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AT LAKE GEORGE

BIOMASS DISTRIBUTION OF ROOTED MACROPHYTES IN THE LITTORAL ZONE OF LAKE GEORGE

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ABSTRACT

This study is concerned with the distribution and abundance of rooted macrophytes in the littoral zone of Lake George and their contribution to the overall aquatic ecosystem. The experimental approaches included biomass determinations, productivity estimates by radioactive CO_2 fixation (photosynthetic growth rate), and an ecological survey of fifty major littoral zones. General trends are discussed as interpreted by a superficial examination of the data collected from both the ecological survey and the macrophyte biomass. Computer analysis of the data collected from all three experimental approaches should provide correlations necessary for determining the role of the rooted macrophytes in the development of Lake George. Such analyses are currently in progress.

KEY WORDS

Aquatic plants, aquatic productivity, biological communities, fresh water, littoral macrophyte distribution, primary productivity

Introduction and Experimental Approach

The littoral zones of Lake George are almost exclusively found in the various bays located around the periphery of the lake. They occupy a relatively small percentage of the total surface area because of the rapid rate at which depth increases even within the bay areas. A variety of rooted macrophytes exist in the littoral zones which in some bays have already reached a seasonal nuisance level within the last three years. The purpose of this study was to provide a basis for assessing the present and future roles of the rooted macrophytes in the total primary productivity of Lake George.

Three experimental approaches were chosen to yield as much information as possible to allow an immediate evaluation of the present importance of these macrophytes in the total productivity of Lake George. The approaches included plant biomass, productivity studies and an ecological survey of the littoral zones. By correlating the results of these studies, the following considerations should be answered.

1) what is the present annual productivity of these plants and can this productivity be mathematically written to yield an accurate prediction of such productivity, 2) what is the relation of the various species which grow in the littoral zone to each other, to bottom type, depth of water, and to water and sediment chemistry of the littoral zone.

The primary productivity macrophyte model for Lake George was developed from the Lake Wingra seasonal macrophyte model (Titus, et al, 1972), the Lake George phytoplankton model (Park and Wilkinson, 1971), and from Westlake (1966). Its general form is as follows:

$$\frac{dM}{dt} = (G_m - R_m - L) * M$$

where: M = Macrophyte Biomass
t = Time (days)
G_m = Photosynthetic Growth Rate (days^{-1})
R_m = Loss Rate due to Respiration (days^{-1})
L = Loss Rate due to Grazing (days^{-1})

The model and its validation by the Lake Wingra group has involved the study of the submergent macrophyte, Myriophyllum spicatum, which now represents 68% of the total macrophyte population of Lake Wingra (Nichols and Mori, 1971). Consequently, the macrophyte model as presently written is a single species model. The various factors involved in the mathematical prediction of macrophyte productivity must involve a determination of certain parameters from a given organism (Titus, et al, 1972). Ogden and Smith (1973) list over 200 different species which have been found to grow in the littoral zone of Lake George; Myriophyllum spicatum is not one of them. To date, there has been no attempt to make any quantitative determinations on the relative dominance of these 200 species within the littoral zone of the entire lake although preliminary studies were made in the summer of 1972 on the macrophyte standing crops of various transects in the southern basin (Stross, 1972).

METHODS

Plant Biomass

Two representative bays were chosen for biweekly biomass collections. Warner Bay, in the southern part of the lake is in a heavily developed area with considerable boat traffic. Hearts Bay, in the northern part of the lake, is relatively isolated from human use and development. Random samplings were collected from both bays between May 1973 and

October 1973. Different collection methods were used according to the macrophyte growth at the site being sampled. These methods included an Eckman dredge (area = .0231 m^2), two rectangular frames (areas = .3180 m^2 and .0640 m^2), and a hinged netted frame (area = .2527 m^2). Each frame was randomly lowered into the water and all plants within the frame were collected by a SCUBA diver (R. B. Sheldon). The plants were transported to the laboratory in water in one liter plastic containers. Plants were separated according to depth, species, and plant sections (leaves, stems, roots, rhizomes, etc.). Prior to sectioning plants were washed to remove epiphyte populations when present. Dry weight measurements were made after 3 days at 105 C. Data was expressed as the amount of plant section biomass/m^2, the total biomass of each species/m^2, and the percent of total plant biomass/m^2 represented by each species at each water depth.

Productivity Studies

During the Spring of 1973, it was found that Potamogeton robbinsii was one of the predominant macrophytes found throughout the lake. Thus it was chosen for experimental use in determining biweekly productivity estimates by radioactive CO_2 fixation (photosynthetic growth rate).

The hourly rates of net photosynthesis of macrophytes were determined using a modification of Wetzel (1965). Plants of P. robbinsii were collected from the lake and removed to the laboratory. Plants were washed to remove the epiphyte community. For radioactive $^{14}CO_2$ uptake the leaves within two centimeters of the tip were removed. The surface of the leaves were blotted and a wet weight quickly obtained. The leaves were placed in vials containing 0.45 μ filter-sterilized Lake George water. Each was stoppered and 1.0 μc $H^{14}CO_3^-$ at pH 9.5

injected into the vial. Incubations were made in full midday sunlight in a shallow stationary waterbath at the temperature of the water from which the plants were taken. Incubations ran for two hours each. The incorporation of label by the plant tissue was terminated by removing the leaf from the radioactive medium and rinsing the leaf successively for five seconds in 0.1 N HCl and distilled water after which the tissue was frozen at -15 C until further processing could be done. Data is expressed in terms of dry weight of tissue converted from the wet weight measurements.

Ecological Survey of Littoral Zones

Fifty major littoral zones were surveyed during the summer by a SCUBA diver (R. B. Sheldon) trained to make biologically critical observations of the plant species present, their relative abundance, the depth at which they were growing, and the nature of the lake bottom sediments. A sheet of plastic 25 cm x 30 cm was used on which to record the data underwater using a regular no. 2 graphite pencil while the diver traversed the specified littoral zone. Initial plant identification followed the keys of Fassett (1957) and Muenscher (1944). Final verification of all plant species was made by Dr. Eugene Ogden, New York State Botanist. Voucher specimens were collected of all plant species removed from Lake George during the course of this study. Specimens were properly preserved and kept on herbarium file. Underwater photography was used to substantiate the qualitative observations made during the survey. Aerial infrared photography was also used to provide an overall view of the emergent macrophytes along the periphery of the lake.

