This is to certify that the

thesis entitled

SOME ASPECTS OF THE ECOLOGY OF THE NEWT,
NOTOPHTHALMUS VIRIDESCENS RAFINESQUE
IN NORTHERN MICHIGAN

presented by

Dean Barrette Premo

has been accepted towards fulfillment
of the requirements for

Masters degree in Science

Marvin M. Hensley
Major professor

Date 11/10/80

SOME ASPECTS OF THE ECOLOGY OF THE NEWT,

NOTOPHTHALMUS VIRIDESCENS RAFINESQUE IN NORTHERN MICHIGAN

By

Dean Barrette Premo

A THESIS

Submitted to

Michigan State University

in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

Department of Zoology

1980

ABSTRACT

SOME ASPECTS OF THE ECOLOGY OF THE NEWT,

NOTOPHTHALMUS VIRIDESCENS RAFINESQUE IN NORTHERN MICHIGAN

By

Dean Barrette Premo

Notophthalmus viridescens Rafinesque was studied in Gibson Lake, Iron County, Michigan. Objectives were to determine subspecies present, chronology of life stages, population size, food habits, potential competitors, home range, distribution within the lake, and nocturnal behavior.

Water temperature, air temperature and water level were recorded daily. Terrestrial and aquatic drift fences monitored newts. Stomach contents were obtained by flushing. Home range was studied using a grid system. Measurements from quadrats were analyzed with factor analysis. Newts were followed to study nocturnal behavior.

Adults occurred in the lake during summer, but migrated to land during fall. Larval metamorphoses occurred over 4 to 6 days. Newts selected prey according to availability. Perca flavescens diet overlapped newt diet. Mean home range was 2.4 m^2. Newts were restricted to littoral zone habitat. Larval habitat significantly differed from adult habitat. Depth, vegetation, and presence of a log were important in defining adult habitat. Nocturnal foraging range was restricted.

ACKNOWLEDGMENTS

I wish to thank the members of my guidance committee: Dr. Marvin M. Hensley and Dr. J. Alan Holman, Department of Zoology, and Dr. Peter G. Murphy, Department of Botany and Plant Pathology, for their conscientious assistance in the development of my research project and this manuscript.

John Matson spent many hours instructing me in the use and interpretation of factor analysis.

To Annette Jarvi, I express sincere appreciation for allowing me access to her property on Gibson Lake. Ann's interest in my project, and natural history in general, gave me inspiration throughout this study.

My Parents, Claude and Jean Premo, have provided tremendous encouragement since the time I collected by first newt many years ago.

My wife, Bette, deserves special credit for the many hours of field work and constructive criticism she offered.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

INTRODUCTION

The newt, Notophthalmus viridescens, has been studied in many geographic locations in eastern North America. The species displays great variation in life history throughout its range and consequently has intrigued scientists. The population investigated in this study is in the Upper Peninsula of Michigan and to my knowledge this species has not been studied in a location of greater latitude. Table 1 presents geographic locations where the newt has been studied by other workers.

One objective of this study was to characterize some of the physical aspects of Gibson Lake habitat. Measurements of air and water temperature and water level fluctuation were recorded. A second objective was to measure total length, snout-vent length and spotting characteristics of newts and determine the subspecies of Notophthalmus viridescens present.

Aspects of newt life history were identified and compared to other newt population studies in the eastern United States. The chronology of Gibson Lake newt life stages was examined. Population size was studied and the sex ratio determined. Food preference of adult newt was characterized and compared to the food habits of potential fish competitors. Home range of the newt has not been extensively examined by other workers, and was characterized for the Gibson Lake

Table 1. Geographic locations of studied populations of *Notophthalmus viridescens*

Location	Latitude	Longitude	Elevation	Author
Highlands, North Carolina	N35°00′	W83°	4,000 ft.	Chadwick, 1944
Raleigh, North Carolina	N35°30′	W78°45′		Brimley, 1921
Virginia	N38°	W79°		Wood and Goodwin, 1954
Rockingham, Virginia	N38°35′	W79°	3,600 ft.	Gill, 1978
Centre Co., Pennsylvania	N40°45′	W77°45′		Bellis, 1968
Sandy Lake, New Hampshire	N42°	W72°		Bennett, 1970
Sunderland, Massachusetts	N42°30′	W72°30′		Smith, 1920 Stein, 1938
Massachusetts	N42°30′	W72°		Healy, 1970 Jordan, 1893
Dryden, New York	N43°	W76°		Hurlbert, 1968
Grafton Co., New Hampshire	N44°00′	W71°30′		Burton, 1977
Manchester, Maine	N44°30′	W69°30′		Pope, 1921
Gibson Lake, Michigan	N46°12′	W88°27′	1,452 ft.	Premo

population. Adult and larval newt distribution in Gibson Lake was studied and their preferred habitat described. Similar work has been performed by Bennett (1970) and Burton (1977). The final objective was to study the nocturnal foraging habits of Gibson Lake newts. This animal is very active in the nocturnal environment and reports on this activity are absent from the literature. Field work was conducted during the summer seasons of 1978-1980.

Taxonomy and Species Description

Conant (1975) recognizes four subspecies of *Notophthalmus viridescens*, the Peninsula newt (*N.v. piarapicola*), the Broken-striped newt (*N.v. dorsalis*), the Central newt (*N.v. louisianensis*) and the Red-spotted newt (*N.v. viridescens*). The range of the latter two races contact in central and northern Michigan (Conant, 1975; Johnson, 1965).

The Red-spotted newt (*N.v. viridescens*) is characterized by having a yellow venter and black-bordered red spots on the olive green dorsum (Ruthven, et al., 1928). Conant (1975) gives the range of *N.v. viridescens* as the Maritime Provinces to the Great Lakes and south to central Georgia and Alabama.

The Central newt (*N.v. louisianensis*) is normally without red spots or has small red spots without black borders. Conant (1975) gives the range of the Central newt as Lake Superior Region to east Texas and east to southern South Carolina.

The population under investigation in this study was composed of *N. v. louisianensis*.

Natural History

Notophthalmus viridescens has an interesting and complicated life cycle which has been investigated and debated by scientists for more than 100 years. Mating behavior has been reported to occur in both spring and fall, although eggs are apparently laid only in the spring (Gage, 1891; Jordan, 1893). Mating behavior involves courtship between a single female and male (Jordan, 1891). The male uses his hind legs to clasp the female. The black horny excrescences on the hind legs may act as friction surfaces to aid in this clasping. After elaborate courtship behaviors, the male releases the female and walks off along the substrate and deposits a spermatophore. The female walks over this spermatophore and picks up the packet of sperm with the lips of her cloaca. Fertilization is internal.

Eggs are usually laid individually in the axils of aquatic plant leaves (Pope, 1924). Oviposition occurs during a period of about seven weeks in the spring (Jordan, 1893). Hatching occurs in about 20-35 days depending on temperature (Bishop, 1941). After two to three months of aquatic development, the larvae metamorphose into a terrestrial stage called the "eft". This transformation involves loss of external gills, dorsal keel, and tail fins (Bishop, 1941). At this time the skin becomes rough and respiration becomes pulmonary (Chadwick, 1950). Smith (1920) states that duration of metamorphosis is brief, lasting only a few days in mid-September, but Gill (1978) observed a prolonged period of larval metamorphosis lasting 3-½ months.

Controversy has revolved around the observation by some workers (Healy, 1966; Noble, 1926, 1929; Jordan, 1893) of neotenous populations and possible omission of the eft stage. Pope (1928) argued that these observations were erroneous, but Healy (1970, 1973, 1974) firmly established the existence of neotenous populations.

The length of the terrestrial eft stage also shows variation. Gage (1891) states that efts transform to adults at the age of 2½ to 3 years. Chadwick (1944) believes the eft stage lasts 3-4 years.

Transforming efts migrate to water during the fall in most locations. In some areas the efts may migrate by the thousands during this fall period (Stein, 1938). Hurlbert (1968) reports a spring migration of efts to water. In other areas efts, although present, are rarely observed and do not move en masse (Pope, 1921, 1924).

Upon transformation into the adult, the animal takes on a more olive-green or viridescent coloration (Gage, 1891) and normally spends the rest of its life in permanent bodies of water. Morgan and Grierson (1932) reported that newts in Massachusetts actively feed all winter long in the aquatic habitat. Deviations from this normal pattern have been observed. Brimley (1921) reports that in Raleigh, North Carolina, adult newts do not stay in the water during the summer, but leave sometime during spring and enter again in November. Hurlbert (1969) reports that adults move between the terrestrial and aquatic habitat throughout the summer. Ruthven et al. (1928) suggest that under unusual circumstances adults may go to land and Gill (1978) observed adults in the Shenandoah mountains emmigrate from ponds to terrestrial hibernacula during August and September.

Adult newts surface periodically to gulp air into the lungs. However, the integument of aquatic adults is well vascularized and they are able to respire via skin in well oxygenated water (Moore, 1964).

Adult newts are opportunistic in their feeding habits, although some items are avoided. Pike (1886) suggested they eat mollusks, tadpoles, fish, aquatic insects, and some vegetation. Hamilton (1932) reported newts change their feeding habits in response to what organisms are most abundant at the time and noted that stomach contents included fairy shrimp, mosquito larvae, Ambystoma eggs, Asellus, Cyclops, midge larvae, small snails, cast newt skins, Rana sylvatica eggs, leeches, caddis worms, small water beetles and scuds. Wood and Goodwin (1954) state that newts eat snails, pill clams, ostracods, and amphibian eggs (including their own). Morgan and Grierson (1932) show dipteran larvae to be very numerous in newt stomachs and Ephemeroptera, Coleoptera, Hemiptera, Trichoptera, and Odonata were also of importance. Behre (1953) observed quantities of fingernail clams (Family Sphaeriidae) in stomach contents of newts.

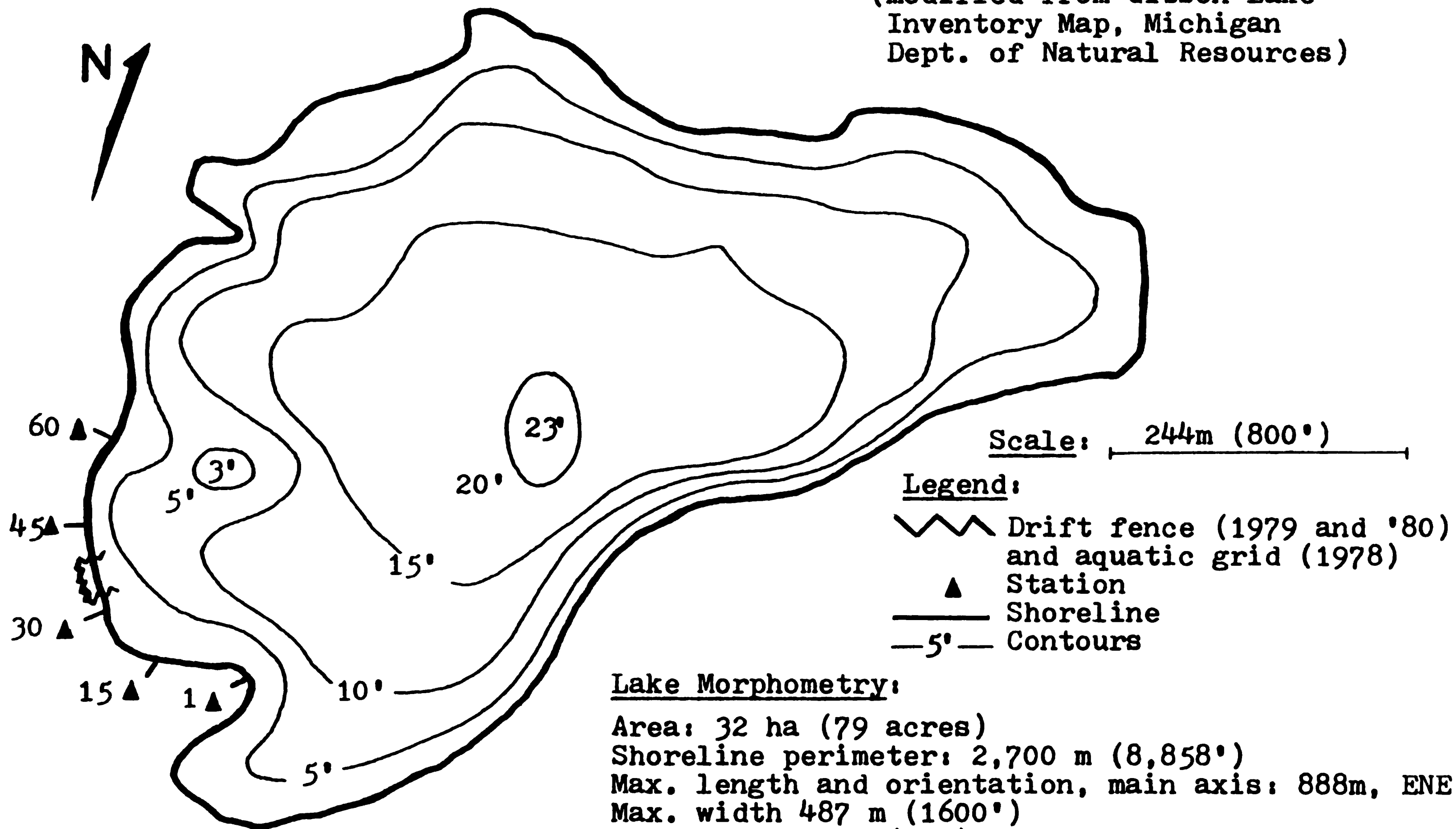
The eft and adult newts have highly potent skin toxins. Both life stages have relatively few predators. Brodie (1968) has shown the eft stage to be more toxic than the adult. Webster (1960) has shown Brook trout are killed if force fed newts, but Bennett (1970) cites two instances of partially digested adult newts taken from the stomach contents of healthy Brook trout.

Description of Study Area

Field work was conducted along 300 m of the western shore of Gibson Lake. Gibson Lake is 2.5 miles south of Amasa, Michigan, in Crystal Falls Township, Iron County (T44N, R33W, Section 21 N½). Gibson Lake is situated N46°12' latitude at an elevation of 443 meters (1452 feet). It has a surface area of 32 ha (79 acres) and a maximum depth of 7 meters (23 feet). Figure 1 presents a morphometric map of Gibson Lake. There is no inlet or outlet and the water level fluctuates from year to year. Two small patches of *Chamaedaphne sp*. bog, each of approximately 0.4 ha (1 acre), occur at the north and south ends of the lake. Fish species present include Yellow perch (*Perca flavescens*), Sunfish (*Lepomis gibbosus*), Golden shiners (*Notemigonus crysoleucas*), Smallmouth black bass (*Micropterus dolomieui*) and Northern pike (*Esox lucius*). *Notophthalmus viridescens* is the only salamander species in the lake.

The north side of Gibson Lake is bordered by cultivated fields and the remainder of the lake's perimeter is largely wooded. The western shore of the lake is closely bordered by mature hardwoods. The surrounding terrain is characterized by undulating to hilly soils formed from acid, stony loams, loams and silt loams (Johnson, 1965). Gibson Lake contains clear soft water with sufficient depth to prevent winter kill. There is very little water temperature stratification during the months of July and August.

(modified from Gibson Lake
Inventory Map, Michigan
Dept. of Natural Resources)



Lake Morphometry:

Area: 32 ha (79 acres)
Shoreline perimeter: 2,700 m (8,858')
Max. length and orientation, main axis: 888m, ENE
Max. width 487 m (1600')
Max. depth: 7 m (23')
Elevation: 443 m (1,452')

Figure 1. Morphometric Map of Gibson Lake

METHODS AND MATERIALS

Physical Measurements

Daily air temperature and water temperature at 25 cm depth were recorded at the study site. A 2 by 2 inch hardwood stake with centimeter graduations was driven into the lake bottom to determine water level changes.

Drift Fences and Aquatic Traps

In order to capture newts and determine the chronology of various life stage events, terrestrial drift fences with pitfall traps and an aquatic drift fence with funnel traps were constructed during the 1979 and 1980 seasons. The terrestrial drift fence was of the type described by Gibbons and Bennett (1974). Thirty meters of 20-inch screen fencing were embedded 8 cm in the soil three to five meters from the shoreline. One by two inch pine stakes supported the fence. Twelve metal cans were used as pitfall traps, and placed six meters apart on either side of the fence. Each can had a 15 cm diameter and 17 cm depth. Can volume was three liters. Approximately 5 cm of water was kept in each can to moisten captive animals. Each pitfall trap was numbered to facilitate record keeping.

