THE BRYOZOA OF MICHIGAN

TAXONOMY, ECOLOGY AND DISTRIBUTION (PART I)

GROWTH, MORTALITY, AND LONGEVITY OF *PLUMATELLA REPENS* (PART II)

Thesis for the Degree of Ph. D.

MICHIGAN STATE UNIVERSITY

John Horace Bushnell, Jr.

1961

This is to certify that the

thesis entitled
THE BRYOZOA OF MICHIGAN

TAXONOMY, ECOLOGY, AND DISTRIBUTION (PART I)
GROWTH, MORTALITY, AND LONGEVITY
OF PLUMATELLA REPENS (PART II)
presented by

John Horace Bushnell, Jr.

has been accepted towards fulfillment
of the requirements for

Ph. D. degree in Zoology

T. Wayne Porter
Major professor

Date August 4, 1961

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AN ABSTRACT OF A THESIS

Submitted to
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1961

ABSTRACT

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The purpose of this investigation was twofold: first to amplify distributional, ecological, and systematic knowledge of Michigan Bryozoa, and second, to obtain growth, mortality, and longevity data on Plumatella repens. No extensive experimental study had previously been conducted, to obtain growth, mortality, or longevity data on fresh-water Bryozoa living in natural habitats. This portion of the study was accordingly conducted in the field.

Collections were obtained from 122 bodies of water in Michigan. Three species not previously reported in Michigan were found: Plumatella fruticosa (10 sites), Lophopodella carteri, and Stolella evelinae. Plumatella orbisperma, found previously only by Kellicott (1882), was discovered in three ponds. This form is more fully described and assigned to the genus Hyalinella. The new designation is Hyalinella orbisperma (Kellicott) 1882. Flabelliform and geminate-flabelliform colonies of Plumatella emarginata were found. Evidence is presented to demonstrate that this growth form may sometimes be the result of a simultaneous germination (with a subsequent loss of the valves) of two contiguous statoblasts. A discussion on the systematics of the species collected in Michigan, and on their relationship with world-wide forms, is presented.

The growth data suggest that the increase in the number of polypides in colonies of P. repens tends to be geometric. This tendency is most clearly revealed by colonies growing under favorable conditions. Healthy colonies at favorable sites doubled in size each 3.4 to 7.4 days. The summer doubling time was 3.4 to 4.9 days, and the spring doubling time was 4.0 to 7.4 days. Temperature is correlated with this difference. Erratic or depressed growth was noted at some stations, and density-dependent and density-independent factors are discussed in relation to variations in growth.

An extremely high attrition of P. repens colonies was observed at some stations. Colonies of several hundred polypides were sometimes destroyed between two observation periods. Occasionally an entire substrate was denuded of colonies. Colonies located largely free of dense vegetation and not too close to the lake bottom were believed most successful because they were less accessible to crawling predators and to deleterious chemical factors. The importance of site and chance in relation to mortality was discussed.

Longevity data for 373 polypides were obtained. P. repens polypides lived from 4 to 53 days. Four ancestrulae survived for 29 to 33 days. The survivorship curve suggests that the greatest number of polypides die between 21 and 36 days. Eighty per cent of the polypides died within 28 days. Twelve of the 373 polypides survived longer than 37 days.

Attention is concentrated on P. repens and P. emarginata. A variant form, classified under P. emarginata, was found at six localities. It has characteristics consistently intermediate between P. repens and P. emarginata, and also shares characters with Plumatella elegans and Plumatella javanica.

Fredericella sultana appeared to be the species most tolerant of marly habitats. P. repens was found to be a lake, pond, and ditch form, and P. emarginata demonstrated a decided preference for streams.

New tolerance limits for temperature are presented, namely; 1.5 degrees centigrade for F. sultana, and 37 degrees centigrade for P. repens and P. fruticosa. P. fruticosa was found in water with the greatest color and the lowest pH.

Lists of plants and animals found in association with Bryozoa are given, and a discussion of bryozoan-sponge and intra-bryozoan associations is presented. Bryozoan predators included Gastropoda, Tendipedidae, Elmidae, and fish. However, Trichoptera were the most frequent predators. In particular, Athripsodes sp. and Orthotrichia sp. were seen repeatedly attacking and eating polypides (and statoblasts) of P. repens.

Growth, mortality, and longevity data were obtained by inserting plastic pegs of different colors into substrates, beside colonies or polypides. Where possible, colonies recently derived from statoblasts were chosen for study. Parallel studies were conducted at several stations on two small Michigan lakes, both of them water-fowl sanctuaries.

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PART I

TAXONOMY, ECOLOGY, AND DISTRIBUTION

INTRODUCTION

The taxonomy of the fresh-water Bryozoa has been a subject of frequent disagreement among Bryozoologists. This disagreement has been particularly evident with respect to the family Plumatellidae. The separation of genera and species within the Plumatellidae has frequently been a challenge to the resourcefulness of systematists. Categories higher than the family, as Hyman (1959) has stated, do not appear justified, or too useful, because of the structural similarities existing among all the phylactolaematous Bryozoa.

Several classification systems have been erected for the fresh-water Bryozoa, the most notable of which have been those of Allman (1856), Jullien (1885), Kraepelin (1887), Vangel (1894), Rogick (1935a), and Toriumi (1956b). The last is a correlative study based upon Toriumi's earlier series of taxonomic studies numbered I through XVI. Other notable contributors to the problem of fresh-water bryozoan classification have been Braem (1890) and Wesenberg-Lund (1896). However, the classifications of Allman and Kraepelin have been most frequently used by investigators in the past. Toriumi's recent studies are the most definitive undertaken in this century and serve to illuminate and clarify several of the taxonomic problems which have made fresh-water bryozoan classification so difficult. His studies are of particular merit, because he has suggested taxonomic characteristics of fresh-water forms, heretofore neglected by other workers. He has also methodically investigated certain of the more per-

plexing aspects of classification (e.g., variations in the incrustation of the ectocyst, variations in colony growth form, and variations in the wrinkling or lamellations of the zooecia). He has found many of these variations to be highly intra-specific. His work thus cautions against a reliance upon certain criteria formerly used to determine species. Much of Toriumi's information has been obtained by growing young colonies in the laboratory. In addition, he has placed certain species in synonymy, and he has reinstated certain of Allman's (1856) species (e.g., Plumatella emarginata and Plumatella fruticosa).

Several workers have given a number of variety designations to species of Bryozoa. Kraepelin (1887) utilized variety designations freely. Certain of his varieties had species status in Allman's classification (e.g., Allman's Plumatella repens became Plumatella polymorpha var. repens in Kraepelin's systematics). All forms which are today generally recognized as belonging in the genus Plumatella, Kraepelin placed in two species: princeps and polymorpha. Other workers have used the variety designations. More recently Rogick (1935a) placed all forms of Plumatella occurring in America, in the species repens, as varieties. She elevated some of these varieties to species status in Fresh Water Biology (Edmondson revision, 1959). Toriumi, in the past decade, has refrained from using the variety designation in classification. Marcus (1942) and Marcus (1946; 1953) have utilized the form and subspecies designations. As Cain (1954)

states, the variety designation has been largely abandoned because of its all inclusive implications. It has been used with reference to seasonal forms, genetic variants, and representatives of morphologically and geographically distinct populations. The subspecies, the criteria for which rest upon the quantitatively demonstrable taxonomic characteristics existing within distinct geographical populations, has received little application. A historical study of the intra-generic categories of the Plumatellidae suggest that this family may contain polytypic species, as defined by the new systematics.

Michigan is one of a relatively few states in which several bryozoan collections have been made. Brown (1933) collected from some 50 sites. However, nearly all of these collections were made in three counties as his study was concerned primarily with a non-systematic study of statoblasts. Rogick and Van der Schalie (1950) summarize and augment the collection records and descriptions for the state.

Brown's investigation includes some ecological data, and more information is given in other papers published throughout the world. Certain of the more important of these reports have been written Allman (1856), Davenport (1904), Harmer (1913), Marcus (1926, 1934), and Hurrell (1927). Biological information on the fresh-water Bryozoa is fragmentary. Bryozoan-plant associations have been reported by several investigators. However, few reports include algal associations. Several investigators have recorded animal associations with fresh-water Bryozoa. Predators of Bryozoa have been reported by Marcus (1926, 1934) and a few others. I have talked to

several biologists who have expressed an interest in bryozoan-sponge associations. Several scattered records have been published.

From the review of the literature and through preliminary collecting of Bryozoa, I came to appreciate the perplexing nature of bryozoan systematics. The present study was conducted in order to amplify the distributional, ecological, and systematic knowledge of Michigan Bryozoa. Particular attention is given, in both sections of this dissertation, to the family Plumatellidae.

METHODS AND MATERIALS

Temperature Data

Temperature readings were taken with a standard 0 to 100 degree centigrade field thermometer.

Chemical Data

A set of sealed standard color tubes manufactured by LaMotte Chemical Products Company was used to obtain pH readings. Second readings were sometimes taken with a Beckman electric pH meter, particularly at sites where the water was colored or murky with suspension.

Alkalinity data were gathered by the standard method employing methyl orange and phenolphthalein as color indicators and titrating with N/50 hydrochloric acid. Standard laboratory glass-stoppered reagent bottles were used to collect water samples from various stations. Analyses were made immediately at the collection site either on shore or in a boat. Alkalinity readings were not made on water which had been in collection bottles for longer than 45 to 60 minutes.

Collections and Study

Bryozoan collections for this study were made over a period of four years, beginning with the summer of 1957 and ending during the summer of 1960. Most of the collections were made from a boat or while walking in shallow water. Occasionally colonies were obtained by diving for them, or by throwing out or towing a standard plant hook from a boat. Collections were obtained from substrates located over organic, marly, and sandy bottoms. They were obtained from lotic and lentic

habitats and from wave-washed shores. In collecting from the littoral area of a lake or in making collections at any specific site on a body of water, stones, sticks, logs, and other likely substrates were examined. The leaves and stems of numerous plants were examined. When algae or animals were present on substrates in close association with Bryozoa, specimens were removed for identification. Numerous animals and plants were identified to genus and species when in particularly close association with Bryozoa. Some identifications were made in the field with the aid of 10X, 15X, and 20X hand lenses. If bryozoan colonies were attached to plants, the portion of the plant to which the colonies were attached was removed. If the colonies were growing on a wood substrate, a piece of wood holding the colonies was removed with a scalpel or knife. Many colonies were growing on stones or rocks. Small stones were collected. Colonies were carefully scraped from the surface of larger rocks or stones. Living colonies were kept in finger bowls and petri dishes until tentacle counts and other observations could be made. Many hours were spent in observing colonies in the laboratory.

Narcotization and Preservation

Careful narcotization is necessary in order to preserve Bryozoa in a fully evaginated and life-like state for purposes of further study. Narcotization is variously accomplished. Chloral hydrate, menthol crystals, cocaine, and chloretone have been used. The author has found chloral hydrate less effective than menthol as an anesthesia. However, a combination of chloral hydrate and menthol has

generally proved very satisfactory. The procedure, when using both substances, was to place the colonies in a one per cent aqueous chloral hydrate solution (in a small stender or petri dish) for 15 minutes. Two medicine droppers full of saturated menthol solution were added every 10 to 15 minutes. Within one or one and one-half hours, the colonies were usually sufficiently insensitive to be placed in a fixative or to be preserved without fixation. Narcotization was successful if several polypides from different parts of the colony failed to retract when tapped rather forcibly on their tentacles and zooecial tips with a small dissecting needle. Experimentation proved that narcotization was not achieved equally well by a single method. Lophopodella carteri, Pectinatella magnifica, and Plumatella repens were generally preserved in a well evaginated state by the method outlined above. Fredericella sultana, Paludicella articulata, Plumatella emarginata, and other Plumatellidae were effectively narcotized using a saturated solution of menthol. This solution was pipetted (two droppers full every 10 to 15 minutes) into small stenders or petri dishes containing the Bryozoa and water from their collection site. The effectiveness of the chemical was judged by the amount of it required for narcotization, by the number of polypides which remained evaginated after preservative was added, and by the completeness of evagination. When effectively accomplished, nearly every polypide remained evaginated and appeared to be maximally extended. Hyalinella orbisperma was most often refractory to chloral hydrate or menthol

anesthetization. These chemicals were used on several occasions with poor results. Then a saturated solution of chloretone was administered (in the manner described for using a saturated menthol solution), and excellent results were obtained each time.

Following narcotization, colonies were preserved in 70 per cent alcohol or in 4 per cent formalin. On occasion Bouins fixative solution was used followed by alcohol or formalin for permanent storage. Formalin is perhaps better for gelatinous colonies as it gives some added stiffness to the soft ectocysts. Collections made during the last year were often preserved in sugar-formalin solutions. This combination is one suggested by Jackson (1919), a medical doctor, and has received little subsequent comment from investigators. This preservative is recommended, particularly for gelatinous colonies. Colonies remain swollen and the delicate tentacles remain straight and expanded. Osmosis and the density of the solution perhaps help to promote the condition. Certain variations of the original formula were found most effective. The following ratio was preferred:

Cane sugar	12 parts
Formalin	5 parts
Distilled water	100 parts

Jackson employed the sugar-formalin combination successfully for the preservation of insect larvae and pupae.

Measurements and Study

Most study and measurements of living and dead colonies were made with a Bausch and Lomb dissecting microscope. The

ocular micrometer was calibrated against a stage micrometer. A Bausch and Lomb compound microscope equipped with an ocular micrometer was used for additional observation and measurement. Tentacles were often difficult to count and several counts were sometimes necessary. Four to 10 tentacle counts were taken on each living colony. Newly budded individuals were avoided as they have fewer tentacles, in most species, than older polypides. On extended field trips tentacle counts were made with a binocular dissecting scope. Dissections of the zooecial tubes were facilitated by watch makers forceps and insect minuten needles.

Illustrations

Most of the illustrations used are photographs. Habitat photographs were obtained in the field with an Argus C-4 camera. The underwater photographs of Fredericella sultana colonies were made with the aid of a square wooden box, three feet long, which was open at the camera end and sealed with a glass plate at the underwater end. The sealed end was submerged to within a few inches above the colonies to be photographed. Photomicrography was accomplished with a Kodak "Pony" camera mounted on a late model American Optical Company compound microscope. A 10X eyepiece was used most successfully in conjunction with the following objective powers and lens speeds: 5X - 1/125 second, 10X - 1/50 second, 43X - 1/25 second. These speeds were generally effective when the variable light source was set at maximum intensity. The variable backgrounds and substrates made it necessary to alter the

above settings occasionally. Kodak Tri-X film was used.

Drawings were made with a monocular compound microscope equipped with a calibrating eyepiece. The drawings were made using graph paper placed under tracing paper so that correct measurements and proportions could be obtained.

COLLECTION DATA

The material for the present study was collected during the years 1957 through 1960, from 122 separate aquatic habitats, including lakes, rivers, creeks, ponds, and ditches, located in 48 counties in Michigan. The distribution, by counties, of the species of Ectoprocta collected in this study is shown in Fig. 1. Each of the species is indicated by a symbol. The larger symbols represent species found during the present study with the exception of those recorded by Dr. T. W. Porter, for Cheboygan and Alger Counties. The small symbols represent reports made by other collectors. Only county species records which are not duplicated by the present study are represented by the small symbols. These were included so that published county records for the state would be as nearly complete as possible. The reports indicated by small symbols were obtained from the Rogick and Van der Schalie (1950) publication on Michigan Bryozoa. A list of the collection sites visited during this study is given in Table 1.

Three species not previously reported for Michigan were collected during this investigation. These species are Plumatella fruticosa, Stolella evelinae, and Lophopodella carteri. Specimens collected near Ann Arbor by Kenk (1949) were identified by Dr. M. D. Rogick as Stolella indica. They were somewhat atypical and in Fresh Water Biology (Edmondson revision, 1959). The only occurrence record given is from Pennsylvania. Stolella indica was collected during this study,

and on the basis of Kenk's report must be assumed to be the second record for the state. A species described by Kellicott (1882) as Plumatella orbisperma was found during this study. Prior to the present investigation, this form had been found only by Kellicott, in a pond near Little Traverse Bay. I have transferred this species into the genus Hyalinella. The flabellum form of Plumatella emarginata and the fungosa form of Plumatella repens are also recorded for the first time in Michigan.

The Bryozoa with the greatest number of occurrences show no pattern in their distribution. They were present in collections from all parts of the state. Pectinatella magnifica has occurred more frequently in the southwestern portion of Michigan. The record for Mackinac County is tentative because only statoblasts of this species were found on rocks in a protected bay on Lake Michigan. These may have been carried by wind or current from the southern portion of the lake.

Eight of the ten collections of Plumatella fruticosa made during this investigation, are recorded from the northern half of the state (north of a line formed by the westward extension of the southern border of Iosco County), and three of these occurrences were from the Upper Penninsula. The uneveness of this distribution may be even greater, since more collecting was done in the southern part of the state.

Plumatella casmiana was not found during this investigation. However, the collection records for this species are indicated

on the distribution map, Fig. 1.

The entoproct, Urnatella gracilis, is not included on the distribution map, but it has been recorded from the Grand River in Ionia County, by Rogick and Van der Schalie (1950).

Fig. 1. Distribution map showing the species of Ectoprocta found in Michigan



Larger symbols represent collections made during the present study. A number following a symbol indicates the number of different localities from which the species was collected in the county.

Smaller symbols represent collections made by previous investigators.

Fig. 1.

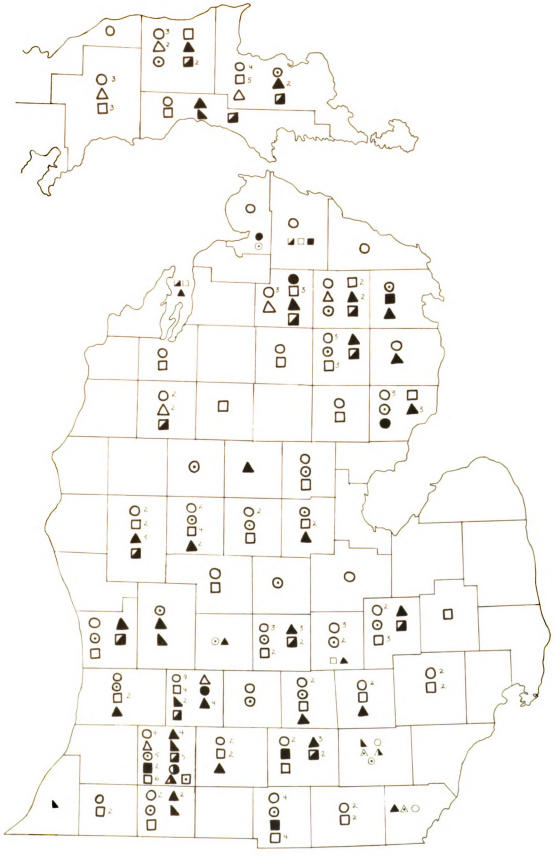


TABLE 1. Distribution records of Bryozoa collected in Michigan between 1957 and 1960.

County	Lake or river, pond or ditch	Plumatella repens	Plumatella fruticosa	Plumatella emarginata	Hyalinella punctata	Hyalinella orbisperma	Fredericella sultana	Paludicella articulata	Pectinatella magnifica	Cristatella mucedo	Lophopodella carteri	Stolella indica	Stolella evelinae
Alcona	Brownlee Lake	X						X					
Alger	Kingston Lake	X											
Allegan	Kalamazoo River offshoot	X		X									
	Pike Lake						X	X					
	small private lake						X						
Alpena	Long lake			X	X			X					
Barry	Hall Lake	X					X		X	X			
	Mill Lake	X											
	Crooked Lake	X											
	Gun Lake	X						X					
	Thornapple Lake	X					X	X					
	Otis Lake	X	X										
	pond *	X				X							
	Clear Lake	X					X	X	X				
	Fair Lake	X						X					
	Pine Lake						X						
Calhoun	Duck Lake	X					X	X					
	Lane Lake	X					X						
Cass	Huyck Lake	X					X						
	Lewis Lake						X						
Cheboygan	Munro Lake	X											
Chippewa	Detour Harbor	X					X	X					
	Bass Lake	X								X			
	Dickenson Lake	X					X						

* located in small valley 1 mile E. of Hall Lake - not named (private)

TABLE 1. (continued)

County	Lake or river, pond or ditch	Plumatella repens	Plumatella fruticosa	Plumatella emarginata	Hyalinella punctata	Hyalinella orbisperma	Fredericella sultana	Paludicella articulata	Pectinatella magnifica	Cristatella mucedo	Lophopodella carteri	Stolella indica	Stolella evelinae
Chippewa	Clark Lake		X										
	Potagannissing Bay	X		X			X	X					
	Lake Huron (Bass Cove)						X						
	Fire Tower Lake						X						
Clare	Long Lake							X					
Clinton	Burke Lake	X		X			X	X					
	Rose Lake	X					X	X					
	Park Lake	X						X		X			
Crawford	Margreth Lake	X					X						
Eaton	Lower Thornapple River	X		X									
Emmet	Carp Lake	X											
Genesee	Byram Lake	X					X	X					
	Myers Lake	X					X						
	Shiawassee River			X			X						
Gladwin	Chapelle Pond	X		X			X						
Grand Traverse	Long Lake	X					X						
Gratiot	Pine River			X									
Hillsdale	private lake	X					X						
	Crystal Lake	X					X						
	Willets Lake	X			X		X						
	Goose Lake	X		X			X						
Ingham	Red Cedar woodlot	X											
	Grand River			X									
	Red Cedar River						X	X					
	game preserve lake (near Mason)			X									
	Williamston ditch	X											

TABLE 1. (continued)

County	Lake or river, pond or ditch	Plumatella repens	Plumatella fruticosa	Plumatella emarginata	Hyalinella punctata	Hyalinella orbisperma	Fredericella sultana	Paludicella articulata	Pectinatella magnifica	Cristatella mucedo	Lophopodella carteri	Stolella indica	Stolella evelinae
Iosco	Au Sable River	X		X		X		X					
	Van Etten Lake	X		X				X					
	Loon Lake	X					X	X					
Isabella	Pony Creek			X									
	roadside ditch	X											
	Hall Lake	X											
	Big Eldon Lake						X						
Jackson	Portage Lake	X			X			X					
	Portage River							X		X			
	Pleasant Lake	X					X	X		X			
Kalamazoo	Gull Lake	X	X		X		X	X		X			
	Gull Lake outlet	X					X	X		X			
	Sunset Lake			X	X		X	X	X	X			
	Little Portage Creek			X									
	Sugar Loaf Lake	X					X	X		X			
	Augusta Creek			X									
	Kalamazoo River			X			X						
	Wintergreen Lake	X		X			X			X	X	X	X
Kent	Thornapple River			X				X	X				
Lapeer	Big Fish Lake						X						
Lenawee	Wolf Lake	X					X						
	Dewey Lake	X					X						
Livingston	roadside swamp	X											
	Indian Lake	X					X						
	Cranberry Creek							X					
Luce	Connor Lake		X										
	Pike Lake	X					X			X			
	Two-Hearted River	X	X	X									
	Muskallonge Lake	X						X		X			

TABLE 1. (continued)

County	Lake or river, pond or ditch	Plumatella repens	Plumatella fruticosa	Plumatella emarginata	Hyalinella punctata	Hyalinella orbisperma	Fredericella sultana	Paludicella articulata	Pectinatella magnifica	Cristatella mucedo	Lophopodella carteri	Stolella indica	Stolella evelinae
Mackinac	Little Brevoort Lake	X					X	X		X			
	Lake Michigan								X*				
Mecosta	Round Lake			X			X						
	Lake Mecosta	X					X	X					
	Little Muskegon River						X	X					
	Blue Lake	X					X	X					
Missaukee	Lake Missaukee						X						
Midland	Chippewa River			X			X						
	Tittabawassee River						X	X					
Montcalm	Tamarack Lake	X					X						
Montmorency	Muskellunge Lake	X	X					X		X			
	Thunder Bay River			X			X	X					
	pond						X						
Newaygo	Pickerel Lake	X					X	X					
	Emerald Lake	X					X	X					
	Muskegon River (Hardy Dam)							X					
Oakland	Crotche Lake	X					X						
	pasture creek	X					X						
Ogemaw	Sage Lake	X					X						
Osceola	Middle Branch River			X									
Oscoda	Saddle Back Lake	X					X			X			
	Bass Lake	X					X						
	Au Sable River	X		X			X	X		X			
Otsego	Chain-o-Lakes	X				X	X						
	shallow pond		X										
	Opal Lake	X					X			X			

* statoblasts only

TABLE 1. (continued)

County	Lake or river, pond or ditch	Plumatella repens	Plumatella fruticosa	Plumatella emarginata	Hyalinella punctata	Hyalinella orbisperma	Fredericella sultana	Paludicella articulata	Pectinatella magnifica	Cristatella mucedo	Lophopodella carteri	Stolella indica	Stolella evelinae
Otsego	Bradford Lake	X					X	X					
Ottawa	Spring Lake			X			X						
	Pigeon River	X						X		X			
Presque Isle	Ocqueoc Lake	X											
Saginaw	woodland ditch	X											
St. Joseph	St. Joseph River	X		X				X	X				
	Portage Lake	X					X	X					
Schoolcraft	Lake Manistique	X					X						
	Lake Ann Louise	X	X				X						
Shiawassee	Vermillion Creek			X									
	Looking Glass River			X									
	Moon Lake	X											
	dam flooded woods	X											
	Colby Lake	X											
Wexford	Lake Mitchell	X	X							X			
	Lake Cadillac	X											
	creek entering Lake Mitchell		X										

TAXONOMICAL DISCUSSION

Cristatella mucedo Cuvier 1798

Colony

The specimens of these elongate and sacciform colonies are typical in all respects with those described by Allman (1856). The colonies are among the most easily identified of the fresh-water Bryozoa. Colonies as long as 35 cm. and 50 cm. were observed on the stems of *Nuphar advena* on *Wintergreen Lake*.

Tentacles

The number of tentacles counted on 84 polypides varies between 78 and 96, averaging 85. This number is consistant with the average of 80 given by Allman (1856) and later investigators.

Statoblasts

Forty-one measured statoblasts average 1.02 mm. in diameter thus falling well within the range given by previous investigators, more recently by Toriumi (1943). Kraepelin (1887) distinguishes two varieties, *idae* and *genuina*, on the basis of the statoblast size and number of spines. However the sizes and spine numbers of the Michigan *Cristatella mucedo* statoblasts overlap Kraepelin's figures. The spine numbers on the dorsal face varied between 30 and 42, while there was a variance of between 15 and 30 on the ventral face. Toriumi (1943) has indicated that Japanese collections reveal intermediate sizes and numbers of spines, and he suggests that seasonal and local factors are responsible for this overlap. Accessory hooks were noted on several statoblasts from

Wintergreen Lake, Kalamazoo County. Hook variations are discussed by Toriumi.

Pectinatella magnifica Leidy 1851

Colony

The colony is typical of that described by Leidy (1851b,c). Older colonies are massive with secondary colonies seen as rosettes, a single layer in thickness, covering the surface of a large central gelatinous matrix. Leidy mentions the dark rose-red color of the margin of the inner tentacles and mouth region. Young colonies collected at Hall Lake in Barry County and Sunset Lake in Kalamazoo County revealed this same characteristic. However, the author has also noted this coloration for Plumatella emarginata and believes this characteristic is variable and thus should not be considered specific.

The largest and most abundant colonies of Pectinatella magnifica were seen in the St. Joseph River, St. Joseph County, and in Hall Lake, Barry County. Rogick and Van der Schalie (1950) record that Dolley collected P. magnifica from the St. Joseph River. Two colonies seen in the present study had diameters of slightly over 10 and 12 inches. Borodin (1928) records that P. magnifica colonies attain the size of a man's head, and he reports one colony with a diameter of 8 by 5 inches. However, Geiser (1937) states that observers have asserted that colonies of 24 inches were not rare in overflow pools in Iowa. He estimates that during the months of July and August in one year "scores of thousands" of tons of Pectinatella passed over a dam. Judd (1950) records a

colony with a diameter of 11 by 14 inches from a marsh near Hamilton, Ontario.

Tentacles

Of 147 polypides, tentacles numbered 62 to 85 with 90 per cent of the polypides having between 70 and 84. Leidy (1851b) gives the tentacle number as between 50 and 80. Davenport (1904) states that tentacles range from 60 to 84.

Statoblasts

Diameters ranged between 0.84 mm. and 1.1 mm. on 48 measured statoblasts. Hooks numbered 12 to 22, with an average of 16. This agrees well with the 14 to 16 spines Leidy (1851b) reports and the 11 to 22 range reported by Davenport (1904). There is some variability in the morphology of the hooks of statoblasts. This has been discussed in detail by Davenport (1900).

Pectinatella magnifica is perhaps the easiest of the fresh-water bryozoans to identify as taxonomic characters are distinct and reliable. Macroscopically, young colonies may sometimes be confused with young Cristatella colonies.

Lophopodella carteri (Hyatt) 1865

The collections from Wintergreen Lake, Kalamazoo County, are the first record of this bryozoan in Michigan, and one of the few reports for the Western hemisphere. The species was first reported by Rogick (1934) from Lake Erie. Statoblasts of this species found in bottom samples were given to the author for identification by Mr. Rudolf Scheibner in March of 1957. The colonies were abundant in all parts of the lake

from 1957 through 1960.

Colony

The colonies are typically globular and gelatinous ranging in form from somewhat round to elongated (Fig. 2). The colony, with proliferation, becomes lobate with from six to 10 or 12 individuals in each lobe. Colonies may break up into daughter colonies. Takahasi (1934) reports colonies that had from 20 to 45 polypides. The Wintergreen Lake colonies were commonly composed of 35 to 55 polypides, and one colony was found with 70 polypides. The polypides range in length, from the anus to the tip of the stomach, 1.08 mm. to 1.52 mm. Lophopodella colonies are motile, moving up to 10 to 12 cm. per day (Dahlgren 1934).

Ectocyst

The ectocyst has a medium, stiff, gelatinous consistency and lacks incrustation. It is hyaline, often appearing somewhat yellowish in color. It is non-sclerotized, and the surface of the ectocyst was observed to be finely papillose. Vorstman (1928a) states that the external surface of the polypides collected from Java are covered with minute tubercles.

Zooecia

Polypides are contiguously situated, withdrawing into a common cavity. As Toriumi (1956a) states, "Only the tip is recognizable as the remnant of each zooecium." The zooecial diameter in the distal region averages 0.5 mm. This figure is in agreement with Rogick's (1934) average of 0.544 mm.

Lophopodella carteri

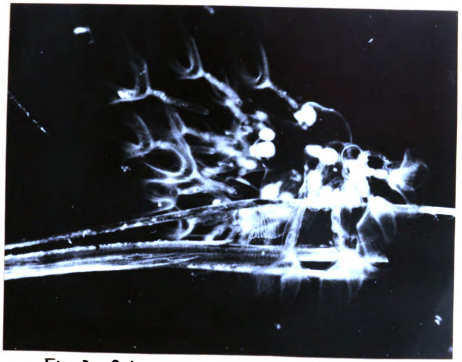


Fig. 2. Colony of Lophopodella carteri

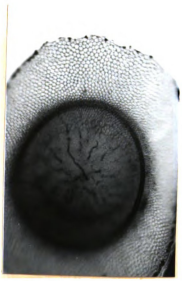


Fig. 3. Statoblast (terminal spines not clear)

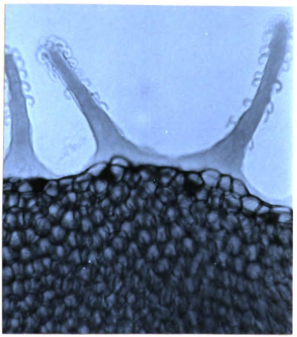


Fig. 4. Statoblast - enlargement showing float cells and terminal spines with barbs.

Septa

Septa are not present.

Tentacles

The tentacles of non-ancestrulae vary in number from 67 to 89 in the Wintergreen Lake collections. The average number was 79 tentacles (145 counts). These figures are in nearly perfect agreement with Toriumi (1956a), who gives the range in the Japanese forms as 68 to 91 tentacles with a central range of 78.5 to 80.8. These figures are higher however, than those given by Rogick (1934) for Lake Erie collections. She states the tentacles varied in number from 52 to 82 with a median number of 64. Several investigators, including the author, have noted environmentally associated variations in tentacle numbers.

Statoblasts

The spinoblasts are saddle-shaped (Fig. 3), varying somewhat in form. The length varies between 0.9 mm. and 1.14 mm. on 53 measured statoblasts (exclusive of spines), with an average of 0.91 mm. The width varies from 0.67 mm. to 0.85 mm. These figures, as well as those on float coverage, capsule length and width, agree perfectly with those of Toriumi and Rogick. The terminal spines vary in number between 7 and 18 with the average between 10 or 11. The number of recurved barbs on the margin of each spine varies from 2 to 21 with the average falling between 12 and 13. Rogick (1936) states that the average number of barbs along the spine margins of her collections was 11.2, with a maximum of 22. Lee (1936)

reports a rather low number of barbs, two to nine for each spine. All of the measurements for the Wintergreen Lake specimens are essentially in agreement with those of Rogick. Variations were noted in the relative development of the spines and barbs. Some of the spines are diminutive or slightly imperfect. The terminal ornamentation of a Lophopodella carteri spinoblast is shown in Fig. 4. One of the spines has 19 barbs. Statoblasts were observed in the process of forming in a colony of 12 individuals. The statoblast from which the colony had germinated was still attached.

Fredericella sultana (Blumenbach) 1779

Fredericella sultana is second only to Plumatella repens in abundance in the Michigan collections. This was not unexpected as the species is one of the most frequent and cosmopolitan fresh-water Bryozoa in the world.

Colony

The colonies from Michigan habitats vary from small and largely repent with widely open branching, to colonies often largely free of the substrate. It was not uncommon to find this form growing in dense tufts, from the underside of logs, or on fine protruding rootlets on the lake bottom or in the sand. Such dense colonies were abundant in the outlet to Gull Lake in Kalamazoo County and in Margreth Lake in Crawford County. The branching is typically antler-like and open. The lophophore is actually of horse-shoe shape when retracted, as Toriumi (1951) has observed. It usually appears circular when the polypide is extended.

Zooecia

The zooecia tend to be elongated and are often vertical to the substrate. A distinct keel is present on repent zooecia while the keel in the free zooecia is sometimes obscure or lacking. The development of the keel in the Michigan specimens is variable, in agreement with Toriumi. The zooecial tips are sometimes smooth, or lamellated. The serrated branches, discussed by Toriumi, were not seen. The width of the zooecia, which tapers little from the proximal to the distal ends varies in measured specimens between 0.17 mm. and 0.33 mm. Rogick (1940) gives diameter measurements of 0.16 mm. to 0.35 mm. for New Rochelle and Lake Erie specimens, with an average of 0.24 mm. The only other United States form, Fredericella australiensis browni (Rogick 1945b) has tubes varying from 0.259 and 0.576 mm. in width. Dendy (1906) reports on an extremely slender form of Fredericella sultana from New Zealand.

Ectocyst

The ectocyst is sandy-brown, greyish, or grey-white in color. It is most often moderately to heavily incrusted. Toriumi (1951) investigated the color and incrustation of the ectocyst and found no field specimens to be colorless and transparent. However, laboratory-reared specimens had nearly hyaline ectocysts. Essentially hyaline and transparent specimens were collected from five lakes in Michigan. These are the first field specimens of F. sultana with these characteristics. Marcus (1946) describes a subspecies, Fredericella

sultana crenulata, in which incrustation with diatoms is always slight. Fredericella australiensis trancaucasica (Abricossoff 1927a) is also a form with light incrustation. The zooecia are essentially hyaline, transparent, and lacking incrustation on specimens from Round, Mecosta, and Blue Lakes in Mecosta County; Dickenson Lake in Chippewa County; and Long Lake in Grand Traverse County. The Mecosta County lakes are connected. In specimens from Crotche Lake, Oakland County, and Little Manistique River, Schoolcraft County, the zooecia are transparent and only faintly yellow. In all other characteristics these colonies are typically Fredericella sultana. These observations and Toriumi's rearing experiments are correlative evidence that variability in incrustation is environmentally related and should be used with caution in systematics. Many F. sultana specimens are heavily incrusted, of which the Gull Lake colonies are representative. These colonies are grey-white in color.

Septa

Allman (1856) states that a more or less perfect septum is frequently found at the origin of the branches, while Toriumi (1942, 1951) declares that a septum is rarely present at the origin of each branch. Kraepelin (1887) reports that he observed septa primarily at the location of main branches. The presence of the septum is variable in the Michigan zooecia, ranging from infrequent to present in nearly every zooecium.

Tentacles

The tentacles, counted on 283 individuals, varied from 19 to 25. The average was 22.2. This is consistent with figures

given by numerous investigators. Marcus (1946), however, gives the number for var. crenulata as 22 to 28. Goddard (1909) describes Fredericella australiensis with 28 to 30 tentacles.

Statoblasts

Only sessoblasts are found in this species. They are, characteristically, bean or kidney-shaped (Fig. 5). The oval type sessoblasts of F. australiensis were not found. The sessoblasts varied in length and width (141 measurements) from 0.31 mm. to 0.52 mm. by 0.18 mm. to 0.31 mm., thus



Fig. 5. Sessoblast of Fredericella sultana

corresponding very closely with those of Kraepelin (1887), Rogick's (1940) New Rochelle specimens, and Harmer (1913). The reticulations on the capsule are obscure to reasonably clear. Toriumi (1951) states that the Japanese specimens tend to have a somewhat indistinct reticulation. Most frequently a single statoblast for each zooecium has been considered usual in F. sultana. Borg (1936) records one or two as common; Rogick (1940) shows a zooecium with two sessoblasts, and Marcus (1946) states that as many as six may be observed in sequence in F. sultana var. crenulata from South America. Borg reports that two or three statoblasts in a row were sometimes found in

a specimen which was possibly F. sultana, and in one case, five were found. In several of the Michigan collections, two sessoblasts occurred commonly in each zooecium. In specimens from a pond in Montmorency County, and from Bass Lake, Oscoda County, several zooecia with three sessoblasts in sequence were noted.

A ciliated larva was noted in a finger bowl containing specimens of F. sultana collected in early September from Little Brevoort Lake, Mackinac County. Larvae have been found most often by other investigators in the spring and early summer. Wesenberg-Lund (1907) suggests, from his observations, that sexual reproduction may decline or cease in habitats progressively more northern in location.

Paludicella articulata (Ehrenberg) 1831

Colony

This species of Gymnolaemata is widely distributed in North America and Europe. Rogick (1940) states that it was scarce in New York collections. However Rogick and Van der Schalie (1950) state that it was the most abundant species in collections from the Grand River and Pigeon Creek (near Flint) in Michigan and from Lake Erie, and the Tippecanoe River in Indiana. The present study reveals that in addition to abundance and a wide distribution, this is one of the most commonly encountered species (third highest number of occurrences in Michigan). This diminutive species may be easily overlooked or dismissed as thick algal filaments. Dr. G. W. Prescott gave the author kodachrome slides taken of an empty

coenecium of Paludicella articulata, which had been sent him by a New York collector for identification as a possible new species of alga. The Michigan specimens are often luxuriant. The colonies are repent but in dense colonies large portions of the coenecia are free of the substrate. The zooecia are often entangled with one another. Branches form typically at right angles to the parent zooecium. Lateral buds develop both proximally and distally on zooecia. The lophophore is circular and lacks the calyx and epistome characteristic of the Phylactolaemata.

Zooecia

The zooecia are spindle-shaped and have the typically squared orifice. Annandale (1916) describes a species, Paludicella pentagonalis, having a pentagonal orifice. Rogick and Brown (1942) have found this species in Guatemala.

The length of the zooecia vary considerably within a colony. The length of the zooecia of Michigan specimens varies between 0.35 mm. and 1.6 mm., but most often between 0.70 mm. and 1.25 mm. The width varies between 0.12 mm. at the narrowest and 0.32 mm. at the widest portions of the zooecium. Newly formed zooecia are often considerably shorter than those found in older portions of the colony. Toriumi(1952a), as a result of laboratory rearing experiments, maintains that the size of the zooecia is environmentally related.

Ectocyst

The ectocyst, on most of the specimens, lacks incrustation, but sometimes it is completely covered with diatoms, particu-

larly Amphora. The ectocyst is pale-yellow to yellow-brown in color.

Tentacles

Allman (1856) and Rogick (1940) state that this species has 16 tentacles. Kraepelin (1887) and Rogick and Van der Schalie (1950) state that the number of tentacles varies from 16 to 18, and Toriumi (1952a) gives the range as 15 to 18. The tentacle numbers of polypides in the Michigan specimens appear to vary more widely than others, at least others in North America. The average tentacle number is 15.7 for 164 animals, but the range is from 12 to 19. Several polypides had 13 and 14 tentacles. Prenant and Bobin in "Faune de France" (1956) give a range of 10 to 18 tentacles but this does not appear to be the generally recognized range.

Septa

The septa are typically present at the base of each zooecium.

Hibernacula

This species does not produce statoblasts, but forms hibernacula. These dormant and sclerotized buds vary considerably in shape. Harmer (1913) describes elongated hibernacula which form within the old zooecia. Others are external. Toriumi (1952a) states that the long clavate form is free from the substrate, and the shorter and indented form is adherent. Similar observations were made in the Michigan specimens, however the indented irregularly shaped hibernacula predominated.

Plumatella repens (Linnaeus) 1785

Colony

Plumatella repens is the most common species in Michigan. Approximately 80 per cent of the colonies collected are open and repent. The remainder are dense, and the most luxuriant of these are fungoid in appearance. The colonies are dendritic and the branching, largely typical. Agglutination of zooecia is present in a few of the colonies. The variation within the genus Plumatella has often obscured systematic relationships. This had been particularly true with respect to P. repens. The budding rate, degree of elongation of the zooecia, and the character of the substrate are of particular importance in determining the form of the colony (Toriumi 1955a). When the zooecial elongation and the budding rate are constant on a limited substratum, for example a stick, a fungoid form may result. Wesenberg-Lund (1896) observed that large "balls" of Plumatella fungosa originate nearly always from a large number of statoblasts in close proximity. As Toriumi (1955a) states, dense colonies are the result of many statoblasts germinating at the same time.

During the spring of 1957, periodic observations were made on some colonies on fallen branches in Gull Lake. These observations reveal how dense or fungoid colonies may form. Examination with a hand lens, revealed that nearly all of the colonies had originated from a floatoblast or larva. In November 1957, when the last of the polypides died, the empty coenecia remained filled with floatoblasts and many adherent

sessoblasts. In the spring of 1958, the coenecia were largely deteriorated, and most of the floatoblasts had been released. However, the sessoblasts germinated, many of them contiguously. Some floatoblasts caught or held on the substrate also germinated, and the branches of some of the colonies intermingled. This growth in 1958 produced a greater density of colonies than in 1957, and when these colonies fragmented and died, a greater number of sessoblasts, than before, remained adherent to the substrate. A late summer germination of all the early summer-produced sessoblasts, and of the floatoblasts which had remained in the vacinity, produced colonies which spread out and intermingled over areas of the substrate which had not previously been colonized. All of these new colonies now produced overwintering statoblasts. The network of linearly arranged autumn sessoblasts, in addition to some floatoblasts, then germinated in the spring of 1959. When the sessoblasts all germinated simultaneously, even the young colonies on the substrate were soon intermingling. The result was an increasingly fungoid mass. By late in the year a portion of two of the main fallen branches was completely covered by the colonies.

Therefore, a new substrate, for example substrate "A", is first populated by colonies originating from floatoblasts and larvae, which are themselves produced by colonies on other substrates. Subsequent colonies on substrate "A" originate predominantly from sessoblasts as most floatoblasts are carried to new substrates, and larvae are believed to be

produced during only a brief portion of the year. Each generation of colonies in turn leaves greater areas of substrate covered by sessoblasts. The luxuriance of later generations is dependent upon the numbers and proximity of sessoblasts, and the sequential rapidity of their germination. High and regular predation would preclude such elaborate bryozoan growths.

Collections of Plumatella repens from a woodland ditch in Saginaw County suggested another means by which colonies often attain dense and irregular growth. Wesenberg-Lund (1896) states that he, like Kraepelin, observed statoblasts of the preceding year germinating in the old zooecia. Marcus (1926; Fig. 8, p. 294) has seen floatoblasts germinating while inside the mother zooecia. The author first collected the Saginaw County P. repens colonies in late April. Numbers of polypides which had germinated from floatoblasts were seen protruding from the blunt open tips of the mother zooecia and from cracks in the mother zooecial wall. The integrity of the old coenecia had apparently been largely preserved, and the floatoblasts had been largely retained within the coenecia. Sometimes most of the 10 to 15 floatoblasts within a single zooecium, irregularly oriented to one another, were germinating. In addition, sessoblasts in the repent portions of the colony were germinating within the zooecia. The composite colony resulting from the simultaneous germination of hundreds of contiguous floatoblasts and sessoblasts, variously oriented, is in effect a multitude of individual colonies each con-

tributing to the final architecture of the total colonial mass. In order for such a colonial mass to develop, old colonies must be preserved through the winter. Such preservation could be expected to occur in the case of particularly stiff and well sclerotized coenecia located where abrasive physical factors (e.g., wave action and current) are absent. Ditches and ponds illustrate such habitats. In shallow protected situations, standing water freezes in the winter thus helping to preserve the old colonies within the ice. In view of the fact that dense colonies may form, as has been described, caution must be used in attributing the presence of luxuriant growths of Bryozoa to a favorable nutrition.

Zooecia

The angle at which the zooecial tips bend upward from the substrate in the Michigan specimens, varies from approximately 30 degrees to approximately 70 degrees and is usually between 40 degrees and 55 degrees.

The zooecia are rounded in contour in 85 per cent to 90 per cent of the Michigan specimens. Rogick (1940) states that a slight keel is evident on certain "older and basal zooecia". Toriumi (1955a) found an obscure keel on some zooecia of several Japanese specimens. Some of these same specimens were furrowed, and he found a few zooecial tips of one specimen to be emarginate. An obscure keel is present distally on some of the older zooecia of specimens from six Michigan collection sites. An obvious keel is present on four others. Wherever an obscure or an obvious keel is present, the furrow is also

seen. Emarginate zooecial tips were present on two specimens, collected from Detour Harbor, Chippewa County, and Byram Lake, Genesee County.

The zooecia of the Michigan specimens generally have a gradual taper from the distal to the proximal end. Occasional colonies have zooecia with an accentuated taper or with very little taper. The zooecial diameter of Rogick's specimens is stated to be between 0.34 mm. and 0.70 mm. Her averages for each of two collection sites is 0.44 mm. and 0.52 mm. Toriumi states that the zooecial width of the Japanese collections compares favorably with that of North American and European specimens. The zooecial diameter of the Michigan specimens varies from 0.19 mm. to 0.69 mm. proximally. Each of these extreme diameters was recorded for exceptional single specimens. Omitting these exceptional specimens, the proximal diameters vary from 0.27 mm. to 0.59 mm. The distal diameters vary from 0.32 mm. to 0.88 mm. The extreme measurements overlap Rogick's maximum and minimum figures, but this is not unexpected, as the Michigan data were obtained from a greater number of specimens. The average diameter of the Michigan specimens is approximately in agreement with those of Rogick's New York specimens. These data indicate that the zooecial diameter of Plumatella repens is highly variable.

Ectocyst

Allman (1856) states, "The quantity of earthy matter deposited in the ectocyst is small, and this tunic is generally more pellucid than we find it in most other species of the

genus; it varies however, in this respect, according to age and locality of growth." His illustrations (Plate 5) are of transparent zooecia. Toriumi (1955a) found only two specimens with heavily incrusted ectocysts. His specimens vary from naked to slightly incrusted. Approximately 70 per cent of Michigan specimens lack incrustation. Four specimens have ectocysts with a somewhat frosted appearance, seemingly attributable to the uniform deposition of very small siliceous particles on the surface of the ectocyst. Some 20 per cent have moderate incrustation, and one specimen has heavy incrustation. The color of the ectocyst is, typically, pale-yellow to yellow-brown or reddish-brown. In three specimens the ectocyst is essentially hyaline and somewhat inflated, superficially suggesting the genus Hyalinella. Longitudinal striations are noted on the zooecia of colonies from 14 collection sites, most often on the naked, frosted, or slightly incrusted colonies. These striations were of comparable occurrence in specimens examined by Toriumi.

The sclerotization of the ectocyst is variable in the Michigan specimens, the stiffness being greatest on the darker coenecia. White dots were sometimes noted on the endocyst of young zooecial tips, as they are on some Hyalinella punctata zooecia. Some agglutination of the ectocysts was noted in eight specimens.

Septation

Allman (1856) states that "transverse septa are most apparent", in the elongated zooecia which are free of the

substrate. He continues, "I have met with specimens of the free variation of this species in which well-formed septa occurred between almost every cell." He illustrates the periphery of these septa (Plate 5, Figure 4) by dark lines. Their extent is not evident. Rogick (1940; Plate IV, Fig. 18) shows no septa in her drawings. Toriumi (1955a) indicates that septa in foreign specimens from the United States, Canada, Europe, Manchuria, and Japan are similar and that only four specimens have septa at the origins of the branches and then only rarely. However, in specimens from the Kurile Islands the septum is present in almost each zooecium of largely repent colonies. With respect to septation, certain otherwise typical Michigan colonies depart somewhat from Toriumi's data. Although over 50 per cent of my specimens are without septa, collections from 14 sites have septa at the base of nearly all zooecia, seven others have septa at the origins of branches, and 16 others have occasional septa. The fungoid colonies have the most frequent septation both in the repent and free branches. The septa are largely of the round peripheral type, and a pale yellow-brown in color. Only five specimens have the stiff, brownish septa with the elongate perforation, so frequently encountered in Plumatella emarginata. A septum similar to the type frequently found in P. emarginata zooecia is shown in Fig. 6. The elongated perforation is even narrower in some P. emarginata septa. Thus, with regard to septation, many of the Michigan colonies have their greatest affinity with Allman's specimens and with

those from the Kurile Islands.

Tentacles

The number of tentacles, according to Allman, is "about sixty", while the number given by Jullien (1885) varies between 44 and 53, most frequently between 49 and 53. Toriumi (1955a) gives a range of 39 to 65 with a central range of 51.1 to 52.7. His Tsuta-numa specimens range in number from 53 to 72 with a central range of 60.7 to 63.9. The number of tentacles of the Michigan polypides compare very closely with Toriumi's non-Tsuta-numa specimens. They number 38 to 65 with an average of 53.5 in 389 counts. Toriumi indicates that the tentacle number of newly evaginated ancestrulae is 18 (12 outer, 4 inner, and 2 anlages). I have counted tentacles on newly evaginated ancestrulae found in a woodland ditch in Saginaw County, which varied from 12 to 19. The most frequent counts were 16 and 17. Other ancestrulae counts have been taken ranging between 24 and 28.

Floatoblasts

The sizes and ratios of the Michigan specimens are in agreement with those obtained by other investigators. Statoblast measurements are given in Table 2. Reticulations on the capsule are variable in distinctness, and they are less evident or absent on the dorsal side, in agreement with Toriumi's observations. Mammillations are present, and usually best developed on the dorsal side and along marginal areas. The float coverage is, in most cases, very typical. The ventral surface has only a thin float nearly equal in

TABLE 2. *Plumatella repens* measurements

Source from which measurements were taken	Number of measurements	Whole statoblasts				
		Length in mm.	Average length	Width in mm.	Average width	Ratio length to width
Floatoblasts						
Present study	252	0.30; 0.44	0.35	0.22; 0.33	0.26	1:1.32
Kraepelin (1906)						1:108,1:133
Rogick (1940)	277	0.26; 0.45	0.33; 0.41*	0.22; 0.29	0.24; 0.28*	
Hozawa and Toriumi (1941) *P. fungosa*		0.35; 0.37		0.21; 0.23		
Borg (1941)						1:1.20
Lacourt (1951)		0.35; 0.38		0.27; 0.28		
Toriumi (1955a)		0.33; 0.41	0.37; 0.38*	0.24; 0.31	0.27; 0.28*	1.2,1.5 (Av. 1.21,1.24)*
Sessoblasts						
Present study	86	0.38; 0.68	0.50	0.31; 0.47	0.38	1:1.31
Rogick (1940)	83	0.42; 0.51	0.47	0.28; 0.38		
Hozawa and Toriumi (1941) *P. fungosa*		0.80		0.39		
Lacourt (1951)		0.56; 0.60		0.43; 0.52		
Toriumi (1955 a)		0.36; 0.51	0.43; 0.45*	0.27; 0.40	0.32; 0.34*	

* Rogick and Toriumi give their averages as a range, therefore they can only be compared approximately with other averages.

Number of measurements	Capsule				
	Length in mm.	Average length	Width in mm.	Average width	Ratio length to width
177	0.19; 0.39	0.27	0.18; 0.29	0.22	1:1.23
277	0.24; 0.31	0.26; 0.27*	0.18; 0.25	0.20; 0.22*	
	0.23; 0.33	0.28; 0.29*	0.19; 0.26	0.22; 0.23*	1.1,1.4 (Av. 1.21,1.24)*
85	0.30; 0.55	0.41	0.27; 0.37	0.30	1:1.36
83	0.36; 0.45	0.37; 0.41*	0.25; 0.35	0.28; 0.30*	

width at the ends and sides of the statoblast, and the dorsal side has somewhat more float coverage at the tips. Variations in the amount of float coverage are more apparent on the dorsal side of the floatoblasts. Differences in float coverage and shape of Michigan P. repens floatoblasts are illustrated by Fig. 7 through 10. A floatoblast, with an incomplete float, is shown in Fig. 11. Where the true float is absent, only a thin reticulate lamella is present, similar to that found in the sessoblast. Naked capsule (area of capsule not covered by float cells) measurements are as follows: Range of lengths and widths, respectively; dorsal side, 0.12 mm. to 0.26 mm. by 0.10 mm. to 0.23 mm. and ventral side, 0.17 mm. to 0.32 mm. by 0.15 mm. to 0.25 mm; the average length and width of the dorsal side are 0.20 mm. by 0.17 mm., and the averages of the ventral side are 0.25 mm. by 0.19 mm. The statoblasts with somewhat greater float coverage than usual, are often similar in appearance to Pateff's (1924; Fig. 1) illustration of a P. repens floatoblast.

Sessoblasts

The measurements and ratios of the Michigan sessoblasts given in Table 2 conform to those of other investigators, although the maximum is somewhat higher (Fig. 12). The width of the lamella given by Toriumi (1955a) ranges between 0.30 mm. and 0.80 mm. The Michigan specimens have lamellae which agree with these figures. Rogick (1940; fig. 20) shows a sessoblast on which the lamellar reticulations are clearly evident. Toriumi declares that his specimens have an obscure

Plumatella repens



Fig. 6. Septum from "fungoid" colony

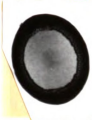


Fig. 7. Floatoblast dorsal surface



Fig. 8. Floatoblast ventral surface



Fig. 9 Floatoblast dorsal surface



Fig. 10. Floatoblast dorsal surface

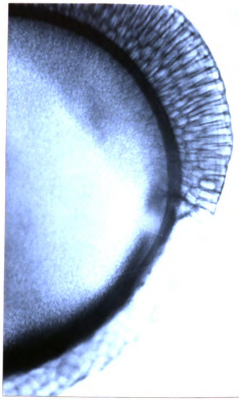


Fig. 11. Defective floatoblast (only lamella evident in picture in lower portion



Fig. 12. Sessoblast (fine mammillations evident on capsule)

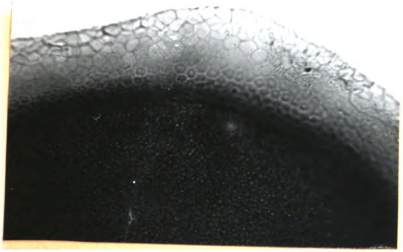


Fig. 13. (left) Sessoblast - showing distinct reticulations of the lamella.

and sometimes distinct reticular pattern on the lamella. The sessoblasts of the Michigan specimens have distinct lamellar reticulations in most cases (Fig. 13). In only a few are they obscure and in only one specimen is the reticulation absent. It is possible that the sessoblasts which lack reticulations are immature. Mammillations are clearly evident on the capsules of the Michigan P. repens sessoblasts.

Detour Harbor, Chippewa County, Specimen

This specimen of P. repens is atypical and requires special comment. The small and compact colony was developed from a floatoblast, and the branches radiate sinuously from this point of origin. There is little elongation of the zooecia, and often two to four zooecia lie parallel and closely conjoined; thus, the individual contour of the zooecia is often obscure. The zooecia are repent and wide, averaging 0.664 mm. in diameter. The zooecial tips are short with numerous lamellations around the distal portions. The massive hyaline and thick zooecia are suggestive of Hyalinella punctata. The ectocyst is stiff and somewhat incrusted. Other characters suggest Plumatella emarginata; a sometimes distinct and broad keel, hyaline furrow, and emargination on the tips of the incrusted zooecia. In some places distinct indentations on the surface of the coenecium form what may be called rugosities. Longitudinal striations are also evident on some of the zooecia. The light incrustation is whitish in color. This is the only form collected which has characteristics of both H. punctata and P. emarginata. The form

was classified as Plumatella repens on the following basis: tentacles approximately 60; septa absent; typical P. repens floatoblast; typical P. repens sessoblast with distinct lamellar reticulations; stiffness of the hyaline ectocyst. The colony is decidedly unusual and the author has not found a similar form in the literature. I believe that the characteristics have been largely dictated by the environment. The colony was situated in a small concave despression in a rock, on a wave washed shore. The nature of the small deep concavity and the agitation of the water may have retarded the elongation of the zooecia, encouraged lateral expansion of them, forced them into close apposition, or checked the elongation of the zooecial tips. The rugosities and lamellations may be the result of physical confinement by the sides of the concavity. The colony by adhering to the contour of the substrate, developed a concavity on its own dorsal surface. The physical stress of this dorsal concavity caused wrinkling and resulting rugosities of the colony surface. The development of the keel and furrow may likewise have been dictated by the substrate contour and the movement of the water.

Plumatella emarginata Allman 1844

Colony

The Michigan specimens vary from widely open and repent to dense with many zooecial branches entangled and free of the substrate. The dense growth form was originally described by Allman (1856) as Alcyonella benedeni. Kraepelin (1887) includes three varieties under his Plumatella princeps,

var. spongiosa, muscosa, and emarginata. Braem (1890) was of the opinion that both spongiosa and muscosa were variations of Plumatella emarginata. Toriumi (1952e) reared colonies which had been germinated from statoblasts of luxuriant colonies, and new branches assumed a widely open orientation. He has confirmed Braem's opinion by finding that variation depends on substrate, budding rate, and the relative elongation of the zooecial tubes. The varieties would thus be phenotypes of the same species; var. spongiosa is the highly luxuriant growth form, and var. muscosa (and Allman's Alcyonella benedeni) somewhat less luxuriant growth forms, while var. emarginata is the open form. I have noted free branches in approximately 25 per cent of the Michigan colonies. This is more frequent than Toriumi has reported from Japan.

Zooecia

Both rounded and truncated tips were observed frequently. Wrinkles, called annulations (sometimes lamellations), were noted at the tips of approximately 25 per cent of the zooecia (Fig. 14). Toriumi (1952e) states that these annulations on Plumatella emarginata are not related to season or locality, and that Plumatella casmiana is the only other species with these characteristics. However, the author has observed rather well developed terminal annulations on older zooecia of Plumatella repens from four collection sites and weakly developed annulations on certain other specimens. Most P. repens colonies with these annulations are essentially typical in other characteristics.

Marked taper was only rarely noted in the zooecia. Annandale (1910), Vorstman (1928 a,b) and Toriumi (1952e) are among those who have commented on the essential uniformity of width of the zooecia from proximal to distal end. Two collections were made of Plumatella Allmani type colonies where the taper toward the proximal end was marked and where some taper was evident at the distal end. These colonies have a clear furrow and emargination and a weakly developed keel. The zooecia vary between 0.215 mm. and 0.44 mm. in diameter proximally and 0.249 mm. and 0.52 mm. distally. Rogick (1940) gives zooecial diameters ranging from 0.31 mm. to 0.45 mm. with a median range of 0.34 mm. to 0.40 mm. The Michigan forms are closely in agreement with hers.

The keel is strongly developed throughout the length of the zooecia in nearly 50 per cent of the Michigan Plumatella emarginata specimens, weakly developed or developed only distally on some 40 per cent, and essentially lacking on two specimens. The furrow is moderately to clearly evident on approximately 90 per cent of the specimens, obscure or lacking in 10 per cent. The emargination is present on most specimens and largely obscure in two specimens. Rogick and Van der Schalie (1950) state that the zooecia of their collections are "noticeably keeled". The keel, furrow, and emargination have all been traits of specific value and were recently reevaluated by Toriumi (1952e). He states that all colonies which he has examined have a furrow on some of the zooecia, all have a keel, though often obscure on the free

branches, and all have at least a few emarginate zooecia. In the present study, when one or two zooecial traits were largely obscure, other specific traits were determinative. Zooecial tips are depressed or flattened against the substrate in nearly 50 per cent of the Michigan specimens.

Ectocyst

Allman (1856) describes the ectocyst as being heavily covered with minute and agglutinated siliceous particles except in the immediate vicinity of the orifice. Toriumi (1952e) reports that the ectocyst is incrusted with a variety of materials which give it various colors, usually grey, yellowish-brown, or black. Annandale (1910) speaks of the dark brown to black color of the ectocyst. Six shades of color from whitish-grey through reddish-brown to black occur with nearly the same frequency in the Michigan specimens. Black colonies with whitish tips were collected from four collection sites (Fig. 17 and 18). Light-colored zooecial tips were noted in a majority of the Michigan specimens. In a number of cases the incrustation is not securely imbedded in the substance of the ectocyst, but rather loosely imposed. With careful scraping, this loose incrustation could sometimes be removed revealing the nearly transparent yellow-brown ectocyst beneath. In newly formed zooecia, the ectocyst is medium soft gelatinous and hyaline. In a few cases the ectocyst is not incrusted. In collections from one location in Wintergreen Lake, unincrusted colonies were present with P. repens, and the colonial aspect of both species is similar. Borg (1936b)

describes an entirely transparent and hyaline colony of P. emarginata from Africa.

Toriumi (1954a) speaks of the agglutination of ectocysts in luxuriant colonies of P. emarginata and Plumatella fungosa. The author noted extensive agglutination of ectocysts in luxuriant colonies and in flabellate colonies from Spring Lake, Ottawa County, and Van Etten Lake, Iosco County.