Results and Discussion

The data collected from both the ecological survey and the plant biomass has been subjected to superficial examination and certain general trends appear. However, a much more in-depth analysis of the data will be provided by cluster analysis using computer programs. This will include such variables as species, depth, light intensity, water chemistry, temperature, pH, sediment characteristics, and geological information.

Most of the species present in the littoral zones were found in both the northern and southern parts of the lake. However the abundance of each specific organism was usually quite different from one end of the lake to the other.

Comparison shows that the total biomass in the southern bay which was heavily developed (Warner Bay) was much greater than the total biomass in the northern, relatively undeveloped bay (Hearts Bay). The total biomass at each station and sampling date is given in Table I. These data are also represented in graph form for Warner Bay (Fig. 1) and Hearts Bay (Fig. 2). Maximum standing crop in Warner Bay was harvested at 3 m in late August and exceeded 200 g dry wt/m^2. Maximum standing crop in Hearts Bay was only 12% that of Warner Bay and also occurred at 3 m depth. Mean biomass production for each bay is shown in Fig 3. The two curves were generated by summing the standing crop at the 1, 3, 5, and 7 m stations on each sampling date and dividing by four. Peak biomass production of all species collected occurred in late July in Hearts Bay and late July in Warner Bay. In general, the macrophytes tended for a slow growth period in June followed by a rapid growth rate in late July and early August. Most of the macrophyte species in Lake George are annuals, overwintering in the form of winter buds or rhizomes. The total plant biomass began its seasonal decrease in late August - early September.

Although over 20 separate species of macrophytes were found in biomass collections over the summer, there were dominant species which varied with depth. At 1 m depth, Vallisneria americana was the dominant species with Sagittaria sp. being the next most abundant. At 3 m depth, V. americana and Potamogeton amplifolius were codominant. The three most abundant species at 5 m were Potamogeton praelongus, P. robbinsii, and V. americana. P. robbinsii was virtually the only species present at 7 m with the exception of many small green balls of the blue-green alga Nostoc. Nitella flexilis, a green alga, was the only species present at depths of 9 m and greater. The biomass represented by V. americana and P. robbinsii is shown in Fig. 4 and 5. P. amplifolius was the only macrophyte found abundant in both bays (fig. 6). Both curves represent data from 3 m.

In Hearts Bay, Utricularia resupinata was dominant at 1 m depth whereas at other depths there was no especially dominant macrophyte. Since the primary concerns of this study were the rooted macrophytes, most of the interpretations did not deal with depths of greater than 7 m since the main plant present at these depths was N. flexilis (see Stross, 1972).

The underwater survey of plant distribution identified over 40 submergent macrophytes. V. americana was the predominant species throughout the lake although 24 other species were found to be quite common (Table 2). Fassett (1930) divided aquatic macrophytes into four different life forms: Forms with long lax stems and flexous leaves (e.g. Vallisneria species); forms with basal rosettes and unbranded stems (e.g. Sagittaria species); forms with vegetative stems and horizontal floating leaves (e.g. Potamogeton species); and forms that are rooted underwater but have photosynthetic parts emergent (e.g., Typha; Nuphar). All these forms are evident in the littoral areas of Lake George as well as the small, free floating plants (e.g. Lemna; Wolfia). However, this study was conducted in depths of 1 m and greater, neglecting for the most part, the highly diversified marsh regions.

Growth patterns of the macrophytes were found to be quite variable. The following distribution classes were developed which follows an exponential increase in total numbers progressing from 1 to 10.

Abundance and Distribution Classes

1	One plant sighted	6	Bed of many plants > 25 sq. ft.
2	Random Scattering of Several Plants	6.5	Several Beds of many plants > 25 sq. ft.
2.2	One bed of a few plants	7	Even growth 3-6 ft. apart
3	Several beds of a few plants	8	Even growth 1-3 ft. apart
4	Even growth > 6 ft. apart	9	Even growth < 1 ft. apart
5	Bed of plants < 25 sq. ft.	10	Plants touching
5.5	Several Beds < 25 sq. ft.		

Most of the macrophytes in the southern bays were characterized by higher distribution and abundance numbers than those found in the northern bays. There were several exceptions to this pattern notably those found near the outlet of Lake George at Ticonderoga, N.Y. This variation was probably due to the great influx of nutrients as the currents passed up from the south end of the lake through the outlet in the northern end of the lake.

Another important variable affecting the abundance and types of species present was found to be the lake bottom sediment types. Thus the following scale was set up and used in the fifty bay survey.

Sediment Scale

1	Rocky	6	Clay
2	Gravelly	7	Silty Sand
3	Terrigynous	8	Silt
4	Gravelly Sand	9	Sandy Organic
5	Sandy	10	Humic

The results of the ^{14}C uptake experiments to determine photosynthetic rates by *P. robbinsii* and their variation with time and temperature are presented in Fig. 7 and 8. The seasonal rates had a great variation at each sampling date; however, a general trend can be noted with the maximum photosynthetic rate occurring in early August.

The photosynthetic rate varies considerably with temperature. The optimum temperature was found to be near 22 C which was approximately the maximum summer temperature at the depth from which the *P. robbinsii* was sampled (7 m). This may be indicative of the organism's adaptation to its environment since this maximum temperature also occurs in August coincidental with the maximal seasonal photosynthetic rate.

Our initial findings indicate that the rooted macrophytes occupy a major role in Lake George ecosystem. It is hopeful the computer analyses incorporating the three aspects of the study -- biomass, productivity, and distribution survey -- will be able to recognize more vivid correlations for determining the exact nature of this role. This assessment should provide a basis for continued research on the role of these plants in the future development of Lake George.