Two aquatic drift fences were positioned perpendicular to the shoreline on each end of the terrestrial drift fence. Screen of appropriate dimension was used so that at least 10 cm extended above the water surface preventing newts from swimming over the top. Each aquatic drift fence was constructed from three meters of 20-inch screen, two meters of 24-inch screen and two meters of 36-inch screen. One by two inch pine stakes supported the screen fence and the bottom of the fence was buried in the substrate about 15 cm. Each aquatic drift fence extended six meters from shore, 3-4 meters beyond the extent of submerged vegetation. The maximum depth at the distal end of each aquatic fence was 80 cm. Newts were never collected or observed in Gibson Lake at depths greater than 30 cm where submerged vegetation was sparse and most newts were captured in water under 20 centimeters depth, effectively making this open ended system of terrestrial and aquatic fences an enclosure.

Four aquatic newt traps (described below) were inserted into openings in the drift fence at the level of the substrate. This was designed so that a newt would enocunter the drift fence and walk along it until it moved into the funnel of a trap and was captured. Terrestrial and aquatic drift fences were checked once daily between 0600 and 1000 hours.

While developing aquatic trapping methods, it was discovered that adult newts could survive prolonged submergence in water if suspended in a mesh cage. Water with 5 mg dissolved oxygen per liter at 21°C supported individual newts for 36 hours with no observable detrimental effects. This simplified construction of aquatic newt traps since no provision allowing newts to surface for air was necessary. Newt traps were constructed from one-half of commercial double funnel minnow traps modified by sealing the open end with mesh hardware cloth. A flap door was provided in the sealed end of each trap for removal of trap contents. Each trap was inserted into appropriately sized holes cut in the aquatic drift fence so that the funnel end of the trap was flush with the drift fence. Trap holes in the drift fence were reinforced with a small wooden frame to which the screen was stapled and this frame was anchored to the substrate with wooden stakes. Newt traps could be easily removed for checking. Efford and Mathias (1969) used minnow traps to trap newts (*Taricha granulosa*) and larval Mole salamanders (*Ambystoma gracile*) in British Columbia and Bell (1977) used funnel traps to sample aquatic populations of the Smooth newt (*Triturus vulgaris*) in southeastern England. As far as I am aware, my system of placing funnel traps into an aquatic drift fence has not been used.

Collection Techniques, Marking and Measurements

The 300 meters of Gibson Lake shoreline designated as the study site were bounded by stations 1 and 60 (Figure 1) and included the terrestrial and aquatic drift fence. Sixty stations were established, one every 5 meters along the shoreline. Numbered stakes marked each station. Stations were used to specifically locate newts or areas of habitat. Six regions of distance from shore were arbitrarily established such that region 1 was 0-1 meters from shore, region 2 was 1-2 meters from shore, ..., region 6 was 5-6 meters from shore. Individual newt location was recorded by noting the station number and a distance from shore region.

Newt larvae were collected by dipnetting large amounts of bottom debris and sorting through this sediment with a forceps. The total lengths of newt larvae were recorded.

Adult newts captured by the drift fence system or by hand were individually marked using a toe-clip system adapted from Martof (1953). Newts have four toes on the front feet and five on the hind feet and this coding system utilized three toes from each foot. The middle three toes on the left rear foot were numbered 1, 2, and 3, and the middle three toes on the right hind food were numbered 4, 5, and 10. The outside three toes on the left forefoot were numbered 20, 30, and 40 and the outside three toes on the right fore foot were numbered 100, 200, and 400. Toe-clip combinations allowed the consecutive designation of 799 individuals. Because of the regenerative capabilities of newts, toe-clipping was not reliable from one season to the next, but was sufficient during a single season.

The benthos of the sublittoral zone of Gibson Lake was periodically inspected for aquatic adult newts by using SCUBA.

The adjacent woodland was monitored for terrestrial efts throughout this study.

Adult newt total length, snout-vent length, and the number of red spots between fore and hind limbs (1979 only) were recorded and the precise capture location was identified.

Sex was determined by a combination of characters. Secondary sexual characteristics distinguish the sexes during June and part of July. Males have hypertrophied cloacal lips and black horny excresences lining the inner thighs. During the breeding season the tail of males is heavily finned. The breeding morphological characters of the male have been described by Gage (1891). Other sex-specific characters include the presence of small facial pits in males (Bishop,

1941) and the black spots on the male's tail that are larger and more diffuse than the well defined small black spots on females' tails.

Several nearby bodies of water were surveyed for the presence of newts over the 1979 and 1980 seasons. Gilbert Lake (T44N, R33W, Sec. 15 and 22), Fire Lake (T44N, R33W, Sec. 19, 20, and 29) and beaver ponds on Fire Lake Creek (T44N, R33W, Sec. 29 and 32) were searched by dipnet, seine, and inspection.

Food Habits and Potential Competitors

To determine newt feeding habits stomach contents were obtained by a stomach flushing method described by Fraser (1976). A 3 cc syringe and 20 gauge hypodermic needle fitted with a 100 mm piece of plastic coating from radio wire with outside diameter of 1.5 mm were used. A bevel cut on the plastic tubing facilitated insertion of the tube into the newt's mouth and down the gullet into the stomach. Injection of approximately 1.5 cc of water initiated regurgitation of food items. Stomach contents were preserved in 95% ethanol for subsequent identification. Newts treated by this method were observed for 72 hours with no ill effects being noted. The efficiency of this method for obtaining complete gut contents is not known. Preliminary use and experiment suggested that use for identification and determination of relative numbers of food items was possible with newts. Fraser (1976) has performed precise quantitative food analyses on *Plethodon cinereus* and *Plethodon hoffmani* using this stomach flushing technique.

In order to compare newt stomach contents to available food in Gibson Lake, five microfauna samples were collected with a plankton net from the feeding areas of foraging newts. The benthic faunal component was not adequately sampled by this method. Specimens were preserved in 95% ethanol and later identified in lab. Pennak (1953) and Merritt and Cummins (1978) were used to identify stomach contents and lake microfauna.

During the 1980 season Sunfish (Lepomis gibbosus), Yellow perch (Perca flavescens), and Golden shiners (Notemigonus crysoleucas) were collected from the littoral zone habitat where newt larvae existed. Fish were collected with minnow traps and hook and line. Fish stomach contents were placed in 95% ethanol for subsequent identification. This data was recorded to determine what overlap occurred in the feeding habits of these fish species and newts and the extent of fish predation of newt larvae.

Diurnal Home Range

In July and August, 1978, Gibson Lake newts were studied to determine their individual home ranges.

A one hundred-square meter grid was constructed on the western shore of Gibson Lake. This grid ran 25 meters along the shoreline and extended four meters out into the lake. Five strings, each 25 m in length were stretched between wooden stakes establishing four one meter wide corridors. Surveying ribbon was tied every meter along these five strings marking off 100 square meters within this grid. This provided a way to accurately locate newts, vegetation, logs, and other components of the substrate. Figure 2 shows the relative location of the aquatic grid.

To determine newt movements, this grid was checked every 2 to 3 days by walking down each of the four corridors and carefully searching for newts. Newts were collected by hand without the use of a seine or net so that the habitat was minimally disturbed. Care was taken not to uproot aquatic macrophytes or change the position of logs and other debris on the substrate.

The location of each newt was determined by noting the corridor and grid number in which it was found. Further accuracy was achieved by visually dividing each square meter into nine sectors. For example, if a newt's location was recorded as B-4-9, it was located in corridor "B", grid number 4, and sector 9 within the square meter.

Upon first collection, newts were toe-clipped and total length and snout-vent length were recorded. In addition, date, air temperature, water temperature, time of day, water depth, weather conditions, and location were recorded.

Distribution Within the Lake

In the 1978 season, the four most frequently used newt homesites were examined in order to characterize this microhabitat. Log characteristics, mean water depth, vegetation, and mean water temperature were calculated from field data.

Two questions prompted further measurement of microhabitat characteristics in 1979: (1) are adult and larval newts selecting a specific microhabitat in which to reside? (2) and if so, to what factors do newts attend in selection of that habitat?

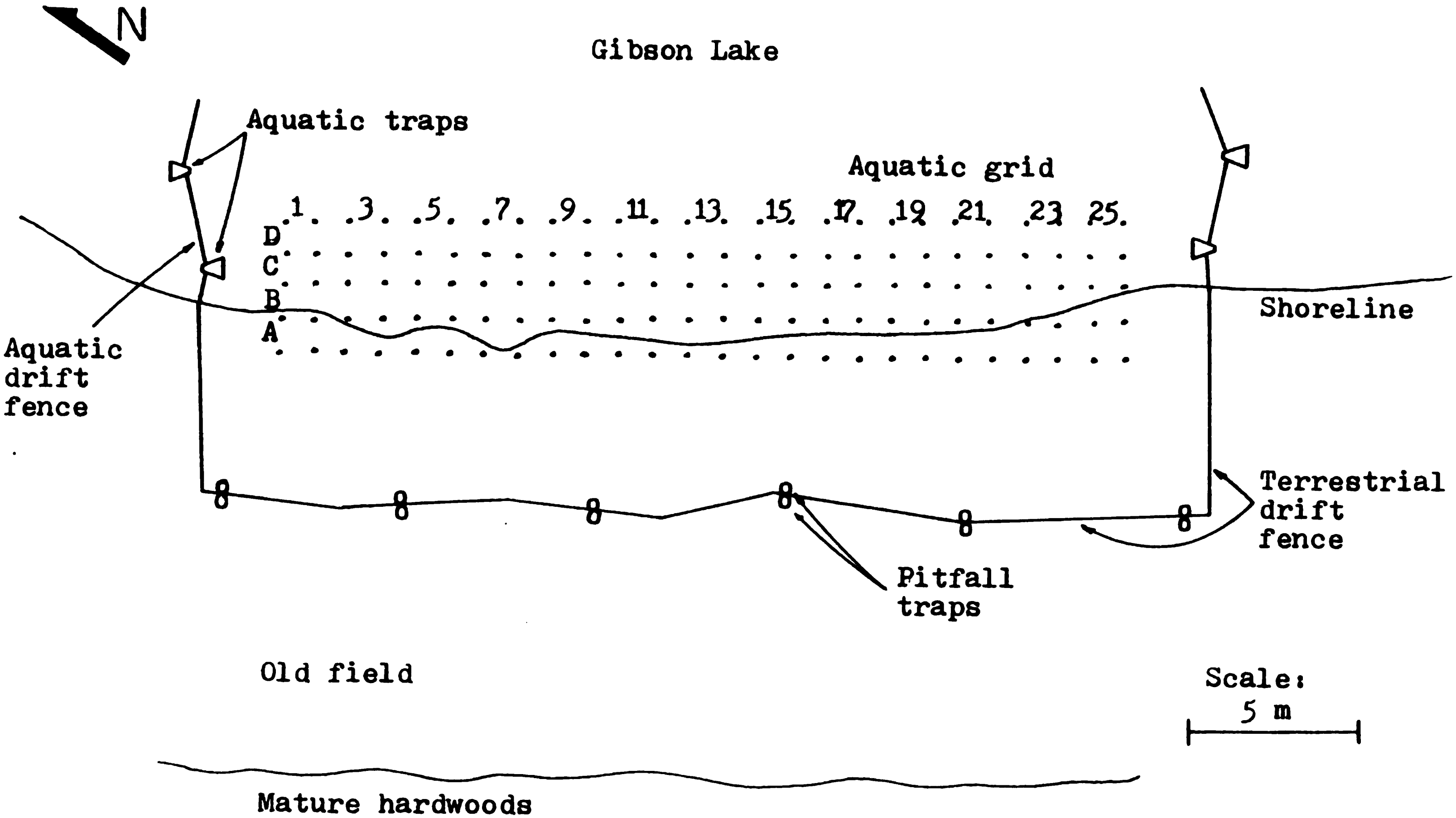


Figure 2. Relative location of aquatic grid, terrestrial drift fence, and aquatic drift fence in the Gibson Lake study area.

The following measurements were taken from 4 m^2 quadrats in the Gibson Lake habitat: mean water depth, percent of substrate obscured from view by vegetation, plant species present, number of plant stem contacts on a fifty centimeter metal rod randomly dropped from the center of the plot (a measure of plant density), and relative percent by number of each plant species present.

The following five microhabitat types were measured: (1) all places where adult newts were found more than once, (2) all places where newt larvae were found, (3) logs where adult newts were never found, (4) areas where newt larvae were not found, and (5) quadrats selected randomly as described below.

Fifteen habitats from the lake's littoral zone were randomly selected by taking combinations of stations 1-60 and regions 1-6. For example, a combination of station 17 and region 3 meant a quadrat would be located 2-3 meters from shore at station 17. A random numbers table (Brower and Zar, 1977) was used to make selections of combinations.

To determine distribution and habitat preference for newt larvae, eleven areas within stations 1-60 were systematically dipnetted. Dipnetting was restricted to a 2 by 2 meter quadrat. Quadrats where larvae were found were studied in terms of the same characteristics measured for adult newt habitat.

A computer procedure called Factor Analysis was applied to the data collected from adult newt habitat to determine what factors were important in describing newt habitat. This computer program was taken from SPSS (Statistical Packages for the Social Sciences).

Nocturnal Behavior

Reports on nocturnal movements of Notophthalmus viridescens are absent from the literature, possibly because the task of observing small foraging nocturnal animals presents some methodological difficulties. In 1978 and 1979, the nocturnal aspect of newt behavior was investigated.

In 1978, preliminary nocturnal observations were made to approximately determine the temporal and spatial range of the newt's nocturnal movements.

In 1979, greater effort was applied to determine precise nocturnal movements and behavior. The foremost consideration was to follow and observe individuals, but not disturb them or disrupt their normal activity patterns.

Initially newts were marked for nocturnal observation with a luminescent vinyl material produced by Canrad-Hanovia, Inc. The vinyl's adhesive quality allowed construction of small collars 0.5 cm wide which were placed directly in front of the newt's hind limbs. This method was abandoned because it became evident that newts would not tolerate this collar.

A second attempt at marking newts with luminescent vinyl involved suturing 3 by 8 mm strips into the tough skin of the dorsal tail fin caudad to the cloaca. Wild individuals in lab aquaria accommodated these tags, however, when tagged newts were introduced into aquaria containing Gibson Lake aquatic macrophytes, four of nine became entangled by the tag in the vegetation and died, apparently by drowning. This seems inconsistent with newts' ability to withstand submergence, but struggling by entangled newts may have increased their oxygen demand, requiring them to surface for more air. This tagging technique was also abandoned.

Based on nocturnal observations performed in 1978 and preliminary observations in 1979, it was determined that a dim flashlight attached to a headband could be used to observe newt movement. It was not necessary to use the flashlight continuously since newts were often stationary for several minutes at a time. This method did not apparently disturb or frighten newts. They continued feeding while being observed and did not swim away from the observer or the light. It was possible to stand in one place for as long as two hours observing a foraging newt. Field notes were delivered into a cassette tape recorder. Numbered flags were periodically placed marking the perimeter of the area used by a foraging newt. The following day, the foraging area's shape, size, distance from shore, and depth were measured. Percentage of substrate obscured by vegetation was estimated and vegetation type identified. Substrate type was determined as sand or mud.

Search for an observation subject began at 2000 hours. Newts were under cover of logs and debris at this time. This search for a newt was often unsuccessful. Observation commenced when a newt was located. An observation subject was followed until it was determined that it was continually moving within a restricted area. To determine when nocturnal activities ceased, searching for foraging newts as well as newts that had returned to cover commenced at 0300 hours.

Observations on foraging behavior, location of foraging, number of seconds elapsed between surfacing for air, amount of time spent stationary and substrate type were recorded.

RESULTS AND DISCUSSION

Characteristics of the Lake

Air and water temperature and water level were monitored to characterize these aspects of the newts' physical environment.

Figure 3 presents ten-day mean air temperatures and water temperatures (at 25 cm depth) taken in the study area over the 1979 and 1980 seasons. As can be seen from the length of confidence bars, air temperature shows greater daily variation then water temperature. During the summer months neither air or water temperatures show sharp changes.

Table 2 presents mean air and water temperatures and 95% confidence intervals for 1979 and 1980 seasons. No significant difference exists between these two seasons.

Figure 4 presents the water level fluctuations in Gibson Lake from 1978 through 1980 seasons. The range of water level change was 58 cm. The lowest water level was on 5 August, 1978, and the highest water level was on 8 June, 1980.

