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Production of Arthropod Pests and Vectors in Coal Strip Mine Ponds

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PRODUCTION OF ARTHROPOD PESTS AND VECTORS IN COAL STRIP MINE PONDS

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ABSTRACT

The objective of this study was to determine the species of aquatic arthropod pests, mainly mosquitoes, that were breeding in abandoned coal strip mine ponds, their population densities, and whether these breeding sites would serve as foci for annoyance to surrounding human populations.

Nine study ponds were selected in Marion County, Alabama, on the basis of age since formation, with a total of three test ponds in each of three age categories: 1 year old, 5 years old, and 10 years old. These ponds were observed for five successive years; thus, data obtained from surveys depict successional changes in aquatic insect and plant species composition over a period of 14 "successive" years.

Mosquito larvae of four genera including eight species were collected from the strip ponds. Mosquito production was not detected until ponds were at least two years old, and ponds five years old and older were the most productive for mosquitoes. Anopheles punctipennis, Anopheles quadrimaculatus, and Culex erraticus were the most prevalent species. Ova of six species of floodwater mosquitoes, Aedes sollicitans, Aedes sticticus, Aedes trivittatus, Aedes vexans, Psorophora columbiae, and Psorophora cyanescens, were found in soil samples taken from transects along pond margins. The most abundant floodwater mosquito ova in the ponds were those of Aedes vexans. The largest number of positive samples for mosquito ova were from ponds 10 years of age or older. No floodwater mosquito ova were found in soil samples taken from ponds less than four years old.

Only two species of mosquitoes found in the strip mine ponds, Culex territans and Uranotaenia sapphirina, have little or no economic or medical importance. Mosquito production in all ponds was sparse and restricted to narrow vegetated areas along shallow marginal shelves, and the level of mosquito activity detected during this 5-year survey was not sufficient to cause severe annoyance to surrounding communities.

The diversity and abundance of aquatic insects collected in benthic and littoral zone samples showed a progressive increase as the ponds increased in age. The largest number of insect taxa were in the 9- and 14-year-old ponds with 97 and 92 insect taxa respectively. The most abundant group of insects both in species composition and numbers collected in the ponds was the Chironomidae, or "nonbiting midges." Odonata were found in large numbers and comprised a large segment of

the aquatic fauna in ponds five years of age or older. The water beetle, Laccophilus maculosus was common in all age ponds (1 to 14 years). The water strider, Trepobates was abundant in ponds three years of age or older. Larvae of the mayfly, Hexagenia munda elegans, were found in 2-year-old ponds and were relatively abundant in ponds 10 years old or older. There was a paucity of insects of medical importance found in benthic samples in the nine study ponds; only three genera of public health importance were collected, which consisted of Palpomyia, Chrysops, and Tabanus. Based on the small numbers of Palpomyia, Chrysops, and Tabanus collected from all pond age categories no public health problem is anticipated.

A total of 80 plant taxa were identified from the nine ponds and surrounding disturbed sites during the study. The number of vascular species increased as the age of the ponds increased reflecting invasion by early successional dominants. Two submersed aquatic macrophytes, Potamogeton diversifolius and Potamogeton pusillus, both of which provide favorable mosquito habitat, became established in the 2-year-old ponds. The most commonly occurring plants found in or around the ponds were Typha latifolia, P. diversifolius, Scirpus cyperinus, Salix nigra, Bidens frondosa, Eleocharis spp., and Panicum spp.

Water chemistry of all ponds studied provided very favorable conditions for supporting various fauna and flora. Data obtained during the 5-year study showed no significant change in the pH of the water in the nine study ponds as they increased in age. The dissolved oxygen content of the water in the ponds varied widely with pond age and seasonal changes, ranging from 9.1 to 14.1 ppm. Water temperatures did not vary significantly between the nine study ponds. Water conductivity measurements were much lower in ponds 11 years old or older than measurements in the other pond age categories.

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LIST OF ABBREVIATIONS AND SYMBOLS

ppm	--parts per million
Y.S.I.	--Yellow Springs Instrument
S-C-T	--Salinity-conductivity-temperature
km	--kilometers
μmhos/cm	--measurement of electrical conductance when measured between opposite faces of a 1-cm cube
^{o}C	--degrees Celsius
I	--Infrequent
C	--Common
A	--Abundant
ha	--hectares
m	--meter
cm	--centimeters

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SECTION 1

INTRODUCTION

Surface mining for coal is carried out extensively in several counties in North Alabama, resulting in formation of numerous permanent to semipermanent ponds. The ponds included in this study are located near the eastern border of Marion County in the vicinity of New River and in the community of Gold Mine, Alabama. An estimated 2428 to 2833 ha of surface coal mines exist in Marion County alone. Demand for coal has been greatly accelerated by the recent energy crisis; this demand, coupled with increases in the price of coal and the availability of larger and more powerful earth-moving equipment, has resulted in the reopening and reworking of many abandoned surface mines that could not be operated economically a few years ago. To support the demand for coal, efforts have been increased to obtain property containing coal suitable for strip mining; these efforts have resulted in the encroachment of mining operations upon many rural towns with moderate population densities. Extensive tracts of barren countryside, containing many small lakes and ponds, often result from these strip mining operations. These bodies of water may vary in size from a few hundred square meters to several hectares. Water depths may vary from 2 to 15 meters, depending on the depth of the final cut. The water level in the ponds may fluctuate several times in a growing season, and depending upon precipitation, the amplitude in fluctuation may be from one to two meters during certain dry seasons.

For centuries man has fought insects as pests and vectors of disease. Mosquitoes, probably the best-known group of insect pests, have adapted themselves to various climates and are found in all the land areas of the world, wherever pools of water are available for a few days or longer for breeding to occur and where sufficient numbers of host organisms are present. Mosquitoes have probably had a greater influence on human health and welfare throughout the world than any other group of insects.

The objective of this study was to determine what species of medically important arthropods, particularly mosquitoes, were breeding in coal strip mine ponds, to what extent, and whether these breeding sites would serve as a focus of annoyance or a potential outbreak center of arthropod-borne disease to surrounding communities. The emphasis of this study involved a comparison of pond age with physical and chemical characteristics of the water and associated vegetation communities. Field surveys employed various sampling techniques to determine the composition and density of the various life stages of the aquatic insect fauna.

Of numerous ponds that were field-inspected, nine were selected by age (time since formation) for study. Three ponds in each of three age categories (1 year, 5 years, and 10 years) were selected for study when the project was initiated in 1976. The six oldest ponds were observed for five successive years and the three youngest ponds have been observed for four successive years since the onset of observations. These nine study ponds are shown on an aerial photograph (Figure 1). The study was initially designed to progress for five consecutive years, so that the data obtained would include 14 "consecutive" years of natural ecological succession. The project was designed to show temporal changes in species composition and relative abundance of aquatic fauna and flora.

SECTION 2

CONCLUSIONS

Results from this study showed that mosquito production did occur in coal strip mine ponds, becoming evident during the second season after pond formation. The degree of mosquito production and the diversity of species composition increased as the ponds aged. Although mosquito production occurred in all but the 1-year-old ponds, production was sparse and restricted to narrow vegetated areas along shallow, marginal shelves. The level of mosquito activity detected during this 5-year survey was not sufficient to cause severe annoyance to surrounding communities. Mosquito larval dipping records in early March indicated that strip mine ponds could provide many favorable sites where over-wintering females of *An. punctipennis* and *An. quadrimaculatus* could deposit eggs for the first spring brood.