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TABLE I

Total biomass at various depths in Warner Bay and Hearts Bay[a,b]

Location	Depth	5/25/73	6/5/73	6/26/73	7/10/73	7/24/73	8/7/73	8/21/73	9/6/73	10/28/73
Warner Bay	1 m	11.7	7.0	26.5	26.4	35.2	122	119	67.5	24.7
	3 m	9.8	36.1	37.0	58.9	76.9	143	206	198	121
	5 m	2.1	.3	15.1	32.1	4.7	14.7	54.6	11.8	30.6
	7 m	11.5	3.5	18.4	15.7	43.5	38.6	50.0	27.0	12.0
	9 m[c]	301	165	64.9	256	347	179	264	140	213
Hearts Bay	1 m	.3	7.4	3.1	15.8	20.8	12.9	20.2	18.1	19.7
	3 m	1.2	.7	2.4	5.4	26.3	31.7	9.0	.7	0
	5 m	6.1	11.9	.8	3.3	15.6	9.3	1.5	1.2	0
	7 m	.2	.2	3.1	.6	1.0	.5	4.5	0	0
	9 m[d]	.1	.9	1.2	1.2	4.6	0	0	0	0

[a] Biomass expressed as dry weight in g/m^2.

[b] Total biomass at each station is a summation of dry weight data on plant sections (leaves, roots, stems, rhizomes) as well as sloughing by individual species.

[c,d] Biomass from 9 m is represented solely by *Nitella* flexilis.

TABLE 2

Most common macrophyte species found in the littoral zone of Lake George[a]

Species	Average Dry Weight of mature plant[b]	Average maximum height of mature plant	Depth of maximum abundance
Bidens beckii	.483 g	56.3 cm	2-7 m
Chara globularis	.075 g	12 cm	1 m
Elatine minima			1 m
Elodea canadensis	.540 g	60 cm	1-9 m
Eriocaulon septangulare	.237 g	2.8 cm	1 m
Heteranthera dubia	.947 g	84 cm	1-3 m
Isoetes echinospora			1-3 m
Isoetes macrospora			3-8 m
Juncus sp.			1 m
Lobelia dortmanna			1 m
Myriophyllum alterniflorum	.268 g	51.3 cm	1-3 m
Myriophyllum tenellum			1 m
Najas flexilis	.080 g	24 cm	1-7 m
Nitella flexilis			>9 m
Potamogeton amplifolius	2.677 g	75.7 cm	3 m
Potamogeton gramineus	.307 g	84 cm	1-5 m
Potamogeton perfoliatus	.284 g	74.5 cm	1-5 m
Potamogeton praelongus	.836 g	73.3 cm	5 m
Potamogeton Pusillus	.081 g	29.3 cm	2-5 m
Potamogeton robbinsii	.873 g	69.7 cm	7 m
Ranunculus longirostris	.154 g	46 cm	1-3 m
Sagittaria sp.	.394 g	11 cm	1 m
Utricularia resupinata			1 m
Vallisneria americana	.536 g	77.7 cm	1-5 m
Subularia sp.	.014 g	6.2 cm	1 m

[a] All species collected from 1 m depth or greater. All were submergent.

[b] Plants were collected on 8/30/73. Visual observation suggests that plants collected were smaller than mature plants found earlier in the summer.

FIGURE LEGENDS

Fig. 1. Standing crop biomass determinations in Warner Bay. Macrophytes were collected at 1, 3, 5, 7 m. Results are expressed in terms of g Dry Wt/m^2.

Fig. 2. Standing crop biomass determinations in Hearts Bay. Macrophytes were collected at 1, 3, 5, 7 m. Results are expressed in terms of g Dry Wt/m^2.

Fig. 3. Mean biomass measurements for Warner Bay and Hearts Bay. Data from 1, 3, 5, 7 m as represented in Fig. 1 and 2, respectively, were totaled for each sampling date and divided by 4.

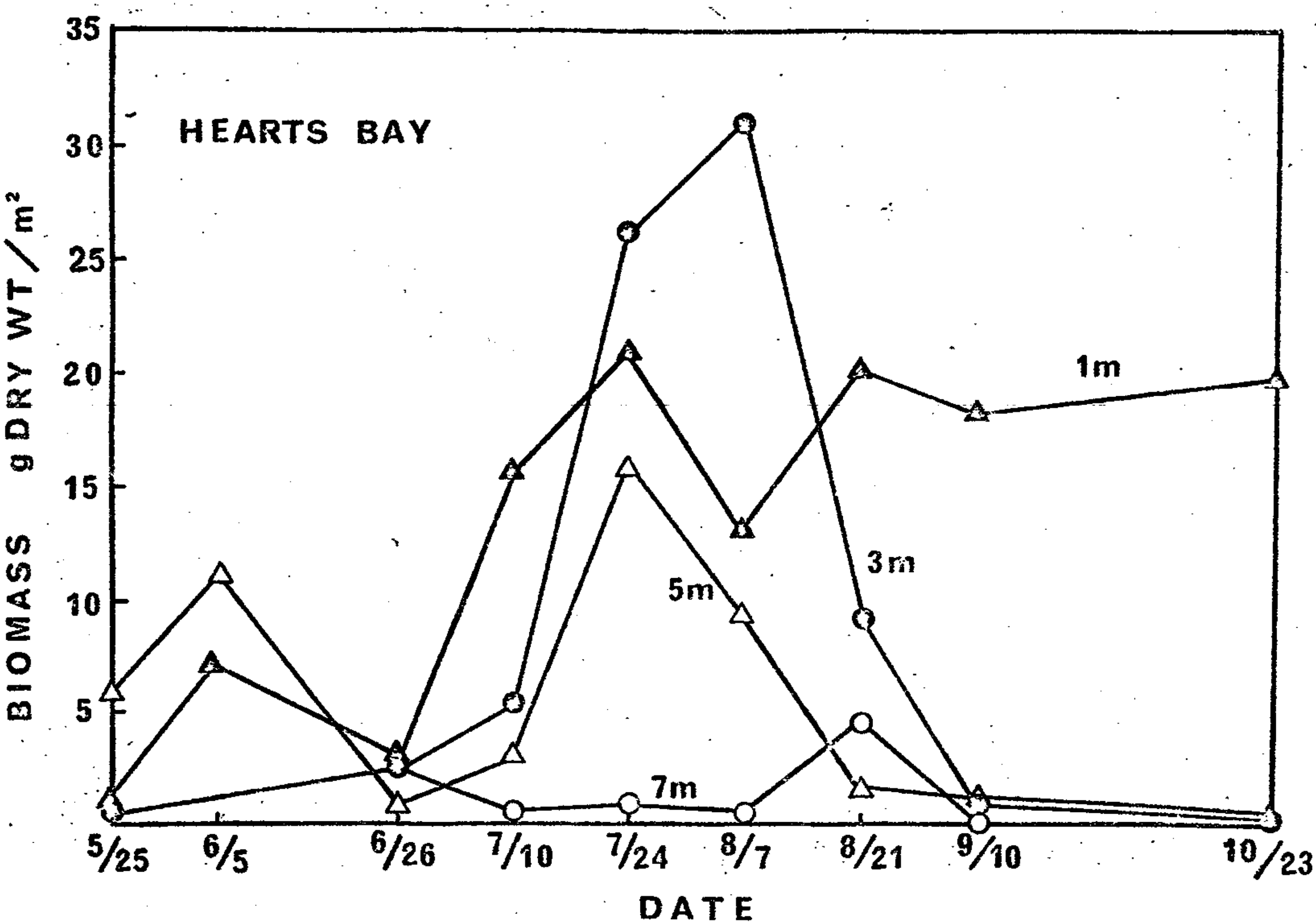
Fig. 4. Biomass distribution of Vallisneria americana in Warner Bay.

