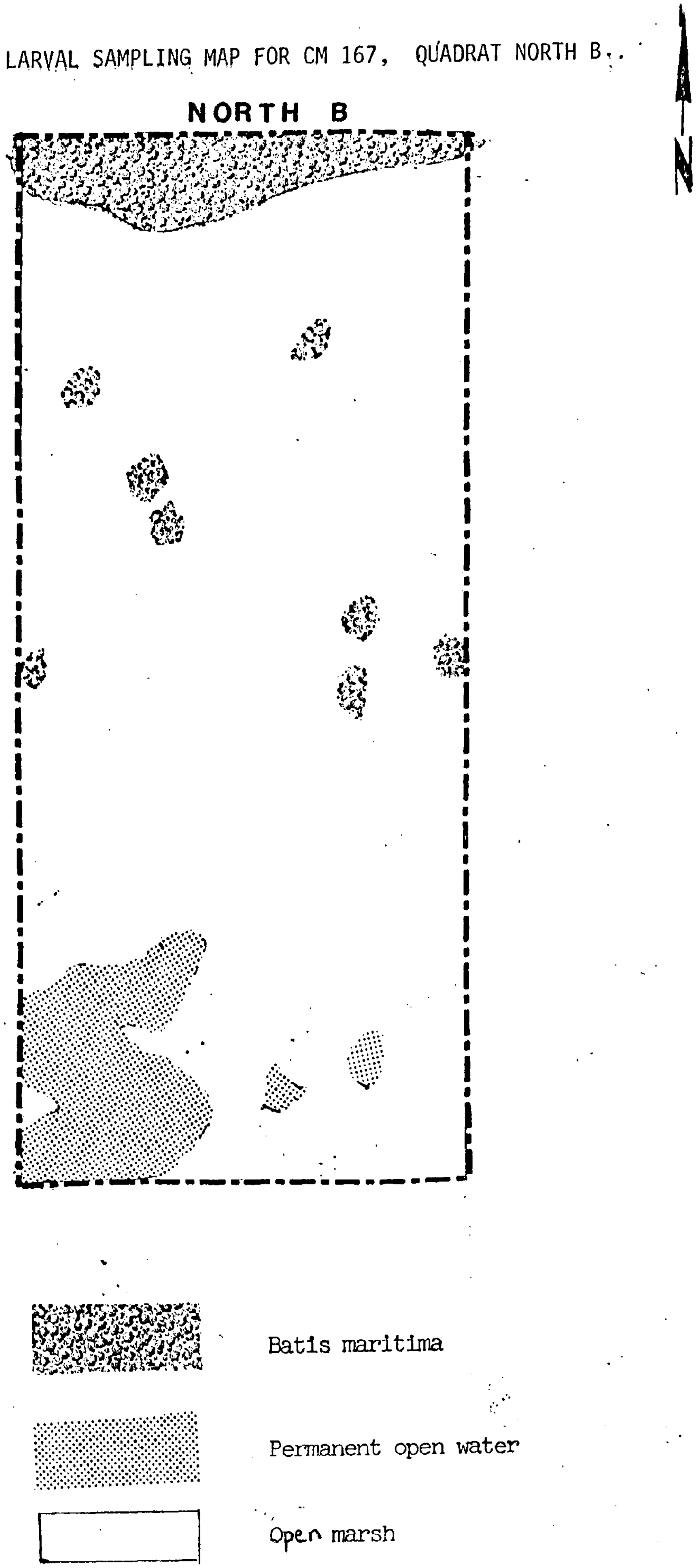

FIGURE 6. MODIFIED LARVAL SAMPLING MAP FOR CM 167, QUADRAT NORTH A.

