

THE TROPHIC STATE OF ROACH AND MORRIS LAKES

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Introduction

With few exceptions lentic ecosystems naturally progress via successional development from an oligotrophic to a eutrophic condition. An oligotrophic lake is characterized by a low surface-to-volume ratio, clear water that appears blue to blue-green in direct sunlight, largely inorganic bottom sediments, and a high hypolimnetic oxygen concentration. The nutrient content of the water is low; although nitrogen may be abundant, phosphorus is highly limiting. Low nutrient availability results from a low input of nutrients from external sources. This in turn causes a low production of organic matter, particularly phytoplankton. Low organic production results in a low rate of decomposition and high oxygen concentration in the hypolimnion. These oxidizing conditions produce low nutrient release from the sediments. The lack of decomposable organic substances results in low bacterial populations and slow rates of microbial metabolism.

A typical eutrophic lake has a high surface-to-volume ratio and an abundance of nutrients, especially nitrogen and phosphorus, that stimulate a heavy growth of algae and other aquatic plants, resulting in a well-developed littoral zone. Increased photosynthetic production leads to increased regeneration of nutrients and organic compounds, stimulating further growth. Phytoplankton becomes concentrated in the epilimnion and metalimnion. The turbidity reduces light penetration and restricts biological productivity to a narrow zone of surface water. Algae, inflowing organic debris and sediment, and the remains of rooted plants drift to the bottom adding to the highly organic sediments. On the bottom bacteria partially convert dead matter into inorganic substances. The activities of these

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adopting the author-date-citation-in-text format.

decomposers deplete the oxygen supply of the bottom sediments and deep water to a point that the deeper parts of the lake are unable to support aerobic forms of life. As the basin continues to fill, the volume decreases and the resulting shallowness speeds the cycling of available nutrients and further increases plant production. (1)

Thus, the ontogeny of a lake ecosystem is governed by many interacting causal mechanisms that characterize the trophic nature of the lake: its amount, composition and distribution of biotic components and rates of nutrient circulation. Direct quantitative measurements of autotrophic productivity, the rate of formation of organic matter per unit time due to phytoplanktonic photosynthesis, are often used in assessing the trophic nature of a lake. However, the general level of a lake's productivity can be inferred from quantitative measurement and qualitative analysis of its biotic and abiotic components; this procedure was followed in conducting this particular study. 8

The purpose of this study was to compare and contrast the trophic nature of Roach and Morris Lakes through analysis of several interrelated, influential factors. These factors included: light penetration, heat penetration and stratification, oxygen penetration and utilization, nutrient circulation, nature of bottom deposits, development of littoral region, and planktonic composition. This was accomplished in two sampling phases, one limnological and the other benthic.

Methods and Materials

Limnological sampling was accomplished and physical parametric measurements obtained by employing four pieces of aquatic equipment: Secchi disk, temperature and dissolved oxygen meter (Y.S.I.), Van Dorn sampler, and plankton net. Secchi disk readings were

performed on the shade side of the boat. The depth of the disk's disappearance upon lowering and that of reappearance upon raising were estimated to the nearest meter. The average of these two values was recorded as the Secchi depth. Temperature and dissolved oxygen content were measured at the lake surface, 0.5 m, and at 1-meter intervals up to 9.0 m with the Y.S.I. after its initial calibration. Two Van Dorn samples were taken from the epilimnion and one from the hypolimnion, the depths of which were determined from the Y.S.I. readings. These corresponded to 2.0 m and 7.0 m, and 1.0 m and 5.0 m, in Roach and Morris, respectively. Plankton net hauls were made ^{Vertical} at ^{from} 8.0 m in Roach and 4.5 m in Morris. Meteorological conditions on the sampling day (July 24) consisted of a mostly sunny sky with scattered clouds and moderate breeze, producing a light chop on the surface of Roach.

In the lab, species of phytoplankton from the two Van Dorn samples, and zooplankton from the plankton haul, were identified for each lake using light microscopy and appropriate identification keys. Soluble ammonium and iron concentration levels of each Van Dorn sample were determined from standard curve plots. Spectrometer absorbance readings of known concentrations were used to construct the absorbance-versus-concentration plots. Each Van Dorn sample was also tested for alkalinity by titration and its initial pH recorded with a pH meter.