Data from benthic and littoral zone sampling reflected a wide variety of aquatic insect taxa in ponds of all age categories. However, the 9-year-old ponds contained the largest number with a total of 97 taxa. There was a paucity of insects of medical importance found in the nine study ponds; only three genera of public health importance were collected, which consisted of *Palpomyia*, *Chrysops*, and *Tabanus*. Based on the small numbers of *Palpomyia*, *Chrysops*, and *Tabanus* collected from all pond age categories no public health problem is anticipated.

Surveys of the plants in each of the nine ponds yielded a total of 80 plant taxa (79 vascular plants and one macroscopic alga). The number of macrophyte taxa increased with the age of the ponds. Two submersed aquatic species (*P. diversifolius* and *P. pusillus*), both of which provide favorable mosquito habitat, became established initially in the 2-year-old ponds.

Water chemistry of all ponds studied provided very favorable conditions for supporting various aquatic fauna and flora.

SECTION 3

RECOMMENDATIONS

1. Data obtained in this study showed some mosquito production along shallow vegetated pond margins. It is recommended, therefore, that in reclamation grading of the spoil around ponds, that plans include filling along the shoreline to produce an almost vertical pond bank, thereby elminating areas with water less than one meter deep in order to minimize the amount of potential mosquito habitat.

2. Ditches should be constructed to eliminate the possibility of ponding of shallow temporary pools which could become favorable oviposition sites for rainpool mosquito species.

3. It is recommended that greater effort be made to establish more rapid permanent vegetative cover on the graded spoil slopes and wetland area around ponds to reduce erosion.

4. Cursory observations suggested that a large number of the abandoned coal strip mine ponds in north Alabama could and should be developed for wildlife and recreational purposes.

SECTION 4

EXPERIMENTAL PROCEDURES

Description of the Study Area

Area stripping was the method generally used for removing the overburden from the coal in the study area (Rainer 1972). The procedure consists of a trench cut to expose the coal and the spoil is piled along the side of the cut. As additional cuts are made parallel to the first, the overburden is deposited in the previous cut where the coal had been removed. The mined site has an uneven appearance with large piles of spoil located throughout the disturbed area.

The slope of the spoil bank around two of the ponds that were one year old at the beginning of the study was moderately steep and short. The other 1-year-old pond was located along a final cut and was enclosed by a 12- to 15-m abrupt spoil bank on one site and a high wall on the other. The maximum water depth in the ponds was about 5 m, and the sampling stations were located along the shallow margins. The water in the ponds was replenished from rainfall runoff and subterranean seepage. The slopes around the ponds were generally barren, except for sparse pioneer colonies of herbaceous species such as pokeweed (*Phytolacca americana*). The margins around the ponds were abrupt, except for those areas in which small alluvial deltas had been formed by siltation.

All the ponds that were five years old (5-year-old ponds) at the beginning of the study were located along the base of highwalls that ranged in height from 9 to 12 m. The spoil was deposited in undulating ridges, which averaged about 5 m in height. Except for access roads extending into the pits, the slopes of the pond margins were very steep. The average water depth in these ponds was about 3 m. The water depth at the sampling stations ranged from 30 to 90 cm. Sericea (*Lespedeza cuneata*) formed a dense colony on the spoil banks around two of the ponds, whereas the other spoil area contained mixed colonies of *L. cuneata* and *P. americana* with some bare soil. The pond water collects from rainfall and subterranean seepage.

The original 10-year-old study ponds occurred in remote areas where the coal had been covered by a shallow overburden. The ponds were enclosed by highwalls and spoil banks, ranging in height from about 6 to 9 m. The dominant herbaceous vegetation on the spoil banks consisted of four genera: *Lespedeza*, *Rubus*, *Andropogon*, and *Phytolacca*. Saplings of sweetgum (*Liquidambar styraciflua*), loblobby pine (*Pinus taeda*), black willow (Salix nigra), and sumac (Rhus spp.) were present on the spoil slopes. The average water depth was about 3 m and water depth at the sampling stations ranged from 30 to 90 cm. Except for the shallow areas along abandoned access roads into the strip pits, the pond margins were very abrupt. Water levels in the ponds were maintained by subterranean seepage and rainfall.

The topography in the Gold Mine area of Marion County is predominantly hilly with steep slopes. The soil is predominantly dark gray sandy-loam, with soil pH ranging from slightly acid to moderately alkaline. The fertility is moderate and the soil is low in organic content. Percolation is moderately rapid, and the available water storage capacity is medium to low. The plant root zone is very shallow due to the abundance of consolidated sandstone outcrops in the strip-mined areas. Erosion is severe due to previous land use practices and especially severe where strip mining operations have been conducted.

Materials and Methods

In each of the nine study ponds three sampling stations were established, either in the vicinity of emergent aquatic vegetation or in shallow marginal areas where emergent or submersed vegetation was likely to occur. Monthly surveys were conducted from April to October to determine the species composition and relative abundance of aquatic arthropods in each pond.

Mosquito larvae were sampled by using the standard dipper technique (Russel 1946). Fifteen dips were taken near each sampling station in the study ponds. The number of mosquito larvae collected per dip and the stage of development of each were recorded, and a representative sample was collected for species identification. To determine the presence and species composition of floodwater mosquito ova, soil samples (15- by 15- by 2.5-cm) were collected from likely oviposition sites along established transect lines in each study pond. Transects were established to coincide with probable habitat and flooded contours within each pond. Each sample was processed through a series of sieves, consisting of 40-, 60-, and 100-mesh sizes, and through a flotation process, which separated the ova from the soil (Horsfall 1956). The mosquito ova from each soil sample were counted and identified to species. All soil samples were collected in the late fall.

Bottom samples for benthic organisms were taken with an Ekman dredge. About 900 cm^2 of substrate, consisting of four 15- by 15-cm samples, were collected at each of the three stations in each pond. The sample was washed through a 40-mesh sieve, and the remaining benthic organisms were recovered and preserved in Hood's solution.

Water surface sampling for aquatic invertebrates was accomplished by using a fine mesh aquatic dip net with a 30-cm opening. A sample consisted of sweeping the net through about two linear meters of water surface. Three samples were taken at each station.

Surveys were conducted in summer and early fall to inventory the existing plant species and to document their relative density and frequency in each study pond. Vegetation was surveyed by visual inspection and the plant taxa enumerated at the selected sampling stations. Physical and chemical parameters of each pond were measured with portable instruments. The pH of the water was determined with an Orion specific ion meter (model 407A). The dissolved oxygen readings in the water were taken with a Y.S.I. model 54A oxygen meter. The oxygen determinations were made between 9 a.m. and 3 p.m. Water temperatures were recorded using a pocket thermometer. A Y.S.I. model 33 S-C-T meter was used to measure salinity and conductivity. Due to difficulties in obtaining an instrument for determining conductivity and salinity of water in the ponds, these measurements were not started until the second year of the study (June 1977). All readings were taken at a depth of about 5 cm.

A staff gauge was placed in each study pond to detect water level deviations from a baseline level. The gauge was constructed of a 1.8-m (2.5- by 10-cm) board divided into 3-cm increments from a zero point at the center of the staff. Water-level readings were made in conjunction with each monthly insect survey. A photographic reference point was established for each pond, and sequential photographs were made from these points to provide a visual record of the physical changes occurring during the course of the study.