Toriumi records that longitudinal striations on the ectocyst are present in specimens from Japan and vicinity and from Tahiti, but that he did not find them on specimens from North America, Sweden, Holland, and Czechoslovakia. Striations are present on several zooecia of colonies of P. emarginata collected from two lakes in Michigan. They are evident on 15 to 20 per cent of the Michigan colonies of P. repens.

Septa

The presence of septa is not indicated by Allman (1856). Annandale (1910) states that partitions are present. Toriumi (1952e) states that generally each zooecium of a repent or open branch has a septum. The number is variable, and sometimes they are present only at the origin of the branch. Septa are present to some degree in all of the Michigan specimens with the exception of one very young colony and one colony fragment. In approximately 60 per cent of the specimens, septa are present in each zooecium. The septa of P. emarginata are usually very dark and stiff and may be arched or moon-shaped. Often the communication between zooecia is only a narrow vertical portal or no more than a slit-shaped

perforation. However, the septa in P. repens are frequently not so dark and stiff and more often have circular perforations (i.e., peripheral septa). There are exceptions, of course, but the thin vertical perforation is approximately five times more common in P. emarginata study colonies than in partitioned P. repens colonies. Thus septation is of some aid in systematics.

Tentacles

The following tentacle numbers are given by several investigators: Allman (1856) "about 40"; Kraepelin (1887) for Plumatella princeps, 28 to 42; Loppens (1908), 42 to 54; Borg (1936b), 40 to 50; Lee (1936), form typica, 40 to 44, and form benedeni, 30 to 32; Rogick (1937), 40 to 54; Rogick (1940), 30 to 42; Hozawa and Toriumi (1941), 36 to 42; Toriumi (1952e), 20 to 51. The counts on the typical Michigan specimens varies from 26 to 54, with an average of 40.6. There are thus wide variations, causally associated by Toriumi with environmental conditions. In the present investigation, variations in tentacle numbers among colonies from different locations of the same lake corroborate this assertion. Low tentacle counts of 14 and 15 were taken on two ancestrulae.

Floatoblasts

Table 3 reveals that colonies of the typical Michigan P. emarginata produce floatoblasts of such variability that the length and width measurements (both whole and capsule) nearly encompass the entire range of variation reported by earlier investigators. The length and width maxima and minima are

TABLE 3. *Plumatella emarginata* measurements

Source from which measurements were taken	Number of measurements	Whole statoblasts				
		Length in mm.	Average length	Width in mm.	Average width	Ratio length to width
Floatoblasts						
Present study (typical)	86	0.33; 0.50	0.41	0.20; 0.32	0.25	1:1.64
(Pony Creek form)	67	0.25; 0.37	0.35	0.20; 0.27	0.24	1:1.45
Braem (1890)		0.47; 0.52	0.49	0.25; 0.27	0.26	
Kraepelin (1906)		0.36; 0.50		0.21; 0.31		
Harmer (1913)		0.33; 0.42	0.37	0.22; 0.26	0.24	1:1.54
Abricossoff (1927a)						
Moscow form		0.50		0.27		
Vladicaucas		0.45		0.25		
Verstman (1928a)		0.37; 0.50				1:1.7,1:2
Lee (1936)		0.34		0.20		
Borg (1936b)		0.46		0.27		
Hastings (1938)						
Type I		0.48		0.27		1:1.8
Type II		0.46		0.30		1:1.53
Rogick (1940)	94	0.35; 0.47	0.40; 0.46*	0.21; 0.31	0.23; 0.26*	
Hozawa and Toriumi (1941)		0.37; 0.42		0.21; 0.24		
Borg (1941)						1:1.50
Lacourt (1951)		0.42; 0.50		0.23; 0.27		
Rogick and Vander Schalie (1950)		0.43		0.23		1:1.88
Toriumi (1952e)		0.35; 0.45		0.20; 0.27		1.66,1.71

* Rogick gives her average as a range. Therefore it can only be compared approximately with other averages.

Number of Measurements	Capsule				
	Length in mm.	Average length	Width in mm.	Average width	Ratio length to width
65	0.23; 0.32	0.27	0.18; 0.23	0.21	1:1.29
48	0.22; 0.25	0.23	0.17; 0.19	0.18	1:1.25
61	0.23; 0.29	0.25; 0.27*	0.18; 0.23	0.19; 0.21*	
	0.25; 0.28		0.18; 0.20		
	0.28		0.21		1:1.36
	0.23; 0.30	0.26; 0.27*	0.17; 0.23	0.198; 0.203*	1.30,1.33

* Rogick and Toriumi give their averages as a range. Therefore they can only be compared approximately with other averages.

TABLE 3. (continued)

Source from which measurements were taken	Number of measurements	Whole statoblasts				
		Length in mm.	Average length	Width in mm.	Average width	Ratio length to width
Sessoblasts						
Present study (typical)	25	0.38; 0.52	0.44	0.30; 0.40	0.34	1:1.32
(Pony Creek form)	22	0.43; 0.50	0.46	0.30; 0.36	0.34	1:137
Harmer (1913)		0.32; 0.48	0.44	0.32 0.37	0.34	1:1.32
Vorstman (1928a)		0.45				
Borg (1936b)		0.39		0.31		
Hastings (1938)		0.48		0.36		1:1.33
Rogick (1940)	19	0.40; 0.58	0.44; 0.47*	0.27; 0.36	0.30; 0.33*	
Borg (1941)						1:1.23
Rogick and Vander Schalie (1950)		0.46; 0.47		0.35; 0.39		
Lacourt (1951)		0.50		0.38		

* Rogick gives her average as a range. Therefore it can only be compared approximately with other averages.

Number of measurements	Capsule				
	Length in mm.	Average length	Width in mm.	Average width	Ratio length to width
20	0.30; 0.46	0.38	0.22; 0.37	0.28	1:1.36
22	0.35; 0.43	0.38	0.25; 0.35	0.27	1:1.36
17	0.35; 0.49 0.40	0.38; 0.40*	0.25; 0.31 0.29; 0.35	0.27; 0.29*	

only slightly more inclusive than Rogick's (1940). The length-width ratios are consistent with those of Toriumi and never reach the extremes given by Hastings (1938) for type I, or by Vorstman (1928a). The floatoblasts measured by Rogick (1940) and Rogick and Van der Schalie (1950) are somewhat narrower than those of the current study. The tips of the Michigan floatoblasts are either truncate or rounded, often comparable in design to those in Plate I, Fig. 1-5 of Rogick and Van der Schalie.

The ventral and dorsal surfaces of the typical Michigan P. emarginata are shown in Fig. 15 and 16. Some variability is noted relative to float coverage with the float in extreme cases covering nearly the entire dorsal surface. The dorsal surface is decidedly flat with a tendency to round only at the peripheral margins of the float area. The ventral surface is typically convex and less covered by float portion. Thus the naked capsule area on the ventral side is greater. The average length and width of the naked capsule are as follows: dorsal side, 0.11 mm. and 0.09 mm.; ventral side, 0.20 mm. and 0.17 mm. The float coverage agrees with figures and illustrations given by Rogick (1940) and Rogick and Van der Schalie (1950). The suture line of the float is visible on dorso-lateral surface of the statoblast. Mammillations are generally uniform and complete on both surfaces.

Sessoblasts

The measurements of the fixed statoblasts agree with those given by other investigators (Table 3). The mammillations are

Plumatella emarginata

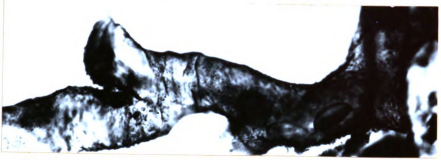


Fig. 14. Zooecium. Annulations are visible as ring-like indentations of the ectocyst.



Fig. 15. Floatoblast dorsal surface



Fig. 16. Floatoblast Ventral surface

complete and uniform on the dorsal surface. Distinct reticulations on the capsule are frequently present. The lamella, or vestigial annulus, is somewhat narrower on P. emarginata than on P. repens. Toriumi has reported that the lamella of of both P. repens (1955a) and P. emarginata (1952e) has obscure reticulations. However Rogick (1940; plate V, Fig. 20 and 24) shows clear reticulations. A partial or complete reticular pattern is evident on the sessoblasts of approximately 40 per cent of the typical Michigan P. emarginata sessoblasts, while it is obscure or essentially lacking on the remainder. Reticulations are clear on nearly all of the P. repens specimens, being obscure on only two. Therefore only partial taxonomic value may be given to this character (i.e., when distinct reticulations are absent, supportive evidence for P. emarginata is enlisted, but when distinct reticulations are present, other characteristics must be wholly determinative).

Plumatella emarginata, flabellate form

Allman (1856) discusses two species, Alcyonella flabellum Van Beneden 1848 and Plumatella jugalis Allman 1850, founded essentially on their geminate fan-like growth form. The former species was described as dense, with zooecia contiguous, and the latter was widely open in form. Jullien (1885) contends that the twin-like character of these two forms is not a basis for specific separation. He places these forms under P. repens. Abricossoff (1927b) suggests that flabellum is a seasonal form. Rogick (1941) discusses these two geminate forms and gives measurements for the jugalis form but leaves

their systematic position undecided. Toriumi (1952d), by means of rearing experiments on statoblasts, concludes that geminate colonies do not originate from statoblasts but come from larvae, which generally have two incipient polypides. These polypides germinate in opposite directions. All geminate colonies of P. emarginata examined by Toriumi are of the jugalis type. The variation flabellum has not previously been reported for Michigan. Rogick and Van der Schalie (1950) reported the collection of P. repens jugalis from Michigan. It is not certain whether their form was P. repens or P. emarginata, as all Plumatella forms were classified under repens at that time. Flabellate and intermediate flabellum-jugalis type colonies were found in Van Etten Lake, Iosco County, and in Spring Lake, Ottawa County during the present study (Fig. 17 and 18). Two of the specimens more nearly like the jugalis form had originated from contiguously located sessoblasts which had germinated simultaneously. The polypides had germinated essentially facing each other, and so one ancestrula had crossed the other in elongating, leaving a narrow connecting portion of the zooecium between the two subsequently formed flabellate portions of the colony. The author noted one geminate and flabelliform colony which had developed apparently from two contiguous floatoblasts. The ventral valves of these two statoblasts remained loosely attached to the narrow interconnecting zooecial area between the colonies. The dorsal valves were no longer present. The basal portions of the two ancestrulae had fused nearly completely,

Plumatella emarginata

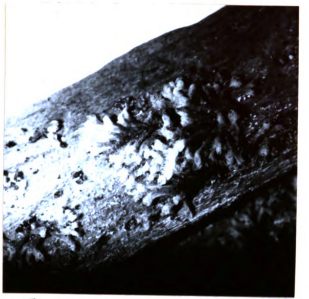


Fig. 17. Center: Flabellate colonies
Lower left: Young, geminate flabelliform colony

(Colonies nearly black in color with whitish tips



Fig. 18. Showing a colony intermediate between flabellum and jugalis forms. (Note dark sessoblasts in vicinity of colony. This colony originated from a sessoblast

and they had elongated away from the point of origin giving rise to geminate flabelliform colonies. During the present study extensive agglutination between the soft gelatinous bases of newly germinated ancestrulae of Plumatella repens has been observed. The author suggests that the soft gelatinous ectocysts of two oppositely directed but contiguous ancestrulae may thus agglutinate, with the fusion so complete as to make it difficult to determine whether the two resulting flabellate colony portions had originated from one larvae or two floatoblasts. This postulate presupposes the loss, subsequent to germination, of the statoblast valves. The two dorsal valves had been lost in one of the cases already cited. Valves would be detached most readily from colonies growing along wave-washed shores (Spring Lake) or in flowing water. One geminate form was found with a thin zooecial connection between the flabellate portions as pictured by Allman (1856; Plate 4, Fig.2) and Braem (1890; Plate II, Fig. 17 and 18). No statoblast valves were seen. This colony may have originated in the manner just discussed or from a larvae as suggested by Toriumi. The flabellate colonies from both Van Etten Lake and from Spring Lake are typical Plumatella emarginata colonies with nearly black, white-tipped zooecia. The development of flabelliform colonies depends upon a rapid budding rate or a reduced elongation of the zooecia, and upon the parallel orientation of the zooecia and their branches.

In summary, observational evidence and discussion are presented for the origin of geminate flabellum-type colonies

from the simultaneous germination of two contiguous statoblasts in conjunction with the fusion of the bases of these statoblasts and the subsequent loss of the valves.

Plumatella emarginata, Pony Creek form

The characteristics of this form, collected at six sites, are consistent and intermediate between those of Plumatella repens and Plumatella emarginata. There has been much disagreement among bryozoologists with respect to the systematic distinctness of Plumatella emarginata and Plumatella repens. P. emarginata has been placed in, or taken out of, synonymy with P. repens a number of times by various investigators. Specimens of one of these species often reveal one, two or sometimes three characteristics which are associated with the other species. However, this taxonomic intergrading is most often confined to a minority of individuals in a population. The present discussion concerns a form which is consistent from one population to another, and which has intra-population stability. This form may be compared to Plumatella elegans, because the characters of that species, as defined by Allman (1856), are embodied in the phenotype of the Michigan specimens. Likewise there is much agreement between the Pony Creek form, which the author has tentatively placed under P. emarginata, and Plumatella javanica. The consideration of this Michigan form again raises the question of the relationship between P. emarginata and P. repens. The author agrees with those who have favored species status for these two Bryozoa. However, such agreement fails to illuminate the position of

reasonably consistent intermediate forms. Environment is known to modify the phenotype of fresh-water bryozoans, but a consistency of characters among several populations argues against a purely environmental shaping of this phenotype. P. emarginata and P. repens appear to be very closely related, but this close relationship does not preclude the existence of intermediate species. On the other hand, hydridization may occur in the family Plumatellidae.

Diagnosis: Plumatella emarginata, Pony Creek form

Colony

The colonies collected during this study are repent. The branching is widely open, and the tips are often raised from the substrate.

Zooecia

The zooecia most often have a very gradual taper. However, some colonies at two collection sites have clavate zooecia. The zooecia vary in diameter from 0.24 mm. to 0.44 mm. proximally and from 0.34 mm. to 0.55 mm. distally. They therefore tend to have greater width distally than P. emarginata, but do not attain the higher maximal dimensions of P. repens.

A feeble keel is present only distally on approximately one-half of the specimens, but it is more strongly defined on the remainder. The furrow is seen on some zooecia in each collection, and it occurs frequently in two of the collections. On three or four zooecia of the Vermillion Creek colonies, the var. furcifer furrowing was evident (i.e., the proximal bifurcation of the unincrusted furrow into two obliquely proceeding

lateral lines). The emarginate orifice is seen on zooecia of all colonies, but not with the same frequency. The above traits are particularly well developed on the Pony Creek specimens. Longitudinal striations are visible on the zooecia of colonies from two collecting sites, while sub-orifice annulations occur in a single case.

Ectocyst

Incrustation is moderate to heavy with the exception of a few Wintergreen Lake colonies which were nearly naked and grey-yellow in color. Incrustment appears to be the usual condition. Siliceous particles and detritus make up the incrustation. The color is most often whitish-grey to yellow-brown. The zooecial tips of one-half of the specimens have whitish tips.

Septa

In small or fragmentary colonies, septation is lacking or only occasionally present. In most colonies septa are numerous. The Pony Creek specimens have dark, stiff, and frequent septa.

Tentacles

The average tentacle number is 45.5 (on 138 counts), while the range is 40 to 54. The lowest of the range figures and the highest of the range figures represent approximately the lowest and highest recorded counts for P. repens and P. emarginata respectively. The average number of tentacles is intermediate between these two species.

Floatoblasts

The statoblasts are of particular significance in this form. They are intermediate in every way. The maximal length is below the maxima for both P. repens and P. emarginata. The ratio of whole length to whole width, 1:1.45, is indicative of a statoblast narrower than P. repens, yet wider than P. emarginata. The capsule measurements are not significant.

The float coverage (Fig. 19 through 22) is lesser on both dorsal and ventral sides than in the typical P. emarginata, and it is greater than in P. repens. The float coverage is consistent, and the average lengths and widths of the naked capsule are as follows: dorsal side, 0.15 mm. by 0.14 mm.; ventral side, 0.22 mm. by 0.17 mm. The dorsal side is flattened but tends to round more at the margins than in P. emarginata, thus bringing the suture closer to the center line. Mammillations are relatively even and complete on both capsule surfaces.

Sessoblasts

The sessoblasts are not particularly distinctive. However lamellar reticulations are reasonably well developed on all of the sessoblasts examined, a characteristic shared with P. repens.

Discussion

Jullien (1885) includes Plumatella elegans and P. emarginata unter P. repens. Kraepelin (1887) places P. elegans in synonymy, along with P. repens, Plumatella fungosa, Alcyonella flabellum and other forms, within his species Plumatella

Plumatella emarginata (Pony Creek form) floatoblasts



Fig. 19. Dorsal surface



Fig. 20. Dorsal surface

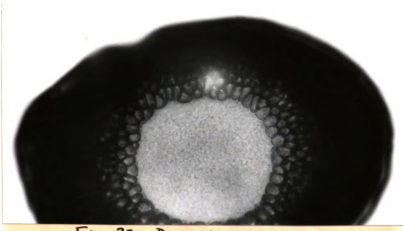


Fig. 21. Dorsal surface

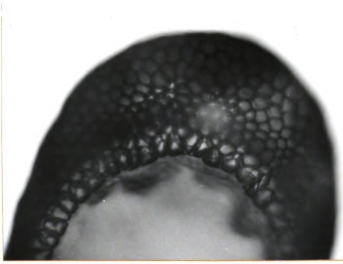


Fig. 22. Ventral surface
(float cells clearly evident)

polymorpha. Thus it is separated from P. emarginata which he includes in his Plumatella princeps group. Braem (1890) considers Plumatella elegans synonymous with P. repens. Toriumi (1952e) states that the statoblasts of P. emarginata fall generally into two catergories, those of type I and those of type II of Hastings (1938). He states that the floatoblast of P. elegans appeared to agree with type I of P. emarginata. So contrary to the opinion of many workers, P. elegans should be regarded as a synonym of P. emarginata. I agree that P. elegans conforms more closely to P. emarginata, but I do not agree that the type I statoblast of Hastings (1938) agrees fully with the floatoblast of P. elegans. Allman (1856) states that "the statoblasts are broad, elliptical, with a widely overlapping annulus; they are narrower than those of P. repens, but wider than the ova of P. emarginata, and present no tendency to the bean-shaped figure of the latter." The ratio of length to width of Hastings type I statoblast is 1:1.8. An examination of Table 3 discloses that this ratio is not intermediate in width between P. repens and P. emarginata, but is actually in the more narrow range even for P. emarginata. Even the typical Michigan P. emarginata is narrower than Hastings' type I statoblast. Type II statoblasts agree more closely with the Pony Creek form as she gives a ratio of 1:1.53. Thus the statoblasts of the Michigan Pony Creek specimens are truly intermediate in width between the two species.

Allman illustrates only one face of the statoblast for Plumatella elegans. The float coverage and round naked capsule area closely resemble the dorsal surface of the Pony Creek form. If Allman's drawing represents the ventral face of the capsule, the dorsal face would have still greater coverage by the float, and would in effect have the typical emarginata float coverage. Neverless, in comparison to P. repens, the float is more widely overlapping in both P. elegans and the Pony Creek form.

Other species which the Michigan specimens resemble are Plumatella javanica and Plumatella vorstmani. P. javanica was described by Kraepelin (1906). The zooecia are similar to the Michigan specimens in that branching is often infrequent and zooecia tend to be elongate. Kraepelin's Fig. 2 shows the distinct furrow and emargination, and is identical in appearance to a number of the Michigan specimens. Annandale (1910) states that P. javanica, which he found abundant in Calcutta, is related to P. emarginata but is distinguished by the infrequently branched linear series of zooecia. He states further that the "zooecia are entirely and invariably recumbent." This is also true of the Michigan specimens. Annandale declares that there is never any "trace of pigment in the ectocyst, which is markedly transparent and delicate; the external surface is smooth." The Michigan colonies are either without pigment or pale yellow, and most often incrusted.

Annandale gives no tentacle data, but Kraepelin gives the tentacle number as 45, and this is in excellent agreement with the Michigan specimens. Vorstman (1928a) considers Kraepelin's

number "a mistake", and states that the Javanese collections have only 20 to 27 tentacles. The floatoblasts shown by Kraepelin (Fig. 3) and described by Annandale have less float coverage than my specimens. Vorstman shows (Fig. 4) a floatoblast somewhat similar to the Pony Creek form but narrower, having a length to width ratio of 1:1.6. She describes the sessoblast as somewhat smaller than the floatoblast. Thus the Plumatella javanica sessoblast does not agree with those of the Michigan specimens. Toriumi (1952c) gives particular importance to the small size of the sessoblast, in erecting the new species, Plumatella vorstmani. He places P. javanica, as described by Vorstman, in synonymy with his new species. The Michigan colonies are in better agreement with Toriumi's P. vorstmani than they are with Kraepelin's and Annandale's description of P. javanica. This is largely because he describes the ectocyst as being naked to slightly incrusted, and also states that a slight keel, in addition to furrowing and emargination, may be present. The zooecia shown in his Fig. 3 and 5 are described as heavily incrusted, and frequently have the keel.

Toriumi's Fig. 4, showing a linear sequence of zooecia, some of which are elongated, resembles colonies from the Thunder Bay River. The floatoblasts of Toriumi's specimens are strikingly similar to the atypical Michigan floatoblasts in size and float coverage. The round naked capsule area on the dorsal side, also the elliptical naked capsule area on the ventral side are the same in both forms. Toriumi gives

a length to width range of 1:1.39 to 1:1.74. This range overlaps the average ratio of 1:1.45 of my specimens. His average ratios of 1:1.55 to 1:1.59 are somewhat higher and essentially within the range of the widest Plumatella emarginata floatoblast.

Plumatella vorstmani differs from the Pony Creek group in the following characteristics: incrustation is not frequently so heavy; the keel is not as distinct or frequent; no septa are present; the tentacle number is considerably lower than in the Michigan form, ranging between 18 and 32, and the sessoblasts are smaller than the floatoblasts.

Plumatella elegans, Plumatella javanica, and P. vorstmani all share many characteristics with P. emarginata and particuwith the Pony Creek group. However the differences between these forms and P. emarginata, and even the Pony Creek group, are of sufficient magnitude to advise against taxonomic combinations at present. Allman's (1856) P. elegans relates closely to the Pony Creek form, but is incompletely described in terms of the more recent systematic characters. Thus, the Pony Creek form is intermediate in many characteristics between P. repens and P. emarginata and likewise between P. emarginata and the European, Javanese, and Japanese forms with which it has been compared.

Future systematic study may prescribe a species or subspecies status for the Pony Creek form. However, such a recommendation at the present time does not appear appropriate and would possibly only serve to amplify the complexity already

existing among intergrading forms. The Pony Creek group shares a greater number of characteristics with the cosmopolitan P. emarginata, and for this reason is delegated to this species. The fact that the two forms have not been found in the same habitat acts in support of this decision.

The information and discussion which have been presented serve to highlight some of the extensive intergradation which exists among members of the family Plumatellidae. A similar overlap exists among other forms in this family, and some of the systematic separations appear tenuous. A thorough examination of the world-wide members of the family Plumatellidae would be of taxonomic value. The results of such a study could conceivably make possible a systematic revision of the fresh-water Bryozoa in terms of polytypic species and subspecies, as discussed by Mayr, Linsley, and Usinger (1953). Cain (1954) refers to the merit of the term "semispecies" as suggested by Mayr. This designator may also have application in bryozoan taxonomy.

Plumatella fruticosa Allman 1844

Colony

Plumatella fruticosa has not heretofore been recorded from Michigan. Collections of this species were obtained from 10 localities during the present investigation. The colony described by Allman is attached only at its origin. Toriumi (1954b) states that the colonies vary from repent to shrubby in appearance. This shrubby appearance is found in Fredericella sultana, and Toriumi (1952b) indicates that the free

branches of Plumatella osburni also show this characteristic. Colonies found in five Michigan collections are largely repent; those in four, have both repent and free portions; those in one, are largely free of the substrate. The branching is shrubby on the free portions and open in pattern. The most luxuriant colonies were collected from Clark Lake, Luce County. The zooecia are most often erect or nearly erect, and the zooecial tips are usually raised a distance of 0.8 mm. to 1.2 mm. above the substrate. The vertical zooecia of the Muskellunge Lake, Montmorency County, specimens are frequently in excess of 2.0 mm. above the substrate. Wiebach (1952) discusses the release of statoblasts in Plumatella fruticosa from a "hyaliner cyste". The statoblasts pass into this thin hyaline protrusion from the side of the vestibule and are released. Marcus (1941, 1942) discusses the release of statoblasts from Stolella evelinae, Stolella agilis, and Hyalinella carvalhoi through a special pore, and Wiebach (1953) reports that he has observed the expulsion of statoblasts from living polypides in Plumatella repens and Plumatella emarginata. The author has not observed this process in living P. fruticosa colonies.

Zooecia

The zooecia of my specimens are typically narrow with the sides at a steep angle to the substrate. A keel is strongly developed on nearly all of the repent zooecia. This keel is often obscure to lacking on the free branches, which often are essentially round, in contrast to the triangular repent

zooecia. Allman (1856) describes the keel as obscure. Braem (1890) describes the keel as mostly distinct. Toriumi (1954b) states that the keel varies from weak to strong and that the furrow is absent except in rare cases. A furrow is present on several of the zooecia from two of the Michigan collection sites. A specific character of P. fruticosa is the formation of a linear series of daughter zooecia from the side of a mother zooecium. The daughter zooecia produced by this unique budding zone are detached from the mother zooecia and are thus believed to be a supplementary source for new colonies. However, Wiebach (1954a, 1954b), after a month of observation, reports that no colonies were formed by these detached buds. After these daughter zooecia have been released, a characteristic serration (stumps of the daughter zooecia) is present on the mother zooecia. Jullien (1885) noted these unusual buds and serrations on Plumatella lucifuga (includes P. fruticosa). He found one zooecium with 12 daughter zooecial locations. One of the daughter zooecia was still attached. Wiebach (1954b; Fig. 2) portrays a portion of a coenecium on the zooecia of which as many as 13 or 14 bud stumps appear to be present. Toriumi (1954b) records that serrated branches are present on nearly all colonies which he collected. In contrast, serrated zooecia are present in colonies obtained from four of the ten Michigan collection sites. The maximum number of daughter zooecia stumps on a single zooecium in the Michigan specimens is eight. Zooecia with daughter buds and characteristic serrations are shown in Fig. 23 and 24.

Plumatella fruticosa. Zooecia with special budding zones.

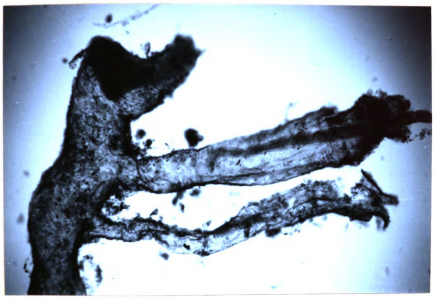


Fig. 23. Mother zooecium with two daughter zooecia still attached. (septum may be seen as the dark line at the base of the upper daughter zooecium)

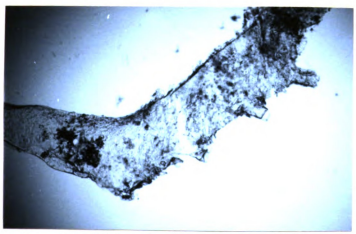


Fig. 24. Serrated zooecium - from which daughter zooecia have been detached.

Ectocyst

The Michigan specimens agree with the description Toriumi gives, in that they are occasionally slightly incrusted, otherwise they are without incrustation. The ectocyst is semi-opaque and pale grey or pale yellow-brown in color.

Septa

Allman (1856) does not refer to septation. Wiebach (1954a) refers to the septa which form in connection with the special daughter zooecia. Toriumi (1954b) states that a septum is present in each zooecium. This is not the case with the Michigan specimens. Septa are frequent or present between most zooecia in six of the collections. However, septa are only occasional in colonies of three collections, and absent in two small colonies from the remaining collection site. The greatest number of septa are pale yellow-brown in color and have a thin vertical perforation. Some septa are nearly complete with only a minute central pore visible with a thin slit or a brownish suture extending from this pore to the substrate.

Tentacles

Jullien (1885) reports that Vaucher gave the tentacle numbers as between 25 and 32 in 1804. Jullien reports that they range in number from 42 to 54, with the most frequent number being 44. Toriumi states that the tentacles range in number from 32 to 50, and that 40.2 to 42.0 is the center of this range. The tentacle numbers of the Michigan specimens vary from 38 to 53 for 102 counts. The average tentacle

number is 45, thus essentially in agreement with both Jullien and Toriumi.

Floatoblasts

Relative to float coverage, the Michigan specimens agree with the statoblasts pictured by Allman (1856), Borg (1941), and Toriumi. The float covers the major portion of the more flattened dorsal surface, often leaving a slender area of exposed capsule (Fig. 25). There is a greater area of exposed capsule on the ventral surface. The average dimensions of the naked capsule are as follows: dorsal surface, 0.23 mm. by 0.07 mm.; ventral surface, 0.31 mm. by 0.15 mm. Statoblast measurements are given in Table 4. The data for the Michigan specimens agree with the data for specimens from other parts of the world except in the capsule ratios. The capsules of the Michigan specimens tend to greater narrowness. Mammillations on the capsule surface are fine. The central portion of the capsule is sometimes smooth.

Sessoblasts

The dimensions of the Michigan P. fruticosa sessoblasts agree with those given by most other investigators. Wiebach (1954a) reports that he has found sessoblasts with a length to width ratio of more than 3:1.

The lamella is wide in this species with a distinct lacy reticulation, and it has a serrated border. The surface contour of the capsule is unique in that prominent tubercles protrude from the dorsal surface. These tubercles are irregular as Toriumi (1954b) reports, and they are more

TABLE 4. *Plumatella fruticosa* measurements

Source from which measurements were taken	Number of measurements	Whole statoblasts				
		Length in mm.	Average length	Width in mm.	Average width	Ratio length to width
Floatoblasts						
Present study	40	0.44; 0.56	0.49	0.17; 0.22	0.20	1:2.45
Braem (1890)		0.50; 0.57	0.52	0.20; 0.21	0.21	1:2.48
Pateff (1924)			0.55		0.20	1:2.75
Lacourt (1951)		0.52; 0.60		0.20; 0.25		
Toriumi (1942)		0.41; 0.48		0.17; 0.20		(Av. 2.36,2.40)*
Toriumi (1954)		0.40; 0.55	0.47; 0.48*	0.17; 0.23	0.20	(Av. 2.36,2.40)*
Sessoblasts						
Present study	21	0.47; 0.71	0.60	0.19; 0.30	0.26	1:2.3
Lacourt (1951)			0.70		0.27	1:2.63
Toriumi (1954)						

* Toriumi gives his average as a range, therefore it can only be compared approximately with other averages.

Number of measurements	Capsule				
	Length in mm.	Average length	Width in mm.	Average width	Ratio length to width
40	0.27; 0.37	0.32	0.08 0.15	0.13	1:2.26
	0.22; 0.27		0.15; 0.17		
	0.27; 0.33	0.30	0.14; 0.19	0.16	1.50,1.69
21	0.33; 0.50	0.44	0.14; 0.20	0.19	1:2.31
	0.39; 0.55	0.45; 0.49*	0.17; 0.21	0.19; 0.20*	2.31,2.59

Plumatella fruticosa



Fig. 25. Floatoblast dorsal surface



Fig. 26. Sessoblast (Note reticulations on capsule)



Fig. 27. Sessoblast (elongated tubercles may be seen clearly along periphery of the capsule)

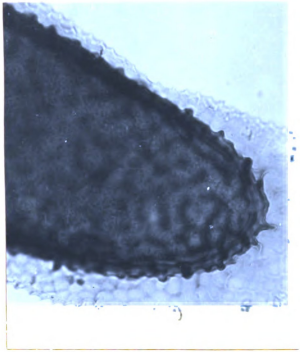


Fig. 28. Sessoblast - greater enlargement showing reticulated lamella and elongated tubercles

elongate along the peripheral portions of the capsule. He also states that these tubercles "show specific character in number, distribution, shape and size." The tubercles on the Michigan sessoblasts (Fig. 26 through 28) appear to be particularly well developed in comparison to Toriumi's Fig. 4, No. 11. They are often bent or twisted and may sometimes be seen to extend out over the lamella. These tubercles are seen greatly enlarged in the photomicrograph, Fig. 28.

Hyalinella orbisperma (Kellicott) 1882 New Designation

Colony

The colony architecture of this species is variable. The Barry County specimens are dendritic with repeated dichotomous branching, and the branches are longer and more sinuous than in other Hyalinella specimens I have collected. In addition, the Barry County colonies are often free of the substrate or only loosely attached to it or to clumps of algae, moss, or detritus. The zooecia, in the basal area of a colony, are frequently intertwined. Colonies collected in this county are luxuriant and irregular in aspect (Fig. 29). The specimens from Otsego and Iosco Counties are more compact and lack free branches (Fig. 30).

The polypides in the Barry County colonies are arranged in distinct clusters of four to eight individuals. In specimens obtained from two other counties, the polypide groups generally include somewhat fewer individuals. The groups in a linear sequence incline, alternately, in opposite directions (i.e., one group leans to the right, and the next group leans

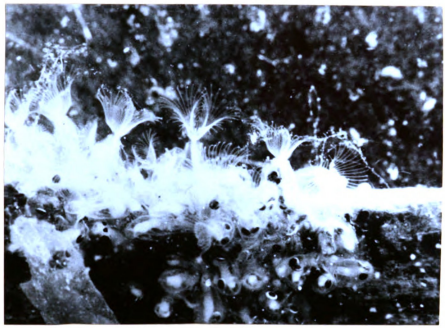


Fig. 29. Colony of Hyalinella orbisperma from Barry County (note circular statoblasts in conical zooecia)

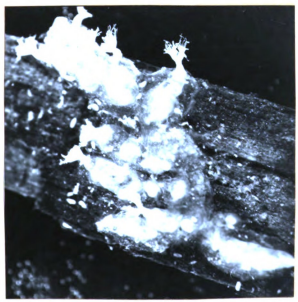


Fig. 30. Colony of Hyalinella orbisperma from Iosco County (zooecia less elongate than in Fig. 29)

to the left in sequence). Except for this slight lateral inclination, individuals in a cluster are essentially vertical. Only terminal groups are inclined forward at approximately a 45 degree angle to the substrate.

The polypide groups are connected by a basal extension of the proximal zooecium in each group. This zooecial extension resembles the pseudostolon characteristic of the genus Stolella. The elongated zooecium is well developed in the Barry and Iosco County specimens; thus, the separated clusters of polypides are readily apparent. The connecting zooecium is not so elongate in the Otsego County specimens.

Except for the elongation of the zooecium of the proximal polypide, successively budded individuals in a group remain contiguous (i.e., their zooecia do not elongate, so they remain in linear sequence, conjoined to the individual from which they were budded). Often the individual zooecia in a group project out from the basal gelatinous matrix of the colony in the form of elongated cones. This is most evident in the Barry County specimens (Fig. 31). The Iosco form has short conical projections, whereas the surface of the Otsego form is nearly flat, as the zooecial tips do not (or rarely) project above the level of the swollen coenecium. The colonies discovered in the latter two counties have a growth form similar to Hyalinella punctata. Otsego and Barry County specimens appear to represent two extremes of colony form, while the Iosco specimens are intermediate.

Kellicott (1882) states that the branches of Plumatella (Hyalinella) orbisperma appear to remain distinct and very dense. The polypides are distinct yet compact, with the coenecium extending to the right and left of the point of origin in two or three "slightly radiating, sparingly branched, trunks." He states further that the polypides are somewhat in clusters and often opposite. The recently collected specimens conform in general, to Kellicott's brief description. The polypides have deeply indented lophophores and a large epistome, often faintly brown at the base.

Zooecia

The zooecial tips are flat and obscure, or round, or short and elongate cones. Only the proximal zooecium of a group is much elongated. The zooecial diameter varies from 0.6 mm. to 2.45 mm., while the zooecia of the Barry County specimens are rarely wider than 1.4 mm. The zooecium is thickest in the Otsego and Iosco County specimens.

Ectocyst

The ectocyst is gelatin-soft and hyaline. The thickness of the ectocyst is highly variable. Kellicott (1882) states that in his form the ectocyst is not so thick as in Plumatella vitrea (synonym of Hyalinella punctata). The ectocyst is not incrusted and only in the Otsego County specimens are lamellations visible in the orifice region of the zooecia. Agglutination of zooecial ectocysts is frequent in the dense repent specimens, but not so frequent even in the intertwining branches of the Barry County Coenecia.

Septa

Septa are lacking. The polypides upon retraction actually come into physical contact, the zooecia being confluent.

Tentacles

Tentacle numbers (maxima, minima, and averages) are given in Table 5. The maximum number, 67, was recorded several times for the Barry County polypides. The minimum number of 47 was recorded for a young colony with only two polypides. The average number of tentacles for polypides counted during the present study is 60.3. This number coincides perfectly with the number of 60 given by Kellicott for Plumatella (Hyalinella) orbisperma.

Statoblasts

Only the floatoblast is present. Colonies from Barry County were observed for four years, summer and fall, and sessoblasts were not found. The floatoblasts are nearly round (Fig. 32 and 33). The ratio of length to width varies from 1:1.01 to 1:1.22 (Table 5). Only one of the measured statoblasts has a ratio of 1:1.22. All others have ratios of 1:1.17 or below. Kellicott (1882) states that the statoblasts of Plumatella (Hyalinella) orbisperma are nearly circular, 0.320 mm. by 0.343 mm., and that the greatest variation between length and width was 0.325 mm. by 0.360 mm. These length and width figures give Kellicott's statoblasts a ratio variation 1:1.08. The statoblasts are almost equally convex on both faces, again in agreement with Kellicott's description. The peak of the ventral capsular convexity is somewhat pointed in

TABLE 5. *Hyalinella orbisperma* and *Hyalinella punctata* measurements.

Source from which measurements were taken	Number of measurements	Whole statoblast				
		Length in mm.	Average length	Width in mm.	Average width	Ratio length to width
Hyalinella orbisperma						
Present study	156	0.30; 0.37	0.34	0.28; 0.35	0.31	1:1.01;1:1.22 Av. 1:1.08
Kellicott (1882)			0.34		0.32	Av. 1:1.07
Hyalinella punctata						
Present study	84	0.54; 0.61	0.59	0.35; 0.40	0.38	1:1.55
Kraepelin (1887)		0.40; 0.54				1:1.2;1:1.5
Annandale (1910) Vorstman (1928)						
var. *densa*		0.35		0.23		1:1.3
var. *prostata*		0.60				2:1
Rogick (1940)	56	0.49; 0.60	0.54	0.33; 0.45	0.37	Av. 1.46
Lacourt (1951)						
large form		0.43; 0.46		0.28; 0.30		
small form		0.30		0.23; 0.30		
Toriumi (1955)		0.37; 0.49	0.42; 0.44*	0.28; 0.34	0.30; 0.31*	1.24;1.56

* Toriumi gives his average as a range. Therefore it can only be compared approximately with other averages.

Number of measurements	Capsule					Tentacle numbers
	Length in mm.	Average	Width in mm.	Average	Ratio length to width	
156	0.25; 0.34	0.28	0.23; 0.32	0.26	(Av. 1.07)	48,67 (Av. 60.3)
84	0.39; 0.41	0.40	0.28; 0.30	0.29	1:1.38	46,65 (Av. 57) 40,60 30,40 28 50
56	0.31; 0.40	0.35	0.25; 0.31	0.27	1.30	35,55
	0.27; 0.34	0.30; 0.31*	0.22; 0.27	0.24; 0.25*	1.13,1.41 (Av. 1.25, 1.29)*	42,58

Hyalinella orbisperma

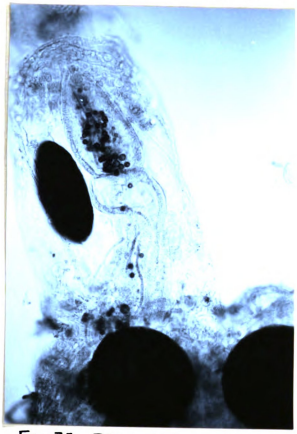


Fig. 31. Elongated zooecium with rounded tip.



Fig. 32. Typical statoblast dorsal surface



Fig. 33. Circular statoblast - (greater enlargement)

contrast to the rounded dorsal convexity.

The float is narrow on both the dorsal and the ventral sides of the statoblasts of Hyalinella orbisperma. The following are the average lengths and widths of the naked capsule: dorsal side, 0.225 mm. and 0.215 mm.; ventral side, 0.25 mm. and 0.24 mm. H. orbisperma (includes Plumatella orbisperma) and Stephanella hina (Oka, 1908; Toriumi, 1955b) are the only forms with circular statoblasts, and the measurements and appearance of the statoblasts of the two agree in general. However, Oka's drawing (Plate x, fig. 5) of a statoblast of S. hina shows more dorsal float coverage than is present in H. orbisperma. He states however that the width of the float varies rather markedly while the size of the statoblast remains more constant. Fine mammillations cover both the dorsal and ventral capsules of the statoblasts of H. orbisperma, and their periphery is entire.

The coenecia of colonies of H. orbisperma were frequently filled with statoblasts in August and September. I have only seen a comparable concentration of statoblasts in colonies of P. repens.

Diagnostic Discussion

The colonies collected during the present study agree with the characteristics recorded by Kellicott (1882) in his brief description of Plumatella orbisperma. The taxonomic position of P. orbisperma has been uncertain for nearly 80 years. Rogick and Van der Schalie (1950) mention the need for a clarification of the status of this species, and the infor-

mation acquired during the present study makes a taxonomic revision of this form necessary. The species must be placed in the genus Hyalinella. A revision is dictated by the following characteristics: polypides often in groups; swollen or inflated ectocyst; ectocyst always without incrustation; absence of septa between polypides and groups of polypides; hyaline and non-sclerotized ectocyst; propensity for contiguous ectocysts to agglutinate; absence of the sessoblast. Plumatella repens often lacks septation, but the other characters are not in agreement with P. repens characters. Another form with which Hyalinella orbisperma might be compared is Stephanella hina. As already stated, the circular floatoblasts are what make this comparison appealing. Also the ectocyst is thick and hyaline as in S. hina. However, the ectocyst in S. hina is very soft, and this species has a more clearly defined stolon-like region than does H. orbisperma. The polypides are single vertical buds not forming the budding clusters in the same manner as H. orbisperma. Also the tentacles of S. hina number only 28 to 46. Finally, S. hina produces sessoblasts. Gelatinella toanensis (Toriumi, 1955e) has an irregular nodular colony form and has elongate conical zooecia. These characteristics are manifest in the Barry County specimens, however, the typical polypide clusters are lacking in this form. In addition the elongated statoblast with the capsular appendage and the presence of the sessoblast discourage further systematic comparison with the Michigan specimens. The evidence thus strongly favors placing the orbisperma form

in the genus Hyalinella. The free or open branches of the Michigan specimens sometimes resemble the branches of Toriumi's (1955c) Hyalinella minuta. However, the low tentacle numbers, the oval floatoblast, and the clavate zooecia of his form are not found in may specimens.

The most difficult consideration regarding Hyalinella orbisperma was whether it should retain full species status, or whether it should be combined with Hyalinella punctata. The statoblast has received particular emphasis in fresh-water bryozoan taxonomy, and H. orbisperma varies from H. punctata chiefly with regard to the statoblast. The Michigan H. punctata statoblasts are large. However, other investigators, as Kraepelin (1887) and more recently Lacourt (1951), have found both large and small statoblasts in H. punctata colonies. Lacourt found two sizes of statoblasts in the same colony. However, whether large or small, the shape of the H. punctata statoblast disagrees with that of H. orbisperma (Table 5). Statoblasts of H. punctata are broadly oval to elongate oval in shape, while those of H. orbisperma range from circular to nearly circular in form.

Kraepelin's (1887) Plumatella punctata var. densa has bigger and broader statoblasts, while his smaller var. prostrata is narrower. Vorstman's data are contrary to Kraepelin's, showing the larger var. prostrata form as being narrower in proportion than the var. densa statoblasts. Vorstman (1928a) and Toriumi (1955d) both mention the serrated peripheral margin on H. punctata which is essentially lacking

on the statoblast of the orbisperma form.

Viewed from the side, the statoblasts of H. orbisperma are approximately equally convex, with the ventral capsule somewhat pointed. Toriumi's (1955d, Fig. 3) illustration of the side view of H. punctata statoblasts shows nearly equal convexity of the dorsal and ventral valves, but the capsules are not as greatly inflated and the ventral side lacks the pointedness of the statoblasts of H. orbisperma. The Michigan H. punctata statoblasts are somewhat more flattened on the dorsal surface and lack the pointed ventral capsule. Rogick (1940; Plate II, Fig. 6-8) shows a typical statoblast of H. punctata with a decidedly flattened dorsal surface. Her figures and illustrations indicate a wide coverage of the capsule by the float, particularly on the dorsal side. Such extensive float coverage is found in the statoblasts of the Michigan H. punctata colonies. Thus there is proportionately much less total float area on the statoblasts of H. orbisperma. Toriumi (1955d; Fig. 3) shows less float coverage of H. punctata statoblasts than is evident in American, European (Kraepelin, 1887), or Javanese (Vorstman, 1928a) specimens. The suture is evident on the extremity of the float as Toriumi (1955d) has described it for H. punctata, and the capsule likewise consists of two layers.

The salient features in the evaluation of H. orbisperma are manifest in the statoblasts. Their smaller size would not be a criterion for giving this form a species status. However, the following combination of characteristics are definitive:

nearly circular, instead of oval, with length to width ratios not overlapping those of H. punctata; fairly strong and equal convexity of capsules with ventral capsule pointed; a considerably smaller float area than H. punctata; absence of peripheral serrations.

The distinctiveness of the statoblasts of H. orbisperma justifies a species status for this form. In addition the range of the colonial phenotype is broader than in H. punctata, since it includes the following characters of the Barry County specimens: the much elongated conical zooecia; sinuous form; large widely separated bud clusters; and often a loose attachment to the substrate. The constancy of the characters possessed by colonies (and statoblasts) in Barry County, over a four year period is supportive evidence for maintaining the species status of this form.

Future information may dictate a reduction to subspecific rank. If colonies are found with both the H. orbisperma statoblasts and the typical H. punctata statoblasts, then H. punctata will bear a similarity to Plumatella casmiana, a form deriving species status largely from the presence of two types of floatoblasts. Such a discovery would necessitate a revision of the species Hyalinella punctata. If, on the other hand, sessoblasts should be found in H. orbisperma colonies, then a comparison with Stephanella hina would perhaps again be demanded.

Diagnostic Revision

Hyalinella orbisperma (Kellicott) 1882 New Designation

Plumatella orbisperma Kellicott 1882

Colony

Sinuous, dendritic, entangled, sometimes loosely attached to substrate, forming irregular globular or elongated masses, or dense, massive, flattened wholly repent colonies. Branches and zooecial tips often agglutinated where in contact. Zooecia most often in distinct clusters with four to eight polypides in each group. Groups separated by usually distinct, long zooecial extensions from proximal individuals in each group. Branching dichotomous, or lateral from a single main coenecial axis. Branches short or longer in sinuous colonies with dichotomous branching.

Zooecia

May be short, flattened, and obscurely visible, but most often projecting as short or long cones from the coenecial mass. Zooecia in groups. Lamellations sometimes evident in zooecial tip region in massive colonies.

Ectocyst

Hyaline, without incrustation, moderately thick and gelatin-soft. Tends to greater thickness in the basal regions of the colony.

Septa

Not evident. Polypides in groups, upon retraction, may come into physical contact.

Tentacles

Tentacles number 47 to 67.

Statoblasts

Only floatoblasts present. Circular to nearly circular. Equally and often strongly biconvex with ventral capsule tending to be somewhat pointed. Narrow and even float coverage around the capsule on both sides; only slightly greater on dorsal side. Mammillations even and complete dorsally and ventrally. Peripheral serration largely lacking.

Hyalinella punctata (Hancock) 1850

Colony

This species was not found frequently in Michigan. The collection colonies are typically soft and hyaline with branches extremely short and composed usually of not more than four to six polypides, as described by Hancock (1850). In form they are often comparable to those described by Rogick (1940; Plate V, Fig. 25) and Toriumi (1955d; Fig. 1). Both the compact dense colonies and the linear dendritic colonies were found. In the former, numbers of short, contiguous and agglutinated branches produced luxuriant growth. Colonies growing on tree stumps in a bay on Gull Lake, Kalamazoo County, were observed for three years, and they were always linear in form, most often with short unilateral branches (Fig. 34).

Zooecia

The zooecial tips are either nearly flat or mostly obscured within the gelatinous coenecium, or slightly protuberant as

rounded or short conical projections. The polypides are sometimes in groups. Their contiguity obscures the individual distinctness of the zooecia. White dots were not always seen on the zooecial tips. The width of the main axis of linear colonies varied between 0.85 mm. and 1.62 mm. The width of the branches was between 0.82 mm. and 0.996 mm. These latter diameters are comparable to Rogick's (1940) data. She gives the average diameter as 0.86 mm. and the range as 0.71 mm. to 1.09 mm.

Ectocyst

The ectocyst may be only somewhat thicker than Plumatella repens or extremely thick or swollen in appearance. Toriumi (1955d) considers that variations in ectocyst thickness are environmentally associated. The ectocyst is hyaline and transparent and, characteristically, lacks incrustation in Michigan specimens.

Septa

Septa are not present.

Tentacles

The tentacle numbers of the Michigan specimens vary between 46 and 64. The average is 57 and comparisons are given in Table 5. Hancock (1850) states that tentacles are not more 60 in number. Rogick (1940) gives somewhat lower figures for colonies collected in New York, as does Annandale (1910) for Indian specimens. Toriumi's (1955d) data and Kraepelin's (1887) data are most nearly compatible with the Michigan specimens.

Statoblasts

Statoblasts vary in size and in ratio as shown in Table 5. All measurements of the Michigan specimens agree closely with Rogick's (1940) data. Kraepelin divides Hyalinella punctata into two varieties, densa and prostata. He states that densa is the autumn form and that prostrata is the summer form. He also indicates that the statoblasts of densa are larger than those of prostrata, and that the length to width ratios differ. The large statoblasts from colonies collected in Michigan agree with Kraepelin's densa rather than with his prostrata. However, no seasonal distinctions were apparent as the Gull Lake colonies were producing these statoblasts as early as July 7. Hyalinella orbisperma produces small statoblasts, but they are circular, and they are not seasonal, as they were observed in both summer and autumn colonies. Vorstman (1928a, 1928b) has also found statoblasts of two sizes in Java, the specimens from East Java being only 0.26 mm. long. More recently Lacourt (1951) reports for the first time, finding statoblasts of two sizes in the same zoarium of colonies from the Netherlands. The ratios vary from approximately 1:1.2 to 1:1.5. The full significance of statoblast size and shape within the genus Hyalinella is not as yet fully apparent.

The suture of the float of the Michigan specimens usually shows an irregular serration, as Toriumi (1955d) has described. Mammillations are visible on the capsule surface, perhaps less apparent in the central portion. The float area on Michigan

Hyalinella punctata

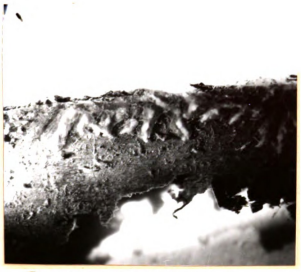


Fig. 34. Linear colony from Gull Lake, Kalamazoo Co., showing unilateral branching.



Fig. 35. Statoblast (Gull Lake, Kalamazoo Co.) dorsal surface (ends somewhat more pointed than usual)

Hyalinella punctata statoblasts is in agreement with Rogick's (1940) specimens, and it is proportionately much greater than the float area on statoblasts of Hyalinella orbisperma. The average lengths and widths of the naked capsule are as follows: dorsal side, 0.22 mm. by 0.19 mm; ventral side, 0.29 mm. by 0.23 mm. The dorsal surface of a H. punctata statoblast, taken from a colony collected in Gull Lake, is shown in Fig. 35. Several statoblasts obtained from Gull Lake colonies tend to be somewhat pointed at the ends.

Stolella indica Annandale 1909

Colony

Coenecia are entirely repent and open. Annandale (1909, 1910) states that he has not seen vertical or lateral branches. Rogick (1943) maintains that both vertical and lateral branches are present on the Pennsylvania specimens. The colonies collected during the present study have lateral branches, but lack vertical branches. Some of the lateral branches are perpendicular to the portion of the coenecium from which they arise. The individuals are oriented usually in groups of two separated often by an elongated pseudostolen-like zooecium. Several zooecial groups are sometimes separated by shorter pseudostolons. The elongated zooecium is clavate, and the tips are sharply elevated. A colony from Wintergreen Lake is shown in Fig. 36.

Zooecium

The clavate zooecia often bend sharply to the right or to the left. The zooecia are also tapered toward the tips. The



Fig. 36. Stolella indica colony

surface of the zooecia are often wrinkled (sometimes shriveled in the narrowest region of the pseudostolon), although this characteristic does not seem quite as well developed as in the specimens described by Rogick (1943). Rogick gives the zooecial pseudostolon lengths as between 1.4 mm. and 4.55 mm. Elongated zooecia of the Michigan colonies are sometimes 1.2 mm. to 5.0 mm. long measuring from the base of one pseudostolon to the base of the next pseudostolon. One elongated zooecium was found to be 6.0 mm. long. Rogick gives minimum and maximum diameter measurements of 0.09 mm. and 0.30 mm; the minimum and maximum diameter at the wider part of the zooecia varies between 0.33 mm. and 0.68 mm. The average diameters of the narrow proximal and widest distal portions of the zooecia are 0.17 mm. and 0.50 mm. respectively. However, Kenk (1949) reports on colonies of Stolella indica, obtained from a pond near Ann Arbor, that were identified for him and described by Dr. M. D. Rogick as being not so tapered as her Pennsylvania specimens. The colonies collected during the present investigation are somewhat wider than Rogick's (1943) specimens. The minimum zooecial diameters vary from 0.18 mm. to 0.40 mm., and the maximum diameter varies from 0.50 mm. to 0.90 mm. distally.

Annandale (1909, 1910) describes the zooecia as being emarginate at the distal end with a furrow proceeding proximally from this emargination. The furrow and emargination on the incrusted zooecia of the colonies from Wintergreen Lake are usually visible on each zooecium. The slight keel which

Rogick (1943) found on a few zooecia was not evident on my specimens. The tips of the lightly incrusted colonies from Wintergreen Lake are hyaline and transparent often for a distance of approximately 0.50 mm. proximal to the tip. This characteristic is clearly evident in Fig. 36. Rogick alludes to the transparency of the zooecial tips in the Pennsylvania specimens.

Ectocyst

Annandale describes the ectocyst as soft, colorless, and transparent. Two small unincrusted colonies show these characters well. The incrusted colonies from Michigan have a very delicate ectocyst, hyaline to faintly yellow in color. Rogick describes the coloration of the cuticle as yellow to amber. She also states the incrustation is gray to hyaline. The Michigan colonies also have a gray incrustation.

Septa

Annandale does not indicate that septa are present. However, Rogick noted crescentic or semi-circular septa in her colonies. No septa were found in the Michigan specimens.

Tentacles

The tentacle number given by Annandale is 30 to 35. Only eleven living polypides were present in my collections. The number of tentacles is somewhat higher than that given by Annandale, varying between 31 and 40.

Floatoblasts

Mature floatoblasts are not present. However two immature floatoblasts were removed from the zooecia. These appeared

very similar to those described by Rogick except that the float coverage appeared to be somewhat greater than in her specimens. Kenk (1949) records that Rogick found that floatoblasts from his collections had a greater float area than her Pennsylvania specimens.

Sessoblasts

Two of the colonies in my collection had developed from sessoblasts. Both valves of one of these sessoblasts were removed and measured as 0.54 mm. by 0.36 mm. The capsule measures 0.43 mm. by -.24 mm. These measurements are within the ranges given by Rogick (1943). The lamella, as in Rogick's specimens, is reticulated.

Stolella evelinae Marcus 1941

Colony

This species has heretofore been collected only in Brazil, and consequently this report represents the first record of Stolella evelinae for North America. The colonies were collected from Wintergreen Lake in Kalamazoo County. They are largely repent and usually tightly adherent to the substrate. However, at the edge of the substrate, zooecia are often only loosely attached, and the coenecia are sometimes coiled about small protruding splinters of wood. I have seen them encircling loosely compacted masses composed of filamentous algae, ephippia, old tendipedid cases, and detritus. The colonies are sometimes widely open, but several luxuriant colonies were collected. Branching is predominantly lateral, and occurs most often from the region of the zooecial group.

In one case, twin lateral branches had been given off in opposite directions from one zooecium.

The zooecia are arranged in groups of two, three, four or five. Groups of five zooecia occur only rarely in the Michigan specimens. Marcus (1941) shows (Plate XII, Fig. 52B and 56A) that the South American specimens are arranged in groups of two to four. He states that groups of three polypides are usual. Groups of polypides are separated from each other, characteristically, by a zooecial extension from the proximal animal of each group. In the Michigan specimens (Fig. 37 and 38), the polypide groups are directed upwards from the substrate at angles of between 60 degrees and 90 degrees. In the central portions of the colony, erect or nearly erect zooecia predominate. The erect orientation of the zooecia is characteristic of Stolella evelinae and Stolella agilis, both at present reported only from the Western Hemisphere. The Michigan colonies agree well with those described by Marcus.

Zooecia

The elongated zooecia, called pseudostolons, are characteristic of the genus Stolella. However, they bear a similarity to the zooecial extensions between polypide groups seen in the genus Hyalinella and this has prompted speculation by Marcus as to whether Stolella and Hyalinella are properly separated as genera. The pseudostolons (distance from base of one pseudostolon to the base of the next) except in terminal or peripheral regions, range from 1.0 mm. to 5.0 mm.

in length in the Michigan specimens. Marcus (1941) describes the vertical zooecia as 1.5 mm. in length or 2.5 mm. in length with tentacles evaginated. These figures are in excellent agreement with the Michigan specimens.

The zooecia are round, sometimes broadly rounded on the upper surface of repent zooecia. The zooecia taper only gradually toward their proximal end; however, in some cases this taper is more distinct. The diameter of the zooecia are somewhat variable, ranging between 0.24 mm. at the narrowest and 0.80 mm. at the widest. The average diameter at the proximal and distal ends respectively is 0.39 mm. and 0.58 mm.

Ectocyst

The ectocyst is delicate, hyaline, and transparent. It is flexible rather than gelatinous as in the genus Hyalinella. In some cases the outline of the ectocyst is scarcely visible, especially in the zooecia adherent to the substrate. Marcus states that his colonies are transparent and usually hyaline, but in older portions of the colony may be tinted a light yellow color. Incrustation is totally absent in the Wintergreen Lake colonies.

Septa

Septa are absent in this form and the endocyst may be observed passing through elongated zooecia from one polypide group to the next.

Tentacles

Marcus gives a tentacle number range of 44 to 64. He states the tentacles are white, and approximately 1.0 mm. in

length. The Michigan specimens vary in number between 46 and 65 (87 counts) with an average of 56. They are also white and are usually between 1.0 mm. and 1.2 mm. long in the case of healthy polypides.

Statoblasts

Only the floatoblast was seen in the Michigan colonies. Marcus was also unable to find sessoblasts. Marcus states that the minimum and maximum length of the Brazilian statoblasts is 0.323 mm. and 0.466 mm. and that the minimum and maximum width is 0.214 mm. and 0.29 mm. These measurements were taken on 100 statoblasts. The length to width ratios ranged from 1:1.26 to 1:1.91. The length to width range for 67 of the 100 measured statoblasts is 1:1.50 to 1:1.69. Essentially equal numbers of the remaining statoblasts were narrower and wider than those in the median range. The minimum and maxium lengths of the 54 measured Michigan statoblasts are 0.35 mm. and 0.41 mm. and the average is 0.39 mm. The ratios are 1:1.127 to 1:1.370. The capsules have an average length of 0.31 mm. and an average width of 0.24 mm. The ratio of length to width of the capsule is 1:1.29. Even though there were fewer measurements taken of the Michigan statoblasts than of the Brazilian, the data suggest that the South American statoblasts have a tendency to be narrower than those from Michigan. This narrowness appears to be primarily related to differences of statoblast width between the two forms rather than differences of length. The size and ratios of the Michigan specimens are however within the mathematical

Fig. 37. A portion of a colony of Stolella evelinae drawn from preserved specimens. Shows vertical groups of polypides and long tapered pseudostolon

Fig. 38. A portion of a colony of Stolella evelinae showing a branch growing parallel to the coenecial trunk from which it was derived. Some of the pseudostolons taper, others do not.

Fig. 39. Dorsal surface of a statoblast of S. evelinae

Fig. 40. Ventral surface of a statoblast of S. evelinae

Fig. 41. Release of a statoblast by a living polypide of S. evelinae through a vestibular pore.

Fig. 39

Fig. 40

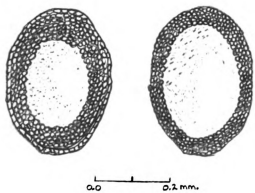


Fig. 41



Fig. 37

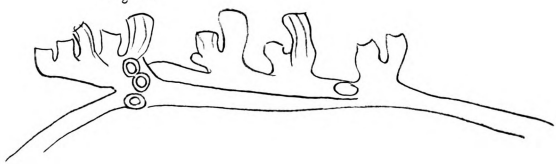
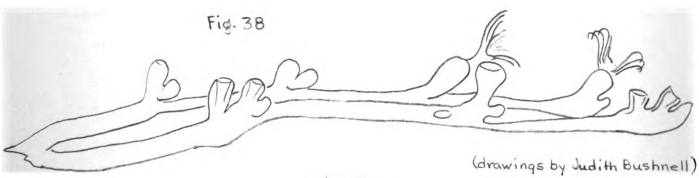


Fig. 38



(drawings by Judith Bushnell)

limits of the Brazilian samples. The tendency to somewhat greater width may prove to be an ecological variation.

The float coverage on the Michigan statoblasts agrees with that shown by Marcus (1941, Plate XII, Fig. 54B; 1942, Plate III, Fig. 9A and 9B) and is nearly the same on both sides. The average width of the float on the ends and sides of the dorsal surface respectively are 0.057 mm. and 0.037 mm.; and on the ventral side 0.045 mm. and 0.028 mm. The dorsal and ventral surfaces of a statoblast are shown in Fig. 39 and 40. The float encroachment on the dorsal surface of the capsule in Fig. 39 is somewhat greater than usual. It represents essentially the maximal float coverage found in the Michigan specimens.