Benthic sampling included sampling of crayfish populations using baited traps and direct sampling of macrophytic vegetation and associated invertebrates using four pieces of equipment: quadrat (.25 m by .25 m), net, rake, and grapnel. The types of sampling gear employed depended on ~~what depth the bottom was being sampled~~; the quadrat was used at 0.5 m and for floating and emergent vegetation at 1.0 m, the net for submersed vegetation at 1.0 m and at 2.0 m, the rake at 3.0 m, and the grapnel at 1-meter intervals from 4.0 m to

7.0 m. Two replicates were taken at each depth point along a transect running perpendicular to the shoreline. Two transects were made for Roach and three for Morris on August 6 and 7, respectively (Figures 7 and 8). Substrate type and degree of wind exposure at each transect were noted. At the lab, macrophytes and associated snails were sorted and identified using appropriate keys; macrophytes were then weighed ^{wet} while snails were counted, by species. Calibration among all equipment types was necessary to compare weight values, since each type sampled a different amount. Thus, each raw sample weight was multiplied by a corresponding conversion factor to generate the data discussed below. | what were the conversions

Crayfish traps were set on the bottom 1-2 m deep equidistant around the lake shoreline, ten in Roach, nine in Morris (Figures 7 and 8). Traps were set on the same day sampling was performed and collected approximately 24 hours later. Substrate type at each site was noted. Individuals collected were classified according to species and sex (and form, breeding or nonbreeding, for males).

Results

Data = plural
Datum = singular

Limnological data ^{one} was categorized into three forms: temperature and dissolved oxygen profiles, tables summarizing chemical test results, and phytoplankton and zooplankton lists. Examination of the temperature and dissolved oxygen profiles of the two lakes reveals three major interesting relationships (Figure 3). First, the epilimnion of Roach extends much deeper (approx. 3 m) than that of Morris. The difference between the two lakes in Secchi depth, which marks the lower boundary of the photic zone, confirms this finding. Second, the thermocline of Morris is a much steeper gradient than that of Roach; that is, the change

in temperature per given change in depth is much greater. Third, the temperature at which the hypolimnetic water stabilizes is lower in Morris than in Roach. Fourth, a prominent metalimnetic maxima of dissolved oxygen content occurs in both lakes.

You should distinguish Tables and Figures.

Chemical test results also show several significant relationships (Figure 4). The degree of water acidity expressed on a logarithmic scale (pH) was lower in the hypolimnion than in the epilimnion of both lakes, although a larger difference between the two layers was detected in Roach. The average pH of Roach was much more acidic than that of Morris, and its alkalinity value was extremely low in comparison to that of Morris. Ammonium ion concentration also differed appreciably between the two lakes, that of Morris being much larger. Interestingly, this chemical parameter increased significantly from the epilimnion to the hypolimnion, in Morris, but slightly decreased in Roach. Ferric ion concentrations were undetected, except in the hypolimnion of Morris where it occurred in massive amounts.

The plankton lists of the two lakes shared many phytoplanktonic and zooplanktonic species. One difference worthy of note was the presence of several predaceous copepods in Morris, which were lacking in Roach.

Benthic data was organized into that comprising density and species distribution of macrophytic vegetation, associated snail fauna, and crayfish populations. Morris was characterized by a much larger mean macrophyte density than that of Roach at all depths, though the mean number of species per unit area were relatively similar. Both lakes exhibited a distribution curve resembling that of a quadratic equation for these two data types; the values would increase to a maximum at 1 m with increasing depth, the decrease as depth continued to decrease, until no macrophytes were found past a given depth (Figure 9). The only exception to this trend was the mean number of macrophyte species per unit

X

area-versus-depth plot, whose maxima occurred around 2 m. Within either lake, total macrophyte density at any given depth was relatively greater at transects less exposed to wind action. Not surprisingly, a soft, mucky substrate consisting of dead organic matter at various stages of decomposition predominated at these transects, while a firmer, more rocky type did at more exposed transects (Tables 1 and 2, Figures 7 and 8). Along a given transect, a spatial succession of macrophyte species seemed to occur (Tables 1 and 2). Each sublittoral zone was dominated by a different species; that is, as depth increased, a particular macrophyte species grew less abundantly, while another grew more so.

Trends in mean snail density and number of species per unit area of Morris closely paralleled those of macrophytic vegetation mentioned above (Figure 10 and Table 3). Only one snail was collected from Roach (Table 3).

Four crayfish of the species Orconectes virilis were collected from Morris, one female each in traps #1-3, and one male in nonbreeding form from trap #9, resulting in an average of .44 crayfish per trap (Figure 8). No crayfish were collected from Roach.