Because of the yearly fluctuations in water level, the characteristics and composition of the shoreline also change from year to year. Especially sensitive to this fluctuation is the amount of emergent vegetation in the shallow water within approximately one meter of shore. In years of high water there is much dead plant material along the edge of the lake and emergent vegetation is very

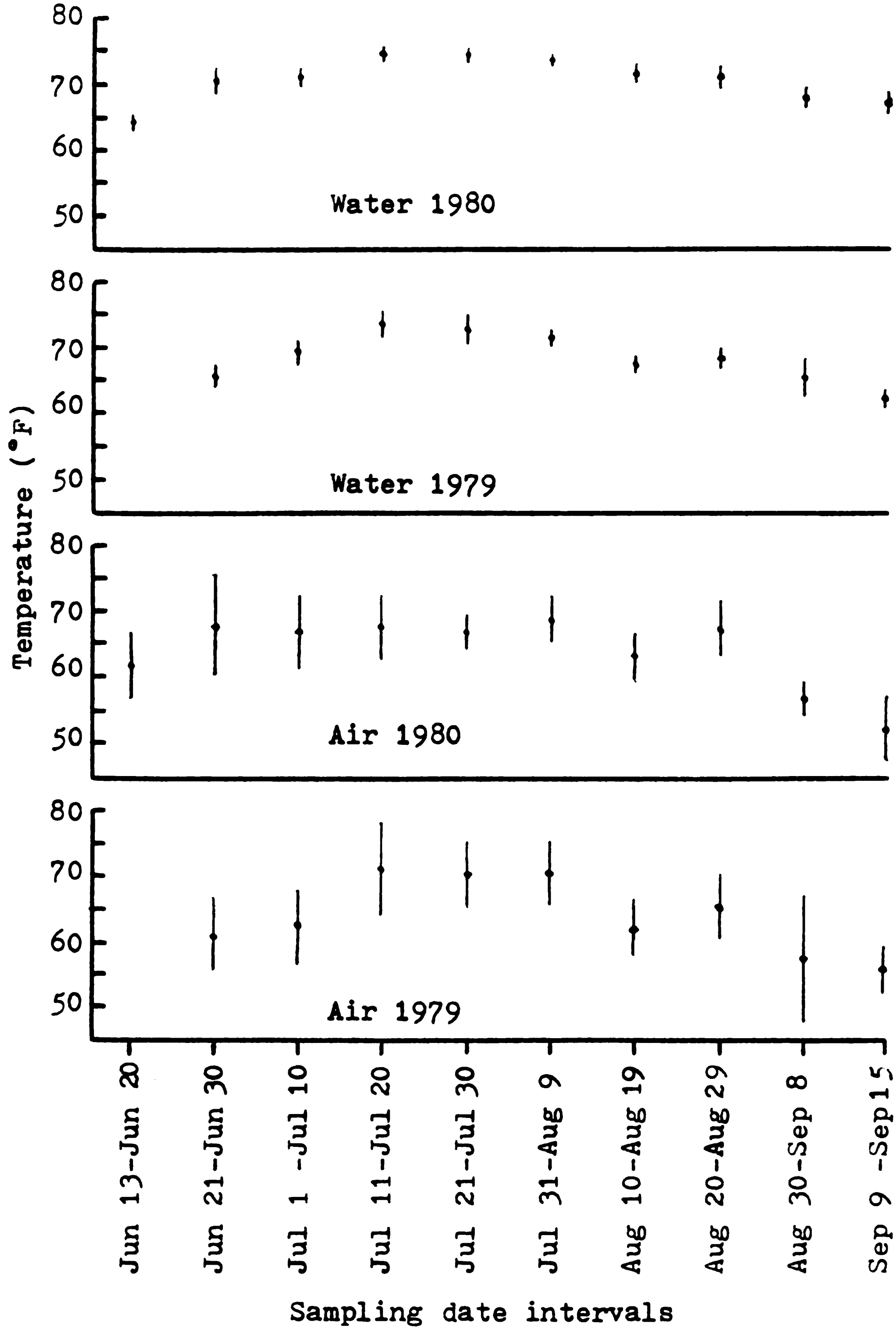


Figure 3. Ten day mean air and water temperatures and 95% confidence bars, Gibson L., 1979 and 1980.

Table 2. Mean air and water temperatures for the Gibson Lake study area, 1979 and 1980.

	Mean Temperature (°F) 1979	1980
Air	63.5 (59.3-67.8)*	66.2 (64.1-68.3)*
Water	68.7 (65.8-71.5)*	71.4 (68.6-74.2)*

* 95% Confidence interval

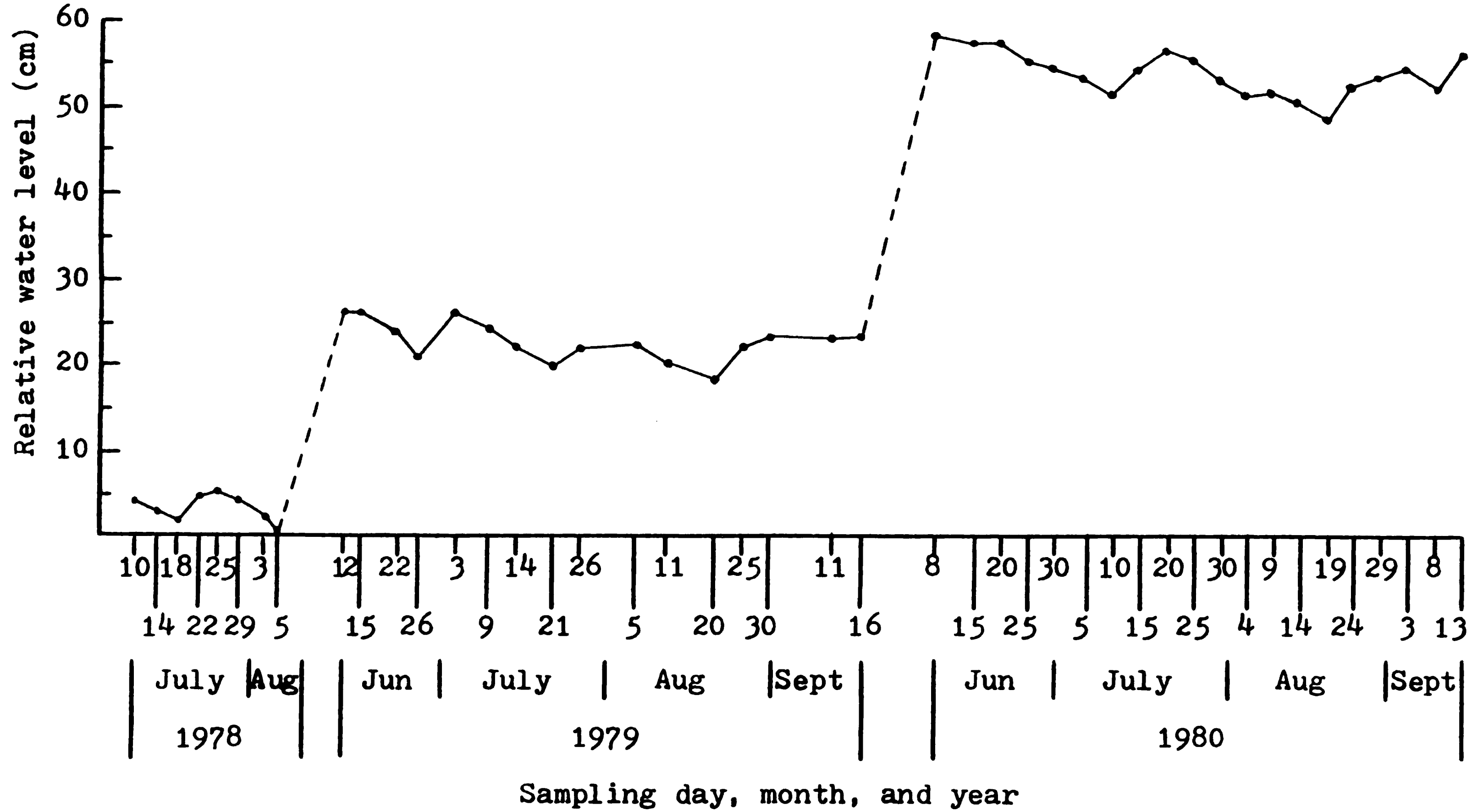


Figure 4. Relative water level fluctuation in Gibson Lake, 1978, 1979, and 1980.

thick and consists mainly of semiaquatic grasses, sedges, and herbs. In low water conditions, as in 1978, there is relatively less emergent vegetation.

Morphological Characteristics of the Newt

Total length, snout-vent length, and secondary sexual characteristics were examined in order to make comparisons to other newt studies. Spotting characteristics were studied to determine the subspecies of *N. viridescens* composing the Gibson Lake population.

In 1978, thirty-three adult newts were captured. The mean total length of these individuals was 79.2 mm (95% CI for total length: 74.6-83.9 mm). The mean snout-vent length was 40.3 mm (95% CI for s-v length: 38.2-42.4 mm).

In 1979, forty-four adult newts were captured. Table 3 summarizes their lengths and spotting measurements. The mean total lengths of both males and females was 82.1 mm. These figures are somewhat smaller than reports in the literature (Bishop, 1941; Conant, 1975; Chadwick, 1944; Bennett, 1970). The snout-vent length of females was not significantly different than that of males (95% level of significance). The male's tail on the average was 55% of total length, whereas the female's tail length was 53% of total length. In a New York pond the females' tails comprised from 49.3% to 52.9% of the total length; males from 50% to 52% (Bishop, 1941). Bishop (1941) states that aquatic adults vary considerably in size in different waters in the same general locality.

Secondary sexual characteristics were evident in males during early season; however, a few individual males lacked the characteristic

Table 3. Summary of morphological measurements of Gibson Lake newts, 1979.

	Males		Females	
Total length (mm)	mean:	82.1	mean:	82.1
	95% C.I.:	79.3-84.9	95% C.I.:	77.5-86.7
	range:	74-93	range:	68-100
Snout-vent length (mm)	mean:	36.6	mean:	38.6
	95% C.I.:	35.3-37.9	95% C.I.:	36.6-40.6
	range:	31-42	range:	33-48
Total number of spots between fore and hind limbs	mean:	10.4	mean:	10.9
	95% C.I.:	8.2-12.6	95% C.I.:	7.2-14.7
	range:	0-27	range:	0-27

hypertrophied tail fin, large cloacal lips, horny excresences on hind legs, and obvious facial pits. The secondary sexual characteristics disappeared in the male population by the last two weeks of July (16 July - 1 August).

Twenty-one males were collected before 16 July. Sixteen of these had secondary sexual characteristics and five did not. Two of the five were quite red in coloration and quite small. These five newts without secondary sexual characteristics had a mean total length of 79.0 mm, significantly less than the mean total length of the other males (95% level of significance). It is likely that these individuals were newly transformed efts that had entered the lake in the spring.

The number of red spots between the fore and hind limbs ranged between 1 and 21 and were not significantly different in males and females (95% level of significance). The spots are variable in number and position and patterns have been used for individual identification (Gill, 1978).

The newts in Gibson Lake are of the subspecies *Notophthalmus viridescens louisianensis*. All Gibson Lake newts lack black-borders surrounding the red spots and in some individuals red spots are absent. Conant (1975) states that *N. v. louisianensis* is normally without red spots, but when spots are present they are small or only partly outlined by black. Bishop (1943) and Johnson (1965) state that the range of the subspecies *N. v. viridescens* and *N. v. louisianensis* meet with an area of intergradation in Alger and Schoolcraft counties, Michigan, with *N. v. louisianensis* occurring to the west of this area. Gibson Lake occurs well to the west of this intergradation zone, placing it in the range of N. v. louisianensis.

Chronology of Life Stages Observed

The timing of newt life stages was monitored in this study for comparison to newt studies in other geographic localities. Gill (1978) suggests that the contrasting evidence reported by various authors on the life history of N. viridescens reveals the great variation this organism exhibits throughout its range. In Gibson Lake newts two main points differ from the majority of reports in the literature: (1) the adult may not be permanently aquatic and (2) no fall migration of transforming efts occurs.

In 1978, aquatic adults were observed in Gibson Lake from 1 July to 5 August. After 5 August, aquatic adults could not be located in the lake. On 23 July 1978, a terrestrial newt which fell within the adult size range was found 25 meters away from the lake shore under a log. This individual had the olive colored dorsum of adults, but had rough, non-wettable skin similar to the eft stage.

Figure 5 presents the chronology of different newt life stages observed in the 1979 season. Aquatic adult newts were found in Gibson Lake on 12 June although it is presumed they were present earlier than this date. Aquatic adults were observed in the lake until 13 August after which no adult newts could be located along the lake's littoral zone or in the deeper areas. The deep areas of Gibson Lake were surveyed using SCUBA.

Starting with 4 August and continuing until 12 September, terrestrial adults were intercepted by the 25-meter drift fence as they

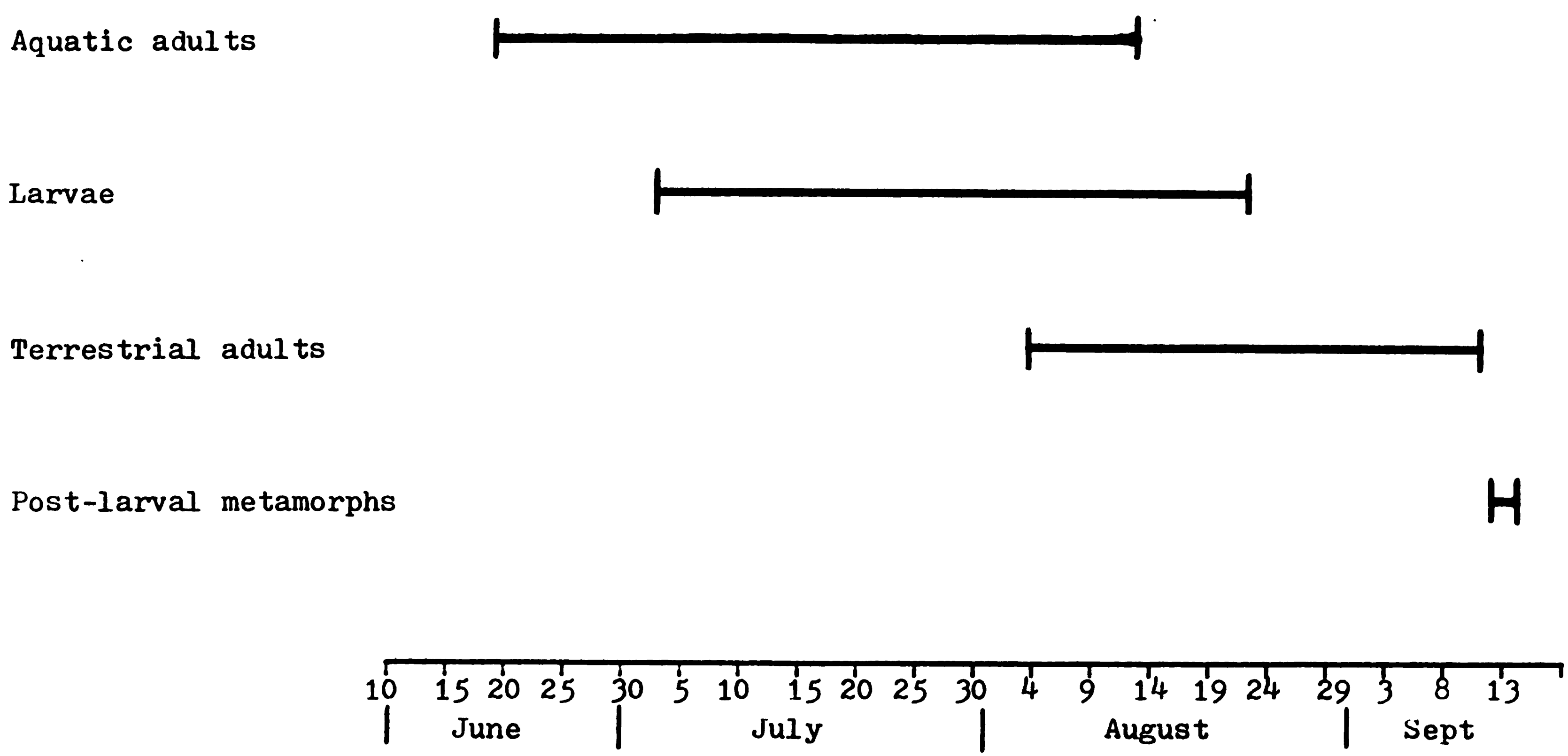


Figure 5. Chronology of the newt life stages observed in Gibson Lake, 1979.

moved from the lake to the land. Five individuals (three males and two females) were intercepted. These five were within the mean adult size range (mean total length of 81 mm and mean snout-vent length of 39 mm) and were not reddish, but had characteristic adult coloration. The mean total length of these individuals was more than twice as great as the mean length of post-larval efts that were also moving to land at this season. Tail finning was reduced and the skin was rough, dry, and non-wettable, similar to the land eft stage. Gill (1978) describes this condition and observed newts in the Shenandoah Mountains of Virginia to leave the ponds in August and September for terrestrial hibernacula. This adult migration out of the water in the fall is contrary to most accounts of the standard newt life history (Bennett, 1970; Bishop, 1941; Chadwick, 1944; Morgan and Grierson, 1932). Ruthven, et al. (1928) suggests that adults may come to land under "extreme conditions", although "extreme conditions" were not defined. Adult newts were not observed to wander in and out of the water throughout the breeding season, unlike observations made by Hurlbert (1969) and Gill (1978). Gill (1978) stated that newts underwent this interhabitat movement to shed themselves of leeches. Gibson Lake newts did not host leech parasites.

