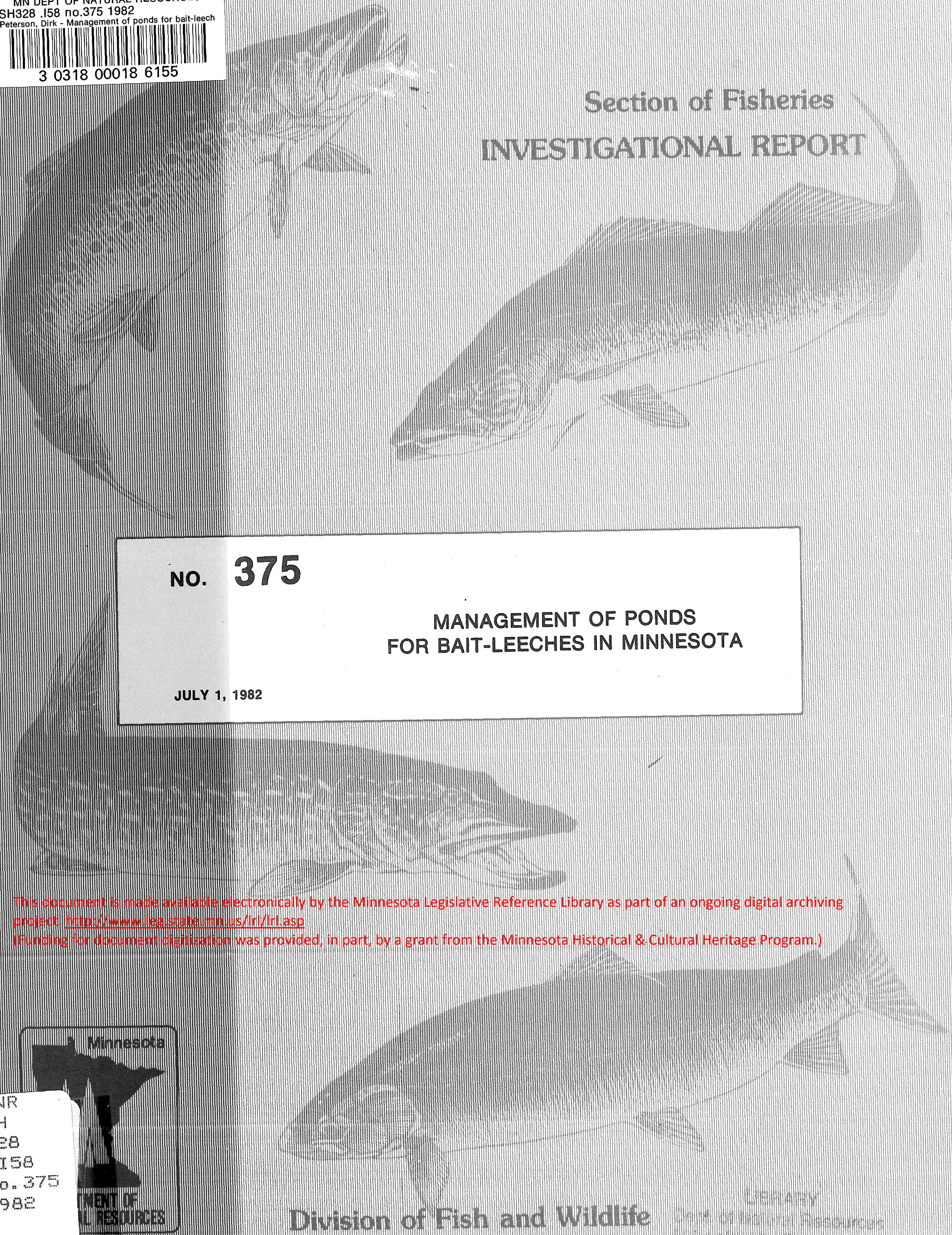

Section of Fisheries

INVESTIGATIONAL REPORT

NO. 375

MANAGEMENT OF PONDS FOR BAIT-LEECHES IN MINNESOTA

JULY 1, 1982

Minnesota
TMENT OF
AL RESOURCES

Division of Fish and Wildlife

MANAGEMENT OF PONDS FOR BAIT-LEECHES IN MINNESOTA[1/]

by

Dirk L. Peterson

ABSTRACT

Background information on the bait-leech, Nephelopsis obscura Verrill, was gathered from 10 permanent ponds in Otter Tail County in response to periodic leech shortages reported by Minnesota live bait dealers. Information concerning life history, ecology and experimental stocking were collected to develop methods for intensive pond culture.

N. obscura followed a 24-month life cycle in Priem's #1 Pond and Early's Pond. Clitellum development required an approximate minimum weight of 1.20 g and mature leeches died shortly after depositing cocoons on aquatic vegetation. The onset of maturity was related to rising water temperature and lengthening photoperiod. Cocoon deposition occurred at midsummer and was correlated to pond water temperatures. Seasonal depth movement of leeches was observed in Priem's #1 Pond but not in Early's Pond. Movement was attributed to oxygen depletion at lower depths during midsummer. Productive leech ponds were adjacent to agricultural or grazed lands, supported green algal blooms and had no fish species present except fathead minnows (Pimephales promelas). Stocking of juvenile leeches in commercially harvestable ponds to supplement natural populations was not found to be a practical management tool. Recommendations are made for management of leech ponds.

[1/] Completion Report, National Marine Fisheries Service Project 3-316-R.

INTRODUCTION

During the past 20 years the popularity of the bait-leech, *Nethelopsis obscura* Verrill, has steadily grown in Minnesota. Like other species of the Erpobdellidae, *N. obscura* is an excellent swimmer and will exhibit this attractive action when pierced by a hook. Minnesota live bait dealers annually harvest over 45,000 kg of bait-leeches having an estimated retail value of $1.5 million (Peterson and Hennagir 1980).

This study was initiated in response to periodic shortages of bait-leeches reported by leech harvesters. It appeared natural populations could not sustain current levels of harvest and that culture and improved management of this species was necessary to produce adequate if not stable supplies of this popular bait for the future. The purpose of this study was to gather background information on this species so methods could be developed for intensive culture in ponds.

Bait culture in Minnesota has a precedent in the rearing of white suckers (*Catostomus commersoni*) as bait (Dobie 1972). Pond culture of this species was developed with Minnesota Department of Natural Resources research in response to bait dealers' need for 10 to 15 cm bait-fish to meet demands in the late 1930's and early 1940's. Minnesota sucker raisers annually produce an average of 254,000 kg of bait-fish.

SITE DESCRIPTIONS

Ten ponds in northern Otter Tail County were selected for study with the aid of two experienced local leech harvesters (Table 1). These permanent ponds were located in the Bemis-Altamont-Gary terminal moraine system which is characterized by hundreds of lentic environments of all sizes and shapes (Schwartz and Thiel 1954). Study ponds ranged in area from 1.2 to 4.6 ha and varied in maximum depth from 1.0 to 6.3 m. Bottom soils of all study ponds were composed of muck and detritus overlying sand. Macrophytes were present throughout the basins of all ponds except Priem's #1 Pond and Kuhlmeyer's #2 Pond where plants were generally restricted to shoreline areas (Table 2). Ponds were selected on the basis of historical leech productivity.

The original intent was to locate ponds with and without N. obscura populations but this was not possible. Davies et al. (1977) reported similar problems in locating Erpobdella punctata Leidy populations without N. obscura in association. E. punctata and N. obscura are apparently cosmopolitan species in northwestern Minnesota ponds (Table 3).

Fathead minnows (Pimephales promelas) were present in Priem's #1 Pond, Early's Pond, Kuhlemeyer's #1 and #2 Ponds and Fudge's Pond. No other fish species were found.

METHODS

Leech populations were sampled once every four weeks with baited traps during ice free periods. Ten traps were evenly placed along the shoreline of each pond for an overnight set. An additional trapline transect was set at 0.6 m intervals to the deepwater hole of all ponds except Priem's #1 and #2 Ponds and Kuhlemeyer's #2 Pond where deepwater traps were set at 1.5 m intervals.

Minnesota leech trappers use a variety of trap designs so a trap with standardized dimensions was constructed for this project (Fig. 1). The standard trap consisted of a removable funnel-shaped throat attached to the open end of a metal can. The throat had a 10 mm opening and was made of plastic screening with 1 mm bar measure.

Leech vulnerability to standard traps depends on a species' ability to swim and the size of individual leeches. Species of the leech families Erpobdellidae and Hirudidae are good swimmers and are the most vulnerable to standard traps. Members of the Glossiphonidae do not swim or do so with great difficulty but occasionally appeared in traps.

N. obscura vulnerability to standard traps increases with heavier individuals of a population. Leach $\leq$ 0.07 g can pass through the throat mesh of the standard trap which partially accounts for the reduced vulnerability of the smallest weight-classes. The ability of larger leeches to swim greater distances/unit time or changes in diet preferences of older leeches are possible explanations for this vulnerability gradation.

Mean weights of leech generations derived from one trap-day samples are biased upwards because of leech size selectivity of standard traps. If successive trap-days are used to obtain a population sample, the resulting weight-class frequency will be positively skewed when compared to a one trap-day sample. These biases are more pronounced with relatively low leech populations and when a generation is not completely vulnerable to standard traps.

Each trap sample was sorted to species, individually counted and each species sample weighed to the nearest 0.1 g. *N. obscura* samples were combined and a random sample of 100 leeches were individually weighed to the nearest 0.01 g after removal of excess moisture. Each weighed leech was examined for the presence or absence of a clitellum as an indicator of maturity. The presence of *N. obscura* weight-classes not vulnerable to standard traps was verified during fall 1981 by washing vegetation raked from Priem's #1 Pond and Early's Pond. These leeches were weighed to the nearest 0.001 g.

As with other erpobdellids, *N. obscura* deposits eggs within cocoons that are attached to any firm substrate. The duration and intensity of cocoon deposition was monitored in two ways during open-water 1981. In Early's Pond and Priem's #1 Pond, ten floating boards (929 cm^2) were evenly placed along the shoreline and anchored in 1 m of water. Samplers were inspected once a week and the position and number of leech cocoons recorded. In Priem's #1 Pond, a randomly selected sample of 100 yellow waterlily leaves (_N. variegatum_) were inspected once a week and the number of cocoons found on each leaf recorded.

Four Ekman dredge samples (225 cm^2) were taken at randomly selected locations in each pond during May 1980. Macroinvertebrates found in each sample were classified to develop a qualitative list of potential prey for _N. obscura_.

Estimates of _N. obscura_ standing crop using the De Lury method (Everhart et al. 1975) were attempted by analyzing harvest data supplied by live bait dealers and by intensively harvesting selected study ponds in 1981. During both summers of the study, one pond was experimentally stocked with juvenile leeches and one pond was stocked with mature leeches. Assessment of stocking was done the following spring or fall depending on time of stocking.

Dissolved oxygen, pH, total alkalinity, chlorophyll _a_, Secchi disk visibility, temperature profile and water level fuctuation were measured bi-weekly during ice-free conditions. During ice cover dissolved oxygen, pH, carbon dioxide, ammonia and hydrogen sulfide were measured bi-weekly. Temperature, dissolved oxygen and Secchi disk visibility for Priem's #1 Pond and Early's Pond are shown in Figures 2, 3 and 4.

RESULTS

Life History of N. obscura

Standard trapping of six study ponds yielded leech population samples large enough to interpret details of N. obscura life history. Three ponds had sample sizes too small to interpret and Fudge's Pond was commercially harvested both summers which obscured details of life history. Priem's #1 Pond and Early's Pond were selected to describe the life history of N. obscura in permanent ponds of northwestern Minnesota.

Four generations of N. obscura were observed during the study. Leech generations were separated by collecting individual weights of leeches taken in standard traps and by noting the presence or absence of a clitellum as an indicator of maturity (Figs. 5, 6). Each generation was assigned a successive number (1 through 4) as it appeared during the study (Figs. 7,8).

Generation 1, in Priem's #1 Pond, had a mean weight of 1.41 g (0.48-2.93 g) on 8 May 1980 that increased to a mean weight of 1.83 g (0.50-3.26 g) on 5 June when 82% were clitellate. Following this peak, Generation 1 (mature leeches) declined in mean weight until postreproductive mortality was complete by 15 October. Lack of normal vigor and poor body condition were common characteristics of mature leeches examined on 23 July and 20 August.

