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ECOLOGICAL APPROACHES TO THE CONTROL OF AQUATIC WEEDS

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RESUME

Les taux annuels de productivité, de respiration et de transpiration ont été établis, à l'aide d'un appareil de mesure d'échanges gazeux, pour deux écosystèmes contrastés situés dans la "Paynes Prairie Preserve" à Gainesville en Floride (E.U.). L'étang Melton, d'une superficie de 1,7 ha, à eau oligotrophe, était dominé par une flore indigène présentant une zonation nette. Le "Biven Arm" était un marais qui, recevant les eaux d'égouts, avait été envahi par des mauvaises herbes aquatiques exotiques.

Les taux moyens annuels de productivité brute, de productivité nette et de respiration des macrophytes aquatiques ont été pour l'étang Melton respectivement de 2.381, 1.682 et 1.385 g C.m^{-2}. Pour les eaux libres ces taux respectifs étaient de 1.116, 469 et 1.311. Enfin pour le "Biven Arm" les valeurs correspondantes ont été de 4.473, 2.872 et 3.577. La biomasse était la plus élevée pour le marais. Les auteurs suggèrent que la différence de concentration nutritive et l'effet multiplicateur possible du courant d'eau sur le niveau nutritif sont responsables des différences observées dans la biomasse, la productivité et la respiration. Les taux de productivité et de respiration montraient des variations saisonnières avec les maxima situés en été.

La transplantation de carpettes de Jacinthe d'eau (Eichhornia crassipes) d'un stock génétique commun aux deux sites expérimentaux démontra que cette plante est un faible compétiteur dans un environnement naturel bien structuré. Des variations morphologiques furent observées après l'expérience de transplantation (plantes de grande taille à fines racines dans les eaux courantes eutrophes du "Biven Arm" et plantes petites chlorotiques à enracinement puissant dans les eaux calmes oligotrophes de l'étang Melton). Les grandes plantes ont un taux de productivité brute supérieur et un maximum de photosynthèse diurne nette supérieur à ceux des petites plantes. La comparaison des taux d'évapotranspiration des communautés végétales et des eaux libres met en évidence que l'évapotranspiration des plantes ne dépasse l'évaporation des

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eaux libres que pendant les périodes de productivité maximale. D'un point de vue annuel, l'évapotranspiration des plantes aquatiques ne dépasse pas la perte d'eau des eaux libres. Les taux de perte d'eau furent supérieurs pour le système eutrophes. On peut donc suggérer que les mauvaises herbes aquatiques doivent être contrôlées par la gestion de la totalité de l'écosystème dont elles font partie.

La gestion des écosystèmes doit être basée sur des études de terrain envisageant l'entièreté des écosystèmes afin d'éviter les pièges des projets compliqués et coûteux déduits d'études couronnées de succès en laboratoire mais ayant peu de rapport avec les conditions de terrain.

ABSTRACT

Annual rates of productivity, respiration and transpiration were determined with gas exchange apparatus for two contrasting ecosystems within the Paynes Prairie Preserve at Gainesville, Florida (U.S.A.). Melton's Pond, a 1.7 ha pond with low nutrient waters, was dominated by a well zoned native flora. Bivens Arm was a marsh receiving sewage effluent that had been invaded by exotic aquatic weeds.

The mean annual rates of gross productivity, net productivity and respiration for aquatic macrophytes at Melton's Pond in gC/m^2 were : 2381, 1682 and 1385. For open water the respective rates were : 1116, 469 and 1311. At Bivens Arm the corresponding values were : 4473, 2872 and 3577. Standing crop was higher in the sewage receiving marsh. We suggest that the difference in nutrient concentration and the possible multiplicative effect of water flow on nutrient levels account for observed differences in standing crop biomass, productivity and respiration. Rates of productivity and respiration were seasonal with highest values occuring in the summer.

Transplants of water hyacingh mats (Eichhornia crassipes) from a common genetic stock to the two experimental sites demonstrated that this plant is a weak competitor in a well structured natural environment. Morphological variations were observed after the transplant experiment (large plants with small roots in the eutrophic flowing waters of Bivens Arm and small chlorotic plants with large root systems in the calm low-nutrient water of Melton's Pond). Large plants had higher rates of gross productivity and maximum net daytime photosynthesis than small plants. However, small plants had lower respiration rates and higher net daytime productivity. Evapotranspiration rates of plant communities and open water revealed that plant evapotranspiration exceeded open water evaporation only during periods of peak productivity. On an annual basis evapotranspiration of aquatic plants did not exceed the water loss over open water. Rates of water loss were higher in the eutrophic system. It is suggested that aquatic weeds must be controlled by managing the whole ecosystem of which they are a component.

Ecosystem management must be based on field studies of whole ecosystems to avoid the pitfalls of complicated and expensive schemes that evolve from successful laboratory studies but have little relevance to field conditions.

INTRODUCTION

With the current increases in both water work programs and the density of human populations, aquatic weeds have become a serious problem in tropical and sub-tropical countries. They choke water bodies, are detrimental to aquatic wildlife, deteriorate water quality and increase evaporative losses in reservoirs as suggested by TIMMER & WELDON (1967). HOLM & al. (1969) indicate that in tropical countries alone, aquatic weeds affect thousands of square kilometers of aquatic systems and cause the annual expenditure of millions of dollars for control measures. In spite of control efforts, these plants continue to expand their ranges.

Our basic knowledge of aquatic weeds in tropical latitudes is very meager. Most of the limnological work has been done in temperate regions or in aquatic ecosystems where macrophyte communities are small. It is evident that ecological work is needed in order to design inexpensive and effective aquatic weed control methods. Traditional methods of control with herbicides, mechanical harvest, etc. are usually harmful to natural aquatic ecosystems and do not seem to be effective or efficient. Furthermore, efforts to control these plants with herbivory and parasitism have not been sucessful in the field where the promising results obtained in experimental tanks cannot always be duplicated.