Discussion

Since solar radiation is fundamentally important in lake ecosystems, the great disparity between the two lakes under study in Secchi depth is highly significant. Secchi depth indicates where photosynthetically-active radiation is ^{about} 10% of that at the surface, a critical level for efficient photosynthesis by most organisms. The severe attenuation of light in Morris suggests its support of a higher plankton population, including photosynthesizing phytoplankton, in comparison to that of Roach. Higher photosynthetic rates correlate ^{positively} directly with higher productivity rates. Since reflection and absorption of sunlight also

increases with increased water turbidity, the shallower Secchi depth of Morris possibly indicates a higher amount of dissolved ^s ~~nutrients~~ ^{colored compounds} and suspended particles circulating within the lake, which indirectly affects productivity. Light penetration has profound effects on thermal structure, circulation patterns, and biotic distribution as well. Secchi depth does vary with environmental conditions and surface location; however, readings were taken on meteorologically-similar days and at the deepest portions of the lakes and did agree with reference values.²

Similar temperature profiles attest to the thermal stratification of both lakes. Lower temperatures carry less dissolved oxygen content, so the higher epilimnetic and lower hypolimnetic amounts of dissolved oxygen in Morris occur as expected. Oxygen is not only ^s ~~essential~~ ^{essential} for the survival of many inorganic nutrients, but also influential in determining the solubility of many inorganic nutrients. Therefore, the experimental results also point to a higher level of biological activity in both phytoplanktonic photosynthesis and microbial decomposition in Morris. Lower hypolimnetic oxygen concentrations in Morris may also be due to a less degree of mixing prohibited by the larger temperature and density metalimnetic barrier. The metalimnetic "bulge" of the oxygen profile in both lakes is caused by ~~acute~~ ^{intense} oxygen production by algal populations concentrated at the epilimnetic-metalimnetic border, where nutrient concentrations are usually higher and light intensity still sufficient for photosynthesis.⁵

Differences of major chemical importance lie in alkalinity between the two lakes. Alkalinity refers to the ability to resist pH changes due to the amounts of dissolved salts present acting as buffers, and, thus, is a good indicator of dissolved nutrient concentrations. Therefore, Roach must contain very low concentrations of dissolved nutrients, as opposed to

Morris. This may largely be due to Rosch being a seepage lake; that is, it receives very little nutrient input from above-ground, inflowing sources. This is verified by the greater concentrations of ammonium and ferric ions in Morris than in Rosch. A high concentration of soluble ferric and ammonium ions, as in the hypolimnion of Morris, correlates with a low oxygen concentration (Figure 11). The biomass of phytoplankton communities is primarily a function of the rates of nutrient supply and algal loss.⁴ In fact, the population dynamics of phytoplankton and species succession may be dependent just as much on remineralization of nutrients as on mortality caused by grazing zooplankton.⁵ Moreover, it has been found that in oligotrophic lakes, invertebrate planktonic predators do not have major compositional or demographic effects on the resident lake community, especially on the dominants.⁶

Therefore, available nutrient supply seems to be a major limiting factor on phytoplankton communities, and, hence, lake productivity. The very acidic nature of Rosch may also be limiting.

I don't think that this is exactly right. They found that Chaoborus had stronger negative effects on herbivores as nutrient supply increased

The littoral region assumes an important role in lentic trophic structure and energy dynamics. As an interface zone between adjacent terrestrial ecosystems and the pelagic community, the littoral region is a site of particle accumulation; its littoral flora acts as a filter in regulating nutrient input from allochthonous sources, absorbing certain nutrients while releasing others from bottom sediments and availabilizing them for open-water organisms. *does Webster like this word?* Macrophytic vegetation also influences light penetration, temperature, dissolved oxygen content, and abundance and distribution of other organisms, in providing shelter and food. Therefore, the littoral flora may significantly contribute to the productivity and regulation of lake metabolism, especially in smaller lakes where the littoral region comprises a major portion of total surface area. Morris has a

well-developed littoral flora, in contrast to Roach, according to the overall macrophyte densities.