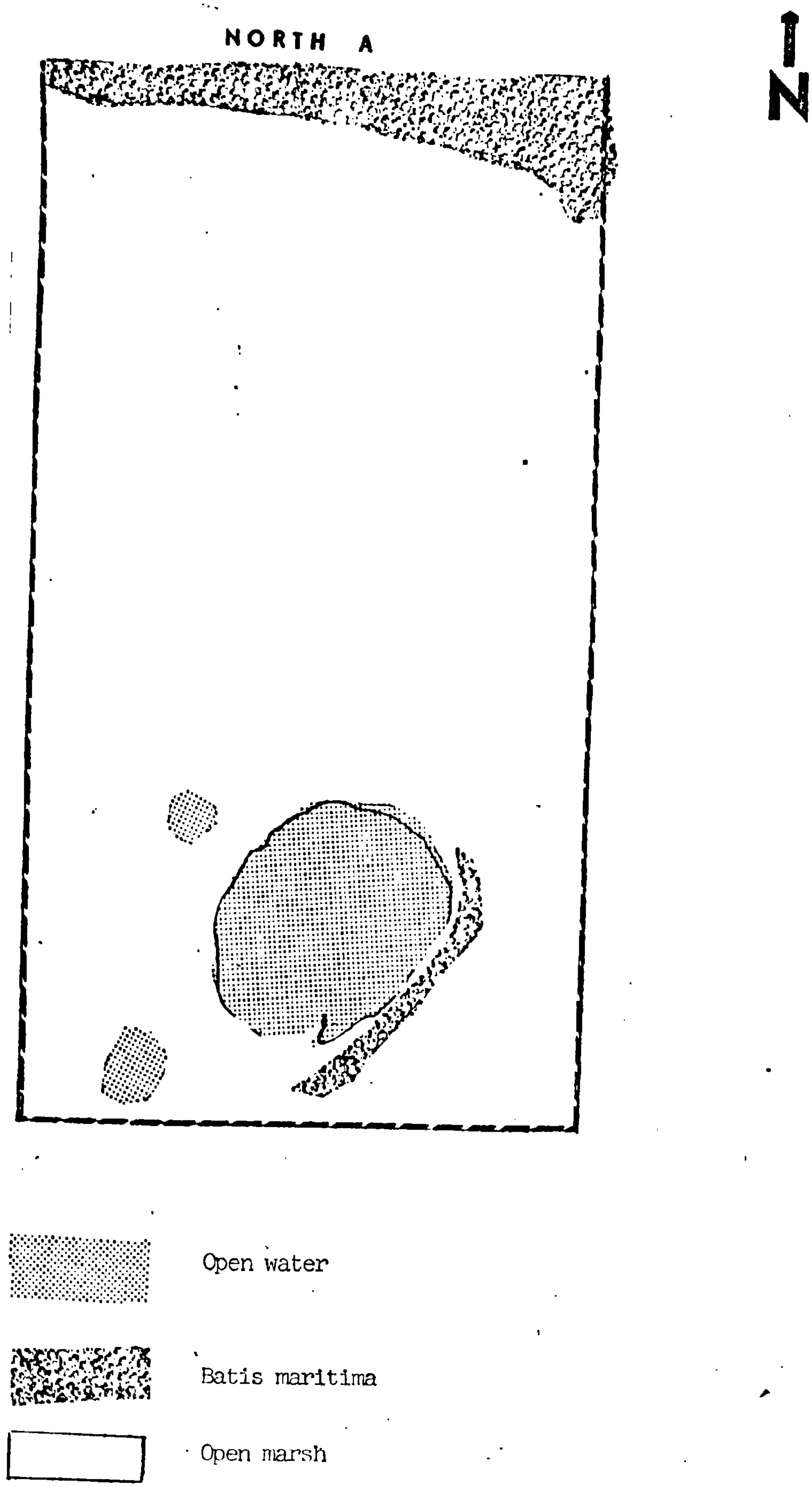

FIGURE 7. MODIFIED LARVAL SAMPLING MAP FOR CM 167, QUADRAT EAST C.