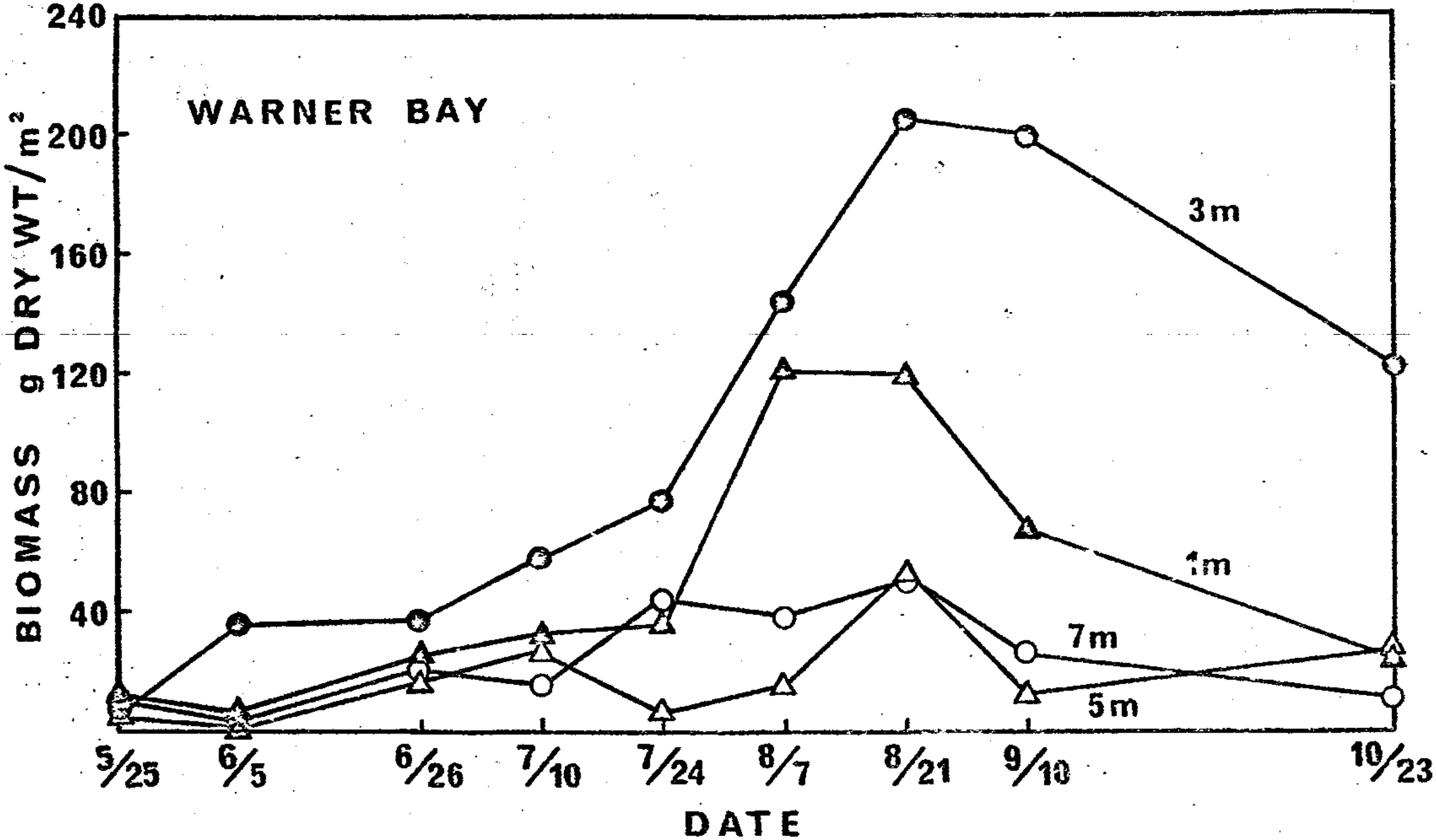
Fig. 5. Biomass distribution of Potomogeton robbinsii in Warner Bay.