The extent of macrophytic vegetational cover is itself governed by a combination of factors, of which one or several may be limiting. The degree of wind-induced wave action along with sediment type and its local rate of deposition has a major impact on the growth, distribution, and zonation of macrophytes.¹ Shoreline currents pose an upper limit to macrophytes chiefly through buffeting action and destabilization of bottom sediments. In shallow lakes where the colonized zone lies entirely within the wave-mixed zone, the principle limiting factor is wave action with sediment. In those lakes where the colonized zone is twice as deep as the wave-mixed zone, light is the principle limiting factor.² A distribution curve such as that constructed results, with optimum depth of highest density occurring at points of gradient compromise. Since different species of organisms respond differently to a given set of interacting factors, including other species, what may be limiting for one species may not be for another. Thus, a spatial succession of macrophyte species with depth typifies the littoral zone. Horizontal macrophyte distribution is also influenced largely by wind-induced currents. Exposed stretches of shoreline therefore harbor less macrophyte cover than sheltered areas, as evidenced by the data. Macrophyte distribution in Roach Lake is profoundly influenced by local perturbations in the sediments caused by the nesting behavior of centrarchid fishes.³ Because of the high degree of water clarity of Roach, light was not a limiting factor; macrophytes were collected at depths below Secchi depth.

Snail populations are strongly affected by macrophyte distribution, for their distribution and density corresponds closely to that of macrophyte vegetation in both lakes.

This exemplifies the close relationship among biotic communities within the lentic ecosystem. ^{In some lakes} ~~Normally,~~ crayfish have an enormous impact on the community structure of both macrophytes and fish populations. However, due to limited concentrations of calcium available for growth needs, crayfish do not appear in large enough numbers in either lake to exert a significant impact on its trophic state.

Obviously, many possible sources of error exist in the macrophyte sampling procedures. Low available light and its scattering underwater may have limited visibility enough to exclude some plants from being sampled. Also, vegetational patchiness is quite common, possibly causing bias in sampling for species diversity and density.

The complex nature of biotic and abiotic interrelationships in accurately assessing productivity must be remembered. Component interactions within the lake work both ways; plankton growth affects nutrient supply, just as nutrient supply affects plankton growth. Such inverse pathways are by no means equivalent, but temporally successional, usually leading to a higher state of eutrophy.

Because planktonic sampling was strictly qualitative, no quantitative determinations of phytoplanktonic and zooplanktonic community structure and biomass could be ^Pforwarded. Therefore, lake productivity could not be directly estimated. However, a general picture of the trophic nature of both lentic ecosystems under study can be drawn, based on the interactive effects of a host of biotic and abiotic factors that include: light penetration, heat penetration and stratification, oxygen utilization, nutrient circulation, nature of bottom sediments, and development of littoral region. Limnologically and benthically, Rosch Lake exhibits characteristics of oligotrophy, while Morris Lake exhibits those of eutrophy.

ENDNOTES

¹Robert Leo Smith, Ecology and Field Biology (New York, Harper & Row Publishers), pp. 213-15.

²Ann St. Amand, Stephen R. Carpenter, and Richard W. Greene, A Student's Guide to U.N.D.E.R.C. (University of Notre Dame, South Bend, IN), pp. 33,39.

³Robert G. Wetzel, Limnology (Philadelphia, Saunders College Publishing), p. 164.

⁴David Tilman, "Phytoplankton Community Ecology," American Review of Ecological Systems (1982), p. 365.

⁵John T. Lehman, "Nutrient Recycling as an Interface Between Algae and Grazers in Freshwater Communities," Evolution and Ecology of Zooplankton Communities (Vol. III), p. 261.

⁶William E. Neill and Adrienne Peacock, "Breaking the Bottleneck," Evolution and Ecology of Zooplankton Communities (Vol. III), p. 723.

⁷D. H. Spence, "The Zonation of Plants in Freshwater Lakes," Advanced Ecological Research (1982), p. 113.

⁸Spence, Advanced Ecological Research, p. 113.

⁹Stephen R. Carpenter and Nancy J. McCreary, "Effects of Fish Nests on Patterns and Zonation of Submersed Macrophytes in a Soft-Water Lake," Aquatic Biology (June, 1985), p. 30.

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Figure 1. List of Phytoplankton Genera Identified in Van Dorn Samples and Noted In Reference¹ From Roach and Morris Lakes

ROACH ²		MORRIS	
<u>Reference</u>		<u>Sample</u>	<u>Reference</u>
Asterionella		Anabaena	Dinobryon
Closterium		Closteridium	
Peridinium		Dinobryon	
		Groenbladia	
		Peridinium	
		Volvox	

Figure 2. List of Zooplankton Genera Identified in Plankton Net Samples and Noted In Reference⁴ From Roach and Morris Lakes

ROACH		MORRIS	
<u>Sample</u>	<u>Reference</u>	<u>Sample</u>	<u>Reference</u>
Daphnia (C)	Bosmina (C)	Asplanchna (R)	Asplanchna
Leptodiaptomus	Bucyclops (P)	Cyclops (P)	Keratella (C)
Diaptomus (P)	Keratella (R)	Daphnia (C)	
Gastropus (R)	Orthocyclops (P)	Eucyclops (P)	
Keratella (R)	Trichocera	Leptodiaptomus	
		Limnocalanus (P)	
		Mesocyclops (P)	

¹ A Student's Guide To U.N.D.E.R.C.