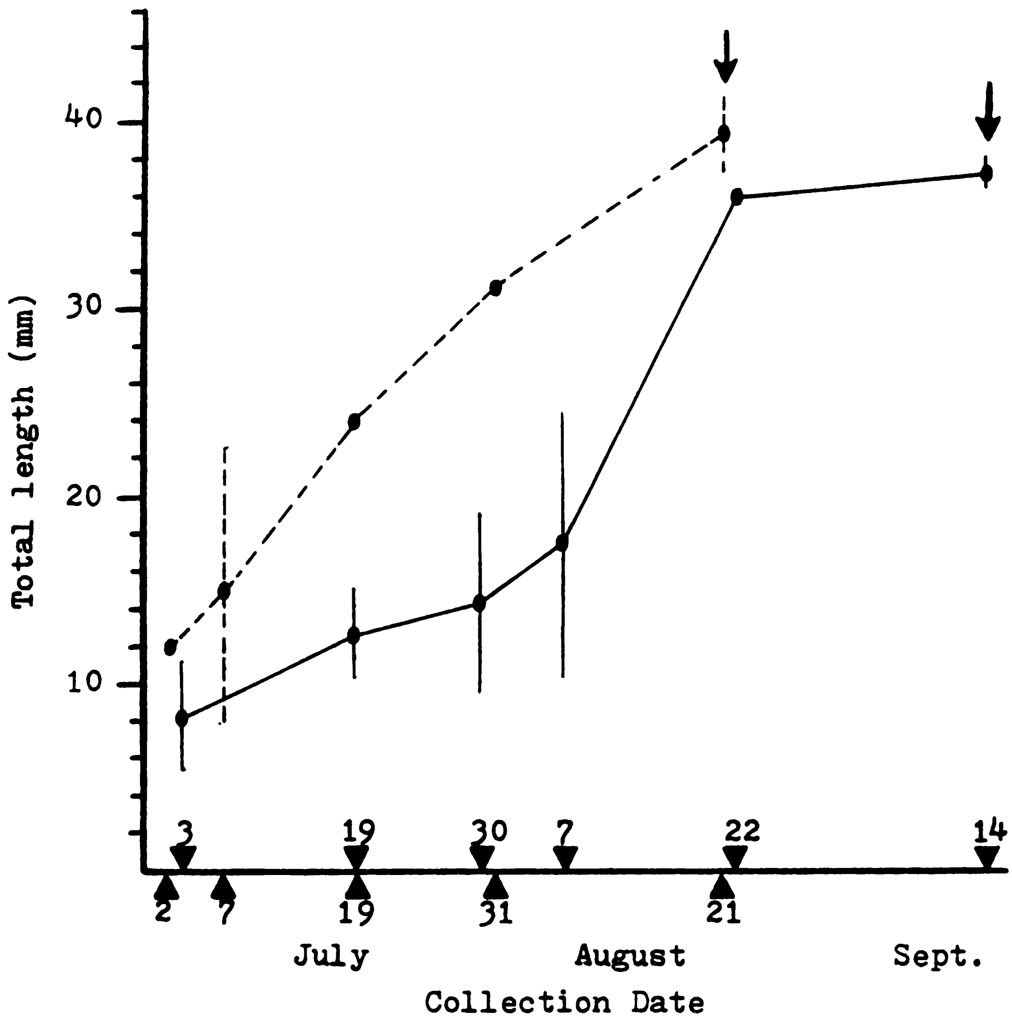
In Gibson Lake it is probable that all adult newts leave the lake environment during the fall to spend the winter months in the adjacent wooded areas. Adult newts have not been found in the littoral zone or in the deeper areas of Gibson Lake after the latter half of August and in September. A few adult newts have been found in past years under logs and debris adjacent the shoreline during late August. These individuals had the same description as those referred to above as terrestrial adults. Terrestrial adults have not been found in the adjacent woods during August and September, however, considering the small population size, they may have been overlooked.

In 1980, only two aquatic adults were collected and no terrestrial adults were intercepted in the terrestrial drift fence.

Newly hatched larvae were observed for the first time on 3 July, 1979 and these were periodically captured and measured until 22 August. Measurements are presented in Figure 6. At the first collection date (3 July, 1979) the mean total length of the larvae was 8.25 mm (95% CI: 5.2-11.3 mm). Bishop (1941) states that newly hatched larvae have an average length of about 7.5 mm. Newly hatched Gibson Lake newt larvae had minimally branched gills present and the front legs were represented by short, blunt limb buds.

Newt eggs were not observed in Gibson Lake. In New York, the egg incubation period may extend 20 to 35 days (Bishop, 1941). If a 35 day incubation period is assumed and this figure is calculated back from the July 3 observation period, it would indicate that the oviposition period occurred somewhere around the last few days of May in Gibson Lake. In New York, eggs were found in the field by 7 May in 1924 (Bishop, 1941).

Bishop (1941) states that post-larval metamorphs have been observed as early as 17 August and thereafter until 15 September. Gill (1978) reported post-larval metamorphs from mid-August through the end of November, which corresponded to a prolonged oviposition period he observed. In Gibson Lake, four post-larval metamorphs were observed between 12 and 15 September in 1979, a period of 4 days. This indicates a larval period of approximately 73 days in Gibson Lake, similar



Key:

- ● Mean total length of newt larvae
- ——— 1979 larvae length and 95% confidence bars
- - - - - 1980 larvae length and 95% confidence bars
- ▼ 1979 collection dates
- ▲ 1980 collection dates
- ↓ indicates this measurement is of post-larval metamorph

Figure 6. Change in length of newt larvae over the 1979 and 1980 summer seasons.

to the 84 day period reported by Bishop (1941). The size of fully developed larvae in Gibson Lake was approximately 36 mm. Post-larval metamorphs had a mean size of 37.25 mm (95% CI: 36.6 - 37.8 mm). These figures are very similar to those presented by Bishop (1941) and Gage (1891).

In 1980, newt larvae were first collected on 2 July. At this time one 12 mm individual was collected. As can be seen in Figure 6, larvae during the 1980 season were larger than larvae collected at comparable dates in 1979. Post-larval metamorphs in 1980 were intercepted in the terrestrial drift fence between 17 August and 24 August, a period of eight days. Six individuals were captured. These post-larval metamorphs were about three weeks ahead of those captured in 1979. The reasons for these differences are unknown.

Older efts were not captured during the 1979 and 1980 seasons and they have proved difficult to locate in past seasons, although a few have been found. In a study near Manchester, Maine, Pope (1921, 1924) reported finding very few efts. Other workers (e.g., Stein, 1939) report finding thousands of efts in mass migrations.

No autumn migration of transforming red efts to the lake was observed in the Gibson Lake population. This agrees with Gill's (1978) findings, but is contrary to most authors' reports (e.g., Bishop, 1941; Stein, 1938; Bennett, 1970) which state that the migratory peak of efts returning to water occurs in the fall.

The reduced population size in 1980 made the estimation of life stage events difficult. Figure 7 presents the observations that were recorded for comparison to the 1978 and 1979 seasons.

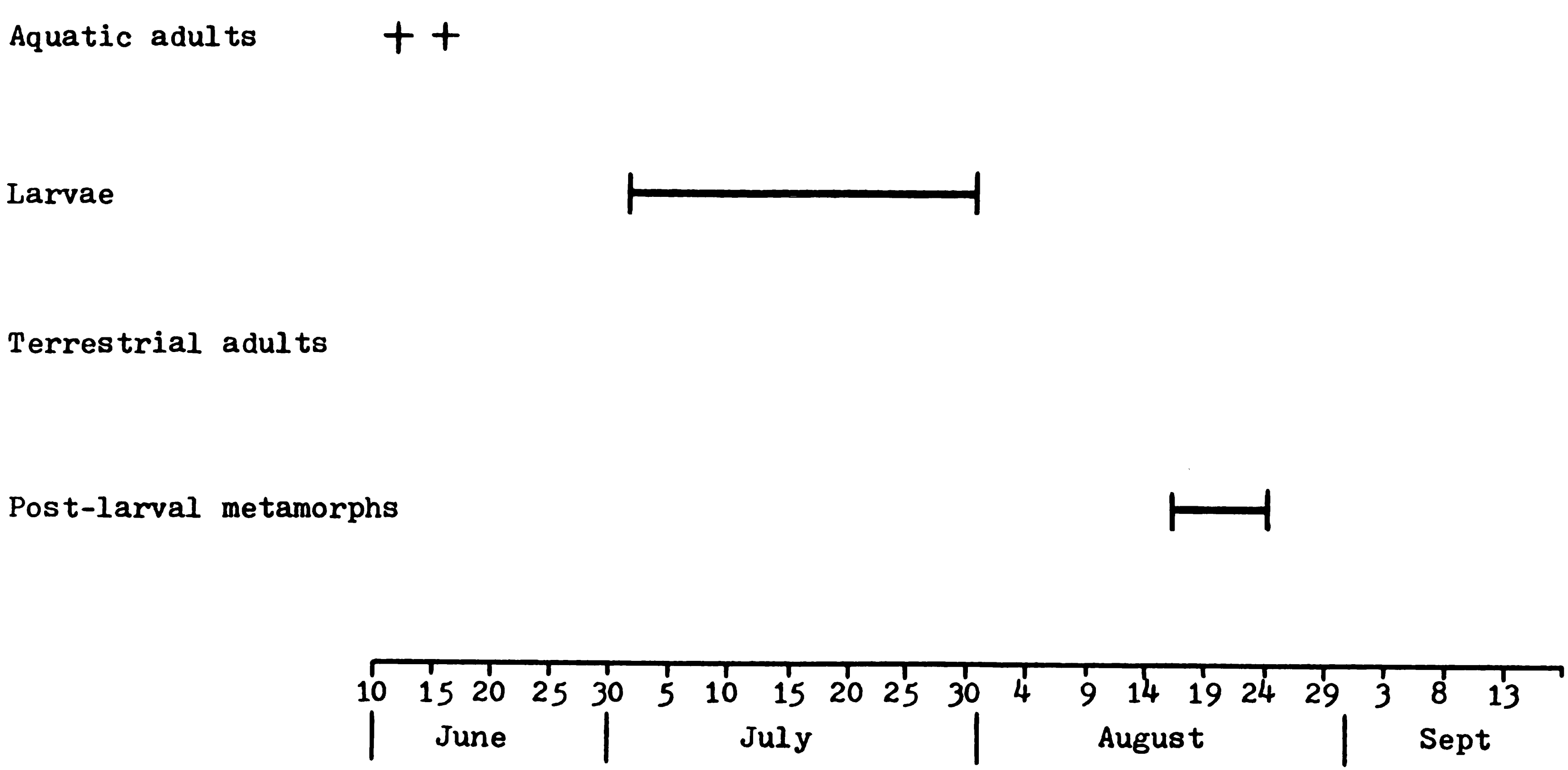


Figure 7. Chronology of the newt life stages observed in Gibson Lake, 1980.

Sex Ratio

In 1979, the sex ratio of newts in Gibson Lake was 1.44 males per 1.0 females. This is similar to Gill's (1978) studies in Virginia populations where he found a sex ratio of 2 to 1 (males to females). Bellis (1968) reported a sex ratio of 3.45 to 1 (males to females) in a small Pennsylvania pond.

Population Size

In all three years of this study, the newt population was low and there was an apparent decline in numbers from 1978 to 1980.

In 1979, 44 adult newts were captured and marked. Ten of 39 aquatic newts marked (25.6%) were captured in the four aquatic drift fence traps. Recapture success of marked individuals was low in 1979 with only one marked newt being recaptured. This made estimation of population size undependable. A Lincoln-Peterson Index or Schnabel method could not be used to estimate the population size of newts because they assume that marked individuals distribute themselves homogeneously with respect to unmarked (Brower and Zar, 1977). This assumption is likely violated because individual newts have a restricted home range. Burton (1977) and Bennett (1970) also note this problem in estimating newt population size. Observationally, the newt population in 1979 was reduced from the 1978 season population size. More individuals were collected in 1978 with much less effort.

In 1980, the newt population size of Gibson Lake appeared to be very reduced. Only two individual aquatic adults were collected by hand and none were trapped in the aquatic drift fence. Larvae were present, although less abundant than in 1979, making it difficult to collect adequate sample size for growth measurements. Six post-larval metamorphs were intercepted in the terrestrial drift fence.

Gill (1978) reports that some ponds he studied in the Shenandoah Mountains had newt populations whose production of juveniles was consistently below adult replacement levels. He found no significant correlation between juvenile production and age of pond, size of breeding adult population, or Ambystoma jeffersonianum predation on newts. The newts Gill (1978) studied are heavily attacked by leeches. This is severe, not only in the debilitating effects of the leech ectoparasitism, but also because the leeches harbor a flagellated blood parasite which infects newts.

Bennett (1970) observed large fluctuations in population size of newts in Sandy Lake, New Hampshire. Between 1966 and 1968 the newt population of Sandy Lake dropped from an estimated 120,800 to 41,500. Bennett (1970) believes the high population of 1966 resulted from lack of competition from fish species that had recently been poisoned out. Subsequent decrease in population size was attributed to the increased competition as fish species became re-established in Sandy Lake and to newt overpopulation.

The reasons for the normally low numbers of newts in Gibson Lake and the observed decline in numbers over the three seasons of this study are not known. All newts appear to be healthy and in good condition.

Gibson Lake does not harbor the species of leech that Gill (1978) has detected. Newt adults or larvae have not been observed in the stomach contents of Perch, Sunfish, Golden shiners, Smallmouth bass, or Northern pike. The possibility of invertebrate predators in the form of Belostomatid bugs or Dytiscid beetles does exist.

Since Gibson Lake efts and adult newts apparently spend the winter months in terrestrial hibernacula, the conditions of the northern Michigan winters are likely to influence mortality. The 1979-80 winter in Iron County had lower than normal snowfall. This may have reduced the amount of insulation that newts usually receive from the snow cover and caused higher than usual mortality. This could be one reason for the observed low population in 1980. Coincident with the low newt population in 1980, was a reduced population of adult and juvenile American toads (Bufo americanus). In 1979, over 2,100 post-metamorphic juvenile toads were caught in the terrestrial drift cans, but in 1980 there were only 6. The number of breeding adults was apparently reduced judging from the size of the spring breeding chorus. This species would also be affected by severe winter weather.

Food Habits and Potential Competitors

Aquatic adult newts fed almost exclusively on small aquatic invertebrates. The food items of Gibson Lake newts were identified and relative percent of each taxon was compared to the invertebrate fauna present in Gibson Lake littoral zone. Perch, Sunfish, and Golden shiners also fed on small aquatic invertebrates and these fishes occurred in the same habitat as newts. Stomach contents of these fishes were also identified and compared to newt diet.

Table 4 presents the organisms present in the stomach contents of 10 Gibson Lake newts and 5 Gibson Lake microfauna samples, as well as the relative percent by number of each taxon.

Table 4. Comparison of stomach contents of 10 adult *Notophthalmus viridescens* with five microfauna samples collected in Gibson Lake, 1979.

Organism	Percent by number in *N. viridescens* stomach contents	Organism	Percent by number in Gibson Lake microfauna samples
Cladocera	33.70	Cladocera	55.10
Oligochaetes	19.56	Copepoda	26.66
Culicidae and Chironomidae larvae	16.30	Culicidae and Chironomidae larvae	7.46
Ephemeroptera larvae	6.52	Diptera larvae	3.93
Vertebrata	4.35	Hydracarina	3.26
Ostracoda	4.35	*Hydra spp.*	2.04
Cast newt skins	3.26	Ephemeroptera larvae	0.68
Chironomidae adults	3.26	Anisoptera larvae	0.34
Copepoda	2.17	Corixidae	0.14
Corixidae	1.09	Collembola	0.14
Sphaeriidae	1.09	*N. viridescens* larvae	0.07
Anisoptera larvae	1.09	Ostracoda	0.07
Zygoptera larvae	1.09	Bryozoan statoblast	0.07
Oligochaete (earthworm)	1.09	Oligochaetes	0.07
Lepidoptera larvae	1.09		
	100.01		100.02

Cladocera, benthic oligochaetes, and Dipteran larvae (Chironomidae and Cuclicidae) play important roles in the newts' diet. Cladocera, Dipteran larvae, and Copepods are abundant in microfauna samples. Copepods are difficult to catch by fish predators (Strickler, 1975; Szlauer, 1965) which may explain their small role in the newts' diet. A few newts had eaten small vertebrates (fish or amphibian) and on one occasion a newt was observed devouring a Bufo americanus tadpole. Monks (1880) observed newts to eat anuran tadpoles.