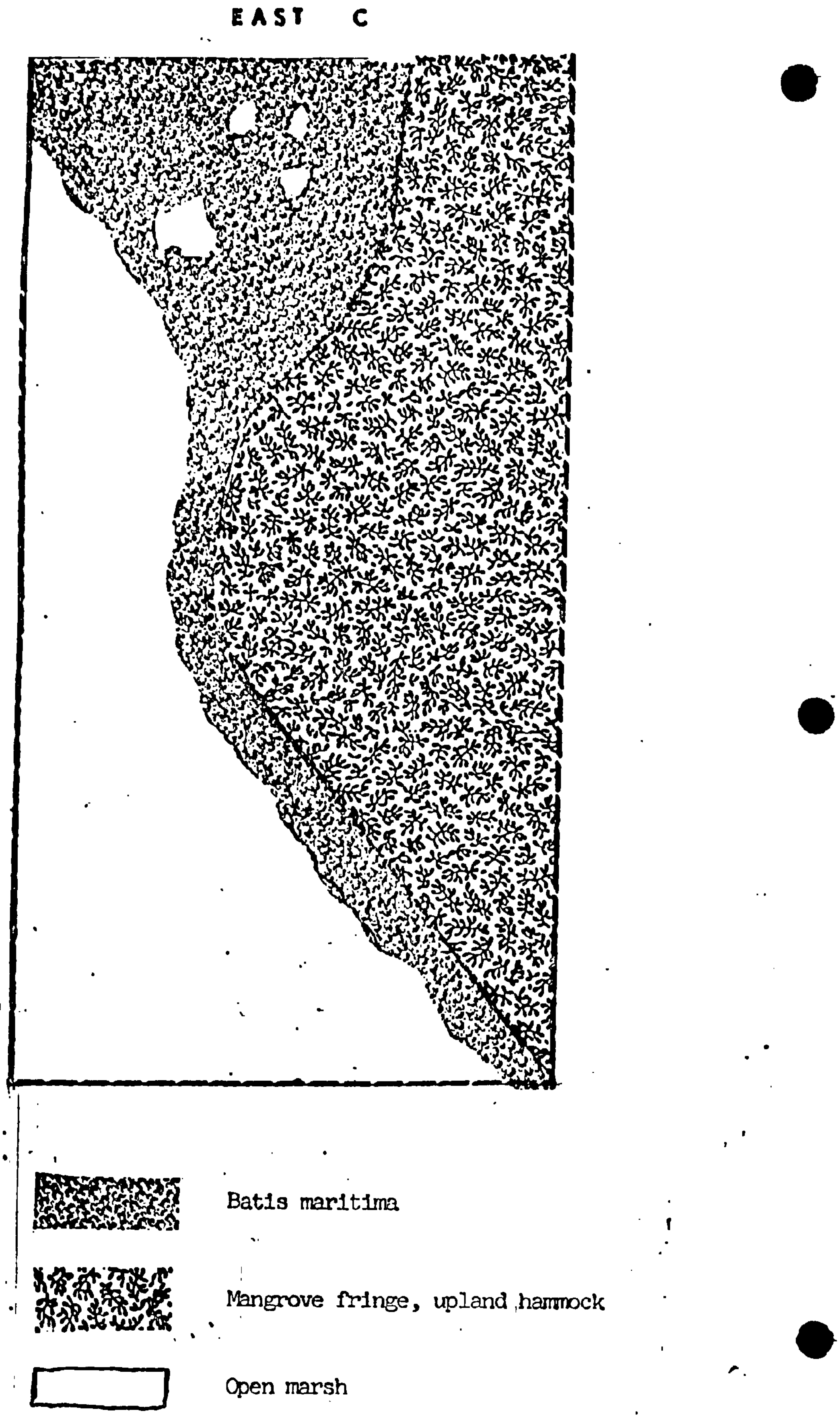

Table 1. LOCATION CODES FOR CM 167 LARVAL SAMPLING

SURFACE CODES

1 = larvae found in, on, or around vegetation

2 = larvae found in open water no nearer than 6" from vegetation

3 = larvae found in open/vegetation interface (w/in 6" of vegetation)

4 = larvae found in other areas such as bootprints, containers, etc.