Mammillations are present on the dorsal and ventral capsule tending to be somewhat smaller at the center of the capsule. The suture is median and peripheral, and the dorsal and ventral capsule are equally convex as in Fig. 9B of Marcus. Statoblasts were observed being released through a vestibular pore (Fig. 41), and two zooecia were preserved in the process of releasing statoblasts. Marcus has described this process for both Stolella evelinae and Stolella agilis (1941, 1942).

Unidentified Specimen

A colony having the much elongated zooecia of the genus Stolella was collected from Wintergreen Lake. However, Lacourt (1948) reports that he has seen elongated zooecia in several species. Polypide groups are occasionally evident. The zooecia lack incrustation and vary from hyaline to yellow in

color. They are often sharply elevated. The floatoblasts are similar in size to Plumatella repens with somewhat more float coverage on both surfaces than is usually found in that species. The author has not identified this colony as it is severely fragmented. Future collecting may make an identification possible. The colony may be an atypical Stolella sp. colony. The statoblasts are similar to Stolella agilis of Marcus (1942), in form, float coverage, and measurements.

ECOLOGICAL DISCUSSION

With the exception of one sphagnum bog in Luce County and a small marl pond in Missaukee County, Bryozoa were collected from each body of water sampled. As Brown (1933) and Hurrell (1927) found, Bryozoa are present in nearly every lake, stream, and pond.

Few attempts were made to collect colonies from depths of greater than eight feet. However, several investigators have found Bryozoa in deeper water. Zschokke (1906) states that Fredericella sultana was common at depths of 20 to 170 meters and that he collected a variation of this species at of depth of 214 meters in Lake Lucerne. Eggleton (1952) claims that years of collecting in Douglas Lake, in Cheboygan County, Have never disclosed "rich populations" of Bryozoa. He indicates that only 20 colonies of Plumatella repens were taken from a depth of 15 feet in the interdepression benthic regions of Douglas Lake during one extensive study. Bryozoa were found abundantly in many lakes in Michigan during the present investigation. On several occasions, four species were found after little more than an hour of collecting. Six different species were collected from Sunset Lake in Kalamazoo County and from Gull Lake in Kalamazoo County. Seven species were found in Wintergreen Lake. However, Plumatella emarginata colonies were scarce in this lake, and only two small colonies of Fredericella sultana were found in 1957, but never in succeeding years. Colonies of this species transplanted to Wintergreen Lake did not survive. The eleven species of

Bryozoa found in Kalamazoo County represents what is probably the most species recorded for any county in the United States.

Considering the rarity of Stolella indica (two previous North American localities), Stolella evelinae (recorded only from Brazil), and Lophopodella carteri, it was unusual to find all of them in Wintergreen Lake. Their presence in a waterfowl sanctuary strongly suggests dissemination of statoblasts by water birds. Some of the water birds migrate from as far as Central and South America. deGuerne (1888) records that one valve of a Plumatella repens statoblast was found in mud on the web of a duck's foot. Harmer (1913) asserts that Garbini communicated that he had found a statoblast attached to a heron's beak. Brown (1933) found that a few statoblasts remained viable after passing through a mallard's digestive tract. Schlichting (1958) has demonstrated how algae may be transported by ducks. Thus the dissemination of statoblasts by birds is a plausible explanation for unusual distribution records. They may be disseminated for shorter distances by turtles and mammals. The author (unpublished research) has found that statoblasts of P. repens are retained in the dry fur of active Microtus pennsylvanicus for as long as seven hours, when the statoblasts have become adherent to the fur while the animal is walking in water.

Physical Factors

Bottom composition

In habitats where the bottom type was predominantly marl, such as Dickenson Lake on Drummond Island, bryozoan colonies

were almost never luxuriant, and they were usually poorly developed and small. A fragment of a P. repens colony and several small colonies of F. sultana were found in this lake. With one exception, Fredericella sultana was found in every habitat where marl was a predominant part of the bottom composition. In several lakes where the bottom was composed largely of marl, F. sultana was the only species found. Paludicella articulata and Plumatella emarginata were rarely found in situations where this condition prevailed. These species were found several times in situations where the bottom was almost wholly organic in composition. However, both species were considerably more frequent at sites where the bottom was constituted of sand or a sandy-organic mixture. Ward (1896) discusses the scarcity of plant and animal growths in marl lakes. P. repens, Hyalinella punctata, Hyalinella orbisperma, and Cristatella mucedo were collected more frequently at sites where an organic or partly organic bottom was present.

Bryozoan species tended to be more luxuriant in the type of habitat where they occurred most often. The presence of Fredericella sultana in several strongly marl lakes did not suggest a preference by the species for this type of habitat. The colonies living in such habitats were small and almost never luxuriant. The tendency for F. sultana to be more frequently encountered than other forms in habitats of this type, is perhaps attributable to a greater tolerance by this species to extreme chemical conditions or a greater

ability to utilize the planktonic organisms common to this type of environment.

Bryozoa were rarely found growing on the lake bottom regardless of substrate type. P. articulata, F. sultana, and P. repens were found growing on the under side of dead leaves which were resting lightly on sandy or organic bottoms. F. sultana colonies were frequently found attached to dead filamentous strands of plant tissue. Forel (1884) and Otto (1921) have found F. sultana growing on the bottom mud or "ooze". Luxuriant tufts of F. sultana were anchored in the sand of the outlet of Gull Lake, Kalamazoo County (Fig. 42). A large P. articulata colony was found attached to the leather of the inside toe region of an ice skate, which was sunk in the bottom ooze of a muddy stream.

Current and water movement

Water movements appear to be significant in the distribution of some of the fresh-water Bryozoa, particularly in the case of Plumatella emarginata. Allman (1856) perhaps suggests this preference for flowing water by P. emarginata more clearly than subsequent investigators when he states, "Plumatella emarginata, unlike most of the other fresh-water Polyzoa, delights in rapid rivulets, though it also flourishes luxuriantly in the more quiet waters of lakes." In collections from 30 streams (creeks and rivers) in Michigan, P. emarginata was found 19 times, while it was found only 10 times in lakes and once in a pond. Plumatella repens, in contrast, was collected in 83 of the 122 collection areas, but was found in only 10

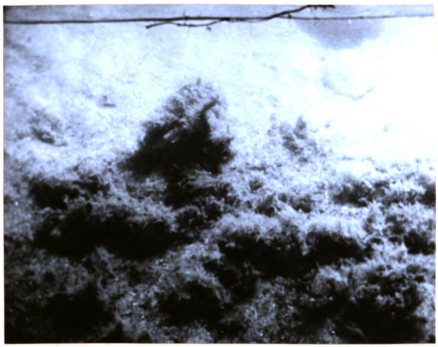


Fig. 42. Dense tufts of Fredericella Sultana adherent to the Sand of the Gull Lake outlet.

of the 30 streams, in 65 Lakes, five ponds or marshes and three roadside ditches. Also, the most luxuriant colonies of P. emarginata were found in lotic situations while the more profuse colonies of P. repens were found in lentic situations. Plumatella repens was found in four of the six ponds and marshes, and it was the only species obtained from three ditches. Plumatella repens thus shows a preference or tolerance for each type of lentic habitat.

Paludicella articulata, found in 44 of the 122 collection areas occurred in 13 streams, 30 lakes and in one marsh. This species was the second most common species in streams. Fredericella sultana occurred 11 times in streams, but it was found in 58 lakes and ponds. However, dense growths of F. sultana were frequently encountered along wave-washed shores of lakes, and Borg (1941) has found this species and P. emarginata in the agitated water under sluice gates. I found luxuriant tufts of F. sultana anchored in the sand of the Gull Lake outlet. These colonies were continually disturbed by abrasive sand and by waves which were washed over them when power boats passed. Hyalinella orbisperma and Hyalinella punctata were found essentially in the quiet waters of protected bays and ponds. Hyalinella orbisperma has been found only in ponds. The pond from which luxuriant colonies of H. orbisperma were frequently collected is shown in Fig. 43. Large colonies of Pectinatella magnifica, a species structurally unsuited for moving water, were found in the slowly flowing marginal waters of the St. Joseph and Thornapple Rivers.



Fig. 43. Pond in Barry County where luxuriant colonies of Hyalinella orbisperma were collected.



Fig. 44. Hall Lake, Barry County, where colonies of Pectinatella magnifica were abundant

Colonies of P. magnifica were extremely abundant and luxuriant in Hall Lake, Barry County during July and August of 1958. Growths of this species could be found on nearly every fallen branch and tree in one portion of the lake. The site at Hall Lake where these colonies were collected by Dr. T. W. Porter and the writer is shown in Fig. 44.

Comparisons may be drawn between Jewell's (1935) study on Wisconsin sponges and the present study on Bryozoa. Spongilla fragilis and Ephydatia (Meyenia) mulleri like Plumatella emarginata in the present study, were encountered more frequently and abundantly in flowing water. Spongilla lacustris, like Plumatella repens or Hyalinella punctata, and Hyalinella orbisperma, was found more often in quiet water.

Temperature

There are variations among the Bryozoa with respect to temperature tolerance. Fredericella sultana has been most frequently reported from colder waters. Houghton (1860) found it in December and January and was the first to suggest that the species was perennial. Forel (1884) reports it from the depths of sub-alpine lakes with temperatures of 4 to 9 degrees centigrade, while Lampert (1899) declares that F. sultana was the only bryozoan positively known to live beneath the ice. Wesenberg-Lund (1907) reports that he found it in a shallow creek in Greenland where the temperature was regularly 9 or 10 degrees centigrade, and Brown (1933) states he collected the species in the Huron River between December and March at temperatures as low as 5 degrees centigrade.

F. sultana was found in even colder water during the current study. Holes were made in the ice of the Gull Lake outlet from December through March, and living colonies were found each month approximately one foot below the ice where the temperature was as low as 1.5 and 2 degrees centigrade.

Brown reports that polypides of P. repens had apparently all died when the temperature fell to 6 degrees centigrade. Comparable observations were made by the writer on colonies of P. repens and Paludicella articulata in Burke Lake. Budding ceased in P. repens at 9 degrees centigrade in Burke Lake. The germination of several statoblasts in late September, or early October, at different locations on Burke Lake, resulted in colonies with 3 to 12 individuals. However, when the temperature fell below 9 degrees centigrade, the colonies failed to bud additional polypides, even though some of them remained alive for an additional two to four weeks. Living Cristatella mucedo colonies were found at a temperature of 6 degrees centigrade in Hall Lake, Barry County. Marcus (1934) reports that Lophopus crystallinus survived the winter in Europe living at temperatures of 5 to 8 degrees centigrade for weeks. For much shorter periods of time, the species has survived a temperature of 0 degrees centigrade.

Records for high temperature tolerance are not so plentiful. Brown reports that Plumatella may be found at temperatures of as high as 30 degrees centigrade in ponds and lakes. The author has found P. repens, Lophopodella carteri, and C. mucedo at temperatures of 32 degrees centigrade in Wintergreen

Lake. P. repens was found in a roadside ditch with a temperature of 36 degrees centigrade. Small colonies of P. repens and Plumatella fruticosa were found in 37 degree centigrade water in a shallow two inch deep basin at the margin of Otis Lake in Barry County. This temperature is the highest reported in the field for species of fresh-water Bryozoa. Numbers of other small animals (notably tadpoles) in the vicinity of the colonies were dead. The leech, Macrobdella sp., was the most abundant living animal.

Chemical Factors

P. fruticosa, in 10 collections, was present four times in water with a decidedly yellow or yellow-brown color. P. repens was obtained from colored water on two occasions. Bryozoa were collected from water ranging in pH from 5.7 to 10.2. In most cases the average pH of the habitats in which each of the species were living was between 7.9 and 8.2. The lowest recorded pH (5.7) was for Clark Lake, Chippewa County, P. fruticosa was found. The average pH of the habitats in which this species occurred is somewhat below 7.0, while the average for Hyalinella orbisperma, with only three occurrences, is 7.3. Tanner (1932) found Fredericella sultana in lakes in Utah with a pH range of 5.3 to 5.8. Cristatella mucedo, Lophopodella carteri, and P. repens were all found at sites in Wintergreen Lake where the pH was as high as 10.2.

Bryozoan colonies were collected from lakes with bicarbonate totals of 20 to 240 ppm. P. fruticosa was found at several sites where some of the lower readings were taken,

while P. repens, C. mucedo, L. carteri, and F. sultana were found at sites with a high alkalinity. Bicarbonate determinations were not made at each collection site. The data are therefore of limited value, and serve only to implement the pH data.

Pollution was given no special emphasis during the current research. Colonies of Paludicella articulata were abundant on stones, in Cranberry Creek, which were surrounded by numerous cow pats. Rogick and Brown (1942) obtained P. repens from a stream in Puerto Rico where pollution was evident. During the present study dense colonies of Plumatella emarginata were collected from the Kalamazoo River near the town of Augusta. The colonies were only about 300 feet downstream from where industrial chemical wastes were entering the river. Richardson (1928) found no Bryozoa in collections from a pollutional zone of the Middle Illinois River. However, in the next, or sub-pollutional zone, he did discover Plumatella fruticosa, along with tendipedidae, leeches, and Sphaeriidae. Much farther downstream, in clearer water, he collected other Bryozoa such as Pectinatella magnifica.

Biological Associations

Botanical

Plants which were found in association with Bryozoa are listed in Table 6. Intimate associations (i.e., where the plants were either in direct contact with the Bryozoa or at least within two cm. of them) are indicated by a Z. The number preceding the Z indicates the number of times that this

TABLE 6. Plants found in association with Bryozoa

The number in parenthesis is the number of times the plant was found in association with the bryozoan.

The number in combination with the letter Z indicates the number of times the plant and bryozoan were found in intimate association (i.e., in physical contact or within two cm. of each other).

TABLE 6.

Plants	Plumatella repens	Plumatella fruticosa	Plumatella emarginata	Hyalinella punctata	Hyalinella orbisperma	Fredericella sultana	Paludicella articulata	Pectinatella magnifica	Cristatella mucedo	Lophopodella carteri	Stolella indica	Stolella evelinae
Chlorophyta												
Bulbochaete sp.	(2)	(2)	(1)			(2)		(1)				
Chaetophora sp.	(1)					1Z						
Chaetophora elegans	(1)					1Z	(1)					
Chaetophora incrassata	(4) - 1Z	(1)	(1)				(1)					
Chaetophora pisiformis	(1)	(1)					(1)		(1)			
Chara sp.	(16) - 1Z	(1)	(1)			(11)	(6)		(4) - 2Z	(1)		
Chara fragilis	(1)					1Z			(2)			
Chara vulgaris						(1)	(1)					
Cladophora sp.	(8)	(1)	(2)	(1)		(4)	1Z					
Cladophora callicoma							(1)					
Cladophora crispata	(1)	(1)	1Z				1Z			1Z		
Cladophora fracta									(1)			
Closterium sp.	(1)			(1)		(1)						
Coleochaete sp.		(1)	(1)			(1)	(1)					
Cosmarium circularis				(1)								
Crucigenia sp.				(1)								
Gloeocystis sp.	(1)						(1)	(1)				
Gloeocystis ampla	(1)						1Z		(1)			
Gongrosira sp.							1Z					
Hydrodictyon sp.			1Z			1Z						
Hydrodictyon reticulum	(1)		(1)									
Mougeotia sp.	2Z	(3)							(1)			
Nitella tenuissima	(1)					1Z						
Oedogonium sp.	(8) - 3Z	(1)	(4) - 1Z	1Z		(7) - 3Z	(5) - 2Z	(1)		1Z		
Ophiocytium sp.		(1)										
Pediastrum sp.						(1)						
Protococcus viridis	(1)		(1)	(1)			(1)					
Rhizoclonium sp.	(5) - 1Z	(2) - 1Z	1Z	(1)		(1)	(2)	(1)	(1)			(1)
Rhizoclonium fontanum	(1)	(1)	3Z	1Z			(3) - 1Z		(1)	1Z		
Rhizoclonium hieroglyphicum	(2)					(3) - 1Z	(2) - 1Z			1Z		

TABLE 6. (continued)

Plants	Plumatella repens	Plumatella fruticosa	Plumatella emarginata	Hyalinella punctata	Hyalinella orbisperma	Fredericella sultana	Paludicella articulata	Pectinatella magnifica	Cristatella mucedo	Lophopodella carteri	Stolella indica	Stolella evelinae
Chlorophyta												
Rhizoclonium Hookeri	1Z		(1)			(1)	1Z		(2)			
Scenedesmus armatus				(1)								
Scenedesmus bijuga				(1)								
Scenedesmus incrassatulus				(1)								
Spirogyra sp.	(5) - 1Z	(1)	(2)	(1)		(4)	(1)		(1)			
Staurastrum sp.	(2)	(1)						(1)				
Stigeoclonium sp.			(1)									
Ulothrix sp.	(1)											
Vaucheria sp.	(1)		(1)			(1)			(1)			
Vaucheria geminata	(1)											
Volvox sp.	(1)								(1)			
Zygnema sp.	(5) - 1Z					2Z	(2)					
Chrysophyta												
Synura sp.	(1)					(1)						
Tribonema sp.	1Z	(1)				(1)				(1)		
Diatoms												
Amphora sp.		(2)		(1)		12Z	7Z		(1)			
Cocconeis sp.						(1)	(1)					
Cymbella sp.	(1)	1Z				(1)			(1)			
Fragillaria sp.	(2)	(1)		(1)		1Z						
Gomphonema sp.	(2)	(1)				(2)	(1)					
Melosira sp.	(1)		1Z				(2) - 1Z					
Navicula sp.	(3)	(1)		(2)		(3)	(1)					
Phoecosphenia curvata						1Z						
Stephanodiscus sp.												
Synedra sp.	(1)			(1)		(1)						
Tabellaria sp.	(2)					1Z						
Diatoms (mixed)	(6) - 1Z	(1)				(6) - 4Z	8Z		(1)			
Pyrrhophyta												
Ceratium sp.	(1)							(1)				

TABLE 6. (continued)

Plants	Plumatella repens	Plumatella fruticosa	Plumatella emarginata	Hyalinella punctata	Hyalinella orbisperma	Fredericella sultana	Paludicella articulata	Pectinatella magnifica	Cristatella mucedo	Lophopodella carteri	Stolella indica	Stolella evelinae
Cyanophyta												
Amphithrix sp.	(1)					(2)						
Anabaena sp.	(1)	(1)				(2) - 1Z	1Z		(1)			
Anabaena affinis	1Z								1Z	1Z	1Z	
Aphanizomenon flos-aquae			(1)			(1)						
Aphanothece sp.	(1)					(1)						
Calothrix sp.	(5)		(2) - 1Z			(4) - 1Z	(2)					
Calothrix epiphytica	(2)					(2) - 1Z	(2) - 1Z					
Calothrix minima						(2) - 1Z	1Z					
Chroococcus sp.		(1)										
Coelosphaerium sp.	(2)		(1)				(1)	(1)				
Dicothrix sp.	(1)	(1)	(2)			(5)	(1)					
Dicothrix gypsophila	(1)					1Z	(2)					
Dicothrix Hosfordii	(6) - 1Z	(1)				(2) - 1Z	(1)		(1)			
Dicothrix Orsiniana	(1)	(1)										
Gloeotrichia sp.	(13)	(2)	(2)			(8) - 1Z	(6) - 1Z		(4)			
Hapalosiphon sp.	(1)		1Z			(1)						
Lyngbya sp.	(4)		(2) - 1Z			(3) - 2Z	(3)					
Lyngbya Hieronymusii	1Z									1Z		
Microcystis sp.	(1)						(1)	(1)	(1)			
Nostoc sp.	(2)					1Z						
Oscillatoria sp.	(3) - 1Z	(1)	1Z			(1)	(2) - 1Z					
Oscillatoria angustissima	1Z		1Z							1Z		
Oscillatoria lacustris	1Z		1Z							1Z	1Z	
Oscillatoria limnetica												
Oscillatoria tenuis	(1)					(5) - 2Z	1Z					
Phormidium sp.			(1)									
Plectonema sp.						(1)	(1)					
Plectonema Wollei	(1)					1Z	(1)					
Rivularia sp.	(3)	(1)	(1)				(3)	(1)	(2)			
Rivularia haematites			(1)			(1)	(1)		(1)			

TABLE 6. (continued)

Plants	Plumatella repens	Plumatella fruticosa	Plumatella emarginata	Hyalinella punctata	Hyalinella orbisperma	Fredericella sultana	Paludicella articulata	Pectinatella magnifica	Cristatella mucedo	Lophopodella carteri	Stolella indica	Stolella evelinae
Cyanophyta												
Sacconema rupestre	1Z						(1)					
Stigonema sp.	(2) - 1Z	(1)		1Z		1Z						
Stigonema mamillosum						(1)						
Tolypothrix sp.	(6) - 1Z	(1)		(1)		(5) - 2Z			(1)			
Tolypothrix distorta			(1)								(1)	
Tolypothrix lanata	(2) - 1Z		1Z			1Z				1Z	1Z	
Tolypothrix limbata						1Z						
Tolypothrix tenuis	(3)		(2) - 1Z			2Z	(2) - 1Z		(1)			
Rhodophyta												
Batrachospermum ectocarpum		1Z										
Batrachospermum moniliforme	(1)		(1)	(1)		1Z	(1)					
Sulfur Bacteria	(2) - 1Z			(1)		(2)						
Fungi												
fungal spores	(1)					(1)			(1)			
Saprolegnia sp.		(1)	(1)									
Bryophyta												
Drepanocladus sp.	(4) - 1Z	(1)			(1)	(4) - 2Z	(1)					
Fissidens sp.	1Z		(1)	1Z			(2) - 1Z					
Fontinalis sp.							1Z					
Riccia fluitans	(1)											
Terrestrial moss	(1)											
Pteridophyta												
Equisetum fluviatile form linnaeanum	1Z											
Salvinia rotundifolia	(1)											
Spermatophyta												
Alisma plantago-aquatica	2Z								(1)			
Brasenia Schreberi	(4)	(2)			(1)	(3)						
Calla palustris	(2)											
Carex sp.	(1)											
Ceratophyllum demersum	(18) - 1Z	(2)	(5) - 2Z			(10) - 2Z	(8)	(1)	(3) - 2Z	1Z		

TABLE 6. (continued)

Plants	Plumatella repens	Plumatella fruticosa	Plumatella emarginata	Hyalinella punctata	Hyalinella orbisperma	Fredericella sultana	Paludicella articulata	Pectinatella magnifica	Cristatella mucedo	Lophopodella carteri	Stolella indica	Stolella evelinae
Spermatophyta												
Decodon verticillatum	(2)					(1)	(1)	(2)				
Eleocharis acicularis	(2)					1Z	(1)		(1)			
Elodea canadensis	(16)-3Z	(2)	(3)	(2)		(22)	(8)	(2)	(1)			
Heteranthera dubia							(1)		(1)			
Hydrocotyle umbellata	(1)						(2)	(1)				
Juncus sp.	(1)	(1)										
Lemna minor	(3)		(3)		(1)	(2)	(1)					
Lemna trisulca	(4)				(1)	(3)	(1)		(1)			
Ludwigia palustris	(2)			(1)		(1)		(1)	(1)			
Myosotis scorpioides	(1)											
Myriophyllum sp.	(16)-1Z	(2)	(2)-1Z	(1)		(7)	(7)	(1)	(2)			
Najas flexilis	(12)-4Z		2Z			(8)	(3)	(1)	(2)-1Z	1Z	1Z	
Nuphar advena	(29)-11Z	(5)	(2)	(1)	(1)	(12)-4Z	(6)-1Z	(2)	(4)-1Z	(2)	(1)	(1)
Nuphar variegatum	(3)		(1)			(1)			(2)			
Nymphaea odorata	(2)-1Z					(1)						(1)
Nymphaea tuberosa	(21)-3Z	(1)	(1)	(2)-1Z		(15)-4Z	(9)-1Z	(3)	(6)-1Z	1Z	(1)	
Peltandra virginica	(2)-1Z					(2)-1Z						
Polygonum natans	(3)				(1)	(5)		(2)	(2)			
Pontederia cordata	(8)-1Z	(3)	(1)	(1)		(8)	(6)		2Z			
Potamogeton sp.	(13)-3Z		(1)	(2)			(6)					
Potamogeton amplifolius	1Z		(1)		(1)	(3)-1Z	(1)					
Potamogeton angustifolius	(4)-1Z					(2)-1Z		(1)	(1)			
Potamogeton crispus	(2)-1Z		(2)			(2)	(3)	(1)	(1)			
Potamogeton foliosus			1Z							1Z	(1)	
Potamogeton gramineus	(5)	(1)	(2)			(2)	(1)	(1)	(1)			
Potamogeton gramineus var. graminifolius	(1)							(1)				
Potamogeton gramineus var. terrestris	(1)											
Potamogeton Hillii			1Z									
Potamogeton illinoensis	(1)						(1)					

TABLE 6. (continued)

Plants	Plumatella repens	Plumatella fruticosa	Plumatella emarginata	Hyalinella punctata	Hyalinella orbisperma	Fredericella sultana	Paludicella articulata	Pectinatella magnifica	Cristatella mucedo	Lophopodella carteri	Stolella indica	Stolella evelinae
Spermatophyta												
Potamogeton natans	(6) - 1Z	(1)	(1)				(1)		(1)			
Potamogeton pectinatus	(2) - 1Z					(2) - 1Z			(1)	(1)		
Potamogeton praelongus	(1)					(1)						
Potamogeton Richardsonii	(3) - 1Z			(1)		(3) - 1Z	(3)		(1)			
Potamogeton Robbinsii	(3)					(2)		(1)				
Potamogeton zosteriformis	1Z						(1)					
Ranunculus sp.	(1)					(1)			(2) - 1Z			
Sagittaria sp.	(5)	(1)	(1)			(2)	(1)					
Sagittaria cristata	(6)		(2)	(1)		(4)	(4)	(1)	(1)			
Sagittaria latifolia	(3)						(3) - 1Z					
Scirpus sp.	(8) - 1Z	(2)	(1)			(1)	(4) - 1Z		(5)			
Scirpus americanus	(5) - 1Z					(9)	(1)					
Scirpus atrovirens georgianus						(1)	(1)					
Scirpus occidentalis	(1)		(1)			(2)						
Scirpus validus	(8)					(3)	(1)		(1)			
Sparganium chlorocarpum			1Z									
Sparganium eurycarpum	(1)		(1)				(1)					
Spirodela polyrhiza	2Z					1Z						
Typha sp.	(6)	(1)				(2)	(1)		1Z			
Typha angustifolia	1Z											
Typha latifolia	(4) - 2Z	(1)				(5) - 1Z	(2) - 1Z		(1)			
Utricularia sp.	(7)	(4) - 1Z				(5)	(3)	(1)	(4)			
Vallisneria americana	(5) - 2Z	(2)	(1)	(1)		(4)	(3)		(1)			
Wolffia punctata	(2)					(1)	(1)					

close relationship was observed. The number in parenthesis refers to the number of times the plant and bryozoan were found at the same collection site on a lake, whether the association was intimate or not. The algae listed were rarely more than one foot away from the Bryozoa (whether indicated by a Z or not). Only algae found on or very near to the same substrate with the animals were identified. Where Z associations are indicated with respect to higher plants, these plants were nearly always serving as a bryozoan substrate. The plant association list is the most extensive which has been recorded. Only a few common algae have been previously reported in association with Bryozoa.

Plumatella emarginata, Plumatella fruticosa, and Pectinatella magnifica do not appear to be as frequently associated with plants as other species. P. articulata and F. sultana were found together frequently in association with certain algae (e.g., Gloeotrichia sp., Calothrix epiphytica, and Calothrix minima). The ectocysts of these two species were frequently "coated" with diatoms, particularly Amphora sp. P. articulata appears to use plants as substrates somewhat less frequently than F. sultana or P. repens. P. articulata was found on three genera (Scirpus, Nuphar, and Fontinalis), with which Borg (1941) found it associated. It was the only species associated with all of the rooted bryophytes. P. repens and F. sultana were found more consistently associated with the plants listed than other species. Both were found with 21 of the Cyanophyta. P. articulata and Plumatella

fruticosa were also recorded several times with Cyanophyta. Oedogonium sp., Cladophora sp., and several species of Rhizoclonium were found with a particularly large number of Bryozoa. P. repens was the only species found attached to a species of Pteridophyta, Equisetum fluviatile.

Somewhat unusual associations were those of Bryozoa with the uncommon Rhodophyta particularly the close associations of F. sultana with Batrachospermum moniliforme and Plumatella fruticosa with Batrachospermum ectocarpum. In the latter association, P. fruticosa was intimately intermingled with the sponge, Tubella pennsylvanica and with the alga, Batrachospermum ectocarpum in the colored, acid (pH 5.7) water of Clark Lake, Chippewa County. Jewell (1935) and Prescott (1951) state that the sponge and alga respectively are often found in water with a low pH. Wesenberg-Lund (1907) states that F. sultana was discovered in dense masses of Fontinalis and Characeae in Greenland. Brown (1933) however reports that "Chara has never been found to serve as a substratum, even though colonies of Fredericella and Plumatella were on practically all other plants growing in the association." He suggests that certain plant "secretions and odors" may be offensive to the animals. During the present study, F. sultana was found growing on Chara fragilis and Plumatella repens, Cristatella mucedo and Lophopodella carteri were also found on Chara sp. Chara sp. was a substrate for C. mucedo in two lakes. P. repens and F. sultana were often found on wood substrates within inches of Chara beds. However,

although the C. mucedo and L. carteri colonies found on Chara sp. were robust and luxuriant, the colonies of F. sultana and P. repens were small and many polypides had deteriorated. For most species Chara is probably not a favorable substrate. Of the three rarest species only Lophopodella carteri was observed on plants. Rogick (1934) refers to the abundance of this species on Elodea, Vallisneria, and Potamogeton. Takahasi (1934) found it on Hydrocharis and Ceratophyllum. In Wintergreen Lake, L. carteri was living on Nymphaea tuberosa, Nuphar advena, Potamogeton foliosus and Najas flexilis, but it was far more abundant on Ceratophyllum demersum.

Hyalinella orbisperma was not observed on aquatic plants and Hyalinella punctata was seen only on Nymphaea tuberosa. Several species of Bryozoa were found on plants, with a frequency comparable to their frequency of occurrence. This suggests that though some species may demonstrate so-called "preferences", most species are probably on plant substrates as a result of chance.

Zoological

Animals found associated with Bryozoa are presented in Table 7. The closest associations are indicated by a "Z", as described in the preceding botanical discussion. The free-swimming animals listed in the table were observed on the surface of the bryozoan substrates or were present in the water collected in the vicinity of the colonies.

The associations which were of greatest interest to the author were those involving congregations of sessile animals,

most of them filter feeders. Sessile Protozoa and sessile Rotifera have been reported by several investigators to be attached around or to the ectocyst of bryozoans. Potts (1884) records that Limnias sp. and Pyxicola sp. were found on the zooecia of Paludicella (Pottsiella) erecta. Other investigators have observed the attachment of other animals to the ectocyst. For example Marcus (1941) reports the presence of Vorticellidae on the ectocyst of Stolella evelinae. Vorticella sp. was the protozoan most frequently found on the ectocysts during the investigation. Stentor sp., Acineta sp., Zoothamnion sp., Vaginicola microstoma, and Vaginicola annulata were observed on the ectocysts of P. repens and F. sultana. These sessile Protozoa and Rotifera are sometimes seen in dense clusters concentrated near the orifice. Here, encircling the lophophore, these animals are situated so that they may ingest small organisms which escape between the tentacles of the Bryozoa. The more powerful action of the tentacular cilia serves to move water and small organisms from greater distances. Many of these planktonic animals and plants are captured by the protozoans and rotifers. When the concentration of Bryozoa is large, the concentration of Protozoa and Rotifera is often also large suggesting a rich plankton, in addition to optimal chemical conditions. In some of these luxuriant communities sponges are also conspicuous. An unusual, and hitherto unreported observation was made on a sessile community collected from Augusta Creek in Kalamazoo County. Plumatella emarginata was intermingled

TABLE 7. Animals found in association with Bryozoa

The number in parenthesis is the number of times the animal was found in association with the bryozoan.

The number in combination with the letter Z indicates the number of times the animal and bryozoan were found intimate association (i.e., in physical contact or within two cm. of each other).

Whenever two or more taxonomic categories within the same phylum are given (e.g., family and genus), the associations listed for the lower category are not included in the association listed for the higher category.

TABLE 7.

Animals	Plumatella repens	Plumatella fruticosa	Plumatella emarginata	Hyalinella punctata	Hyalinella orbisperma	Fredericella sultana	Paludicella articulata	Pectinatella magnifica	Cristatella mucedo	Lophopodella carteri	Stolella indica	Stolella evelinae
Protozoa												
Acineta sp.	2Z					1Z						
Actinosphaerium sp.	(1)											
Amoeba sp.	(1)							(1)				
Arcella sp.			(1)				1Z					
Campanella rugosa	1Z											
Carchesium sp.	(5) - 1Z	(1)	(1)			(2)	(1)	(1)	(1)	1Z		
Carchesium polypinum			1Z									
Colpidium sp.						1Z						
Difflugia sp.					(1)							
Epistylis sp.	(6)	(1)	(2)		(1)	(2)						
Euplotes sp.	(1)	(1)				(1)						
Halteria sp.	(2)					1Z	(1)					
Halteria grandinella					1Z							
Hypotricha	(2)		(1)			(1)			(1)			
Kerona polyporum										1Z		
Lionotus fasciola						(1)			(1)			
Opercularia plicatilis										(1)		
Ophrydium ectatum	(1)		(1)			(1)						
Ophrydium sessile	(2)				1Z							
Oxytrichidae			(1)		(1)							
Paramecium sp.			(1)		(1)	(1)						
Stentor sp.	(3)		(3) - 1Z			(2)	(3)	(1)				
Stentor amethystinus			1Z									
Stentor coeruleus	(8) - 2Z	(1)	(4) - 3Z		(1)	(8) - 1Z	(4) - 1Z	(1)				(1)
Stentor igneus		(1)										
Stentor mulleri	(4) - 2Z	(2)				(3) - 1Z			(1)	(1)		
Stentor polymorphus	(3)		(2) - 1Z		(1)	(2)	(1)					
Stentor roeseli	(2)	(1)				(2)	(1)		(1)			
Stylonychia sp.	(2)		(1)			(2)						
Stylonychia pustulata						(1)			(1)			
Vorticella sp.	(19) - 3Z	(2)	(6) - 2Z		(1)	(16) - 8Z	(7) - 1Z	(1)	(1)			(1)

TABLE 7. (continued)

Animals	Plumatella repens	Plumatella fruticosa	Plumatella emarginata	Hyalinella punctata	Hyalinella orbisperma	Fredericella sultana	Paludicella articulata	Pectinatella magnifica	Cristatella mucedo	Lophopodella carteri	Stolella indica	Stolella evelinae
Protozoa												
Vorticella campanula	(1)		(1)			1Z	1Z					
Vorticella microstoma	(1)					(1)	1Z					
Vaginicola sp.			1Z									
Vaginicola annulata	1Z											
Vaginicola leptosoma	1Z											
Zoothamnion sp.	(5) - 2Z	(2)				(5) - 1Z	(4) - 1Z					
Porifera												
Heteromeyenia argyrosperma	(1)	(1)										
Heteromeyenia repens	(1)					(2) - 1Z		(1)	(1)			
Meyenia mulleri	1Z	(1)	(3) - 2Z									
Spongilla fragilis	(2)		3Z		1Z	(2) - 1Z	(1)		(2)			
Spongilla ingloviformis	(1)											
Spongilla lacustris	(4) - 2Z		(2) - 1Z		1Z	(3) - 2Z			(1)			
Tubella pennsylvanica		2Z										
Unidentified sponges	(16) - 2Z	(1)	(2)	(1)	(1)	(9) - 4Z	(8)	(3)	(5)			
Coelenterata												
Chlorohydra viridissima	(1)				(1)	(1)						
Craspedacusta sowerbii			1Z									
Hydra sp.	(2) - 1Z	(1)			(1)	(1)	(2)	(1)	(2)			
Hydra pseudoligactis	(1)		1Z									
Gastrotricha						1Z						
Chaetonotus sp.						1Z	(1)					
Tardigrada												
Tardigrades						1Z	(1)					
Platyhelminthe												
Castrella sp.						1Z						
Dalyellia sp.	1Z					(2) - 1Z						
Dugesia tigrina			1Z			1Z						
Microdalyellia sp.		(1)										
Planaria sp.	(11)	(1)	(3)			(7)	(6)	(1)	(1)			
Stenostomum sp.	(3)			(1)	(2)	(3)	(1)					
Unidentified Turbellarians	(3)	(1)	(1)	(1)		(5)	(2)					

TABLE 7. (continued)

Animals	Plumatella repens	Plumatella fruticosa	Plumatella emarginata	Hyalinella punctata	Hyalinella orbisperma	Fredericella sultana	Paludicella articulata	Pectinatella magnifica	Cristatella mucedo	Lophopodella carteri	Stolella indica	Stolella evelinae
Nematoda												
Nematodes	(7)		(1)	(1)	(2)	(5) - 1Z	(4)	(2) - 1Z				
Rotifera												
Epiphanes sp.		(1)										
Floscularia sp.	(4)	(2)	(1)	(2)		(7) - 2Z	(4) - 1Z	(1)	(1)			
Keratella cochlearis	(1)						(1)	(1)				
Keratella quadrata	(1)							(1)				
Lacinularia sp.	(3)					(3)	(1)	(1)	(3)			
Limnias sp.	(2)	1Z	(1)			(2)	(3) - 2Z		(2)			
Loricate rotifers	(2)	(1)				(1)	(1)	(1)				
Philodina sp.			(1)				(1)					
Platyias sp.									(1)			
Unidentified rotifers	(16) - 2Z			(2)		(5)	(4) - 1Z		(3)			
Annelida - Oligochaeta												
Aelosoma sp.	(1)						1Z					
Aelosoma beddardi	(1)			(1)		(1)						
Aelosoma tenebrarum			1Z				1Z					
Aulophorus sp.			1Z			(2)	(1)					
Chaetogaster sp.						1Z						
Dero sp.			(1)									
Dero limosa	1Z											
Stylaria sp.	(2) - 1Z		1Z		(1)							
Unidentified Oligochaeta	(4)		(1)		(1)	(2)	(2) - 1Z					
Annelida - Hirudinea												
Macrobdella sp.	(8)	(1)			(1)	(1)	(3)	(2)				
Placobdella sp.	(7)		(3)	(1)		(4)	(5)	(1)	(2)			
Unidentified leeches	(1)	(1)		(2)	(1)	(4)	(1)	(2)	(2)			
Mollusca - Pelecypoda												
Anodonta sp.	(1)		1Z				(1)					
Anodonta marginata	(1)					(1)	(1)		(1)			
Elliptio dilatatus			(2)				(1)		(1)			
Fusconaia flava	(1)		2Z									
Lampsilis sp.	(2)					(1)						

TABLE 7. (continued)

Animals	Plumatella repens	Plumatella fruticosa	Plumatella emarginata	Hyalinella punctata	Hyalinella orbisperma	Fredericella sultana	Paludicella articulata	Pectinatella magnifica	Cristatella mucedo	Lophopodella carteri	Stolella indica	Stolella evelinae
Mollusca - Pelecypoda												
Lampsilis siliquoidea			(1)			(1)						
Lampsilis ventricosa							1Z (1)					
Lasmigona complanata			1Z									
Sphaerium sp.			(1)									
Unidentified Mussels	(4)					(2)	(1)		(1)			
Mollusca - Gastropoda												
Amnicola limosa (porata)						(1)	(1)					
Aplexa hypnorum	2Z		(1)			(1)	1Z					
Campeloma decisum	(4)	(2)					1Z					
Ferrissia sp.	(3)					(2)	(1)					
Gyraulus sp.						(1)	(1)					
Helisoma sp.	(1)					(1)	(1)	(1)				
Helisoma trivolvis	(2) - 1Z					(2)	(2)		(1)			
Lymnaea sp.		(1)				(2)						
Lymnaea stagnalis	(2)			(1)		(2)						
Lyogyrus granum						(1)	(1)					
Physa sp.	(6)	(1)	(2)			(4) - 1Z	(6)	(1)	(2)			
Promenetus exacuous	(2) - 1Z					(1)						
Unidentified snails	(6)			(1)		(3)	(2)		(1)			
Arthropoda - (except Insects)												
Amphipoda	(6)	(2)	(1)	(2)	(2)	(8)	(4)	(1)	(1)			
Asellus militaris	1Z		(3) - 2Z			1Z	(2) - 1Z					
Bosmina sp.	(1)							(1)				
Ceriodaphnia lacustris	(1)							(1)				
Cladocera	(2)						(1)		(1)			
Copepoda	(3)					(1)						
Cyclocypris sp.	(1)							(1)				
Daphnia sp.	(1)					(1)						
Daphnia pulex	(1)											
Decopoda	(3)	(1)	(3)			(1)	(4)					
Diaptomus sp.	(1)				(1)				(1)			

TABLE 7. (continued)

Animals	Plumatella repens	Plumatella fruticosa	Plumatella emarginata	Hyalinella punctata	Hyalinella orbisperma	Fredericella sultana	Paludicella articulata	Pectinatella magnifica	Cristatella mucedo	Lophopodella carteri	Stolella indica	Stolella evelinae
Arthropoda (except Insecta)												
Gammarus sp.	(1)					(1)			(1)			
Hyalella sp.	(2)	(1)				(1)						
Hydracarina	(6)	(2)	(2)			(6)	(6)					
Isopoda				(1)			(2)		(1)			
Lirceus lineatus						1Z	(1)		(1)			
Oribatidae	(5)		1Z	(1)		(3)	(2)		(3)			
Ostracoda	(7)	(1)	(1)	(1)		(5)	(4) - 1Z	(2)	(1)			
Trichoptera	(6) - 3Z		(3) - 1Z		1Z	(4) - 2Z		(1)	(1)			
Arthropoda - Insecta												
Agraylea sp.	(1)											
Athripsodes (ancylus)	2Z		1Z									
Bellastomatidae		(1)										
Brychius sp.	(1)		(1)			(1)						
Cheumatopsyche sp.	(1)					(1)						
Coleoptera	(1)		(1)			(1)						
Corydalus cornutus							(1)					
Diptera larvae	(1)					(1)						
Elmidae larvae	1Z					1Z	(1)					
Ephemeroptera	(4)		(1)			(2)	(1)					
Gyrinidae	(1)					(1)						
Helichus lithophilus			1Z									
Helicopsyche							(1)					
Hydroptilidae larvae	(2)			(1)		(1)						
Leptoceridae	(5) - 3Z		(3) - 1Z			(1)	(1)					
Libellula commanche						1Z						
Limnephilidae			(1)									
Limnephilus sp.	(1)		(1)									
Nepidae	(1)					(1)						
Odonata	(2)		(1)									
Orthotrichia sp.	3Z		1Z			(2)	(2)					

TABLE 7. (continued)

Animals	Plumatella repens	Plumatella fruticosa	Plumatella emarginata	Hyalinella punctata	Hyalinella orbisperma	Fredericella sultana	Paludicella articulata	Pectinatella magnifica	Cristatella mucedo	Lophopodella carteri	Stolella indica	Stolella evelinae
Arthropoda - Insecta												
Plecoptera	(1)					(1)						
Pelopiinae	(5) - 12		(1)		(1)	(5)	(1)					
Tendipes sp.	(2)		(1)			(1)			(1)			
Unidentified Tendipedidae	(22) - 12	(1)	(5)	(1)	(2)	(8) - 22	(4)		12	(1)	(1)	
Stratiomyiidae						(1)						

with the sponge Meyenia mulleri. Stentor coeruleus and hydroids of Craspedacusta sowerbyi were attached at the base of the zooecia and sponge, and Vorticella sp. and Vaginicola sp. were abundant on the ectocyst of the bryozoan.

Sponges were found in association with Bryozoa at 29 of the 122 collection sites or at nearly 24 per cent of them. This frequency of association does not indicate that the distributional relationship between the two phyla is more than accidental.

Plumatella repens was found at nearly every collection site where sponges were collected but was seen interpenetrating sponges only four times, on one occasion the relatively rare Heteromyenia repens. F. sultana and P. emarginata were discovered in intimate association with sponges eight times and four times respectively. Eight of the 10 associations of P. emarginata with sponges were recorded for streams and on six of these occasions the sponges were Spongilla fragilis and Meyenia mulleri. Hyalinella orbisperma was found in intimate association with S. fragilis. Perhaps, the most provocative relationship was that of Plumatella fruticosa with Tubella pennsylvanica. The sponge was collected twice and both times entangled with the bryozoan. Both of these associations were made in deeply colored, acidic water. Jewell (1935) reports that Tubella pennsylvanica is found frequently in water of this type. The occurrence of P. fruticosa in such water has already been discussed.

Other investigators have reported on bryozoan-sponge associations. For example, Potts (1884) found Paludicella (Pottsiella) erecta interpenetrating a species of Meyenia. Vangel (1894) claims that F. sultana was most frequently associated with S. fragilis and S. lacustris. Despax (1926) reports on a close asscciation between Plumatella repens and S. lacustris; Tanner (1932), an association of F. sultana with S. lacustris; and Borg (1941), the frequent intimacy of F. sultana and Ephydatia (Meyenia) mulleri.

Table 8 summarizes the frequency of occurrence of the species of Ectoprocta with each other. Plumatella emarginata occurred in the same river or lake with P. repens 12 times and with Paludicella articulata 11 times. In proportion to the number of times each species was collected, P. articulata occurred more frequently with P. repens and P. emarginata than either of these did with each other. This suggests a wide adaptability by P. articulata. It also suggests an ecological basis for the separation of the closely intergrading P. repens and P. emarginata. The two species were, however, observed in close association on two or three occasions during the present study. Cunnington (1920) found them together in three African lakes. Other records exist of their occurrence together. F. sultana was collected at 25 more lakes and streams than P. articulata, but it occurs with P. emarginata approximately the same number of times as does P. articulata. These records, all taken together, suggest that P. emarginata may tend to occur

TABLE 8. Showing the frequency of association of the species of Michigan Ectoprocta collected.

Number of times collected	Species	P. repens	P. fruticosa	P. emarginata	H. punctata	H. orbisperma	F. sultana	P. articulata	P. magnifica	C. macedo	L. carteri	S. indica	S. evelinae
83	P. repens	--	6	12	3	3	49	31	3	19	1	1	1
10	P. fruticosa	6	--	1	1	--	2	2	--	3	--	--	--
30	P. emarginata	12	1	--	2	1	12	11	3	3	1	1	1
5	H. punctata	3	1	2	--	--	3	4	1	2	--	--	--
3	H. orbisperma	3	--	1	--	--	1	1	--	--	--	--	--
69	F. sultana	49	2	12	3	1	--	25	3	14	1	1	1
44	P. articulata	31	2	11	4	1	25	--	4	15	--	--	--
6	P. magnifica	3	--	3	1	--	3	4	--	2	--	--	--
22	C. macedo	19	3	3	2	--	14	15	2	--	1	1	1
1	L. carteri	1	--	1	--	--	1	--	--	1	--	1	1
1	S. indica	1	--	1	--	--	1	--	--	1	1	--	1
1	S. evelinae	1	--	1	--	--	1	--	--	1	1	1	--

more often with P. articulata than with any other species.

P. articulata and F.sultana were found with P. repens with approximately the same frequency. However, P. articulata and F. sultana were intimately associated together on 13 occasions, and P. repens was not found intimately associated with either of them more than two times. Thus, even though there is little difference among these three species with respect to the number of mutual occurrences, there is a decided indication that F. sultana and P. articulata have an affinity for a similar microhabitat. This contention is supported by the additional observation that many of the most luxuriant growths of the two species collected during this study were obtained from eight of the 13 sites where they were intimately associated. Evidence of a similar ecology for P.articulata and F. sultana is provided by earlier investigators. Wesenberg-Lund (1907) reports that they are commonly found entwined in the lakes of Scandinavia and Greenland. Harmer (1913) records the occurrence of P. articulata and F. sultana, along with Plumatella fungosa and P. emarginata in British waterworks. Annandale (1922) reports only P. articulata from the waterworks of Japan. Hurrell (1927) states that the two species are associated more frequently than not, and Borg (1941) found F. sultana frequently associated with P. articulata on the underside of stones, but sometimes Plumatella fruticosa was found with F. sultana.

Plumatella fruticosa, on the basis of only 10 collections, appears to be somewhat more exclusive than other forms. It was the only species collected in four bodies of water, and it was found in each of the other six collection areas with P. repens. However, P. fruticosa was never found closely associated with any species of Bryozoa with the possible exception of Hyalinella punctata and P. articulata. These three forms were removed from large dead tree stumps, which were situated in the organic ooze in a bay of Gull Lake.

Fredericella sultana was discovered in one of the most unusual associations ever reported. A small colony of this bryozoan (Fig. 45) was attached to the dorsum of a live Odonata larva, Libellula commanche. The small colony had produced two sessoblasts.

Predation: Leidy (1851) saw Plumatella diffusa (emarginata) colonies being attacked by larvae of Hydrophilus. Marcus (1926) observed Hydrozetes lacustris, an oribatid mite, eating Cristatella mucedo statoblasts and colonies. He asserts that Dendrocoelum and Polycelis eat living Bryozoa, and that Tendipedidae eat both polypides and statoblasts and are congregated in large numbers in and around the coenecia. He suggests that this "biocoenose" must be an indirect source of nutrition for fish. Brooks (1929) reports that flatworms eat young Pectinatella magnifica colonies. Marcus (1934) states that additional enemies of Lophopus crystallinus, are snails, Trichoptera larvae, and Oligochaeta (eg., Chaetogaster sp. and Nais josinae). Rusche (1938)

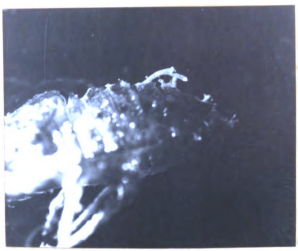


Fig. 45. Fredericella Sultana colony attached to dorsum of Odonata larva, Libellula commanche.



Fig. 46. Trichopteran case composed largely of Lophopodella carteri statoblasts.

declares that tendipedids decimate Plumatella fungosa polypides.

Tendipedids were frequently found, often in abundance, with Bryozoa collected during the present study. Some were living or eating in the empty zooecia, and others were seen browsing the surface of the zooecia eating mostly vegetable matter. In some cases profuse growths of Bryozoa and equally dense populations of tendipedids covered a portion of the substrate. The larvae lived in cases which lay parallel to and filled up the spaces between zooecia. Tendipedids would sometimes bite at the surface of the ectocyst but only rarely would they damage it. Even when they did, they have been seen to leave the damaged area. Thus the majority did not appear interested in the Bryozoa, but rather in the organic material adherent to the zooecia, or in other small animals. Sometimes portions of bryozoan fecal pellets were eaten by the midge larvae. In several collections where dense populations of both animals lived in close association, essentially all of the polypides were healthy and evaginated. These communities suggested mutualism rather than predation. Pelopiinae were often seen moving across a colony and feeding, but on only one occasion did the writer see what could be termed an attack on a polypide of Plumatella emarginata. The larva took hold of the lophophore, but finally released its hold and in doing so pulled off three tentacles. Tentacles were frequently missing presumably as a result of predation. Whether or not tendipedids, often found living

or eating in the zoocecia, were primarily predators or scavengers was not determined. Perhaps fewer species of tendipedids are predacious on Bryozoa in this part of the world than in places from which high predation has been reported.

An Elmidae larva attacked two polypides. One polypide survived and there was some uncertainty regarding the disposal of the other polypide. When the larva departed, the polypide looked essentially uneaten. Several Helichus lithophilus larvae were observed inside the zoocecia of what appeared to be a deteriorating colony of Plumatella emarginata. These larvae may have been scavengers. A Lymnaea sp. killed and partially ingested two polypides of a Plumatella repens colony, and Helisoma trivolvis injured several polypides in moving across a P. repens colony. Whole statoblasts and parts of statoblasts were found in the excreta of H. trivolvis.

A portion of a Cristatella mucedo colony and three or four statoblasts were found in the stomachs of two specimens of Perca flavescens from Wintergreen Lake. Twenty-seven of the fish had been netted by a class in Ichthyology and given to the author for examination.

Trichoptera were unquestionably the most carnivorous predators of Bryozoa found during this investigation. Several different species were seen attacking polypides. The most frequent predation, observed repeatedly on colonies of Plumatella repens from Wintergreen Lake and Burke Lake, was caused by Athripsodes sp. in the family Hydroptilidae,

and by Orthotrichia sp. in the family Leptoceridae. Athripsodes sp. either attacks the evaginated polypide or with unintended sagacity eats a hole in the zooecium and devours portions of the polypide commencing with the proximal or stomach region. Often Athripsodes sp. eats a portion of a statoblast, and then proceeds to another zooecium.

Orthotrichia sp., a relatively small and rare tricopteran, was perhaps the most savage predator observed. The larva would very rapidly grasp an evaginated polypide, and then thrash about rather forcibly in order to gain a hold with it's mouthparts. This characteristic attack was followed by an equally consistent period of ingestion. The time required for the complete predation of one polypide of P. repens by Orthotrichia sp. was 33 minutes. The polypide was alive for 15 minutes after the initial attack, and several violent contractions of the digestive tract occurred during this period. The trichopteran never moved its body while ingesting the polypide. First the tentacles, lophophore, and pharyngeal region were eaten; then the polypide was drawn progressively farther out of the zooecium by the insect. When the tricopteran departed, the lower portion of the caecum and the funiculus were all that remained of the polypide.

Trichopteran larvae frequently adorn their cases with statoblasts. A larval case composed almost wholly of Lophopodella carteri statoblasts is shown in Fig. 46.

SUMMARY

1. A distribution map showing the species of Bryozoa recorded in each county was prepared. Collections were made in 122 bodies of water. The map includes Bryozoa reported by earlier investigators.
2. Three species of Ectoprocta not previously recorded in Michigan were found. They are *Lophopodella carteri*, *Plumatella fruticosa*, and *Stolella evelinae*. *P. fruticosa* was found in 10 localities.
3. *Plumatella orbisperma*, reported only once previously, was found and is assigned to the genus *Hyalinella*. The new designation is *Hyalinella orbisperma* (Kellicott) 1882.
4. A discussion of the variability and systematics of the species found in Michigan includes comparisons with worldwide forms. Attention is concentrated on *Plumatella repens* and *Plumatella emarginata*. A variant form (the Pony Creek form) is disucssed, and assigned to *P. emarginata*. It has characteristics consistently intermediate between *P. emarginata* and *P. repens*, and shares characteristics with *Plumatella elegans* and *Plumatella javanica*.
5. Both flabelliform and geminate-flabelliform colonies of *P. emarginata* were found. Evidence is presented to demonstrate that this growth form may be the result of a simultaneous germination (with the subsequent loss of the valves) of two contiguous floatoblasts.

6. Fredericella sultana appears to be more tolerant of conditions in marl lakes than other species.
7. P. repens was found most often in lakes, ponds, and ditches, than in streams as were Hyalinella punctata and Hyalinella orbisperma. P. emarginata demonstrated a decided preference for streams or moving water. Paludicella articulata demonstrates an adaptability to flowing, roily and still water.
8. New tolerance limits for temperature are given. Living colonies of Fedricella sultana were collected during the winter months in water with a temperature of 1.5 degrees centigrade. Living colonies of P. repens and Plumatella fruticosa were collected in water with a temperature of 37 degrees centigrade.
9. Plumatella fruticosa was found in water with more color and a lower pH, than were the other forms.
10. Tables listing plants and animals associated with Bryozoa are given. Particular attention is given to sponge-bryozoan and intra-bryozoan associations.
11. Predators of Michigan Bryozoa were snails, Tendipedidae (infrequently), Elmidae and Perca flavescens (at least indirectly). However Trichoptera were the most frequent predators. Athripsodes sp. and Orthotrichia sp. were seen repeatedly attacking and eating polypides and statoblasts of Plumatella repens.

PART II

GROWTH, MORTALITY, AND LONGEVITY OF *PLUMATELLA REPENS*

GROWTH, MORTALITY, AND LONGEVITY OF PLUMATELLA REPENS

INTRODUCTION

Studies on the growth, mortality, and longevity of invertebrate animals have been few. In the Ectoprocta, for example, information on growth dynamics is scarce, and completely lacking for most species. Among the fresh-water Ectoprocta, most growth and longevity data have been obtained from laboratory-reared animals. Data for animals living under natural conditions in lakes, ponds, and streams are essentially non-existent. This investigation was made in an attempt to obtain such information. The data were all collected in the field. Parallel studies on growth, longevity, and mortality were conducted on two Michigan Lakes, Wintergreen Lake in Kalamazoo County and Burke Lake in Clinton County. Numerous colonies as well as individual polypides were marked and observed at regular intervals, and data were recorded during these observation periods. This research was conducted in the spring, summer, and fall of 1959 and during the spring and the summer of 1960.

The investigation was conducted on Plumatella répens, believed by many bryozoologists to be the most common and cosmopolitan species of fresh-water Ectoprocta in the world. No comparable field or laboratory research has been conducted on this organism. P. repens thus appeared to be a particularly desirable animal for such a study.

The most comprehensive growth data are those acquired by Rogick (1945[4]), in a laboratory study on colonies of

Hyalinella punctata. This species and Plumatella repens are considered by most investigators to be closely related, and they are both in the family Plumatellidae. Rogick (1938, 1945a) gives some information on the longevity of H. punctata and Lophopodella carteri.

The data of the present study indicate that growth tends to be geometric in P. repens under favorable conditions. There was, however, much variation in growth rate. Individual polypides of P. repens rarely live longer than six weeks. Mortality varied considerably with respect to site. The total predation on both large and small ectoproct colonies was extensive suggesting that these animals are perhaps more significant prey organisms than has previously been suspected.

Wintergreen Lake

In 1926, W. K. Kellogg of Battle Creek, Michigan, purchased the 500-acre farm which surrounds Wintergreen Lake. The lake was established as a sanctuary for waterfowl. In 1929, Mr. Kellogg gave both the farm and sanctuary to Michigan State University for agricultural experimentation and scientific investigation.

Wintergreen Lake is located in Tier 1 south, Range 9 west, Section 8 of Ross Township, Kalamazoo County, Michigan. Fetterolf (1952) states that the lake had an area of 39.99 acres, a mean depth of 7.56 feet, and maximum depth of 21.33 feet. There were no permanent feeder streams. At the south end there was an outlet emptying into Yale Lake, one-half mile away. Springs at the north and northeast shores help

to maintain the water level. Wintergreen Lake is one of many small pit lakes in the Kalamazoo-Mississianawa morainic out-wash plain system. Fetterolf (1952) states:

> Bottom deposits are variable. The south and west shore is (generally) pulpy peat to a depth of three feet, where marl becomes intermixed with it. Marl is predominant to a depth of about twelve feet in all other parts of the lake except the east and northeast shore. These shores are exposed to wave and wind action and are sandy to a depth of 2.5 feet where marl again becomes predominant. Beyond the twelve-feet depth the bottom is of a fine organic ooze.

He continues:

> Chara is dominant in the shallow areas of the lake. As the depth increases, two species of Potamogeton become abundant: Sago pondweed, Potamogeton pectinatus, and leafy pondweed, Potamogeton foliosus. Coontail, Ceratophyllum demersum, and bushy pondweed, Najas flexilis, combine with the potamogetons to give dense weed bed extending to about the four meter contour. Beds of spatterdock, Nuphar advena, occur along the shore in the southwestern half of the lake. There are two patches in the northeastern half; one in the eastern corner and another in the northwestern corner. White water lily, Nymphaea (Castalia of authors) odorata, is limited to the lagoon area at the southern tip. The shoreline vegetation consists predominately of two species: Swamp loosestrife or water willow Decodon verticillatus var. laevigatus, and button bush, Cephalanthus occidentalis.

Fetterolf further states:

> This lake is perhaps one of the richest in the country from the standpoint of the nutrients added by natural fertilization. Each fall from 6,000 to 10,000 Canadian geese use the sanctuary as a stopping over place on their southward migration. An equal number of ducks are also present at this time and a flock of about 70 swans, geese and ducks use the lake the year around. The extent to which the tremendous amount of natural fertilizer in their droppings improves the environment for fish production is unknown.

However Sokolowski (1960) states that the swan, by feeding on vegetation, prevents the development of stagnant conditions. He maintains that the swan's "abundant droppings falling

into the water favour the development of vegetative and animal plankton."

Burke Lake

Burke Lake is located in Tier 5 north, Range 1 west, Section 23, of Bath Township, Clinton County, Michigan. The lake is in the Grand River drainage system and has an area of 1.8 acres. Roelofs (1941) states that there were no inlets or outlets of appreciable size, although a small outlet existed at the north end of the lake. The lake had a maximum depth of 39 feet, and very little shoal area, as the bottom drops off rapidly. The lake was surrounded by a "quaking bog".

Roelofs wrote that the bottom was essentially marl with some organic content in the shoal area. In the deeper areas he asserts that the bottom was marl and fibrous peat and had a 15 to 20 feet layer of organic material.

The most common water plants in the outlet were Ceratophyllum, Chara sp., Najas flexilis, Potamogeton angustifolius, Nuphar variegatum and Typha latifolia. Roelofs gives one reading, 175 ppm., for bicarbonates. He reports a pH variation of from 6.8 to 8.5. The author found the pH to vary from 7.4 to 8.5.

Burke Lake is surrounded by trees and shrubs with tamarack prominent, particularly along the entrance to the outlet where the majority of Plumatella repens study stations were located. The physical characteristics and the vegetation of the shallow marginal areas of the lake and in the

outlet were at the time of this study, generally, in agreement with information given by Roelofs.

METHODS

The data on growth, mortality, and longevity were gathered at regular intervals from numerous colonies of Plumtella repens located at several different stations on Wintergreen Lake in Kalamazoo County, and on Burke Lake in Clinton County, Michigan. These lakes, and stations on these lakes, are shown in Fig. 47 to 53. Many of the colonies chosen for study in the spring consisted of one or two polypides derived from newly germinated statoblasts. A number of the colonies selected for study in 1959 and 1960 consisted of more than two polypides.

In choosing colonies, it was necessary to examine a number of substrates at several different sites on the lakes. The criteria for favorable sites were the availability of colonies at the site, suitability of substrates for marking, and permanency and structural integrity of substrates. The most favorable substrates were logs or planks semi-anchored along the shore line. Most stations on Burke Lake were logs or floating posts, while most of them on Wintergreen Lake were flat planks. Tables 9 and 10 give information on the stations established on Burke Lake and Wintergreen Lake respectively. There was some contrast in the environment among the different stations.