² No Data available from Van Dorn sample

³ P = Copepod, C = Cludoceran, R = Rotifer

Figure 2. Temperature and Dissolved Oxygen Profiles at Roach and Morris Lakes

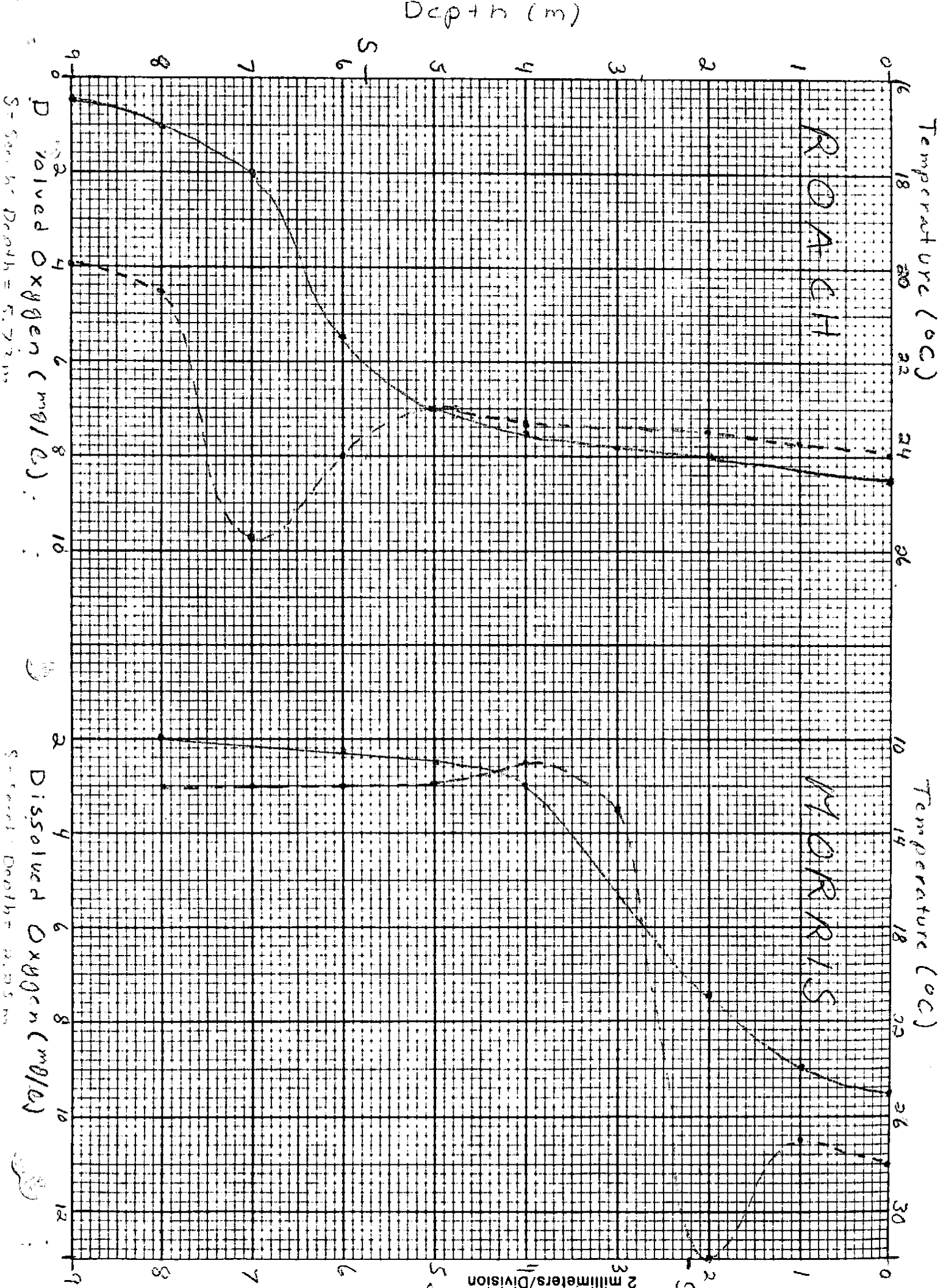


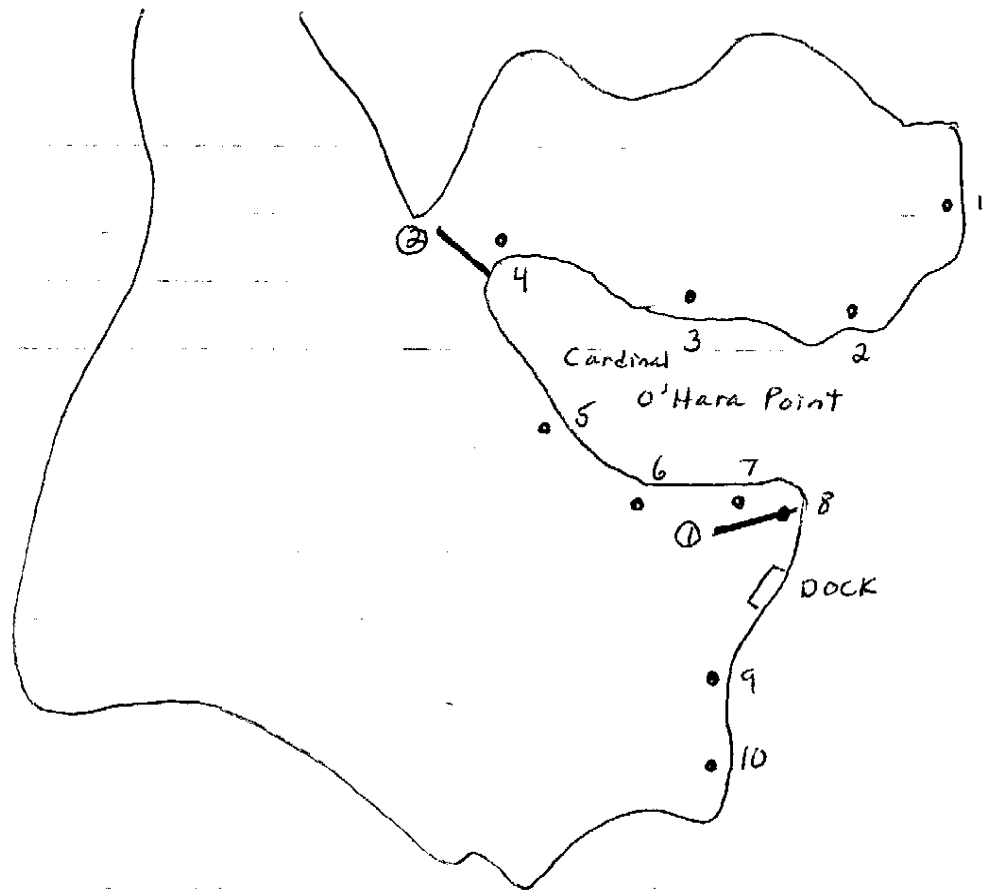
Figure 5. List of Macrophyte Species Sampled In Roach and Morris Lakes

<u>Family</u>	<u>Genus / Species</u>
ROACH:	
Eriocaulaceae	① Eriocaulon septangulare
Haloricidaceae	② Myriophyllum tenellum
Lobeliaceae	③ Lobelia Dortmanna
Musci <small>not a family</small>	④ Drepanocladus sp.
MORRIS:	
Characeae	⑤ Chara sp.
Najadaceae	⑥ Potamogeton amplifolius
Nymphaeaceae	⑦ Nuphar variegatum

Figure 6. List of Snail Species Sampled In Roach and Morris Lakes

<u>Family</u>	<u>Genus / Species</u>
ROACH:	
Hydrobiidae	① Amnicola limosa
MORRIS:	
Hydrobiidae	Amnicola limosa
Planorbidae	② Gyraulus parvus
	③ Helisoma anceps
	④ Helisoma campanulata

Figure 7. Diagram of Southern Portion of Roach Lake Indicating Location of Transects and Crayfish Traps