SECTION 5

RESULTS AND DISCUSSION

Mosquito Larval Sampling

Results obtained from larval sampling for mosquitoes during a five year succession study (1976-1980) in nine study ponds are summarized in Table 1. The average number of larvae per dip listed for each age category is a composite record for three study ponds in each age classification. The most significant data relate to species composition and show that eight species representing four genera of mosquitoes were collected during the five growing seasons. Six of the mosquito species collected will bite man and all have a flight range of about 2 km. However, one of the species collected in this study, Psorophora columbiae, has been retrieved by light trap at a distance of 9.7 km (Horsfall 1942). Culex territans and Uranotaenia sapphirina, two of the eight species collected, are of no known economic or medical importance in the Tennessee Valley.

Figure 2 illustrates the mosquito population densities and species composition in strip mine ponds ranging in age from 1 to 14 years old. Species diversity increased as the ponds became older. No mosquito species were found in the 1-year-old ponds, compared with seven species in the 5- and 7-year-old ponds. As indicated in Figure 2, mosquito production was not detected until ponds were two years old and ponds five years old and older were the most productive for mosquitoes, both quantitatively and qualitatively. In general, Anopheles punctipennis and C. erraticus were the dominant species present in all the ponds, However, only limited production of these two mosquito species was recorded in the 3- and 4-year-old ponds. In addition, C. erraticus egg rafts also were found attached to leaf margins of floating leaves of variable-leaf pondweed (Potamogeton diversifolus) in a 3-year-old pond. Anopheles quadrimaculatus, the malaria vector, was found in ponds that had been established for five or more years and average larval counts ranged from 0.05 to 0.16 per dip.

Only one species of the floodwater or rainpool group of mosquitoes was collected from the nine study ponds. One larval specimen of P. columbiae was found in a 7-year-old pond. However, extensive rains in August and September 1977 flooded many semi-aquatic depressions, colonized by Typha latifolia, throughout the strip mine study area and produced a brood of this floodwater mosquito. Larval sampling yielded an average of three larvae per dip in the flooded depressions. Psorophora columbiae deposits its eggs on the damp soil in depressions that are intermittently flooded. Usually, large numbers of larvae are produced at a hatching, and adults may appear as early as six days after flooding. This species causes serious annoyance to man and livestock and has also been implicated in the transmission of equine encephalitis and dog heartworm disease.

Heavy rainfall in February 1977 flooded vegetated marginal areas of the study ponds. Supplemental larval dipping records in early March showed mosquito production of An. punctipennis, An. quadrimaculatus, Culex restuans, and C. territans in areas colonized by T. latifolia in the 6- and 11-year-old ponds. These data suggest that strip mine ponds could serve as a major habitat for the first spring brood of permanent pool species of mosquitoes.

Figure 3 further shows that the seasonal average number of mosquito larvae collected per dip increased as the ponds became older. The total mosquito population based on average larval counts ranged from a low of 0.01 in the 2-year-old ponds to a high of 1.68 per dip in the 6-year-old ponds. The highest mosquito production was in the 6- and 12-year-old ponds with seasonal averages of 1.68 and 1.50 larvae per dip, respectively.

The data in Figure 4 substantiate the increase of mosquito species compositon as the ponds increased in age from time of formation. No mosquito breeding was detected in 1-year-old ponds, but mosquito taxa counts varied from three in the 2-year-old ponds to six in the 14-year-old ponds. However, the 3-year-old ponds had only one taxa whereas the 5- and 7-year-old ponds had a species composition of seven each. This upward trend in the number of taxa is also illustrated in Figure 4 for the other aquatic insects and plants.

Mosquito larval occurrence in all the ponds was primarily associated with areas colonized by aquatic macrophytes such as variable-leaf pondweed (P. diversifolius), small pondweed (Potamogeton pusillus), woolgrass (Scirpus cyperinus), and cat-tail (Typha latifolia). The heaviest mosquito production occurred during June through September.

Although data in Table 1 show that significant mosquito production occurred in coal strip mine ponds that had been formed for five or more years, the mosquito habitat occurred only around the periphery of the ponds and consisted of only a small percentage of the total water surface area. The mosquito habitat was located in narrow vegetated areas along shallow, marginal shelves. Because of the abrupt pond margins and the small amount of vegetation in the ponds, the mosquito breeding potential, especially for permanent pool species, was limited in most of the ponds. As a general rule, the intensity of mosquito production of permanent pool species is directly related to the amount of plants and flotage breaking the water surface (Bishop 1947). However, in those ponds where the water level recedes and extensive shoreline areas are dewatered, floodwater species of mosquitoes could become a problem.

Adult mosquitoes were sparse in the vicinity of the study ponds. A few specimens of the rainpool mosquito, P. columbiae were collected biting in the general area of 7-year-old ponds. In addition, three pestiferous floodwater mosquito species that are well distributed throughout the Tennessee Valley (Aedes canadensis, Aedes trivittatus, and Aedes vexans) were collected in small numbers along shaded margins of 9-, 13-, and 14-year-old ponds. These species of mosquitoes generally deposit their ova on damp soil in grassy depressions, in low shaded woodland habitats, and along vegetated shorelines that are intermittently flooded. No adult specimens of the permanent pool group of mosquitoes, anopheline or culicine were observed during the field collections.

Mosquito Ova Sampling

Table 2 summarizes data from soil samples collected to determine the extent and successional changes of floodwater mosquito populations along strip mine pond margins; oviposition data are used as an indicator. Soil samples were taken in November each year after oviposition had ceased and the ova were dormant. The total number of soil samples collected from the different pond-age categories was governed by the size of the dewatered pond margin, with the high water level serving as the upper limit. The data in Table 2 show that most of the floodwater mosquito ova collected were from ponds that had been established for 10 or more years. Of the total number of floodwater mosquito ova collected, about 89 percent were from the 10-, 11-, 12-, and 13-year-old ponds, and 11 percent of the ova were from ponds ranging in age from 5 to 9 years old. No floodwater mosquito ova were found in soil samples collected from the 1-, 2-, 3-, and 4-year-old ponds. Floodwater mosquito species present in the nine study ponds, as indicated by soil sampling data collected over a period of five years, were Ae. sollicitans, Ae. sticticus, Ae. trivittatus, Ae. vexans, P. columbiae, and Psorophora cyanescens. Data from soil samples showed Ae. vexans was the dominant floodwater mosquito species in the study ponds. Results from the soil sampling program showed only three ova of Ae. sollicitans present, which were found in the 5- and 10-year-old pond categories. Soil sample data revealed Ae. sticticus and Ae. trivittatus ova counts of three and one respectively from a 13-year-old pond. The ova were collected from a transect located along a forested pond margin. Ova of P. columbiae and P. cyanescens were found in small numbers in the 9- and 12-year-old ponds. No floodwater mosquito ova were recovered in soil samples from the 7- and 14-year old ponds. Due to high water level in the ponds at the time soil samples were collected from the 2-, 6-, and 11-year-old ponds, the number of samples collected and the number of sampling transects evaluated were limited in several study ponds, and this limitation may have influenced the collection of mosquito ova. Positive soil samples in all pond age categories were collected in association with the following vegetation: Typha latifolia, Salix nigra, Scirpus cyperinus, Aster pilosus, and Andropogon virginicus.