Marking: The colonies chosen in these studies were marked with the tips of plastic toothpicks. With a blunt dissecting probe, a boring was made in the substrate 2 mm. to 6 mm. to the right of a newly germinated statoblast. The right

TABLE 9. General data for each study station at Burke Lake, Clinton County

Station	Substrate	Bottom type	Colony depth and location		Vegetation and relation to substrate	Misc. characteristics including colony growth
1.	fallen tree	marly organic	3½ inches	N.E. Shoreline	———	greatly depressed colony growth
2.	log post	marly organic	5 inches	outlet entrance	dense, mostly Chara vulgaris	colonies on end nearest dense vegetation expunged first
3.	square milled plank	marly organic	3½ inches	outlet entrance	clumps of vegetation touching portions of substrate	mostly free in outlet channel, notched log, good growth
4.	flat plank	marly organic	1½ inches	outlet entrance	touching Chara along one side, free opposite side	growth generally somewhat depressed predation relatively high.
5.	square milled plank	marly organic	3½ inches	outlet entrance	sparse vegetation near shore and approximately 2 inches off bottom	depressed growth and high mortality numerous snails
6.	round log	marly organic	5 inches	outlet entrance	settled in heavy Chara bed and few inches from the bottom	medium growth rate and reasonably high mortality
7.	round post	marly organic	5 inches	outlet entrance	sparse to essentially lacking	held in outlet by stick later colonies excellent growth
8.	milled plank	marly organic	2 inches	outlet entrance	largely free of plants first few weeks, in contact with dense Chara later	good growth during first 3 weeks
8b.	round log	marly organic	5 inches	outlet entrance	mostly free of dense vegetation in open water near outlet	growth generally good
9	branched tree trunk	marly organic	8 inches	middle south shoreline	little except dense growths of Tolypothrix and Calothrix and bottom leaves	high mortality and depressed growth 2 to 4 inches off bottom
10.	long twig	marly organic	6 inches	S.W. Shoreline shore indentation	Some sparse algal growth	marl encrusted substrate, 3 to 6 inches from bottom, growth depressed
11.	thick short plank	marly organic	2 inches	50 feet into outlet	against shoreline, Typha latifolia	in shallow flowing water, high predation

TABLE 9. (continued)

Station	Substrate	Bottom type	Colony depth and location	Vegetation and relation to substrate	Misc. characteristics including colony growth
12.	short thick plank	marly organic	2 inches 60 feet into outlet	heavy mat plant growth algae and Typha latifolia	near bottom, growth depressed, high mortality
13.	smooth log	marly organic	5 inches outlet entrance	clumps touching two portions of center	essentially free, some mortality, good growth
14.	thick milled plank	marly organic	1½ inches just outside outlet entrance	anchored just free of substrate	in open water, good growth

TABLE 10. General data for each study station at Wintergreen Lake, Kalamazoo County

Station	Substrate	Bottom Type	Colony depth and location	Vegetation and relation to substrate	Misc. characteristics including colony growth
1.	Discontinued				
2.	log disappeared	Discontinued			
3.	log with bark	sandy with some organic	7 inches N. side near boathouse	dense ceratophyllum demersum	good growth side
4.	Discontinued				
5.	milled plank	sandy	2 inches S.E. corner	dense ceratophyllum demersum mixed	wire fence, growth generally good, predation heavy
6.	milled plank	sandy	2 inches S. shore side	dense Rhizoclonium hookeri, Ceratophyllum demersum, dense-mixed	low fence, growth good, predation heavy
6b.	milled plank	sandy	2 inches South shore	Potamogeton sp., Najas sp., Ceratophyllum sp. fairly dense	early colony predation
7.	milled plank	sandy	2 inches South shore	Potamogeton sp., Najas sp., Ceratophyllum sp.	under shrubbery along bank, early mortality

TABLE 10. (continued)

Station	Substrate	Bottom type	Colony depth and locality	Vegetation and its relation to substrate	Misc. characteristics including colony growth
8.	milled plank	sandy	2 inches South shore	dense Rhizoclonium hookeri	placed in small indentation in shore
9.	milled plank	sandy	2 inches South shore	dense Rhizoclonium hookeri, Ceratophyllum sp.	next to shore, sharp mortality
10.	cracked wide milled plank	sandy	2 inches S.W. corner	dense Rhizoclonium hookeri	under willows, several good growth colonies
11.	bark log	sandy leaves	6 inches S.W. corner	Najas sp., Rhizoclonium sp.	few early good growth colonies
12.	short bark log	sandy, light layer of organic	5 inches S.W. corner	Najas sp., Rhizoclonium sp.	few good growth colonies
13.	bark log	sandy, light layer of organic	4 inches S.W. corner	moderate and mixed	growth depressed
13b.	bark log	sandy, light layer of organic	5 inches S.W. corner	moderate and mixed	growth depressed
14.	short bark log	sandy organic	4-12 inches S.W. corner	dense and mixed	under trees.
15.	short bark log	sandy organic	4-12 inches S.W corner	dense and mixed	under trees
16.	milled plank near station 11.	sandy	2 inches South shore	moderate and mixed	under trees, a few good growth colonies



Fig. 47. Station 7, Burke Lake, Clinton County
Stations 4-6



Fig. 48. Station 9, Burke Lake, Clinton County



Fig. 49. Length view of Burke Lake, Clinton County



Fig. 50. Stations 4-7, Burke Lake, Clinton Co.



Fig. 51 Stations 6 and 6b. Wintergreen Lake, Kalamazoo County.



Fig. 52. Station 8, Wintergreen Lake, Kalamazoo County.



Fig. 53. Stations 10-13, Wintergreen Lake, Kalamazoo County

side of the statoblast was determined from the direction of germination. After the boring was made, the tapered tip of one-half of a toothpick was pressed firmly into the hole with the thumb. From two to 28 colonies were designated in this fashion at each of a number of stations on the lakes. Often all six toothpick colors - red, blue, green, yellow, white, and pink - were used to designate colonies at a given station. Colored plastic pegs marking colonies on two substrates are shown in Fig. 54 and 55. When numerous colonies were chosen on one substrate, several series of colonies were marked (e.g., a yellow series, Y-1, Y-2, Y-3, Y-4; a red series, R-1, R-2, R-3, R-4, R-5).

Each substrate was divided arbitrarily into a proximal and distal end. This designation was made with respect to a structural peculiarity or an artificial marker or tag placed at one end of the substrate. The criteria for the distal and proximal ends were noted on the field data sheets. The designation of proximal and distal ends made a color series possible (e.g., the yellow peg nearest the proximal end was designated Y-1). In some cases colonies were designated by two pegs often of different colors.

Sometimes pegs were broken off, presumably by fish or turtles. Small fish were occasionally observed snapping at them. In most cases the broken tip was still imbedded in the substrate so that a new peg could be inserted next to the broken one. Rarely was a marker completely pulled and a color series discontinued. The peg pattern of heavily

marked substrates was mapped on a field sheet, which made it possible to locate a missing peg without having to remove an entire color sequence.

The method of marking so far described was satisfactory for designating entire colonies for obtaining data on growth and mortality, but for data on longevity, specific individuals had to be marked. These individuals were often in colonies other than those bing followed for growth data. When a polypide was observed for longevity, a marking peg was placed beside that individual. For longevity study, terminal individuals were chosen (i,e., newly budded polypides), and pegs were then placed to the right of them. On substrates where colonies were also being followed for growth and gross mortality data, one color of peg (e.g., white) was used to designate individuals for the longevity study only. Thus terminal individuals were marked by a white peg.

As the colonies developed and grew in size, there was a tendency for them to intermingle. When intermingling occurred to such an extent that accurate counts could not be made, the colonies were discarded. In the 1960 studies, the intermingling of colonies was prevented by destroying all unmarked colonies which were in close proximity to marked colonies. Many young colonies, derived from newly germinated statoblasts, were found closely associated or in direct apposition at the time that study colonies were first chosen. After certain young colonies were randomly chosen for study, other young colonies and ungerminated statoblasts in the

Plumatella repens growth study colonies designated by colored plastic pegs



Fig. 54.



Fig. 55.

immediate vicinity were sacrificed. Later in the study, some colonies, which had been formerly widely separated, grew so that they threatened to intermingle. In this case one (or more) of the colonies was destroyed. Sometimes the destroyed colony was an unmarked colony and thus not important to the study, but at other times both approaching colonies were marked colonies. One of the colonies was then removed and the collection of growth data on this colony was discontinued. Colonies to be removed were scraped off the substrate with a blunt probe or a small pen knife. The substrate had to be scraped clean to assure that none of the mutilated colony remained, as the subsequent decomposition of dead polypides would tend to alter the environment of the closely associated colonies. Through vigilance, germinated statoblasts, newly settled larval colonies, or expanding older colonies could be observed and destroyed when necessary. This made it relatively easy to follow the progress of the marked study colonies.

Random choice: The choice of study colonies was arbitrary. Most colonies were sufficiently separated, so that all of them could be marked for study. When germinating statoblasts were closely associated, a number of young colonies, as previously described, had to be removed. This process was essentially at random, as a choice was made quickly and without the aid of the 10X or 20X lenses. By using this method no preliminary appraisal could be made relative to the efficacy of the site or the robustness of newly germinated

polypides. After sacrificing certain of the closely associated small colonies, the hand lenses were used to ascertain whether the chosen polypides were actually alive. Polypides were recorded as living when the lophophore was evaginated.

Checking colonies: Not all stations were selected on the same date. However, numerous stationswere established in late April on both lakes. After a station was designated and a number of colonies and individual polypides had been marked for study, subsequent examinations of the colonies were made atregular intervals. This interval was generally seven days. The time required to check the numerous colonies on each lake varied from two hours to seven hours, depending on the number of colonies under observation at a given time. Observations at the two lakes were made on different days of the week.

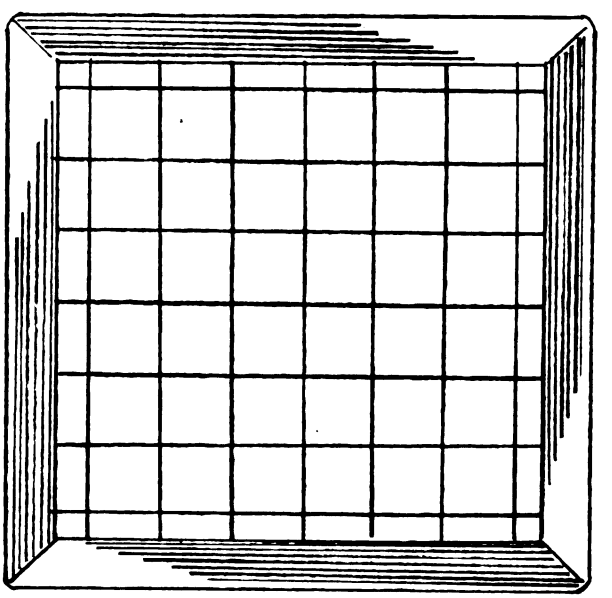
Habitat observations and temperature readings were made each time that the colonies were checked. Other data were obtained less frequently. The observation of the individual colonies was a painstaking routine. Substrates were turned over so that the colonies could be examined. The substrate was submerged every two or three minutes, and on clear days it was generally kept just beneath the water most of the time to reduce excessive exposure to the sun. The author has kept non-study colonies out of water in the shade for two or three hours without deleterious effects.

After the substrate was turned upward, each colony was

observed and the individuals in each were counted. These counts were made with the aid of 10X, 15X, and 20X lenses. The number of polypides in colonies of each color series was obtained consecutively. The counting of polypides had to be accomplished carefully, even with magnifying lenses, as a determination of the presence of small new buds was sometimes difficult. However, buds are usually turned slightly to one side or the other of the coenecial growth plane, thus making them easier to see. Counting errors were minimized by recounting the polypides in large colonies, sometimes four or five times. The counting of larger colonies was facilitated by the use of a miniature quadrat developed by the author (Fig. 56). A small square frame was constructed of quarter inch doweling. Fine drill holes were then made at one centimeter intervals along all four sides of this frame. The frame was strung like a tennis racket using a fine, colorless, number two nylon leader. This miniature grid (found valuable by the author for counting all sessile invertebrates, including Protozoa) is an adaptation of the field quadrat method of terrestrial ecology. By placing this grid over large colonies, the polypides within each of the squares could be counted and recorded, thereby assuring an accurate polypide number for each colony,

It was not necessary that each polypide be extended or even alive for purposes of studying colony growth. As long as the total number of polypides which had beenbudded by a particular colony could be determined growth data could be

Fig. 56. Miniature grid divided into one centimeter squares used in counting dense Bryozoan colonies



obtained. Often the colony was composed mostly of living polypides. In some cases, when polypides in the older inner region of the colony had died, the coenecium and its separate zooecia were still easily discernible. Thus accurate polypide counts could still be made. When disintegration had proceeded so that portions of the colony were lost and fragmentation was definitely in progress, it was necessary to record an X after the polypide number indicating an incomplete count. Such a colony was no longer of use for the growth study. When entire colonies were destroyed by predators, the loss was recorded as gross mortality.

It was necessary to verify that polypides being studied for longevity data were still alive. This was done, each time the lakes were visited, by either waiting for the polypides to evaginate or for the zooecial tips to move. Verification may even be made on retracted polypides, because when alive the tentacular sheath appears as a sharp thin line suggestive of the bore of a fine pipette. The digestive tract is distinct in living polypides, while in those undergoing decomposition, the digestive tract is globular, and the tentacular sheath is diffuse and milky-white in appearance.

RESULTS

Growth

Growth and mortality data are given in Appendix Tables 1 through 37. Each of the colonies is designated by a symbol, in most cases a letter or letters followed by a number. The numbers of polypides in the colonies were recorded at regular intervals. The data plotted on the growth graphs (Appendix Fig. 1A,B - 28A,B) were obtained from robust and actively growing colonies. Budding was erratic or retarded in numerous colonies, as is evident in the Tables. The apathetic colonies were not representative of the growth potential for colonies of Plumatella repens and were therefore not graphed.

Growth data were graphed to determine whether populations of P. repens exhibit geometric increase. The data for more than 50 individual colonies, and 30 multiple colonies were plotted. The multiple colony graphs were plotted from averages obtained by totaling the number of polypides in several colonies. Only colonies chosen on the same date, at the same station, and with the same initial number of polypides were combined. The number of colonies included in such a composite population total was variable and is indicated on the graphs.

The data for the colonial populations were first transferred to graphs (Appendix Fig. 1A - 28A) on which the natural logarithm of the number of polypides in a colony or colonies was plotted on the ordinate, and the number of days from zero time was plotted on the abscissa. A straight line was then drawn along the linear course of the points, after making

certain that approximately equal numbers of them were present on either side of the line. Somewhat less weight was given to the first and last plotted points where they deviated from a line which was otherwise dictated by all the other points. Second graphs (Appendix Fig. 1B - 28B) were then constructed to exhibit growth rate on an arithmetical scale. These graphs in general followed the equation:

$$N_t = No\ e^{rt}$$

where No is the initial number of polypides in a colony or the mean number of polypides (in the case of multiple colony graphs) at the time that observations were begun, and N_t represents the population number at the end of t days. The base of Napierian logarithms is e, and r is the instantaneous growth rate. The value of r is obtained as the slope of the straight line graph.

Finally, the doubling time (i.e., the time required for a colony to double its polypide number) was computed and is indicated at the bottom of Appendix Fig. 1A - 28A. This was computed by dividing the natural logarithm of two by r. Doubling rates were computed for many colonies not included in the graphs and were consistent with those given.

Mortality

Gross mortality is indicated in Appendix Tables 1 through 37 by an X. The letter X indicates that no trace of the colony (or at least no more than a few sessoblasts or fragments of zooecia) remained on the date that the X was recorded. Other symbols are used to indicate that the colony was incom-

plete on that date. Colonies were often incomplete due to partial predation or to natural disintegration of portions of the colonies. When a number precedes the letter X, it indicates the number of polypides remaining in a colony which has been partially destroyed. In such cases either single polypides or larger parts of the colony, sometimes growing tips, were missing. This type of attrition appeared to be patternless and predation was assumed to be the main cause of colony incompleteness. In contrast, disintegration of a colony generally follows a pattern, taking place from the center of the colony outward. In this case, the isolated growing tips which remain, are the remnants of former large complete colonies. Therefore the term "tips" in the Tables implies that the older central portions of the colonies were essentially absent, as a result of natural disintegration. PG and MG are designations applied to colonies which were "partly gone" or "mostly gone", respectively. Whether colonies so indicated were incomplete as a result of predation, disintegration, or both was not clear.

The symbol TM stands for "too mixed" and indicates that colony growth or the intertwining of zooecia was too complex to permit an accurate polypide count. This condition resulted when a single colony became too dense to count, or when two or more colonies had become entangled so that their respective polypides could no longer be reliably determined. The term TMX implies that the colony was too densely entangled to count and was also incomplete.

Gross mortality, or total colony predation, for several stations is plotted on the natural logarithm versus time graphs (Appendix Fig. 29 - 36).

Longevity

Appendix Tables 38 through 42 give the field data on longevity for 373 marked polypides. The letters in these Tables refer to the colors of the pegs which were used to mark the polypides. In cases where only one color symbol is given for the individuals marked at a station on a given date, all polypides were marked with pegs of the same color. It was not necessary to give symbols to each polypide in studying longevity, as only the total number of living polypides was recorded. In a few cases polypides were marked with two pegs.

Appendix Fig. 37 is a survivorship curve, prepared from the collective survival data on 373 polypides. The natural logarithm of the number of individuals is plotted against time. The following is a summation (from which the survival curve was prepared) of longevity data obtained from colonies at both lakes during the years, 1959 and 1960.

232	or	62.2%	of the 373 polypides survived	11+ days
176	or	47.2%	of the 373 polypides survived	21+ days
78	or	20.0%	of the 373 polypides survived	28+ days
57	or	15.3%	of the 373 polypides survived	31+ days
12	or	3.2%	of the 373 polypides survived	37+ days
3	or	.8%	of the 373 polypides survived	46 to 53 days

GROWTH DISCUSSION

More than 100 graphs were plotted from individual and multiple colony growth data, and in all but a few cases a geometric growth rate was indicated for Plumatella repens. The geometric growth pattern is illustrated particularly well by colonies at stations 3, 7, 8b, 13, and 14 on Burke Lake and at stations 5, 12, and 16 on Wintergreen Lake. At these stations most of the colonies appeared in good physical condition, and they were showing positive increase. This only serves to support the premise that P. repens proliferates new polypides in a geometric manner, as the most favorable sites demonstrate most perfectly this type of growth. The colonies at these sites generally revealed the lowest doubling time, an additional indication of favorable habitat. Graphs demonstrating geometric growth are seen in Appendix Fig. 1A through 15A for Burke Lake and Appendix Fig. 16A through 28A for Wintergreen Lake. Graphs plotting the theoretical increase in the number of polypides are shown in Fig. 1B through 15B for Burke Lake and 16B through 28B for Wintergreen Lake.

The observed mean number of polypides for a sequence of time intervals was compared with the number expected from the geometric growth law. The observed and expected numbers were generally in close agreement. Appendix Fig. 2B gives both values for one of the stations on Burke Lake. The observed number of polypides departs appreciably from the predicted number only on the last number. This discrepancy

at the end of the recorded growth period suggests either the approach of the asymptote stage of the logistic curve or a worsening of environmental conditions. Several other colonies reveal this decline in growth on the final polypide count, but numerous others do not show the same decline, as may be seen by an examination of the graphs. In some cases, the graphs plotted for large colonies of several hundred polypides failed to suggest a leveling off of the growth rate, while the graphs plotted for certain smaller colonies did show this. Polypide counts of colonies which do not show this leveling off were, perhaps of necessity, discontinued too early; in effect prior to the onset of growth limiting density-dependent and density-independent factors. It is not reasonable to assume that all colonies would reveal a decrease in growth rates at the same time. This phenomenon might relate to the environmental resistance existing in the vicinity of each individual colony. It is probable, that the full biotic potential of this species is not attained, and that the rate of growth is in time progressively curtailed by environmental factors.

Stations 1, 2, 4, 6, 9, and 10 on Burke Lake and station 13b on Wintergreen Lake show, in general, fewer colonies with high and steady growth rates than do other stations, and at stations 1, 9, 10, and 11 at Burke Lake, many colonies reveal a nearly complete cessation of growth. These poorly growing colonies were of course not graphed. Graphs showing some slight deviation from the geometric growth pattern, evident in

the other graphs, are Appendix Fig. 5A for Burke Lake and Appendix Fig. 23A and 26A for Wintergreen Lake.

In Appendix Fig. 3A, 13A, and 25A, the points representing later polypide counts are above the line and earlier counts are below the line. The tendency is evident in a number of colonies. It is essentially associated with colonies which were observed beginning with late April or early May germinations. The tendency, of course, suggests a slowly increasing growth rate, in effect a tendency toward a greater steepness in the slope of the growth line. This tendency is rarely seen in colonies which were chosen in early June or during the summer months.

An examination of the doubling rates (Appendix Fig. 1A through 28A) supports the contention that growth rates tend to increase during the spring. The doubling rates for colonies marked in late April and observed into early June generally vary between 4.0 and 7.4, meaning that these colonies could be expected to double in size each 4.0 to 7.4 days. The doubling rates for many active colonies marked in early June and observed into July ranged from 3.4 to 4.9. This difference in the rate of colony proliferation suggests that either nutritional, chemical, or physical conditions were more nearly optimum around the first of June. All of these factors may contribute to an increase in the rate of colony growth. However, the fact that the colonies at the favorable sites, which are the sites under primary consideration, appeared well fed and healthy from the end of April

into June, suggests that there was no lack of food at these stations. Moreover, the abundance of other sessile animals (e.g., protozoans, rotifers), insect larvae, and snails suggests that the chemical conditions were not restricting the animal community. If physical factors are considered, temperature appears to be the most important. Temperature remained above 20 degrees centigrade from the latter part of May into the summer in both lakes (Table 43). The increase in growth rate appeared steady in many of the graphs drawn for spring colonies and the growth rate was steady for most colonies observed during the late spring and summer. The steadiness of the increase in growth rate argues against the sudden rise of a particularly suitable prey species, and suggests instead an environmental element which is steadily changing in the spring and attains an optimum during the summer. Temperature is of course such a factor.

A somewhat greater number of the more successful colonies from Wintergreen Lake had doubling rates of between 4.0 and 5.0 for the late April to June periods than did colonies from Burke Lake. In fact, colony Y-4 at station 5, Wintergreen Lake, chosen on April 29, 1960, had a doubling rate of 3.75. Perhaps the somewhat lower spring doubling rates evident for Wintergreen Lake colonies may be attributed to more favorable nutrition. Even though successfully proliferating Burke Lake colonies appeared adequately fed, planktonic food may not have been quite as nutritious as the Wintergreen plankton. Interestingly enough, plankton samples taken from Wintergreen

Lake during the spring and summer of 1960 contained a greater abundance of organisms than did those from Burke Lake, meaning that a richer food source was available to the Wintergreen Lake colonies. This suggestion is strengthened by the fact that there were fewer colonies in Wintergreen Lake with sharply decreased growth rates.

A drop in lake temperatures during the first half of May could have been responsible for the decrease in growth noted for some spring colonies. In the fall, budding ceased when the temperature fell to 9 degrees centigrade (see station 8, Burke Lake, 1959). Colonies at this station appeared well fed, so the steadily decreasing temperature was assumed to be the major cause of growth depression.

An examination of the growth Tables for the different stations at Wintergreen and Burke Lakes reveals a great deal of variability among colonies at different sites. Certain sites, as stations 1, 5, and 9 on Burke Lake reveal a general colony apathy. The colonies at these stations had little more than begun when growth was depressed. Few of the colonies attained a size greater than four or five individuals. Algae, sessile animals, snails, and insect larvae were scarce at these stations. In effect the microhabitat at these stations was more barren than that at other sites. The digestive tracts of the animals at these sites were frequently not filled with food or were not as dilated as were those of animals observed at sites where growth was continual and regular. The stomach contents of the poorly nourished animals

were observed to be more hyaline. In the better nourished animals, the color of the stomach contents were generally yellow, yellow-brown, or green, and the digestive tracts were expanded. An inadequate diet undoubtedly helped to depress growth at these sites.

A variation in food did not appear to be correlated with an increase or decrease in growth. However, variations of diet, regardless of an abundance of food, probably do affect growth rates. This has already been suggested for spring colonies in Wintergreen Lake. Rogick (1945a) declares that green algae are unsuitable food and that colonies of Hyalinella punctata fed on green algae degenerated early. Green algae did not appear to depress growth or promote early disintegration in Plumatella repens. Many rapidly growing colonies were seen from time to time with their digestive tract largely filled with green algae. However certain green algae are possibly a less suitable food than others for Bryozoa. Rogick found also that when food was both "adequate and suitable", buds formed and evaginated at a rapid rate. A growth study involving a continual analysis of the flora and fauna of a microhabitat would be of interest in order to determine the importance of specific planktonic organisms on bryozoan growth rates.

As might be expected, both density-dependent and density-independent factors appear important in these growth studies. In addition to the density-independent factor, temperature, such factors as nearness to the bottom or nearness to dense

plant growths, were seen to be associated with increasingly rapid disintegration of colonies. As the water level in the Burke Lake outlet became lower and colonies were only one to three inches above the bottom, colony disintegration was accelerated. The growth of newly germinated young colonies was depressed when these colonies were close to the bottom, or enclosed by heavy vegetation. When a substrate became marooned on the tops of heavy plant growth, notably Chara sp. (e.g., C. vulgaris) in Burke Lake, there was a decrease in the growth rate and disintegration of polypides. The underside of the logs were closely pressed into the dense vegetation. In this situation, movement of water was probably impeded. Noxious metabolites from plants and animals, including the ectoproct colonies, may well have accumulated in the poorly circulating water of such a microhabitat and initiated the deterioration of the colonies. Brown (1933) suggests that close association between Bryozoa and Chara may be unfavorable for the former, because Bryozoa had never been found growing on Chara. The author has found four genera associated with Chara, but not often.

The retarded growth which was apparent in colonies situated near the organic lake bottom may have been caused by products of decay, bacterial metabolites, lowered oxygen, or increased carbon dioxide; thus density-independent factors. The metabolites of the Bryozoa themselves and the unavailability of sufficient suitable food (after the colonies reach a certain size) are possibly density-dependent factors. Both

types of factors doubtless work in conjunction to depress growth and accelerate the deterioration of colonies.

A cyclic fluctuation was noted for populations of P. repens. Many spring colonies deteriorated by late in June, and in early July sessoblasts produced by some of them, germinated and produced new colonies. These summer colonies formed sessoblasts which in turn germinated (a third generation) in later September or early October. However, the decline in temperature in October precluded further growth, and these colonies proliferated no more than three to twelve polypides. In November these small retarded colonies died. Marcus (1926) discusses a second generation of colonies in the summer, originating from statoblasts produced in the spring.

Polypide evagination rates for Hyalinella punctata as given by Rogick (1945a; Table II and III) may be compared with those for P. repens in the present study. Rogick's data indicate that second polypides evaginated 6 to 18 days after first polypides; third polypides, 8 to 18 days after first polypides; fourth polypides, 9 to 20 days after first polypides; fifth polypides, 10 to 21 days after first polypides; and sixth polypides, 13 to 21 days after first polypides. Fourteen day averages of numbers of polypides were computed for combined colonies, each of which was begun with one polypide, at Wintergreen Lake. These colonies were located at stations 5, 10, and 12. In colonies approximately 14 days old the polypide number varied generally between four and

eight. These figures are in no way sharply at variance with Rogick's data, which showed that for five different colonies, the sixth polypide was present between 13 and 21 days after the first polypide had evaginated. However, the data for P. repens were obtained for spring colonies, thus the water temperature was probably colder than that in which laboratory-reared colonies of H. punctata were kept. Her data suggest that the growth rate of very young H. punctata colonies was perhaps only somewhat below that of the most actively proliferating P. repens colonies. The time interval between the evaginations of successive polypides of Lophopodella carteri (Rogick, 1935b) is in the beginning somewhat longer than for either P. repens or H. punctata. Rogick presents data largely for two colonies of L. carteri which indicate that second polypides evaginated 19, 21, 38, and 43 days after first polypides; third polypides, 8 and 3 days after second polypides; fourth polypides, 2 and 3 days after third polypides; fifth polypides, 4 and 4 days after fourth polypides; seventh polypides, 1 and 3 days after fifth polypides; twenty-seventh polypides, 7 and 8 days after eighth polypides. One of these colonies budded its thirty-seventh polypide 68 days after germination, and the other budded its forty-fifth polypide 70 days after germination. The time which these colonies required to attain 37 and 45 polypides is considerably greater than for the more actively growing colonies of P. repens. More slowly growing colonies, such as R-2 and R-3 at station 4, Burke Lake, only required an estimated 40 to

43 days from the germination of statoblasts to reach the 41 and 42 polypide stage respectively. Colonies at stations where growth was depressed, of course, increased more slowly than the L. carteri colonies. Rapidly growing colonies of P. repens developed 150 to 200 and more polypides in 35 to 45 days. The proliferation of the first several polypides of a colony requires proportionately more time than the proliferation of later polypides in colonies of all three species being discussed. Early budding was particularly delayed in L. carteri. However, some increase in the growth rate was noted in the proliferation of later polypides. One L. carteri colony tripled during a seven day period. Many P. repens colonies tripled in size in a seven day period. Some colonies of P. repens increased by four, five, six, and even seven times their size in a seven day period.

Rogick (1938) gives additional growth data for L. carteri colonies reared in the laboratory. Second polypides developed 4 to 20 days after germination of the first polypides. However, her data indicate that it took from 30 to over 40 days for colonies to triple (from 6 to 18 individuals), and the lowest doubling time for a single interval was seven days (single interval doubling times are only comparable to single interval times for P. repens, not to doubling rates). Rogick's (1945a) data indicate that the most successful colonies of H. punctata doubled in a period of three or four days, once they had attained a size of six polypides. Three colonies tripled (6 to 18 polypides) in 4, 5, and 11 days. Comparable

increases may be found in the data on P. repens.

Rogick counted the total number of polypides in her colony R-4b until it had 45 individuals, after which she counted only evaginated polypides. If the growth of the R-4b colony of H. punctata is graphed up to the forty-fifth polypide stage, an essentially geometric growth is evident. Admittedly this only represents a single colony in a relatively early stage of development. However, as the most successful colony of those studied, its growth suggests that another species of Ectoprocta tends to grow in a geometric manner.

Certain colonies of P. repens reveal startling increases during a single interval of time. Colonies R-3 and Y-4 at station 5 and colonies P-3 and P-4 at station 6 on Wintergreen Lake, 1960, serve to demonstrate this increase. Several other colonies were observed to double one week and triple or quadruple the next week. Some sharp variations could be caused by temporary changes in the immediate environment of a colony; however, the author suggests that these variations are attributable in part to the nature of the budding process. On the maternal cystid wall, three buds usually form; a main bud ventral to the vestibular region, a duplicate bud which is developed from the ventral proximal surface of the main bud, and an adventitious bud located on the side of the main bud nearest the mother polypide wall. When the main bud grows out and away from the mother polypide, the adventitious bud above it become the main bud of the mother polypide. The

duplicate bud becomes the main bud of the original main bud which has grown away from the mother polypide. This process has been observed by the author and has been studied in detail by Brien (1936, 1953). Incipient buds may be seen forming with close microscopic examination. However, when a number of mother polypides have a series of buds about to evaginate polypides, these are not readily apparent under low power magnification nor can they be counted as mature individuals. If, hypothetically, a majority of individuals in a colony each had incipient buds which were nearly completely developed, but still non-evaginable, then a count of the colony at this particular time would be considerably lower than a count of the same colony, a matter of a few hours or a day later when a particularly large number of incipient buds had become evaginable polypides. If each polypide of such a colony then proliferated one or more subsequent animals in addition to the nearly mature polypides which had not been counted the week before, then the second count, several days later, would be relatively greater than that recorded at the previous observation period. This third observation could reveal a proportionate decrease when compared with the sudden comparatively large increase of the second observation. Rogick's (1945a; Table III) illustrates how different the data would be if a polypide count of colony R-4b had been taken early on the 20th day after statoblast germination. Polypides 32 through 45 all evaginated on the same day. An early count in this case would have disclosed as many as 14 fewer polypides than

a later count the same day. The 14 polypides not included in the early count would then be compounded with any additional mature buds proliferated by the next observation period. If a majority of polypides, in addition, had proliferated new mature buds just prior to the second observation, then this latter count, by virtue of timing and the recency of a large-scale proliferation of buds, might have revealed a relatively unusual rate of increase between these two observation periods.

MORTALITY DISCUSSION

Gross mortality, indicated by an X in the growth tables, is graphed for a number of stations in Appendix Fig. 29 to 36. The data are provocative, because they show that entire substrates were completely denuded of Bryozoa in only a few days. Often the chitinous (Hyman, 1958) coenecia and even the sessoblasts were removed from the substrate. In the case of many of the marked colonies only the colored pegs remained to mark the site of the expunged colonies. Stations 5, 6, 6b, and 9 (Appendix Fig. 29, 30, 31) at Wintergreen Lake and, stations 2 and 5 (Appendix Fig. 32, 33, and 36) at Burke Lake demonstrate especially well the sudden annihilation of Bryozoa from a substrate. These data suggest that the Ectoprocta may play a reasonably important role as a prey species. Marcus (1925, 1926) states that tendipedids are noteworthy predators of Bryozoa. The author has not observed excessive predation by these animals, but has observed it by Trichoptera. Such large scale predation suggests the possible survival value of the thousands of statoblasts produced by the polypides of Plumatella repens (often 15 to 20 per polypide) on a single substrate.

Sometimes one portion of a substrate was attacked by predators and later another portion was attacked. At station 9 on Wintergreen Lake, colonies G-1 through G-6 were missing on May 13, and most of the remaining colonies were gone on June 7. The second wave of destruction included a number of large colonies. This does not indicate incidental predation or

predation on an occasional polypide, but rather a methodical and total obliteration of all polypides. This destruction of colonies, on one area of the substrate at a time, is also evident at stations 2 and 9 on Burke Lake. From these observations, it appears that predators may sometimes concentrate on just one portion of a substrate. Increased numbers of snails and insect larvae, particularly Trichoptera, have been noted on substrates, concurrent with heavy attrition of bryozoan colonies. These same predators have been observed attacking and devouring polypides in the laboratory. Possibly the periodic devastation of bryozoan populations was associated with a peak in the population of certain predators.

Further examination of the data reveals that certain substrates are singularly free of gross predation (e.g., stations 6, 7, 8b, 13, and 14 on Burke Lake; Appendix Fig. 32,34, 36). Substrates which were largely free of heavy and sudden predation, were those substrates which were not closely appressed or surrounded by dense mats of vegetation or by other substrates. They were in most cases fixed in open water, (or in areas of moderate plant growths) in the slowly flowing current of the outlet, or they were fixed outside the perimeter of the dense shore line vegetation. These substrates were often held in place by a thin projecting tree root or by a stick across the outlet. Those substrates partially resting on the bottom, surrounded by dense vegetation, or closely appressed on both sides by other substrates were naturally more accessible to crawling predators, which were often found heavily

concentrated in the vegetation. Thus where the substrate was not easily accessible to crawling predators, or where the substrate could not readily be used as a bridge to other substrates, predation was reduced.

The question of whether site of chance played the primary role in determining which colonies survived predation merits attention. If there was a sharp decrease in the number of colonies on a substrate, followed by a leveling off in the predation, it might be concluded that either the colonies had the most satisfactory sites, or the number of predators had decreased. When predation is high, then the suitability of a site is tested. At many of the sites, the substrate was a flat plank. There were some substrates, however, with splits or checks in the wood, or with rough bark, which by the nature of their irregular contours offered some colony site variation. Colonies G-1, G-2, and G-3 at station 3 on Burke Lake, were located on the roughened end of a plank and retained their colony integrity longer than any on this plank. Probably it was the special location of the colony, being on the end farthest away from contact with adjacent substrates, which accounts for these colonies being spared. The chances of predators proceeding to the free end were less than for other locations on the substrate. Station 12 on Wintergreen Lake was a rough-bark log. Large colonies had developed on this substrate, but within approximately two weeks, there was no trace of a polypide on the five foot log. Colony R-1, composed of more than 1200 polypides, had been completely

obliterated in approximately 10 days. Only one or two of numerous sessoblasts were still found cemented to the substrate.

There were colonies on certain substrates, which had grown down into very thin checks in the wood. On several occasions these deeply entrenched colonies were the only ones left on a substrate. These colonies were not marked, because of the impossibility of making careful observations on polypides. Their survival was probably attributable to a favorable site. Large predators, such as most Trichoptera larvae, snails, and fish, could not reach them. These colonies were still accessible to many tendipedids.

The graph for Wintergreen Lake, station 8 (Appendix Fig. 29), shows a gradual attrition of colonies. Other substrates with a similarly uniform surface demonstrate a relatively constant attrition. These substrates were probably subject to the continual movement of a limited number of predators across their surfaces. There is nothing to indicate that certain sites were more suitable at these stations. In time most of the colonies were removed or partly removed which suggests that chance is the primary factor operating in the sequential attrition of these colonies.

As indicated earlier, the location of a substrate with reference to its closeness to vegetation and other substrates is correlated with a high attrition. Chance plays, perhaps, the major role in determining which colonies on a substrate are ravaged. However, the physical restrictiveness of a site may preclude decimation by certain predators.

LONGEVITY DISCUSSION

The longevity data reveal that Plumatella repens polypides survive between 4 and 53 days. Neither the time that each of the polypides had existed prior to being marked, nor the time they survived beyond the last observation is known. Therefore, longevity data represent minimal time, and an unknown plus value may be assigned to each longevity record. This plus value may conceivably vary from a few hours to a few days. Longevity data were obtained from polypides in colonies which appeared to be healthy. Station 1 at Burke Lake was an exception. None of the polypides studied at this station lived longer than 19 days. The survivorship curve (Appendix Fig. 37), based on 373 polypides, indicates an appreciable polypide death rate between 21 days and 36 days. The maximum longevity was 53 days, recorded for one polypide from station 4 and one from station 5 on Burke Lake in 1959. Two polypides survived for 44 days, and still others, for more than 35 days.

Hyatt (1868) states that Bryozoa with stiff ectocysts, such as Plumatella and Fredericella live longer than Bryozoa with gelatinous ectocysts, such as Cristatella, Lophopus, and Pectinatella. However, he offers no concrete data. Marcus (1925) estimated that few bryozoan polypides live longer than six weeks. Brooks (1929) declared that polypides of Pectinatella magnifica remained alive for six weeks in the laboratory, and Rogick (1938) reports that ancestrulae (first polypides) of Lophopodella carteri live from 6 to 47

days and subsequent individuals for a shorter time. Marcus (1941) estimated that polypides of Stolella evelinae live for 3 to 4 weeks. The data given by Rogick (1945a) for Hyalinella punctata indicate that the longest lived individuals die sometime between 3 and 4 weeks. The longevity data for Plumatella repens overlap, in range, the data given for other species.

Rogick (1945a) indicates that ancestrulae of H. punctata were generally the first to degenerate, the process taking place between 3 and 21 days after statoblast germination. This is a considerably shorter life span than the 47 day maximum longevity that she recorded for L. carteri. Four ancestrulae of P. repens lived from 29 to 32 days: two B polypides from station 4, Burke Lake, 1960, survived until May 29; one P polypide survived to the same date at station 10, Burke Lake, 1960. The ancestrula of colony R-1 at station 12, Wintergreen Lake, lived 29 days and possibly 11 days longer. The density of the colony at the time of the June 7 observation, made it difficult to determine which of two polypides, one alive and one dead, was the ancestrula. Rogick found that some colonies of H. punctata had 17 individuals before the ancestrula began to degenerate. In colony R-1 above, of P. repens, the colony was composed of 76 polypides when the ancestrula was definitely still present.

The polypide longevity data for P. repens appear to agree more closely with those for Lophopodella carteri, than

with those for Hyalinella punctata. However, comparisons must remain somewhat tentative, in that the Plumatella repens data were collected in the field, while the data for the other species were obtained in the laboratory.

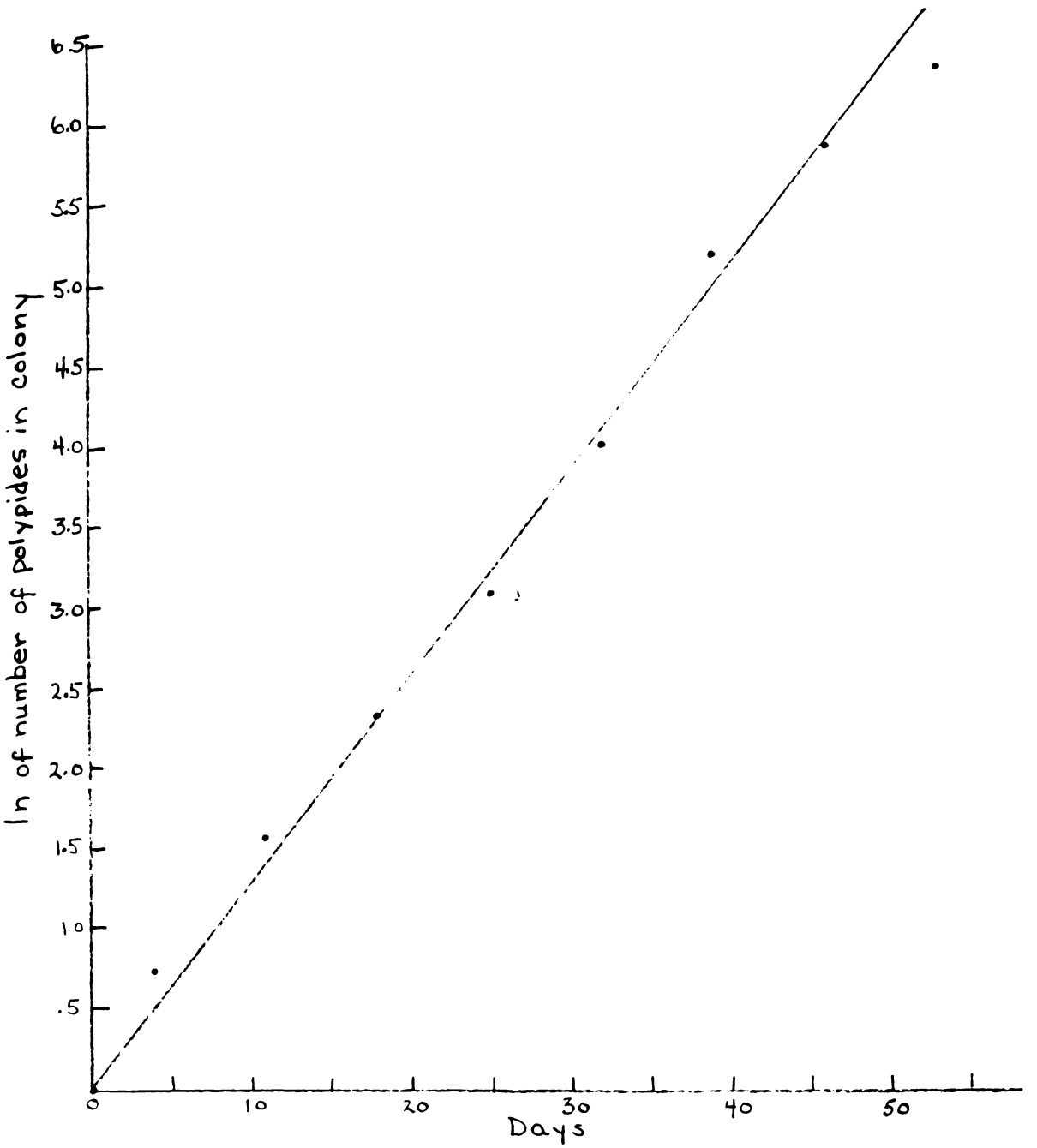
SUMMARY

1. The growth data suggest that the increase in the number of polypides in colonies of Plumatella repens tends to be geometric. This tendency is most clearly revealed by colonies growing under favorable conditions.
2. Robust colonies at the more favorable sites doubled in size each 3.4 to 7.4 days. The summer doubling time was 3.4 to 4.9 days, and the spring doubling time was 4.0 to 7.4 days.
3. Growth was often erratic. Many colonies, during a single seven day interval, failed to double, while others increased four, five, six, and even seven times in size during a single seven day period.
4. Some colonies attained a size of approximately 40 polypides in a 40 to 45 day period, others proliferated as many as 200 or more polypides at the end of a 40 day period.
5. The growth rate was affected by temperature, extreme nearness to dense plant growths (e.g., Chara) or to the marl-organic lake bottom, and by insufficient food.
6. Growth was completely depressed at some stations, with colonies rarely surpassing four to six polypides.
7. Predation on Plumatella repens colonies was very high at a number of stations. Colonies of several hundred polypides were sometimes destroyed between two observation periods. Occasionally an entire substrate was denuded of colonies.

8. Colonies located largely free of dense vegetation and not too close to the lake bottom were believed the most successful, because they were less accessible to crawling predators and deleterious chemical effects.
9. Colonies located in small checks in the surface of a substrate were seldom victims of predation. The physical limitations of such sites protected the colonies from predation by fish, snails, and most Trichoptera.
10. Colony attrition was steady and gradual at many stations suggesting that chance, rather than site, was of most importance at these sites.
11. Longevity data for 373 polypides were obtained. Plumatella repens polypides lived from 4 to 53 days.
12. The polypide death rate appeared to be highest between 21 and 36 days after statoblast germination.
13. Few polypides lived longer than six weeks. Eighty per cent of them died within 28 days, and only 12 of the 373 polypides studied lived longer than 37 days.

APPENDIX

Fig. 1A. Relation of natural logarithm of the number of polypides in colonies with time, for 24 colonies each begun with one polypide, chosen at Burke Lake, Clinton County, station 3, April 27, 1960.



Doubling rate 5.38

Fig. 1B Theoretical increase in the total number of polypides for 24 colonies, begun with one polypide each, chosen at Burke Lake, Clinton County, station 3, April 27, 1960.

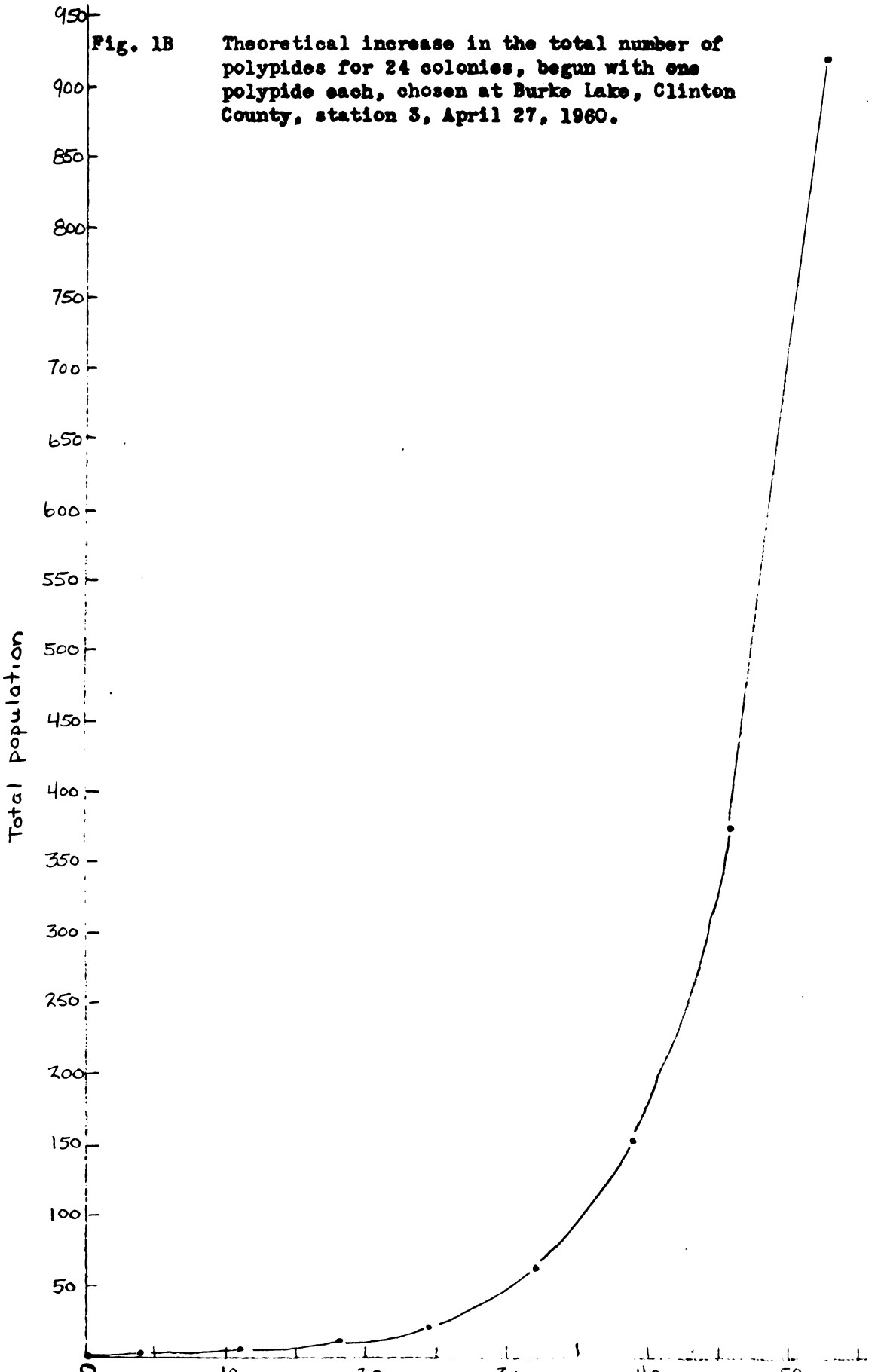
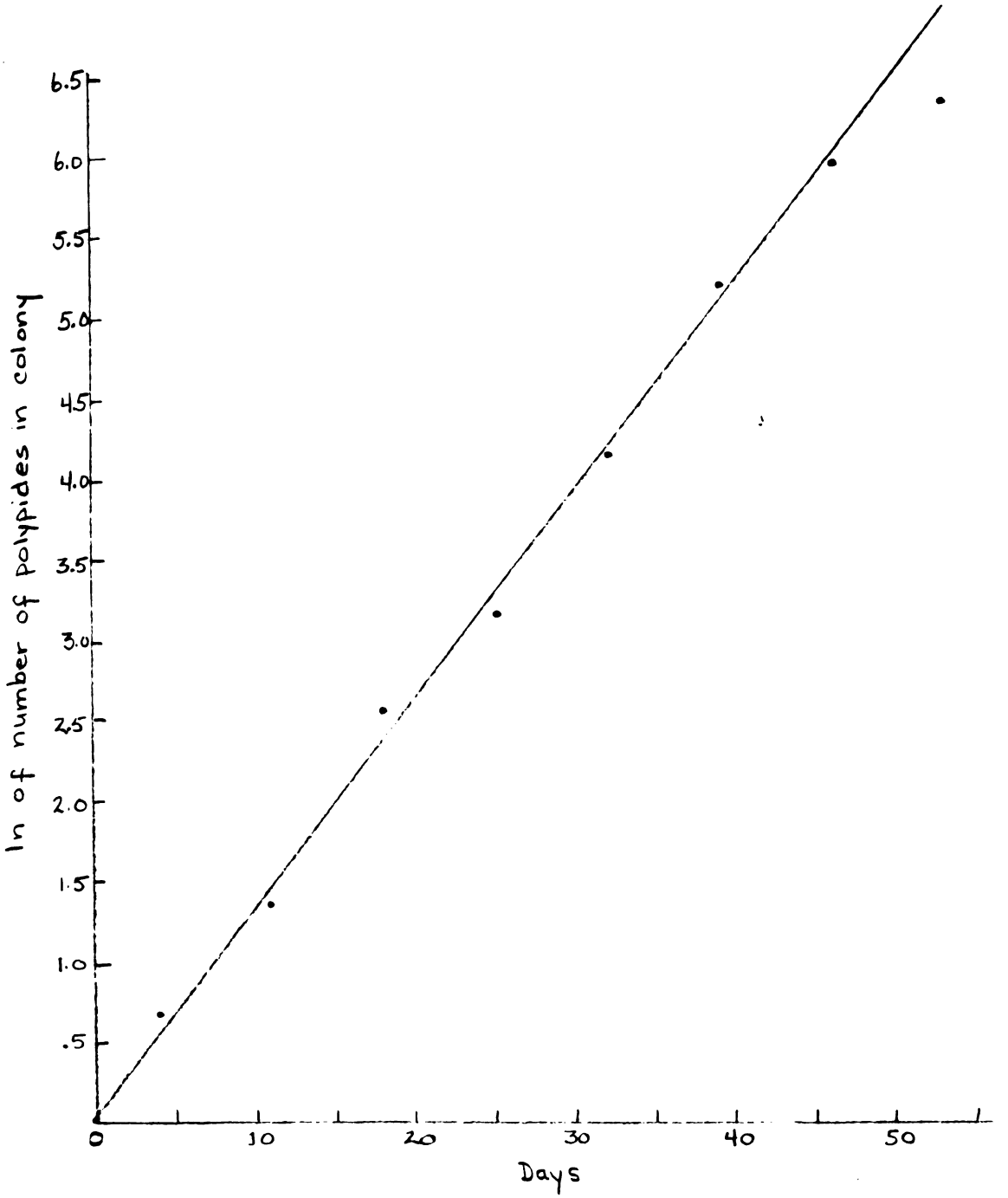


Fig. 2A. Relation of the natural logarithm of the number of polypides in colonies with time, for colonies G-1, G-2, and G-3, each begun with one polypide, chosen at Burke Lake, Clinton County, station 3, April 27, 1960.



Doubling rate 5.33

Fig. 2B. Theoretical increase in the total number of polypides for colonies G-1, G-2, G-3, begun with one polypide each, chosen at Burke Lake, Clinton County, station 3, April 27, 1960.

Time	Equation derived polypide numbers	Actual mean number of polypides
T=4	1.68	2.00
T=11	4.18	4.00
T=18	10.38	13.00
T=25	25.79	23.33
T=32	64.07	65.33
T=39	159.17	183.33
T=46	395.50	400.00
T=53	982.59	600.00

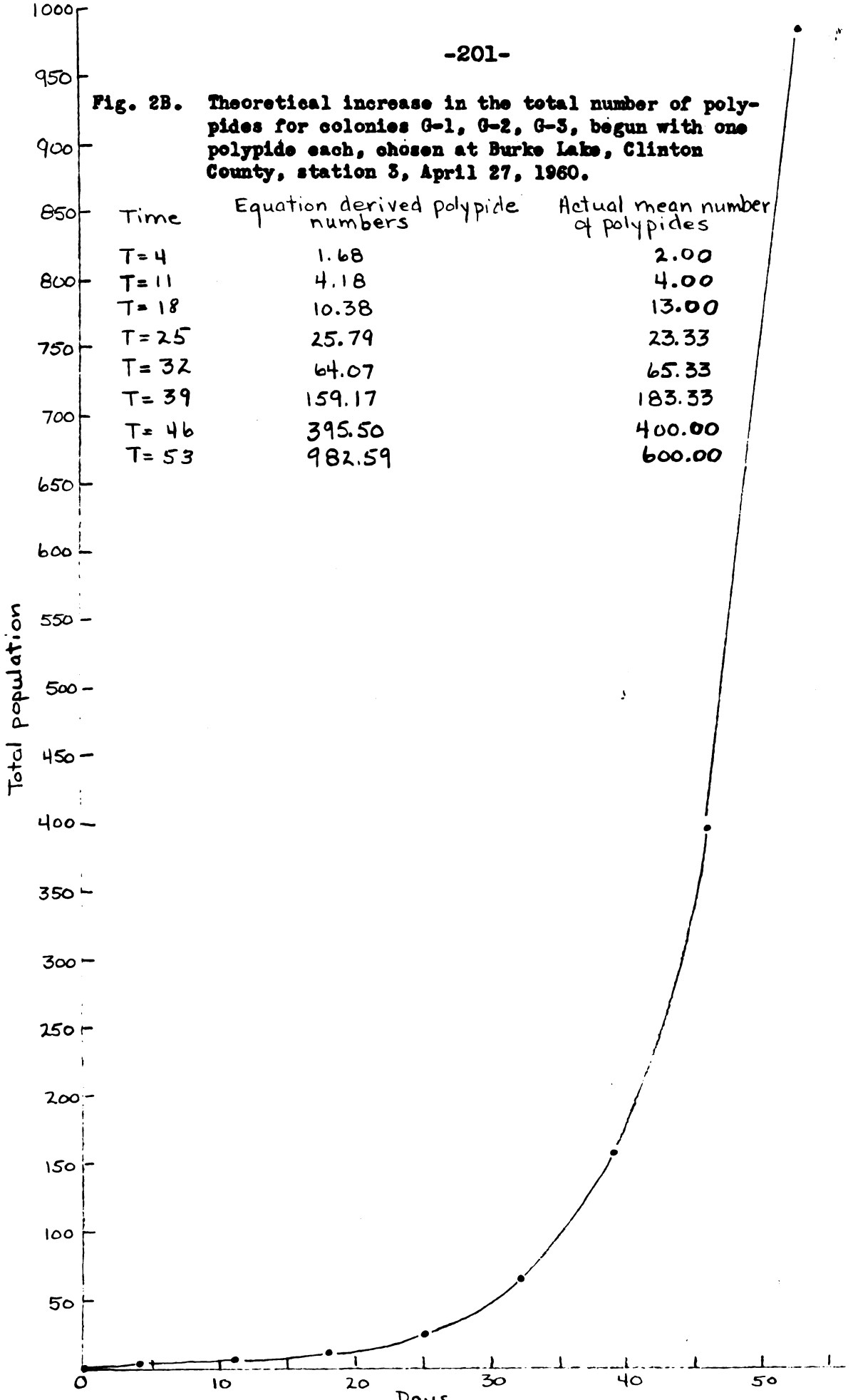


Fig. 3A. Relation of the natural logarithm of the number of polypides in colonies with time, for 11 colonies, begun with two individuals each, chosen at Burke Lake, Clinton County, station 6, April 27, 1960.

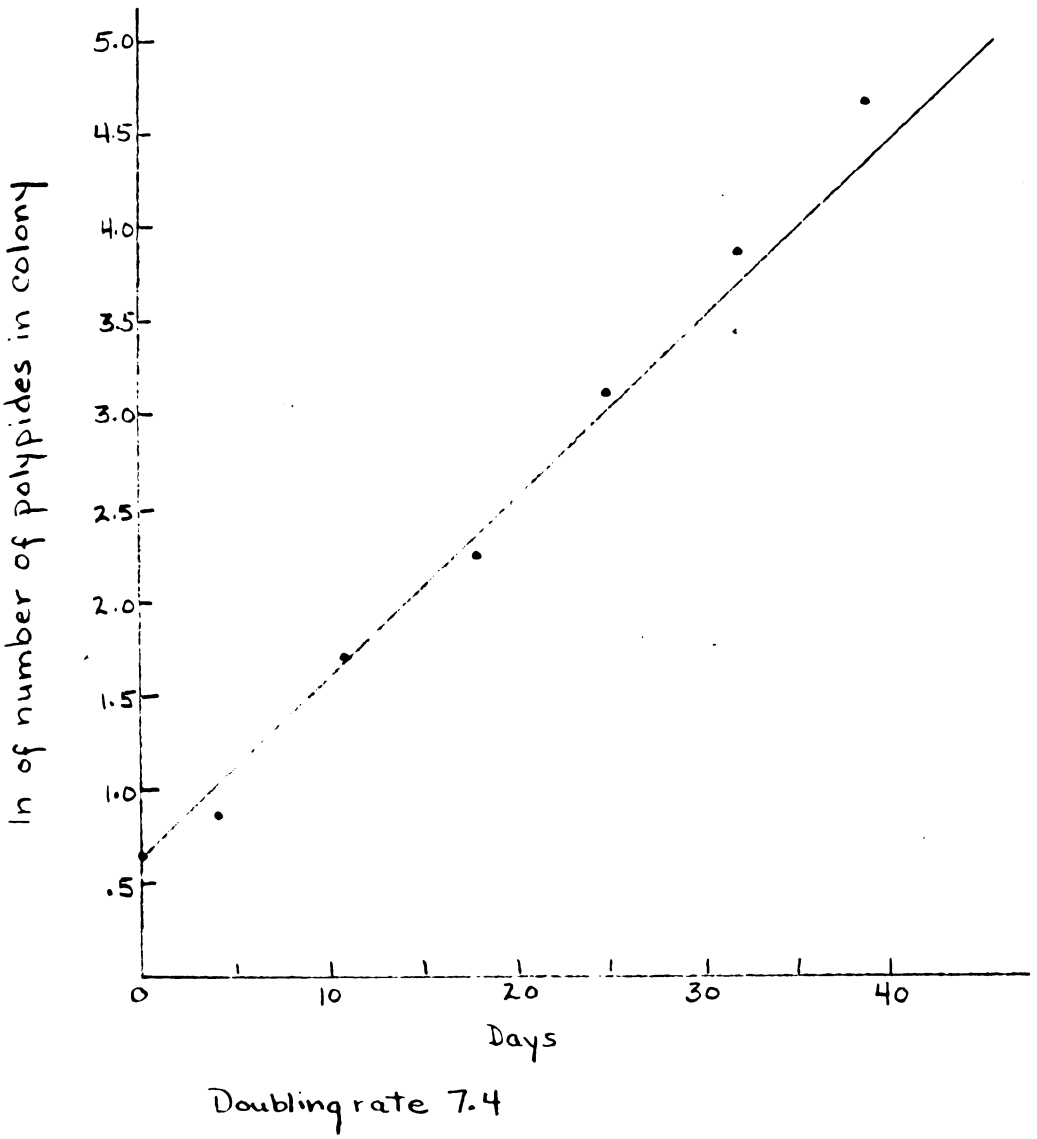


Fig. 38. Theoretical increase in the total number of polypides for 11 colonies, begun with two individuals each, chosen at Burke Lake, Clinton County, station 6, April 27, 1960.