Water mites (Hydracarina) were not found in newt stomach contents in this study. Water mites are present in the lake, however, and were observed in great numbers around foraging newts. Some workers (Kerfoot, in press; Reissen, in press) have shown water mites to be distasteful to several fish species. Hungry newts in aquaria ignored water mites that were introduced. This has also been reported by Wood and Goodwin (1954) and Hamilton (1932).

Oligochaetes seem to be important in newt diet even though they do not show up in great numbers in the microfauna samples. This may be an artifact resulting from the sampling technique which did not adequately sample the benthic region.

When comparing the lake microfauna to newt stomach contents (Table 4) adult newts seem to be taking prey items in response to which organisms are most abundant except for the few exceptions discussed above. This has also been observed by Hamilton (1932). Gibson Lake newts, during the month of July, rely heavily on Cladocera as food items. Cladocera make up 34% by number of organisms consumed. This large number of Cladocera in newt stomach contents was not reported by Hamilton (1932), Wood and Goodwin (1954), or Morgan and

Grierson (1932). Burton (1977) reports that Cladocera make up 38% by number of newt diet in Mirror Lake, New Hampshire during early July. During this same time Burton showed Diptera (29%) and Amphipoda (21%) to also contribute substantially to newt diet.

The results of the food analyses of Gibson Lake Yellow perch (Perca flavescens), Sunfish (Lepomis gibbosus), and Golden shiners (Notemigonus crysoleucas) are presented in Table 5. In the twenty Yellow perch examined, Cladocera make up 61.5% by number of their diet and Chironomidae make up 20.2%. This is similar to newt stomach contents which contained 34% Cladocera and 16% Chironomidae and Culidae. Golden shiners also utilize Cladocera to a large extent (25% by number) although only two individual fish were examined. No appreciable similarity of major food items was observed between 36 Sunfish examined and newts. No newt larvae were found in the stomach contents of any of these fish species.

Yellow perch are abundant in Gibson Lake and may be substantial competitors with newts for food. This could contribute to the consistently low newt population size in Gibson Lake.

Diurnal Home Range

The following section presents the physical and vegetative characteristics measured in the aquatic grid and the individual home ranges of 15 newts. The home ranges of Gibson Lake newts is restricted. This has also been reported for newts in a small Pennsylvania pond (Bellis, 1968).

Figure 8 presents the depths in centimeters measured at the corners of each square meter and the location of the shoreline within

Table 5. Stomach contents of 3 species of Gibson Lake fish, *Lepomis gibbosus*, *Perca flavescens*, and *Notemigonus crysoleucas*.

Fish species	Food organism	Number	Percent by Number
Lepomis gibbosus (n=36)	Odonata larvae	76	45.5
	Phylobius glaucus	55	32.9
	Terrestrial Insecta	11	6.6
	Cladocera	6	3.6
	Chironomidae larvae	6	3.6
	Sphaeriidae	5	3.0
	Gastropoda	4	2.4
	Copepoda	2	1.2
	Collembola	1	0.6
	Oligochaeta	1	0.6
Perca flavescens (n=20)	Cladocera	64	61.5
	Chironomidae larvae	21	20.2
	Odonata larvae	8	7.7
	Copepoda	6	5.8
	P. flavescens	4	3.8
	Terrestrial Insecta	1	1.0
Notemigonus crysoleucas (n=2)	*Phylobius glaucus*	15	62.5
	Cladocera	6	25.0
	Odonata larvae	2	8.3
	Terrestrial Insecta	1	4.2

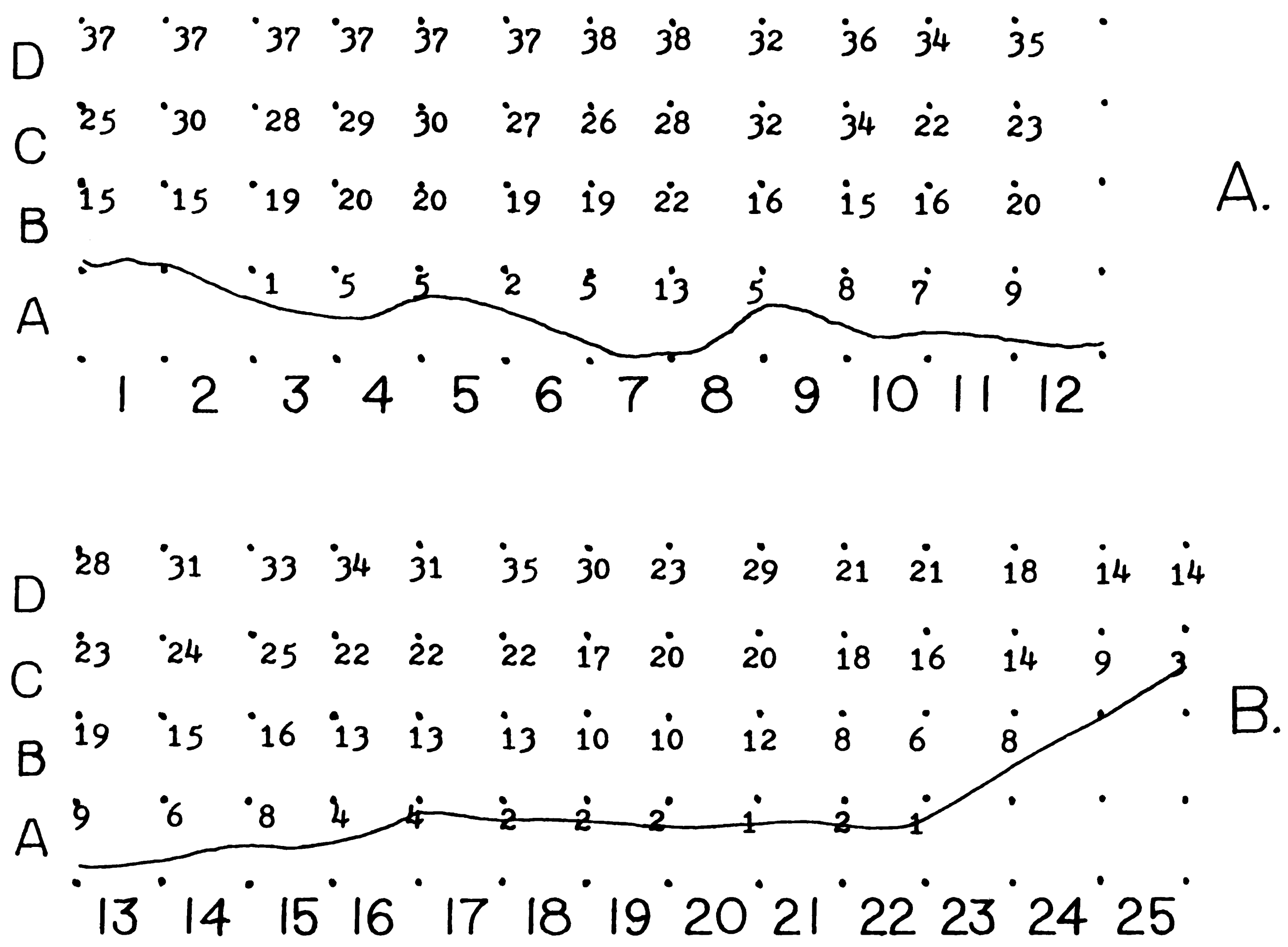
the grid. Depths ranged from 1 cm to 38 cm within the grid area. Depth measurements in Figure 8 were made on 1 July, 1978. The water level fluctuations that occurred during the 1978 season are presented in Figure 4.

In 1978, the shore adjacent the waters' edge was sandy and the vegetation consisted of grasses, sedges, and other herbs. The lake bottom ran off from the shore at approximately five degrees to the horizontal and consisted of sand, mud and organic debris such as sticks and dead vegetation. Patches of pipewort (Eriocaulon septangulare) covered much of the bottom in shallow water.

Figures 9 and 10 present maps of the distribution of aquatic macrophytes within the 100 m square grid. Figure 8 shows the distribution of the floating vegetation, Water shield (Brassenia schreberi) and Bur weed (Sparganium sp.). Both of these species have their main vegetative parts floating on or near the surface and provide very little cover for newts on the substrate.

Figure 10 is a map of the distribution of pipewort (Eriocaulon septangulare) within the 100 m^2 grid. Pipewort is a small plant, 8 to 12 cm high, and tends to grow in thick mats. It provides cover for newts and for the invertebrate fauna that serve as newt food. Pipewort grew best in quite shallow water and the thickest mats of this plant grew in water with depth between 1 and 20 cm. Pipewort formed the dominant bottom vegetation in the 100 m^2 grid.

Figure 11 presents a map of the location and relative size of sticks, logs, and woody debris within the aquatic grid. Newts were always found under sticks or logs during the diurnal collection periods



Legend:

A. North end of aquatic grid

B. South end of aquatic grid

——— Shoreline (measured on 1 July, 1978)

Corners of one square meter subdivisions are indicated by a • and adjacent numbers indicate depth readings in centimeters (measured on 1 July, 1978)

Figure 8. Shoreline contour and depth readings of aquatic grid, 1978.

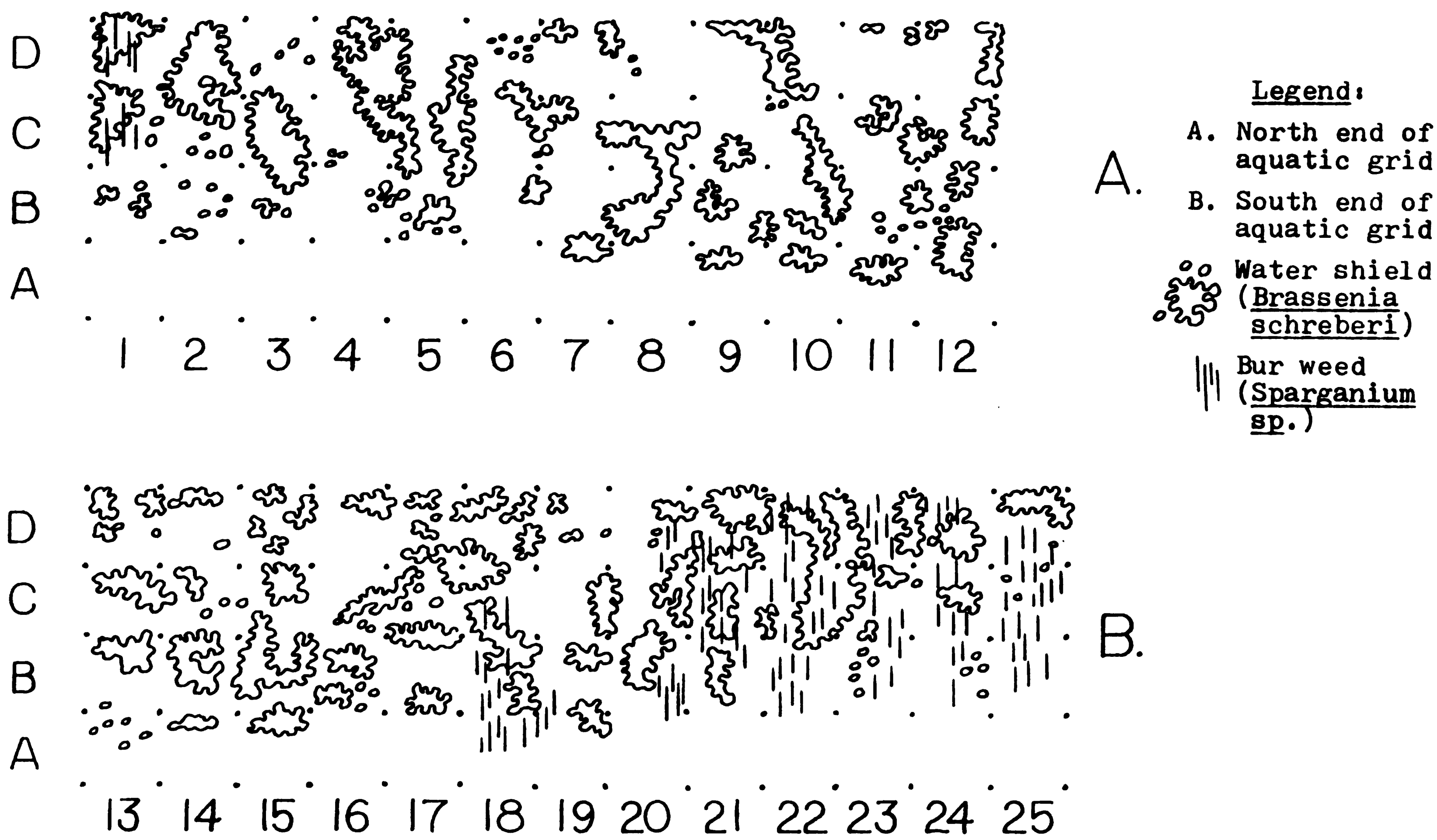
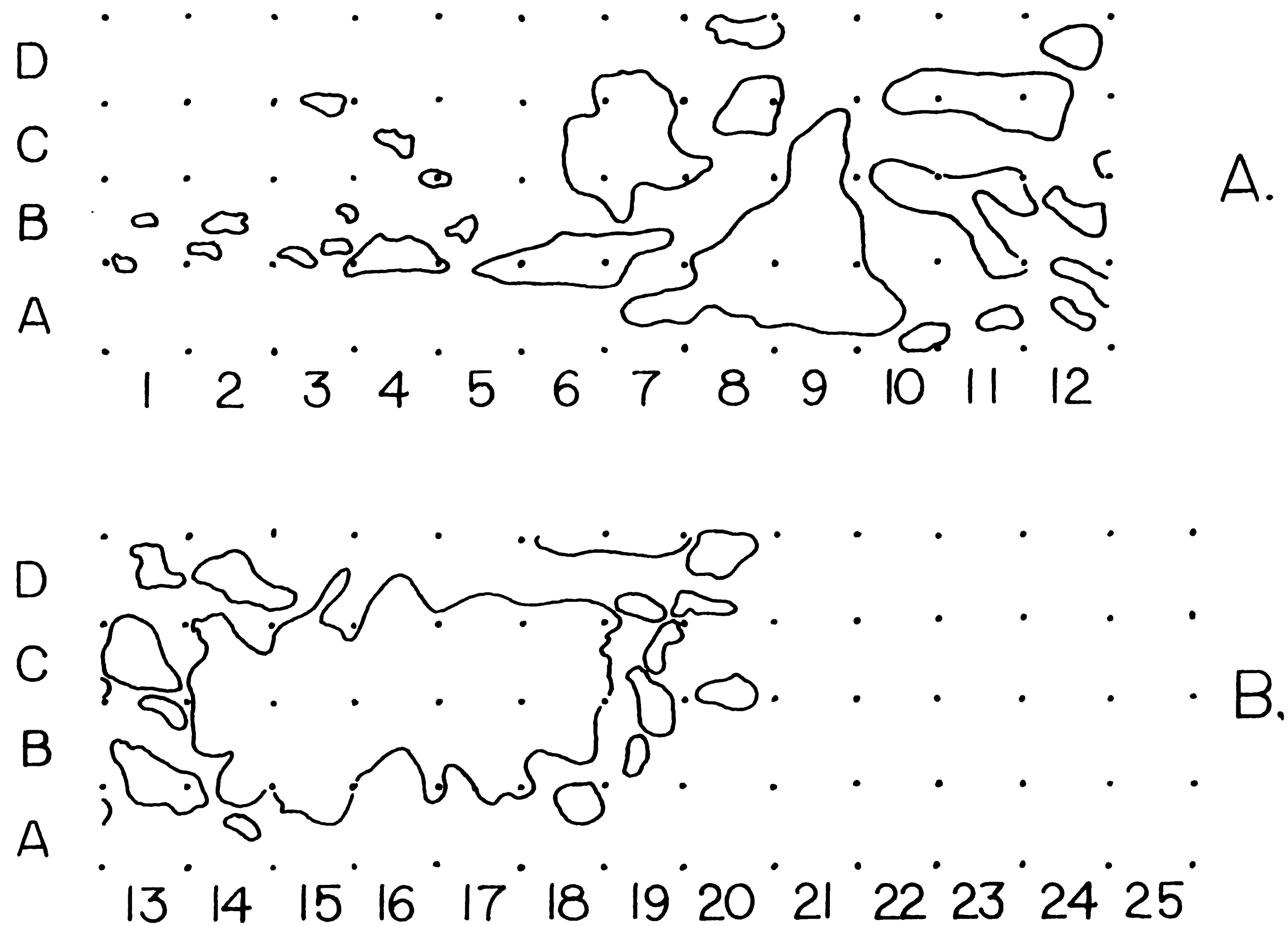


Figure 9. Distribution of floating vegetation in the aquatic grid, 1978.