Adult females of Ae. sollicitans, Ae. sticticus, Ae. trivittatus, Ae. vexans, P. columbiae, and P. cyanescens all bite man, and all species except Ae. trivittatus will migrate in large numbers from their breeding sites into populated areas in search of a blood meal. The females of Ae. sticticus, Ae. trivittatus, Ae. vexans, P. columbiae, and P. cyanescens generally deposit their ova on the damp soil in vegetated depressions that are intermittently flooded. These five floodwater mosquito species are widely distributed throughout the Tennessee Valley and are five of the most important pest species. The females of Ae. sollicitans normally deposit their ova on the soil in the tidewater salt marshes containing brackish or saline water, which are subject to intermittent flooding. Other oviposition sites may include pools of effluents from certain factories, pools around oil wells, and coal mine ponds (Horsfall 1955). In addition to being a serious pest, Ae. sollicitans is also the primary vector of eastern equine encephalitis to man and horses.

The paucity of floodwater mosquito production in most of the coal strip mine study ponds is attributed in part to the frequent silting of pond margins caused by extensive erosion from barren spoil areas after heavy rains. Mosquito ova are covered by layers of silt during the winter, and mosquito larvae from the enclosed ova cannot emerge through the soil when the habitat is inundated the following spring. The lack of floodwater mosquito production along pond margins may also be due to the sparse vegetation, surface detritus cover, and excessively dry soil, which make these areas unattractive to ovipositing females.

Benthic and Surface Sampling for Aquatic Insects

A composite listing and the degree of abundance of the insect taxa from benthic and littoral fauna samples taken in nine strip mine ponds during a 5-year-succession study are shown in Table 3. Insects were identified to genus and species when possible. In the table, abundance of taxa is represented by a symbol (I = 1 to 5; C = 6 to 19; A = 20 and above) which could be misleading in calculating totals from the table since the symbols vary in the representation of a range in number of specimens. The data positively show increased faunal diversity with increasing pond age.

Figure 3 shows the average number of insect specimens per Ekman dredge (900 cm^2) and aquatic dip net (sweep) samples for each pond age. The number of specimens in the dip net were considerably lower when compared to the Ekman dredge. For example, the aquatic dip net samples showed a range of 0.94 to 8.38 compared to 1.37 to 19.95 in the dredge. Productivity increased as reflected by increased numbers of invertebrates in both the dredge and net samples as the ponds increased in age. Based on aquatic dip net samples the 14-year-old ponds were the most productive, whereas the 12-year-old ponds showed the greatest productivity based on benthic counts.

The data of Figure 4 show the number of insect taxa collected by the dredge and net sampling methods in the different age ponds. The dredge and net samples yielded about the same number of insect taxa, but the species composition and the number of specimens collected differed significantly, especially in dredge samples for aquatic Diptera. Except for the relative low number of taxa in the 10-year-old ponds, data in Figure 4 show a progressive increase in the number of insect taxa as the ponds increased in age. In Figure 4, it is demonstrated that dredge samples produced a range of insect taxa from 18 to 69 as compared to 16 to 77 in the net. The largest number of taxa for both dredge and net was in the 14-year-old ponds with counts of 69 and 77, respectively.

The number of insect taxa in 1-, 2-, 3-, and 4-year-old ponds detected by dredge and net sampling methods was 24, 44, 54, and 45 taxa respectively. The most significant increase, both in species composition and in the number of specimens collected, was in the Chironomidae, or "nonbiting midges." By comparison, data from bottom samples yielded the following Chironomidae counts; 1-year-old ponds--9 taxa, total of 21 specimens; 2-year-old ponds--14 taxa, total of 147 specimens; 3-year-old ponds--20 taxa, total of 433 specimens; and 4-year-old ponds--19 taxa, total of 446 specimens. In general, as the ponds increased in age the number of taxa detected increased and the number of specimens increased. A high of 26 taxa occurred in the 9-year-old ponds and the largest number of specimens, 1130 occurred in 12-year-old ponds. However, sampling results from the 14-year-old ponds showed only 22 taxa and 672 Chironomidae specimens.

Larvae of the mayfly, Hexagenia munda elegans, were found in the 2-year-old ponds, the youngest ponds in which they were detected. This species was also found to be relatively abundant in ponds that were 10 and 11 years old, but there was a significant decrease in the population in the 13- and 14-year-old ponds. This decrease in the number of mayfly larvae was due to heavy siltation which destroyed or significantly reduced much of the habitat. Mayflies occupy an important place in the food chain of aquatic communities because both larvae and adults are eaten by fish.

The most common benthic insect genera encountered in the 1- to 4-year-old ponds were Gomphus, Notonecta, Laccophilus, Dineutus, Ablabesmyia, Polypedilum, and Procladius. These same genera were also abundant in all pond age categories (1 to 14 years old).

Survey results revealed the presence of only two genera of medically important insects in the 1- to 4-year-old pond age category. Larvae of Palpomyia (Ceratopogonidae), sometimes called biting midges or punkies, were relatively abundant in 2-, 3-, and 4-year-old ponds. Because of their bloodsucking ability, the adults of Ceratopogonidae can be serious pests along margins of streams and lakes. However, based on the number of larvae found in samples from the different age strip mine ponds (1 to 14 years old) there appears to be no problem with this biting insect.

Two specimens of Chrysops (deer fly) were found in the 3-year-old ponds. Chrysops, which are persistent biters of man and livestock, are potential vectors of tularemia.

Data in Table 3 show that diversity and productivity in the 5- to 9-year-old ponds significantly increased when compared to the younger ponds. Data from surveys of the 5-, 6-, 7-, 8-, and 9-year-old ponds yielded 47, 54, 63, 68, and 68 insect taxa respectively. Dragonflies, often called "mosquito hawks" increased both qualitatively and quantitatively, especially Enallagma basidens and Celithemis elisa. Counts of the water strider, Trepobates, continued to increase with increases in the pond age and it was very abundant in the 9-year old ponds. The major increase in species composition and in number of specimens collected was in the non-biting midge group, Chironomidae. The dominant genera of midges on the basis of frequency in collected samples, were Ablabesmyia, Chironomus, Polypedilum, Procladius, and Stictochironomus.

Three insect genera of public nuisance or health importance were recovered in dredge samples from the 5- to 9-year old ponds. Larval specimens of the small biting gnat, Palpomyia, were fairly abundant in the ponds, especially in samples from the 5- and 8-year-old ponds. A total of 14 larval specimens of the genus Chrysops was found in the 5-, 7-, 8-, and 9-year-old ponds. No Chrysops larvae were detected in samples from the 6-year-old-ponds. Two larvae of Tabanus (horse fly) were found in samples from the 6- and 8-year-old ponds. Both deer flies and horse flies are fierce biters of man and livestock and may cause transfer of blood-inhabiting pathogenic organisms to man and animals (Jones 1964).

Data from benthic and littoral zone faunal samples in the 10- to 14-year-old ponds showed this age group to have the greatest aquatic insect taxa diversity of the ponds studied. Sampling data from the 10-, 11-, 12-, 13-, and 14-year-old ponds showed 42, 58, 66, 77, and 92 insect taxa respectively.