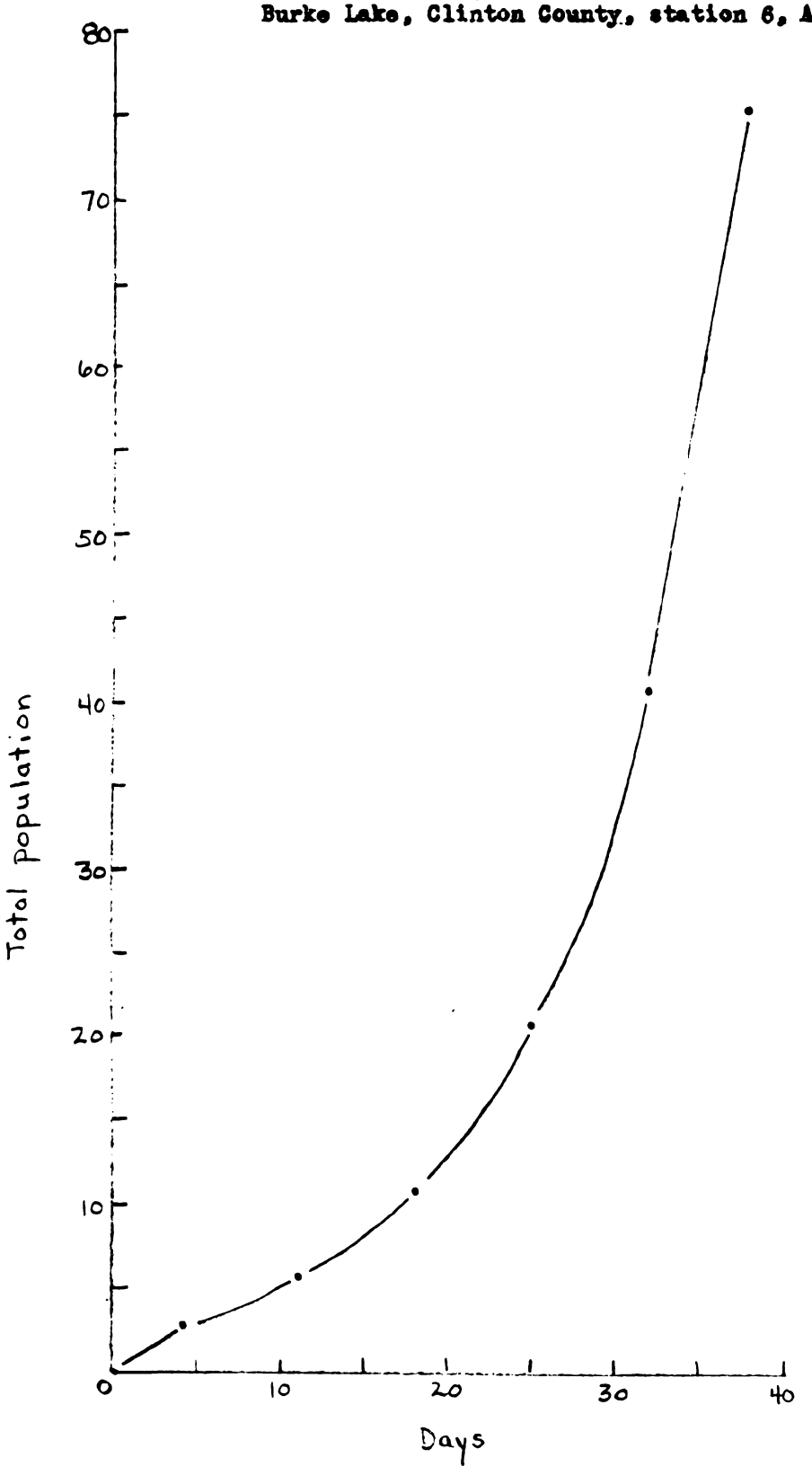
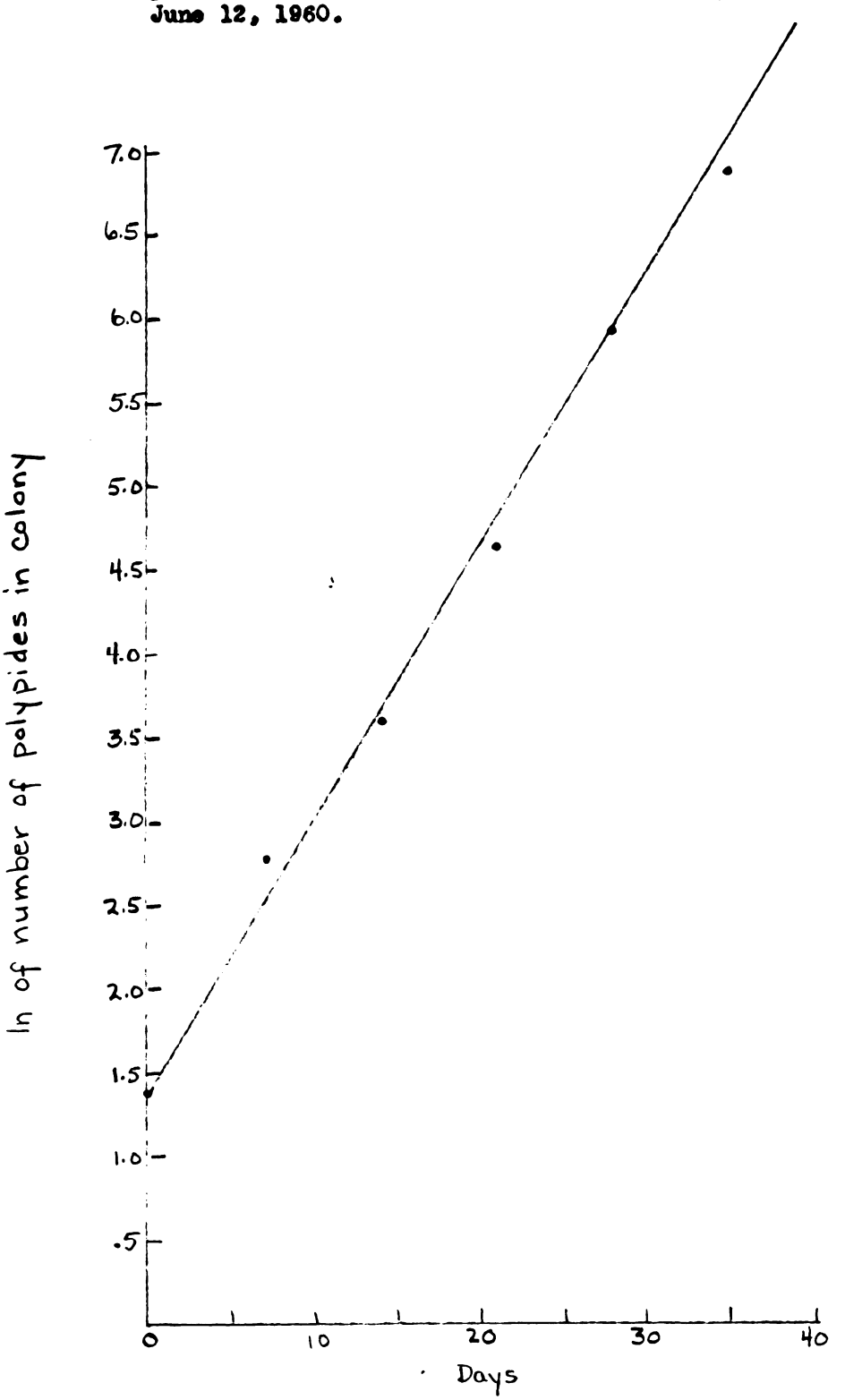


Fig. 4A. Relation of the natural logarithm of the number of polypides in colonies with time, for colony G-2, begun with one polypide, chosen at Burke Lake, Clinton County, station 7, June 12, 1960.



Doubling rate 4.25

Fig. 4B. Theoretical increase in the total number of polypides for colony G-2, begun with one polypide, chosen at Burke Lake, Clinton County, station 7, June 12, 1960.

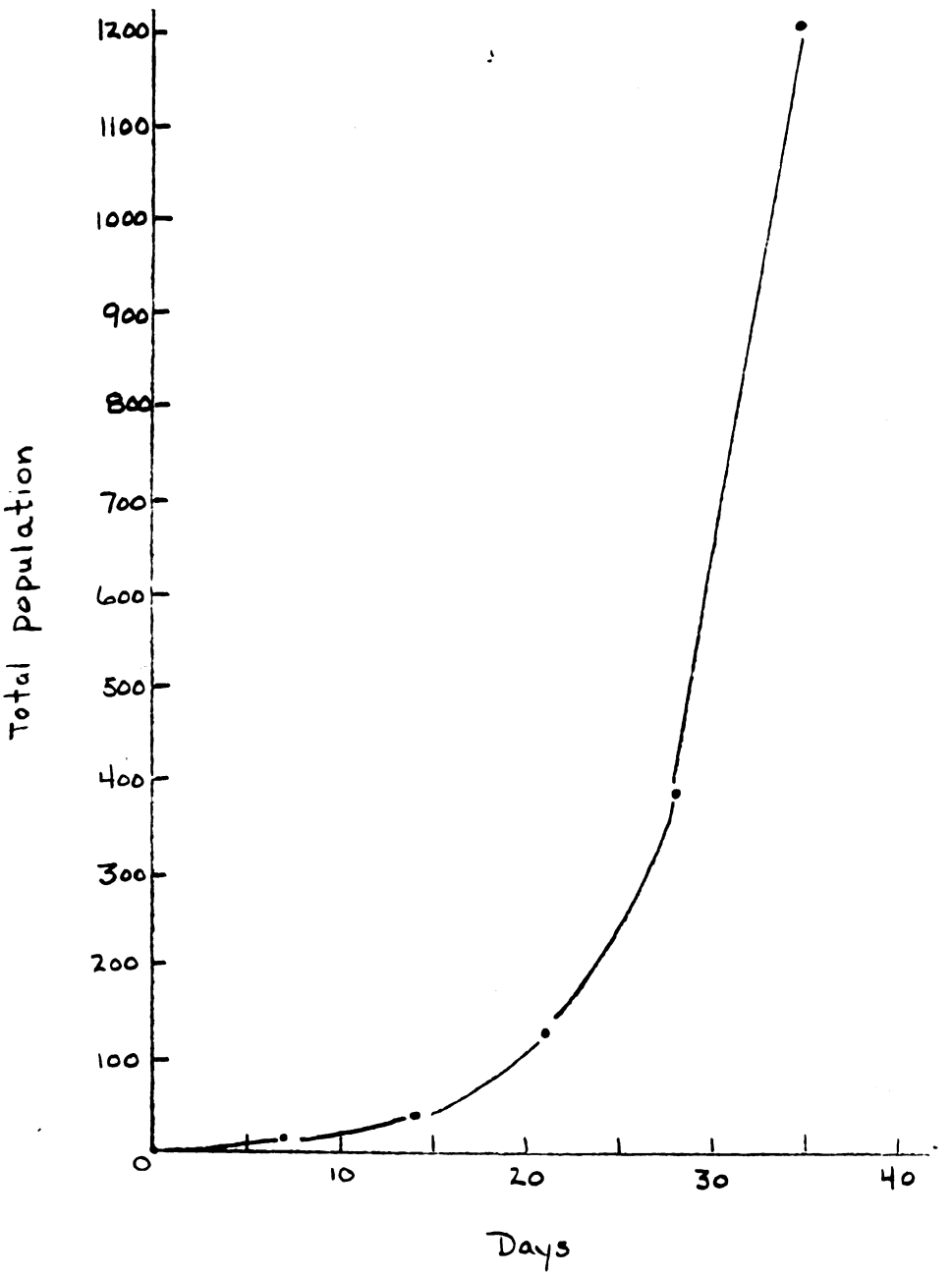


Fig. 5A. Relation of the natural logarithm of the number of polypides in colonies with time, for eight colonies, each begun with two individuals, chosen at Burke Lake, Clinton County, station 7, April 27, 1960.

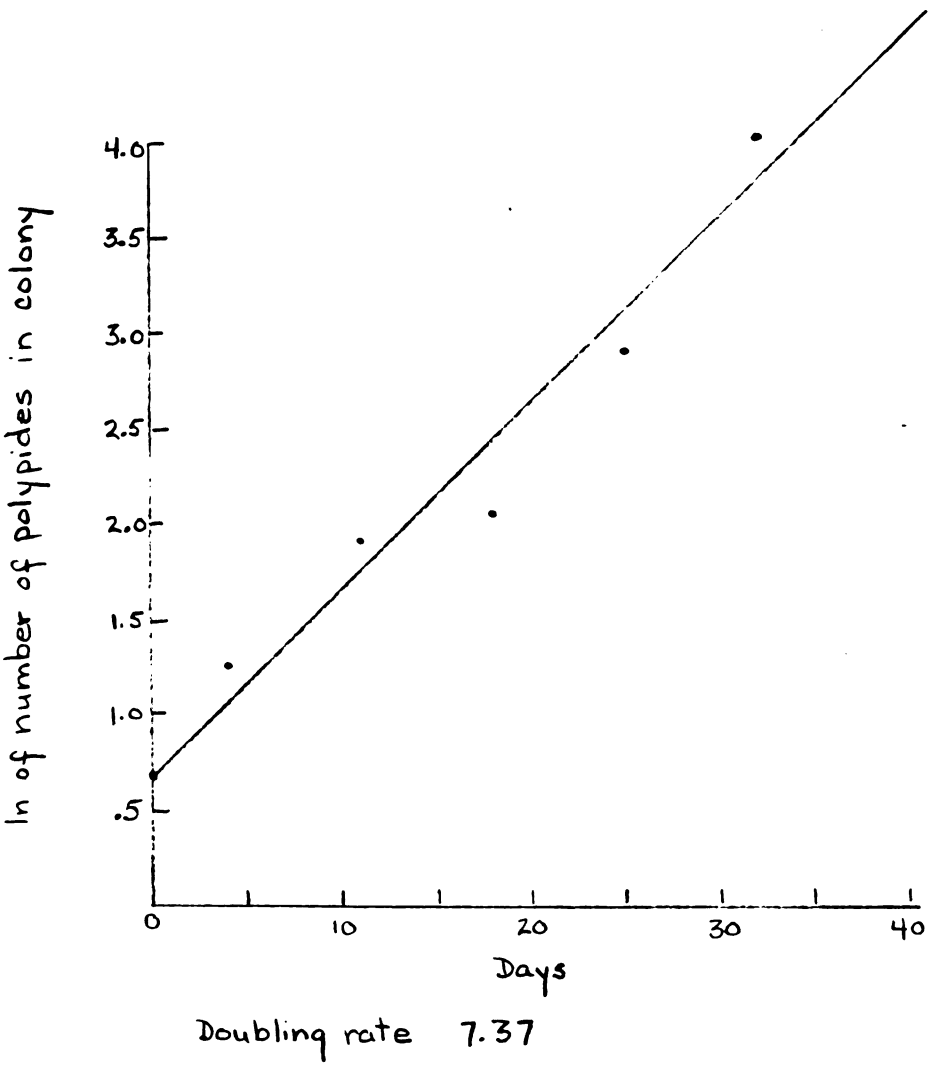


Fig. 5B. Theoretical increase in the total number of polypides for eight colonies each begun with two individuals, chosen at Burke Lake, Clinton County, station 7, April 27, 1960.

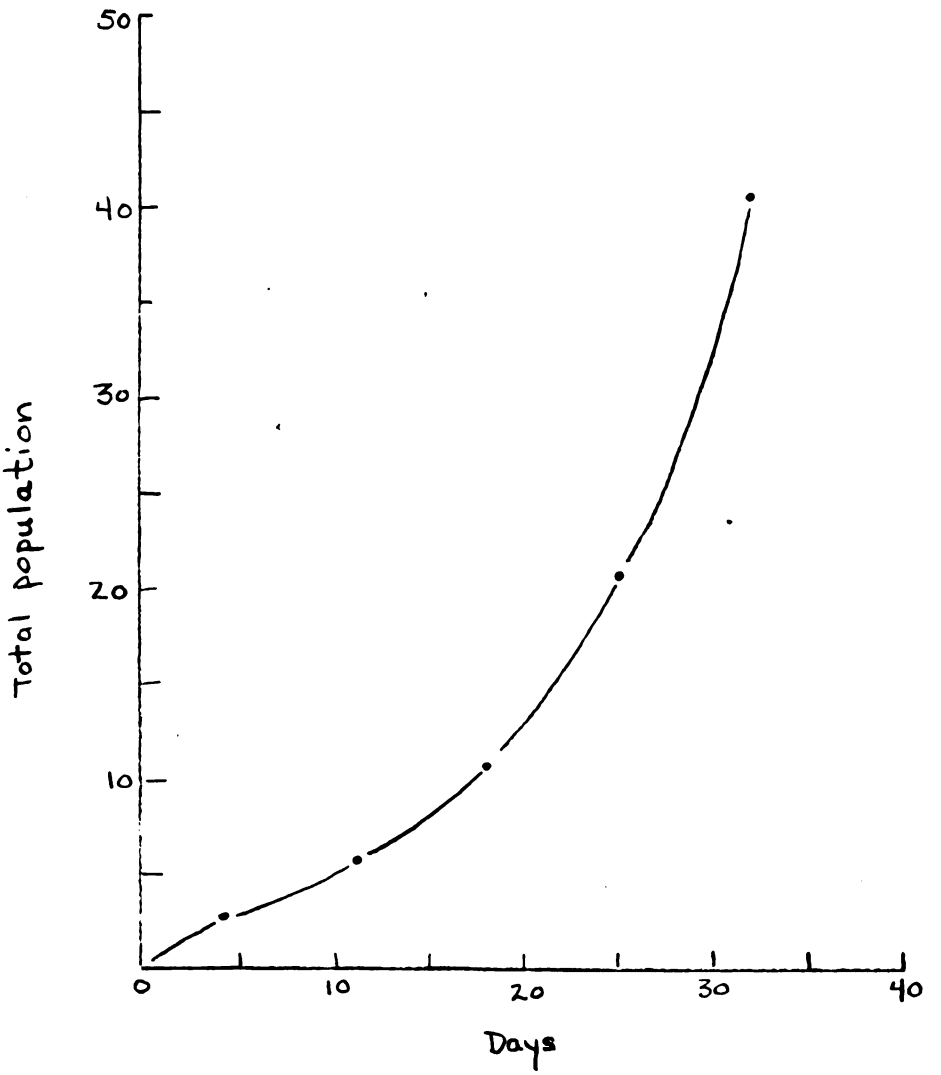
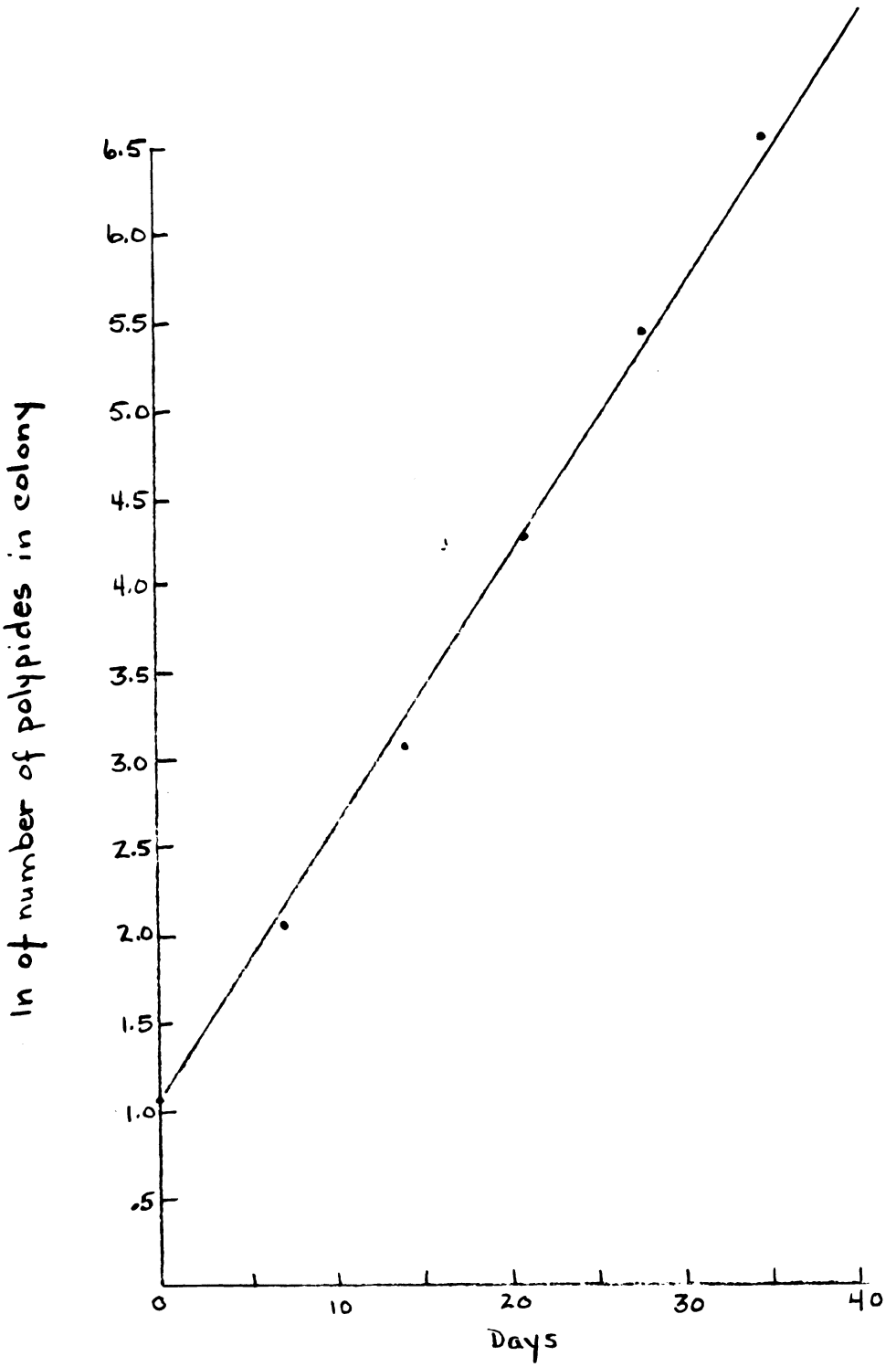


Fig. 6A. Relation of the natural logarithm of the number of polypides in colonies with time, for colony B-1 begun with three individuals, chosen at Burke Lake, Clinton County, station 7, June 12, 1960.



Doubling rate 3.86

Fig. 6B. Theoretical increase in the total number of polypides for colony B-1 begun with three individuals, chosen at Burke Lake, Clinton County, station 7, June 12, 1960

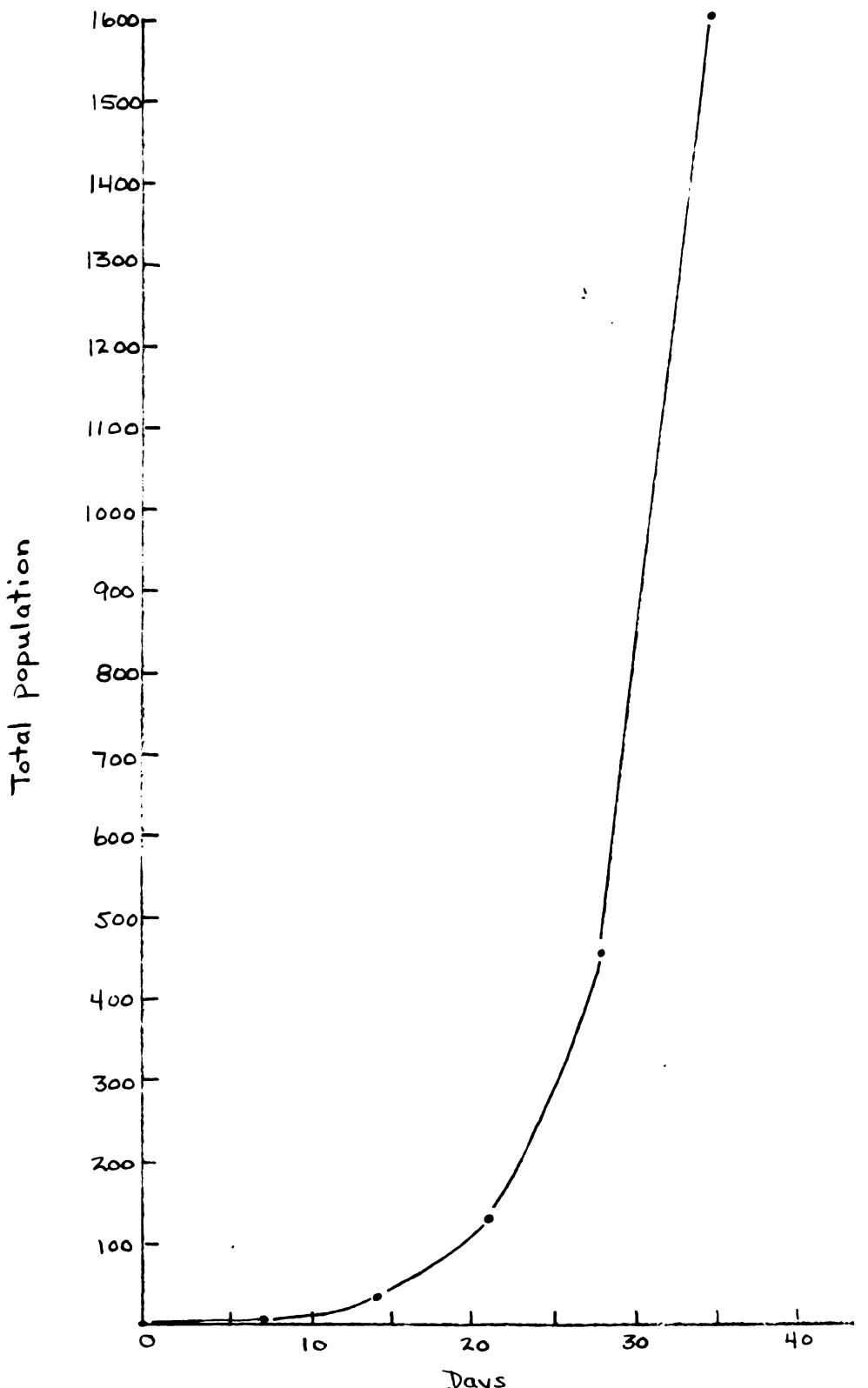


Fig. 7A. Relation of the natural logarithm of the number of polypides in colony with time, for colony W-1 begun with one individual, chosen at Burke Lake, Clinton County, station 7, June 12, 1960.

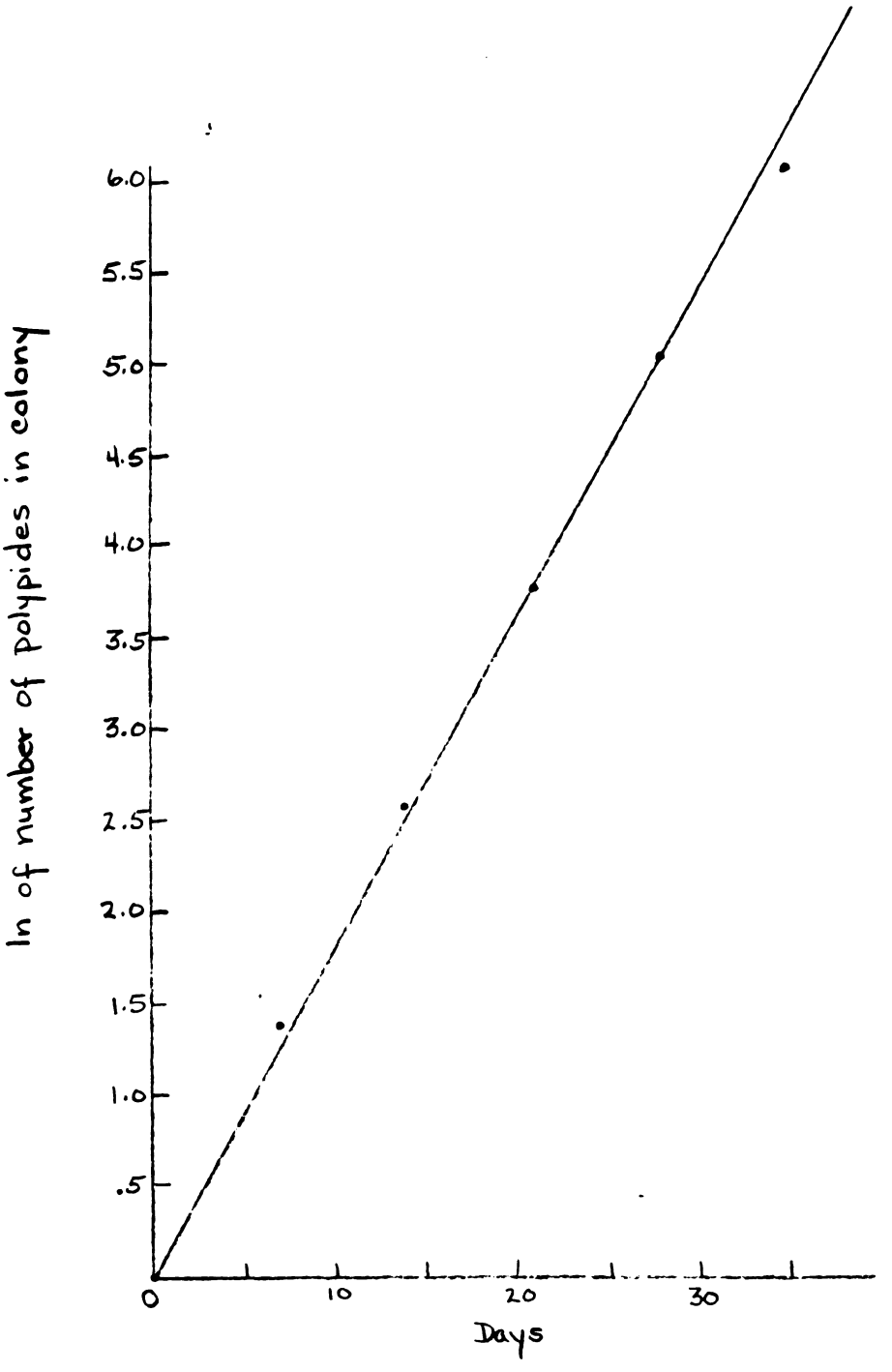


Fig. 7B. Theoretical increase in the total number of polypides for colony W-1 begun with one individual, chosen at Burke Lake, Clinton County, station 7, June 12, 1960.

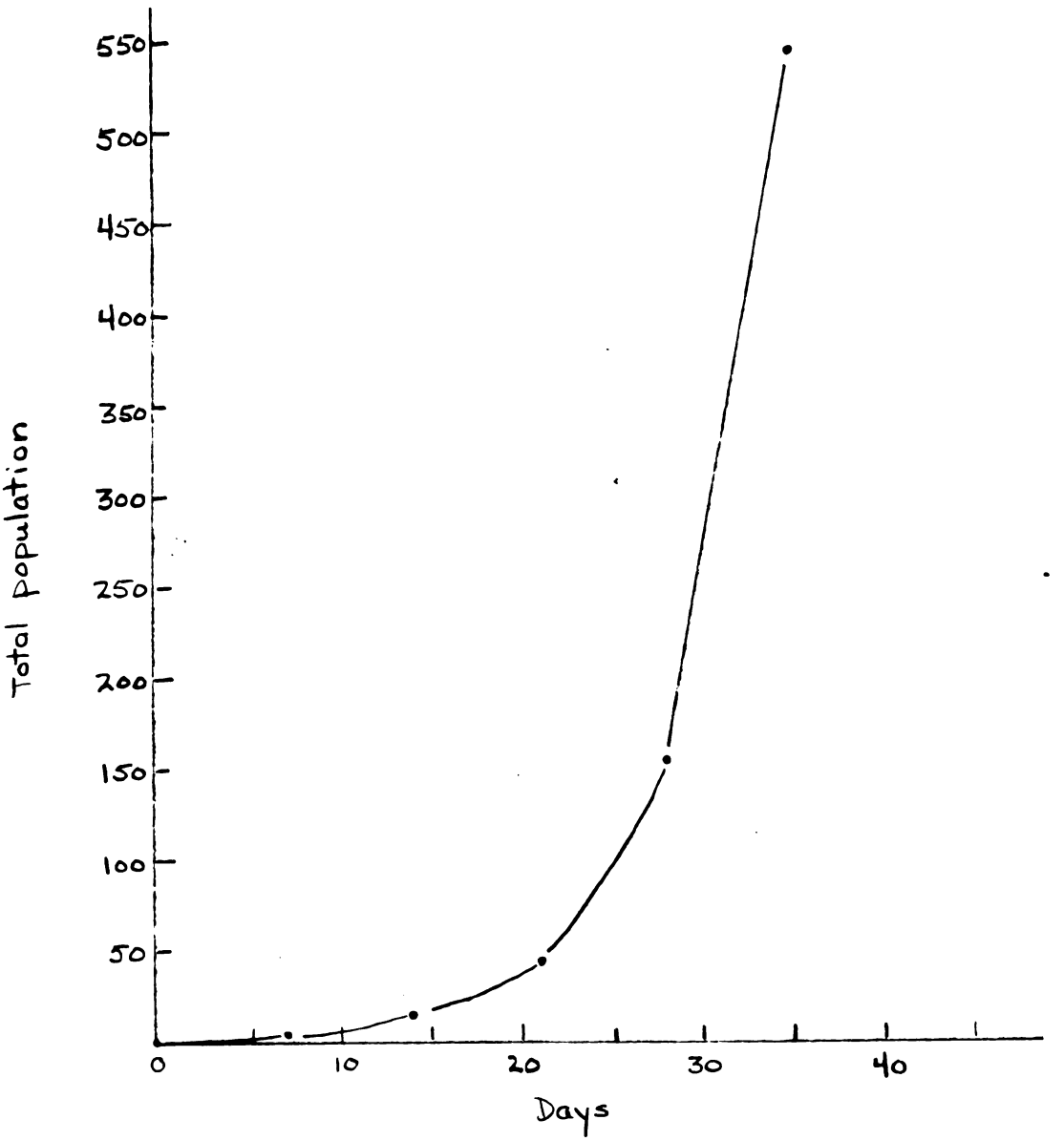


Fig. 8A. Relation of the natural logarithm of the number of polypides in colony with time, for colony P-1 begun with one individual, chosen at Burke Lake, Clinton County, station 8b, May 8, 1960.

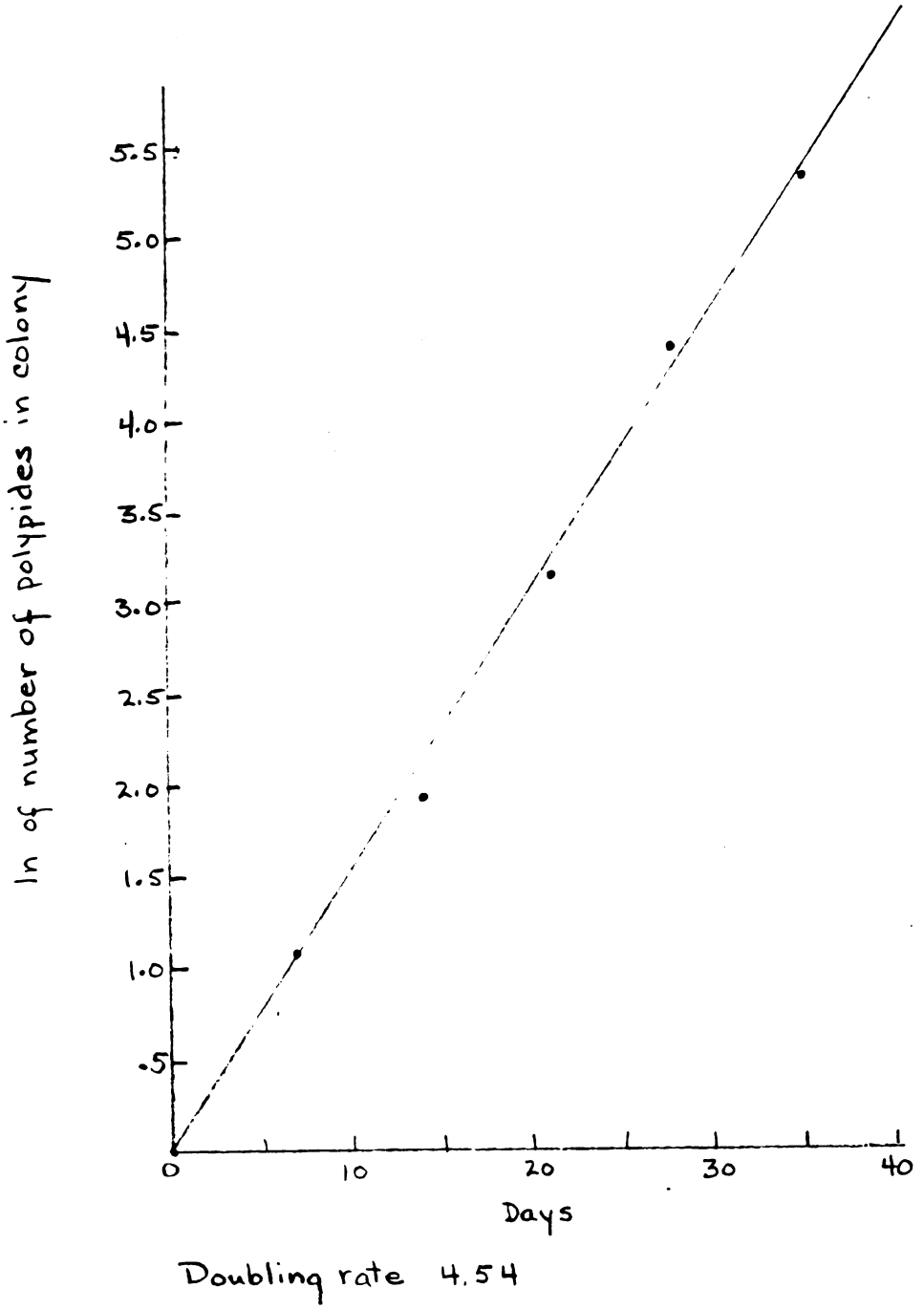


Fig. 88. Theoretical increase in the total number of polypides for colony P-1 begun with one individual, chosen at Burke Lake, Clinton County, station 8b, May 8, 1960.

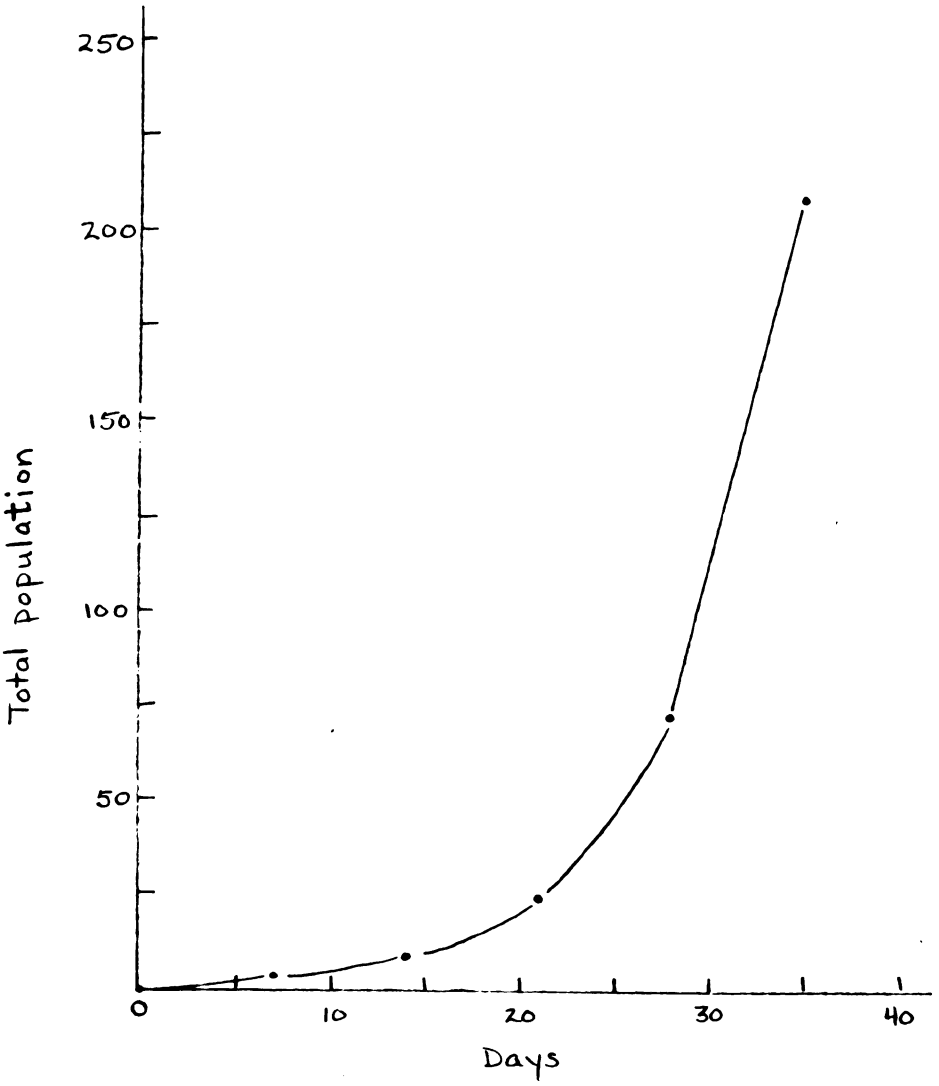


Fig. 8A. Relation of the natural logarithm of the number of polypides in colonies with time, for five colonies each begun with three individuals, chosen at Burke Lake, Clinton County, station 7, June 12, 1960.

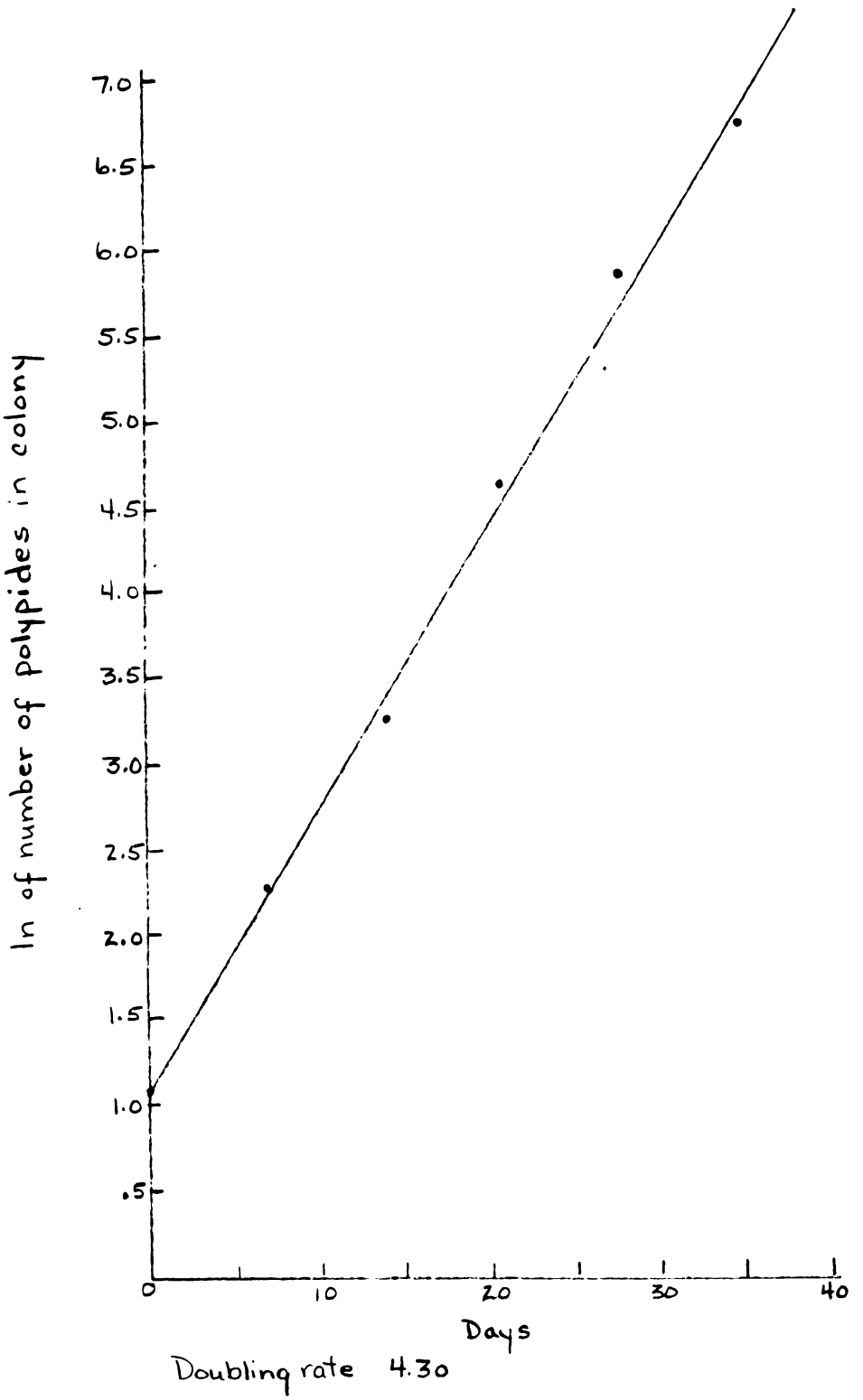


Fig. 9B. Theoretical increase in the total number of polypides for five colonies each begun with three individuals, chosen at Burke Lake, Clinton County, station 7, June 12, 1960.

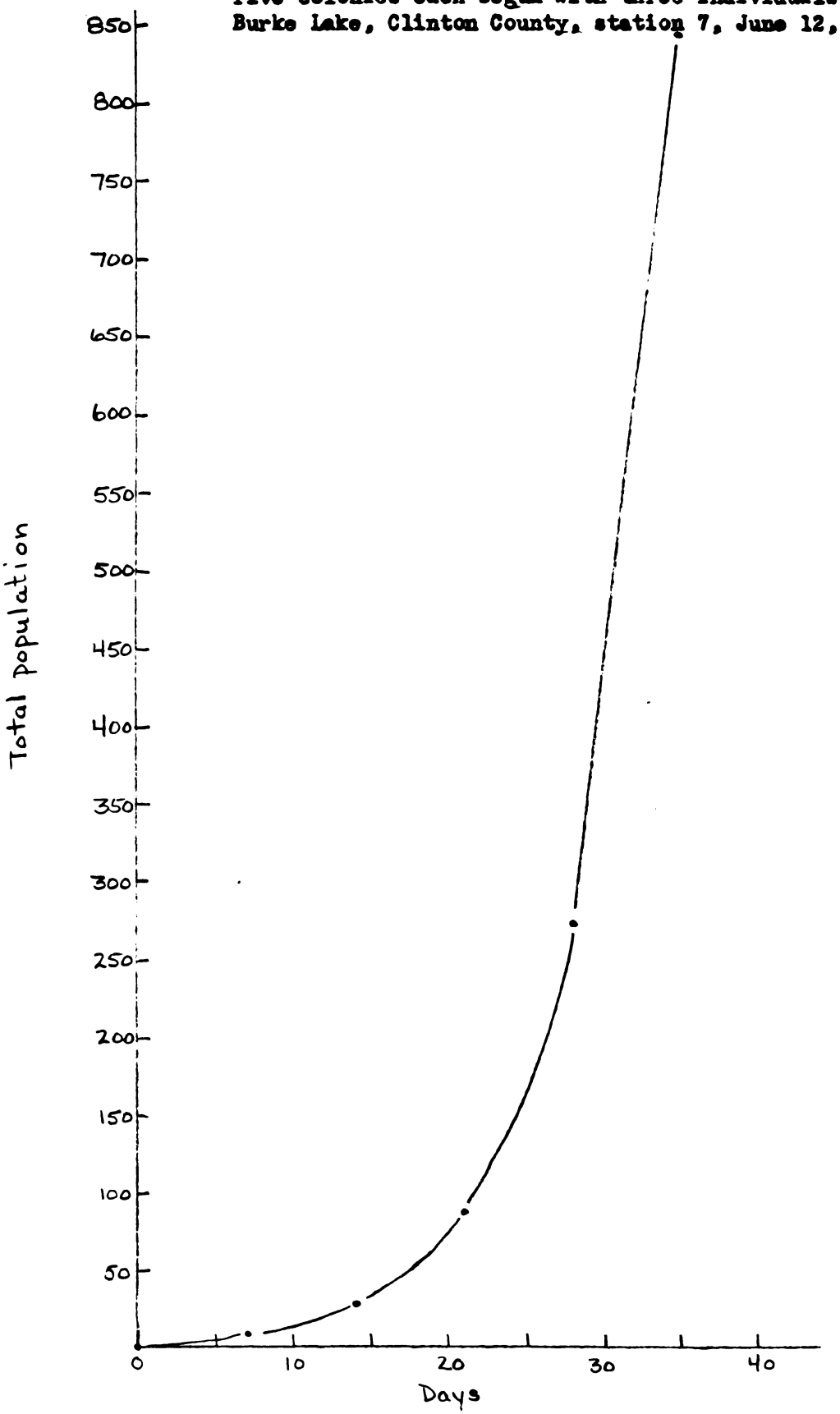
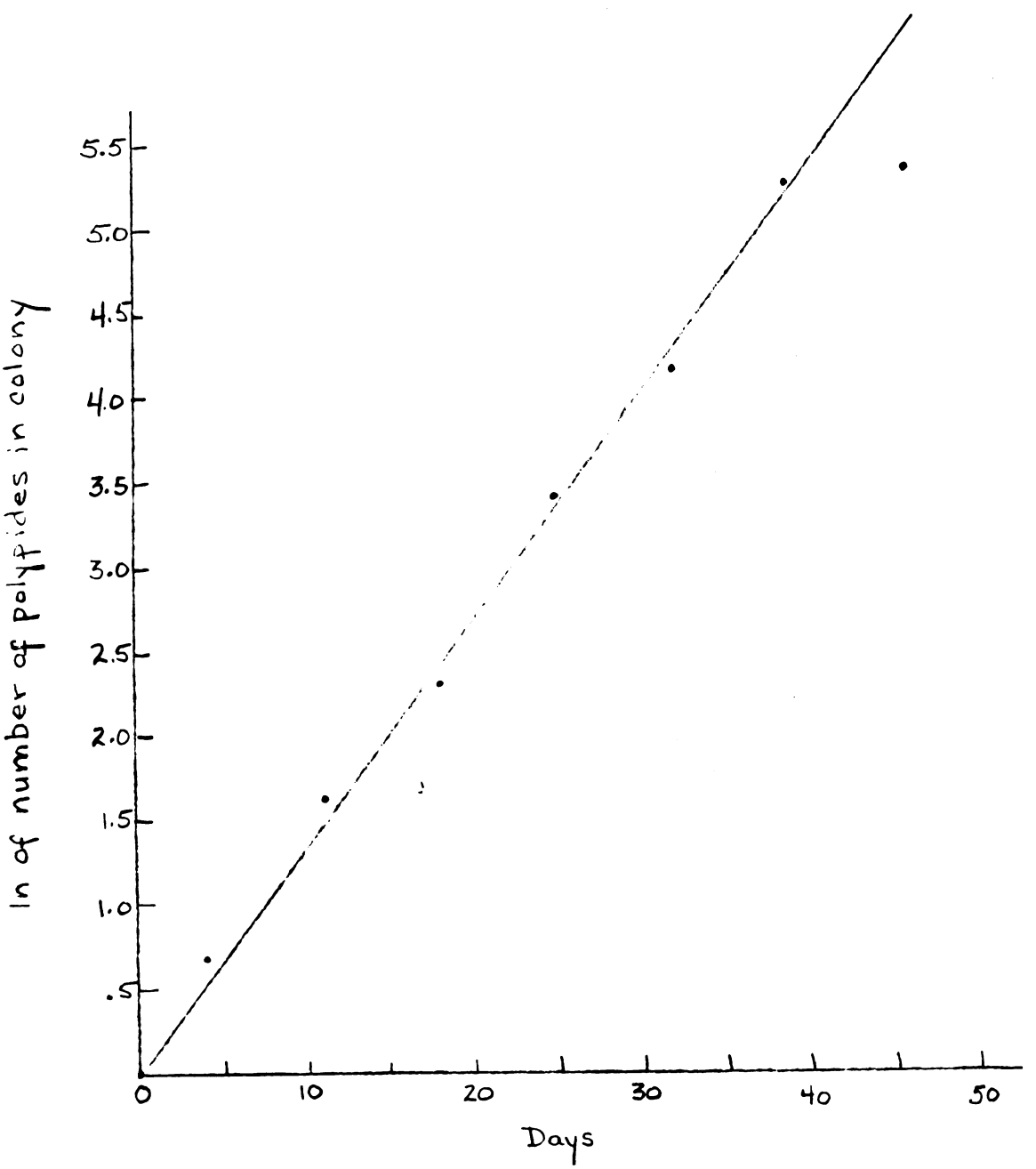


Fig. 10A. Relation of the natural logarithm of the number of polypides in colonies with time, for colony Y-1 begun with one individual, chosen at Burke Lake, Clinton County, station 14, April 27, 1960.



Doubling rate 5.17

Fig. 108. Theoretical increase in the total number of polypides for colony Y-1 begun with one individual, chosen at Burke Lake, Clinton County, station 14, April 27, 1960.

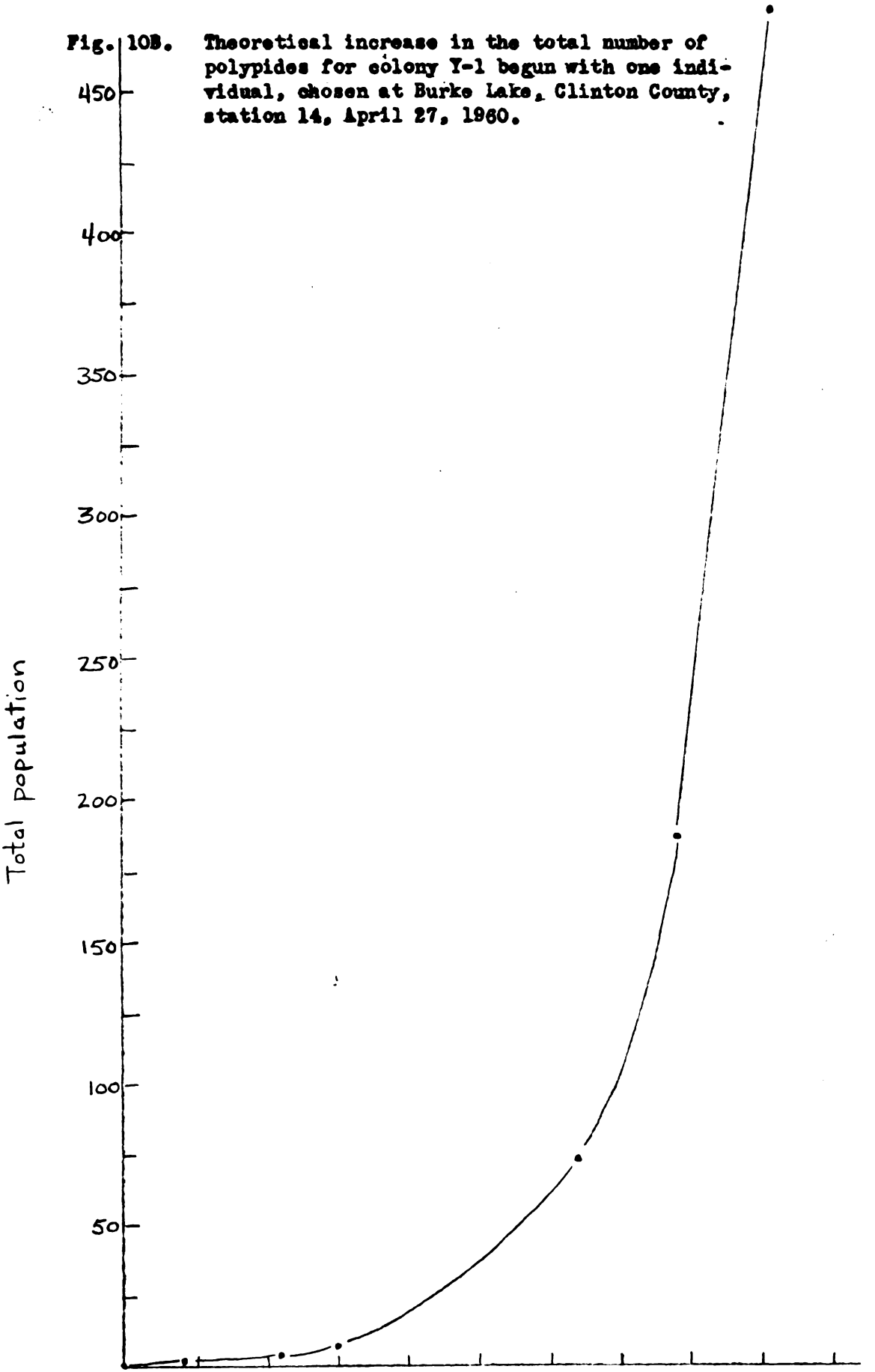
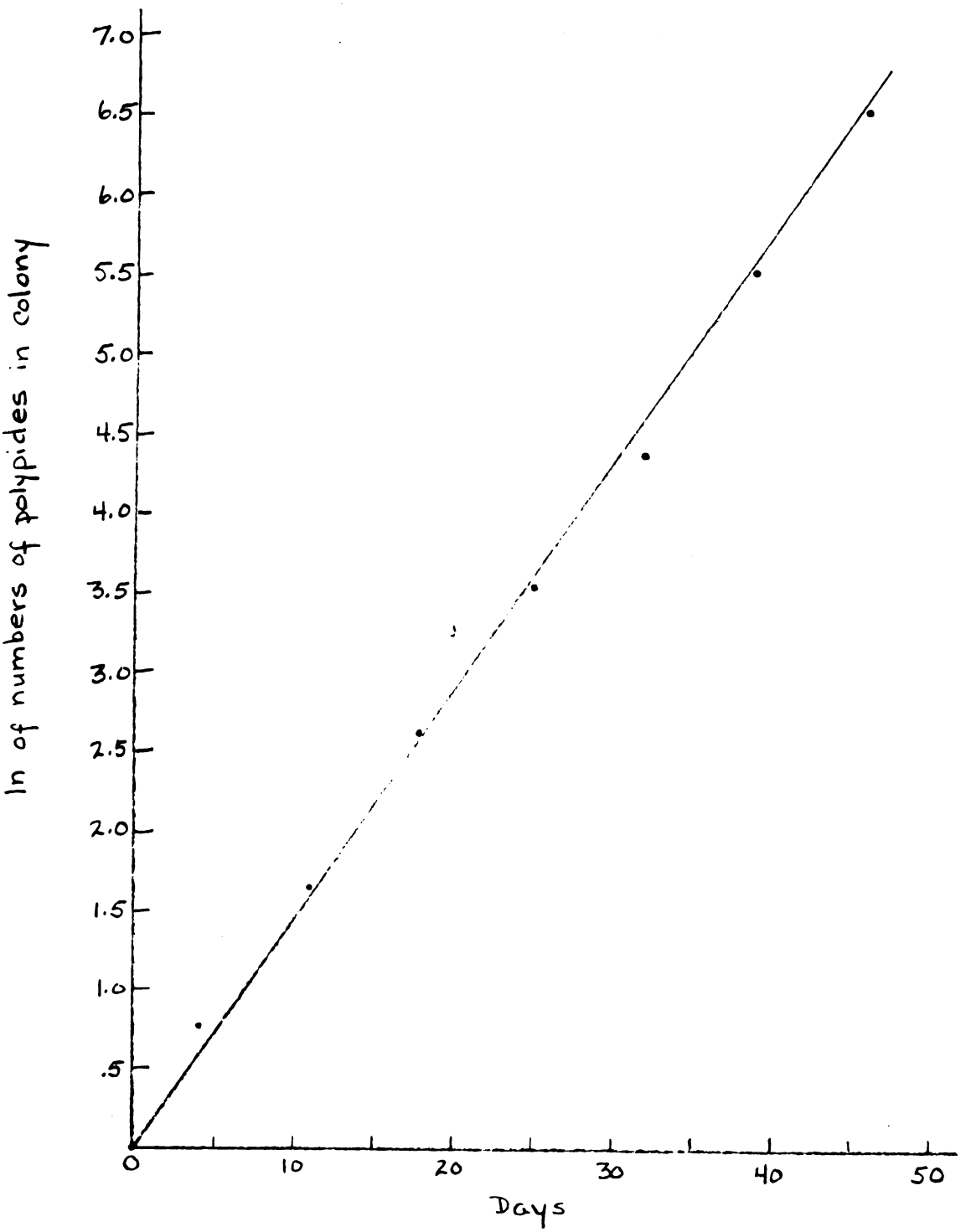


Fig. 11A. Relation of the natural logarithm of the number of polypides in colonies with time, for 11 colonies begun with one individual each, chosen at Burke Lake, Clinton County, station 14, April 27, 1960.



Doubling rate 4.85

Fig. 11B. Theoretical increase in the total number of polypides for 11 colonies, each begun with one individual, chosen at Burke Lake, Clinton County, station 14, April 27, 1960.