We suggest that in order to manage aquatic weeds one must manage the system to which they belong. Ecosystem management is based on the idea that species and populations are part of a larger system (ecosystem) which regulates their mineral and energy flow. In order to manage any part of such an integrated system, one must manage the whole ecosystem. This permits the manager to have control over the principal energy and matter flows that allow a particular species to become successful during a given time period. The fallacy of single species or single factor management is that it concentrates too much attention on one detail which may or not be important to the management objective. Meanwhile, conditions in the region may be leading to the opposite end to which management is intended. This situation is characteristic of aquatic weed management where emphasis has been on the elimination of those plants that tend to grow excesively under certain conditions. Little attention has been given to the basic questions of why these plants exhibit explosive growth rates in certain systems and remain a small components in others.

In order to study this question one must utilize several approaches. One approach is to describe the structure and energy flow in a variety of aquatic ecosystems. These ecosystem properties should then be correlated with changes in environmental factors such as nutrient levels, water flow, geomorphology of the system, etc. Another approach is to study the habit and behavior of certain plant species in a variety of environments where they must cope with different physical and biological conditions.

In our studies, we have followed both of the approaches discussed above. We have selected a variety of aquatic ecosystems in the vicinity of Gainesville, Florida and have described their structure, physical environment and nutrient and energy flow. We have also conducted detailed studies on the ecology, anatomy, morphology and physiology of the water hyacinth (*Eichhornia crassipes*), a plant that is an exotic aquatic weed in Florida. This paper is a preliminary report with highlights of two years of study and results for two of the seven sites under study. Each of us will report elsewhere the results of the various phases of the study. Here we will consider the following questions :

1) What are the magnitudes of productivity and respiration of aquatic macrophytes under natural conditions and how great is the seasonal variation ?
2) How do patterns of aquatic plant productivity vary along plant zones ?
3) What are the natural rates of evapotranspiration of aquatic plant communities and how do they compare with rates of evaporation from open water surfaces ?
4) How successful is the water hyacinth as a competitor with native plant species in man-altered ecosystems and in natural ecosystems ?
5) What is the ecological significance of the morphological variants of the water hyacingh that are observed in the field ?

METHODS

The study was conducted at Paynes Prairie State Park in Florida, U.S.A. This is a large marsh surrounded by numerous sink holes and natural ponds that support both native and exotic aquatic vegetation. The Prairie receives sewage from the city of Gainesville on its northern boundary and all its waters flow through a system of canals and into the deep floridian aquifer through a sink hole (Alachua Sink).

The two sites that were selected for this report represent two extremes with regard to water eutrophication characteristics and native plant composition. The Bivens Arm site was located where sewage effluent enters the Prairie. Melton's Pond was a 1.7 ha pond at the edge of the Prairie with native vegetation. Exotic aquatic weeds found in the vicinity, had not invaded Melton's Pond. Results span for one year of field work (Summer of 1973, Spring of 1974).

Structural and Environmental Parameters.

After each gas exchange determination (described below) plants were identified and harvested. Wet and dry weights were obtained for above water live and dead plant parts. Leaf and photosynthetic stem area indexes were determined before drying the material at 70° C for three days, and presented as total Leaf Area Index.

Water characteristics in a network of 10 stations throughout the Prairie and 3 stations at Melton's Pond were monitored on a monthly basis. Here, we report results from two stations in the Bivens Arm area and one of the three stations at Melton's Pond. At each station the following parameters were monitored, using standard field procedures : water flow rate, pH, temperature, dissolved oxygen, conductivity and Biological Oxygen Demand (BOD). For BOD studies, bottles were incubated in situ and sampled at 1, 3 and 5 days. Water samples were taken to the laboratory and analyzed for Chemical Oxygen Demand (COD) and during the growing season for the following elements and nutrients : NO_3, P, K, Ca, Mg, Mn, Fe, Cu, Zn, Pb, Na and Cl. These analysis were done with standard procedures at the University of Florida Soils Department Analitical Laboratory.

Climatic parameters were measured with standard weather measuring instruments including a Weather Measure Pyrheliometer used to measure incoming radiant energy input to the area (360-2500 nanometers).

Productivity, Respiration and Evapotranspiration of Aquatic Macrophytes.

Plant productivity, respiration and transpiration was measured using the gas exchange method described by CARTER & al. (1973). Four chambers of 0.5 or 0.25 m^2 (depending on vegetation type) were fitted over representative sections of each plant zone and the monitored simultaneously for temperature, relative humidity and carbon dioxide. Each experiment lasted 24 hours and over fifty such diurnals were done at each of the two sites. Comparing ambient with chamber exhaust levels of CO_2 and humidity, and correcting for temperature and flow, we calculated rates of net daytime productivity, nighttime respiration and transpiration. Dividing by the area of the chamber and intergrating for 24 hours, we were able to calculate net daytime productivity (Pn), nightime respiration (Rn) and evapotranspiration. Assuming that daytime respiration remained constant, we also calculated gross productivity (Pg) and 24 hours respiration (Rt) by adding daytime respiration to net daytime productivity and to nighttime respiration respectively.

Productivity and Respiration of the Water Column.

The productivity and respiration of the water column was measured using the dissolved oxygen diurnal method described by ODUM & HOSKIN (1958). Dissolved oxygen was measured throughout the water column in several locations. Hourly values were corrected for diffusion utilizing the dome method described by COPELAND & DUFFER (1964). Rates were converted to gC/m^2 using a photosynthetic and respiratory quotient of 1 and multiplying by the depth of the water column. Diurnal curves were integrated and analyzed as described above for the CO_2 diurnals.

RESULTS

Environments at Melton's Pond and Bivens Arm.

Figure 1 summarizes the climate of the region for the year of study. Levels of solar radiation (Figure 1-a) varied considerably and peaked early in the summer. Air temperature followed the normal temperature regime for the region except during January which was abnormally warm. Rainfall periods alternated between high rainfall and drought intervals.