Generation 2 was first taken in traps on 26 June 1980 at 0.37 g mean weight (0.23-0.57 g) and increased to a mean weight of 1.30 g (0.22-2.68 g) by 15 October. The overall catch-rate and percentage of larger leeches taken in standard traps had decreased by 12 November which caused a decline in mean weight in Generation 2 leeches.

Generation 2 apparently lost weight during ice cover. On 16 April 1981, this group had a mean weight of 1.21 g (0.14-3.05 g) and 3% were mature. Generation 2 grew and matured during May and June 1981 until 1.80 g mean weight (1.00-3.08 g) was attained on 1 July when 72.6% were clitellate. With the onset of postreproductive mortality, Generation 2 (mature leeches) declined in mean weight and disappeared from trap samples by 22 September. Many mature leeches trapped on 29 July and 26 August were of poor condition and similar to postreproductive Generation 1 leeches.

Generation 3 first appeared in traps on 4 June 1981 at 0.20 g mean weight (0.04-0.29 g) and grew to 0.65 g mean weight (0.22-0.95 g) by 1 July. This immature group had attained a mean weight of 1.53 g (0.10-2.67 g) on 21 October, the final sampling date for Priem's #1 Pond.

Generation 4 did not grow to a size vulnerable to standard traps before the study was terminated but was found by washing aquatic vegetation raked from Priem's #1 Pond. This group averaged 0.013 g in weight on 1 October

In Early's Pond, Generation 1 had a mean weight of 2.32 g (0.22-5.58 g) on 7 May 1980. This group attained maximum mean weight of 2.55 g (0.54-4.34 g) by 4 June when 97% were clitellate and then declined in mean weight until they disappeared from trap samples on 18 September.

Generation 2 was first taken in traps on 27 June 1980 at 0.47 g mean weight (0.06-0.96 g). Growth continued for this immature group until a mean weight of 1.17 g (0.02-4.16 g) was reached on 16 October. Generation 2 declined in mean weight just prior to ice cover (12 November) as in Priem's #1 Pond.

Generation 2 was at 1.04 g mean weight (0.24-3.90 g) on 15 April 1981 and apparently lost weight under ice cover. These leeches increased in percentage mature from 2.2% on 5 May to 59.5% on 2 July. Peak mean weight was attained by 3 June. Generation 2 then declined in mean weight until it was absent from trap samples on 27 August.

Generation 3 was first observed on 3 June 1981 at 0.12 g mean weight (0.05-0.19 g). This group grew to a mean weight of 0.59 g (0.05-1.99 g) on 23 September, the final sampling date for Early's Pond.

Generation 4 was not vulnerable to standard traps before the study was terminated but was sampled by washing aquatic vegetation raked from Early's Pond. This generation had a mean weight of 0.031 g on 1 October 1981.

N. obscura rarely used the wooden substrate samplers for attachment of cocoons in either pond but readily used the yellow waterlily leaves in Priem's #1 Pond. The rate of cocoon deposition rose rapidly following the initial observations on 18 May to a peak of 3.9 cocoons/leaf on 20 July (Fig. 9). Cocoon deposition declined to 0.1 cocoons/leaf by 21 September when observations were discontinued.

Peak cocoon deposition occurred shortly after Generation 2 was at maximum mean weight. Two immature leech generations were present in Priem's #1 Pond following the disappearance of mature Generation 2 leeches. Generation 4 was clearly the progeny of Generation 2; therefore, Generation 3 was the progeny of Generation 1. The relationships of leech generations in Priem's #1 Pond were also evident in Early's Pond.

Seasonal depth movement of *N. obscura* in Priem's #1 was investigated by noting the presence or absence of leeches in standard traps set along the shoreline and at 1.5 m contour intervals (Fig. 10). Population movement patterns were considered generalized instead of specific because the distance leeches travelled to a baited trap was not known. Seasonal depth movement patterns in Priem's #1 Pond were similar during both summers of the study. Leeches were trapped at all depths immediately following ice cover. Movement was generally inshore until midsummer when leeches were not trapped below the 3 m contour. Leeches were taken in traps at 4.5 m by September and were present in traps at all depths prior to ice cover.

In Early's Pond, patterns in seasonal depth movement were not detected at 0.6 m intervals by using traps. Leeches were generally taken in traps at all depths during both summers.

N. obscura productivity in study ponds

Relative productivity of *N. obscura* expressed as grams/lift was derived from standard trapping of study ponds (Table 4). This was an artificial system that encompassed two leech generations vulnerable to standard traps and assumed that traps did not compete with each other.

Review of leech harvest data (pounds/day) suggested harvest was intensive and the De Lury estimator of standing crop could be applied if the amount of effort were included. Although the study was intended to measure relative productivity, standing crop estimates provided quantitative "reference points" of leech productivity. Fudge's Pond was commercially harvested during 1980 and 1981 while Kuhlemeyer's #1 and #2 Ponds were commercially harvested during 1981 (Table 4).

De Lury estimates of standing crop were attempted on McDonald's Pond, Brown's Pond and Priem's #2 Pond immediately following ice cover. During April 1981, ponds were trapped with 25 traps/ha set along the shoreline of each pond. After seven days of intensive trapping, no significant drops in catch-rates were observed. Traps were removed from McDonald's Pond and Brown's Pond and effort was increased to 82 traps/ha in Priem's #2 Pond. An additional five days of increased effort did not induce the necessary drop in catch-rate and traps were removed from Priem's #2 Pond because of poor data correlation. Leeches were returned to the harvest sites following the intensive trapping period.

Physical Characteristics of Study Ponds

Below average rainfall fell on northwestern Minnesota during the study and as a result ponds lost water. Table 5 summarizes the changes in water level fluctuation of each pond. Maximum surface water temperatures of the study ponds ranged from 26 C to 28 C in 1980 and from 23 C to 28 C in 1981. Only Priem's #1 Pond thermally stratified each summer.

Chemical Characteristics of Study Ponds

Dissolved oxygen concentrations during ice-free periods were high at air-water interface of all study ponds. Only in the deepest ponds was oxygen depleted at lower depths during midsummer (Priem's #1 and #2 Ponds and Kuhlemeyer's #2 Pond).

Oxygen generally dropped below 1 mg/l during ice-cover periods and fathead minnows winterkilled when they were present. Oxygen did not fall below 2 mg/l at the surface in three ponds during the mild and dry winter of 1980-1981 (Priem's #1 and #2 Ponds and Kuhlemeyer's #1 Pond). The remaining ponds fluctuated in oxygen concentration during ice cover 1980-1981 as snow cover appeared and melted periodically. Study ponds were usually depleted of oxygen at the water-substrate interface during ice cover periods.

Undissociated hydrogen sulfide concentrations rose above the USEPA (1972) guideline of 0.002 mg/l for aquatic life in eight ponds during ice cover 1979-1980 and in four ponds during ice cover 1980-1981. Un-ionized ammonia and free carbon dioxide concentrations never rose above EPA guidelines for aquatic life during ice cover periods. Total alkalinity of the study ponds ranged from 85 to 180 mg/l.

Biological Characteristics of Study Ponds

Although a physical parameter, Secchi disk visibility was related to plankton density (Almazan and Boyd 1978). Because of shallow depths or low plankton densities, some study ponds had visibilities greater than maximum pond depths. Ponds where visibility data could be averaged are shown in Table 5.

Chlorophyll *a* concentrations were determined as an indicator of phytoplankton abundance (Dust and Shindala 1970). Average chlorophyll *a* concentrations ranged from 24.2 ppb (Kuhlemeyer's #2 Pond) to 1.1 ppb (Cazpewski's Pond) in 1980 and from 17.5 ppb (Brown's Pond) to 1.4 ppb (Priem's #2 Pond) in 1981. Chlorophyll *a* averages for each pond are found in Table 5.

A wide variety of macroinvertebrate taxa were found in dredge samples from study ponds. All ponds had species representing the Oligochaeta, Cladocera, Copepoda and Chironomidae. Most ponds had populations of Amphipoda, Anisoptera, Zygoptera, Ephemeroptera, Trichoptera and Gastropoda.

Experimental Stocking of *N. obscura*

Czapewski's Pond was stocked in August 1980 with approximately 2,500 juvenile *N. obscura* reared at the University of Minnesota at Duluth (UMD) leech hatchery facility [2/]. Before assessment of the stocking was attempted in May 1981, an employee of the harvester of this pond inadvertently

---

[2/] Development of a leech hatchery was originally a part of the project proposal for this study. Hatchery responsibilities were assumed by Dr. Hollie Collins at the University of Minnesota at Duluth under Sea Grant-Project R/A-1.

released 35-40 kg of subsaleable *N. obscura* into Czapewski's Pond that effectively masked any attempts at separation of stocked and resident populations

A former bass rearing pond at the Detroit Lakes Area Fisheries Headquarters was stocked in June 1980 and 1981 with 1500 sexually mature *N. obscura*. This pond was 0.8 ha, 1.0 m deep and had no resident *N. obscura* population. Assessment trapping (25 traps/ha) of this pond in May and September 1981 took no *N. obscura*.

Soo Pass Pond near the Detroit Lakes Area Fisheries Headquarters was stocked in September 1981 with 7,000-10,000 juvenile *N. obscura* reared at the UMD facility. This pond was 0.8 ha with a maximum depth of 1.2 m. Intensive trapping (49 traps/ha) in September yielded a De Lury estimate of 1.1 kg/ha on 1 September 1981 (r=0.89). No assessment of stocking was done in spring 1982.

DISCUSSION

Life History of N. obscura

Clitellum development of *N. obscura* in Minnesota required an approximate minimum weight of 1.20 g. Mature leeches < 1.20 g generally lacked normal vigor and had poor body condition. These leeches were considered postreproductive when observed following the maximum mean weight of a generation. Declining mean weights of mature leech generations were assumed to be the cumulative effect of weight loss from cocoon deposition and postreproductive mortality of larger leeches. Other investigators have drawn similar conclusions about weight loss of mature erpobdellids. Sawyer (1970, 1972) concluded that mean size decreases in respective mature populations of _E. punctata_ and _Mooreobdella bucera_ Moore were the results of energy expended during the reproductive season. Hartley (1962), in his study of _Trocheta subviridis_ Du Trochet, also observed a declining mean weight of mature leeches during summer. These leeches looked shriveled, did not appear later in the population and were considered senescent.

Pond water temperature in conjunction with minimum weight appeared to affect clitellum development and consequent cocoon deposition. During 1981, rising surface water temperatures were correlated to increasing percentages of mature Generation 2 leeches $\geq$ 1.20 g in Priem's #1 Pond (r=0.98) and Early's Pond (r=0.92). The warmer spring of 1980 and high percentage of Generation 1 leeches $\geq$ 1.20 g in both ponds likely contributed to the nearly complete maturation of both populations by June. In Priem's #1 Pond, rising surface water temperature was directly related to increasing cocoon deposition (r=0.88). The presence of immature leeches $\geq$ 1.20 g in August and September when the water was still warm suggested that the lengthening photoperiod may also influence the onset of maturity. During 1981, increasing percentages of mature leeches $\geq$ 1.20 g were correlated to lengthening photoperiod in Priem's #1 Pond (r=0.93) and Early's Pond (r=0.95).

Seasonal depth movement of _N. obscura_ in Priem's #1 Pond followed the rise and fall of pond water temperatures but also appeared related to midsummer oxygen depletion at lower depths. Priem's #1 Pond thermally stratified during midsummer and macrophytes were not found deeper than 3.0 m. In Early's Pond, seasonal depth movement was not detected with traps. A more suitable environment for leeches at all depths during summer was attributed to macrophyte growth at all depths, thermal homogeneity and greater wind aeration and circulation of this shallow pond.

Most investigators have reported finding erpobdellid cocoons attached to the surface of rocks and stones. In northwestern Minnesota, rocky substrates are usually not available for cocoon deposition because pond bottoms are primarily composed of muck and detritus overlying sand. Under these conditions, leeches affix cocoons to aquatic vegetation. Monitoring the duration and intensity of cocoon deposition on yellow waterlily leaves was enhanced by two phenomena. Macrophyte growth was restricted to the shoreline of Priem's #1 Pond because of basin shape and average plankton density that limited the penetration of light ($\bar{x}$ Secchi disk visibility = 64 cm). Secondly, inshore movement of leeches concentrated mature animals in vegetation. As a result, cocoon deposition was confined to a small percentage of the pond area.