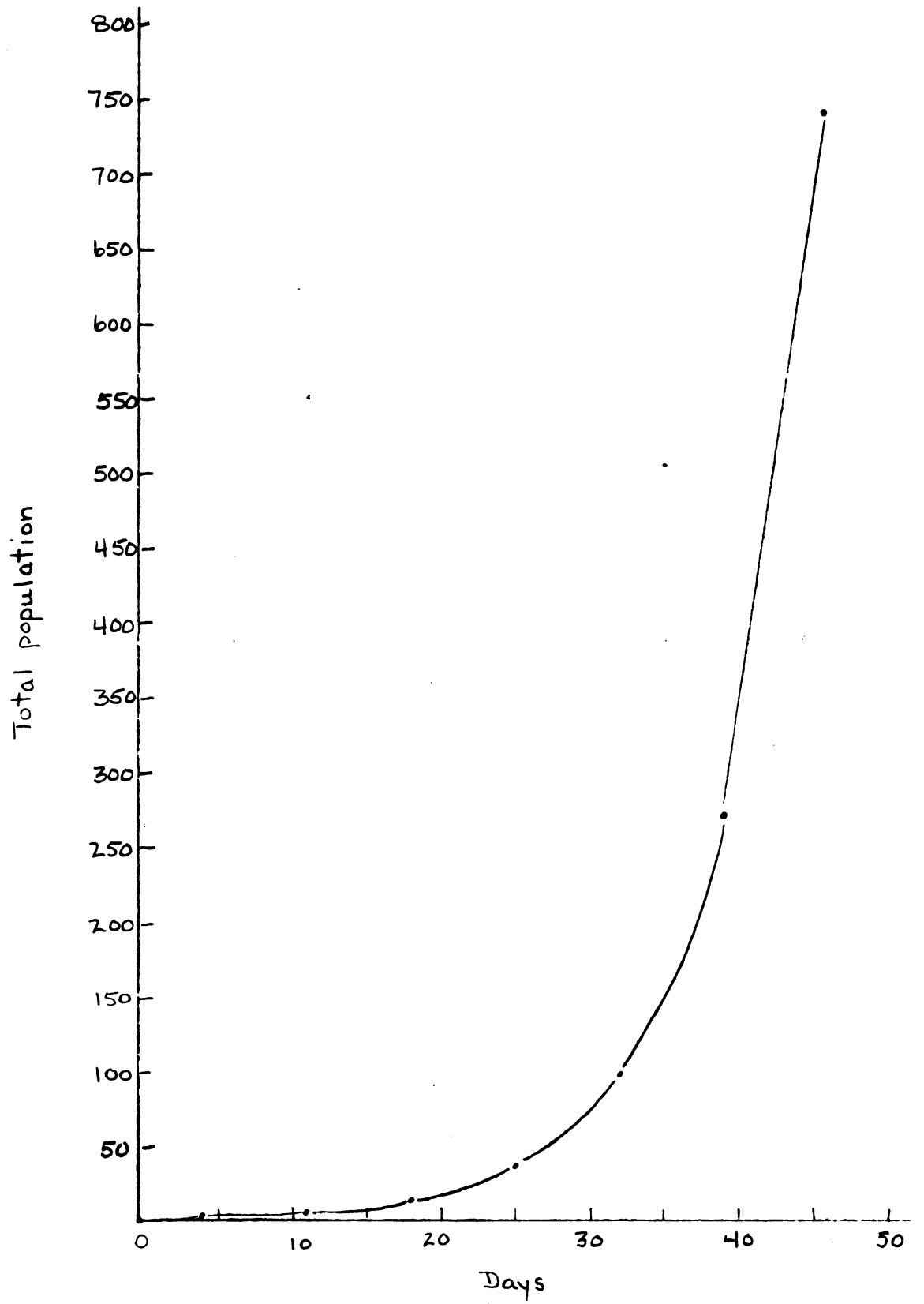
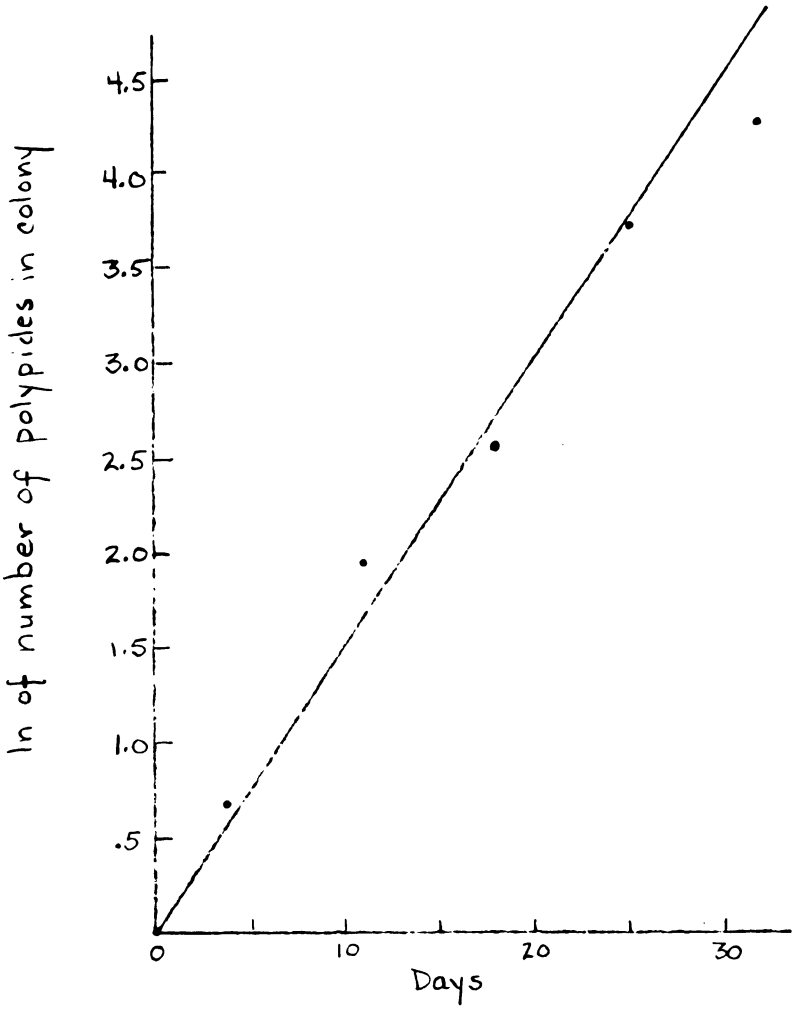


Fig. 12A. Relation of the natural logarithm of the number of polypides in colonies with time, for colony Y-7, begun with one individual, chosen at Burke Lake, station 3, April 27, 1960



Doubling rate 4.62

Fig. 12B. Theoretical increase in the total number of polypides for colony Y-7, begun with one individual, chosen at Burke Lake, Clinton County, station 3, April 27, 1960.

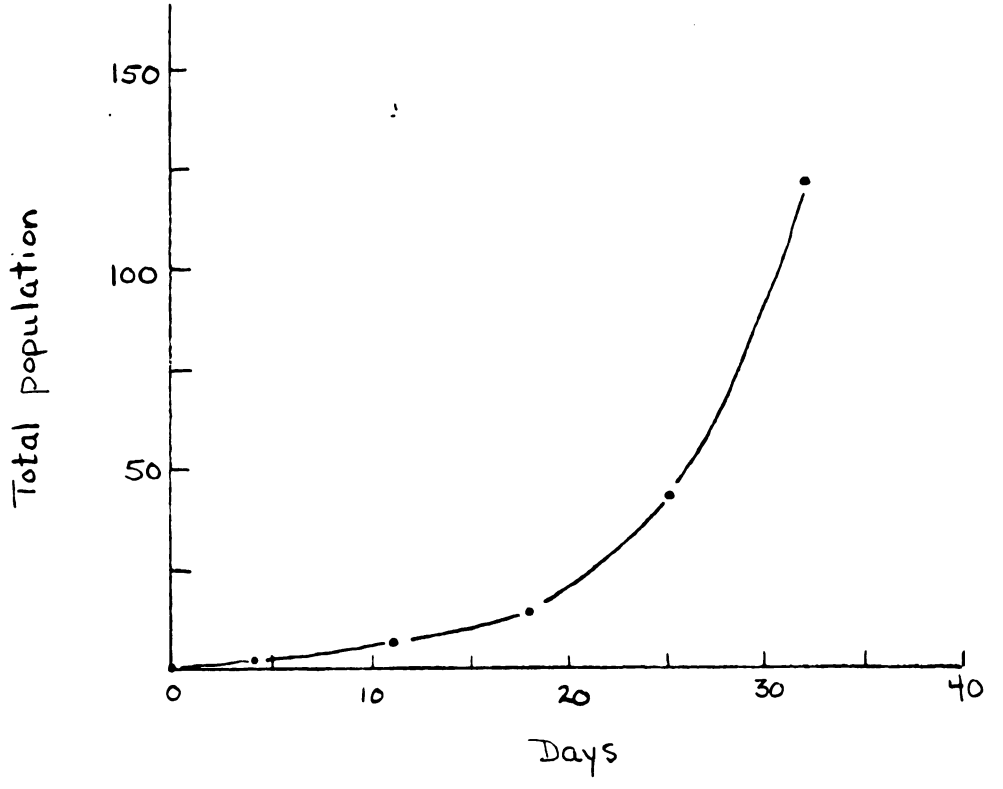
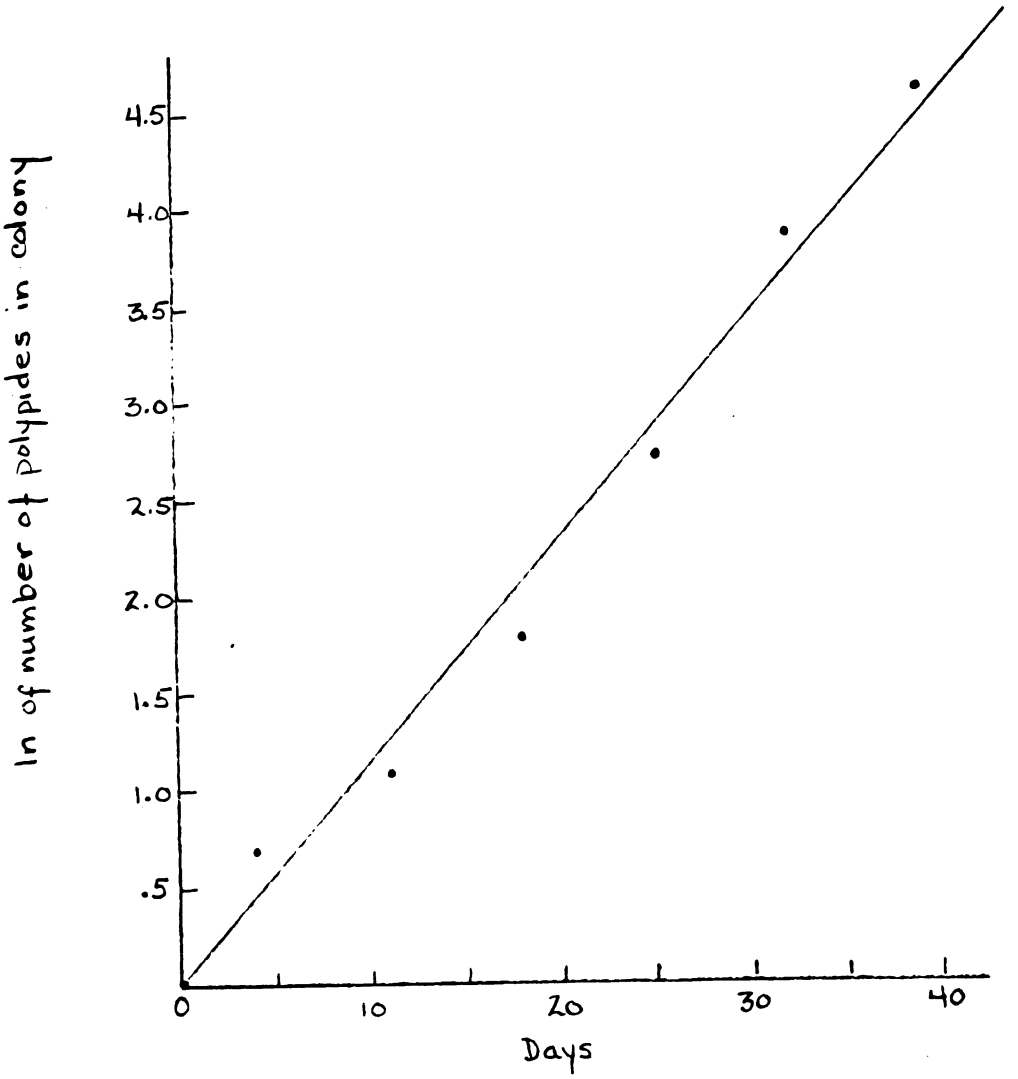


Fig. 15A. Relation of the natural logarithm of the number of polypides with time, for colony B-4, begun with one individual, chosen at Burke Lake, station 4, April 27, 1960.



Doubling rate 6.03

Fig. 13B. Theoretical increase in the total number of polypides for colony B-4, begun with one individual, chosen at Burke Lake, Clinton County, station 4, April 27, 1960.

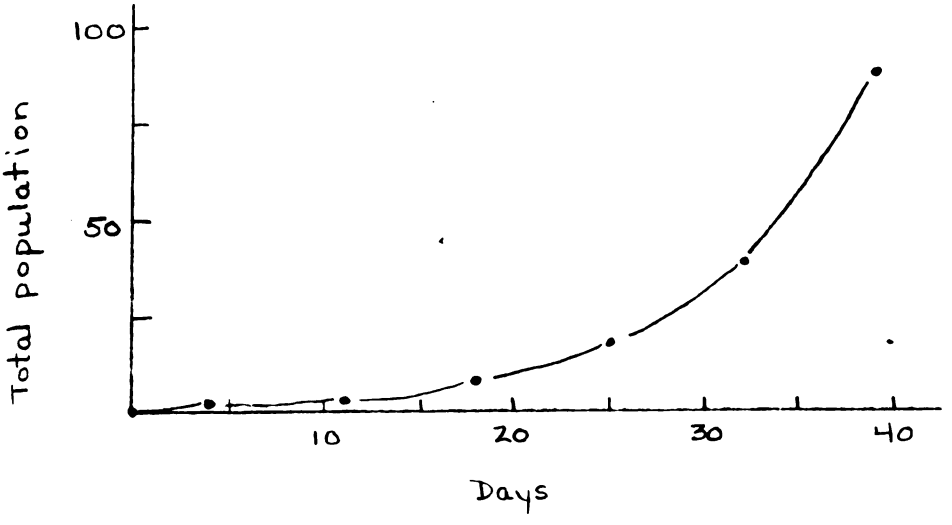


Fig. 14A. Relation of the natural logarithm of the number of polypides in colonies with time, for colony F begun with two individuals, chosen at Burke Lake, Clinton County, station 4, June 20, 1959

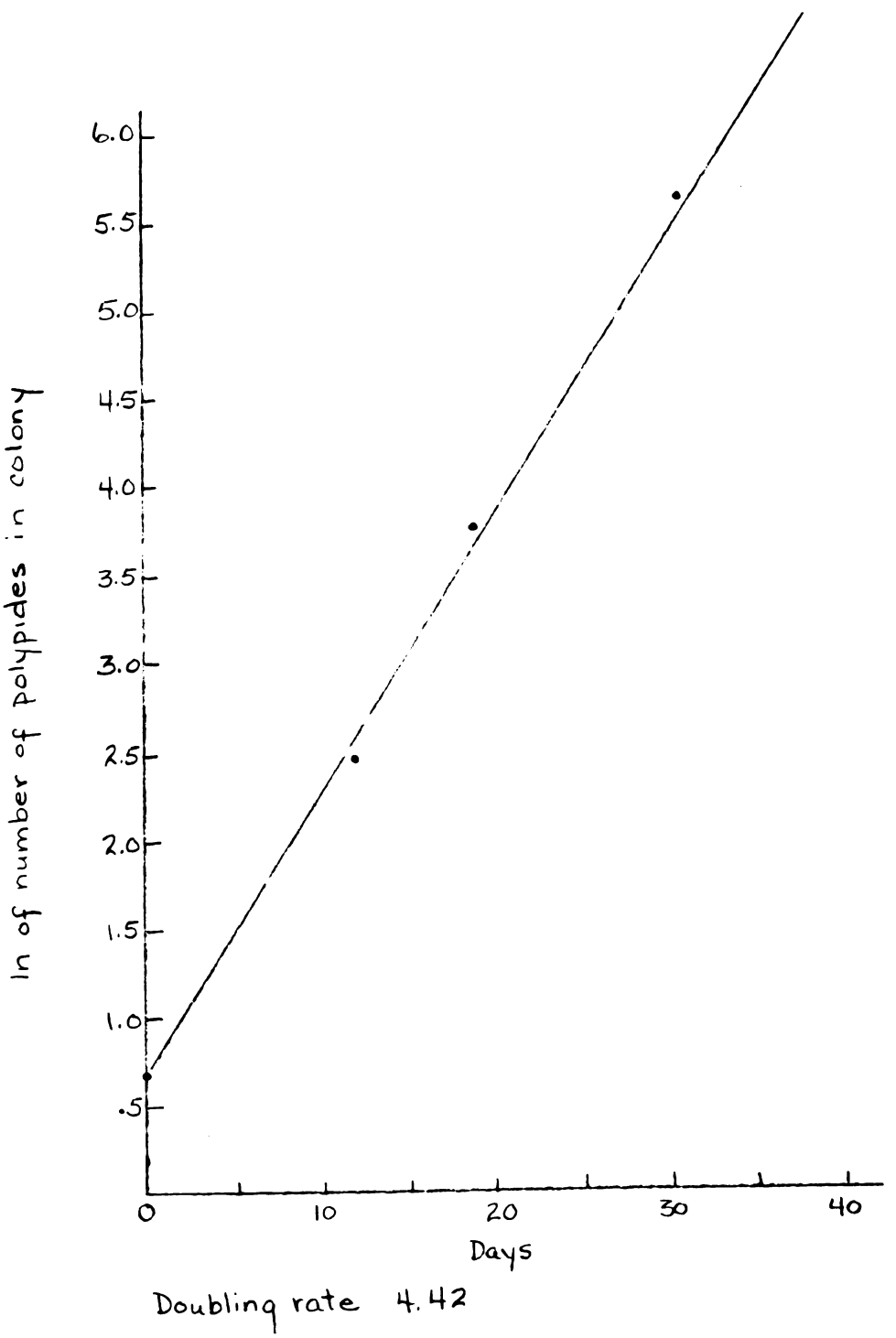


Fig. 14B. Theoretical increase in the total number of polypides for colony F begun with two individuals, chosen at Burke Lake, station 4, June 20, 1959

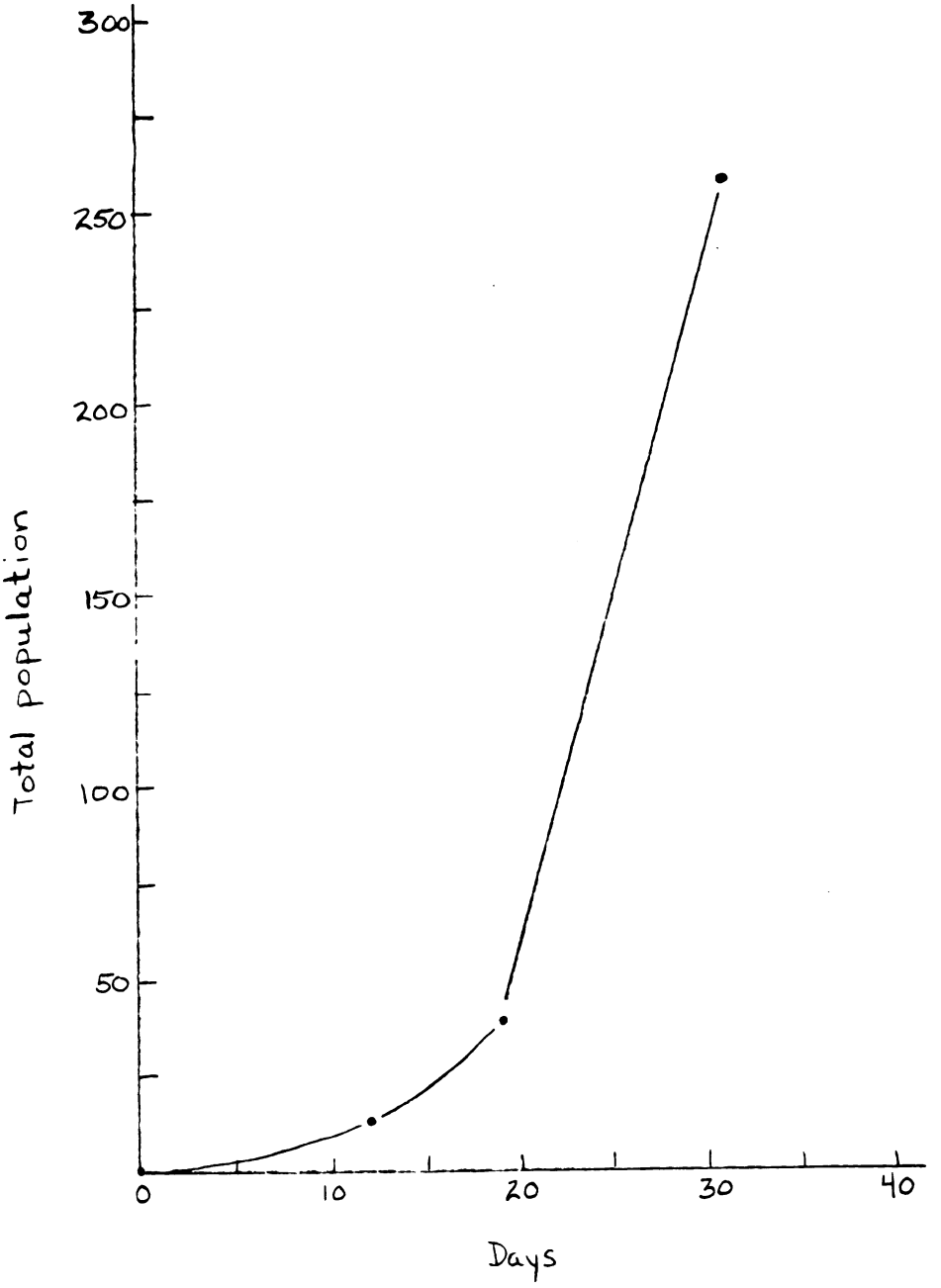


Fig. 15A. Relation of the natural logarithm of the number of polypides in colonies with time for three colonies, each begun with two individuals, chosen at Burke Lake, station 4, May 17, 1959.

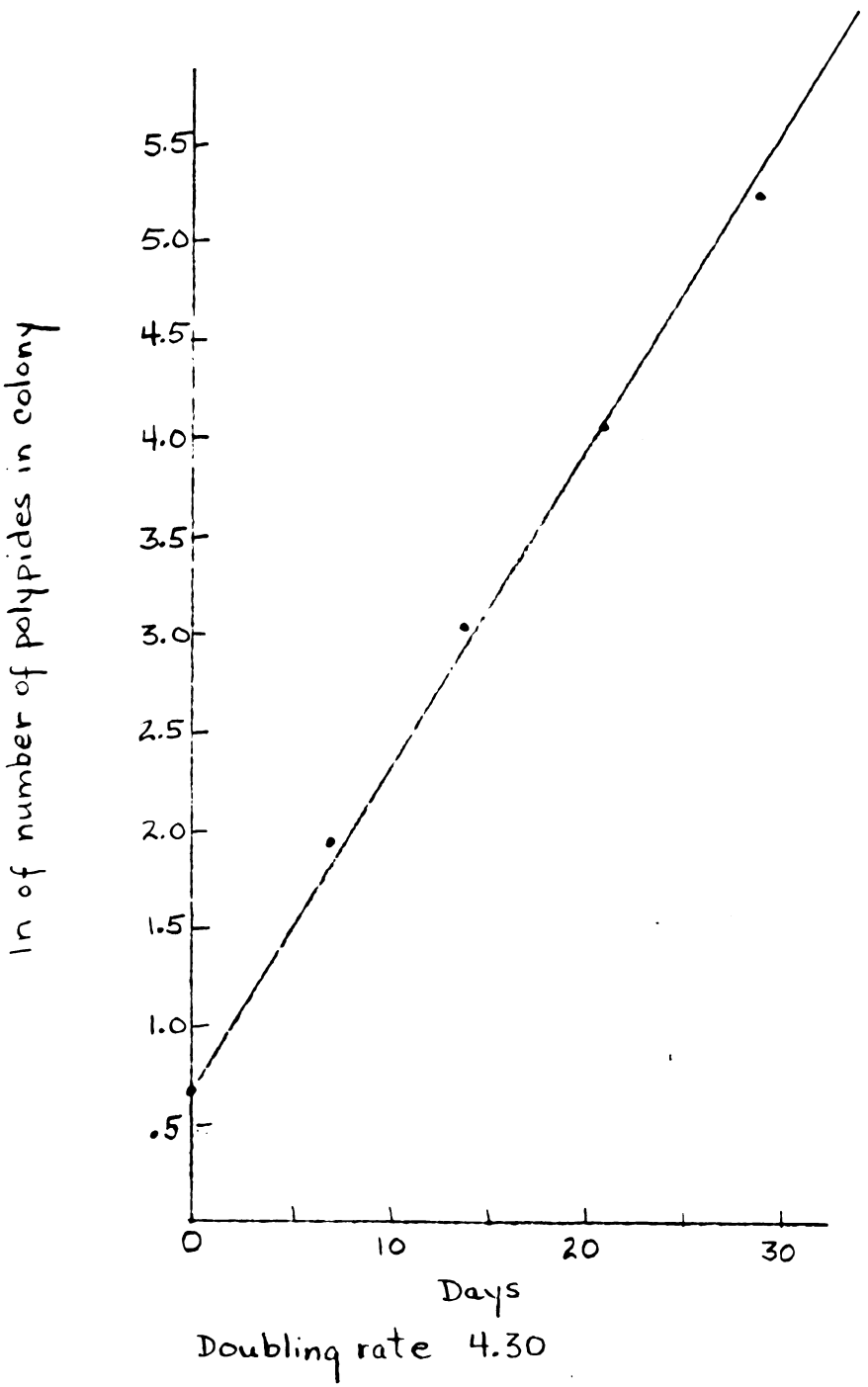


Fig. 15B. Theoretical increase in the total number of polypides for three colonies, each begun with two individuals, chosen at Burke Lake, Clinton County, station 4, May 17, 1959

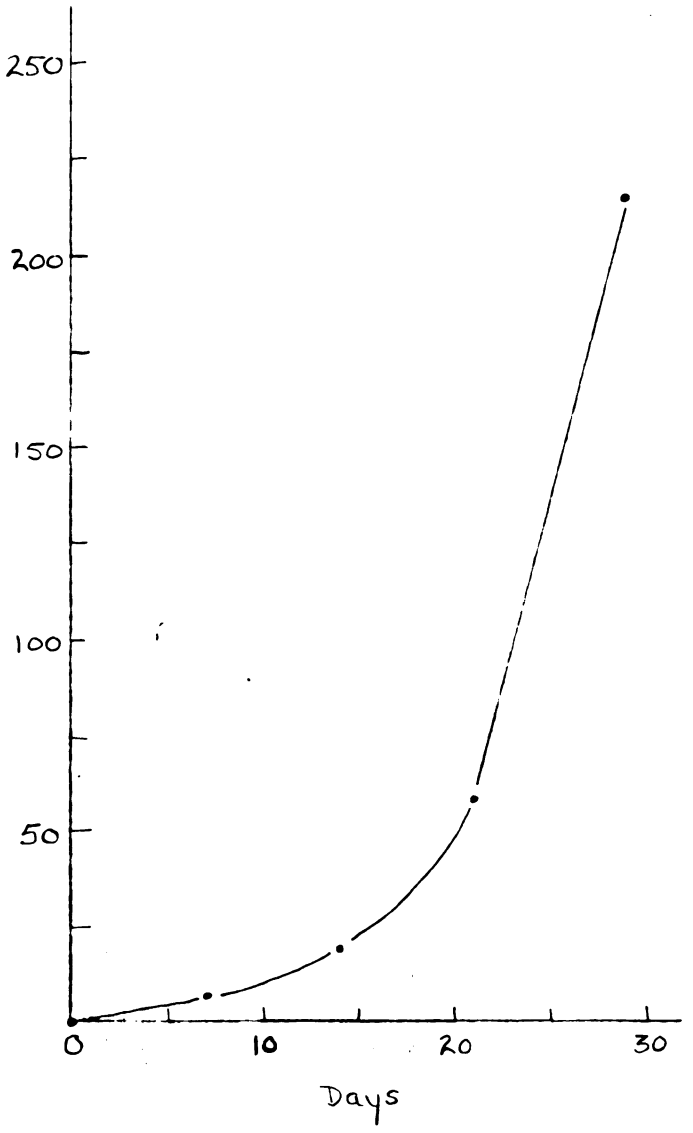


Fig. 16A. Relation of the natural logarithm of the number of polypides colonies with time for colony W-3, begun with two individuals, chosen at Wintergreen Lake, Kalamazoo County, station 5, April 29, 1960.

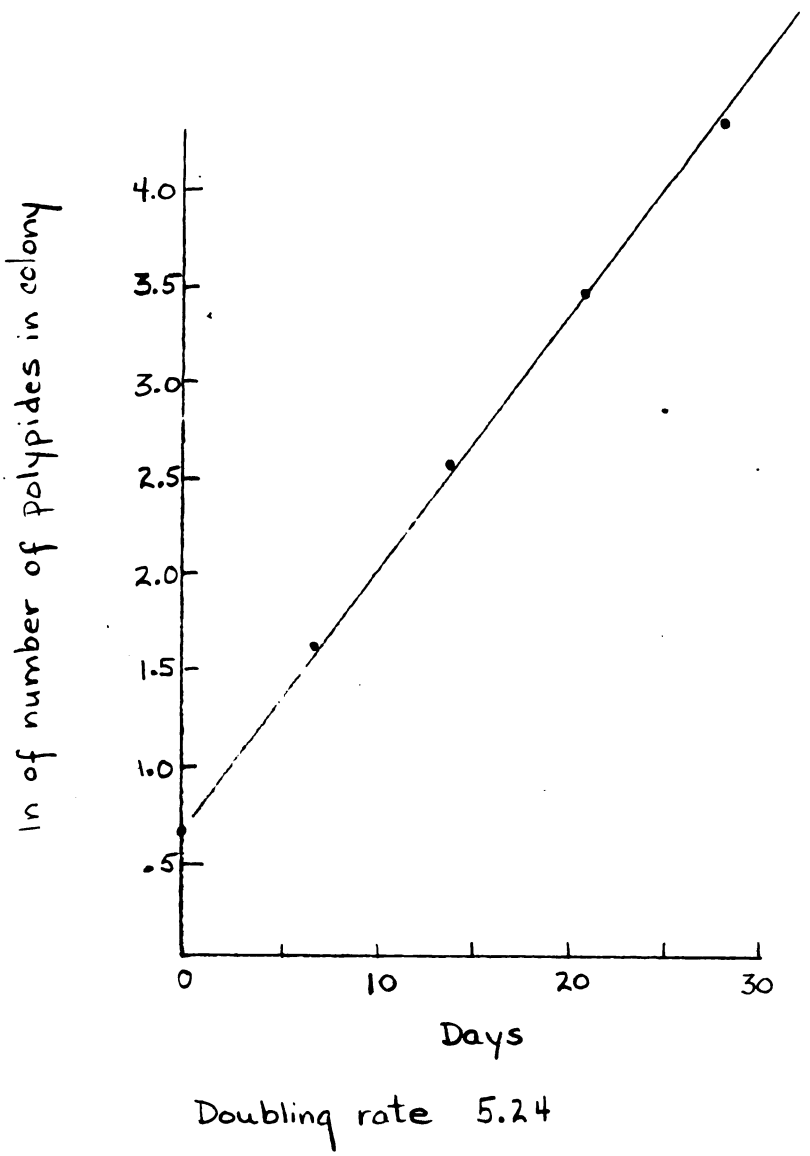


Fig. 18B. Theoretical increase in the total number of polypides for colony W-3, begun with two individuals, chosen at Wintergreen Lake, Kalamazoo County, station 5, April 29, 1960.

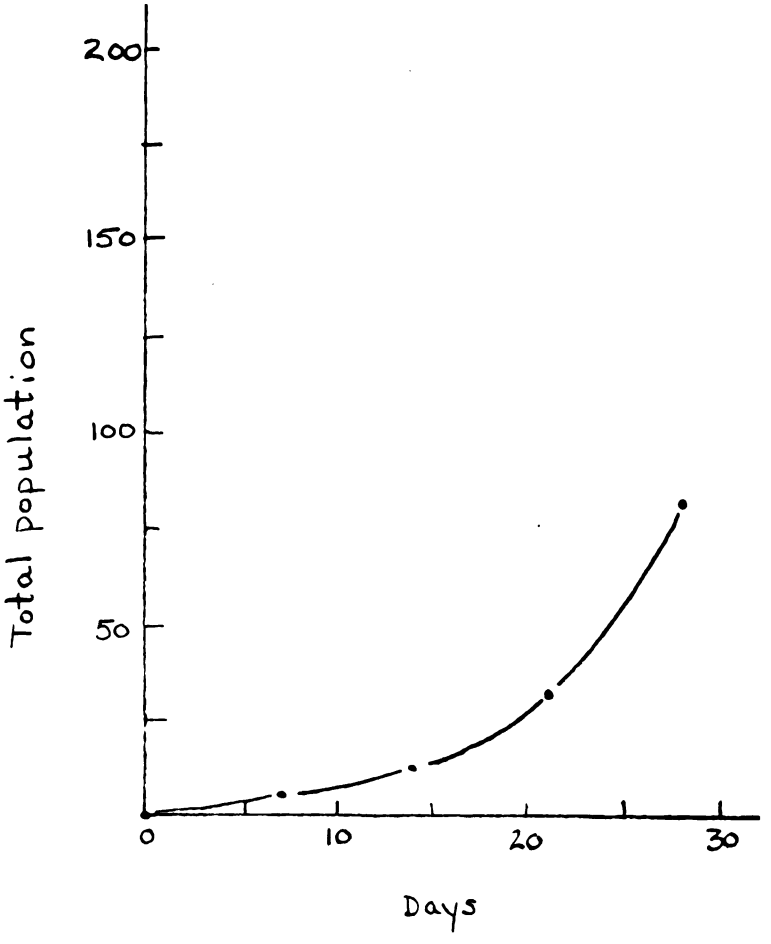


Fig. 17A. Relation of the natural logarithm of the number of polypides in colonies with time, for 10 colonies each begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 6, May 6, 1960

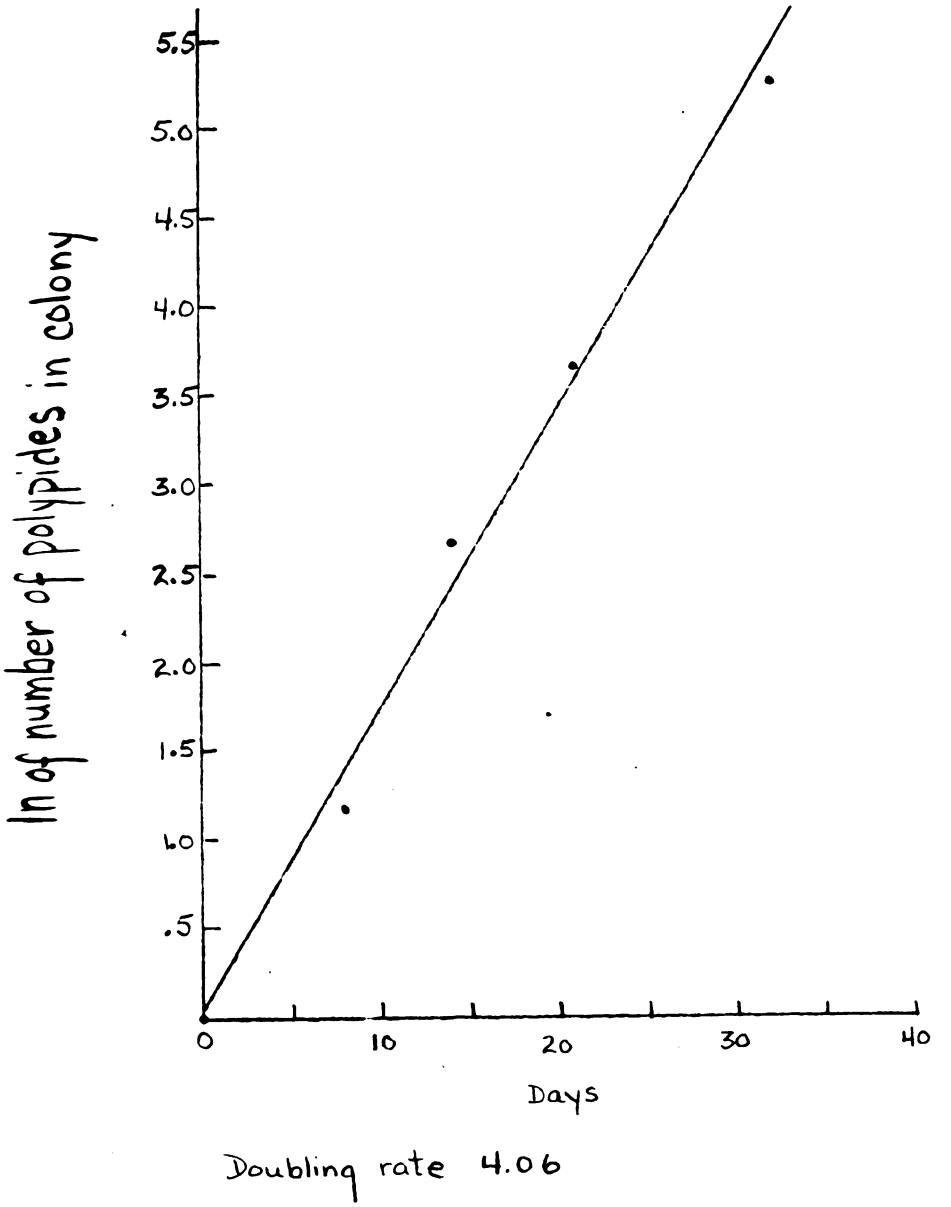


Fig. 17B. Theoretical increase in the total number of polypides for 10 colonies, each begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 6, May 6, 1960.

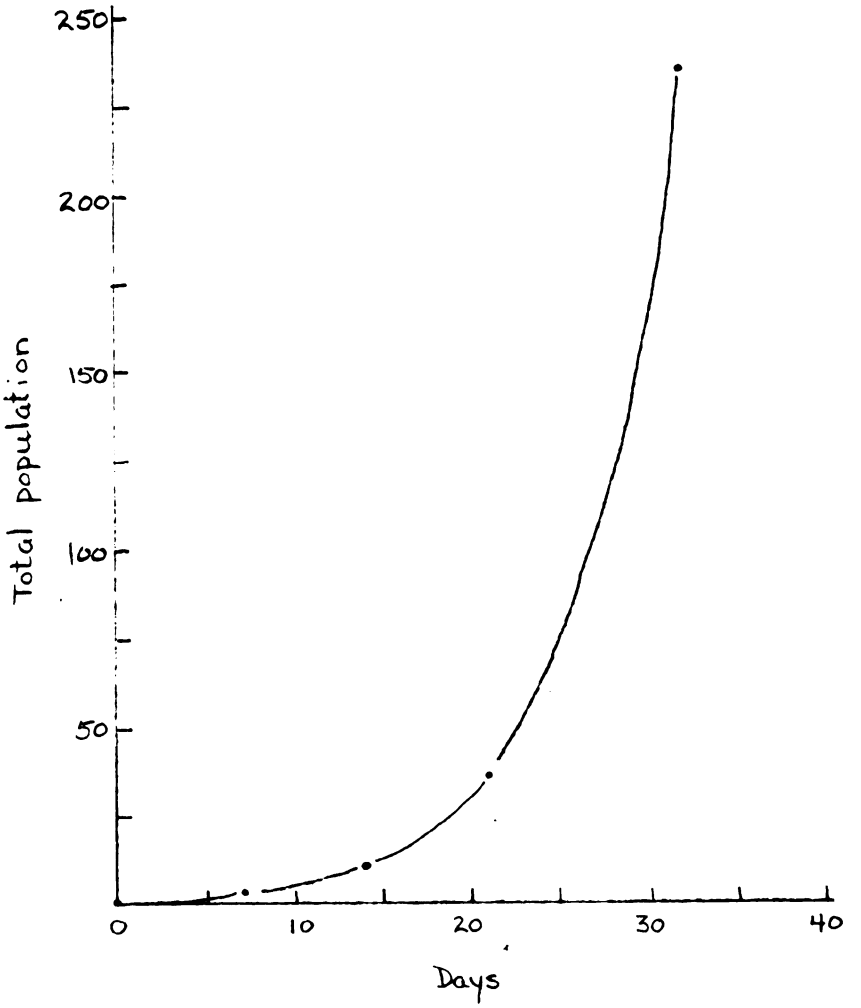


Fig. 18A. Relation of the natural logarithm of the number of polypides in colonies with time for colony G-7, begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 9, April 29, 1960.

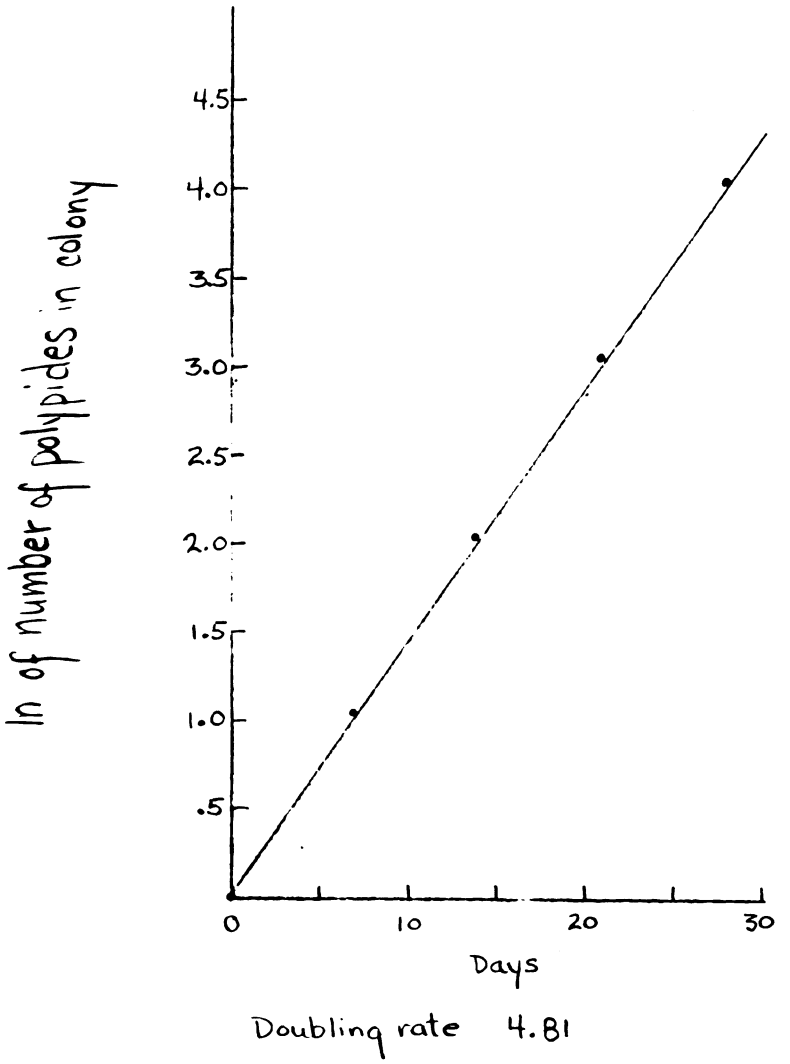


Fig. 18B. Theoretical increase in the total number of polypides for colony G-7, begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 9, April 29, 1960.

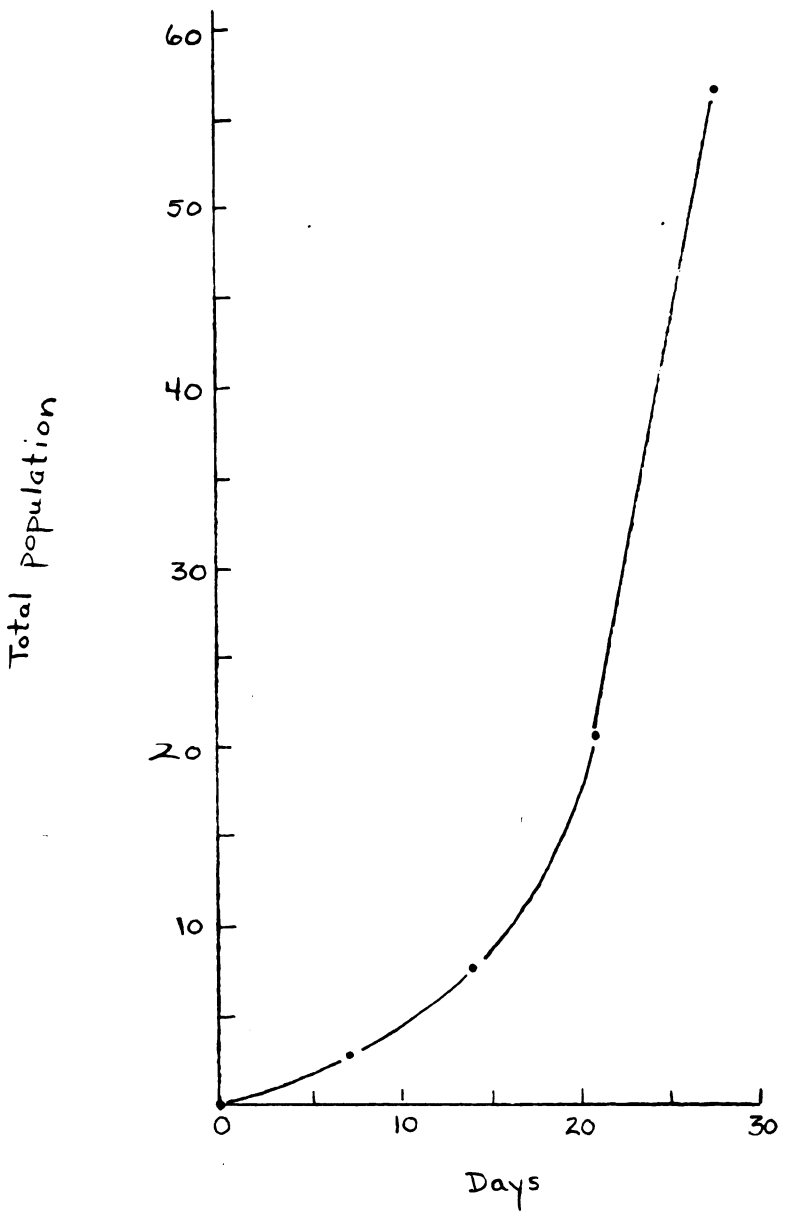


Fig. 19A. Relation of the natural logarithm of the number of polypides in colonies with time for colony G-1, begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 8, April 29, 1960.

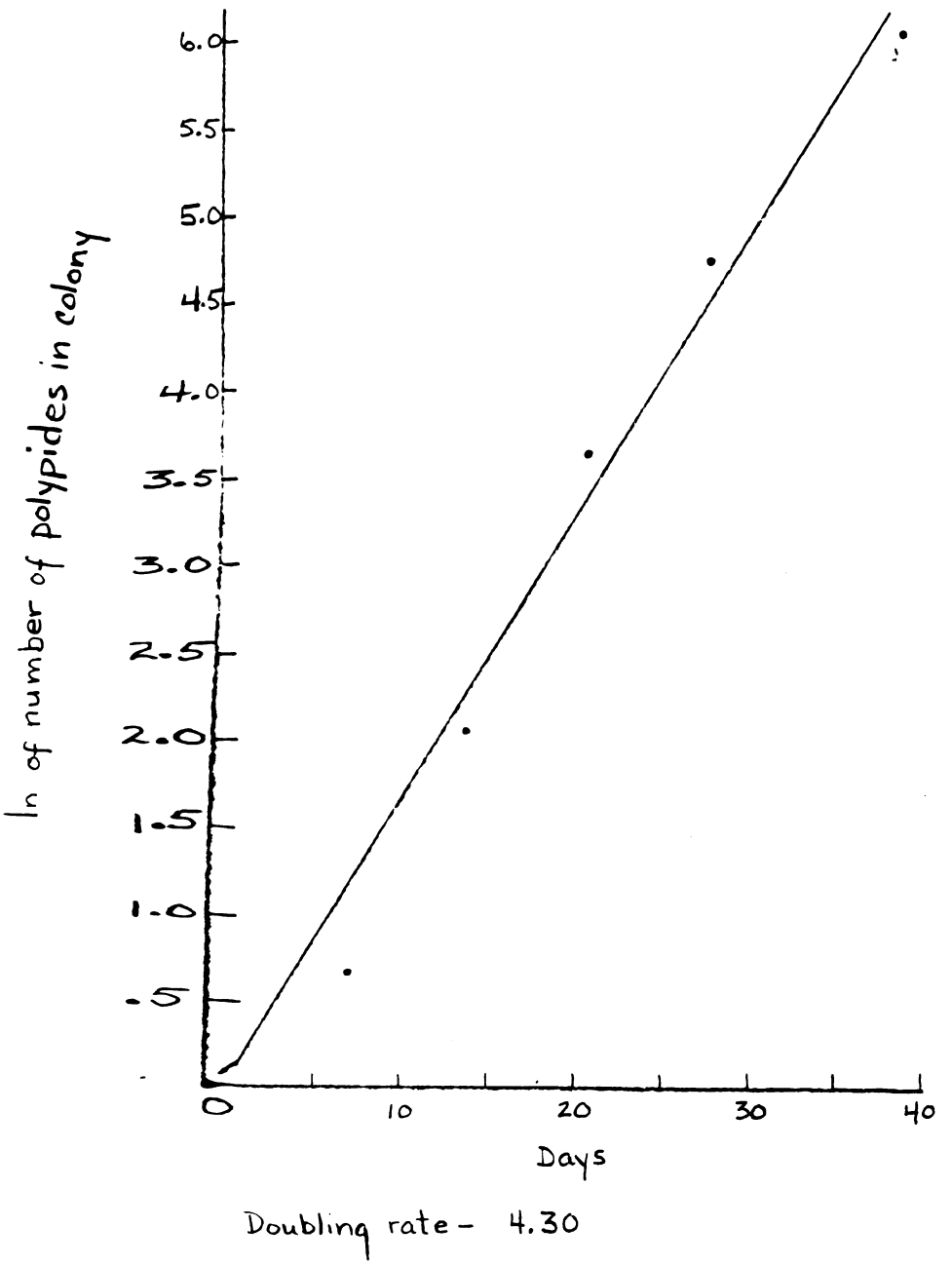


Fig. 19B. Theoretical increase in the total number of polypides for colony G-1, begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 8, April 29, 1960.

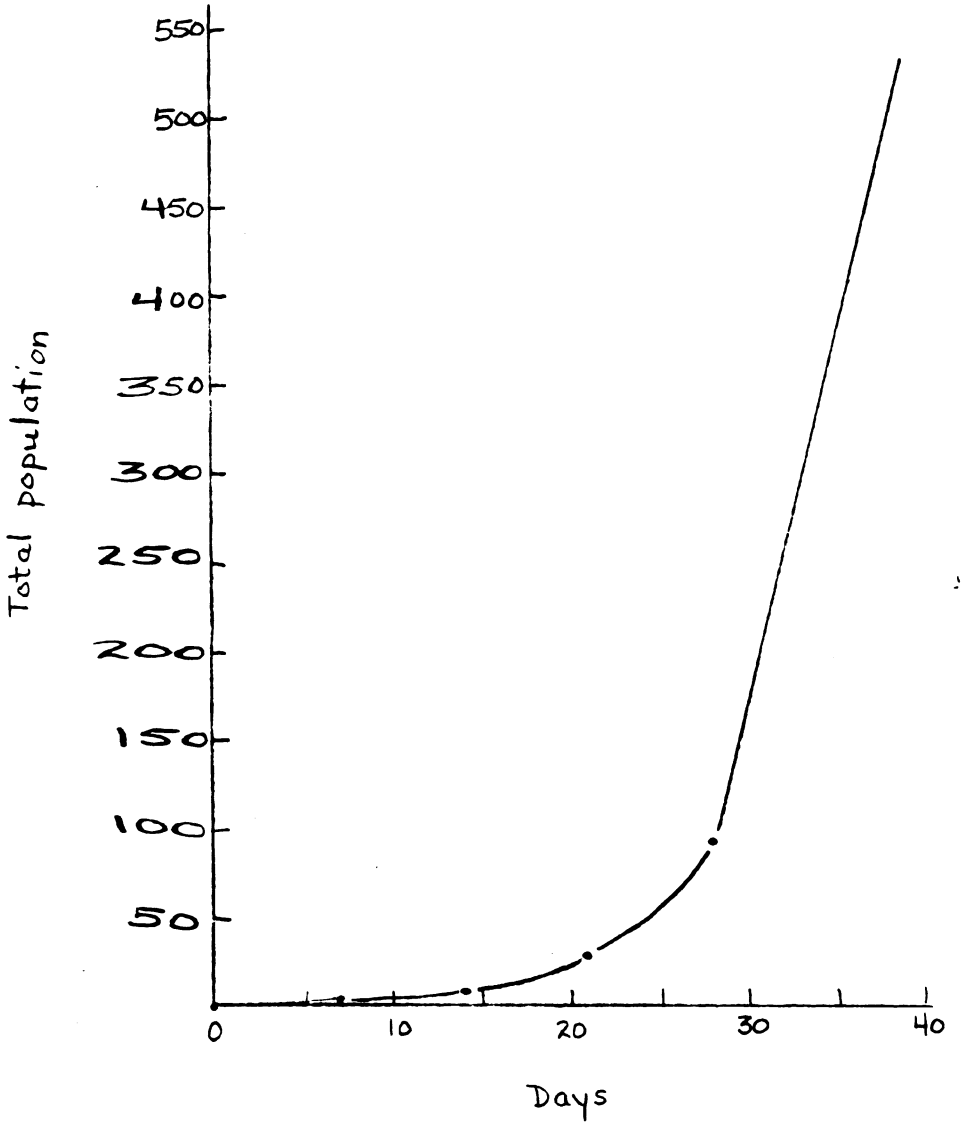
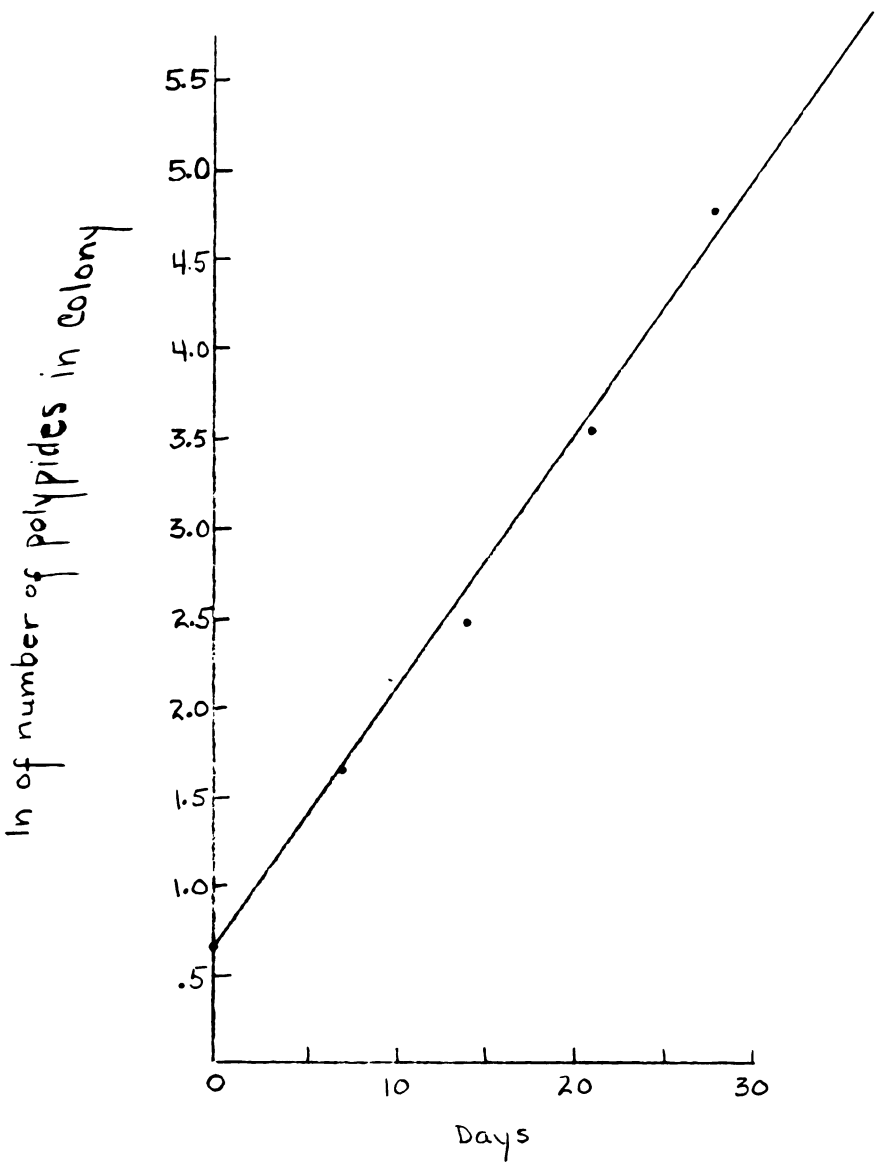


Fig. 20A. Relation of the natural logarithm of the number of polypides in colonies with time, for five colonies, each begun with two individuals, chosen at Wintergreen Lake, Kalamazoo County, station 11, April 29, 1960.



Doubling rate 4.91

Fig. 20B. Theoretical increase in the total number of polypides for five colonies, each begun with two individuals, chosen at Wintergreen Lake, Kalamazoo County, station 11, April 29, 1960.

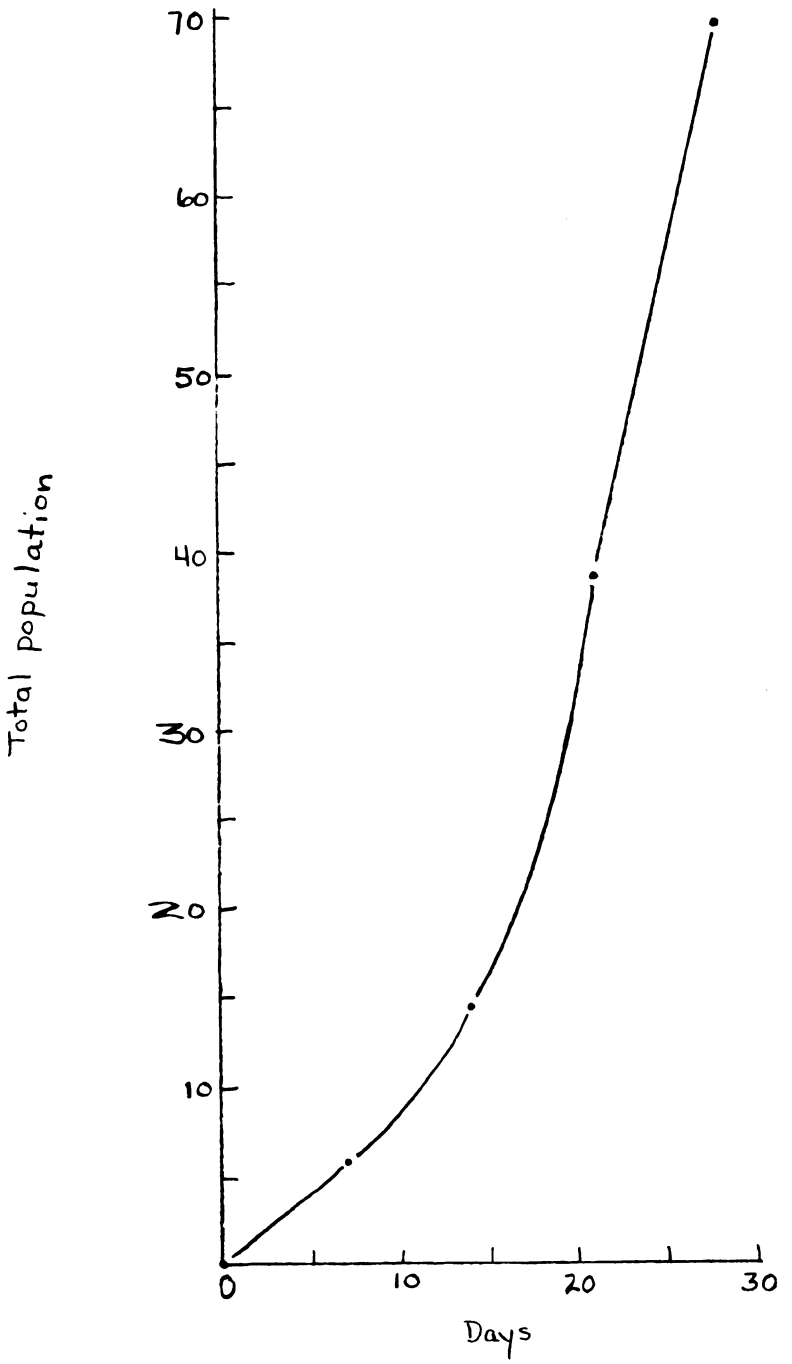
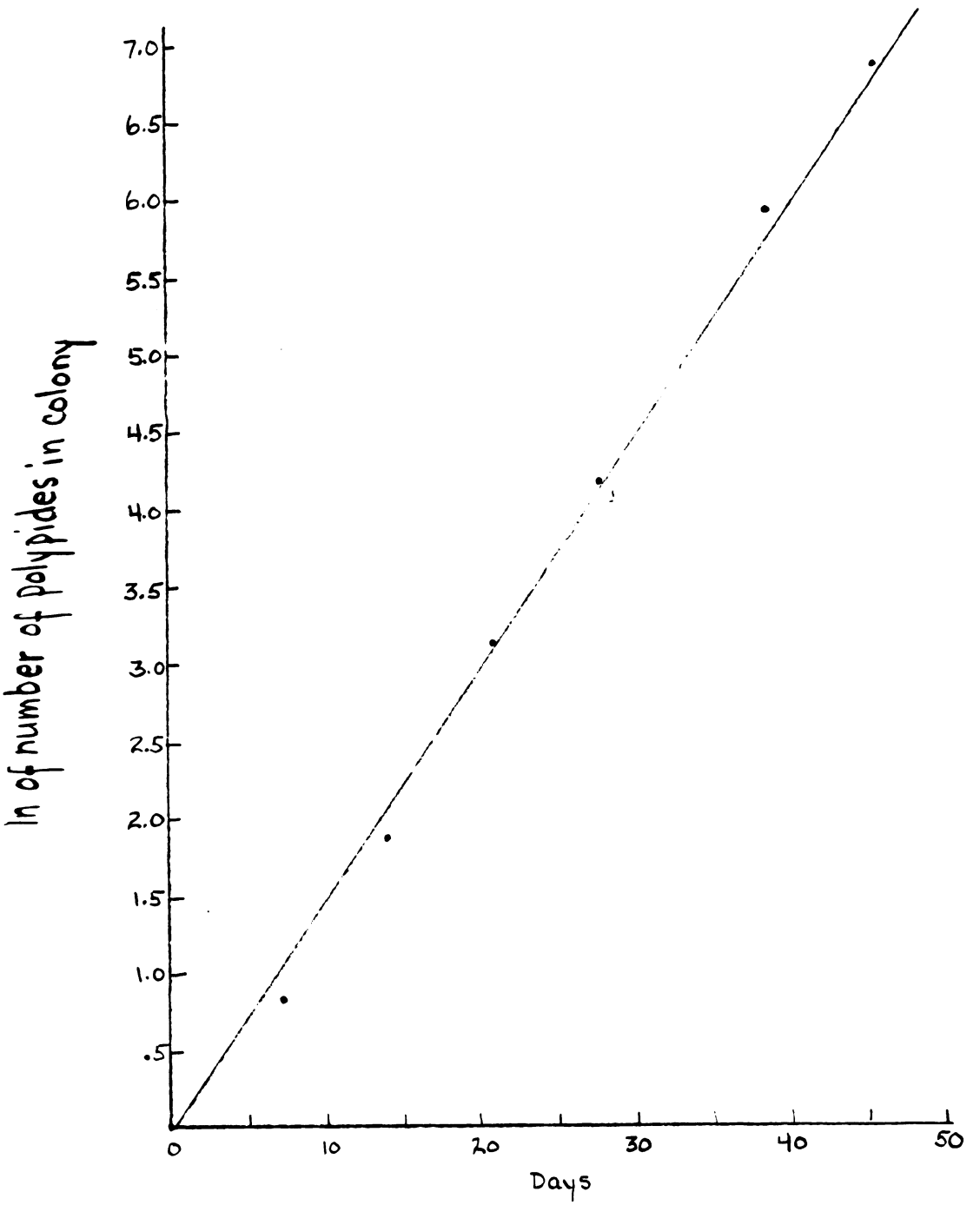


Fig. 21A. Relation of the natural logarithm of the number of polypides in colonies with time for six colonies, each begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 12, April 29, 1960.