Legend:

A. North end of aquatic grid

B. South end of aquatic grid

Enclosed space represents Pipewort (Eriocaulon septangulare)

Figure 10. Distribution of the major bottom vegetation in the aquatic grid, 1978.

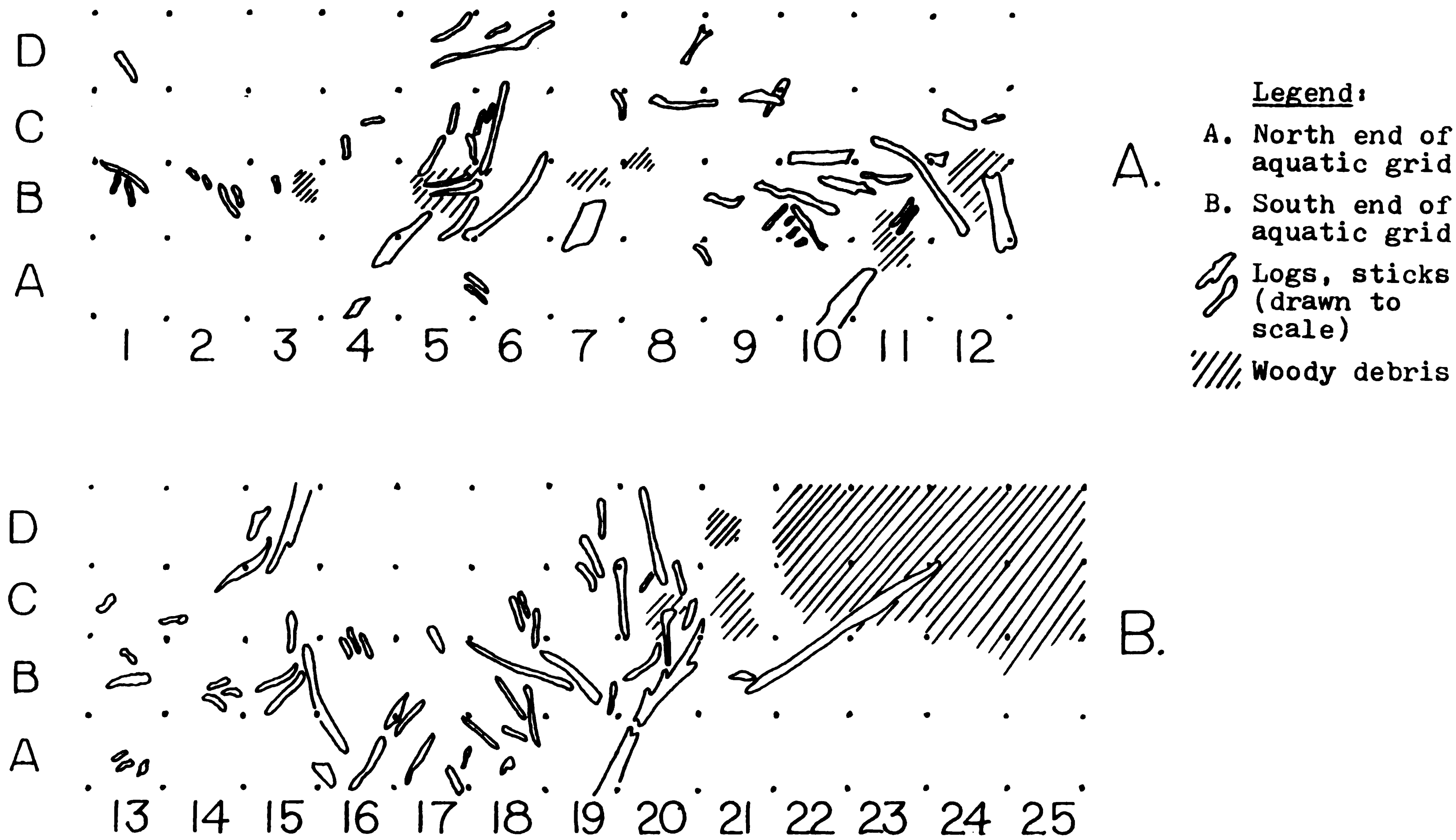


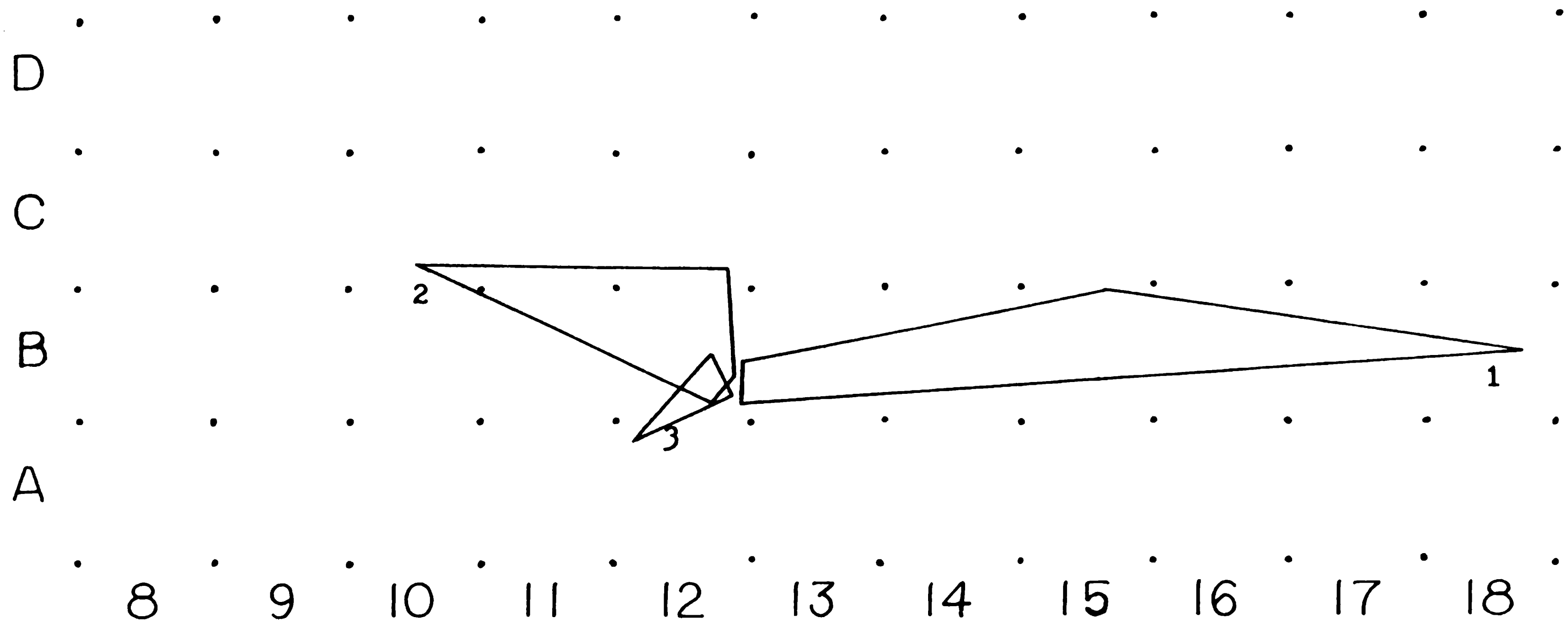
Figure 11. Distribution of sticks, logs, and woody debris in the aquatic grid, 1978.

in this study. Logs and sticks provide the "home sites" which will be discussed later.

Using the toe-clipping system, 36 newts were marked and systematically recaptured during 21 sampling dates from 1 July to 11 August, 1978. Preferred "home sites" for newts were submerged logs and sticks occurring within three meters of shore and usually associated with pipewort. Individuals utilized more than one "home site", but were usually found under one log for several consecutive days. During daytime collection periods all newts observed or collected were under logs or sticks in the littoral zone.

Fifteen individual newts were captured three or more times and these were used in calculation of diurnal home range. The mean number of captures per individual is 6.4 and the maximum number of captures is 12. The diurnal home ranges for these 15 newts are presented in Figures 12, 13, 14, and 15. The size of diurnal home range for these 15 newts ranged from 0.1 m^2 to 8 m^2. The mean size of diurnal home range is 2.4 m^2 (95% CI: 1.0 - 3.8 m^2), and the median value is 1.3 m^2. During a three week mark and recapture study, Bellis (1968) found that 60.4% of recaptures were within 10 feet of the marking sector and 74.8% were within 20 feet.

The mean depth of the preferred home sites of the 15 newts is 12.1 cm (95% CI: 10.9 - 13.4 cm; n = 93). The mean depth of all newts (including the above 15) captured in 1978 is 12.2 cm (95% CI: 11.1 - 13.2 cm; n = 127). No newts were ever observed or captured in water deeper than 30 cm. This observation includes three hours of SCUBA in Gibson Lake during July and August in water up to four meters deep. Interestingly, the mean depth at which newts were found



Legend:

Distance between two adjacent dots equals one meter

Each numbered polygon represents one diurnal home range

Numbers and letters bordering the dots represent location in the aquatic grid

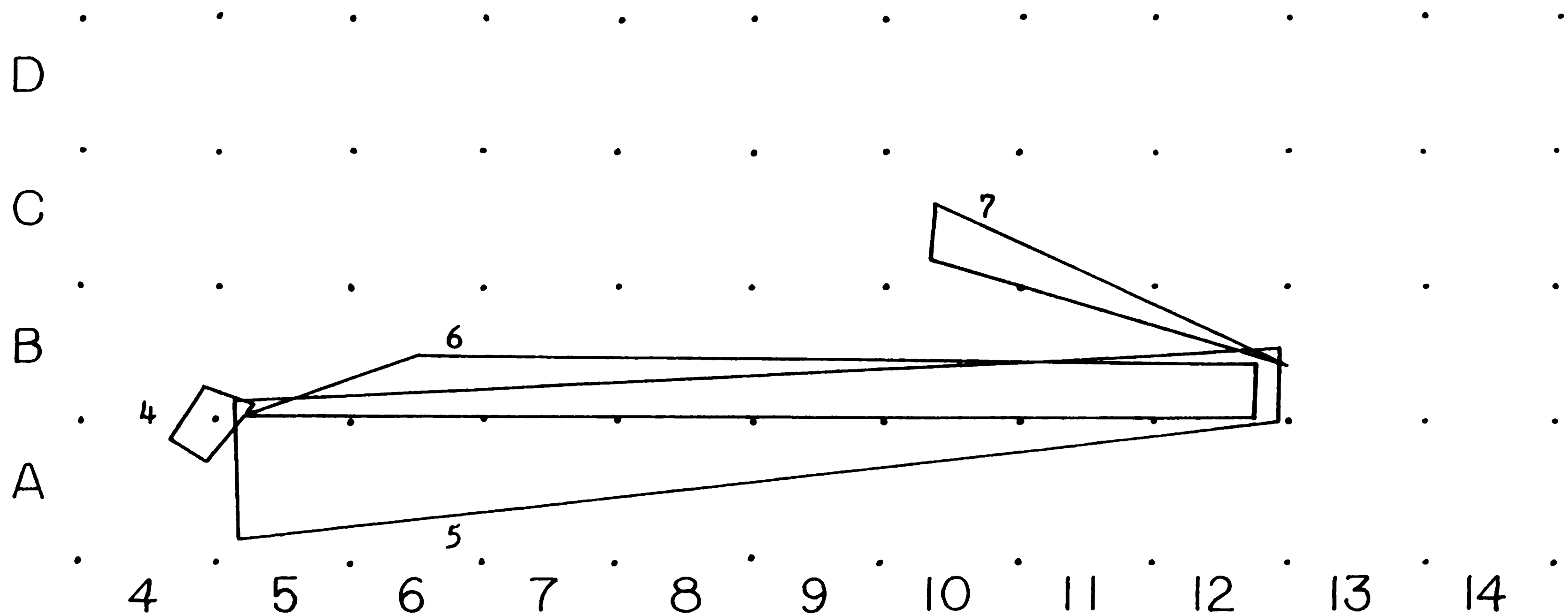
Diurnal home range

Newt 1: 2.4 m^2

Newt 2: 1.2 m^2

Newt 3: 0.2 m^2

Figure 12. Diurnal home ranges of newts 1, 2, and 3, 1978.



Legend:

Distance between two adjacent dots equals one meter

Each numbered polygon represents one diurnal home range

Numbers and letters bordering the dots represent location in the aquatic grid

Diurnal home range

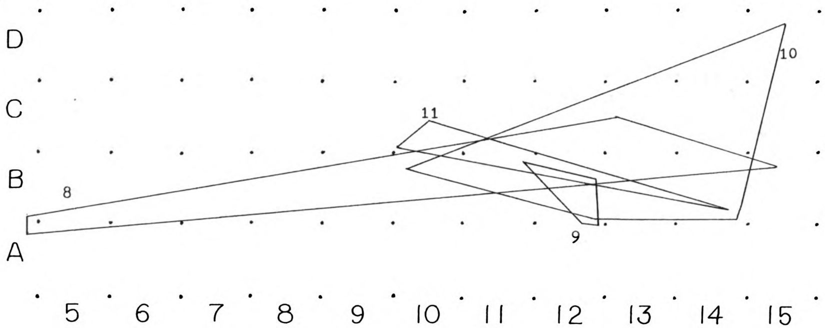
Newt 4: 0.2 m^2

Newt 5: 5.8 m^2

Newt 6: 3.4 m^2

Newt 7: 0.6 m^2

Figure 13. Diurnal home ranges of newts 4, 5, 6, and 7, 1978.



Legend:

Distance between two adjacent dots equals one meter

Each numbered polygon represents one diurnal home range

Numbers and letters bordering the dots represent location in the aquatic grid

Diurnal home range

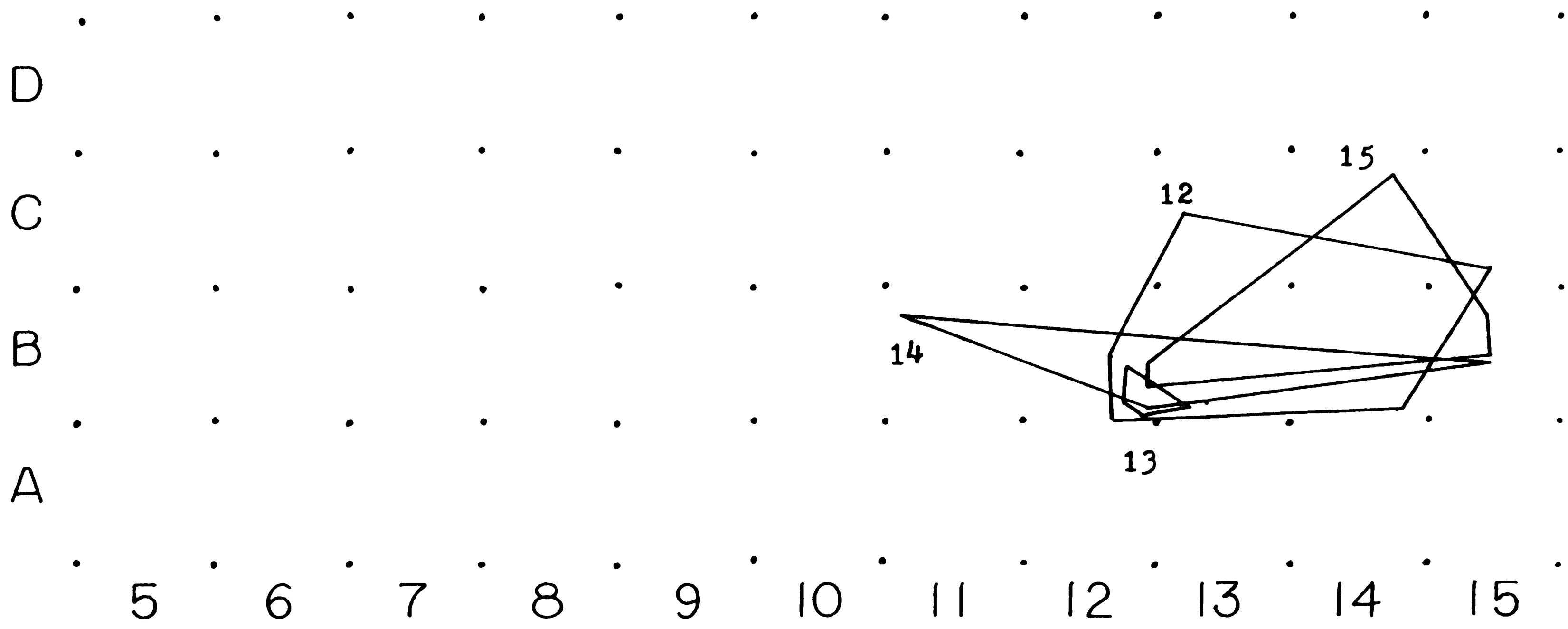
Newt 8: 6.2 m^2

Newt 9: 0.4 m^2

Newt 10: 8.0 m^2

Newt 11: 1.0 m^2

Figure 14. Diurnal home ranges of newts 8, 9, 10, and 11, 1978.