N. obscura followed a 24-month life cycle in Priem's #1 Pond and Early's Pond. Methods used in this study did not identify leeches that may survive longer than 24 months. Mature leeches deposited eggs in cocoons during midsummer and eventually suffered postreproductive mortality. After hatching, leeches grew slowly and did not attain a size vulnerable to standard traps until June, the following spring. Growth continued until ice cover when mean weight decreases were observed. This occurred because heavier leeches appeared to be less vulnerable to standard traps as cold water temperatures depressed feeding behavior. No growth took place under the ice and apparently some weight loss occurred. Priem's #1 Pond and Early's Pond frequently undergo oxygen depletion during ice cover, especially at the water-substrate interface. Because leeches are primarily benthic organisms, it is speculated that *N. obscura* became dormant to withstand adverse winter conditions. When leeches became active in the spring following the second winter of life, growth continued until the appropriate weight and temperature were reached for clitellum development and cocoon deposition.

Variable erpobdellid life cycles have been reported for *Erpobdella octoculata* L. (Mann 1953; Elliot 1973; Aston and Brown 1975) and *E. punctata* (Sawyer 1970; Davies et al. 1977). In Minnesota, the 24-month life cycle of *N. obscura* contrasted distinctly with the life cycle in Alberta reported by Davies and Everett (1977). Their findings purported a spring and fall reproductive pulse when leeches reached 12 and 15 months or 12 and 19 months of age, depending on the time of cocoon deposition and when the appropriate breeding weight was attained (> 150 mg). Breeding in Alberta was not primarily correlated to pond water temperatures as in Minnesota. Although this was the common life cycle observed in Alberta, Davies (personal communication 1981) suggested possible expanded cycles of 15 and 22 months, 19 and 25 months or even longer life spans. These life cycle variations may partially account for differences in weight ranges cited in Davies and Everett (1977) (1-400 mg) and those observed in Minnesota (1-4,000 mg). However, various environmental conditions if not subtle taxonomic differences may influence the growth potential of this animal between Alberta and Minnesota.

The primary reason for reported shortages of saleable sizes of *N. obscura* in Minnesota appeared to be a natural function of leech life history. Following the collapse of a breeding generation, the succeeding generation did not become vulnerable to traps until June and generally did not reach saleable size until October or November. Overharvest may occur on a pond by pond basis but was not considered the principal reason for periodic leech shortages.

Ecology of *N. obscura*

Ponds supporting green algal blooms appeared to have higher relative productivity of *N. obscura*. Priem's #1 Pond and Kuhlemeyer's #2 Pond had the highest relative leech productivity during 1980 in association with low average visibility (greater plankton density) and relatively high chlorophyll *a* concentration (greater phytoplankton density). Ponds with green algal blooms probably produced more biomass of invertebrates than ponds where available nutrients were bound in dense crops of macrophytes (Bennett 1948; Boyd 1973; McVea and Boyd 1975). Because *N. obscura* is a scavenger and invertebrate predator, factors increasing invertebrate production likely affected leech production.

Literature review by Davies and Everett (1975) showed *N. obscura* fed on insect larvae, Oligochaeta, snails, carrion, "Gammari" and *Tabanus* spp. Prey-range experiments conducted by Davies and Everett (1975) added members of the Anisoptera, Chironomidae, Cladocera, Copepoda, *Gammarus lacustris*, *Helobdella stagnalis*, Mollusca, *N. obscura*, Ostrocoda, Oligochaeta, Zygoptera and other insects which included winged forms and larvae of other species. Using a serological technique to evaluate prey, Davies et al. (1978) reported Chironomidae, Gastropoda, Oligochaeta, Amphipoda and Copepoda-Cladocera in decreasing importance were eaten by *N. obscura* in three Alberta ponds. Sawyer (1974) asserted no other factor limited leech distribution more than availability of food organisms. This problem is more critical for leeches that are host-specific parasites but not nearly as crucial for *N. obscura* which have opportunistic feeding habits. Nearly all taxonomic groups cited as *N. obscura* prey were found in dredge samples taken in study ponds and the variety of taxa present in any single pond probably did not affect *N. obscura* distribution.

Green algal blooms were present in productive leech ponds because of basin shape and adjacent land use. Priem's #1 Pond and Fudge's Pond were next to agricultural lands while Kuhlemeyer's #1 and #2 Ponds were surrounded by cattle-grazed woodland that contributed to nutrient runoff. Priem's #2 Pond had a basin shape similar to Kuhlemeyer's #2 Pond but did not support a green algal bloom. This pond was surrounded by unused woodland that probably reduced nutrient loading from runoff (Boy 1976).

Ponds having higher relative leech productivity also supported fathead minnow populations. Study ponds typically experienced oxygen depletion during ice cover and winterkilled minnows were observed at water sampling holes in February and March. Held and Peterka (1974) studied fathead minnows in North Dakota saline lakes approximately 280 km W of Detroit Lakes and reported most spawning fish were one year old and few were two or three years old. Isaak (1961), as reported by Held and Peterka (1974), also observed that most spawning fathead minnows were one year old in Horseshoe Lake 160 km ESE of Detroit Lakes. If these examples represented fathead minnow age structures in study ponds, then annual winterkilling of minnows likely provided a readily available food for dormant leeches emerging in the spring.

Firm substrates like rocks and stones have been reported to be preferred over mud and sand by N. obscura for movement and cocoon deposition (Sapkarev 1968). Commercially harvestable densities of leeches are frequently found in northwestern Minnesota where pond bottoms are composed primarily of muck and detritus overlying sand. Like other erpobdellids, N. obscura is an excellent swimmer and can travel relatively long distances in search of food. Many authors have reported finding erpobdellid cocoons attached to rocks and stones but macrophytes were the primary available substrates in these study ponds. Minimum leaf or stem size was required for cocoon deposition. N. obscura cocoons were frequently found on leaves of yellow waterlilies (N. variegatum), white pond lilies (N. tuberosa), large-leafed pondweed (P. amplifolia) and claspingleaf pondweed (P. richardsoni). Cocoons were occasionally present on stems of stiff wapato (S. rigida), arrowhead (S. latifolia), softstem bullrush (S. validus), cattail (T. latifolia) and leaves of flatstem pondweed (P. zosteriformis). Cocoons were never observed on leaves or stems of coontail (C. demersum), water milfoil (M. exalbescens), stonewort (Nitella sp.), muskgrass (Chara sp.) or narrow-leaf pondweed (P. strictifolius).

Seasonal changes in dissolved oxygen concentrations at various depths were an important factor in the ecology of N. obscura in permanent ponds. Oxygen depletion at the air-water interface during ice cover was probably the cause of elimination of fish as leech predators in ponds. The plethora of small ice block basins without connecting waterways in northwestern Minnesota may also have limited fish distribution. Absence of fish, other than minnows, that may prey on leeches likely allowed for increased leech density. To survive oxygen depletion and toxic accumulation of sulfides at the water-substrate interface during ice cover, it was speculated N. obscura became dormant. Trapping data from Early's Pond and Priem's #1 Pond indicated weight-loss during ice cover but the mortality occurring because of severe winter conditions was not known. Many leeches can survive considerable dessication in temporary ponds or streams by burrowing into damp soil and forming mucus-lined tunnels or cavities (Hall 1922). N. obscura may have used pond bottom soils as insulation from severe winter conditions.

Water level fluctuation may have adversely affected ponds with commercially harvestable N. obscura populations. Czapewski's Pond and Sazama's Pond froze into the bottom in February 1981 and both ponds froze into the bottom in January 1982. Leech populations may have been partially destroyed by ice penetration into pond bottom soils.

Use of De Lury Estimator for N. obscura

Using the De Lury method to estimate standing crop of *N. obscura* in permanent ponds appeared to have the best application during May. Estimates calculated from harvest data from Fudge's Pond (1980) and Kuhlemeyer's #1 and #2 Pond had the best correlation of data and were attributed to warm water temperatures (> 13 C). Poor correlation of data from McDonald's Pond, Brown's Pond and Priem's #2 Pond in 1981 was ascribed to cold water temperatures that never rose above 10 C during the intensive trapping period. Cold water temperatures apparently depressed feeding behavior and reduced leech movement. In conjunction with elevated pond temperatures in May, compared to April when ice cover melts, only one generation of leeches was vulnerable to standard traps. These leeches represented saleable sizes and would thus provide the most meaningful De Lury estimate.

Experimental Stocking of N. obscura

Stocking of juvenile leeches in Czapewski's Pond was unsuccessful in part because of the inadvertent stocking of subsaleable leeches from other harvest sites. Because details of vulnerability of juvenile leeches to standard traps were not fully known until 1981, it seemed likely stocked juveniles were of the same weight-classes as the natural reproduction of the resident population. Complete vulnerability of both juvenile groups would not have occurred until September or October 1981 and weight-class separation of stocked and resident immature leeches seemed improbable. Assessment of juvenile leech stocking in Soo Pass Pond was not attempted for similar reasons cited for Czapewski's Pond. Although the standing crop estimate of the vulnerable leech generation was significant, stocked juveniles were likely the same weight-classes as the nonvulnerable natural reproduction in the pond. Weight-class separation of the two stocks would have been unlikely in spring to fall 1982 as leeches increased in vulnerability to standard traps.

Unsuccessful attempts at establishing leech populations in the former bass-rearing pond was probably because of water-level functuation. During the study, water level was reduced to where ice penetrated bottom soils during the winter which possibly destroyed any reproduction from stocked mature leeches.

Considering the magnitude of standing crop estimates and the difficulty in evaluating stocked individuals, it appeared stocking of hatchery-reared juveniles to supplement natural populations was not a practical management technique for commercially acceptable ponds. Intensive management of commercially harvestable ponds through other techniques is likely more practical.

RECOMMENDATIONS FOR MANAGEMENT OF LEECH PONDS

The goal of a leech pond manager is to maximize production of saleable size leeches on a sustained basis year after year. Although some results of this study are preliminary and further research is needed, the following recommendations are suggested for management of leech ponds:

1. <u>Selection of ponds</u> - Good leech ponds should maintain a minimal maximum depth of four to five feet. Shallower ponds may produce larger sized leeches in years of high water but can be subject to critical fluctuations in water level. Ponds with green algal blooms that have no fish species present except minnows tend to be better producers of leeches

(pounds/acre). Leeches, in general, benefit in growth from some organic enrichment (Sawyer 1974; Aston and Brown 1975) and consequently ponds adjacent to agricultural or grazed lands produce more pounds of leeches than ponds surrounded by woodland. Ponds with soft or loose bottoms should also have some large-leafed plants to serve as substrates for cocoon deposition. Rocks and submerged plastic tiles can also serve this purpose (Aston and Brown 1975).

2. Leasing of ponds - If a pond is not owned, long-term leases of three to five years or longer should be negotiated with the landowner. Benefits realized from intensive pond management can only occur if a live bait dealer controls the harvest and manipulation of a leech population. Long-term leasing of ponds can reduce the average rent paid and minimize annual bidding with other live bait dealers for known commercially harvestable ponds.

3. Selection of gear - Leech trappers use a variety of gear but some trap designs are more efficient in harvest than others. In an experiment conducted in 1980, standard traps used in this study were found to harvest 25% more by weight than cans with the open end compressed. The effectiveness in harvest of other trap designs is not known.

4. Maintenance of harvest records - Maintain accurate records of leech harvest from ponds that are leased or owned. Harvest records should minimally include date, pounds harvested and number of traps used. From this information gross annual production (pounds/year) and De Lury estimates of standing crop (pounds/acre) may be calculated. The live bait dealer can observe trends in production and adjust annual harvest until sustained yield is approached.

5. Separation of grade-sizes - Subsaleable sizes of leeches can

represent varying percentages of harvest and are frequently wasted or released into lakes or streams where recapture is not practical. Subsaleable leeches can be managed in the following ways:

a. Return subsaleable leeches to the harvest site for continued growth and additional cocoon deposition.

b. Stock subsaleable leeches in small (< 2 acres) shallow (< 3 feet deep) ponds for continued growth and harvest when saleable size is reached.

c. Feed subsaleable leeches artificially prepared diets in controlled environments until saleable size is attained under criteria developed at the University of Minnesota-Duluth. For further information contact:

Dr. Hollie Collins
Department of Biology
University of Minnesota-Duluth
Duluth, Minnesota

AREAS FOR FUTURE RESEARCH

Development of a commercially acceptable mechanical grading system for separation of leech grade-sizes is the fundamental problem facing the leech industry. To maximize production from harvested stocks, efficient separation of subsaleable weight-classes is necessary to implement extensive and intensive culture methods. If leech grade-sizes could be easily separated, live bait dealers could command appropriate prices for refined products and the angler would get what he pays for.