Doubling rate – 4.69

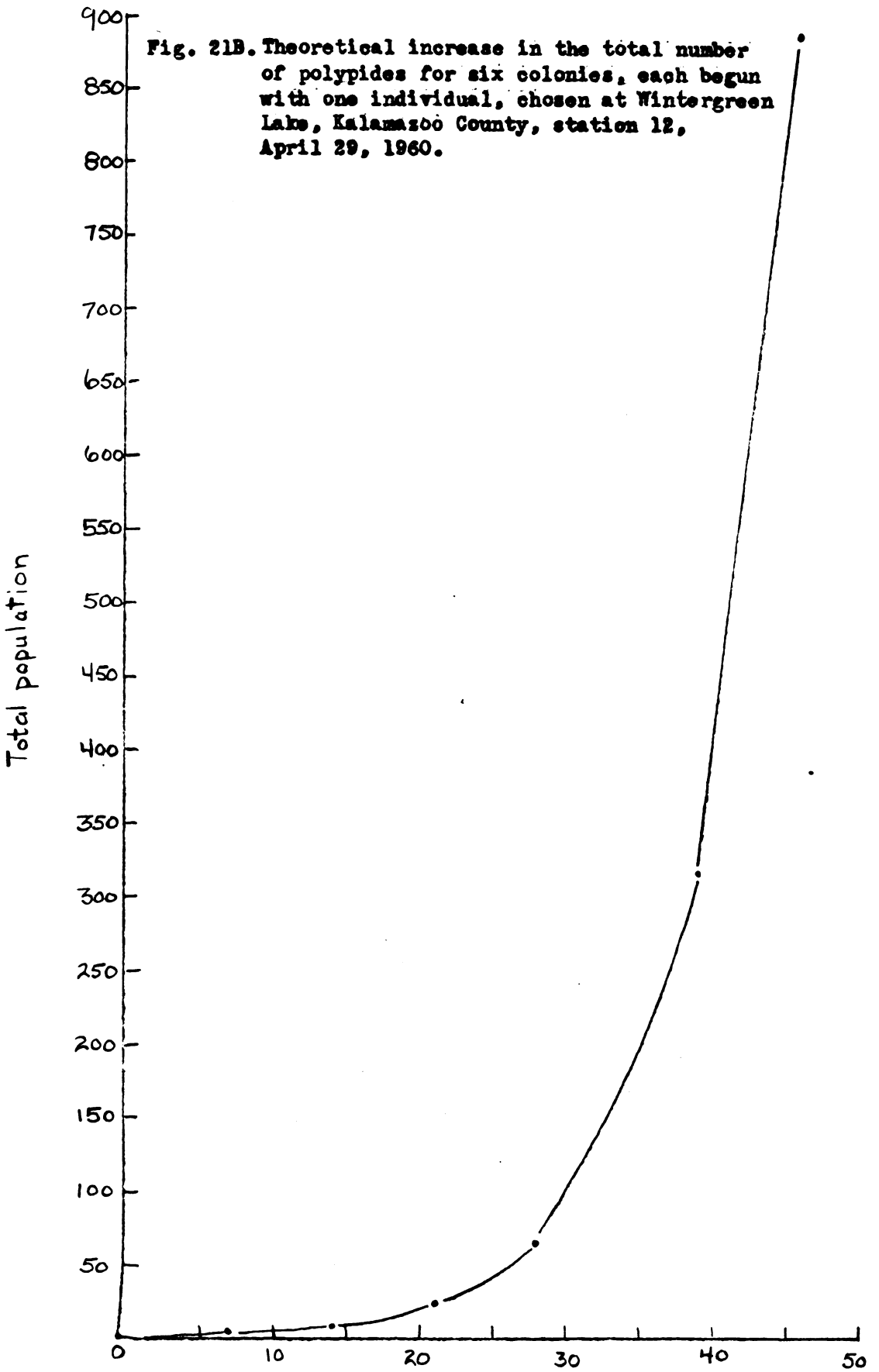
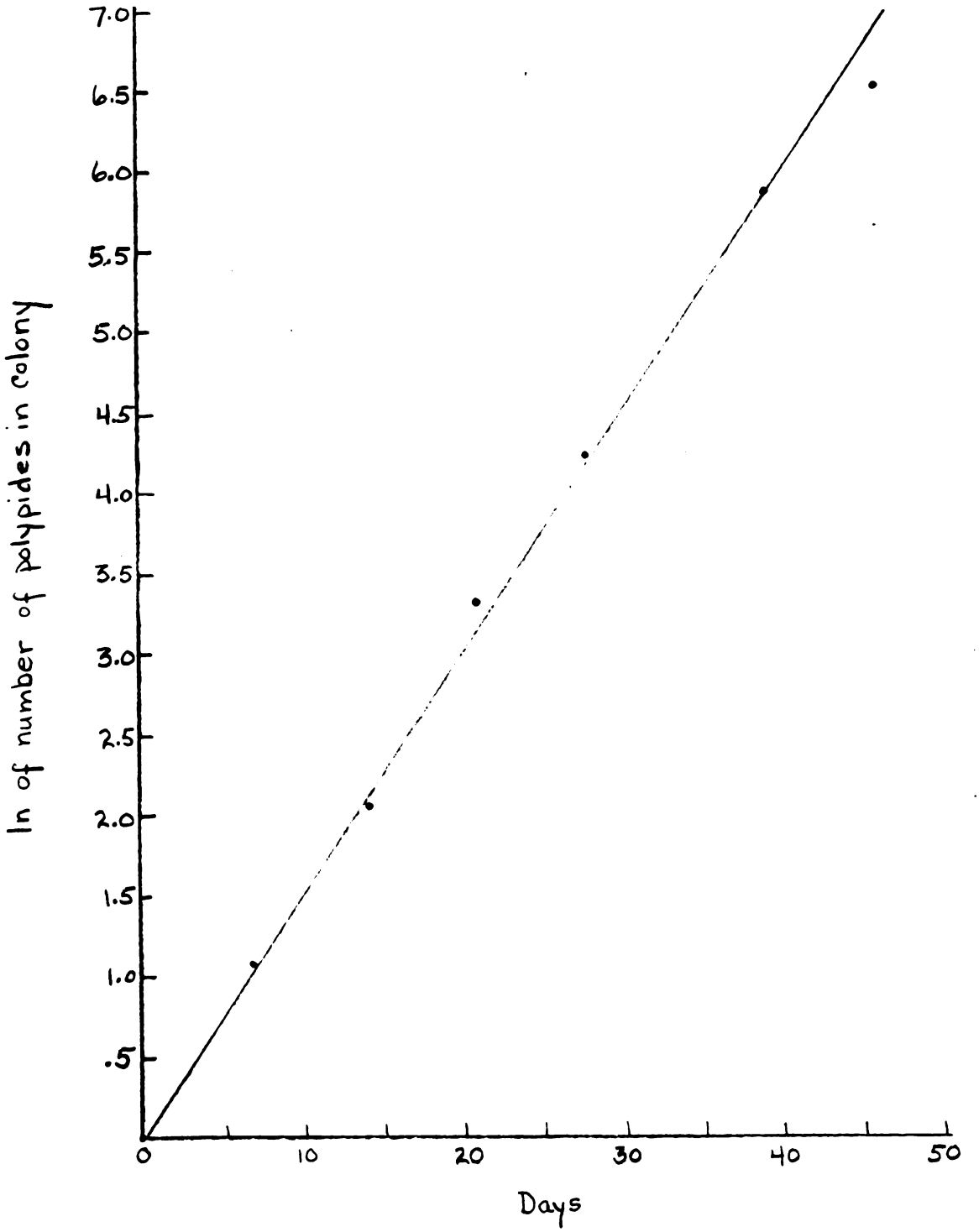


Fig. 21B. Theoretical increase in the total number of polypides for six colonies, each begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 12, April 29, 1960.

Fig. 22A. Relation of the natural logarithm of the number of polypides in colonies with time, for colony P-1, begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 12, April 29, 1960.



Doubling rate - 4.62 .

Fig. 22B. Theoretical increase in the total number of polypides for colony P-1, begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 12, April 29, 1960.

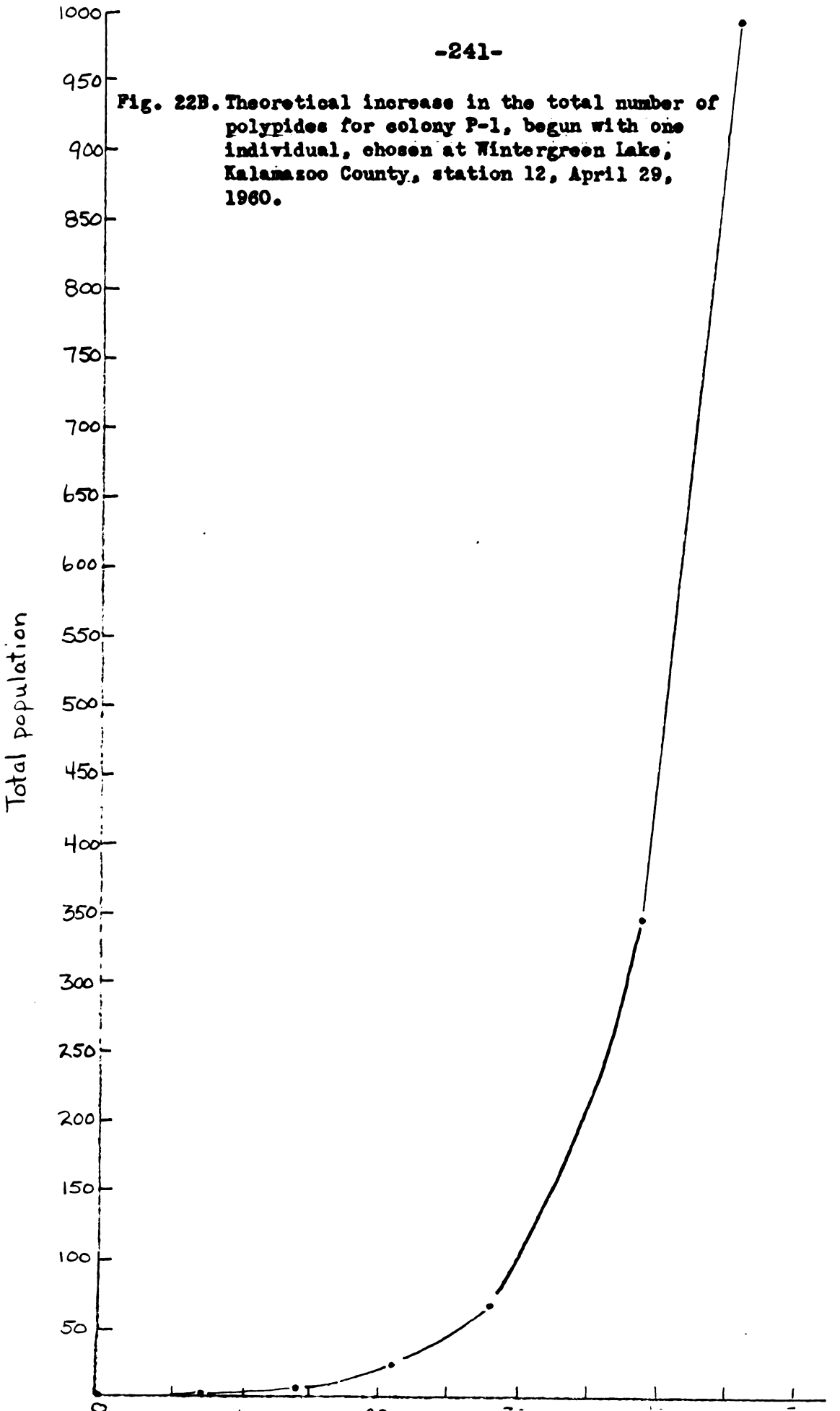
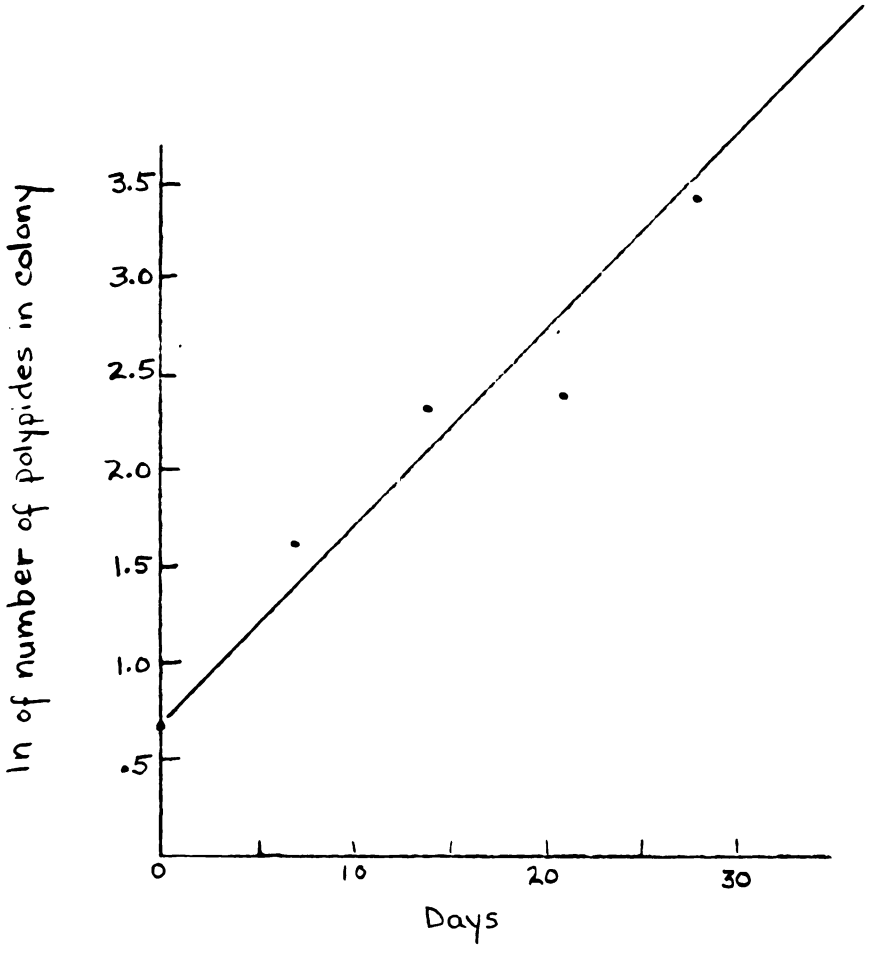


Fig. 23A. Relation of the natural logarithm of the number of polypides in colonies with time, for colony R, begun with two individuals, chosen at Wintergreen Lake, Kalamazoo County, station 11, April 29, 1960.



Doubling rate - 6.89

Fig. 23B. Theoretical increase in the total number of polypides for colony R, begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 11, April 29, 1960.

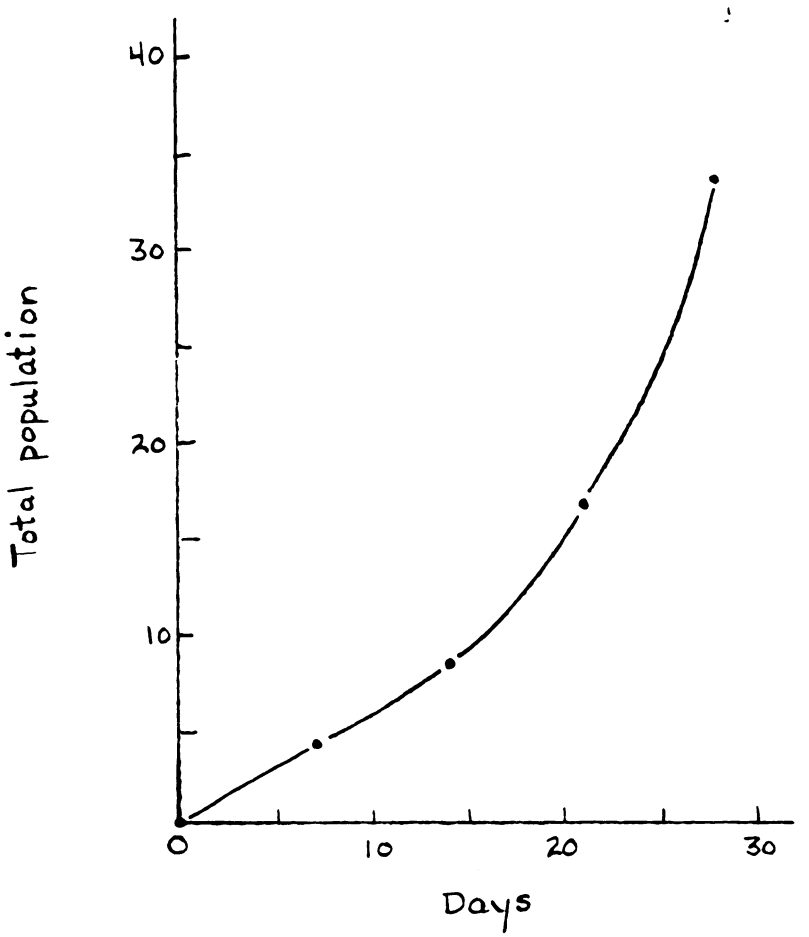
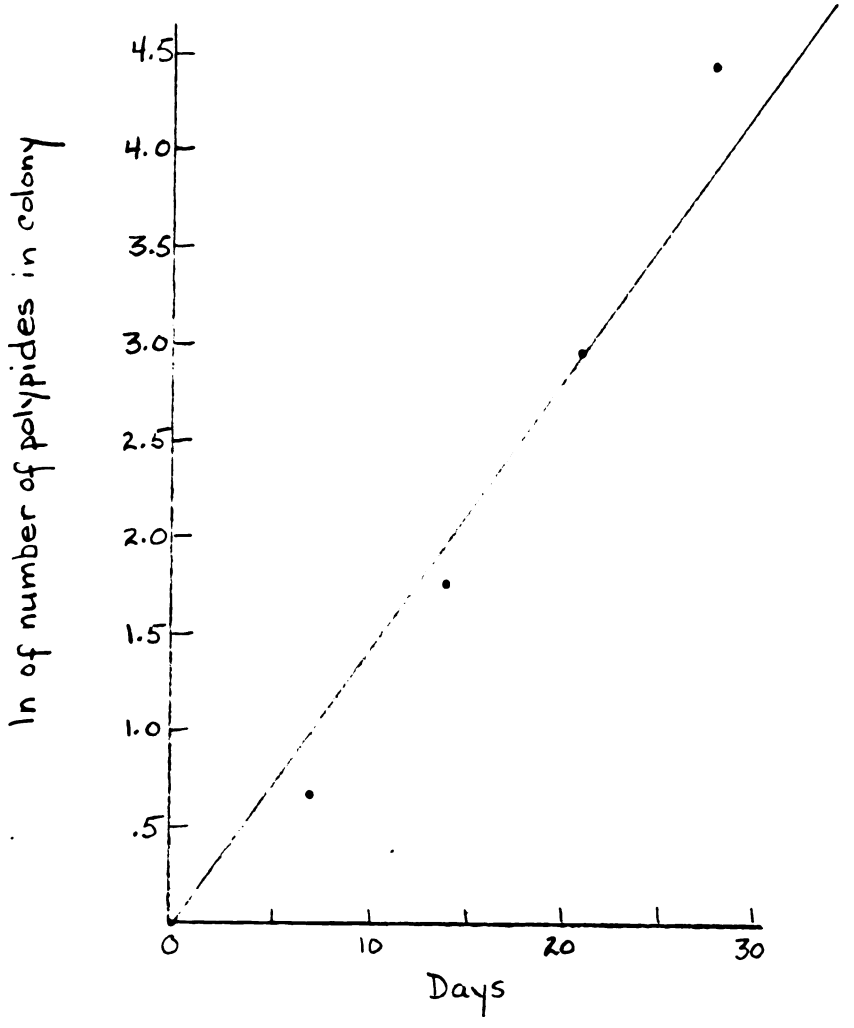


Fig. 24A. Relation of the natural logarithm of the number of polypides in colonies with time, for colony Y+R, begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 5, April 29, 1960.



Doubling rate 4.95

Fig. 24B. Theoretical increase in the total number of polypides for colony Y-R, begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 5, April 29, 1960.

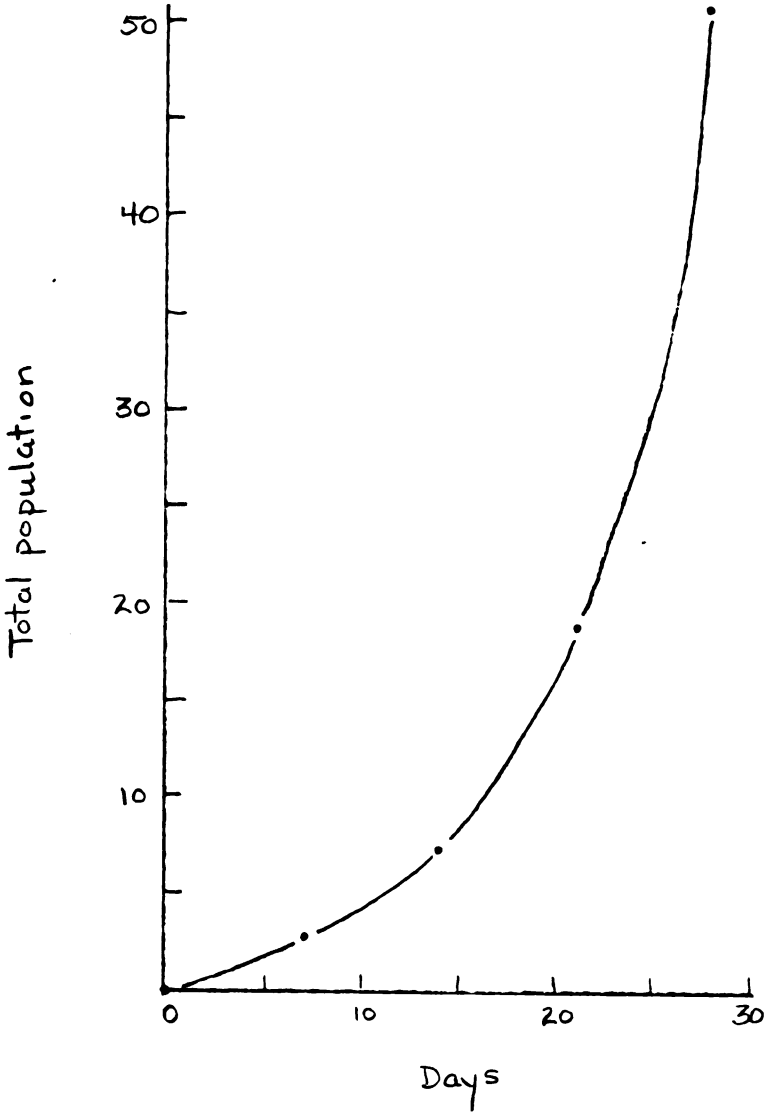
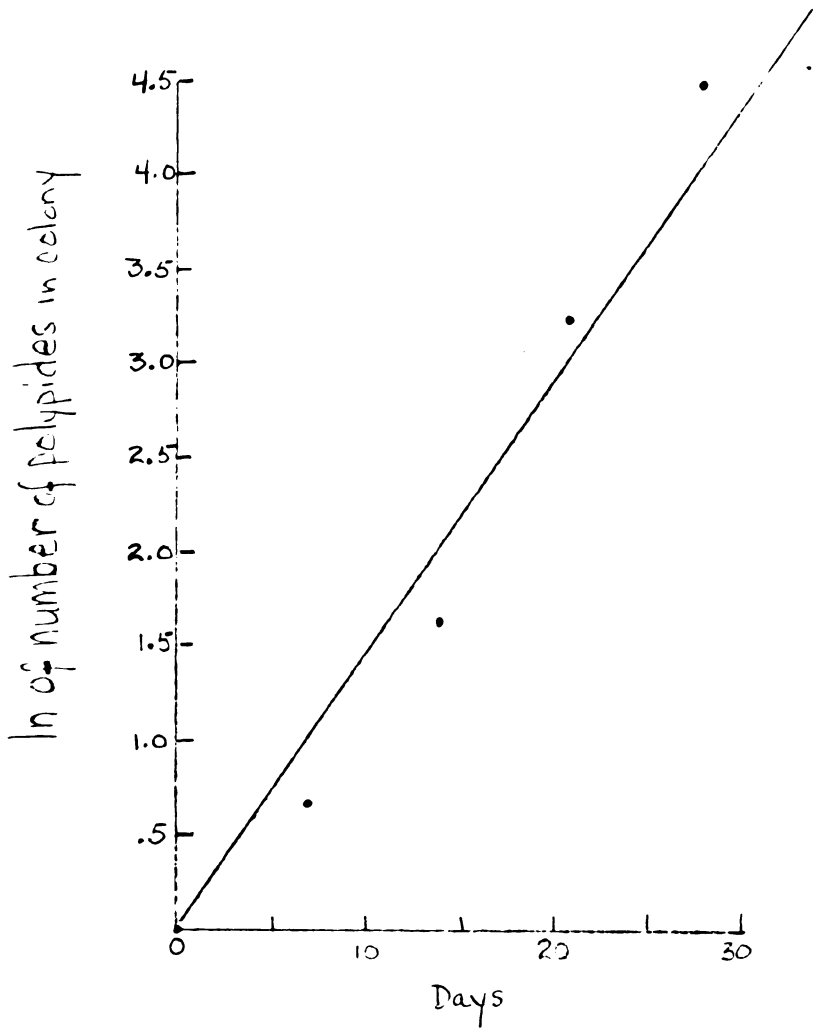


Fig. 25A. Relation of the natural logarithm of the number of polypides in colonies with time, for colony P-3, begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 6, April 29, 1960.



Doubling rate – 4.83

Fig. 25B. Theoretical increase in the total number of polypides for colony P-3, begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 6, April 29, 1960.

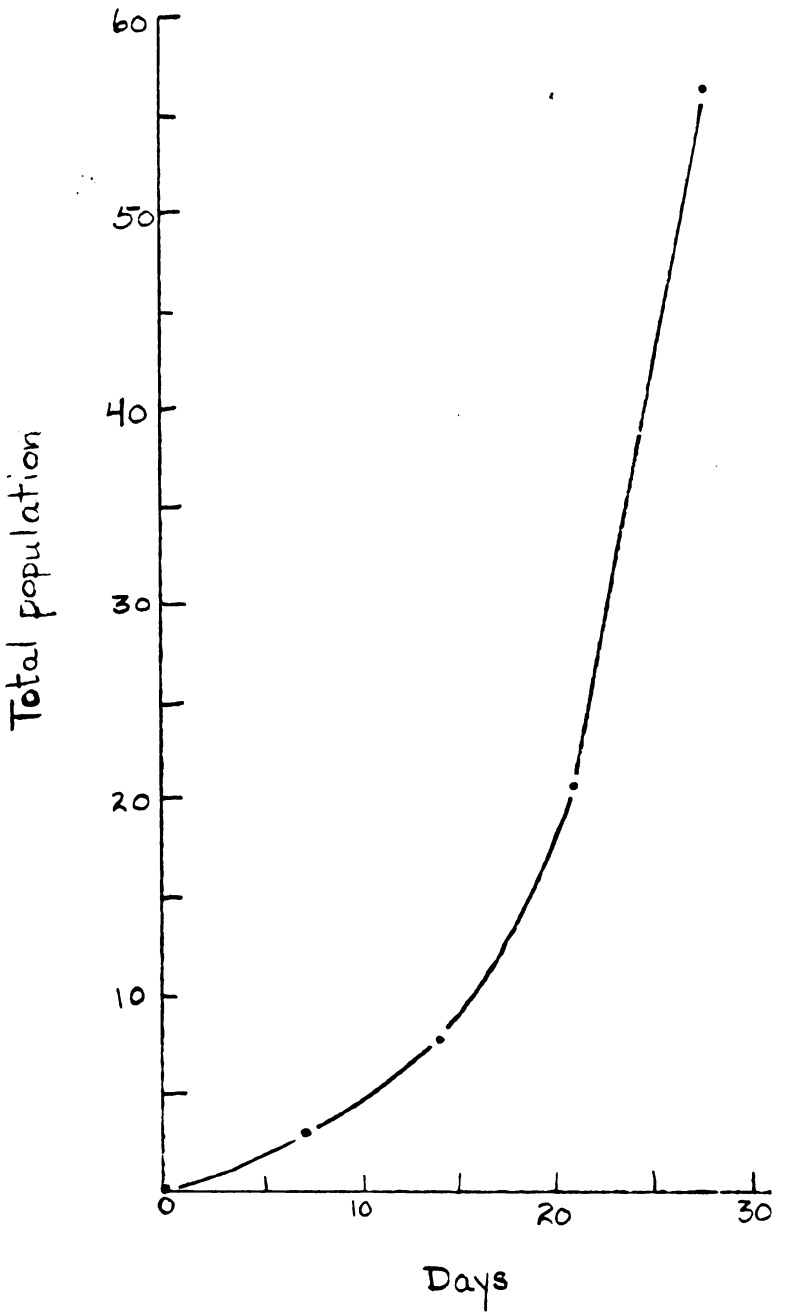
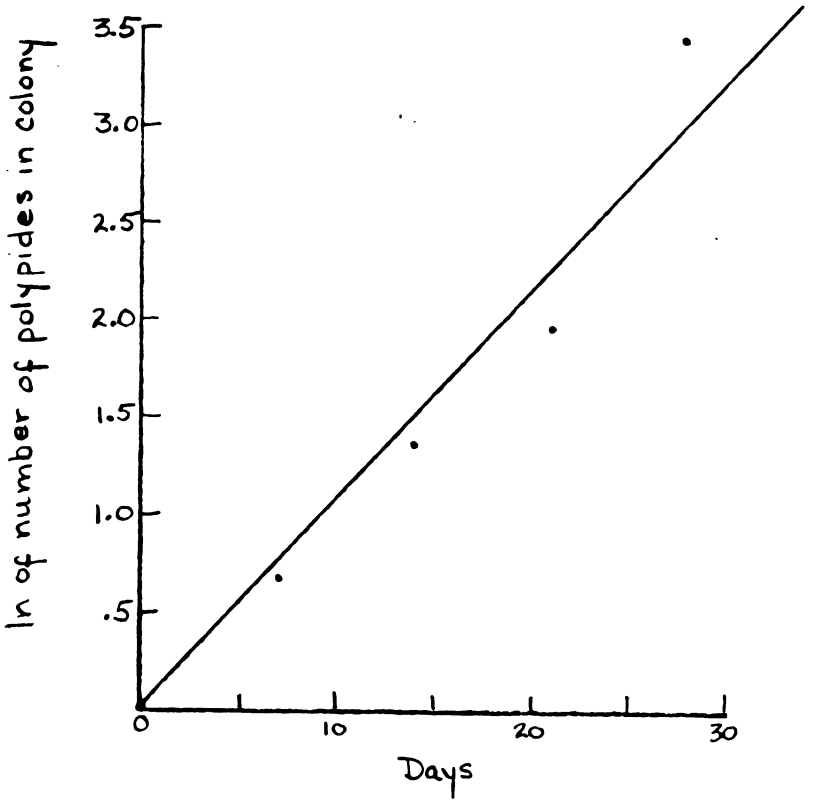


Fig. 26A. Relation of the natural logarithm of the number of polypides in colony with time, for colony P-2, begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 6, April 29, 1960.



Doubling rate - 6.52

Fig. 26B. Theoretical increase in the total number of polypides for colony P-2, begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 6, April 29, 1960.

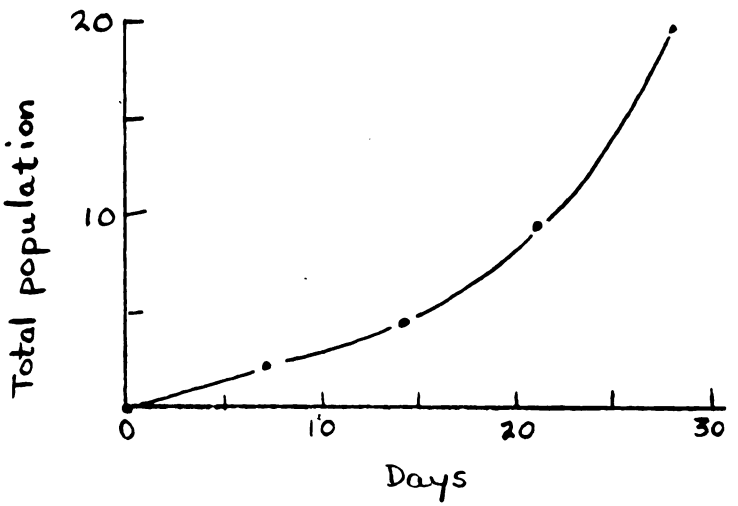
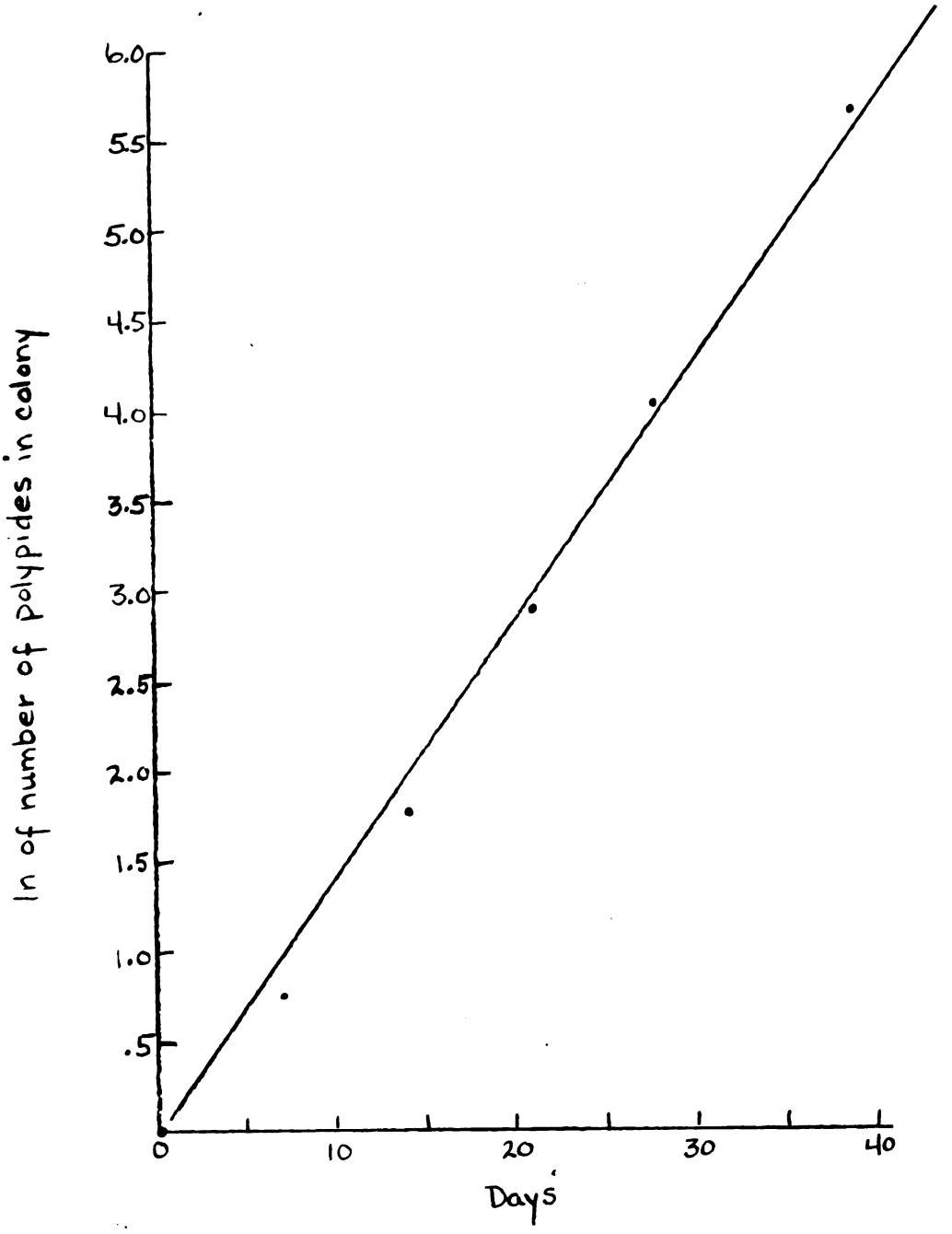


Fig. 27A. Relation of the natural logarithm of the number of polypides in colonies with time, for seven colonies each begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 9, April 29, 1960.



Doubling rate - 4.82

Fig. 27B. Theoretical increase in the total number of polypides for seven colonies each begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 9, April 29, 1960.

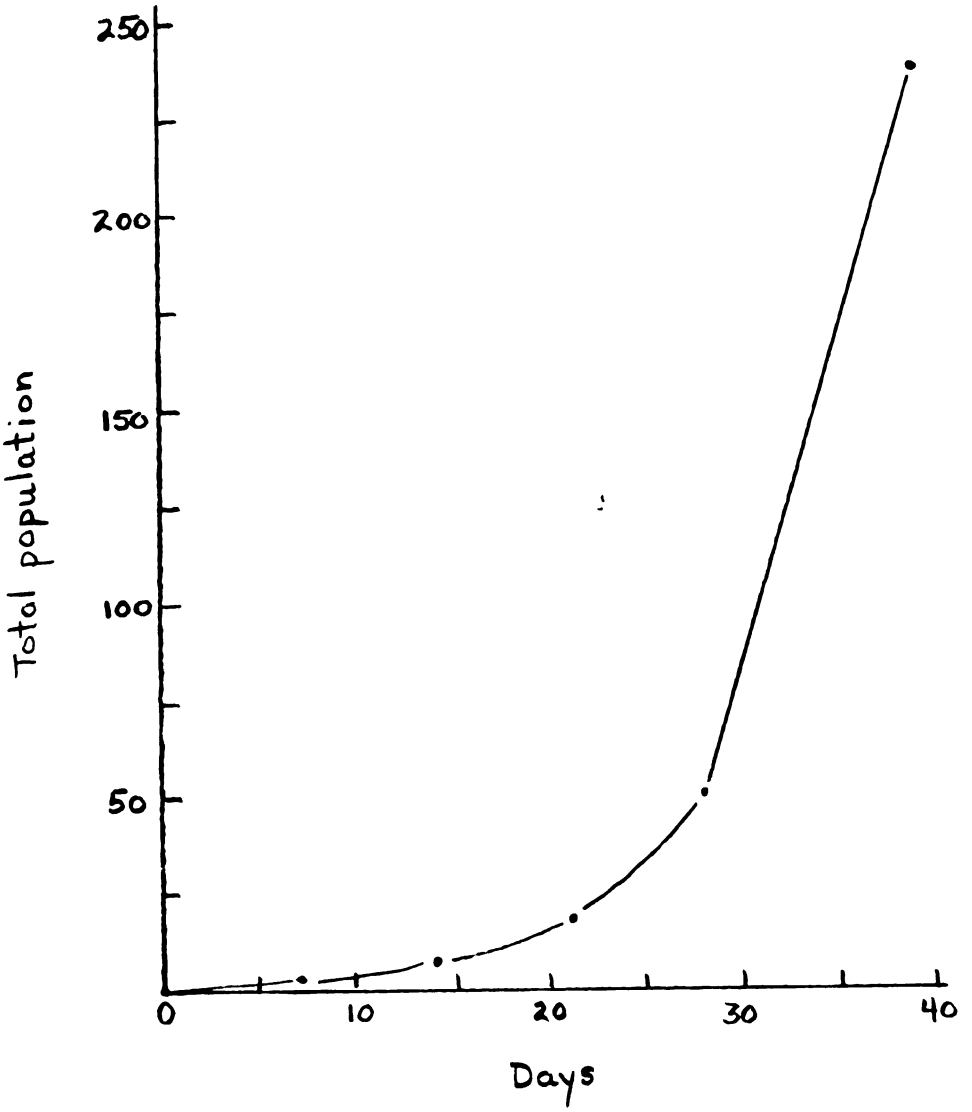
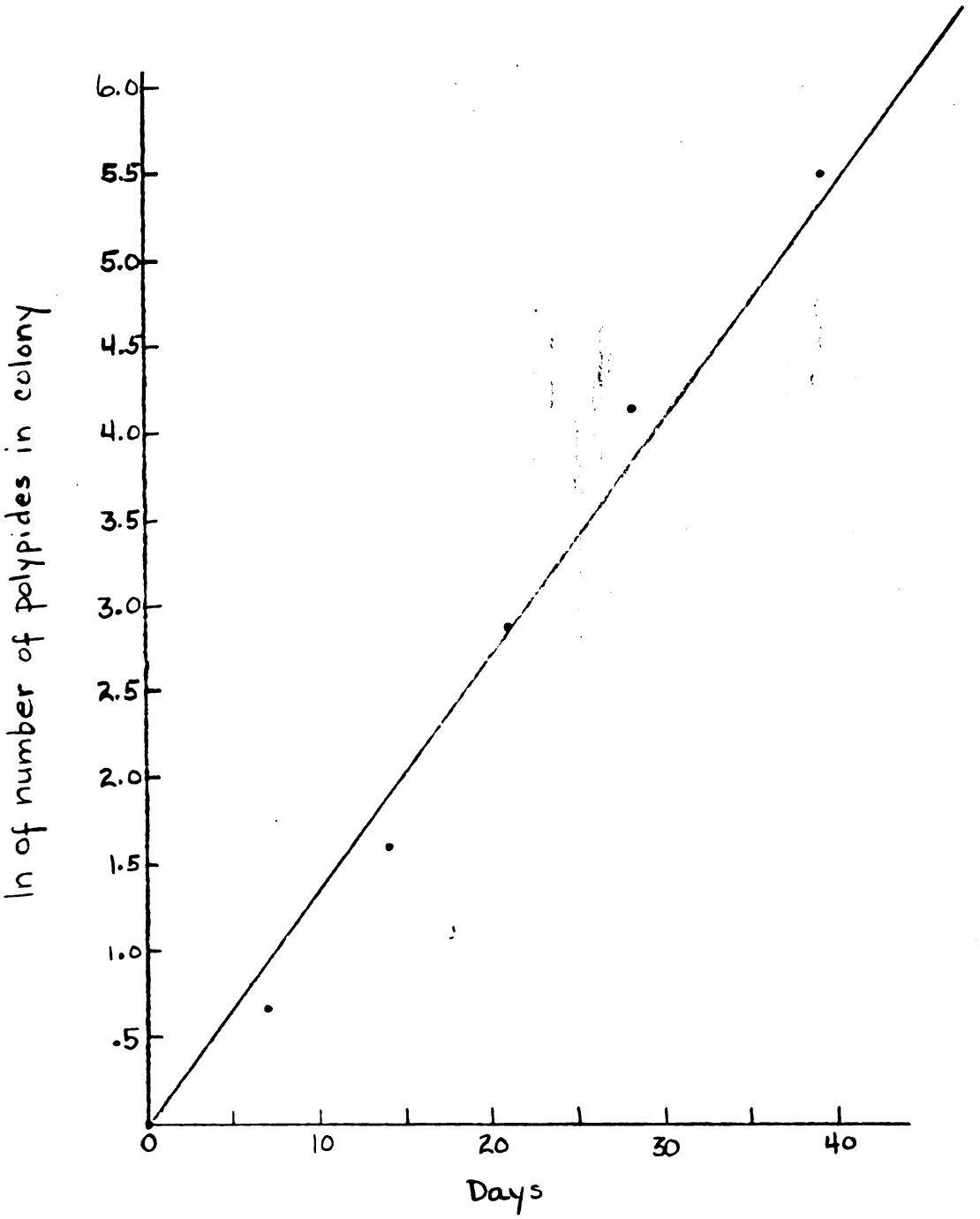


Fig. 28A. Relation of the natural logarithm of the number of polypides in colonies with time, for colony G-2, begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 3, April 29, 1960.



Doubling rate - 5.10

Fig. 28B. Theoretical increase in the total number of polypides for colony G-2 begun with one individual, chosen at Wintergreen Lake, Kalamazoo County, station 3, April 29, 1960.

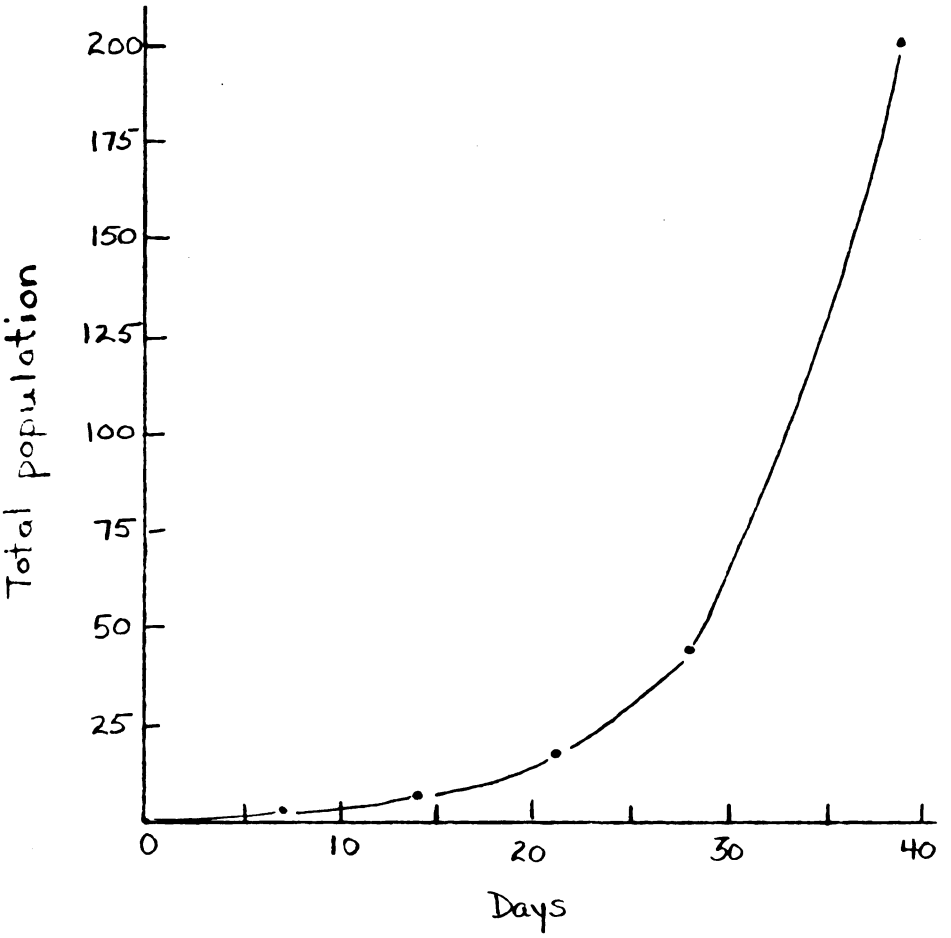


Fig. 29. Showing gross colony mortality for total colonies chosen at stations 5, 6b and 8 at Wintergreen Lake, Kalamazoo County in 1960. The natural logarithm of the number of marked colonies remaining at each station is plotted against time.

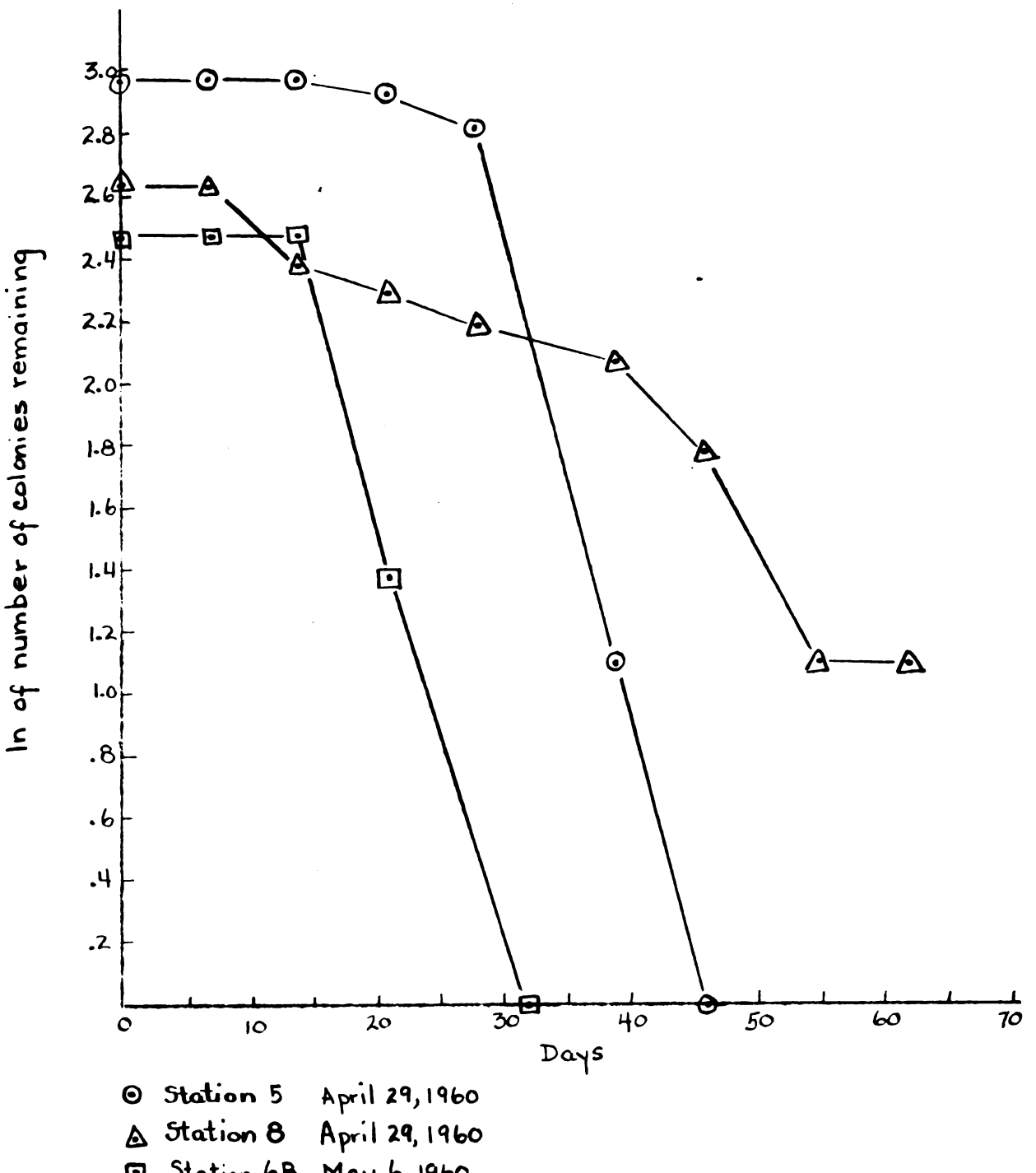


Fig. 30. Showing gross colony mortality for total colonies chosen at stations 6, 3 and 13b at Wintergreen Lake, Kalamazoo County in 1960. The natural logarithm of the number of marked colonies remaining at each station is plotted against time.

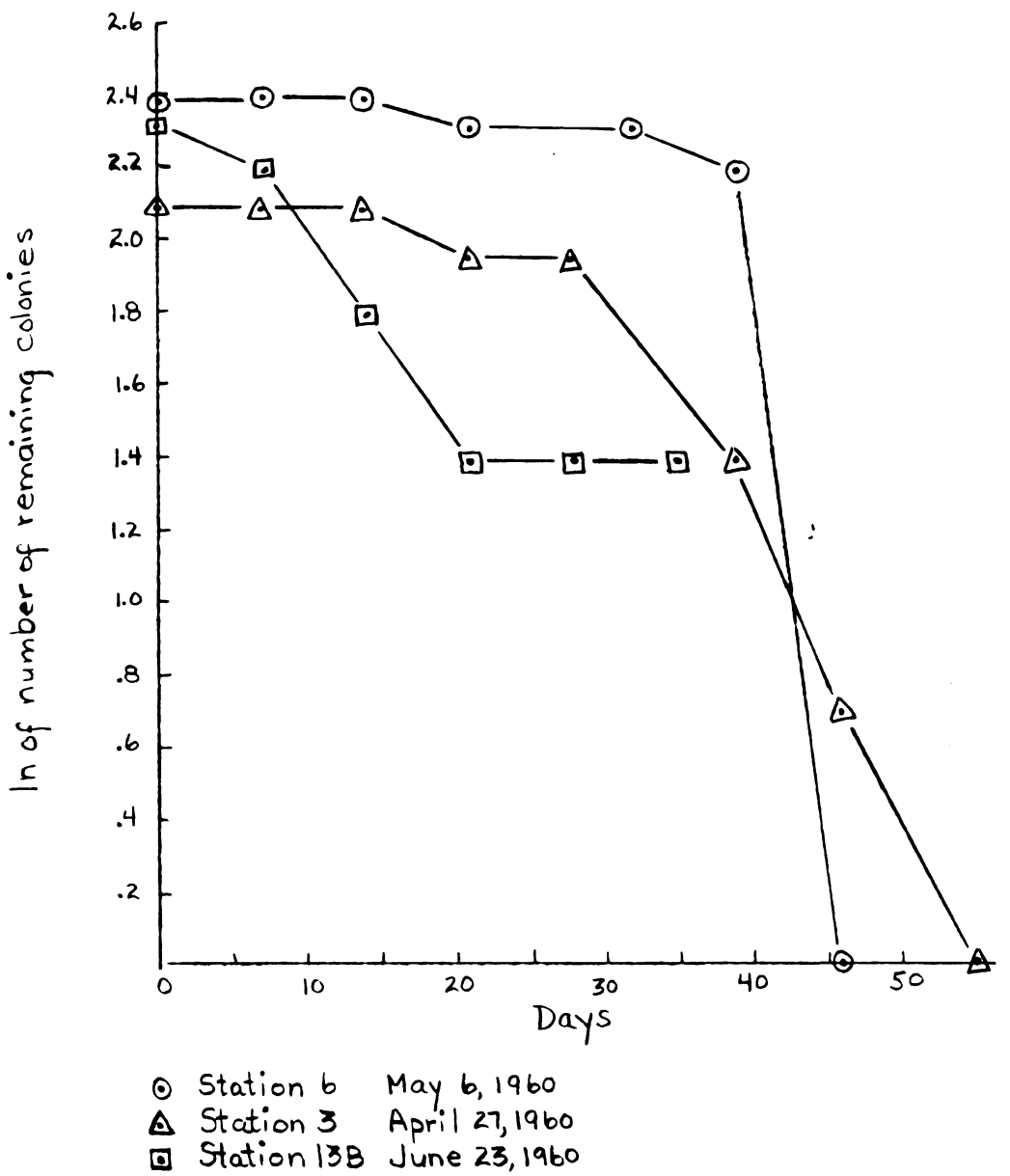


Fig. 31. Showing gross colony mortality for total colonies chosen at station 9, April 29, 1960, at Wintergreen Lake, Kalamazoo County. The natural logarithm of the number of marked colonies remaining at each station is plotted against time.

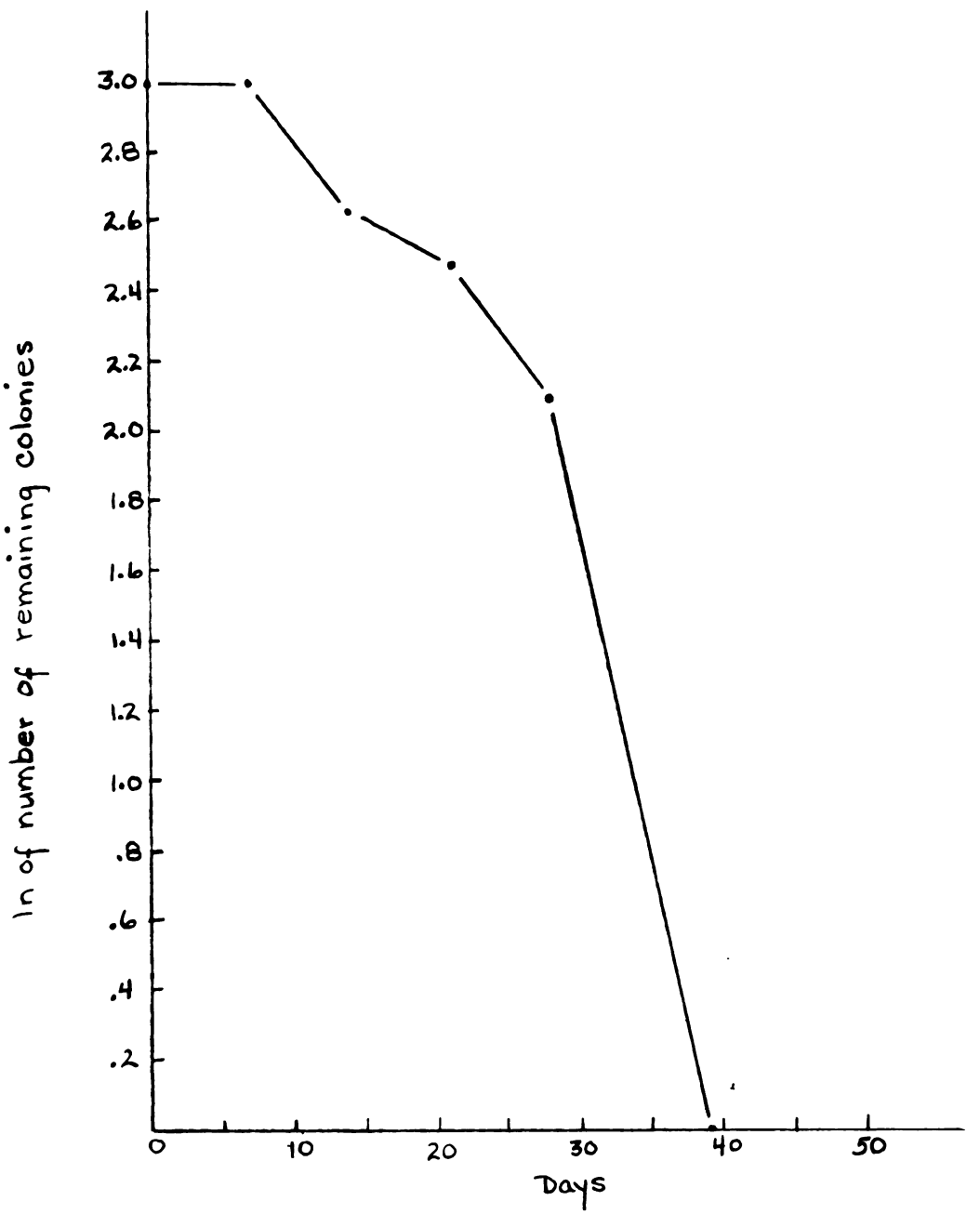


Fig. 32. Showing gross colony mortality for total colonies chosen at stations 2, 6 and 7 at Burke Lake, Clinton County, in 1960. The natural logarithm of the number of marked colonies remaining at each station is plotted against time.

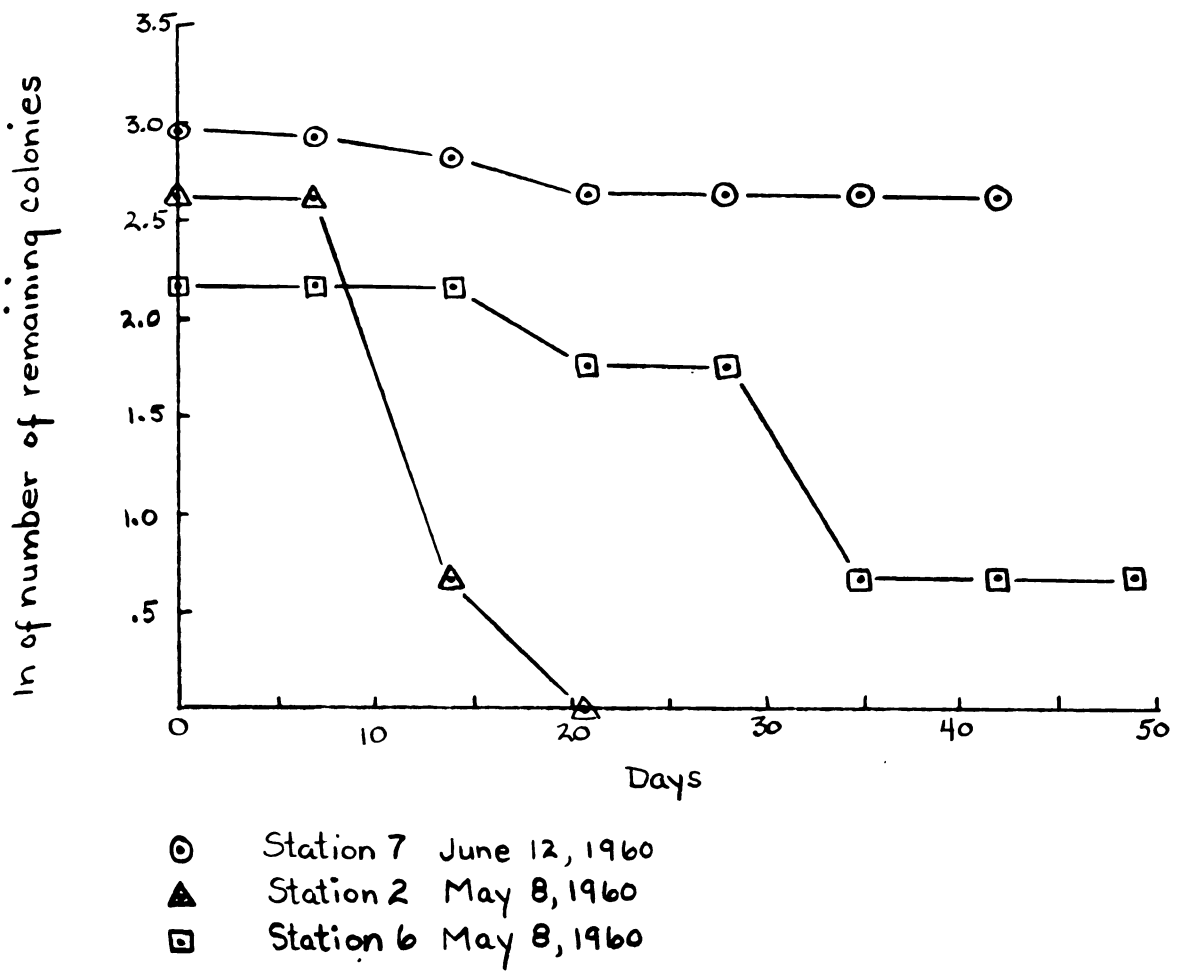


Fig. 33. Showing gross colony mortality for total colonies chosen at stations 2 and 4 at Burke Lake, Clinton County in 1960. The natural logarithm of the number of marked colonies remaining at each station is plotted against time.