Observations in the 10-year-old ponds showed heavy concentrations of mayfly larvae, H. munda elegans. However, counts of mayfly larvae in the 14-year-old ponds showed a decrease of about 94 percent when compared to records from the 10-year-old ponds. As previously discussed this reduction of the mayfly population was likely due to alteration of habitat by siltation. Odonata were found in large numbers in the 10- to 14-year-old ponds and the following species were very common: Anax junius, Enallagma aspersum, Ischnura posita, Gomphus exilis, Celithemis elisa, and Tramea sp. The dragonfly, Tramea sp., was not found in large number until the ponds were 14 years old. In general, Odonata were found in large numbers and comprised a large segment of the aquatic fauna in ponds 5 years old and older.

The most abundant benthos in numbers and species composition in the 10- to 14-year-old ponds were the Chironomidae. Diptera larvae were common with the following genera being the most abundant: Palpomyia, Ablabesmyia, Chironomonus, Clinotanypus Polypedilum, and Procladius. Diptera were the most numerous larvae in all ponds from 1 to 14 years old and the abundance significantly increased as the ponds increased in age. Other benthos which were abundant in the 10- to 14-year-old ponds consisted of the following genera and species: Sigara, Trepobates, Buenoa, Notonecta, Coptotomus interrogatus, Laccophilus maculosus, Dineutus, and Sialis.

The water beetle, L. maculosus was common in all age ponds (1- to 14-years), but sampling data showed a significant decline in the population as ponds increased in age. By comparison, a total of 532 specimens of L. maculosus were collected in the 1- and 2-year-old ponds and 94 specimens were collected in the 13- and 14-year-old ponds indicating a 82 percent decline in the population.

Data from the 10- to 14-year-old ponds showed a paucity of insects of medical importance, both in species composition and abundance. Larvae of the biting midge Palpomyia were fairly common in the 11-, 13-, and 14-year-old ponds. However, Palpomyia larvae were fairly abundant in the 2-year-old ponds and except for the 5- and 8-year-old ponds, larval counts showed no significant increase as the ponds increased in age. Deer fly larvae were sparse with only a total of 31 Chrysops specimens collected from the 10- to 14-year-old pond age groups.

Adult Tabanidae Collections

Several adult specimens of the family Tabanidae (horse flies and deer flies) were collected from inside a parked sedan car located near the strip mine study ponds. These biting insects constitute one of the most annoying groups of bloodsucking insects that attack livestock and man. The eggs are laid in masses on vegetation extending over the water surface or in emergent vegetation, where the larvae can develop in water or damp soil. Most species of horse flies are strong fliers and have a flight range of several kilometers from the larval habitat. Very few Tabanid larvae were detected in the benthic samples from the study ponds because a concerted, specialized effort is required to collect them from pond margins. However, the strip mining occurs over an extensive area, and many ponds and wet areas are found in surrounding areas which are considered the most likely source for those that were collected. Twenty-three adult specimens of Tabanids, representing two genera, were collected and included Hybomitra trispilus (1), Tabanus cheliopterus (2), Tabanus melanocerus (1), Tabanus nigripes (2), Tabanus sparus milleri (2), Tabanus fulvulus pallidescens (1), and Tabanus fulvulus (14).

Woody and Herbaceous Vegetation

A total of 80 plant taxa (79 vascular plants and one macroscopic alga) were identified from the nine ponds during the study period. These are categoried in Table 4, according to their habitat zone, as submersed, emergent, wetland, or terrestrial. The submersed category consists of those plants that are rooted in the substrate and entirely submersed with the exception of emergent inflorescences. The emergent species include plants that are firmly rooted in the substrate and have vegetative structures that extend above the water surface. Wetland species include plants growing in the transition zone just above the waterline in soils that are continually or seasonally saturated, while those plants growing above the transition zone in unsaturated soils are classified as terrestrial.

Potamogeton diversifolius was the dominant submersed species found in ponds more than one year old. Two other submersed species, Potamogeton pusillus and the macroscopic alga Chara sp., occurred sporadically in a few ponds (see Table 4). Ten emergent species were recorded with Typha latifolia, Scirpus cyperinus, Eleocharis obtusa, and Juncus acuminatus being the most common. Twenty-eight wetland taxa were found, the most abundant being Polygonum spp., Panicum dichotomiflorum, Echinochloa crusgalli, Aster pilosus, Bidens frondosa, Ludwigia alternifolia, Pluchea camphorata, and Salix nigra. Many of the 39 terrestrial species identified during this study are common plants that invade disturbed sites. Some species such as Lespedeza cuneata and L. striata represent introductions associated with reclamation efforts. Since terrestrial species seldom contribute to the mosquito breeding habitat, they will not be discussed in further detail.

Newly formed ponds (one year old) were sparsely colonized and the macrophytes present were primarily common pioneer wetland and terrestrial species. No submersed species and only one emergent species (Typha latifolia) were noted to colonize these ponds. The most common wetland species around the perimeter of the newly formed ponds were Polygonum pensylvanicum and Salix nigra. By the second year, two submsersed taxa (Potamogeton diversifolius and P. pusillus) had become established. Emergent taxa established by the third year include Scirpus cyperinus and Eleocharis obtusa. Several additional wetland species became established during the second and third years with the most common being Cyperus odoratus, Echinochloa crusgalli, Panicum dichotomiflorum, Polygonum lapathifolium, and Populus deltoides. In the older ponds (5 to 9 and 10 to 14 years) several additional taxa occurred as noted in Table 4.

Scirpus cyperinus, Potamogeton diversifolius, and P. pusillus provide a very favorable habitat for permanent pool mosquito species. While these species are undesirable from the standpoint of mosquito production, the pondweeds (P. diversifolius and P. pusillus) have been documented as a food source for waterfowl.

The vegetational changes and the habitats available for plant colonization are shown in figures 5, 6, and 7. Figure 5 shows one of the ponds in the 1-to 4-year-old category. The slopes around ponds of this age group were graded and seeded as a part of reclamation activities. The emergent and wetland plant communities occurred primarily as a narrow band around the pond margin and in general increased in width and density as the pond aged.

Figures 6 and 7 are ponds belonging to the 5- to 9- and 10- to 14-year-old categories. The steep banks shown in Figure 6 are typical of ponds where no reclamation activities were implemented. Habitats available for plant colonization were primarily limited to the narrow land-water interface around low spoil banks, marginal flats such as that shown in Figure 8, and alluvial outwashes (Figure 9). Cat-tail (*Typha latifolia*), woolgrass (*Scirpus cyperinus*), and black willow (*Salix nigra*) were common inhabitants of outwashes and marginal flats.

While erosion and siltation created habitats for plant colonization, they were also a major factor in the decline and reduction in size of some plant communities. This is illustrated in figures 7A, B, and C, where siltation has substantially reduced the area colonized by cat-tail.

Species diversity increased as the ponds became older (Figure 10). Twenty species were found in the 1-year-old ponds, compared with 47 species in the 13-year-old ponds. However, as shown in Table 4 only 22 plant species were found in the 14-year-old ponds. This reduction in the number of plant species when compared to the 13-year-old ponds was most likely due to (1) the high water level in the ponds during the spring (see figures 6D and 7D) which prevented or delayed the development of marginal vegetation and (2) the extended drought during the summer of 1980. The plants in the wetland and terrestrial habitat zones of the 14-year-old ponds were heavily impacted showing a decrease in plant species from 19 and 21 plant species in 13-year-old ponds to 6 and 8 plant species in 14-year-old ponds. Since no discernible patterns of species replacement have been observed, the increase in species diversity represents the addition of species to previous vegetation.