Evaluation of growth of subsaleable leeches in small shallow ponds requires investigation. A few leech harvesters are presently stocking small private ponds with subsaleable leeches and harvesting saleable sizes later in summer with some success. Research regarding stocking rates versus grade-size is necessary to determine what combinations will yield saleable sizes at desired times.

Determining the range leeches travel to baited traps relative to different baits at various temperatures is suggested. Knowing the minimum number of traps necessary to trap a pond would result in time and material saving benefits.

An electrophoretic study comparing N. obscura from Alberta and Minnesota might elucidate differences in weight ranges from the two geographic areas. If bait-leech culture is to expand to other areas, strains of N. obscura that attain heavier weights would have to be secured to initiate viable culture efforts.

LITERATURE CITED

Almazan, G., and C.E. Boyd. 1978. An evaluation of Secchi disk visibility for estimating plankton density in fish ponds. Hydrobiologia 65: 601-608.

Aston, R.J., and D.J.A. Brown. 1975. Local and seasonal variations in populations of the leech *Erpobdella octoculata* L. in a polluted river warmed by condenser effluents. Hydrobiologia 47: 347-366.

Bennett, G.W. 1948. The bass-bluegill combination in a small artificial lake. Illinois Nat. Hist. Surv. Bull. 24: 377-412.

Boyd, C.E. 1973. Summer algae communities and primary productivity in fish ponds. Hydrobiologia 41: 357-390.

______________. 1976. Water chemistry and plankton in unfertilized ponds in pastures and in woods. Trans. Am. Fish. Soc. 105: 634-636.

Davies, R.W., and R.P. Everett. 1975. The feeding of four freshwater Hirudinoidea in Southern Alberta. Verh. Int. Ver. Limnol. 19: 2816-2827.

______________________________. 1977. The life history, growth, and age structure of *Nephelopsis obscura* Verrill, 1872; (Hirudinoidea) in Alberta. Can. J. Zool. 55: 620-627.

Davies, R.W., Reynoldson, T.B., and R.P. Everett. 1977. Reproductive strategies of *Erpobdella punctata* (Hirudinoidea) in two temporary ponds. Oikos 29: 313-319.

________________, Wrona, F.J., and R.P. Everett. 1978. A serological study of prey selection by *Nephelopsis obscura* Verrill (Hirudinoidea). Can. J. Zool. 56: 587-591.

Dobie, J. 1972. Rearing suckers for bait in Minnesota. Minn. Dept. Nat. Res., Sect. of Fish., Div. Fish and Wildl. Investig. Rpt. No. 256. pp 1-34.

Dust, J.V., and A. Shindala. 1970. Relationship of chlorophyll *a* to algal count and classification in oxidation ponds. J. of Water Poll. Control Fed. 42: 1362-1369.

Elliot, J.M. 1973. The life cycle and production of the leech *Erpobdella octoculata* L. (Hirudinea: Erpobdellidae) in a Lake District stream. J. Anim. Ecol. 42: 435-448.

Everhart, H.W., Eipper, A.W., and W.D. Youngs. 1975. Principles of fishery science. Cornell Univ. Press, Ithaca, New York. pp 94-97.

Hall, F.G. 1922. The vital limits of exsiccation of certain animals. Biol. Bull. Mar. Biol. Lab., Woods Hole. 42: 31-51.

Hartley, J.C. 1962. The life history of Trocheta subviridis Du Trochet. J. Anim. Ecol. 31: 519-524.

Held, J.W., and J.J. Peterka. 1974. Age, growth, and food habits of the fathead minnow, Pimephales promelas, in North Dakota saline lakes. Trans. Am. Fish. Soc. 103: 743-756.

Isaak, D. 1961. The ecological life history of the fathead minnow, Pimephales promelas (Rafinesque). Ph.D. Thesis, Univ. Minnesota, 150 p. Microfilm 61-4598, Ann Arbor, Michigan.

Klemm, D.J. 1972. Freshwater leeches (Annelida: Hirudinea) of North America. Environmental Protection Agency, U.S. Government Printing Office, Washington, D.C. pp. 1-53.

Mann, K.H. 1953. The life history of Erpobdella octoculata L.J. Anim. Ecol. 22: 197-207.

McVea, C., and C.E. Boyd. 1975. Effects of water hyacinth cover on water chemistry, phytoplankton, and fish in ponds. J. of Environ. Qual. 4: 375-378.

Peterson, D.L., and F.A. Hennagir, 1980. Minnesota live bait industry assessment study. Minn. Dept. Nat. Res., Div. Fish and Wildl, Sect. of Fish. Investig. Rept. No. 367. pp. 1-75.

Sapkarev, J.A. 1968. The taxonomy and ecology of leeches (Hirudinea) of Lake Mendota, Wisconsin. Wisc. Acad. Sci. Arts Lett. 56: 225-253.

Sawyer, R.T. 1970. Observations on the natural history and behavior of Erpobdella punctata Leidy (Annelida: Hirudinea). Am. Midl. Nat. 83: 65-80.

________________. 1972. North American freshwater leeches, exclusive of the Pisicicolidae, with a key to all species. University of Illinois Press, Urbana. pp. 1-155.

________________. 1974. Leeches (Annelida: Hirudinea). Pages 81-142 in C.W. Hart and S.L.H. Fuller, eds. Pollution ecology of freshwater invertebrates. Academic Press, New York.

Schwartz, G.M. and G.A. Thiel. 1954. Minnesota's rocks and waters: a geological story. Univ. of Minn. Press, Minneapolis. 366 pp.

United States Environmental Protection Agency. 1972. Water quality criteria. U.S. Government Printing Office, Washington, D.C. pp 139, 186-187, 191-193.

Table 1. Surface area, maximum depth and mean depth of study ponds.

Pond	Area (ha)	Maximum depth (m)	Mean depth (m)
Priem's #1	4.6	6.3	3.2
Priem's #2	1.2	3.7	1.2
Early's	2.5	2.0	1.0
Kuhlemeyer's #1	2.2	1.8	0.9
Kuhlemeyer's #2	1.5	3.4	1.3
McDonald's	2.6	1.8	0.8
Brown's	3.3	2.1	0.8
Czapewski's	2.2	1.1	0.5
Sazama's	4.0	1.0	0.5
Fudge's	3.7	1.8	1.2

Table 2. Macrophytes found in each study pond.

Vegetation	Pond									
	Priem's #1	Priem's #2	Early's	Kuhlemeyer's #1	Kuhlemeyer's #2	McDonald's	Brown's	Czapewski's	Sazama's	Fudge's
Emergent Plants										
Sagittaria latifolia	X									
Sagittaria rigida					X		X		X	X
Typha latifolia	X	X	X	X		X			X	X
Scirpus validus	X		X	X			X	X	X	X
Eleocharis palustris						X		X	X	
Zizania aquatica				X						X
Floating and Submerged Plants										
Potamogeton amplifolia	X									
Potamogeton zosteriformis			X	X	X			X		X
Potamogeton Richardsonii	X									
Potamogeton Friesii						X				
Myriophyllum exalbescens						X		X	X	X
Ceratophyllum demersum	X	X	X	X		X	X	X	X	
Nymphaea tuberosa							X			
Nuphar variegatum	X				X					X
Utricularia intermedia	X				X					
Nitella sp.				X	X				X	X

Table 3. Leech species found in each study pond [a/].

Leech Species Present	Priem's #1	Priem's #2	Early's	Kuhlemeyer's #1	Kuhlemeyer's #2	McDonald's	Brown's	Czapewski's	Sazama's	Fudge's
Erpobdellidae										
Nephelopsis obscura Verrill	X	X	X	X	X	X	X	X	X	X
Erpobdella punctata Leidy	X	X	X	X	X	X	X	X	X	X
Hirudidae										
Percymoorensis marmoratis Say	X	X	X	X			X	X	X	X
Bdellarogatis plumbea Moore				X						
Mollibcella grandis Verrill	X		X							
Macrobdella decora Say	X	X	X	X	X	X	X	X		X
Glossiphonidae										
Helobdella stagnalis Linnaeus	X		X	X	X	X	X	X	X	X
Glossiphonia complanata Linnaeus	X	X	X	X	X		X	X	X	X
Placobdella hollensis Whitman	X	X	X	X	X		X	X		X
Placobdella parasitica Say	X		X	X	X		X	X		
Placobdella pediculata Hemmingway			X							X
Actinobdella inequiannulata Moore			X							
Theromyzon rude Baird		X	X		X					
Theromyzon macedosum Rathke	X									

[a/] Leech nomenclature used is found in Klemm (1972).

Table 4. *Nephelopsis obscura* productivity in study ponds.

Pond	Relative productivity (g/lift) 1980	1981	De Lury estimate [a] (kg/ha) 1980	1981
Priem's #1	68.3	75.5	-	-
Priem's #2	1.1	2.3	-	-
Early's	41.2	35.1	-	-
Kuhlemeyer's #1	37.4	-	-	261.7 (r=0.79, 17 May)
Kuhlemeyer's $2	58.2	-	-	473.0 (r=0.39, 17 May)
McDonald's	10.3	8.0	-	-
Brown's	20.1	38.5	-	-
Czapewski's	24.6	Data not usable	-	-
Sazama's	4.0	Data not usable	-	-
Fudge's	-	-	112.0 (r=0.95, 15 April)	

[a] Breeding generation of leeches.

Table 5. Net changes in water level fluctuation, mean visibility and mean chlorophyll a concentrations in study ponds.

Pond	Changes water level fluctuation (cm)		$\overline{X}$ visibility (cm)		$\overline{X}$ chlorophyll a (ppb)	
	1980	1981	1980	1981	1980	1981
Priem's #1	-39	-58	79	64	15.6	9.9
Priem's #2	-71	-126	207	-	3.2	1.4
Early's	-36	-50	-	-	8.6	4.1
Kuhlemeyer's #1	-34	-67	-	63	16.7	5.3
Kuhlemeyer's #2	-63	-116	22	45	24.2	5.7
McDonald's	-24	-30	-	-	10.9	11.0
Brown's	-53	-101	-	-	23.9	17.5
Czapewski's	-22	-51	-	-	1.1	1.5
Sazama's	-27	-57	-	-	4.1	5.2
Fudge's	-22	-38	20	46	15.1	6.2