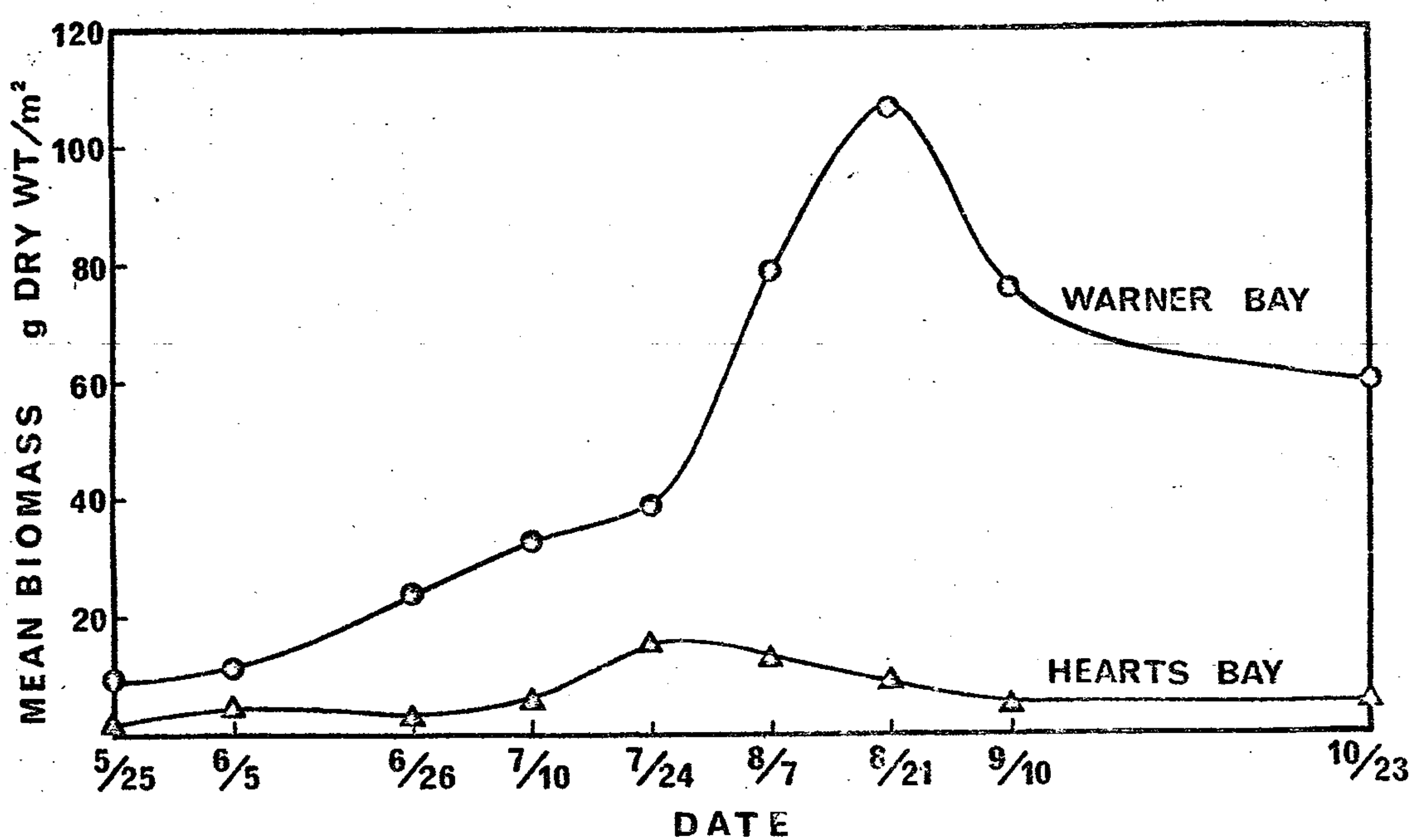
Fig. 6. Biomass distribution of Potomogeton amplifolius in Warner Bay and Hearts Bay.

Fig. 7. Seasonal photosynthetic rate for carbon assimilation (mg C/g/hr) by Potomogeton robbinsii. Refer to methodology for experimental protocol.

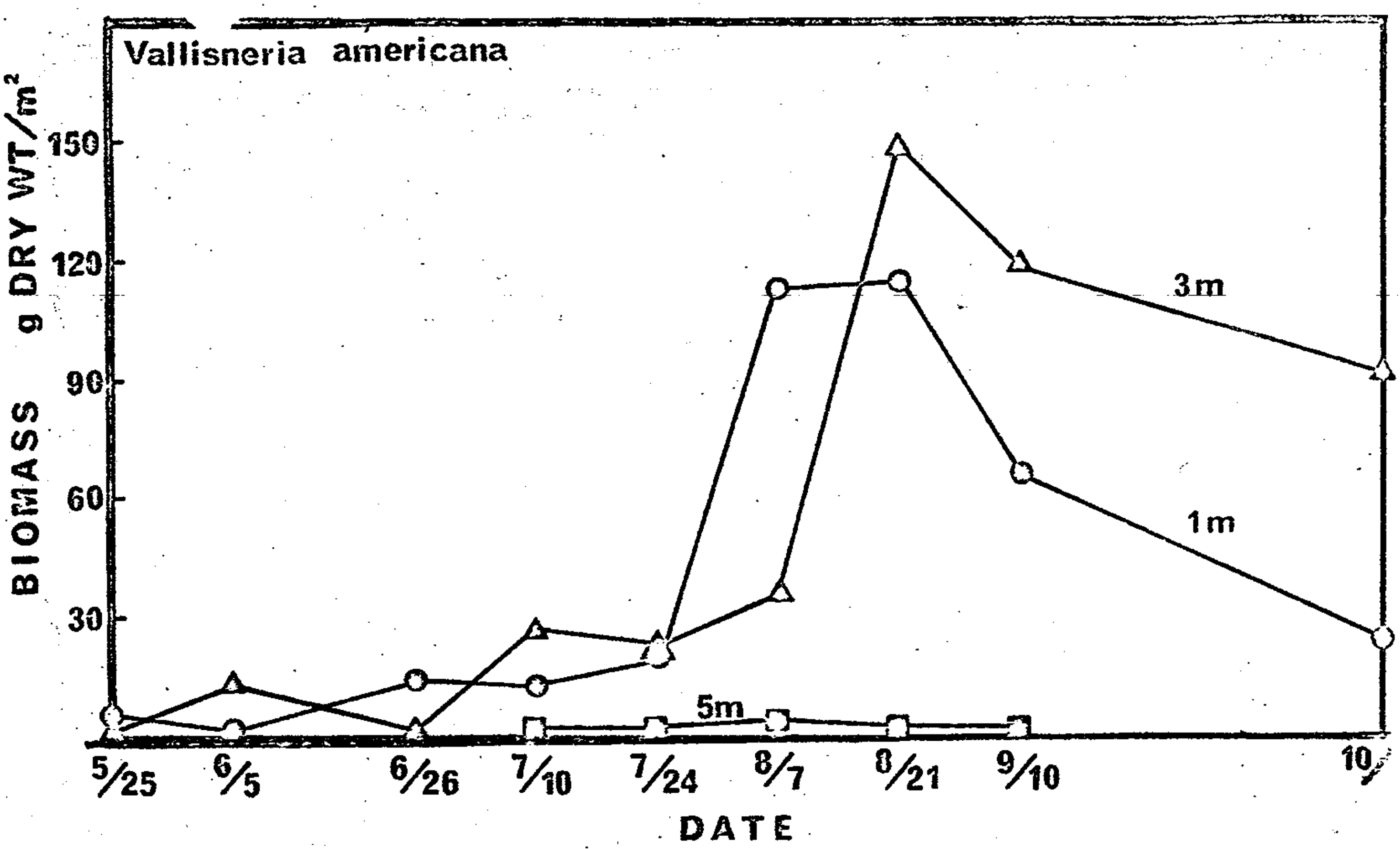
Fig. 8. Dependence of photosynthetic rate (mg C/g/hr) by Potomogeton robbinsii upon temperature. Plants were taken from Warner Bay at 7 m on August 9, 1973. Bay temperature was 22 C. Refer to methodology for experimental protocol.