VEGETATION CODES

BM = exclusively *Batis maritima* bed

SB = exclusively *Salicornia bigelovei* bed

SV = exclusively *Salicornia virginicia* bed

M-R,B,W =mangrove habitat, red, black, or white

BM-SB = mixed beds list the primary vegetation first then secondary(s) in decreasing order of prominence

OPEN BOTTOM CODES

HS = hard, sandy bottom

AD = algal, detrital bottom

OS = oyster, clam shell bottom

MC = mud clay bottom

example larvae found in Batis bed code = 1 - BM
example larvae found in interface of Batis, Salicornia bed code = 3 - BM,SB
example larvae found in open water over detrital bottom code = 2 - AD

Table 2. Mosquito production in Impoundment #12 (September 16, 1986 - September 30, 1987)

Date	North A	North B	North C	West A	West B	West C	South A	South B	South C	East A	East B	East C	Hatching stimulus
Sept. 16, 1986 - Water management regime: Flapgates removed both culverts													
Feb. 9, 1987 - Water management regime: two 30 in. culverts installed Feb. 16, 1987 - Water management regime: existing 18 in. culverts blocked off													
February 20		0.2									0.2	11.5	B
March 8												11.1	R
March 14		1.2	2.0								1.2	65.8	T
April 2												2.0	R
April 27		0.2	0.2									8.6	T
May 13												13.5	R
June 1												64.0	T
June 12												1.8	R
June 18, 1987 - Water management regime: 18 in. culverts re-opened to river													
July 15				15.2								1.4	B
July 31												15.6	R
September 5	8.6	3.8										25.8	T

Broods are dated on day of hatching and expressed in X/dip.

R= rainfall; T= tides; B= both; P= pumping

TABLE 3. SUMMARY OF DIPS POSITIVE FOR SALT MARSH MOSQUITO LARVAE INDIAN RIVER IMPOUNDMENT #12 (OCTOBER 1986 - SEPTEMBER 1987)

	LARVAL STAGE			
LOCATION CODE	FIRST	SECOND	THIRD	FOURTH, PUPAE
1 - BM	9	15	13	5
2 - AD	5	20	15	18
3 - BM	4	6	7	5
3 - AD	–	3	–	7
4 - AD	1	5	4	13
TOTAL	19	49	39	48

1 - BM ===> Larvae located in vegetation, in *Batis maritima*

2 - AD ===> Larvae located in open area, over algal-detrital bottom

3 - BM ===> Larvae located in open\vegetation interface, near *Batis maritima*

3 - AD ===> Larvae located in open\vegetation interface, over algal detrital bottom

4 - AD ===> Larvae located in bootprint, crabhole, etc, over algal detrital bottom

TABLE 4. SALT-MARSH MOSQUITO PRODUCTION FROM INDIAN RIVER IMPOUNDMENT #12 UNDER DIFFERENT MANAGEMENT REGIMES (MAY 1 - SEPTEMBER 30)

MANAGEMENT REGIME	RAINFALL (IN.)	# OF MOSQ. BROODS	BROOD SIZE RANGE	BROOD SIZE MEAN
OPEN WITH 1 CULVERT (18 in.) (CM 47 1982)	26.3	41	0.2-150.2	27.6
PASSIVE RETENTION (CM 73 1983)	24.2	14	1.6-349.0	66.5
OPEN WITH 2 CULVERTS (18 in.) (CM 93 1985)	27.3	43	0.2-1290.0	115.0
RIM (CM 122 1986)	22.9	4	1.2-635.8	171.3
OPEN WITH 2 CULVERTS (30 IN.) (CM 167 1987)	10.8	21	0.2-65.8	12.09