Table I summarizes the water environment at the two sites. With the exception of micronutrients the waters of Bivens Arm were highly eutrophic when compared with those of Melton's Pond. At Bivens Arm there was always a measurable flow of warm and slightly basic waters. The waters were low in dissolved oxygen and high in conductivity and COD. Melton's Pond waters were calm, slightly acid and very low in conductivity. Surprisingly, they had a higher BOD and COD than Bivens Arm waters.

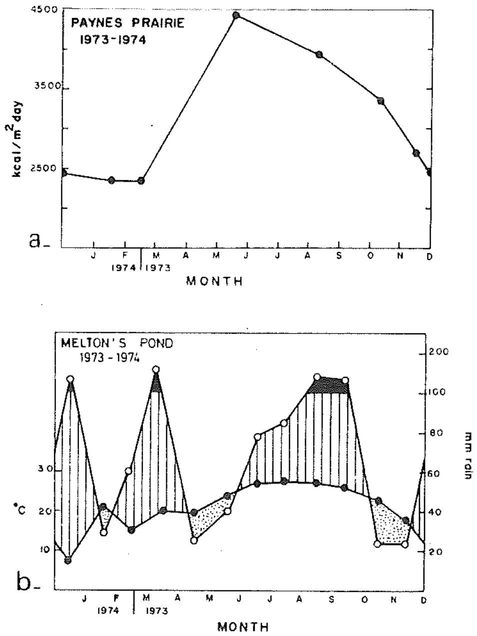


Fig. 1 : Incident light (a) and climate diagram (b) for the study area during the year of study. The light energy values are based on measurements taken during the gas exchange studies. Dark areas in the climate diagram (b) represent periods when rainfall exceeded 100 mm (notice the change in scale). Stipled area represent periods when potential evapotranspiration exceeded rainfall.

Characteristic	Melton's Pond	Bivens Arm
Sum of NO_3, P, K, Ca and Mg concentrations (mg/l)	8.04	52.33
Sum of Mn, Fe, Cu and Zn concentrations (mg/l)	0.07	0.04
Sum of Pb, Na and Cl concentrations (mg/l)	17.50	43.80
Water Flow rate (m^3/sec)	0	0.36
pH	6.4	7.2
Water depth (m)	2.7	1.1
Water Temperature (° C)	24.1	24.4
Chemical Oxygen Demand (mg/l)	54.9	43.67
Dissolved oxygen (mg/l)	3.0	1.3
Conductivity (micromhos/cm.)	79.2	447.5
Five-day Biological Oxygen Demand (mg/l. day)	1.11	0.95

Tab. I : Comparative physical and chemical characteristics of Melton's Pond and Bivens Arm waters.