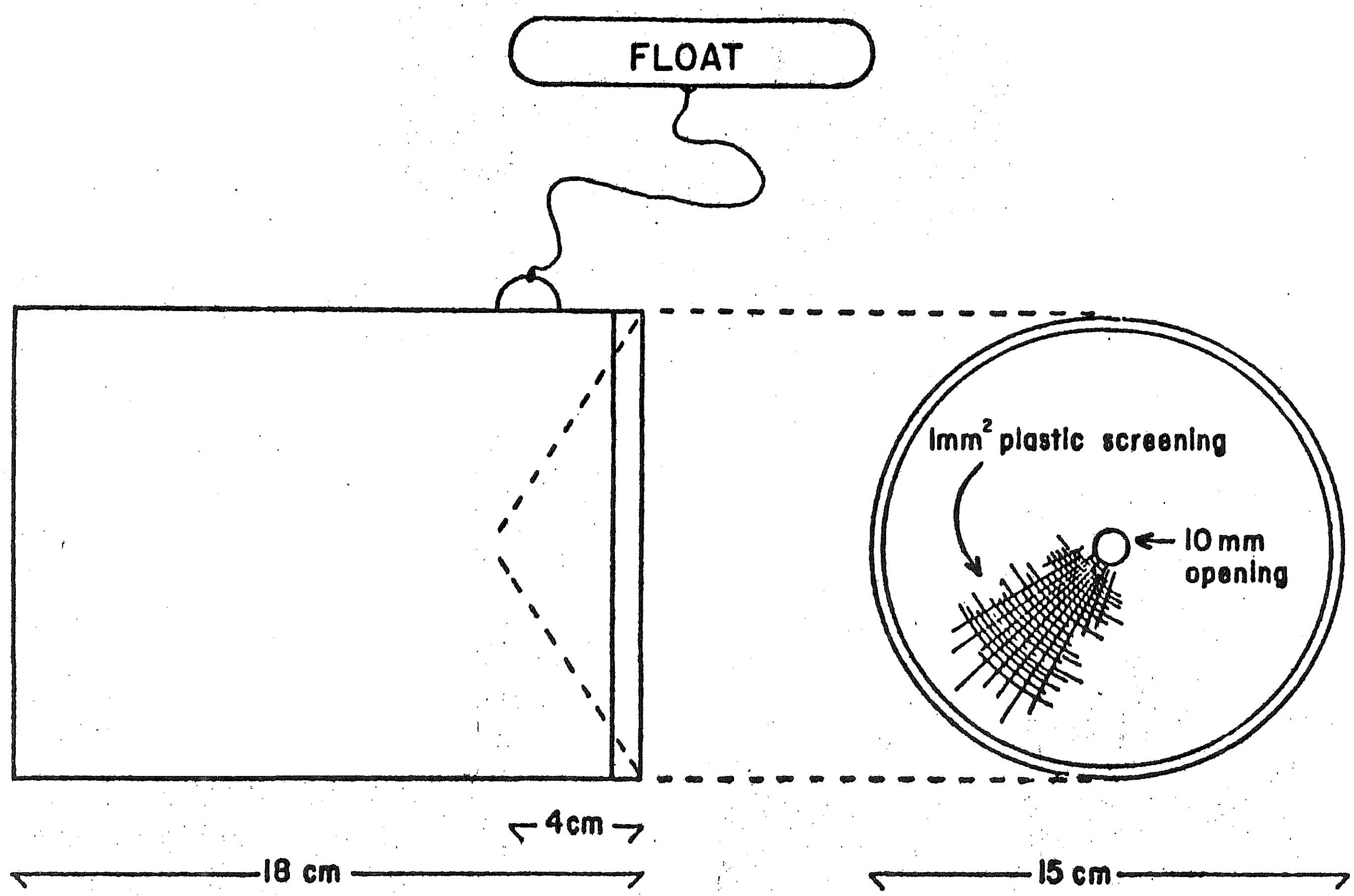

Figure 1. Standardized leech trap.

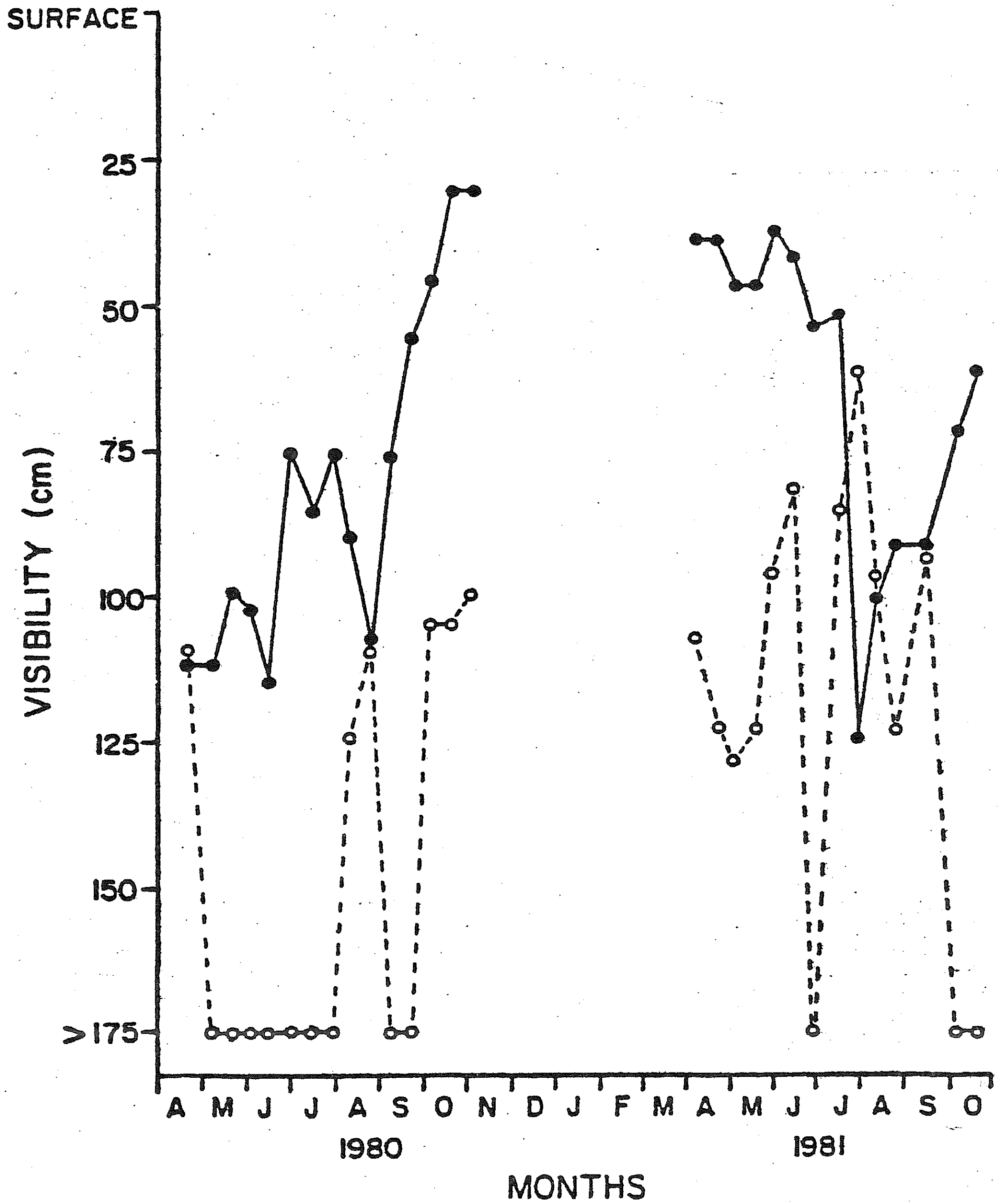

Figure 2. Secchi disk visibility (cm) in Priem's Pond (solid circles) and Early's Pond (open circles).

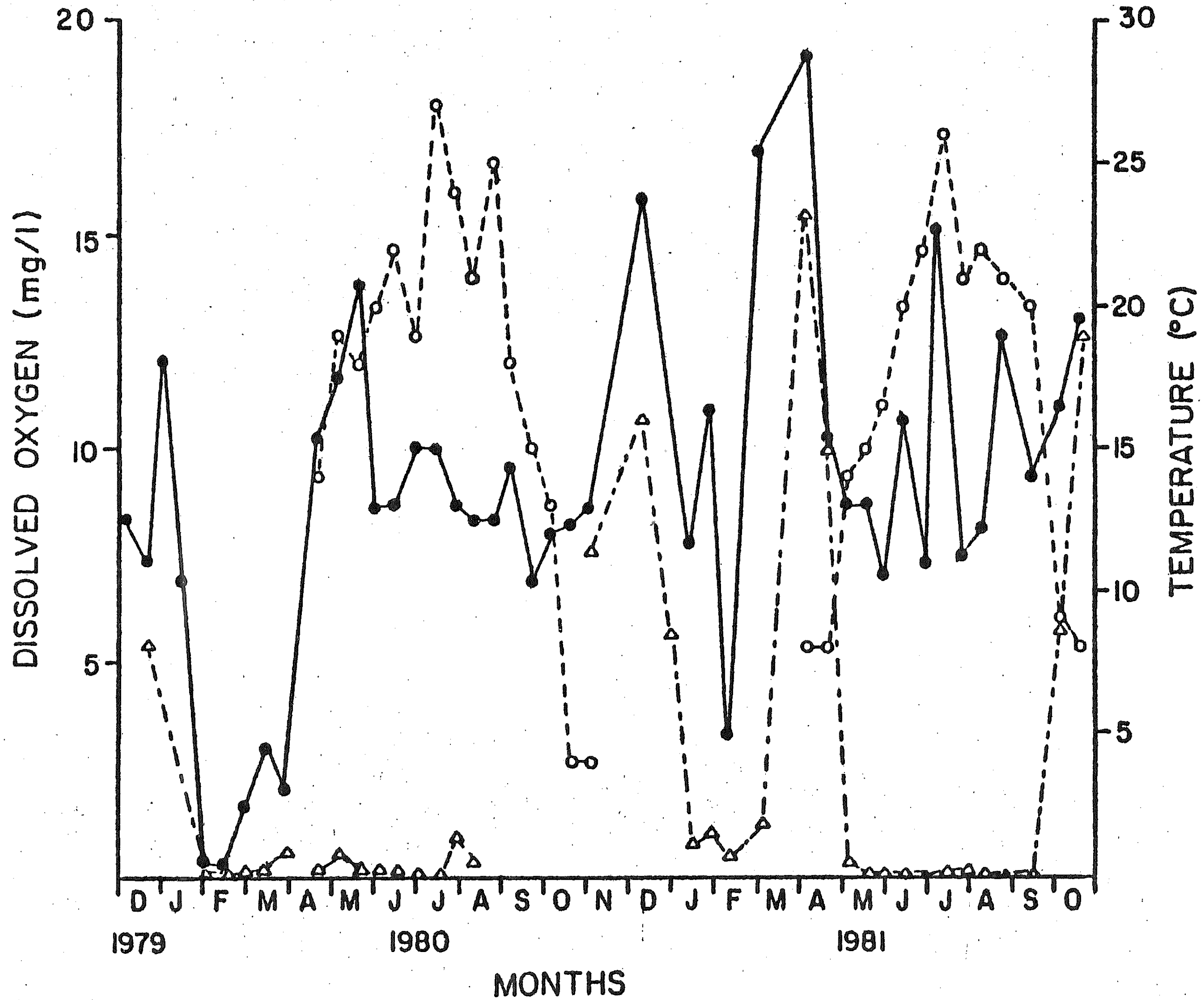

Figure 3. Dissolved oxygen (solid circles) and temperature (open circles) at the surface of Priem's #1 Pond. Triangles are dissolved oxygen at 4.5 m.

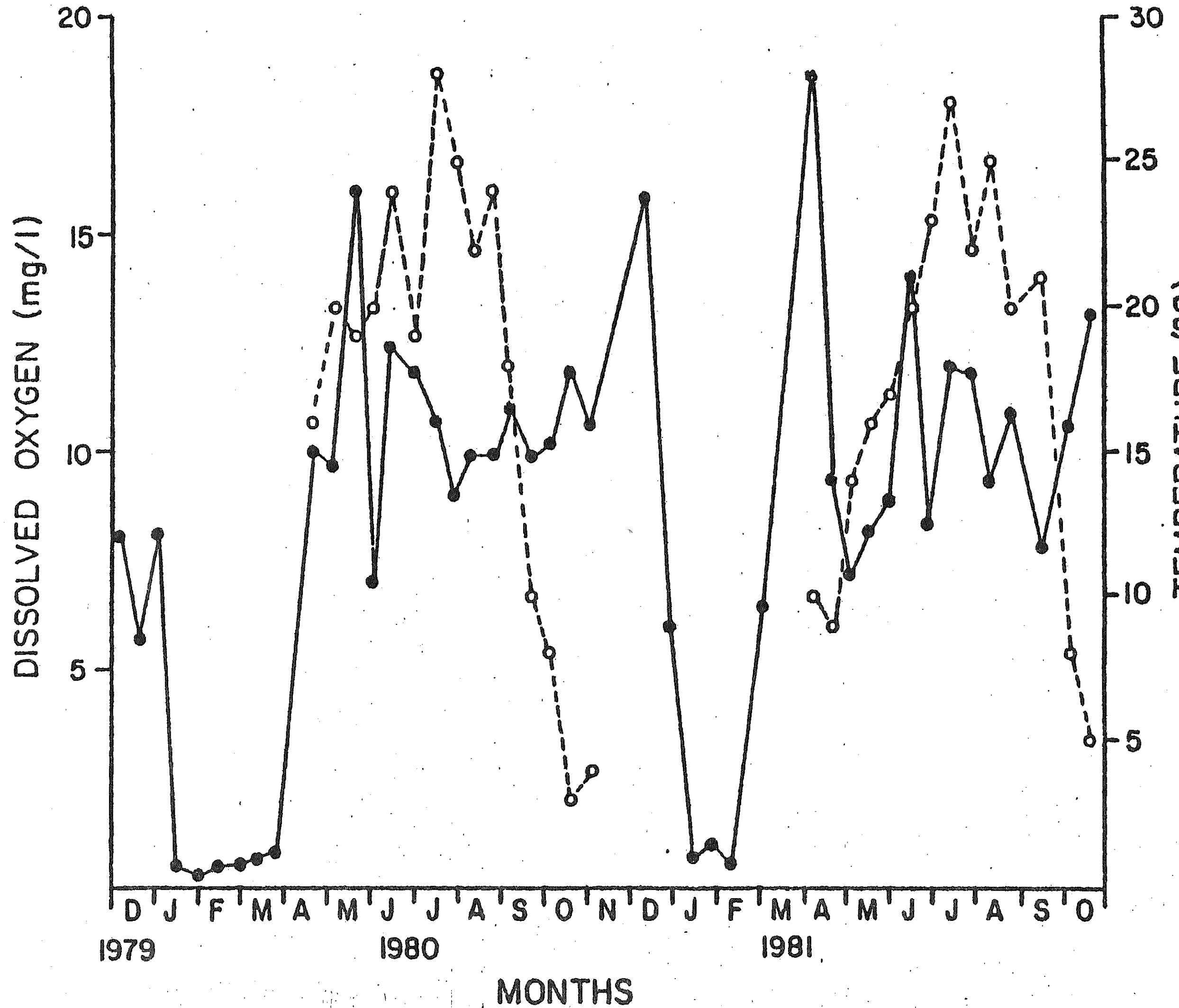

Figure 4. Dissolved oxygen (solid circles) and temperature (open circles) at the surface of Early's Pond.