Legend:

Distance between two adjacent dots equals one meter

Each numbered polygon represents one diurnal home range

Numbers and letters bordering the dots represent location in the aquatic grid

Diurnal home range	
Newt 12:	3.1 m^2
Newt 13:	0.1 m^2
Newt 14:	1.3 m^2
Newt 15:	1.8 m^2

Figure 15. Diurnal home ranges of newts 12, 13, 14, and 15, 1978.

in 1979 was 21.5 cm, significantly higher than the 1978 observations (95% level of significance). Possible reasons for this difference will be discussed later.

Home sites were often occupied by more than one newt at a time and as many as 14 newts occurred together under one log. No newt was consistently found with another specific individual for more than two or three collection periods, suggesting they were incidentally sharing the same hiding place, and not moving together from one place to another.

Distribution Within the Lake

The distribution of newts in Gibson Lake is restricted to the littoral zone habitat and dispersion within this area can be described as "clumped" or "contagious spatial distribution" (Pianka, 1978). Certain factors such as water depth, vegetation, and the presence of a log are important in the definition of newt habitat. This section examines the various factors which may affect adult and larval newt distribution within Gibson Lake.

Table 6 presents descriptions of the four most frequently used home sites in 1978. In all cases a partly or wholly submerged log was utilized as a home site. The log was never deeply embedded in the substrate, but was slightly elevated by debris lying underneath it. In every instance the water depth was less than 17 cm. In three of four home sites dense mats of pipewort (Eriocaulon septangulare) were closely associated with the log.

Water temperatures at the specific sites of all newt collections ranged between 63°F and 86°F with the mean being 73.1°F (95% CI:

Table 6. Comparison of four newt microhabitats in Gibson Lake, 1978.

Log Location	Log length/ circumference	Water depth	Surrounding vegetation	Mean temperature and 95% C.I. under log at time of newt capture	Log description	newt utilization of log
B5-7	127 cm/ 30 cm	2-10cm	pipewort borders log, but only a few roots under log	mean: 79.6 F C.I.: 77.2, 82.0 F n=5	3 sticks under log; substrate under log sandy with little sediment; knots on log hold it off the substrate; log partly on shore.	used by 5 individuals with 5 captures
B12-9,4	107 cm/ 40cm	5-17cm	thick mat of pipewort borders log, dense mat of pipewort roots under log	mean: 72.9 F C.I.: 71.4, 74.4 F n=52	3 sticks under log; substrate under log is sand and sediment; knots on log hold it off the substrate; log does not contact shore	used by 19 individuals with 52 captures
B15-2	66 cm/ 8 cm wide, 1.5 cm thick (slab)	10-17cm	thick mat of pipewort occurs around and under log, roots under log	mean: 75.5 F C.I.: 67.2, 83.8 F n=4	1 stick under log; substrate under log is sediment; stick and twigs hold slab off substrate; log is completely submerged	used by 4 individuals with 4 captures

Table 6. (cont'd.).

C23-5	320cm/ 7 cm wide, 2 cm thick (slab)	2-14cm	not in close association with pipewort, bur reed and water shield roots occur all around the slab	mean: 69.5 F C.I.: 61.2, 77.8 F n=4	several small sticks under log; substrate under log is sandy, but thick sediment occurs on all sides of log; slab does not rest heavily on the substrate; slab is completely submerged	used by 4 individuals with 4 captures

72.1, 74.1°F). Water temperatures of the four observed microhabitats taken at the time of newt collection can be seen in Table 6.

Home site B-12-9,4 was used by newts many more times than other home sites. This log had the greatest amount of pipewort growing around and underneath it. Reasons why this home site was preferred by newts are not apparent.

During 1978-1980, the population of newts in Gibson Lake was restricted to approximately 0.8 ha of the 32 ha lake (2.5% of total area). Six hours of snorkling and SCUBA diving were performed over 1978-1980 and no newts were observed outside of the littoral zone in the deeper vegetation-free areas of Gibson Lake.

In 1979, two of eleven quadrats examined had newt larvae. The means and standard deviations of the measurements on these quadrats are presented in the last column of Table 7. Mean values for percent vegetative cover, number of contacts per 50 cm depth, and number of plant species present are greater in newt larvae habitat than for random habitat, adult newt habitat and non-newt habitat. Because of the small sample size the strength of parametric statistical tests is reduced. Several differences existed between larval quadrats and adult newt quadrats. The mean depth of larval quadrats was significantly different than mean depth of adult quadrats using the Student's "t" test and 95% level of significance (Bhattacharyya and Johnson, 1977). Mean percent vegetative cover, number of plant stem contacts per 50 cm, and distance from shore are all significantly different between larval quadrats and adult quadrats when using the non-parametric Mann-Whitney test and 90% level of significance (Brower and

Table 7. Means, standard deviations, and 95% confidence intervals for measurements taken on Gibson Lake quadrats.

Variable measured in Quadrats	Random Quadrats (n=15)		Newt present Quadrats (n=5)		Newt absent Quadrats (n=10)		Newt larvae Quadrats (n=2)	
Mean depth (cm)	mean:	39.1	mean:	21.8	mean:	31.3	mean:	34.6
	sd:	18.0	sd:	2.3	sd:	14.5	sd:	1.6
	C.I.:	29.2-49.1	C.I.:	18.6-25.0	C.I.:	20.9-41.7		
Distance from shore (cm)	mean:	306.7	mean:	181.0	mean:	220.1	mean:	275.0
	sd:	162.4	sd:	15.2	sd:	146.1	sd:	106.1
	C.I.:	217.0-396.4	C.I.:	159.9-202.1	C.I.:	115.7-324.5		
Number of plant species present	mean:	4.9	mean:	5.4	mean:	5.2	mean:	5.5
	sd:	2.5	sd:	0.6	sd:	1.8	sd:	2.1
	C.I.:	3.5-6.3	C.I.:	4.6-6.2	C.I.:	3.9-6.5		
Number of stem contacts per 50 cm	mean:	21.0	mean:	23.1	mean:	17.9	mean:	38.6
	sd:	16.1	sd:	4.9	sd:	7.3	sd:	3.3
	C.I.:	12.1-29.9	C.I.:	16.3-29.9	C.I.:	12.7-23.1		
Percent vegetative cover	mean:	46.8	mean:	66.8	mean:	51.0	mean:	98.9
	sd:	35.7	sd:	12.3	sd:	25.3	sd:	1.8

Zar, 1977). Observationally, the amount of mud and organic debris is much greater in newt larvae quadrats than in adult quadrats.

These differences in habitat characteristics may help to separate the newt larvae and adults in the littoral zone and reduce potential competition for food between these two life stages. No analysis of larval stomach contents was performed, but Burton (1977) reports that Cladocera make up 35% by number and Chironomids make up 14% by number of food items ingested by newt larvae in Mirror Lake, New Hampshire. These are also very important items in the diet of Gibson Lake adult newts.

The presence of a log is essential to the definition of aquatic adult newt habitat. All adult newts found during diurnal collection periods in Gibson Lake were under logs. The following habitat analysis considers other factors that are important in describing aquatic adult newt habitat.

In factor analysis, two factors account for a total of 84% of the variation seen in the variables measured from Gibson Lake quadrats. Factor 1 which accounts for 59.6% of observed variation between quadrats is composed of the variables mean depth and distance from shore. Factor 2, percent cover and number of contacts, explains 25.2% of the variation (Table 8). Other factors contribute relatively little to the variation observed.

Factor 1 (mean depth - distance from shore) seems to be an important factor in the distribution of adult newts within Gibson Lake. Distance from shore and mean depth variables exhibit significantly less variation in newt quadrats than in either random or non-newt quadrats at 95% level of significance (F-test, Bhattacharyya and

Table 8. Contribution of factors to the observed variance in Gibson Lake quadrats.

Factor	Percent of variance accounted for by factor	Cumulative percent of variance
1	59.6	59.6
2	25.2	84.7
3	7.9	92.6
4	5.9	98.5
5	1.2	99.7
6	0.7	100.4
7	-0.4	100.0

Johnson, 1977). This can be seen in the small standard deviations and narrow confidence intervals of newt quadrats in Table 7.

Factor 2 (percent vegetative cover - number of contacts) is also an important factor in newt distribution within the lake. The values of percent vegetative cover and number of contacts in newt quadrats showed relatively little variation in comparison to the random and non-newt quadrats (Table 7), but this is not significant at the 95% level of significance (F-test, Bhattacharyya and Johnson, 1977).

Table 9 gives correlation coefficients for five variables measured from Gibson Lake littoral zone habitat. All correlations are significant at the 95% level of significance except for the correlation coefficient of distance from shore and number of contacts per 50 cm. Test of significance were taken from Bhattacharyya and Johnson (1977). In general, these "r" values suggest that as mean depth or distance from shore increases, the amount of vegetation as measured by percent cover and number of contacts per 50 cm, and number of plant species present decreases.

There is a strong positive correlation (r = 0.88) between percent vegetative cover and number of contacts per 50 cm, supporting the fact that these two variables both estimate the amount of vegetation present. Figure 16 shows a plot of data points of these two variables.

Positive correlation also exists between mean depth and distance from shore, as seen by the plot of data points in Figure 17.

The mean depth of newt habitat in 1979 is significantly greater than that observed in 1978. Gibson Lake water level was also higher

Table 9. Correlation coefficients between variables measured on Gibson Lake quadrats.

	Mean depth (cm)	Distance from shore (cm)	Number of plant species present	Number of stem contacts per 50 cm	Percent vegetative cover
Mean depth (cm)	+1.00				
Distance from shore (cm)	+0.85	+1.00			
Number of plant species present	-0.65	-0.62	+1.00		
Number of stem contacts per 50 cm	-0.44	-0.33	+0.61	+1.00	
Percent vegetative cover	-0.50	-0.37	+0.66	+0.88	+1.00

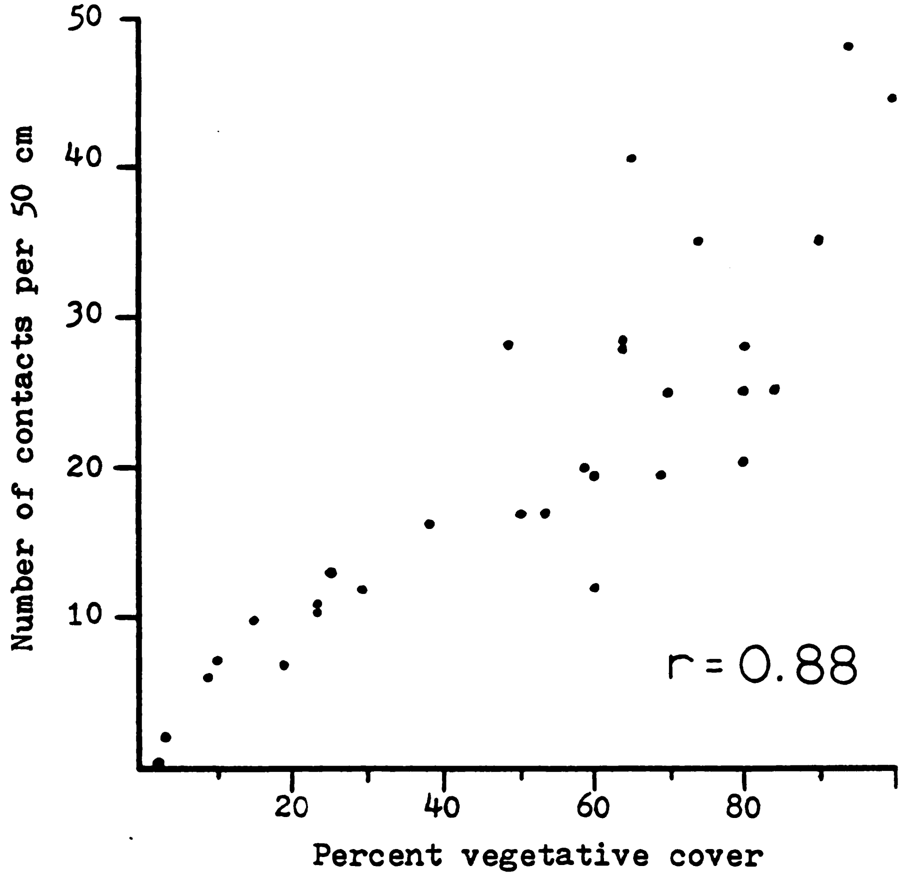


Figure 16. Relationship between number of plant stem contacts per 50 cm and percent vegetative cover in Gibson L. quadrats.

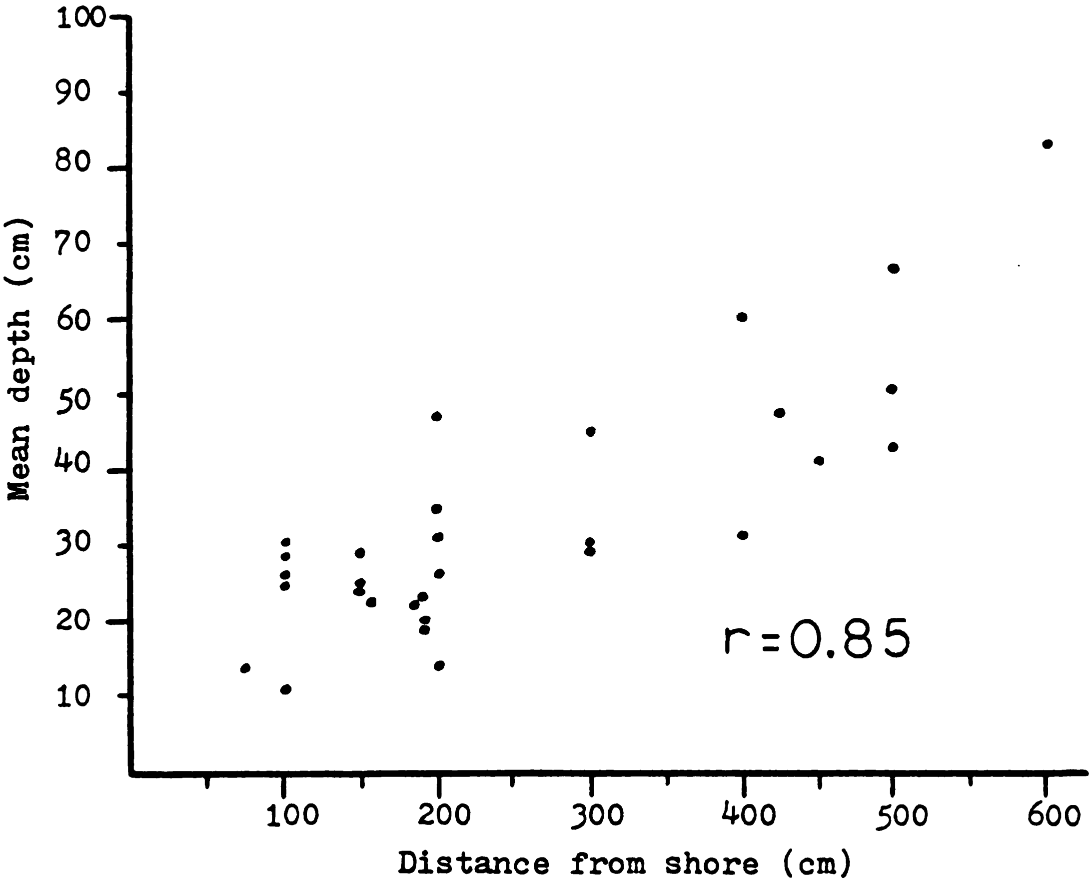


Figure 17. Relationship between quadrat mean depth and quadrat distance from shore.

in 1979. No quantitative measurements on amount of vegetation present were taken in 1978.

It is likely that newts were selecting home site habitat by a combination of preferred depth and amount of vegetation or that these factors contributed to the presence of the invertebrate fauna that newts consumed. The presence of logs was important for the cover they provided during the day. Other factors were likely to be involved as well. An alternate explanation for the 1978-1979 difference in newt habitat water depth is that the presence of a log or stick was the controlling factor for selection of home site and since this structure was relatively stable in the lake, newts sought out the logs in the littoral zone, regardless of depth. In 1979, since the lake level was up several centimeters, this may have elevated the mean depth where newts were found, although they actually occupied the same areas as the previous year.