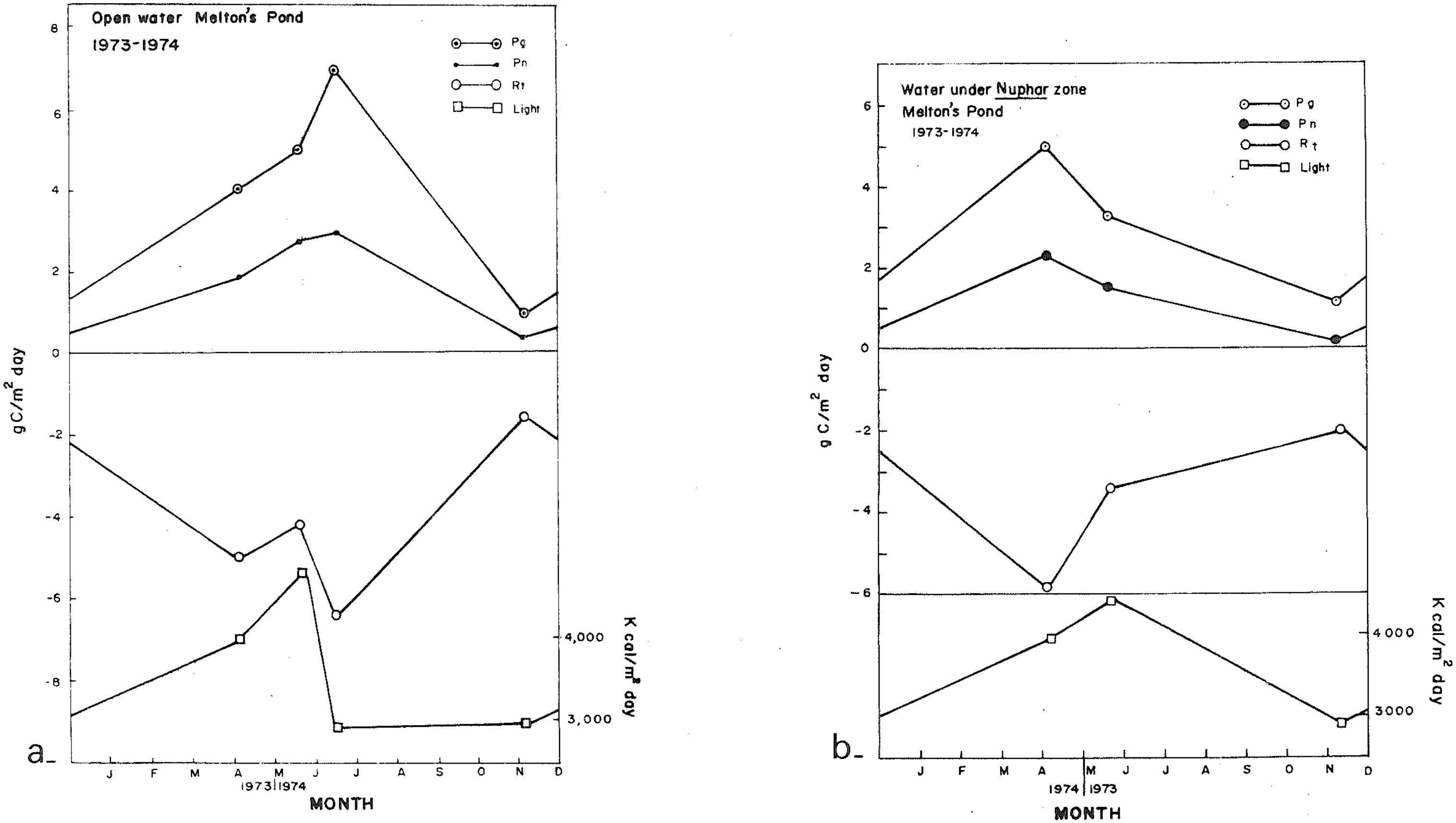


Fig. 2 : Annual rates of gross productivity (P_g), net daytime productivity (P_n), and 24-hour respiration (R_t) for open water (a) and the water column below the plant coverage of *Nuphar advena* (b). All values were corrected for diffusion. The submerged plan *Ceratophylum demersum* dominated the open water column. Light insolation measurements were taken simutaneously with the productivity studies.

Annual Patterns of Productivity and Respiration.

Water Column.

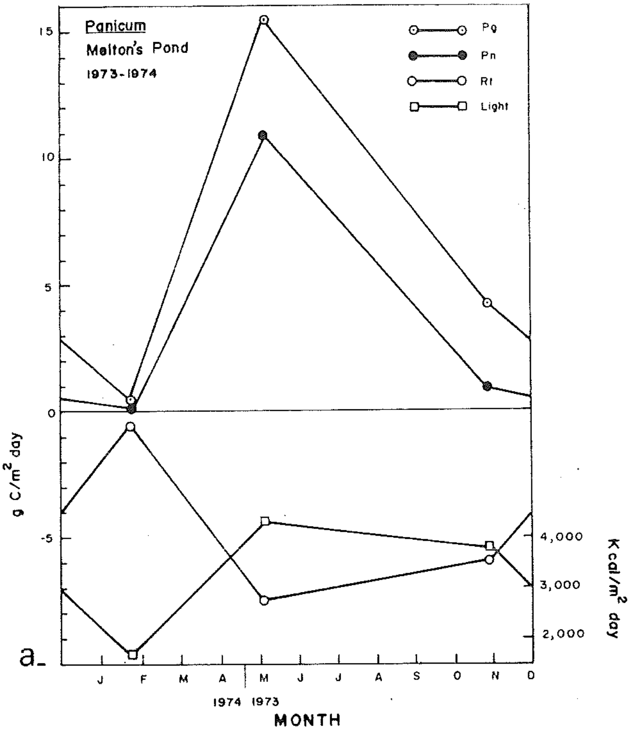
Figure 2 shows the annual pattern of net daytime productivity, gross productivity and total respiration for open water (Figure 2-a) dominated by the submerged plant *Ceratophylum demersum* and the water column under the *Nuphar advena* zone (Figure 2-b). In the open water the time of peak productivity corresponded with the peak of light intensity. Under the *Nuphar* plants, rates of productivity peaked several months earlier. In both areas rates of total respiration followed the plant productivity pattern suggesting the respiration of labile organic matter.

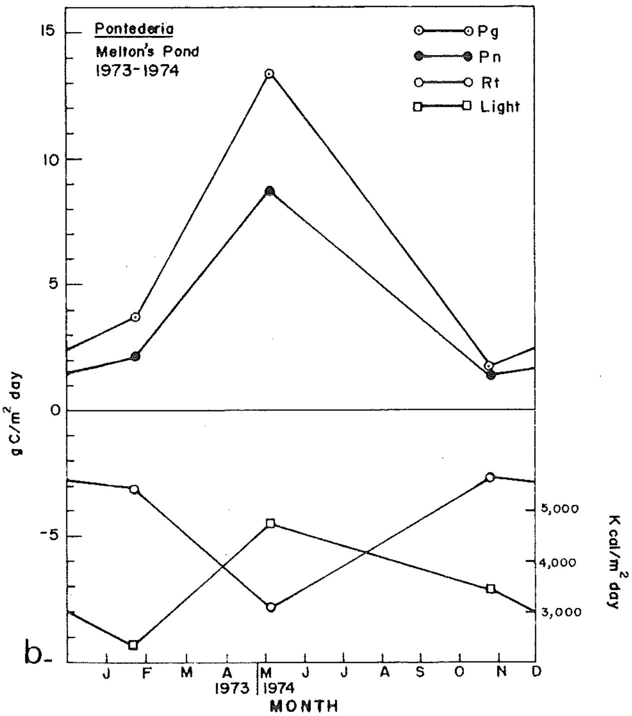
Table II contains the results of the integration of the annual curves of productivity and respiration. It shows that annual rates were higher in open water as compared to rates in water under the *Nuphar* zone. This is probably due to the difference in light intensity arriving at each site. The ratio of gross productivity to total respiration was less than one in both locations even though net daytime gains were measured in both sites. The high respiration rate is apparently due to the respiration of organic matter produced by aquatic macrophytes. No productivity studies were conducted in the waters of Bivens Arm which were covered by aquatic plants. LUGO & al. (1978) reported on the productivity of similar environments in a nearby pond. The magnitude of their results were 1/5 of those found in Melton's Pond.

Macrophytes.

Figure 3 summarizes annual patterns of productivity and respiration for three plant zones at Melton's Pond. All zones showed a response to the annual course of incident light energy. Respiration rates increased and decreased with similar changes in productivity. The maidencane (*Panicum hemitomon*) (Figure 3-a) zone had higher gross productivity and higher total respiration than the other two zones growing towards the water (Figure 3-b and c). The *Nuphar* zone, however, exhibited higher net gains and lower respiration rates (Table II). The large underground rhizomes of this plant may account for the observed difference. They store the organic production transferred from the leaves and may exchange CO_2 with the sediments and not through leaf stomata.