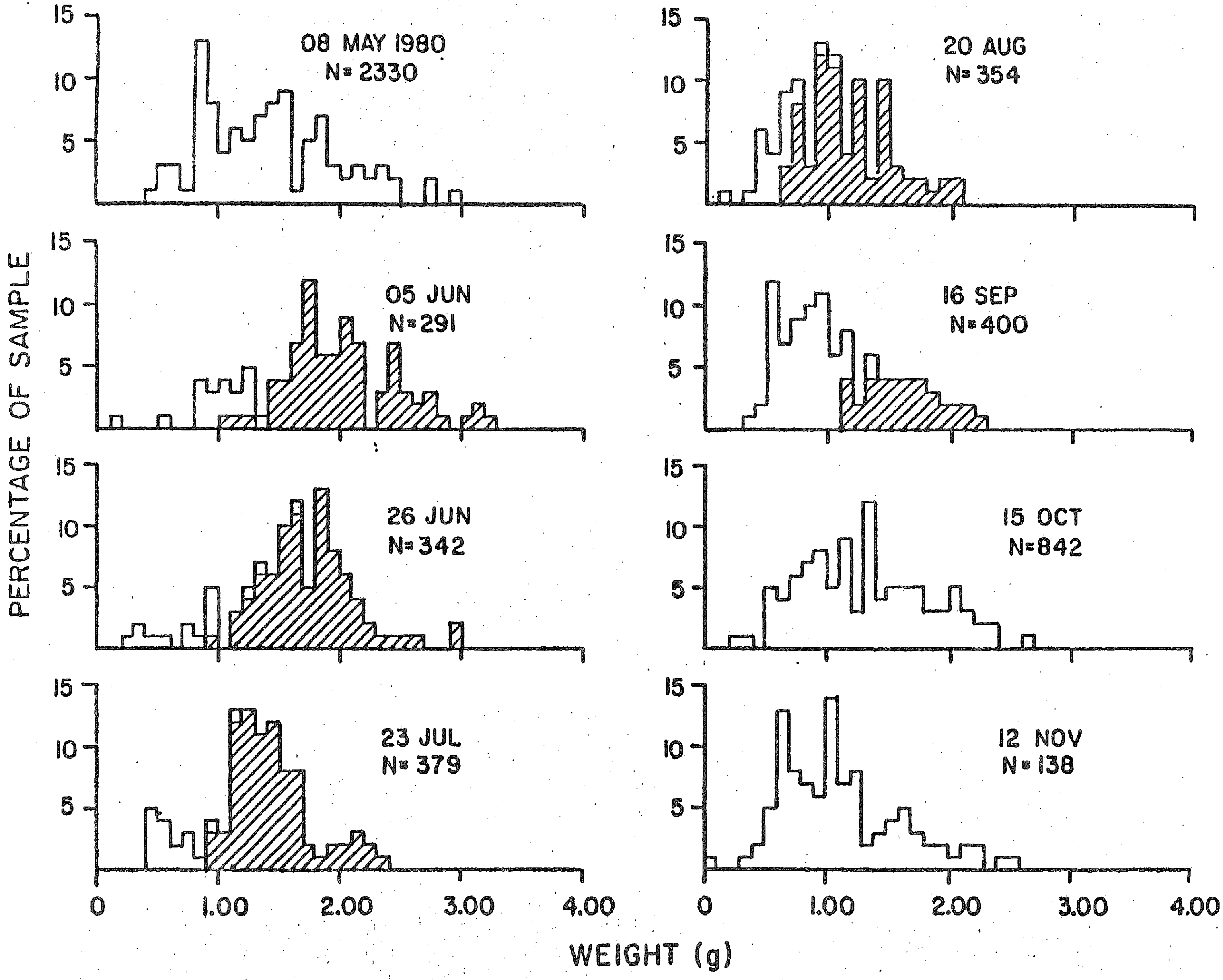

Figure 5. Seasonal changes in population size structure of Nephelopsis obscura from Priem's #1 Pond. Hatched areas represent mature animals. Total sample size is indicated with each histogram.

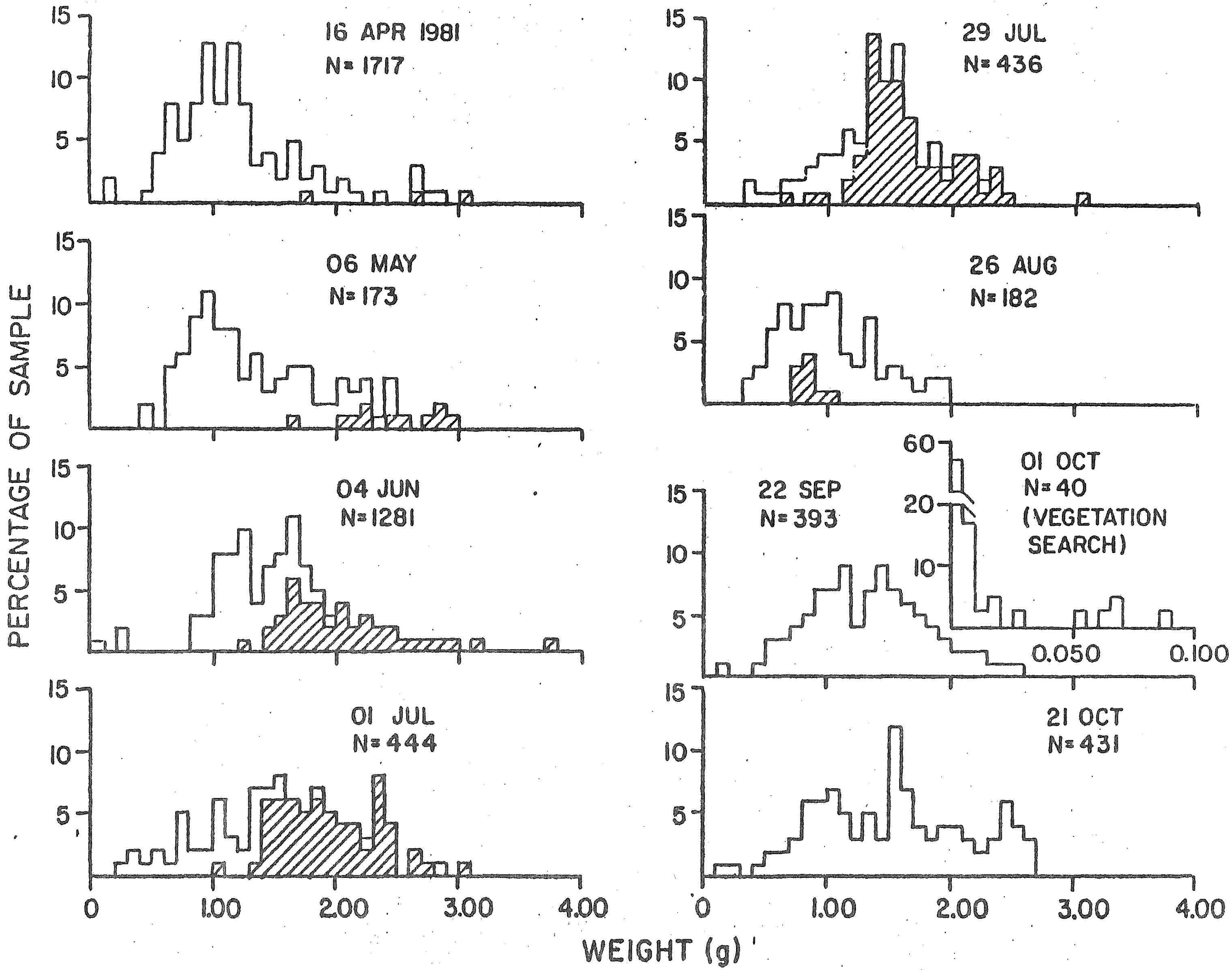

Figure 5. Continued.

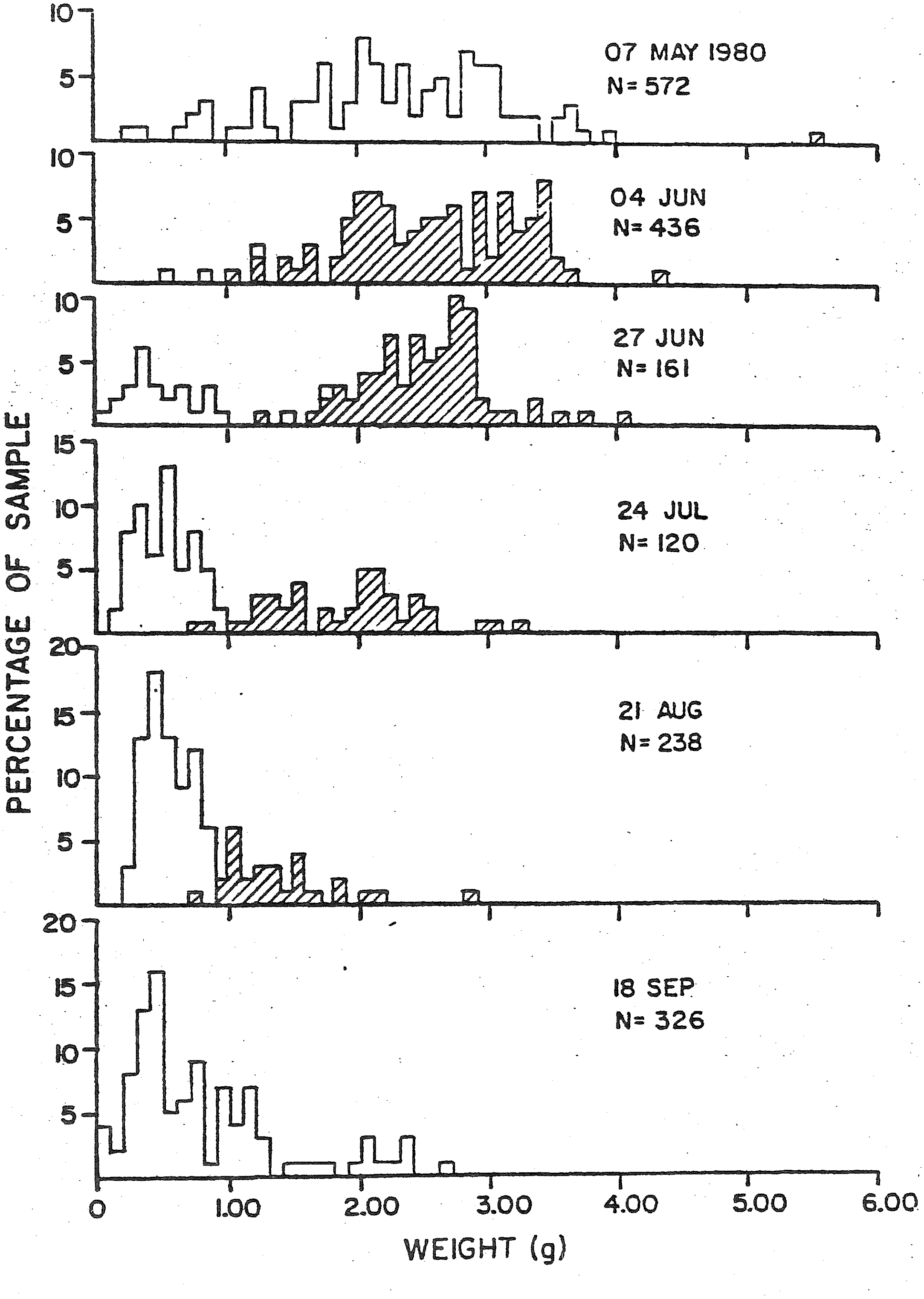

Figure 6. Seasonal changes in population size structure of Nephelopsis obscura from Early's Pond. Hatched areas represent mature animals. Total sample size is indicated with each histogram.