The distribution of newts within Gibson Lake was restricted to the narrow peripheral littoral zone and seems to be correlated with the distribution of aquatic macrophytes within a depth range of 0-30 cm. Exceptions to the aquatic macrophyte correlation were several beds of Water shield that existed about 30 meters from shore in one to two meters of water to the southeast of the newt enclosure. No newts were observed in these areas. As discussed previously, Water shield provides little cover for newts on the substrate as most of the vegetative parts are floating on the surface.

In Mirror Lake, New Hampshire, Burton (1977) noted a high correlation between newts and the distribution of rooted macrophytes in water less than two meters deep. Bellis (1968) observed that the greatest abundance of newts occurred in weed beds of *Nitella spp.* in a small pond in Pennslyvania. Bennett (1970) reports low density of newts in the sandy periphery of Sandy Lake, New Hampshire, where no vascular vegetation exists and he reports an "extremely good" correlation between the distribution of high density newt area and that of weed beds of *Nitella spp.*

Bennett (1970) reported that newts were distributed in 7.2 - 7.6 hectares of a total 8.5 ha Sandy Lake. The one hectare area of unpopulated lake bottom was the deep central portion of the lake. Bennett (1970) suggests that newt absence from this area may be related to low temperatures that, although tolerable to newts, were not preferred by them. This explanation may be over-simplified. In Gibson Lake the center portion of the lake was also uninhabited by newts but unlike Sandy Lake, Gibson Lake showed very little thermal stratification so that summer temperature at the surface was only three or four degrees warmer than the bottom at the deepest point (72 - 68°F). Bennett later suggests that a combination of factors such as lack of vegetative cover, food, and dissolved oxygen mitigates against colonization of this deep area by newts. A combination of these factors and perhaps others seems a more reasonable explanation for newt distribution within a habitat.

Bennett (1970) cites Reese (1912) and Copeland (1913) in stating that vision is important in food capture to *N. viridescens* and he speculates that light levels may be too low at the bottom of the lake. Since newts do most of their feeding at night (at least in Gibson Lake) it seems that they would have the ability to operate in fairly low light levels. A test of this would be to determine the light intensity at the lake bottom during the day and the lake's periphery at night.

In 1979, because newt population size was small, newts may not have been forced into marginal habitats by intra-specific competition and the habitat they occupied may have been truly optimum.

Nocturnal Behavior

Observations of newts in 1978 indicated that nocturnal foraging habits take the newts away from the home site, but that they return to these home sites after foraging. During six observation periods in 1978 (7/13, 7/21, 7/23, 7/31, 8/1, 8/2) lasting from 2130 hours to 2230 hours newts that had been located under specific marked logs during the day could not be located. In each case, newts had returned to these logs by morning at 0700 hours. It was presumed that newts were foraging in the aquatic vegetation at night, although none were located. In order to insure that adult newts were not moving onto shore as has been observed by Hurlbert (1969), a five meter drift fence was constructed about one meter away from the water's edge partially encompassing a large log that was the home site for several newts. From 1 August to 10 August, 1978, no newts were caught in this drift fence.

At 1945 hours on 7 August, 1978, two unmarked newts were located under a log in the lake in approximately 15 cm of water. I carefully replaced the log and remained to observe when the newts would leave this cover. At 2100 hours, one newt came out from under the log and slowly walked along the substrate. At 2107 hours the second newt appeared. After 45 minutes of observation using a flash-light, both newts were still within 1.5 meters of the log. At this time observation was terminated. The next morning at 0700 hours, two newts were located under the log.

As observed in the summer of 1978, newts during 1979 remained under cover (logs) during daylight hours, but moved out to feed during darkness. Newts left their cover at the mean time of 2116 hours or 9:16 p.m. (n = 8 observations; 95% CI is between 2054 and 2139 hours). Newts terminated foraging and returned to cover between 0300 hours and 0400 hours (n = 10 observations). The newts observed left cover to forage just after darkness and stopped foraging and returned to cover just before dawn.

Newts moved very little while foraging. Two general feeding methods were observed: (1) the newt remained stationary and elevated a few centimeters off the substrate in vegetation while it picked off Cladocera and other swimming microfauna, (2) the newt slowly walked along frequently pausing for several minutes to nose vegetation and eat food items. A single individual would perform both sorts of foraging.

Foraging newts seldom surfaced for air. Three of five newts observed did not surface to breath for the duration of two hour periods, presumably having sufficient gas exchange via cutaneous respiration. The two other newts observed surface more frequently; one surfaced every 3½ minutes and the other every 14 minutes on the average.

The newts observed foraged within a restricted area and showed little variation in size of foraging areas. The foraging area was always in close proximity to the newt's home site. The mean area and 95% confidence interval for foraging area utilized was 0.49 m^2, 0.82 m^2, 1.15 m^2. Mean depth and 95% confidence interval for depth of the foraging area was 12.2 cm, 18.37 cm, 24.6 cm. The average percent of vegetative cover for the foraging area was 74%, but the variation for this measurement is quite high and the range of values went from 40% to 90%.

Table 10 lists measurements taken on foraging area for four individual newts. Grass, sedge, and pipewort are common in the shallow water around Gibson Lake's margin and they are also present in all four foraging areas.

The restricted foraging area coincides with the restricted diurnal home range determined for newts during 1978. The mean size of diurnal home range during 1978 was 2.48 m^2 (95% CI: 1.02 - 3.76 m^2). Considering that restricted nocturnal movements take place close to the home site, it seems that the diurnal home ranges determined in 1978 closely approximate the true home range of this species at Gibson Lake. Bellis (1968) also observed restricted home range in *N. viridescens*.

Table 10. Measurements taken on newt foraging area in Gibson Lake, 1979.

Sample number	Mean depth	Far point from shore	Near point from shore	Percent vegetative cover	Area	Plant species present
1	18.3cm	2.5 m	1.5 m	90%	0.98 m^2	pipewort, bur reed, grass, and sedge
2	16.1cm	2.0 m	1.0 m	65%	0.75 m^2	pipewort, grass, sedge
3	15.2cm	1.2 m	0.5 m	100%	0.56 m^2	pipewort, bur reed, grass, and sedge
4	23.9cm	2.0 m	1.0 m	40%	1.00 m^2	pipewort, grass, sedge

SUMMARY AND CONCLUSIONS

(1) A population of _Notophthalmus viridescens_ Rafinesque was studied in Gibson Lake, Iron County, Michigan, during the summer seasons of 1978, 1979, and 1980.

(2) Aspects of Gibson Lake newt life history were compared to other newt population studies. Individual home range, adult and larval newt distribution, nocturnal behavior, and adult newt food preference and possible fish competitors were examined.

(3) A terrestrial drift fence and aquatic drift fence with funnel traps were constructed to capture newts during 1979 and 1980. Adult newts were marked by toe-clipping, sexed, and measured. Adult newt stomach contents were obtained by stomach flushing and these were compared to the composition of Gibson Lake microfauna samples collected with a plankton net. Gibson Lake fish were caught by hook and line and in minnow traps and their stomach contents analyzed to determine overlap with newt diet. To determine diurnal home range, a grid system was established and individual newts were regularly located. Home range was calculated by connecting outside capture points with a line. Gibson Lake quadrats were measured for various habitat characteristics and these data were subjected to statistical analyses including Factor Analysis. Individual newts were followed at night by using a head lamp and their nocturnal foraging behavior observed.

Size, depth, and vegetation present were measured on the foraging area.

(4) Aquatic adult newts occurred in Gibson Lake during June, July and the first two weeks of August after which time adult newts migrated to land over a period of 30 days during August and early September. Sex ratio of adults was 1.44/1 (males/females).

(5) Newt larvae occurred in Gibson Lake from early June until mid-August after which larvae metamorphosed to efts and migrated to land. This migration period was short, occurring in less than seven days.

(6) Because of restricted newt home range, no statistical estimation of population size by mark-recapture methods was made. There was an apparent reduction in newt population over the three years of this study.

(7) Cladocera, benthic Oligochaetes and Dipteran larvae were important in the newt diet. Newts selected prey items that were most abundant in available lake microfauna with the exception of water mites and copepods. Yellow perch showed large overlap in diet with newts and may have been substantial competitors.

(8) Diurnal home range of newts ranged from 0.1 m^2 to 8 m^2 with mean size of 2.4 m^2 and median size of 1.3 m^2. Diurnal home sites of newts were invariably submerged logs.

(9) The newt population was restricted to 0.8 ha of the 32 ha lake. No newts were observed outside of the narrow peripheral littoral zone. Newts were never observed in water deeper than 30 cm.

(10) Mean depth, amount of vegetation, and distance from shore of newt larvae quadrats were significantly different than those of adult quadrats. This may have reduced competition between larvae and adults.

(11) Depth, amount of vegetation, and presence of a log were important characteristics in the definition of Gibson Lake adult newt habitat.

(12) Gibson Lake newts foraged at night during a period ranging from approximately 2116 hours to 0300-0400 hours. Newts foraged within a mean area of 0.82 m^2.

(13) Due to the restricted nocturnal range, the diurnal home range approximates the true home range of Notophthalmus viridescens in Gibson Lake.

LITERATURE CITED

LITERATURE CITED

Behre, E.H. 1953. Food of the salamander Triturus viridescens viridescens. Copeia 1953:60.

Bell, G. 1977. The life of the smooth newt (Triturus vulgaris) after metamorphosis. Ecol. Monogr. 47:279-299.

Bellis, E.D. 1968. Summer movement of red-spotted newts in a small pond. Journal of Herpetology 1(1-4):86-91.

Bennett, S.M. 1970. Homing, density and population dynamics in the adult newt, N. viridescens. Unpubl. PhD Thesis, Dartmouth College, Hanover, N.H.

Bhattacharyya, G.K. and R.A. Johnson. 1977. Statistical concepts and methods. John Wiley and Sons, New York, New York. 639 p.

Bishop, S.C. 1941. The salamanders of New York. New York State Museum Bulletin, University of the State of New York, No. 234. Albany, N.Y.

Bishop, S.C. 1943. Handbook of salamanders. Comstock Pub. Co., Ithaca. 555 p.

Brimley, C.S. 1921. The life history of the American newt. Copeia. 1921:31-32.

Brodie, E.D. Jr. 1968. Investigations of the skin toxin of Notophthalmus v. viridescens. Amer. Midl. Nat. 80:276-280.

Brower, J.E. and Jerrold H. Zar. 1977. Field and laboratory methods for general ecology. Wm. C. Brown Pub., Dubuque, Iowa. 185 p.

Burton, Thomas M. 1977. Population estimates, feeding habits and nutrient and energy relationships of N. v. viridescens in Mirror Lake, N.H. Copeia, No. 1: 139-143.

Chadwick, C.S. 1944. Observations on the life cycle of the common newt in western N. Carolina. Amer. Midl. Nat. 32:491-494.

Chadwick, C.S. 1950. Observations on the behavior of the larvae of the common American newt during metamorphosis. Amer. Midl. Nat. 43:392-398.

Conant, Roger. 1975. A Field Guide to Reptiles and Amphibians. Houghton Mifflin Company, Boston, Mass. 429 pp.

Copeland, M. 1913. The olfactory reactions of the spotted newt, Diemictylos viridescens (Raf.). J. Anim. Behav. 3:260-273.

Efford, I.E. and J.A. Mathias. 1969. A comparison of two salamander populations in Marion Lake, British Columbia. Copeia 1969: 723-735.

Fraser, D.F. 1976. Empirical evaluation of the hypothesis of food competition in salamanders of the salamanders of the genus Plethodon. Ecology 57(3):459-471.

Gage, S.H. 1891. Life-history of the vermillion-spotted newt. Amer. Nat. (December) 1084.

Gibbons, J.W. and D.H. Bennett. 1974. Determination of anuran terrestrial activity patterns by a draft fence method. Copeia 1974: 236-243.

Gill, D.E. 1978. The metapopulation ecology of the red-spotted newt, Notophthalmus viridescens (Rafinesque). Ecol. Monogr. 48:145-166.

Hamilton, Wm. J. Jr. 1932. The food and feeding habits of some eastern salamanders. Copeia (2) July 1, 83-86.

Hayne, D.W. 1949. Calculation of size of home range. Journal of Mammalogy 30(1):1-18.

Healy, W.R. 1966. The effect of alternative life histories on population structure in the common newt, Notophthalmus viridescens. PhD Thesis, University of Michigan, Ann Arbor, Michigan.

Healy, W.R. 1970. Reduction in neotony in Massachusetts populations of Notophthalmus viridescens. Copeia 1970:578-581.

Healy, W.R. 1973. Life history variation and growth of juvenile Notophthalmus viridescens from Massachusetts. Copeia 1973:641-647.

Healy, W.R. 1974. Population consequences of alternative life histories of Notophthalmus viridescens viridescens. Copeia 1974: 221-229.

Hurlbert, S.H. 1969. The breeding migrations and interhabitat wandering of the vermillion-spotted newt, Notophthalmus viridescens (Rafinesque). Ecol. Monogr. 39:465-488.

Hurlbert, S.H. 1968. The migrations and other interhabitat movements of Diemictylus viridescens (Raf.) in Dryden, New York. Ph.D. Thesis. Cornell University, Ithaca, N.Y.

Johnson, W.J.W. 1965. A zoogeographical analysis of the herpetofauna of northern Michigan and adjacent Isle Royale. Masters Thesis, Michigan State University, E. Lansing, MI.

Jordon, E.O. 1891. The spermatophores of Diemyctylus. Journal of Morphology 5:263-270.

Jordan, E.O. 1893. The habits and development of the newt Diemyctylus viridescens. J. Morphol. 8:269-366.

Kerfoot, W.C. Quantification of the distastefulness of aquatic mites for freshwater fish. Zooplankton Ecology. Third Special Symposium of the Society of Limnology and Oceanography. In Press.

Martoff, B.S. 1953. Territoriality in the green frog R. clamitans. Ecology 34(1):165-174.

Merritt, R.W. and K.W. Cummins. 1978. An introduction to the aquatic insects of North America. Kendall/Hunt Pub., Dubuque, Iowa. 441 p.

Mohr, C.O. 1947. Table of equivalent populations of North American small mammals. Amer. Midl. Nat. 37:223-249.

Monks, Sarah P. 1880. The spotted salamander. Amer. Nat. 15:371-374.

Moore, J.A. 1964. Physiology of the amphibia. Academic Press, New York. 654 p.

Morgan, A.H. and M.C. Grierson. 1932. Winter habits and yearly food consumption of adult spotted newts (Triturus viridescens). Ecology 13:54-62.

Noble, G.K. 1926. The Long Island newt: A contribution to the life history of Triturus viridescens. Amer. Mus. Novitates (228):1-11.

Noble, G.K. 1929. Further observations on the life history of the newt, Triturus viridescens. Amer. Mus. Novitates 348:1-22.

Pennak, R.W. 1953. Fresh-water invertebrates of the United States. Ronald Press Co., New York. 769 p.

Pianka, Eric R. 1978. Evolutionary Ecology. Harper and Row, Publishers, New York, N.Y. 397 p.

Pike, N. 1886. Some notes and the life history of the common newt. Amer. Nat. 20:17-25.

Pope, P.H. 1921. Some doubtful points in the life history of N. viridescens. Copeia 91:14-15.

Pope, P.H. 1924. The life history of the common water newt (N. viridescens), together with observations on the sense of smell. Annals of the Carnegie Museum. 15:305-368.

Reese, A.M. 1912. Food and chemical reactions of the spotted newt, Diemictylus viridescens. J. Animal Behavior 2:190-208.

Riessen, H.P. Diel vertical migration of pelagic water mites. Zooplankton Ecology, Third Special Symposium of the American Society of Limnology and Oceanography. In Press.

Ruthven, A.G., C. Thompson, and H.T. Gaige. 1928. The herpetology of Michigan. Publ. by University of Michigan in Michigan Handbook Series No. 3:15-19.

Smith, L. 1920. Some notes on Notophthalmus viridescens. Copeia 80:22-24.

Stein, K.F. 1938. Migration of Triturus viridescens. Copeia. 1938: 86-88.

Strickler, J.R. 1975. Swimming of planktonic Cyclops species (Copepods, Crustacea): Pattern, movements, and their controls. In Swimming and Flying in Nature, ed. Y.T. Wu, C.J. Brokaw and C. Brenner. Plenum Press, pp. 599-613.

Szlauer, L. 1965. The refuge ability of plankton animals before models of plankton eating animals. Polski Arch. Hydrobiol. 13:89-95.

Webster, D.A. 1960. Toxicity of the spotted newt, Notophthalmus viridescens, to trout. Copeia 1:74-75.

Wood, J.T. and O.K. Goodwin. 1954. Observations in the abundance, food, and feeding behavior of the newt (N. viridescens) in Virginia. J. Elisha Mitchell Sci. Soc. 70:27-30.