Table II demonstrates that the productivity and respiration of macrophyte plants are significantly higher than corresponding rates in the


Panicum
Melton's Pond
1973-1974
Pg
Pn
Rt
Light
15
10
5
0
-5
g C/m² day
4,000
3,000
2,000
Kcal/m² day
J F M A M J J A S O N D
1974 1973
MONTH


Pontederia
Melton's Pond
1973-1974
Pg
Pn
Rt
Light
15
10
5
0
-5
g C/m² day
5,000
4,000
3,000
Kcal/m² day
J F M A M J J A S O N D
1973 1974
MONTH

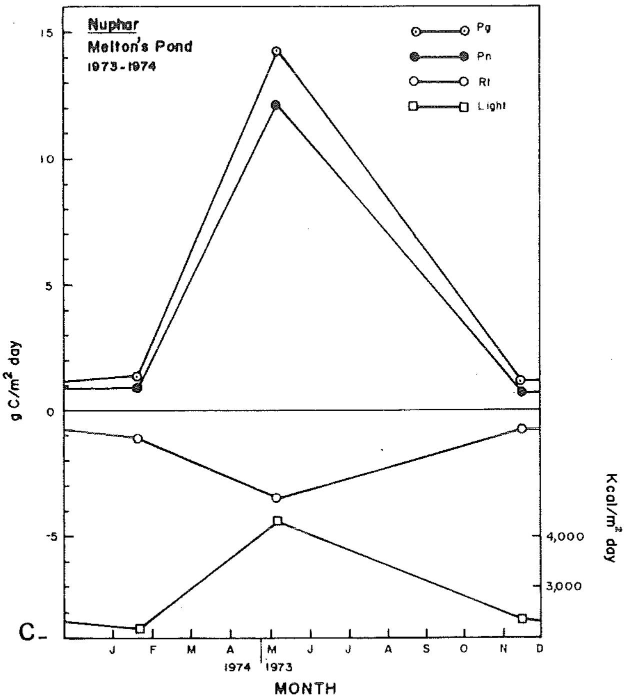


Fig. 3 : Annual patterns of gross productivity (P_g), net daytime productivity (P_n), and 24-hour respiration (R_t) for the three zones of aquatic macrophytes at Melton's Pond. The zone near the land was dominated by *Panicum hemitomon* (a), *Pontederia lanceolata* dominated the next zone (b), and *Nuphar advena* grew in the zone towards the center of the pond (c). Each point represents the mean of several diurnal determinations. Light measurements were taken simultaneously with the productivity measurements.

water column. Ratios of productivity to respiration are greater than one and only decrease below one during certain times in the winter. The mild winter temperatures of the year of study may account for the relatively high productivity that was measured at that time.

The plant community at Bivens Arm was dominated by the water hyacinth, *Hydrocotyle umbellata* and *H. ranunculoides*, cutgrass (*Zizaniopsis miliacea*) and *Pontederia lanceolata*. Their annual patterns of productivity and respiration were similar to those observed at Melton's Pond. Table II contains the results of our measurements. It is apparent that all the rates were significantly higher (nearly twice as high) than those observed in Melton's Pond. *Pontederia*, the only plant growing on both sites exhibited rates of gross productivity in Bivens Arm that were twice as high as those in Melton's Pond.

	Gross Productivity gC/m^2		Net Productivity gC/m^2		24-hours Respiration gC/m^2	
Melton's Pond	Annual	Day	Annual	Day	Annual	Day
Open Water	1248	3.42	543	1.49	1391	3.81
Water Under *Nuphar*	985	2.70	395	1.08	1232	3.38
Mean (SE)	1116 (131)	3.06 (0.36)	469 (74)	1.29 (0.21)	1311 (79)	3.60 (0.22)
Nuphar advena	2290	6.27	1933	5.30	691	1.90
Pontederia cordata	2254	6.18	1530	4.19	1620	4.44
Panicum hemitomon	2600	7.12	1583	4.34	1846	5.06
Mean (SE)	2381 (109)	6.52 (0.30)	1682 (126)	461 (0.35)	1385 (353)	3.80 (0.97)
Bivens Arm						
Eichhornia crassipes	5980	16.38	4200	11.51	3450	9.45
Leersia hexandra	3265	8.95	1540	4.22	3155	8.64
Pontederia cordata	4570	12.52	2550	6.99	3420	9.37
Hydrocotyle umbellata	5280	14.47	3200	8.77	4285	11.74
Mean (SE)	4473 (579)	13.08 (1.59)	2872 (558)	7.8 (1.53)	3577 (244)	9.80 (0.67)

Tab. II : Annual and daily rates of productivity and respiration at Melton's Pond, an undisturbed natural ecosystem and Bivens Arm a highly eutrophic, man-altered ecosystem.