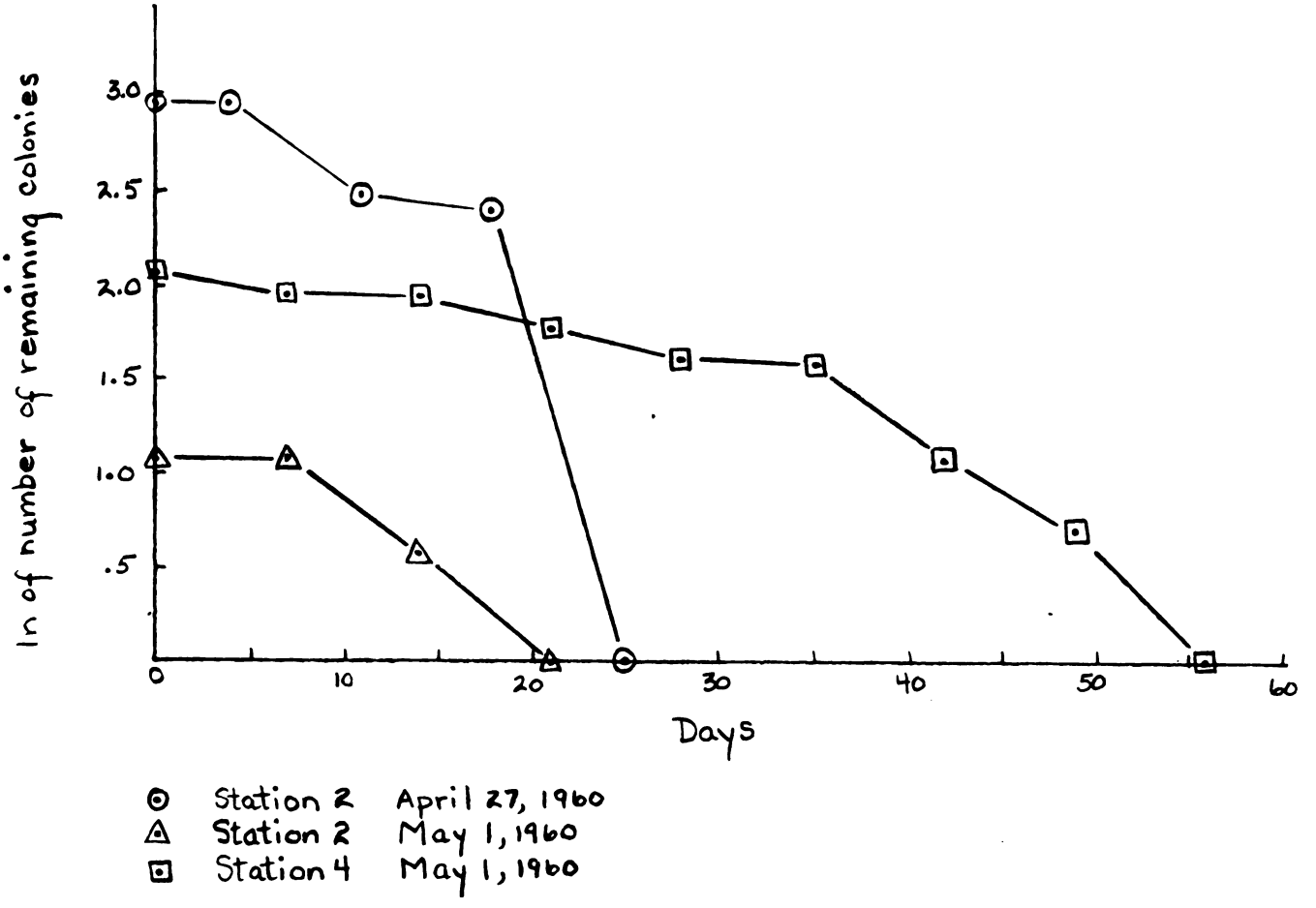


Fig. 34. Showing gross colony mortality for total colonies chosen at stations 6 and 9 at Burke Lake, Clinton County. The natural logarithm of the number of marked colonies remaining at each station is plotted against time.

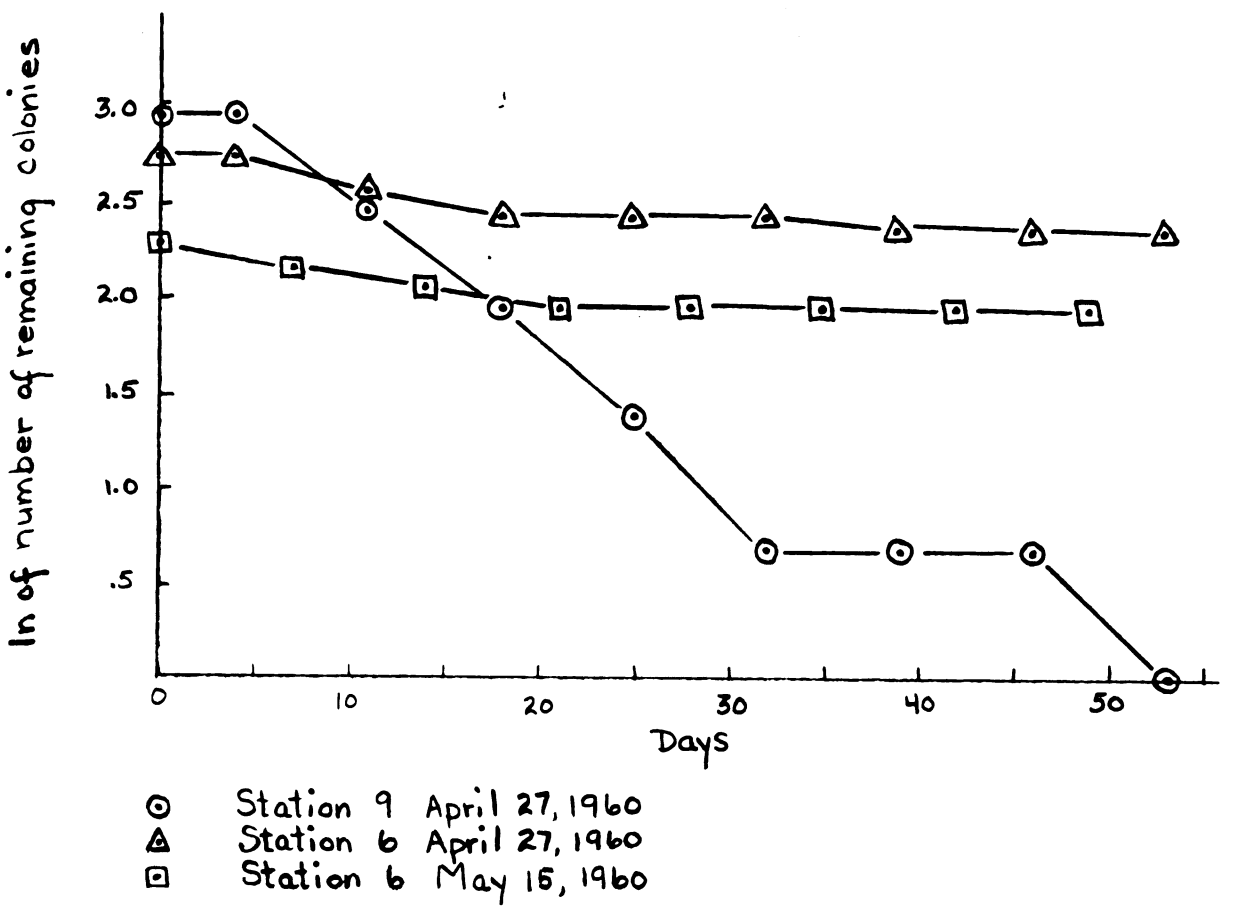


Fig. 35. Showing gross colony mortality for total colonies chosen at stations 4 and 5 at Burke Lake, Clinton County in 1960. The natural logarithm of the number of marked colonies remaining at each station is plotted against time.

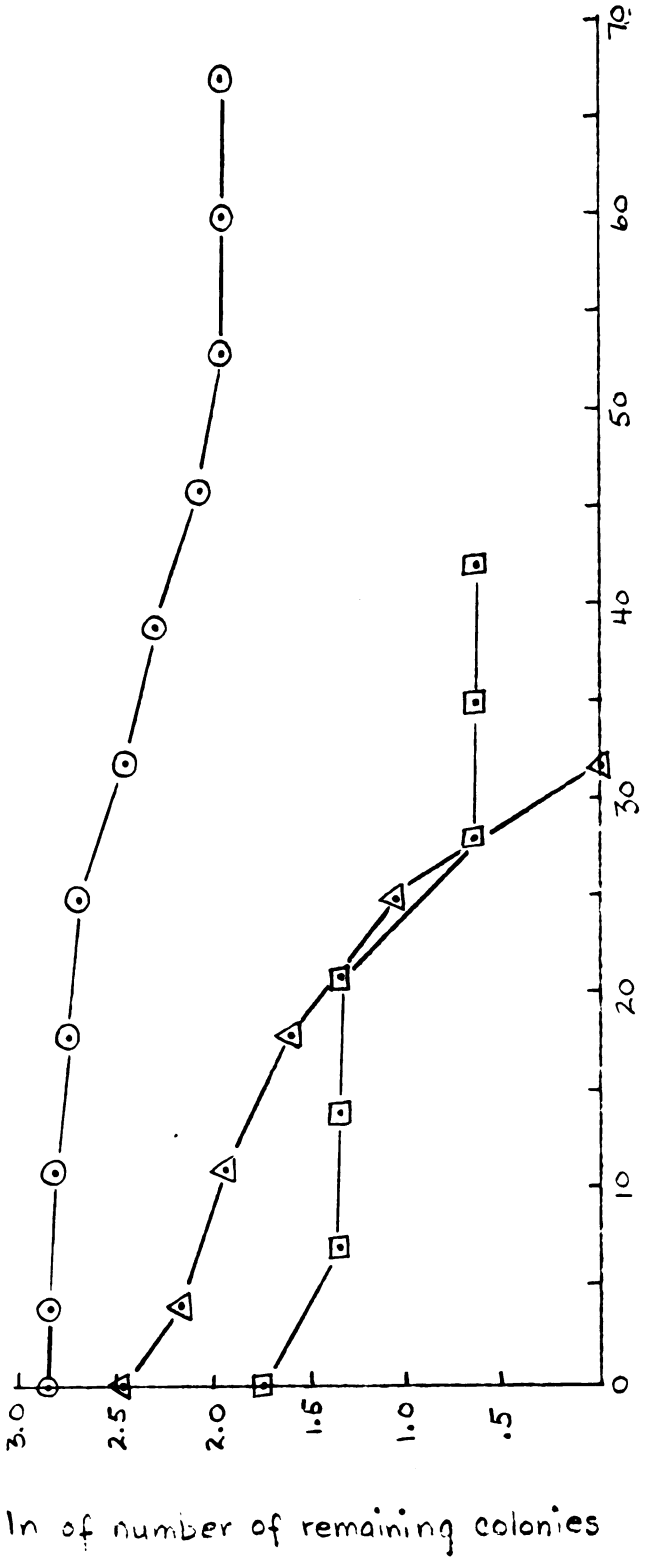


Fig. 36. Showing gross colony mortality for total colonies chosen at stations 5, 7 and 8b at Burke Lake, Clinton County in 1960. The natural logarithm of the number of marked colonies remaining at each station is plotted against time.

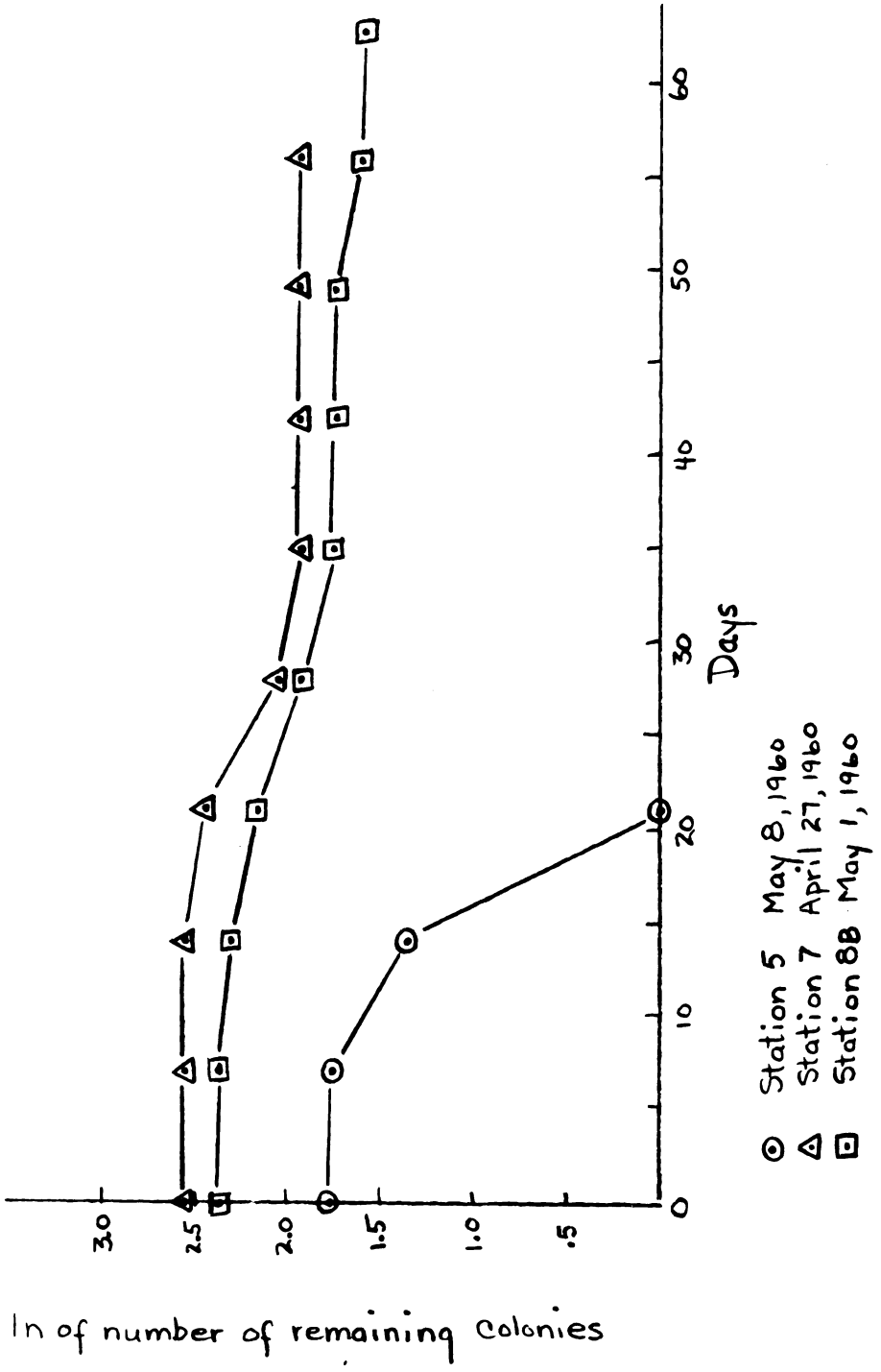
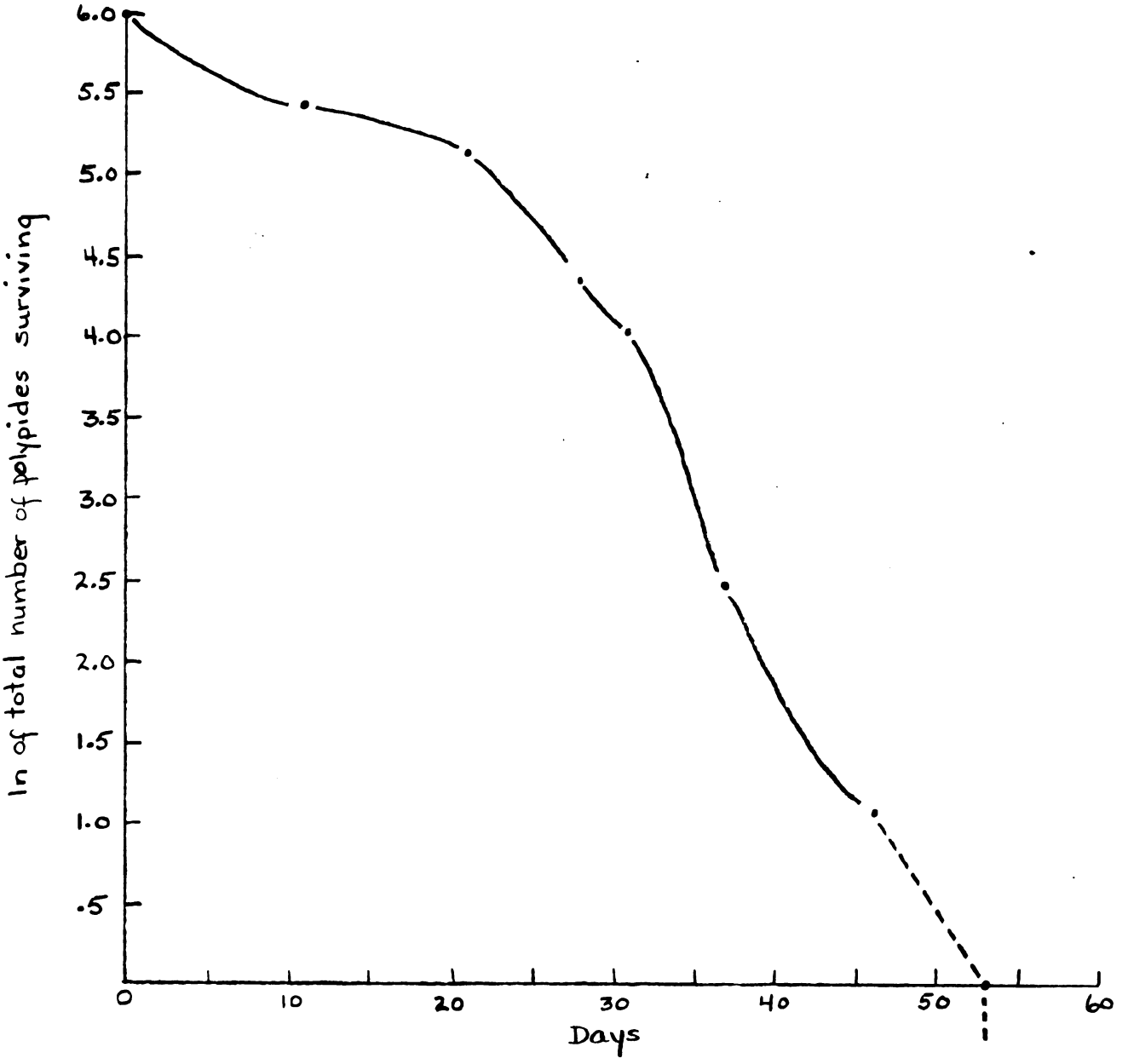


Fig. 37. Survivorship curve for 373 polypides of Plumatella repens. The natural logarithm of polypides surviving is plotted against time. Data are from appendix tables 38 through 42 for Wintergreen and Burke Lakes.



Legend for symbols used in the growth, mortality and longevity tables

Further discussion of these symbols appears in the text.

1. X — colony or polypide completely removed from substrate by a predator

2. number + X — designated number of polypides in colony remain, however portions of the colony are missing probably as a result of predation

3. tips — younger tips only of colony remain, older central portion largely missing, probably as a result of natural disintegration.

4. PG — colonies partly gone
5. MG — colonies mostly gone

these symbols used where relative rolls of predation and disintegration were difficult to judge

6. TM — colonies too mixed to count, indicates intertwining of zooecia; were too complex to permit an accurate polypide count.

7. TMX — colony was both too densely entangled to count and also incomplete.

8. * — colony counts so designated were approximate, error here not more than plus or minus ten.

9. *** — board or log (substrate) missing or had been pushed out into the lake

10. CX — colony removed by predator; symbol used only in longevity tables

11. XX — marked polypide was a victim of predation; symbol used only in longevity tables

TABLE I. Growth data for each marked colony of Plumatella repens at Station 1, Burke Lake, Clinton Co., 1960

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.					
	IV-27	V-1	V-8	V-15	V-22	V-29
R-1	1	2	2	X		
R-2	1	2	2	1	X	
R-3	1	2	2	3	3	X
R-4	1	2	2	3	2	X
R-5	1	2	2	2	X	
R-6	1	2	X			
Y-1	1	2	2	3	X	
Y-2	1	2	2	X		
G-1	1	2	2	X		
G-2	1	2	2	X		
P-1		1	X			
P-2		2	2	4	X	
RA-6			2	X		

TABLE 2. Growth data for each marked colony of Plumatella repens at Station 2, Burke Lake, Clinton Co., 1960. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.					
	IV-27	V-1	V-8	V-15	V-22	V-29
Y-1	1	2	5	4	X	
Y-2	1	2	3	11	X	
Y-3	1	2	2	8	X	
Y-4	1	2	3	9	X	
Y-5	1	2	3	6	X	
Y-6	1	2	4	6	X	
Y-7	1	2	5	3	X	
Y-8	2	2	2	7	X	
Y-9	1	2	3	3	X	
Y-10	1	2	3	6	X	
Y-11	1	2	6	X		
Y-12	2	2	X			
Y-13	1	2	X			
Y-14	1	2	X			
Y-15	1	2	X			
Y-16	1	2	X			
B-1	1	2	X			
B-2	1	2	X			
G-1	2	2	4	9	X	
G-2	1	2	X			
R-1		2	2	4	X	
R-2		2	2	X		
R-3		2	2	1	X	
P-1			5	9	X	
P-2			2	3	X	
P-3			5	12	X	
P-4			3	6	X	
P-5			3	7	X	
P-6			3	6	X	
W			7	13	6X	X

TABLE 3. Growth data for each marked colony of Plumatella repens at Station 3, Burke Lake, Clinton Co., 1960. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.									
	IV-27	V-1	V-8	V-15	V-22	V-29	VI-5	VI-12	VI-19	VI-26
G-1	1	2	4	18	20	73				
G-2	1	2	4	13	25	52	550*	1200*	1800*	tips
G-3	1	2	4	8	25	71				
G-4	1	2	5	10	31	61	TM			
Y-1	2	3	7	8	26	86	TM			
Y-2	1	1	1	2	3	7	TM			
Y-3	1	2	5	10	22	X				
Y-4	1	3	5	9	31	38pg	TM			
Y-5	1	2	5	9	10	34	TM			
Y-6	2	3	7	11	36	75	TM			
Y-7	1	2	7	13	42	73	TM			
Y-8	1	3	6	13	21	80	TM			
P-1	1	2	4	9	21	19	TM			
P-2	1	2	3	11	X					
P-3	1	2	3	14	25	14X	TM			
P-4	1	2	6	13	18	43X	TM			
R-1	1	2	5	8	19	21pg	TM			
R-2	1	2	3	5	X					
R-3	1	2	2	X						
R-4	1	2	6	11	32	60	TM			
R-5	2	3	9	15	45	88	TM			
R-6	1	2	6	8	18	X				
R-7	1	3	8	17	X					
R-8	1	2	5	9	31	67	X			
R-9	1	2	5	9	16	X				
R-10	2	4	8	16	22	X				
R-11	2	2	3	7	9	X				
R-12	1	2	4	4	6	X				
R-13	1	2	7	9	30	70	X			
B-1		1	2	6	20	44	X			
B-2		1	2	3	13	X				
B-3		1	3	7	36	73	X			
B-4		1	2	6	21	46	X			
B-5		2	4	8	32	67	X			
B-6		2	3	7	17	57	X			
P-5				8	29	103	280	450*	850*	tips
P-6				7	14	44	X			
W-1				10	29	96	262	630	TM	
W-2				8	15	23	TM			
MG-4							75	300	600*	MG
G-5							4	30	77	X
NY-1							27	95	190	tips

TABLE 3-(continued)

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.										
	IV-27	V-1	V-8	V-15	V-22	V-29	VI-5	VI-12	VI-19	VI-26	VII-3
NB-1								18	21X	4-5X	5-6X
NB-2								37	120	tips	tips
NB-3								30	95	tips	tips

TABLE 4. Growth data for each marked colony of Plumatella repens at Station 4, Burke Lake, Clinton Co., 1960. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.										
	IV-27	V-1	V-8	V-15	V-22	V-29	VI-5	VI-12	VI-19	VI-26	VII-3
B-1	1	2	X								
B-2	1	2	3	3	7	X					
B-3	2	3	6	6	X						
B-4	1	2	3	6	15	48	103	PG	PG	PG	tips
B-5	1	2	5	6	14	25X	64	X			
B-6	1	2	7	11	20	X					
B-7	1	2	8	7	17	34	44X	TM	TM		
B-8	1	2	6	8	23	12X	16X	X			
B-9	2	3	9	10	26	50	65X	75X	38X	30X	11X
B-10	1	2	3	3	7	X					
R-1	1	2	3	X							
R-2	1	3	5	5	3	12	41	50X	30X	tips	tips
R-3	1	2	6	4	14	24	42	55	75X	20X	tips
R-4	1	2	4	2	6	18	33	tips			
R-5	1	2	8	16	15	17X	X				
R-6	1	2	6	7	21	25	48X	tips	tips	tips	tips
R-7	1	2	8	11	13	17X	X				
R-8	1	2	4	6	7	16X	26	70X	15X	tips	tips
Y-1		2	7	12	X						
Y-2		2	5	11	21	32	14X	1X	X		
Y-3		2	5	6	21	88	20X	tips	X		
Y-4		2	5	2	7	14X	7X	tips	tips		
Y-5		2	6	7	17	X					
Y-6		2	5	6	8	15	30	136	78X	tips	
G-1		2	8	12	27	39X	MG	X			
G-2		2	X								
MG-2			7	7	17	X					
P-1					4	17	18	20	25X	89X	X
P-2					21	76	X				
MG-1									4	1	X
G-3									15	12X	6X

TABLE 5. Growth data for each marked colony of Plumatella repens at Station 5, Burke Lake, Clinton Co., 1960. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.										
	IV-27	V-1	V-8	V-15	V-22	V-29	VI-5	VI-12	VI-19	VI-26	VII-3
P-1	2	2	2	2	2	X					
P-2	2	3	2	2	X						
P-3	2	2	2	2	X						
P-4	2	2	3	1	4	X					
P-5	2	2	X								
P-6	2	2	2	3	8	X					
P-7	2	2	4	X							
P-8	2	2	4	X							
P-9	2	2	X								
P-10	2	X									
P-11	2	X									
P-12	2	X									
R-1			1	2	5	X					
R-2			1	2	7	X					
R-3			2	3	3	X					
R-4			2	2	X						
R-5			4	2	X						
R-6			3	3	8	X					
NP-1								7	X		
NP-2								6	14X	14X	44X
NP-3								7	17	18X	14X

TABLE 6. Growth data for each marked colony of Plumatella repens at Station 6, Burke Lake, Clinton Co. 1960. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.											
	IV-27	V-1	V-8	V-15	V-22	V-29	VI-5	VI-12	VI-19	VI-26	VIII-3	VII-10
R-1	2	3	8	11	16	45	TM	TM	TM			
R-2	2	3	8	15	28	37	TM					
R-3	2	3	8	10	13	16X	TM					
R-4	1	2	6	10	10	44	TM					
R-5	1	2	5	7	17	45	TM	TMX	150X	60X		
R-6	2	2	7	8	28	66	133	TM	TM			
R-7	2	2	3	5	8	35	107	TMX	TM			
R-8	1	2	3	5	8	14X	37X	24X	TM			
R-9	2	2	5	7	17	38X	X					
R-10	2	2	3	6	22	59	84	TM	TM			
R-11	1	2	5	5	11	34	30X	TM	TM			
R-12	1	2	X									
R-13	2	2	X									
R-14	2	3	5	15	48	TM	TM	TM	TM			
R-15	2	2	3	X								
R-16	2	2	X									
G-1			4	5	12	35	40X	X				
G-2			5	6	18	50	76X	X				
G-3			5	6	5	X						
G-4			5	6	13	X						
G-5			4	6	12	16X	5-6X	X				
G-6			3	4	19	24	107	X				
G-7			6	11	14	34	95	221	TMX	tips	tips	
G-8			3	4	4	X						
G-9			2	3	5	13	36	TM	TM	TM		
P-1				4	8	7X	7X	7X	7X			
P-2				3	6	10X	10X	10X				
P-3				4	7	12X	12X	12X				
P-4				2	5	10X	7X	tips				

TABLE 6.-(continued)

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.											
	IV-27	V-1	V-8	V-15	V-22	V-29	VI-5	VI-12	VI-19	VI-26	VII-3	VII-10
Y-1				4	X							
Y-2				9	22	34	76	TM				
Y-3				5	10	27	67	80X	80X			
Y-4				7	17	56	182	110X				
Y-5				9	21	47	140	X				
Y-6				3	6	X						
B-1					6	X						
B-2					5	18	53	30X				
B-3					3	3X	X					
B-4					8	X						
NY-1									17	31	30X	45X
NY-2									4	17	X	
NY-3									4	2	18X	25X
NY-4									6	10	12X	8X
NY-5									8	27	5X	X
NY-6									11	38	32X	40X

TABLE 7. Growth data for each marked colony of Plumatella repens at Station 7, Burke Lake, Clinton Co., 1960. See legend opposite Table 1 for explanation of symbol.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.						
	IV-27	V-1	V-8	V-15	V-22	V-29	VI-5
P-1	2	4	8	3	16	X	
P-2	1	3	6	6	14	TM	
P-3	1	3	6	9	22	44	TM
P-4	2	3	5	6	13	TM	
P-5	1	3	6	9	18	39	TM
P-6	2	4	8	9	X		
P-7	2	4	8	7	X		
P-8	1	2	4	8	X		
P-9	2	3	5	9	26	63	TM
P-10	2	3	6	X			
P-11	2	4	7	13	X		
P-12	2	3	7	9	18	50	TM
P-13	1	2	4	7	14	37	TM
	VI-12	VI-19	VI-26	VII-3	VII-10	VII-17	
G-1	16	34	17X	12X	tips	tips	
G-2	4	16	37	104	374	990	
G-3	4	X					
G-4	38	155	356	990*	2000*	2200X	
Y-1	5	22	73	279	795	480X	
Y-2	8	19	X				
Y-3	4	15	39	122	390	1200*	
Y-4	3	11	39	156	547	1260*	
Y-5	3	7	19	X			
B-1	3	8	22	73	228	695	
B-2	4	14	40	129	316	460X	
B-3	6	18	51	162	510	PG	
B-4	4	14	X				
W-1	1	4	13	44	155	458	
W-2	3	9	27	92	324	692*	
W-3	3	13	27	94	303	220X	
W-4	1	3	4X	X			
R-1	1	3	13	41	134	150X	
R-2	5	14	60	X			
R-3	2	6	19	64	284	791	

TABLE 8. Growth data for each marked colony of Plumatella repens at Station 8, Burke Lake, Clinton Co. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.										
	V-15	V-22	V-29	VI-5	VI-12	VI-19	VI-26	VII-3	VII-10	VII-17	VII-24
Y-1	4	16	51	188	X						
Y-2	3	4	12	57	X						
Y-3	3	7	26	90	6X						
R-1	3	6	6	28	5X	X					
R-2	5	6	6	14X	X						
R-3	2	4	10	35	50X	40X	55X	tips	X		
G-1		15	42	132	PG	PG	PG	tips			
G-2		3	8	54	X						
G-3		3	X								
W-1		5	14	X							
W-2		2	8	14X							
W-3		4	9	40	35X	tips	122X	140X			
P-1		7	18	70	tips						
P-2		4	18	32TMX	X						
P-3		9	22	62	90X						
B-1			3	30							
B-2			20	45X	45X	17	12X	15X	tips		
B-3			6	25	X						
NP-2						16	43	40X	30X	27X	tips
B-4						16	8X	11X	X		
B-5						21	X				

TABLE 9. Growth data for each marked colony of Plumatella repens at Station 8B, Burke Lake, Clinton Co., 1960. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.								
	V-1	V-8	V-15	V-22	V-29	VI-5	VI-12	VI-19	VI-26
R-1	1	2	4	14	43	168	460	tips	X
R-2	1	2	5	19	62	205	tips		
R-3	1	3	7	20	52	167	PG		
R-4	1	3	X						
Y-1	1	2	4	16	50	X			
Y-2	1	3	6	23	67	189	tips		
Y-3	1	2	6	8	X				
W-1	1	2	5	17	59	161	120X	tips	X
W-2	1	2	5	X					
W-3	1	2	4	15	36	30X			
W-4	1	2	5	18	X				
P-1		1	3	7	24	82	213	PG	
P-2		1	2	5	13	50	25X		X
P-3		2	5	X					
P-4		1	2	5	12	X			
P-5		2	4	17	57	173	PG	tips	X
B-1		1	3	9	33	106	288	21X	
B-2		1	3	7	19	X			
B-3		1	3	9	23	5X	X		
B-4		1	2	6	X				
G-1		2	4	14	43	136	70X	10X	X
G-2		1	3	11	40	112	35X	tips	
G-3			2	5	8	tips	X		
G-4			2	4	12	38	126	tips	
G-5			2	5	14	36	102*	13X	X
YA-1			2	4	12	44	11X	tips	
YA-2			2	4	11	30	X		
WA-1				2	7	24	3X	X	
WA-2				2	6	18	MG		

TABLE 10. Growth data for each marked colony of Plumatella repens at Station 9, Burke Lake, Clinton Co., 1960. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.								
	IV-27	V-1	V-8	V-15	V-22	V-29	VI-5	VI-12	VI-19
R-1	2	2	5	7	14	X			
R-2	2	3	X						
R-3	2	2	X						
R-4	2	2	X						
R-5	2	2	X						
R-6	2	2	X						
R-7	2	3	X						
R-8	2	2	5	3	3	8	8	3X	X
R-9	2	3	3	2	X				
R-10	2	2	4	3	X				
R-11	2	2	4	X					
R-12	2	2	6	X					
R-13	2	3	5	X					
R-14	2	2	X						
R-15	2	2	4	X					
R-16	2	3	5	6	6	8	8	5X	X
R-17	2	2	4	3	3	X			
R-18	2	2	X						
R-19	2	2	2	X					
R-20	2	2	5	5	X				
P-1		2	3	3	3	14	X		
P-2		2	7	8	X				
P-3		2	4	4	4	X			
P-4		2	X						
P-5		2	4	X					
Y-1			3	7	12	4	X		
Y-2			7	14	32	75	X		
Y-3			2	3	6	6X	X		
Y-4			3	3	X				
G-1				2	5	10	X		
G-2				3	6	X			

TABLE 11. Growth data for each marked colony of Plumatella repens at Station 10, Burke Lake, Clinton Co., 1960. See legend opposite Table 1 for explanation of ymbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.						
	IV-27	V-1	V-8	V-15	V-22	V-29	VI-5
R-1	1	1	X				
R-2	2	X					
P-1		1	2	2	X		
P-2		1	3	3	7	4	X

TABLE 12. Growth data for each marked colony of Plumatella repens at Station 11, Burke Lake, Clinton Co., 1960.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.				
	V-8	V-15	V-22	V-29	VI-5
W-1	2	2	9	X	
W-2	2	3	X		
W-3	5	6	X		
P-1	2	4	10	X	
P-2	2	5	12	X	
P-3	2	X			
P-4	3	5	16	X	
B-1	4	8	X		
B-2	2	3	8	X	
Y-1	2	3	9	X	
Y-2	5	6	X		
Y-3	5	5	X		
G-1	6	X			
G-2	3	7	20	X	
R		3	11	X	

TABLE 13. Growth data for each marked colony of Plumatella repens at Station 12, Burke Lake, Clinton Co., 1960.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.				
	V-8	V-15	V-22	V-29	VI-5
P-1	3	5	7	X	
G-1	2	4	X		
G-2	2	3	7	X	
Y-1	2	3	X		
Y-2	3	5	5	X	
R	2	3	3	4	X
P-2		5	15	X	
B-1		4	6	X	
B-2		2	2	X	

TABLE 14. Growth data for each marked colony of Plumatella repens at Station 13, Burke Lake, Clinton Co., 1960. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.								
	V-1	V-8	V-15	V-22	V-29	VI-5	VI-12	VI-19	VI-26
Y-1	1	2	6	20	X				
Y-2	1	2	4	9	30	102	PG		
Y-3	1	3	7	22	57	146	80X		
Y-4	1	2	4	10	X				
Y-5	1	3	5	14	39	X			
R-1	1	2	5	10	28	63	TMX		
R-2	1	2	6	17	54	X			
R-3	1	3	8	21	67	40X	X		
R-4	1	2	4	10	29	X			
P-1	1	2	4	14	35	111	74X		
P-2	1	2	4	12	28	81	258	510*	
P-3	1	2	5	14	37	99	274	300X	X
P-4	1	2	3	8	23	X			
G-1		1	2	5	16	47	182	120X	X
G-2		2	4	11	34	89	278	180*	
G-3		2	4	7	11	X			
G-4		1	2	6	17	61	X		
W-1		1	2	6	20	86	20X	X	
W-2		1	2	5	23	99	tips		
W-3		1	3	6	22X	X			
W-4		2	4	9	26	X			

	VI-12	VI-19	VI-26	VII-3	VII-10	VII-17	VII-24
B-1	1	3	14	51	168	487*	X
B-2	3	10	32	115	384	1135*	
B-3	3	15	62	228	75X		
B-4	3	7	23	87	291	785	
B-5	5	16	X				

TABLE 15. Growth data for each marked colony of Plumatella repens at Station 14, Burke Lake, Clinton Co., 1960. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.									
	IV-27	V-1	V-8	V-15	V-22	V-29	VI-5	VI-12	VI-19	VI-26
B-1	1	2	5	9	25	86	271	140X	X	
B-2	1	2	5	13	34	95	120X	tips		
B-3	1	2	4	X						
B-4	1	3	6	15	39	89	tips			
B-5	1	2	4	14	33	81	293	805*		
Y-1	1	2	5	10	30	66	190	505*	tips	X
Y-2	1	2	6	20	X					
Y-3	1	3	11	24	62	X				
Y-4	1	2	4	11	25	69	40X			
Y-5	1	2	3	7	X					
W-1	1	2	4	X						
R-1		2	4	7	16	X				
R-2		2	3	5	13	28	77	110X		
R-3		2	4	8	19	52	144	328	165X	
R-4		2	5	8	21	45X	X			
R-5		2	4	X						
R-6		2	5	14	39	98	X			
R-7		2	4	12	32	101	111X	tips		

TABLE 16. Growth data for each marked colony of Plumatella repens at Station 2, Burke Lake, Clinton Co., 1959. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.				
	VI-14	VI-20	VII-2	VII-9	IX-21
Br	44	MG	X		
Dp	5	14	X		
Ep			38	30	X

TABLE 17. Growth data for each marked colony of Plumatella repens at Station 3, Burke Lake, Clinton Co., 1959.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.					
	V-17	V-24	V-31	VI-6	VI-14	VI-20
B	2	6	20	55	191	142X
G	2	7	26	79	267	X
R	4	17	49	137	540	X
Y	2	8	22	41	97	

TABLE 18. Growth data for each marked colony of Plumatella repens at Station 4, Burke Lake, Clinton Co., 1959.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.									
	VI-20	VII-2	VII-9	VII-21	VII-28	VIII-7	VIII-14	VIII-24	IX-5	IX-20
Ay	6	34	X							
Bg	2	10	21	8X	3X					
Cp	2	13	32	30X	25X					
Dpg	2	10	X							
Epr	4	27	8X	X						
F	2	12	44	281	110X					
Fb					3	26	60X	X		
Gg					263	630				
Hp					17	121				
Ww					4	15	52	263	710	
Pw					2	9	32	168	902*	X
R						1	3	16	131	X
Y						1	3	21	208	X

TABLE 19. Growth data for each marked colony of Plumatella repens at Station 5, Burke Lake, Clinton Co., 1959. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.									
	V-24	V-31	VI-6	VI-14	VI-20	VII-2	VII-9	VII-21	VII-28	VIII-7
Pgb	6	19	32	125	155	X				
Ryw	8	28	104	129	204	X				
G-1	1	4	11	31	48	X				
G-2	1	3	8	26	72	X				
Y-1	5	15	51	161	345	40X				
D			2	6	15	98	257	890X	110X	MG
E			2	5	14	81	228	1141*	47X	17X
F			2	6	21	80	295	318X		

TABLE 20. Growth data for each marked colony of Plumatella repens at Station 6, Burke Lake, Clinton Co., 1959.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.				
	V-31	VI-6	VI-14	VI-20	VII-2
Ce	19	59	194	176PG	X

TABLE 21. Growth data for each marked colony of Plumatella repens at Station 7, Burke Lake, Clinton Co., 1959.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.									
	V-24	V-31	VI-6	VI-14	VI-20	VII-2	VII-9	VII-21	VII-28	VIII-7
B	18	51	X							
Y	30	X								
G			31	38	X					
W			21	X						
P					2	8	42	136	60X	
R					2	13	38	174	PG	X
YA					5	26	24X	12X	X	

TABLE 22. Growth data for each marked colony of Plumatella repens at Station 8, Burke Lake, Clinton Co., 1959. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.						
	V-24	V-31	VI-6	VI-14	VI-20	VII-2	
B	2	7	39	182	125X		
G	2	8	34	151	500*		
	X-20	X-29	XI-7	XI-15	XI-22	XI-29	XII-6
Bb	7	12	3	3	X		
Gg	3	4	5	3	2	2	X
Y	2	4	7	5	5	3	X
W	1	X					
R	3	3	X				
P	4	6	10	4	4	1	X
Br	3	4	6	5	2	2	X
Yw	2	4	6	3	3	1	X
Pg	2	5	8	6	3	2	X
Py	3	5	X				

TABLE 23. Growth data for each marked colony of Plumatella repens at Station 3, Wintergreen Lake, Kalamazoo Co., 1960. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.							
	IV-29	V-6	V-13	V-20	V-27	VI-7	VI-14	VI-23
B-1	1	2	5	13	37	X		
B-2	1	3	8	X				
Y-1	1	2	6	19	49	16X	X	
Y-2	2	5	13	57	169	X		
Y-3	2	6	18	61	192	70X	X	
Y-4	2	5	17	59	200*	437	tips	X
G-1	2	5	12	47	154	X		
G-2	1	2	5	18	62	248	85X	X

TABLE 24. Growth data for each marked colony of Plumatella repens at Station 5, Wintergreen Lake, Kalamazoo Co., 1960.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.							
	IV-29	V-6	V-13	V-20	V-27	VI-7	VI-14	VI-23
G-1	2	5	16	65	125	X		
R-1	1	2	5	19	50	X		
R-2	1	3	9	36	95	X		
R-3	2	5	13	77	226	X		
R-4	1	3	8	22	60	X		
R-5	1	2	7	21	45	X		
Y-1	2	6	17	70	120X	X		
Y-2	2	4	14	TMX	X			
Y-3	1	3	9	X				
Y-4	1	3	11	56	177	X		
Y-5	1	1	3	15	40	X		
W-1	2	5	17	14X	42	X		
W-2	2	4	7	33	95	X		
W-3	2	5	13	32	80	8X	X	
W-4	2	6	21	76	190	X		
P-1	3	8	17	67	110X	X		
B-1	2	6	23	60	85	X		
B-2	2	5	18	64	218	74X	X	
Y+R	1	2	6	20	84	tips	X	
R+B	1	3	7	23	X			
P-2		1	3	11	MG	MG	X	
P-3		1	2	X				
P-4		2	3	16	78	X		
P+R		1	3	8	35	9X	X	
B+Y		1	2	8	46	70X	32X	X
P-5			1	2	11	X		

TABLE 25. Growth data for each marked colony of Plumatella repens at Station 6, Wintergreen Lake, Kalamazoo Co., 1960. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.								
	IV-29	V-6	V-13	V-20	V-27	VI-7	VI-14	VI-23	VI-30
B-1	4	8	19	80	208	250X	240X	X	
B-2	2	6	13	35	110	100X	tips	X	
P-1	1	2	5	20	20X	X			
P-2	1	2	4	7	30	tips	tips	X	
P-3	1	2	5	25	90	tips	tips	X	
P-4	1	2	4	23	74	MG	MG	X	
R-1	1	2	4	12	22	3X	X		
R-2	1	3	6	11	20	8X	tips	X	
G-1	1	2	5	11	32	tips	tips	X	
R-3		1	3	12	23	PG	MG	X	
R-4		1	2	8	24	PG	MG	X	
W-1		1	2	5	TMX	MG	X		
W-2		1	4	18	59	TMX	MG	X	
G-2		1	3	12	36	118	tips	X	
G-3		1	3	20	30	tips	tips	X	
G-4		1	4	10	X				
Y-1		1	5	26	60	278	120X	X	
Y-2		1	4	23	tips	tips	tips	X	
Y-3		1	3	12	43	191	tips	X	
Y-4		2	5	15	45	242	tips	X	
YA-1								8	X
YA-2								18	X
YA-3								4	X

TABLE 26. Growth data for each marked colony of *Plumatella repens* at Station 6B, Wintergreen Lake, Kalamazoo Co., 1960. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.					
	V-6	V-13	V-20	V-27	VI-7	VI-14
P-1	1	4	13	X		
P-2	1	2	6	X		
Y-1	1	2	9	X		
Y-2	1	4	16	7X	X	
G-1	1	4	14	X		
G-2	1	2	8	33	X	
G-3	1	3	12	X		
G-4	1	4	15	X		
B-1	1	3	11	5X	X	
B-2	1	3	9	X		
R-1	1	3	10	34	X	
R-2	1	3	12	X		
P-3			10	X		
P-4			4	X		
Y-3			4	20	X	
Y-4			1	X		
R-3			7	X		
R-4			4	X		
W-1			5	X		
W-2			11	19	7X	
W-3			3	X		
W-4			2	15	X	
WA-1				8	X	

TABLE 27. Growth data for each marked colony of Plumatella repens at Station 7, Wintergreen Lake, Kalamazoo Co., 1960. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.				
	V-6	V-13	V-20	V-27	VI-7
G-1	1	3	7	21	X
G-2	1	X			
G-3	1	X			
G-4	1	X			
G-5	1	X			
G-6	1	X			
G-7	1	X			
G-8	1	1	X		
R-1	1	X			
R-2	1	3	8	X	

	VI-30	VII-7	VII-41
GA-1	2	3	X
YA-1	1	X	

TABLE 28. Growth data for each marked colony of Plumatella repens at Station 8, Wintergreen Lake, Kalamazoo Co., 1960. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.									
	IV-29	V-6	V-13	V-20	V-27	VI-7	VI-14	VI-23	VI-30	VII-7
G-1	1	2	8	37	116	496	70X	tips	tips	X
G-2	1	2	X							
G-3	1	3	8	20	70	20X	X			
G-4	1	3	X							
G-5	1	2	5	13	48	18X	tips	X		
G-6	1	2	4	15	29	4X	X			
R-1	1	2	5	35	138	X				
R-2	1	3	9	26	X					
R-3	1	3	X							
R-4	1	2	5	19	60	tips	tips	tips	X	
R-5	1	2	5	22	10X	X				
R-6	1	2	10	TM	40*	50X	tips	X		
R-7	1	3	7	X						
R-8	1	3	8	33	106	20X	tips	tips	tips	
B-1		1	3	16	53	19X	tips	tips		
B-2		1	3	14	X					
Y-1		1	4	TMX	X					
Y-2		1	3	18	tips	X				
GA-2			2	8	29	X				
GA-4			2	10	36	14X	X			
B-3					9	X				
B-4					9	X				
P-1								10	X	
P-2								5	3	X
P-3								6	14	X
P-4								4	X	
GA-1								1	1	X
NGA-2								1	X	
GA-3								1	X	
BA-1								1	X	
BA-2								1	X	
BA-3								5	X	
RA-1								2	X	
RA-2								1	X	

TABLE 29. Growth data for each marked colony of Plumatella repens at Station 9, Wintergreen Lake, Kalamazoo Co., 1960. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.								
	IV-29	V-6	V-13	V-20	V-27	VI-7	VI-14	VI-23	VI-30
G-1	1	2	X						
G-2	1	2	X						
G-3	1	2	X						
G-4	1	3	X						
G-5	1	2	X						
G-6	1	2	X						
G-7	1	3	8	26	58	X			
G-8	1	2	6	19	30	X			
G-9	1	2	5	7	19	X			
G-10	1	2	4	26	36	X			
G-11	1	2	3	9	26	X			
G-12	1	2	4	13	26	X			
G-13	1	2	3	11	20	X			
G-14	1	2	4	14	X				
B-1	1	2	5	20	53	X			
B-2	1	3	8	27	69	X			
B-3	2	5	12	PegX					
Y-1	1	2	6	24	X				
Y-2	1	3	10	X					
Y-3	1	3	12	41	137	X			
W-1		1	4	19	60	X			
W-2		1	3	13	42	X			
W-3		1	3	X					
YA-1								1	X
YA-2								12	X
P-1								5	X

TABLE 30. Growth data for each marked colony of Plumatella repens at Station 10, Wintergreen Lake, Kalamazoo Co., 1960. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.						
	IV-29	V-6	V-13	V-20	V-27	VI-7	VI-14
R-1	1	2	3	TM	TM		***
R-2	1	3	8	23	56	365	***
R-3	1	3	2	X			***
R-4	1	2	5	12	X		***
R-5	1	2	6	18	X		***
R-6	1	3	X				***
G-1	1	2	6	21	69	304	***
G-2	1	3	6	23	X		***
G-3	1	2	5	19	X		***
G-4	3	6	21	60	220	836	***
G-5	1	2	5	18	60	262	***
G-6	1	2	5	16	52	X	***
Y-1	1	2	4	11	X		***
Y-2	1	1	4	11	X		***
Y-3	1	2	2	9	X		***
Y-4	1	3	10	29	82	457	***
Y-5	1	2	6	17	63	343	***
Y-6	3	7	17	53	202	459	***
B-1	1	2	3	9	X		***
B-2	1	2	5	X			***
B-3	2	4	3	X			***
B-4	1	1	3	9	34	176	***
B-5	1	2	4	11	35	148	***
B-6	1	3	8	X			***
P-1			6	20	X		***
P-2			2	6	30	162	***
W-1			1	2	7	42	***
W-2			1	3	11	61	***

TABLE 31. Growth data for each marked colony of Plumatella repens at Station 11, Wintergreen Lake, Kalamazoo Co., 1960. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.						
	IV-29	V-6	V-13	V-20	V-27	VI-7	VI-14
R	2	5	10	11	30	X	
Y	2	5	12	47	20-30X	X	
P	2	6	18	70	248	110X	tips
G	2	5	9	26	65	X	
W	2	5	12	41	139	50X	X

	VI-23	VI-30	VII-7	VII-14
B-1	1	X		
B-2	1	X		
GA-1	1	4	1X	X
GA-2	1	5	X	
YA-1	2	8	X	
RA-1	1	X		
PA-1	1	X		
WA-1	5	X		
WA-2	6	X		
BA-1		6	X	
BA-2		3	X	

TABLE 32. Growth data for each marked colony of Plumatella repens at Station 12, Wintergreen Lake, Kalamazoo Co., 1960. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.									
	IV-29	V-6	V-13	V-20	V-27	VI-7	VI-14	VI-23	VI-30	VII-7	VII-14
R-1	1	2	7	23	76	420	1200*	X			
R-2	1	3	8	20	68	463	225X	X			
B-1	1	2	4	21	60	15X	X				
B-2	1	2	6	17	53	306	962	210X	X		
P-1	1	3	8	28	69	365	695	300X	X		
P-2	1	2	7	25	64	288	110X	28X	X		
G-1						17	X				
R-1								1	X		
R-2								6	7	5	X
R-3								1	X		
R-4								1	X		
Y-1								3	X		
Y-2								8	9	X	
Y-3								4	X		
Y-4								2	X		
W-1								2	3	4	X
W-2								6	4	X	

TABLE 33. Growth data for each marked colony of Plumatella repens at Station 13, Wintergreen Lake, Kalamazoo Co., 1960.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.					
	IV-29	V-6	V-13	V-20	V-27	VI-7
B-1	2	6	6	18	20	***
B-2	1	2	10	3X	X	***
R-1	1	2	7	12	10	***
R-2	1	3	X			***
P-1	1	2	X			***
P-2	1	2	6	31	42	***

TABLE 34. Growth data for each marked colony of Plumatella repens at Station 13B, Wintergreen Lake, Kalamazoo Co., 1960. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.					
	VI-23	VI-30	VII-7	VII-14	VII-21	VII-28
R-1	1	2	X			
R-2	1	2	3	10	7X	
R-3	1	2	4	14	8X	
R-4	1	2	2	X		
Y-1	2	X				
Y-2	1	2	X			
P-1	2	5	10	38	tips	
P-2	3	5	8	29	32X	
P-3	20	62	6X	X		
P-4	5	20	X			
Y-3		2	3	X		
Y-4		1	X			
W-1		1	2	X		
W-2		2	X			
G-1		1	2	X		
G-2		3	2	5	X	
G-3		2	3	X		
G-4		1	2	7	4X	X

TABLE 35. Growth data for each marked colony of Plumatella repens at Station 14, Wintergreen Lake, Kalamazoo Co., 1960.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.		
	IV-29	V-6	V-13
Y	1	3	X
B	1	3	X
G	1	3	X
W	1	3	X

TABLE 36. Growth data for each marked colony of Plumatella repens at Station 15, Wintergreen Lake, Kalamazoo Co., 1960. See legend opposite Table 1 for explanation of symbols.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.						
	IV-29	V-6	V-13	V-20	V-27	VI-7	VI-14
B-1	1	2	7	32	112	17X	X
W-1	2	3	4	X			
P-1	1	3	13	54	PG	X	

TABLE 37. Growth data for each marked colony of Plumatella repens at Station 16, Wintergreen Lake, Kalamazoo Co., 1960.

Individual colony symbol	No. of polypides in each colony from time of first observation to final observation. Months are indicated by Roman numerals.								
	IV-29	V-6	V-13	V-20	V-27	VI-7	VI-14	VI-23	VI-30
Y-1	1	2	5	22	69	376	505pg	X	
Y-2	1	2	8	25	62	312	720	tips	X
Y-3	1	3	8	23	56	265	X		
G-1	1	2	7	20	63	X			
G-2	1	2	6	13	44	60X	X		
G-3	1	2	6	17	X				
G-4	1	2	X						
P-1	1	3	7	22	49	X			
P-2	1	2	9	18	53	327	X		
P-3	1	2	5	16	51	235	65X	X	

TABLE 38. Longevity data for each marked polypide of Plumatella repens at designated stations on Burke Lake, Clinton County, 1959.

Station number	Polypide symbols	No. of live polypides from date of marking to final observation. Months are indicated by Roman numerals.												
		V-31	VI-6	VI-14	VI-20	VII-2	VII-9	VII-21	VII-28	VIII-7	VIII-15	VIII-24	IX-5	IX-21
3	BGWYRP	6	6	6	1	1	X	log						
	BR			3	1	X		on						
	G				3	3	3	dry						
	R					13	4	land						
	P					2	1							
4	R					11	3	2	1	1	1	1	X	
	P					2	2	2	1	1	X			
	P-G					2	X							
	G					2	1	1	X					
	Y					2	CX							
	YY									5	4	3	1	log
	W										2	2	2	on dry
	WY										5	5	2	land
5	PGB	3	3	3	2	2	1	X						
	RTW	3	3	3	2	CX								
	W			4	2	CX								
	R					10	6	6	4	4	3	1	X	
	RB					2	2	1	X					
	B							8	4	3	1	1	X	
	Y								4	4	2	1	1	
	P								1	X				
	BB								2	1	CX			
6	RB	6	5	4	2	1	X							
	BGY	3	3	2	2	1	X							
7	G		3	3	3	2	1	X						
	R		5	5	4	3	1	X						
9	R			2	2	1	1	X						
	P			3	3	1	X							
	Y			10	9	5	5	1	X					
	RR					10	6	1	X					
	G						2	1	1	X				
	B							2	2	1	1	X		
	W							5	4	3	3	1	X	

TABLE 39. Longevity data for each marked polypide of Plumatella repens at designated station, Burke Lake, Clinton Co., 1959.

Station number	Polypide symbols	No. of live polypides from date of marking to final observation. Months are indicated by Roman numerals.											
		VIII-15	VIII-24	IX-5	IX-21	IX-29	X-10	X-20	X-29	XI-7	XI-15	XI-22	XI-29
5	G	8	8	5	5	4	2	X					
	WW	4	4	2	X								
	YY			5	5	4	2	1	CX				
	PP			2	CX								
	GG					5	4	4	2	1	X		
	PPP							9	7	7	2	2	X
	PR							7	7	2	X		
	BBB							2	2	1	X		
8	B							2	2	1	1	CX	
	G							1	1	1	1	X	
	Y							1	1	1	X		
	W							1	CX				
	R							3	3	CX			
	P							1	1	1	1	1	X

TABLE 40. Longevity data for each marked polypide of Plumatella repens at designated station, Burke Lake, Clinton Co., 1960.

Station number	Polypide symbols	No. of live polypides from date of marking to final observation. Months are indicated by Roman numerals.												
		IV-27	V-1	V-8	V-15	V-22	V-29	VI-5	VI-12	VI-19	VI-26	VII-2	VII-9	VII-16
1	R-1	1	1	1	XX									
	R-2	1	1	1	1	XX								
	R-3	1	1	1	1	1	XX							
	R-4	1	1	1	1	X	XX							
	R-5	1	1	1	1	XX								
	R-6	1	1	XX										
	Y-1	1	1	1	1	XX								
	Y-2	1	1	1	XX									
	G-1	1	1	1	XX									
	G-2	1	1	1	XX									
2	P			6	6	XX								
3	W							8	4	4	2	2	1	X
4	B	10	10	10	6	4	3	1	X					
	R	8	8	7	7	5	2	X						
	W							6	3	3	2	1	X	
5	R								4	XX				
7	Y			6	6	4	4	4	3	1	1	X		
	R				8	8	8	5	4	2	X			
	B								4	2	2	2	2	X
8	Y							7	5	4	3	2	1	X
10	R	2	2	XX										
	P		2	2	1	1	1	X						
13	P			6	5	XX								

TABLE 41. Longevity data for each marked polypide of Plumatella repens at designated stations, Wintergreen Lake, Kalamazoo Co., 1959.

Station number	Polypide symbols	No. of live polypides from date of marking to final observation. Months are indicated by Roman numerals.				
		VI-5	VI-17	VI-27	VII-4	VII-24
3	4W	4	3	3	1	X
	4Y	4	2	1	X	
6	BB-RR-WW	3	1	X		
7	RYGP	4	2	2	2	X
8	4G	5	4	2	2	X
	4Y	4	4	3	1	X
9	P	2	1	X		
	R	2	2	1	X	
	W	4	4	1	X	
10	R	2	2	2	X	
	P	4	2	2	1	X

TABLE 42. Longevity data for each marked polypide of Plumatella repens at designated station, Wintergreen Lake, Kalamazoo Co., 1960.

Station number	Polypide symbols	No. of live polypides from date of marking to final observation. Months are indicated by Roman numerals.									
		IV-29	V-6	V-13	V-20	V-27	VI-7	VI-14	VI-23	VI-30	VII-7
1	R	6	3	2	2	2	X				
5	G	8	7	7	1	X					
7	G					6	1	1	1	1	X
8	P		4	3	3	3	X				
	W			4	4	4	X				
	PP					10	2	X			
9	P			8	6	6	X				
14	R		2	1	1	1	X				
15	R	3	3	3	3	3	2	X			

Table 43. Water temperatures taken at Wintergreen Lake and Burke Lake on the date when data were collected.

Wintergreen Lake, Kalamazoo Co., 1960

IV-29	V-6	V-13	V-20	V-27	VI-7	VI-14	VI-23	VI-30	VII-7	VII-14
17° C.	16° C.	14° C.	24° C.	21° C.	24° C.	28°C.	29° C.	28° C.	29.5° C.	30° C.

Burke Lake, Clinton Co., 1959

V-21	VI-6	VI-14	VI-20	VII-2	VII-9	VII-21	VII-28	VIII-7	VIII-15	VIII-24
24° C.	26° C.	28° C.	28° C.	29.2° C.	29°C.	31.5°C.	30.5°C.	31°C.	29.5°C.	31.5°C.

IX-5	IX-21	IX-29	X-10	X-20	X-29	XI-7	XI-15	XI-22	XI-29	XII-6
30° C.	26° C.	22° C.	17° C.	15° C.	12.5°C	8.5°C.	8 °C.	6.5°C.	5.5°C.	4.5°C.

Burke Lake, Clinton Co., 1960

IV-27	V-1	V-8	V-15	V-22	V-29	VI-5	VI-12	VI-19
17.6°C.	14.5°C.	15°C.	18°C.	20.5°C.	28° C.	26.5°C.	26° C.	28.5°C.

VI-26	VII-2	VII-9	VII-16
28°C.	28.5°C.	29° C.	30° C.

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