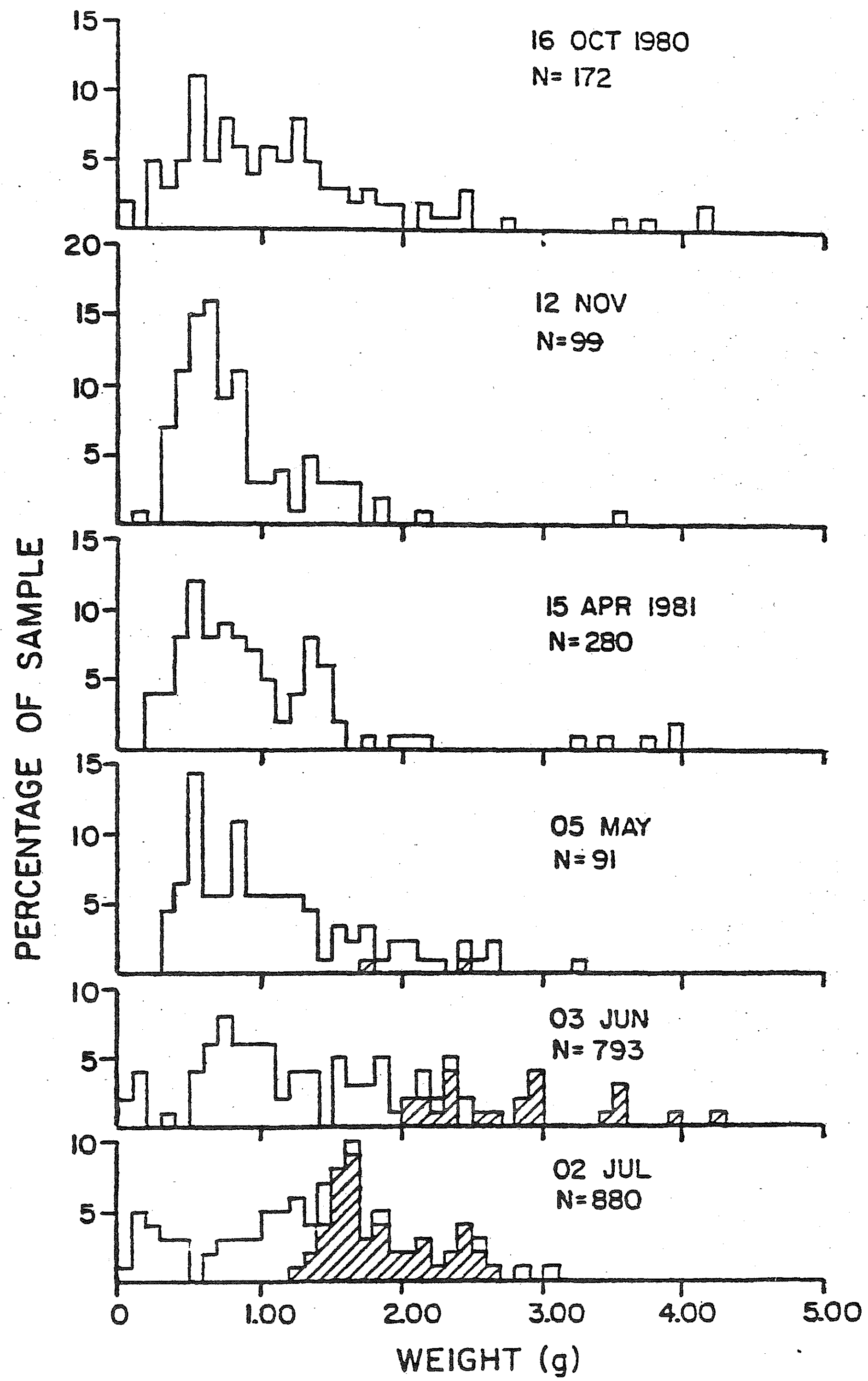

Figure 6. Continued.

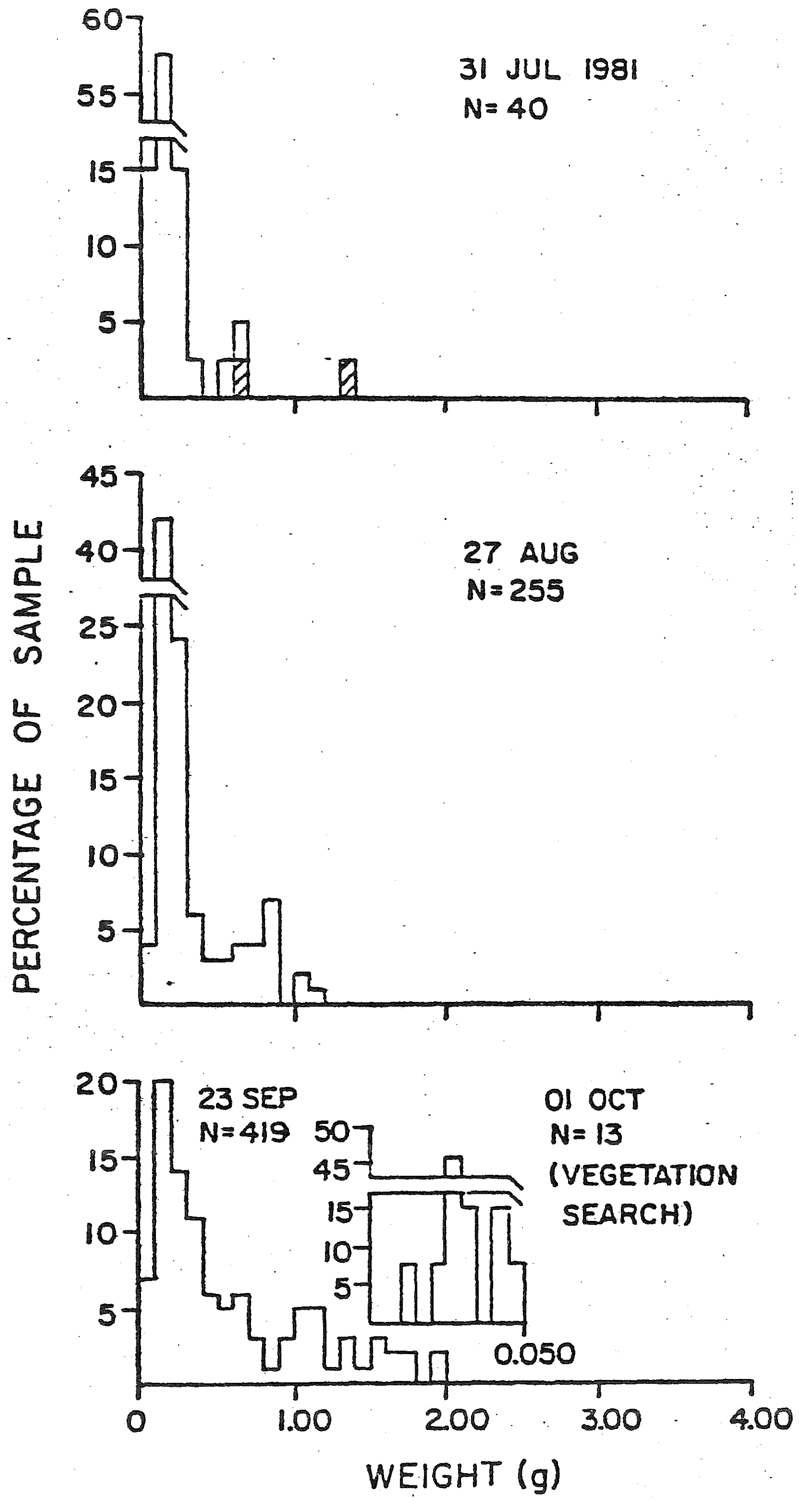

Figure 6. Continued.

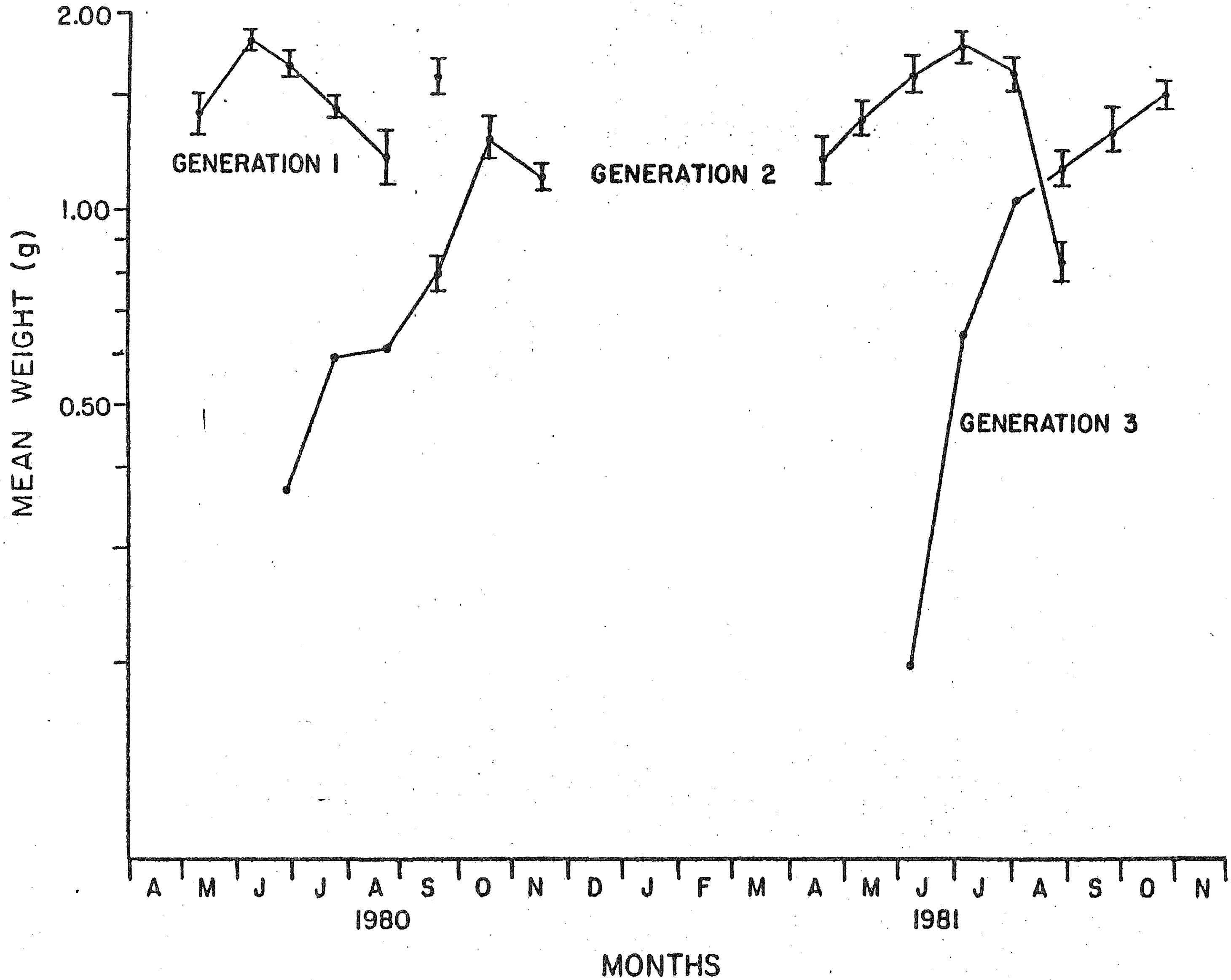

Figure 7. Growth curves for generations of Nephelopsis obscura in Priem's #1 Pond. Standard error of means weights (± 95% confidence limits) are shown where leeches were considered completely vulnerable to standard traps.