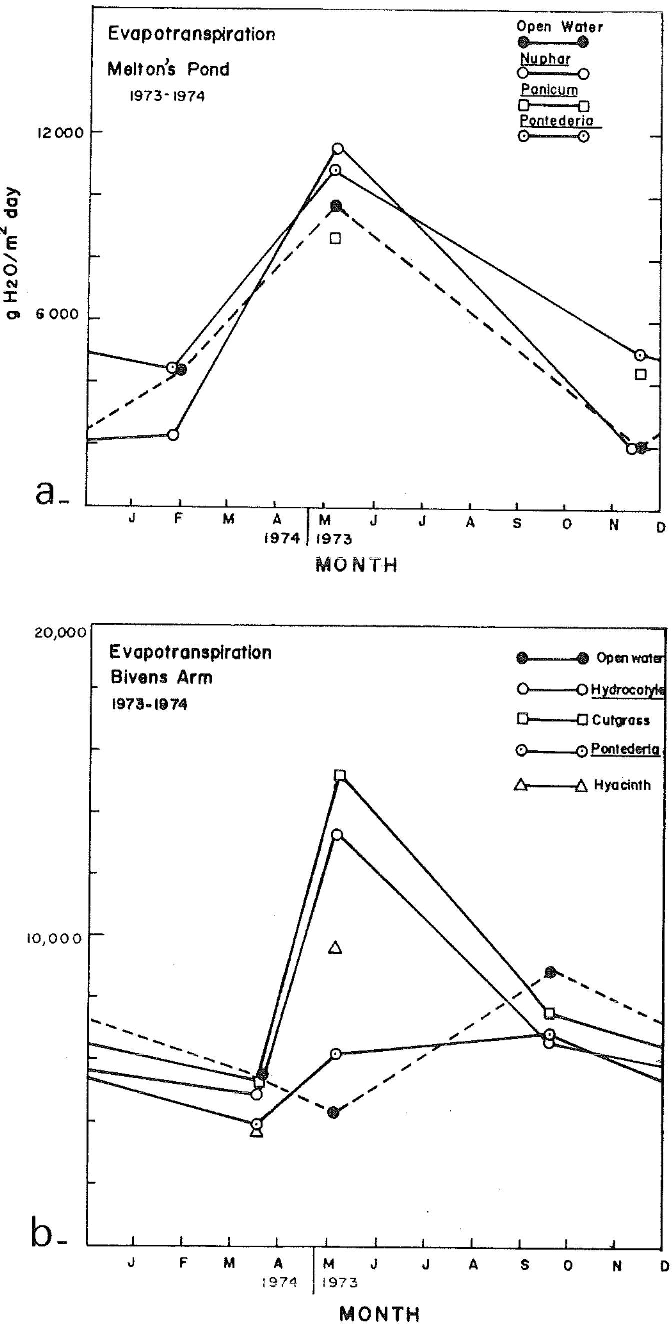


Fig. 4 : Annual rates of evapotranspiration at Melton's Pond (a) and Bivens Arm (b). The evapotranspiration of open water is shown with a dotted line. Each point is the mean of several diurnal determinations.

Annual Patterns of Evapotranspiration.

Figure 4 presents the annual rates of evapotranspiration for plants at Melton's Pond (Figure 4-a) and Bivens Arm (Figure 4-b). The rate of water loss from open water is also shown with a dotted line. These rates were determined by placing a chamber over open water. Evapotranspiration rates followed the same pattern that was observed for productivity. Peak of plant productivity corresponded with those of evapotranspiration. In Melton's Pond, where rates of productivity were lower than in Bivens Arm, evapotranspiration rates were also lower. With two exceptions at Melton's Pond, plants evaporated water at higher rates than open water only during the peak of the growing season.

Late in the study we found some evidence of a possible acceleration of plant transpiration by infrared radiation trapped in the acetate chamber. If this was happening, it would have two effects on our results and conclusions.

1) Actual water loss rates would be lower.
2) Plant transpiration would be more affected than open water evaporation because excess heat would have less effect on the water surface than on plants whose surfaces tend to overheat. Therefore, plants should be more water conservative than what our results show.

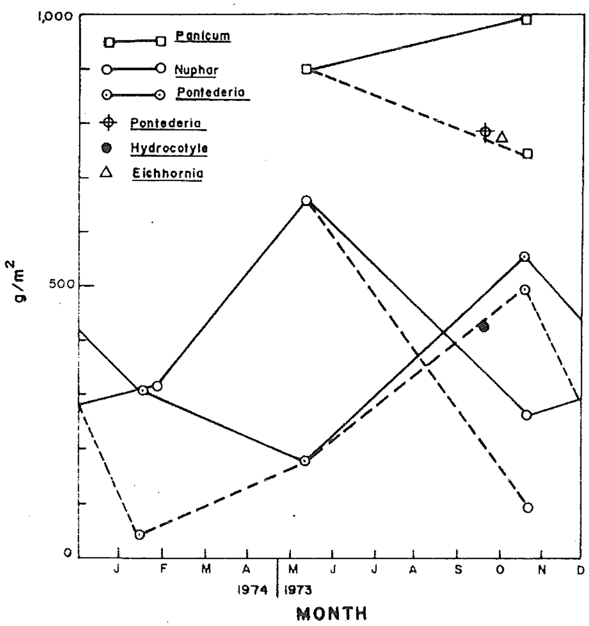


Fig. 5 : Annual changes in standing biomass at Melton's Pond (points connected by lines) and standing biomass at Bivens Arm during the month of November (unconnected points). Solid lines are for live biomass results and the dotted line for dead biomass.

Structural Changes.

Figure 5 presents some of the biomass changes that were observed at Melton's Pond during the study. Biomass accumulation in each zone corresponded with the productivity of the zone. The *Panicum* zone was the most productive zone and had the highest above water biomass. It was followed by the *Nuphar* and *Pontederia* zones. These last two species, however, showed different strategies in the growth pattern of above water biomass. Standing crop at Bivens Arm in October was equal or higher than the corresponding value at Melton's Pond.

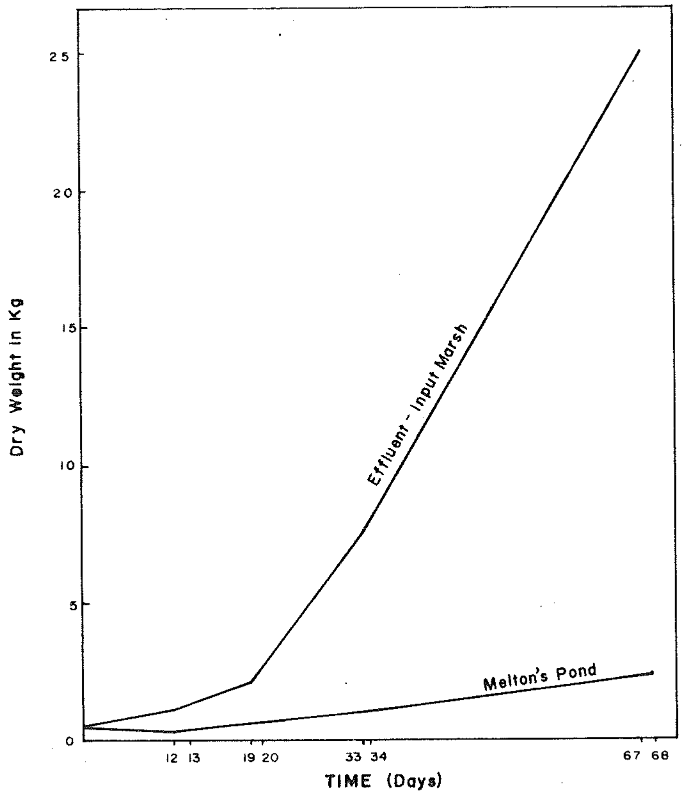


Fig. 6 : Standing biomass in two water hyacinth populations during the growing season. The populations were transplanted from the same habitat. The figure was redrawn from MORRIS (1974).