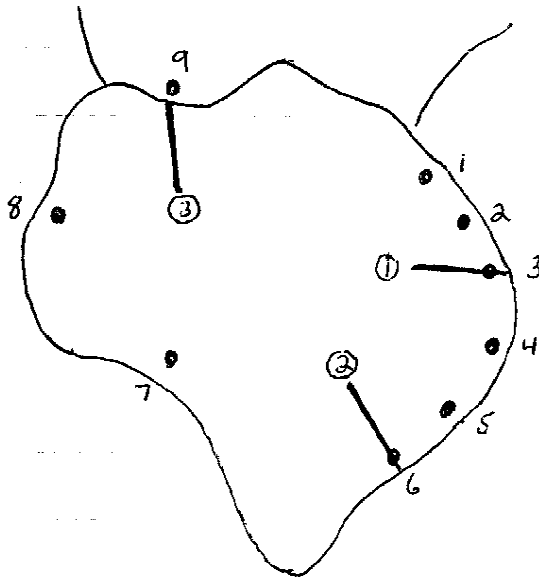


<u>Transect No.</u>	<u>Substrate Type</u>	<u>Degree of Wind Exposure</u>
①	Soft: Dead Leaf/Twig Layer	Low
②	Rocky near shore; Underlying Mud	High

Legend

- = shoreline
- = transect
- = trap site

Figure 8 . Diagram of Morris Lake Indicating Location of Transects and Crayfish Traps



<u>Transect No.</u>	<u>Substrate Type</u>	<u>Degree of Wind Exposure</u>
①	Soft: Organic Muck	?
②	Soft: Organic Muck	?
③	Mixed: Rocky & Organic	High

NOTE: Soft substrate, broken bed of macrophytes throughout

Legend

— = shoreline

— = transect

• = trap site

Table 1. Macrophyte Data For Roach Lake

Trans. No.	Depth (m)	TOTAL MAC. WT. (g)		\bar{x}	Total Mac. (g/m^2) ¹	Total Mac-Sp. #	Sp. in decreasing abundance ⁵
		Sample 1	Sample 2				
1	0.5	241.84	377.91	309.88	4958.08	2	①, ③
	1.0	187.45	1.20	47.14	2692.64	2	①, ④
	2.0	.75 ²	24.31	12.53	15.72	3	②, ①, ③
2	0.5	12.34	8.62	10.48	167.68	2	①, ③
	2.0	6.68	4.30	5.49	671.70	3	②, ①, ③

Depth (m)	Total Mac. (g/m^2) ³	Total Species No. ⁴
0.5	2562.88	2
1.0	2692.64	2
2.0	343.71	3

¹ \bar{x} x conversion factor

² Sampled with rake

³ Average of all transects (= mean mac. density)

⁴ Average of all transects (= mean mac species no.)

⁵ See Figure 5

Table 2 • Macrophyte Data For Morris Lake

Trans. No.	Depth (m)	TOTAL MAC.WT.(g)		\bar{x}	Total Mac. (g/m^2) [*]	Total Mac. Sp. #	Sp. in decreasing abundance ⁵
		Sample 1	Sample 2				
1	1.0	969.58	111.22	590.40	33723.60	2	⑤, ⑥
	2.0	121.37		121.37	6932.70	1	⑤
2	0.5	1215.97	390.35	233.17	3730.70	3	⑦, ⑤, ⑥
	1.0	298.10	141.45	219.75	3516.50	1	⑦
	2.0	163.36	709.36	436.36	24924.90	1	⑤
3	0.5	294.92	442.64	368.78	5900.50	2	⑤, ⑦
	1.0	106.60	407.69	357.15	14688.40	1	⑤
	2.0		.96	.96	54.24	1	⑤

Depth (m)	Total Mac. (g/m^2) [†]	Total Species No. [‡]
0.5	4815.60	2.50
1.0	17,309.50	1.33
2.0	3501.35	1.00

* \bar{x} X conversion factor

† average of all transects (= mean macrodensity)

‡ average of all transects (= mean mac. species no.)

⁵ see figure 5

Figure 1. Mean Macrophyte Density vs. Depth and Mean Macrophyte Species No. vs. Depth Plots of Roach and Mornis Lakes