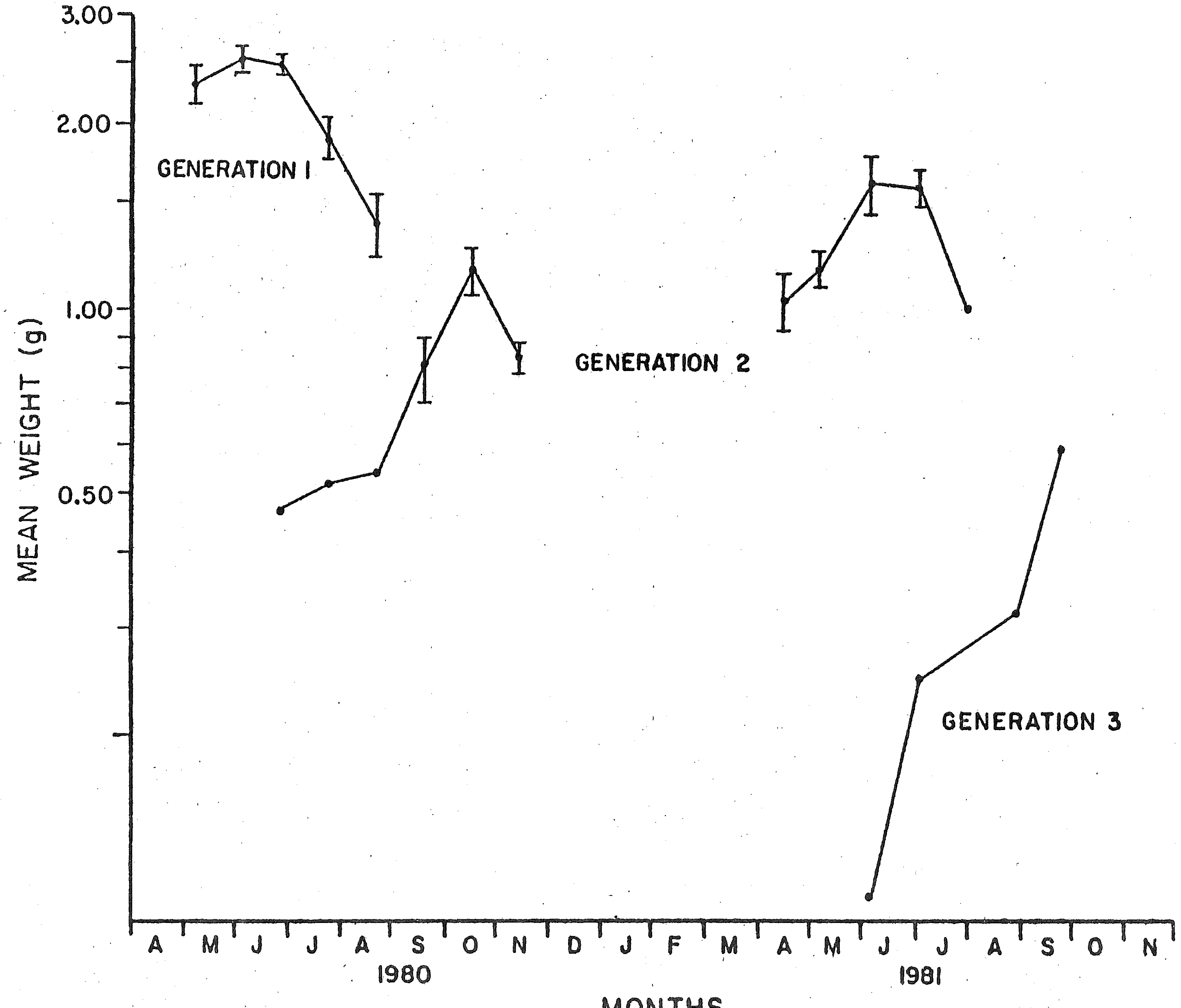

Figure 8. Growth curves for generations of Nephelopsis obscura in Early's Pond. Standard error or mean weights (± 95% confidence limits) are shown where leeches were considered completely vulnerable to standard traps.

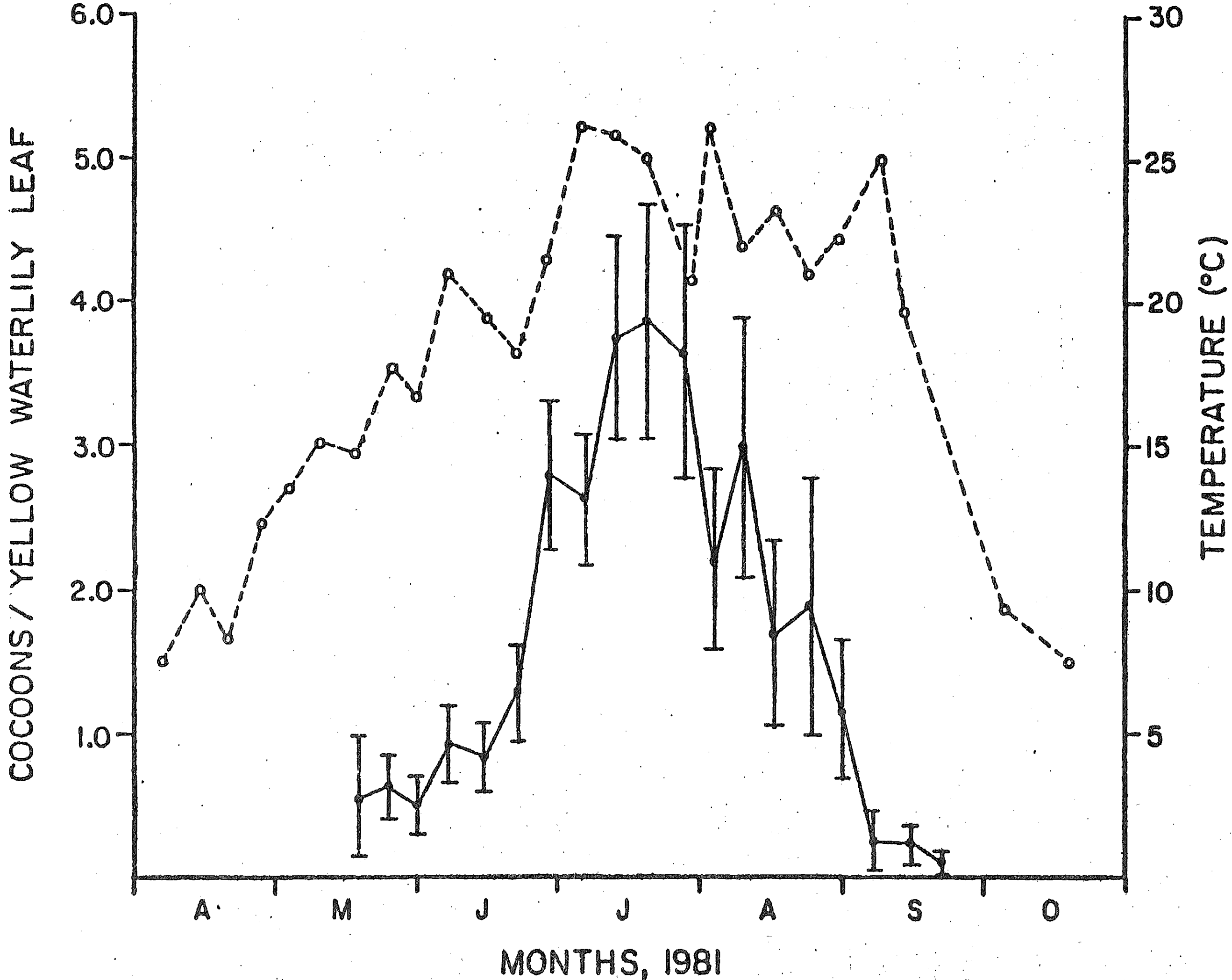

Figure 9. Mean number of *Nephelopsis obscura* cocoons (± 95% confidence limits) observed per yellow waterlily leaf (*Nuphar variegatum*) in Priem's #1 Pond. Open circles indicate surface water temperature.

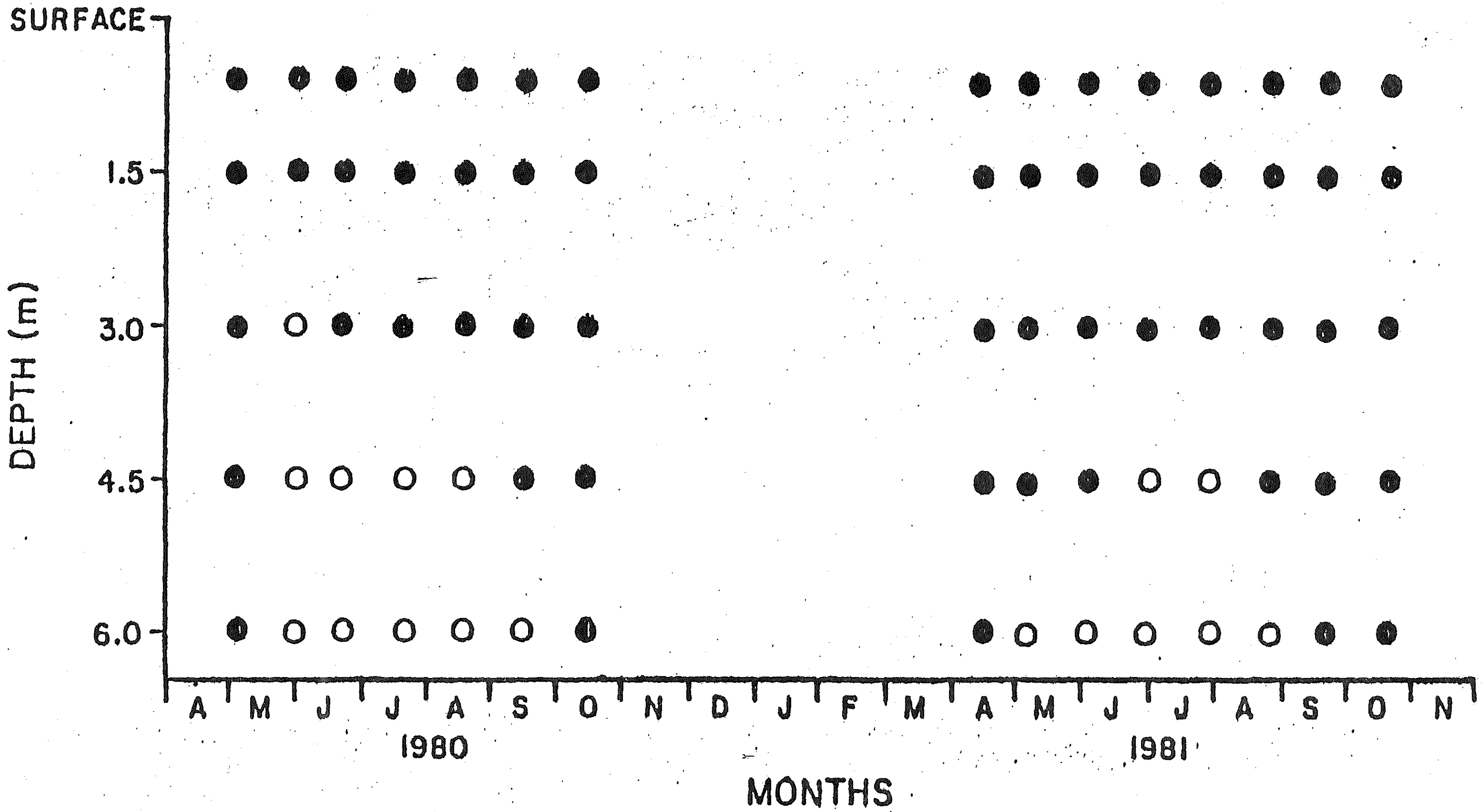

Figure 10. Seasonal depth movement of Nephelopsis obscura in Priem's #1 Pond. A solid circle indicates leeches present in standard traps and an open circle indicates leeches not present in standard traps.