Water Hyacinth Transplants.

Figure 6 shows the change in biomass in two hyacinth populations growing in two contrasting environments. The site termed "Effluent-Input Marsh" corresponds to the Bivens Arm site. The population at Bivens Arm accumulated nearly eight times more biomass than the population at Melton's Pond. In addition, plants in each population developed contrasting morphological characteristics. At Melton's Pond plants were small and chlorotic, with a large purple root mat. At Bivens Arm plants grew to almost a meter in height with very small roots and dark green leaves.

DISCUSSION

Productivity in Natural and Man-Altered Systems.

Melton's Pond represents a natural system dominated by native plants. In contrast, Bivens Arm represents a system altered by man by the addition of sewage and by changes in the rates of water flow and patterns of drainage. The differences in plant productivity between Melton's Pond and Bivens Arm can be attributed to the effects of those factors that were altered by man. The new conditions also favor the establishment of exotic plant species. These species grow very fast and take advantage of the alteration of community organization that follows man's interventions at the site.

In a survey of plant biomass distribution in the Paynes Prairie region, LUGO & al. (1976) found a linear correlation between nutrient levels in water and biomass in the community. They suggested however, that the synergistic effect of water flow on response to nutrient concentrations could be responsible for controlling plant growth. Our results of productivity measurements at Melton's Pond and Bivens Arm support their suggestion. It can thus be expected that, within certain limits aquatic plant productivity will increase with increasing nutrient and/or water flow levels. Eventually, light becomes the only limiting factor to plant growth.

Evapotranspiration of Aquatic Macrophytes.

TIMMER & WELDON (1967) and KNIPLING & al. (1970) found higher evapotranspiration rates for water hyacinth than for open water. These findings have led many to believe that aquatic plants should be exterminated in order to conserve water. However, the experiments of TIMMER

& WELDON were interfered by rainfall and the interference was not controlled properly while those of KNIPLING & al. were done under laboratory conditions with rapidly growing plants. Our annual field studies and those of LUGO & al. (1976) demonstrate that aquatic plant evapotranspiration exceeds open water evaporation only during periods of rapid growth. These periods usually coincide with abundant water supply. During drought or other conditions when plants are not growing rapidly, evapotranspiration rates are lower than open water evaporation. This is accomplished by stomatal control and protection of the water surface from excessive solar radiation and drying wind. Waters that become highly eutrophic as a result of human activity accelerate plant growth and evapotranspiration but not above the limits of potential evapotranspiration which are set by atmospheric conditions.

Success of Aquatic Weeds in Altered Environments.

The low growth rates of water hyacinth plants in Melton's Pond and the dramatic changes in their habit and morphology agree with our introductory discussion about the role of abiotic factors in the ecosystem in regulating the growth of individual plant species. In Melton's Pond only its waters are low in nutrients. The system as a whole is eutrophic as indicated by the extensive organic deposits. Nutrients are bound and recycled in biomass and sediments and species grow in pure stands at depths to which they are best adapted. Under these conditions, the space and nutrient capital required to support an invading species, are limited. Water hyacinths, even when transplanted to this system did not grow well (Figure 6).

At Bivens Arm, the continuous influx of nutrient-rich waters, and the construction of drainage canals have altered the structure of the native vegetation and thus allowed exotic species such as the hyacinth to grow fast enough to be considered a weed. MORRIS (1974) demonstrated that hyacinth growth and competitive success was correlated with water eutrophication and the extent of native vegetation development. Our productivity measurements confirm his findings.

In order to find out if the morphological variants of the water hyacinth had different metabolic rates, we conducted a diurnal gas exchange determination on a large (> 70 cm) and a small (< 40 cm) water hyacinths at Lake Alice, located several kilometers north west of Paynes Prairie. Figure 7 and Table III show the results. Large plants (Figure 7-a) exhibited higher gross photosynthetic rates but had higher respiration rates than small hyacinth (Figure 7-b). Maximum rates of net