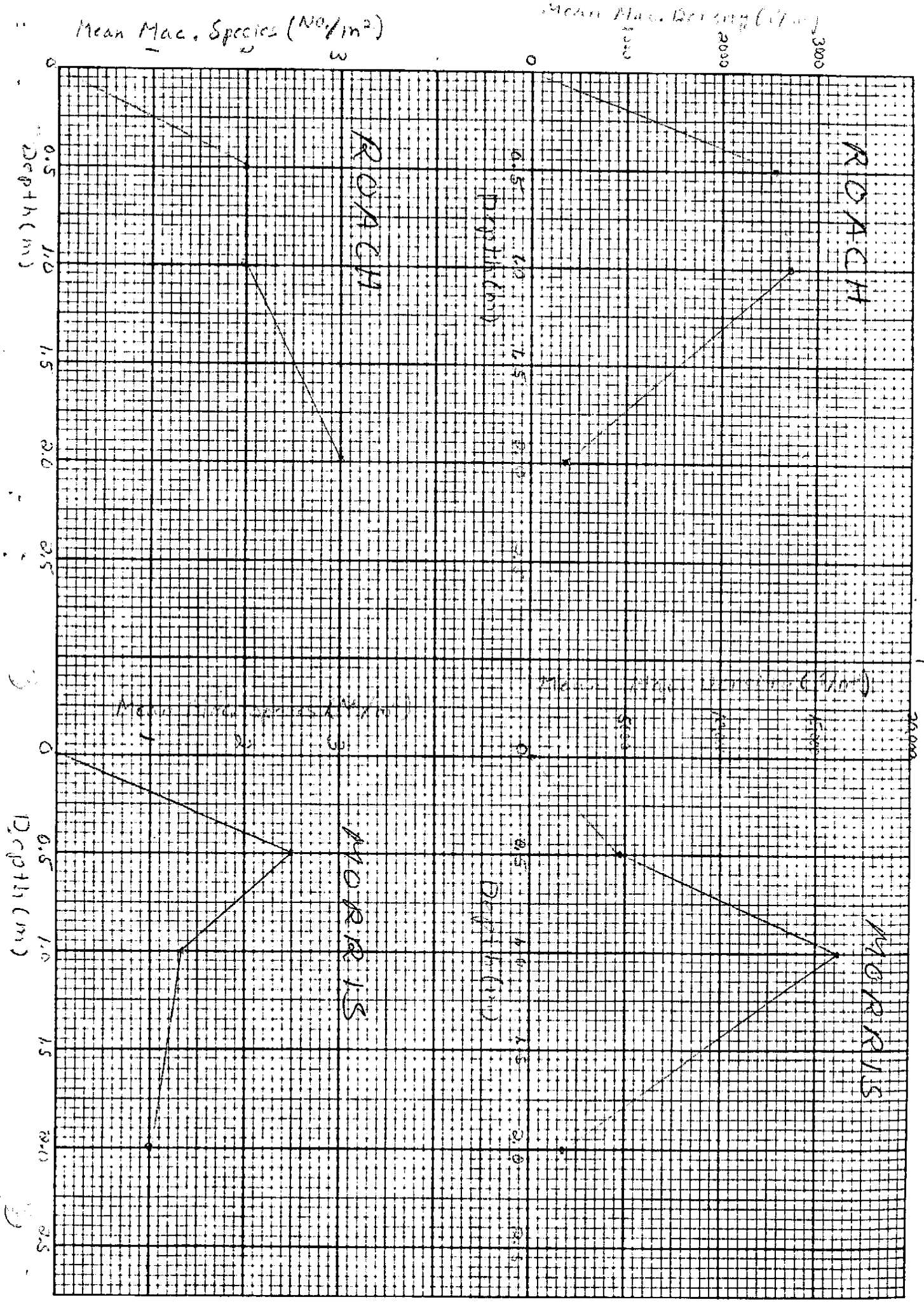


Table 3 . Snail Data For Roach Lake

Trans. No.	Depth (m)	TOTAL SNAIL NO.		\bar{x}	Total Snails (No./m ²)*	Total Sp. No.	Sp. in decreasing abundance
		Sample 1	Sample 2				
1	1	2	—	2	41.92	1	①

Table 4 . Snail Data For Morris Lake

Trans. NO.	Depth (m)	TOTAL SNAIL NO.		\bar{x}	Total Snails (No./m ²)*	Total Sp. No.	Sp. in decreasing abundance ⁵
		Sample 1	Sample 2				
1	1.0	1	—	0.5	28.56	1	③
	2.0	1	—	0.5	28.56	1	②
2	0.5	—	2	1.0	16.00	2	④, ③
	2.0	1	—	0.5	28.56	1	①
3	0.5	3	—	1.5	24.00	1	①
	1.0	2	1	1.5	85.70	2	④, ①
	2.0	—	—	0	0	0	

Depth (m)	Total Snails (No./m ²) [†]	Total Sp. No. [•]
0.5	20.00	1.50
1.0	57.13	1.50
2.0	19.04	0.67

* \bar{x} x conversion factor

† average of all transects (= mean snail density)

• average of all transects (= mean snail species no.)

⁵ see Figure 5

Figure 10. Mean Snail Density vs. Depth and Mean Snail Species No. vs Depth
Plots For Morris Lake ^{2 millimeters/Division}