Physical Parameters

The seasonal average for pH, dissolved oxygen, temperature, and conductivity in the different age strip mine ponds is shown in Figures 11 and 12. The pH remained fairly constant (Figure 11) throughout the study and showed only a 0.9 unit variation between the 1- and 14-year-old ponds. In general, the dissolved oxygen recordings in the ponds showed no significant difference as the ponds increased in age. For example, the average dissolved oxygen recording in the 1-year-old ponds was 9.6 ppm compared to 9.4 ppm in the 14-year-old ponds. The temperature variation in Figure 10 shows no definite trend as the ponds increased in age. Temperature recordings showed a range of $22^{o}C$ to $27^{o}C$ which was mainly due to variation in climatic conditions. Of all the physical parameters recorded, conductivity showed the greatest diversity according to chronological age of the ponds. Recordings in ponds 11 years old and older showed extremely low conductivity (59 to 73 μmhos/cm) whereas recordings in ponds 2 to 9 years old were high (267 to 534 μmhos/cm).

Water pH--The average monthly water surface pH readings for each study pond group for the April 1976 to October 1980 growing seasons are given in Table 5. In general, the pH of the water in all the ponds is within the tolerance ranges that can support a large number of species of both plants and animals. This high pH value (5.5-9.2 seasonal range) of the water in the strip mine ponds is most likely due to the large content of alkaline parent materials in the overburden. The 11-year-old ponds had a lower seasonal pH range than the other pond age groups. The seasonal pH range of the water in the 1-, 2-, 3-, and 4-year-old ponds does not appear to differ significantly from that in the older ponds.

Conductivity and Salinity--The data in Table 5 show that the water conductivity recordings in the 11-, 12-, 13-, and 14-year-old ponds were significantly lower than those in the other pond-age categories. Water in the 6-year-old ponds had the highest conductivity recordings, with a seasonal range of 195 to 1400 mmhos/cm. The high conductivity reading in the pond water probably resulted from the buildup of electrolytes dissolved in water as a result of weathering of the adjacent spoil, which consists mainly of exposed rock. All the ponds showed an absence of salinity.

Dissolved Oxygen--Table 5 also summarizes the results of the dissolved oxygen determinations in each of the nine study ponds. These determinations indicate that no statistically significant differences in the dissolved oxygen content occurred among the ponds. Some of the elevated dissolved oxygen readings in ponds five years old or older were likely influenced by colonies of P. diversifolius, which could have increased the midday dissolved oxygen eontent. However, much of the dissolved oxygen in the ponds, especially in the 1-, 2-, 3-, and 4-year-old ponds, is probably derived from the atmosphere by surface water agitation caused by wind and wave action.

Water Temperature--The average water temperature for each study pond is shown in Table 5. The variable temperature readings in the ponds were attributed to the inflow of ground water. Some differences occurred between the monthly temperature readings recorded in the different pond age categories, but these small variations could have resulted from localized weather changes.

Water Level--Seasonal water level deviations in the ponds for the 1979 season are graphically illustrated in Figure 13. The water recession in the study ponds for the 1979 season exhibited about the same pattern as in 1976, 1977, 1978, and 1980. However, drought conditions in 1977 and 1980 caused abrupt water level recession in all the study ponds. This drop in water level was greatest in the 6- and 9-year-old ponds, with a drawdown of about 2 m. Heavy rainfall in the late summer of 1977 filled the 2-, 6-, and 11-year old ponds to above the normal level, which inundated the terrestrial plant zone around the ponds. These extreme water level fluctuations could have influenced the quantity and diversity of aquatic insect species collected in the sampling program, especially mosquitoes, because most of the likely vegetated habitats were dewatered early in the growing season.

Management of water levels to control mosquito production in ponds is a very effective naturalistic control measure. The strip mine ponds are usually filled during the wet period from late winter through spring, but water levels recede at the beginning of the dry season. This seasonal water level recession (Figure 13), coincides with the active breeding season for permanent pool mosquitoes, thus effectively controlling these types of mosquitoes. However, wide amplitudes of water level fluctuations that periodically expose large areas of shoreline, as occur in the 6- and 9-year-old ponds, can be very conducive to the production of floodwater mosquitoes. The floodwater species of mosquitoes generally deposit their eggs on the damp soil along vegetated shorelines that are intermittently flooded. A brood of floodwater mosquitoes can be produced if the water level in the pond first recedes enough to allow deposition of eggs and then is followed by sufficient rainfall to raise the water level again and inundate the eggs, causing them to hatch. However, results from soil samples collected from these dewatered pond margins actually showed a paucity of floodwater mosquito ova.

REFERENCES

Bishop, E. L., and M. D. Hollis. Malaria Control of Impounded Water. Federal Security Agency, U. S. Public Health Service and Tennessee Valley Authority, Health and Safety Department, 1947. 422 pp.

Horsfall, W. R. A Method for Making a Survey of Floodwater Mosquitoes. Mosquito News, 16 (2): 66-71 pp., 1956.

Horsfall, W. R. Biology and Control of Mosquitoes in the Rice Area. Arkansas Agricultural Experiment Station, Bull. No. 427, 1942. 46 pp.

Jones, C. M., and D. W. Anthony. The Tabanidae (Diptera) of Florida. Agricultural Research Service, United States Department of Agriculture, Tech. Bull. No. 1295, 1964. 85 pp.

Rainer, Rex K. Strip Mining In Alabama and Its Effect Upon Navigable Waterways. Report to the Corps of Engineers. Mobile, Alabama, 1972. 42 pp.

Russell, Paul F., West, Luther S., and Reginald, Manwell D. Practical Malariology. W. B. Saunders Company, Philadelphia, 1946. 683 pp.

Figure 1. Aerial photograph of strip mine area, showing locations of the mine study ponds.