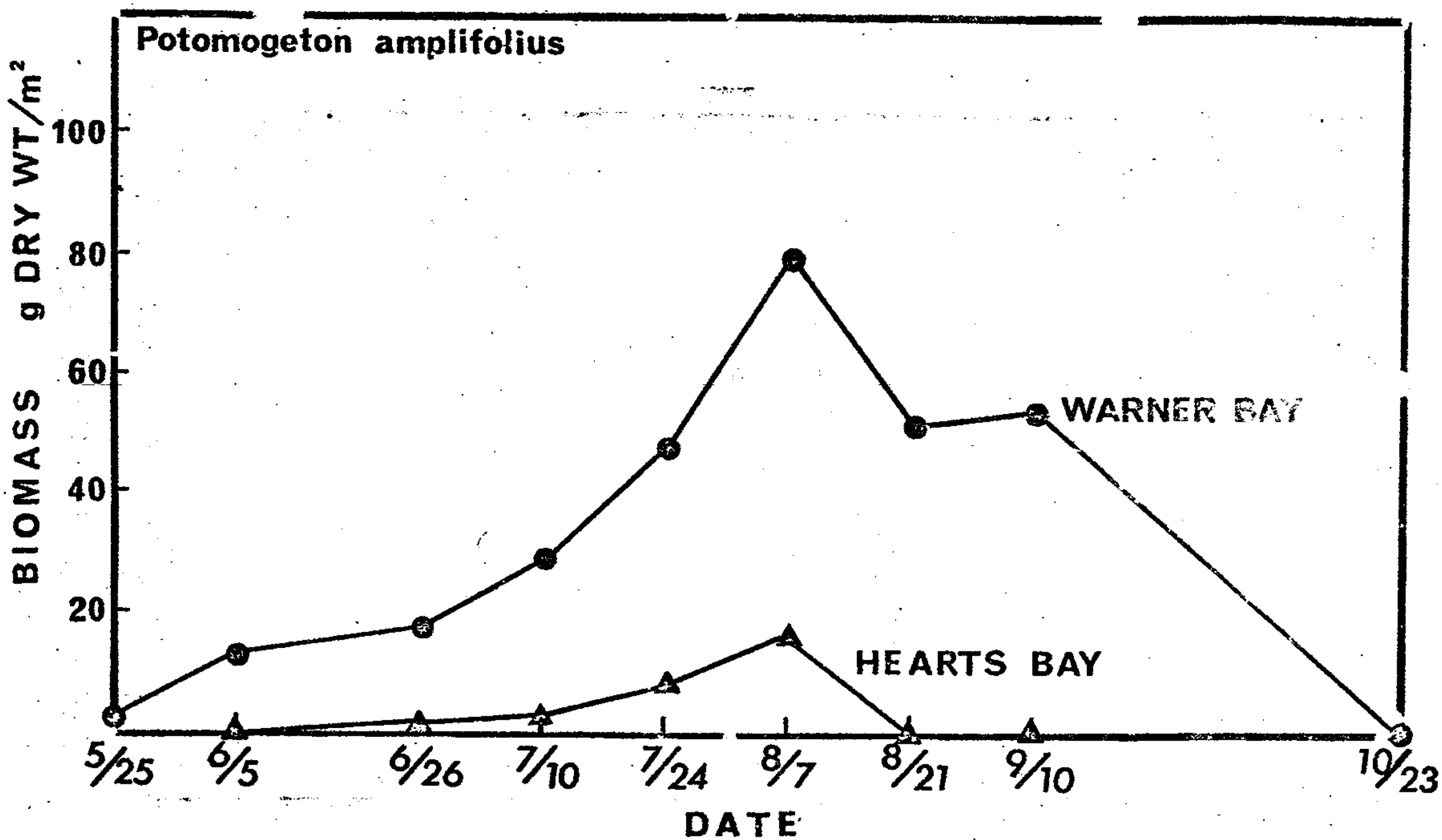

HEARTS BAY
BIOMASS g DRY WT / m²
35
30
25
20
15
10
5
1m
3m
5m
7m
5/25
6/5
6/26
7/10
7/24
8/7
8/21
9/10
10/23
DATE


WARNER BAY
BIOMASS g DRY WT/m²
240
200
160
120
80
40
3m
1m
7m
5m
5/25
6/5
6/26
7/10
7/24
8/7
8/21
9/10
10/23
DATE

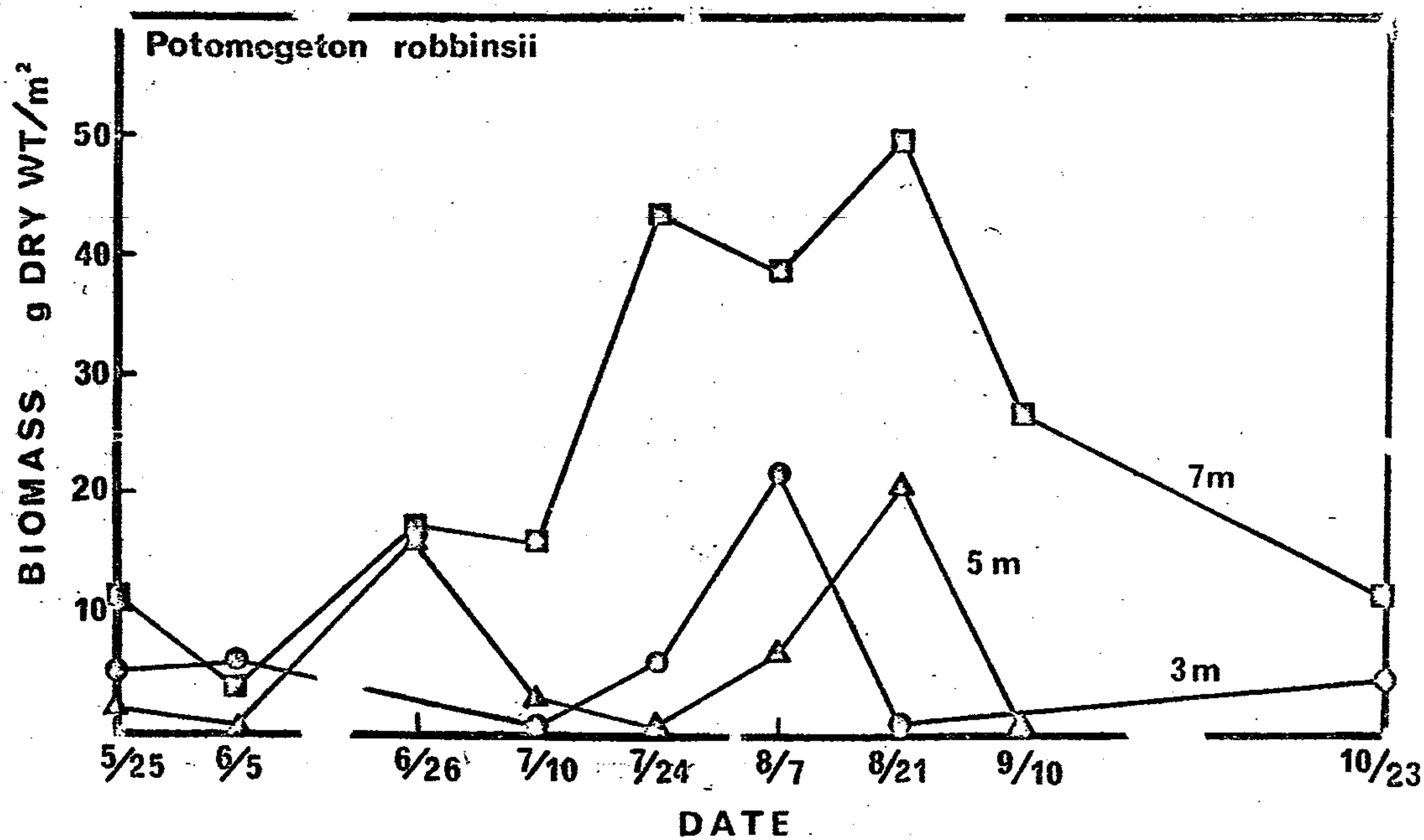


MEAN BIOMASS g DRY WT/m²
120
100
80
60