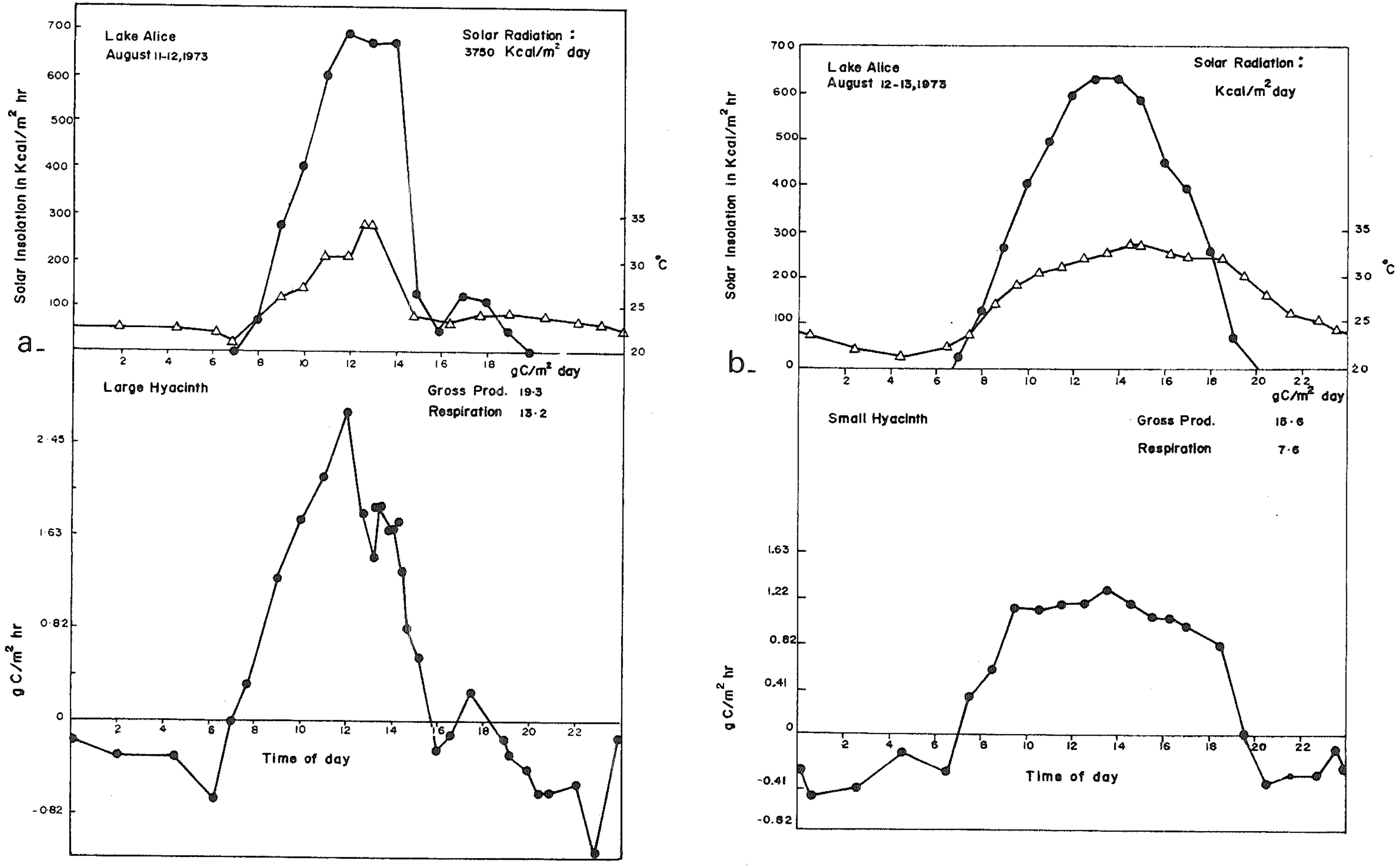


Fig. 7 : Diurnal rates of net daytime photosynthesis and nighttime respiration for large (a) and small (b) water hyacinth plants. These data were collected for a class research project by W. MITSCH, S. BROWN, T. CENTER and K. DUGGER. Table III summarizes the results.

daytime photosynthesis were higher in the large plants, but the efficiency of incident radiation to total daytime net photosynthesis was similar (1.6 %). Another experiment by LUGO & al. (1978) showed similar results.

It is clear that a high productivity, large biomass accumulation, varied morphology, and competitive success of aquatic weeds such as the water hyacinth are properties intrinsic to that species and are fully expressed when factor other than light are not limiting. The plasticity of the invading plant and its ability to take advantage of a transient environment gives it a competitive edge over climax native species. This competitive edge however requires a disruption of the structure of the native plant population. If transient conditions such as changes in nutrient levels and water flow, or if alterations in the structure of native plant communities is not present, the plants will not succeed in replacing a native and well organized ecosystem.

	Large Hyacinths	Small Hyacinths
Solar Insolation (Kcal/m^2 day)	3750	4900
Gross Productivity (Kcal/m^2 day)	193	156
24-hour Respiration (Kcal/m^2 day)	132	76
Ration of Gross Productivity to 24-hour Respiration	1.46	2.06
Net daytime Productivity Kcal/m^2 day	61	80
Efficiency of Gross Productivity	5.1 %	3.2 %
Efficiency of Net Daytime Productivity	1.6 %	1.6 %

Tab. III : Water Hyacinth Productivity in Lake Alice (August 11-13, 1973).

Management Implications.

The management implications of our studies are clear : aquatic plant weeds cannot be controlled by simply removing the plants or increasing herbivory while conditions for plant growth continue to remain optimal. An essential step in ecosystem management is the control of nutrient influx into the system. Little progress will be made in aquatic plant control while waters remain high in essential nutrient concentrations. The multiplicative effects of water flux and nutrient concentration on plant productivity also requires consideration. It should be clear however, that there is no ecological evil intrinsic to eutrophic waters. If their productivity can be channalized into well organized and balanced systems, eutrophic waters become assets to the region. The development of such types of ecosystems is the objective of ecosystem management. To achieve this goal, the growth of native plant and animal species should be encouraged. Their growth and organization will lead to greater diversity and maximum beneficial work for the region. In the Paynes Prairie area, this beneficial work is in the form of aesthetic beauty and diversity of wildlife. Such diversity is reduced with the introduction of conditions that favor exotic weed invasions. The productivity of aquatic weeds is channalized into few compartments and the plants alter the microenvironment eventually excluding other native plant and animal species (ULTSCH, 1973; LUGO & al., 1970). Useful regional work is thus minimized.

Our results and discussion of the productivity and evapotranspiration of aquatic macrophytes emphasize the need for field work and the systems approach to the study of aquatic plant control. Extreme care should be taken in extrapolating laboratory or short term studies such as biological control by insects and fungi, destructive methods, etc. into expensive and intricate management schemes that provide only short-term relief to complicated environmental problems. We believe that ecosystem management saves money and provides long-term solutions to the problems that arise from the high intensity of use that man imposes on natural ecosystems.

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