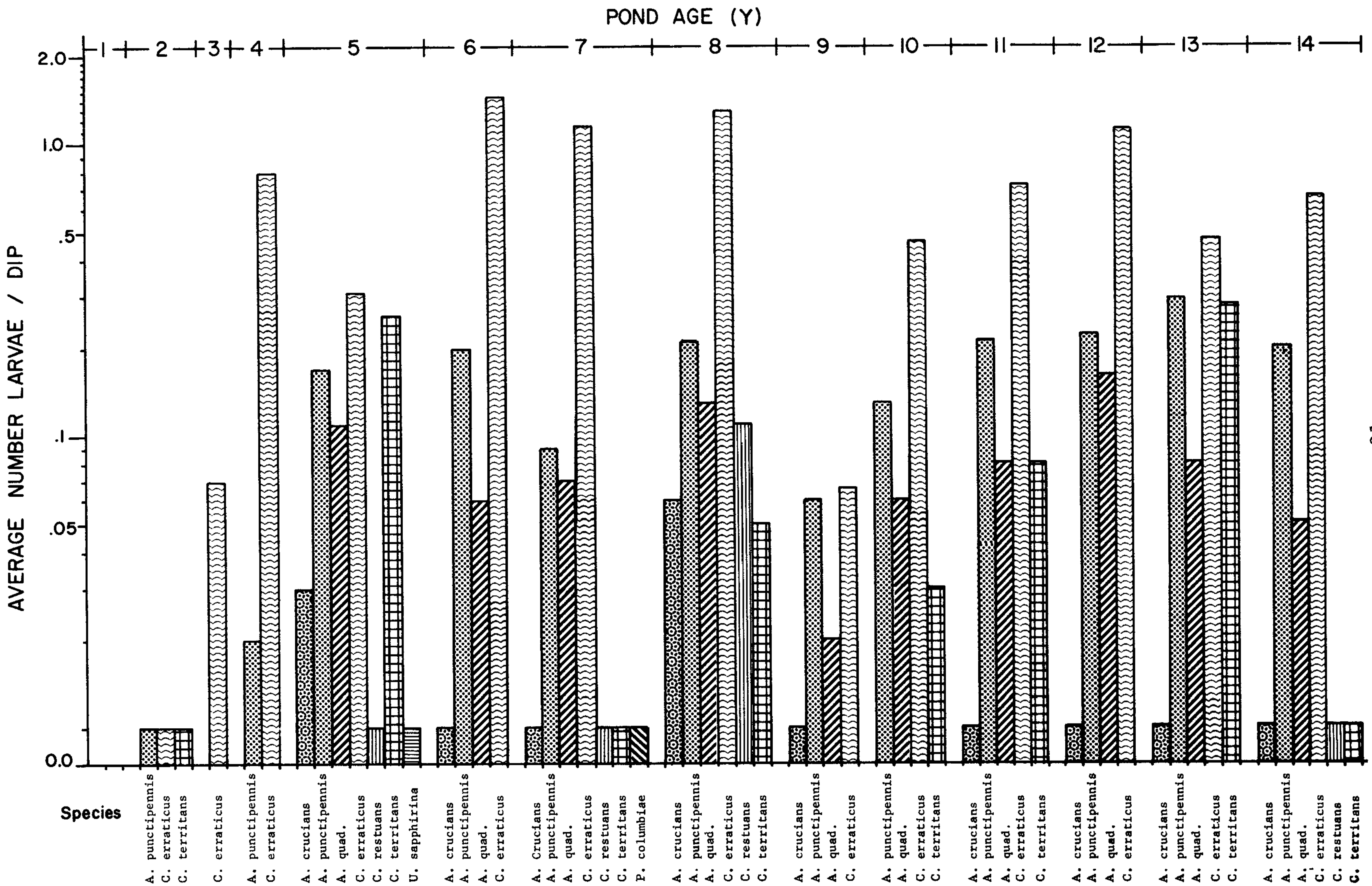

Figure 2. Population densities and species composition of mosquito larvae occurring in strip mine ponds, April-October 1976-1980

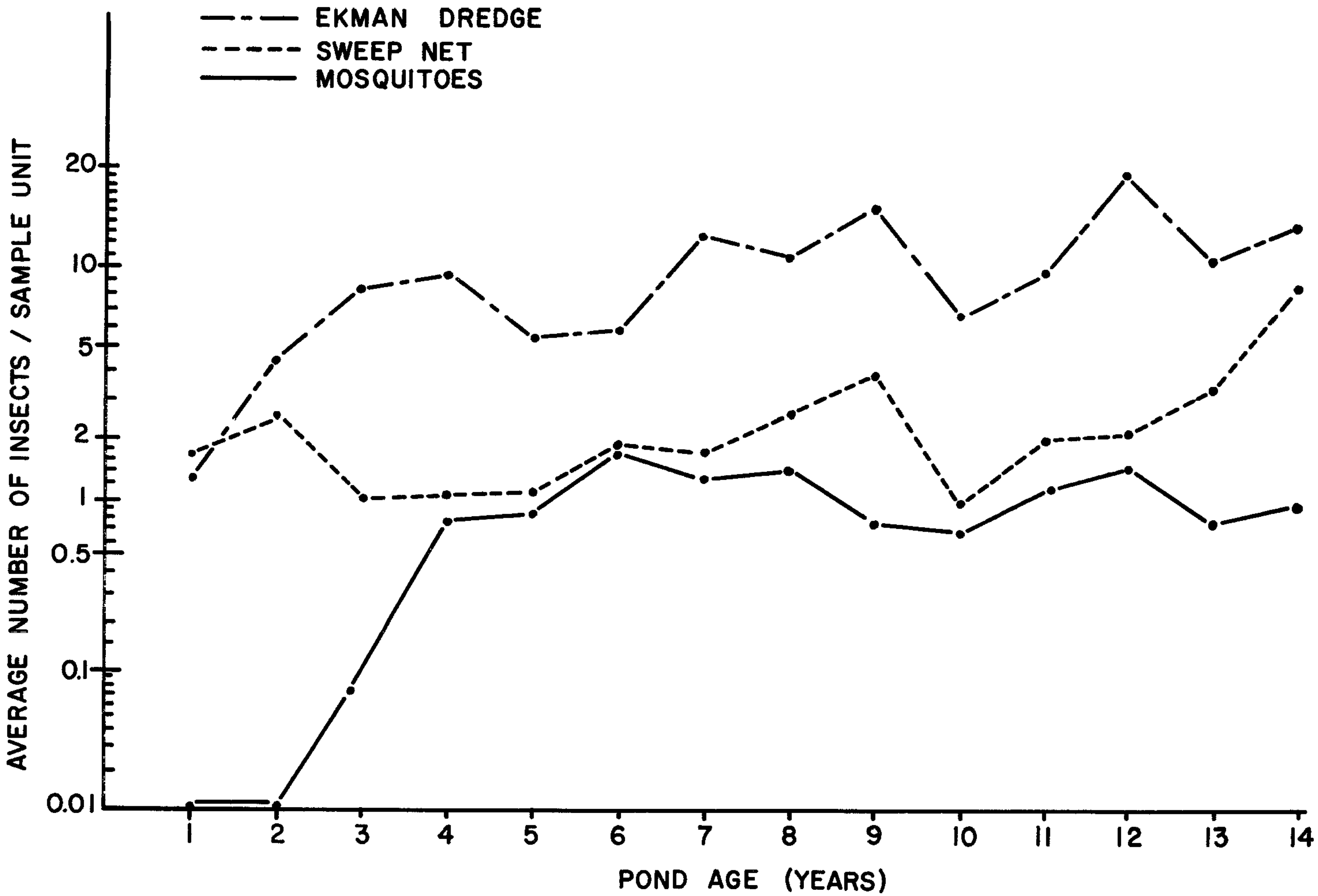

Figure 3. Average number of organisms per sample unit using dipper, aquatic sweep net, and Ekman dredge sampling methods, April-October 1980.