40
20
WARNER BAY
HEARTS BAY
5/25
6/5
6/26
7/10
7/24
8/7
8/21
9/10
10/23
DATE

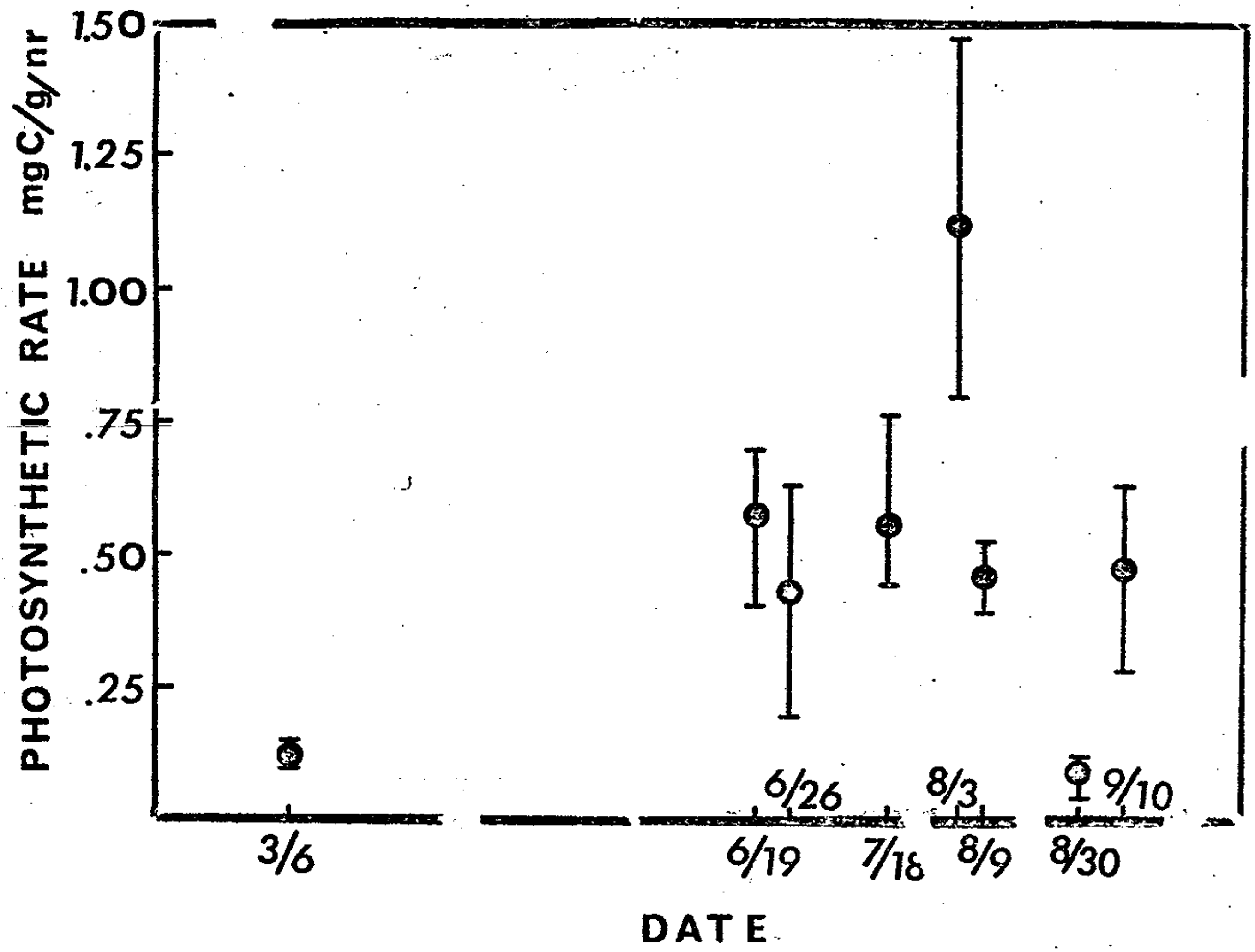

Vallisneria americana
BIOMASS g DRY WT/m²
150
120
90
60
30
3m
1m
5m
5/25
6/5
6/26
7/10
7/24
8/7
8/21
9/10
10
DATE



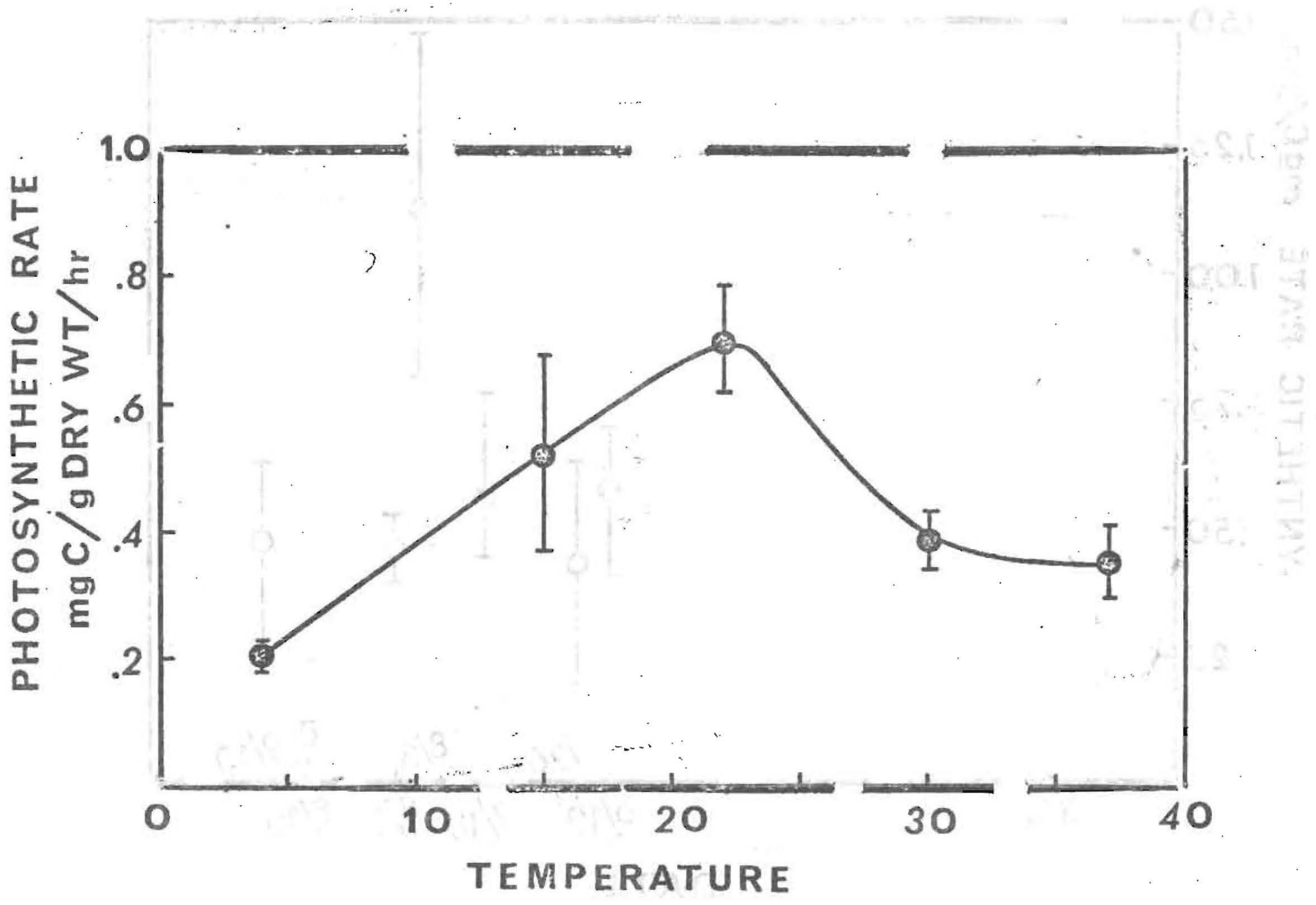
Potomogeton amplifolius
BIOMASS g DRY WT/m²
100
80
60
40
20
WARNER BAY
HEARTS BAY
5/25
6/5
6/26
7/10
7/24
8/7
8/21
9/10
10/23
DATE



Potomogeton robbinsii
BIOMASS g DRY WT/m²
50
40
30
20
10
7m
5 m
3 m
5/25
6/5
6/26
7/10
7/24
8/7
8/21
9/10
10/23
DATE



PHOTOSYNTHETIC RATE mgC/g/hr
1.50
1.25
1.00
.75
.50
.25
3/6
6/19
6/26
7/18
8/3
8/9
8/30
9/10
DATE



PHOTOSYNTHETIC RATE
mg C/g DRY WT/hr
1.0
.8
.6
.4
.2
0
10
20
30
40
TEMPERATURE