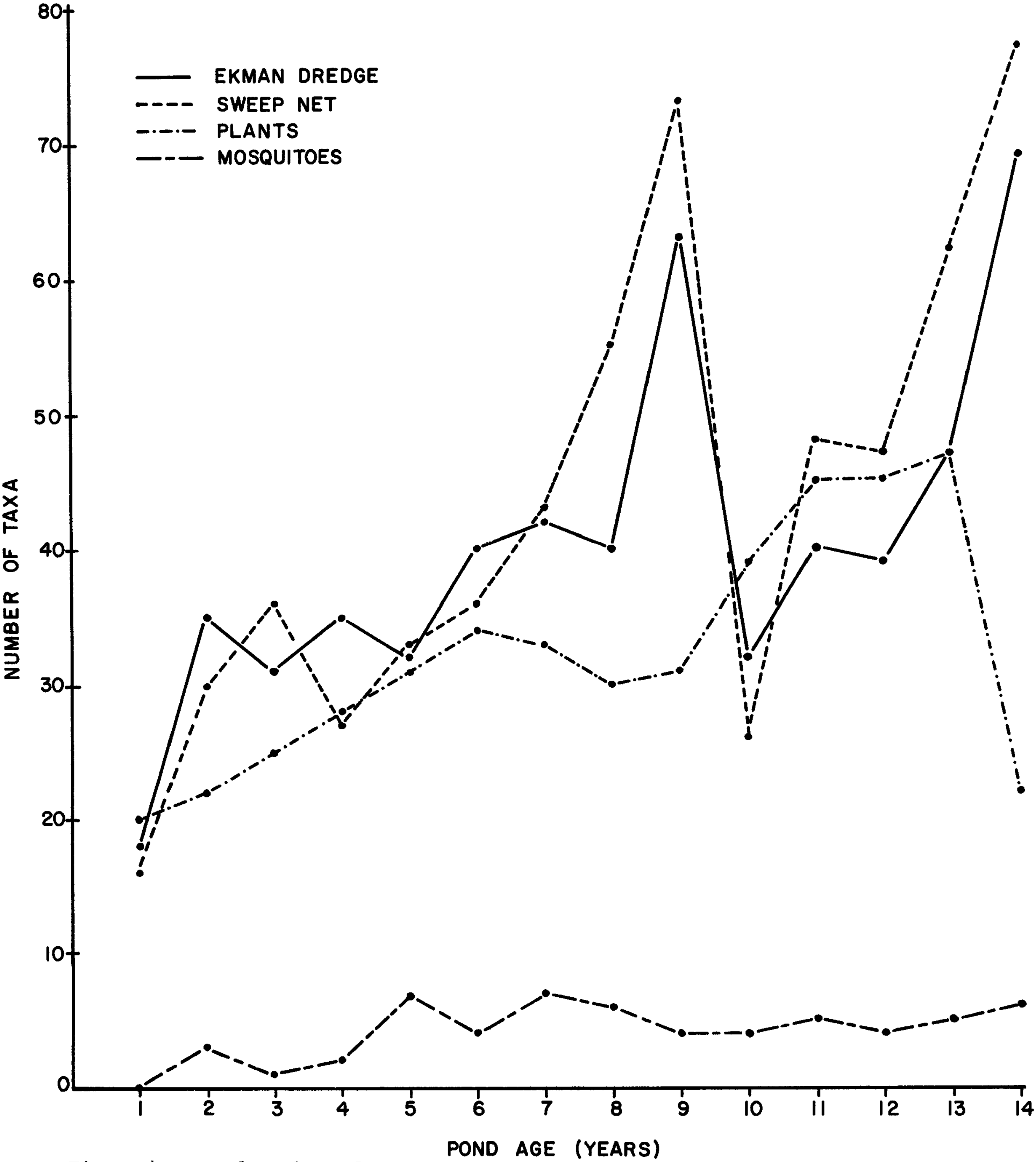

Figure 4. Total number of aquatic insect and plant taxa in strip mine ponds ranging in age from 1 to 14 years old, April-October 1976-1980.

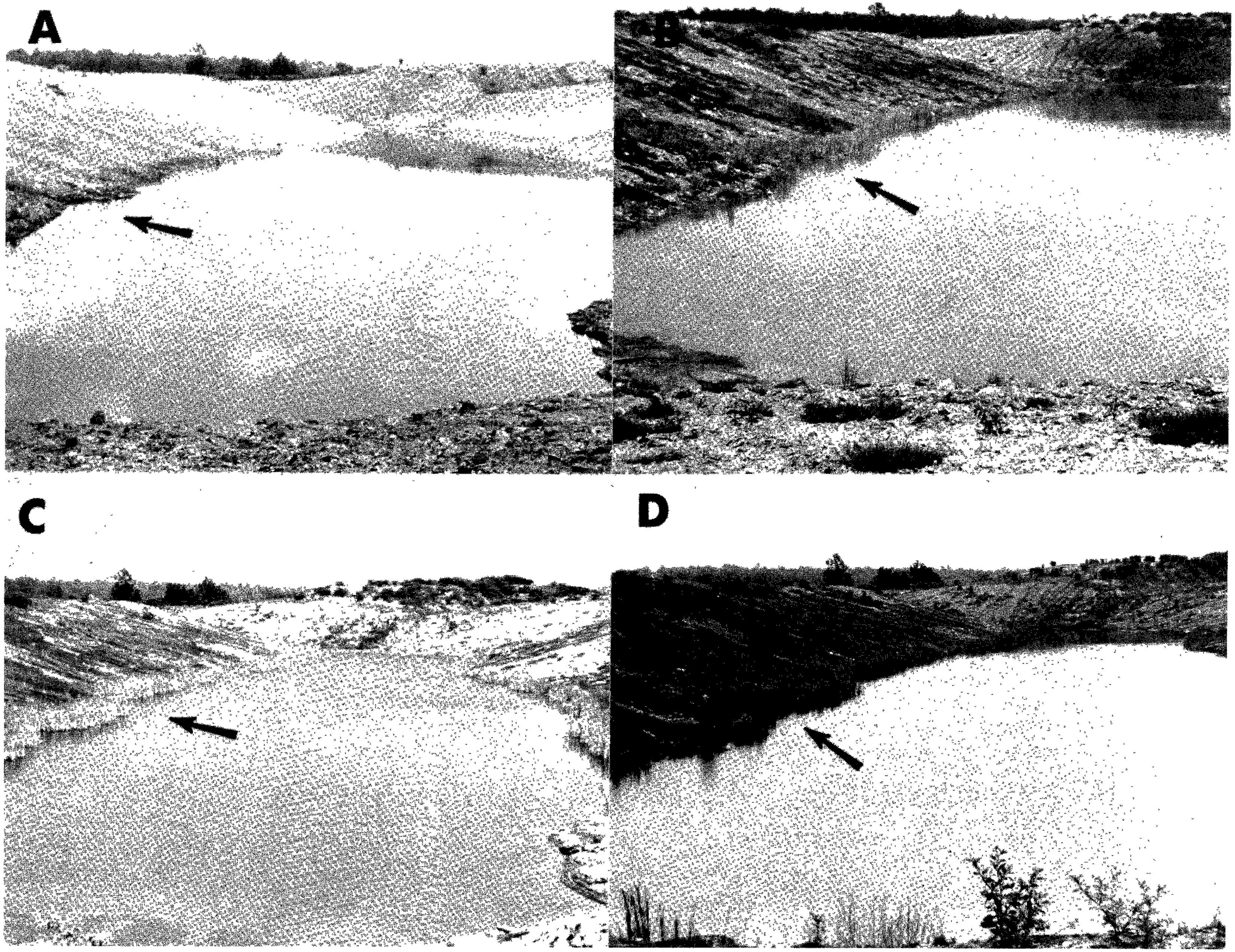

Figure 5. Example of 1- to 4-year-old ponds with spoil area reclaimed. A. 1-year-old pond; B. 2-year-old pond; C. 3-year-old pond; D. 4-year-old pond.

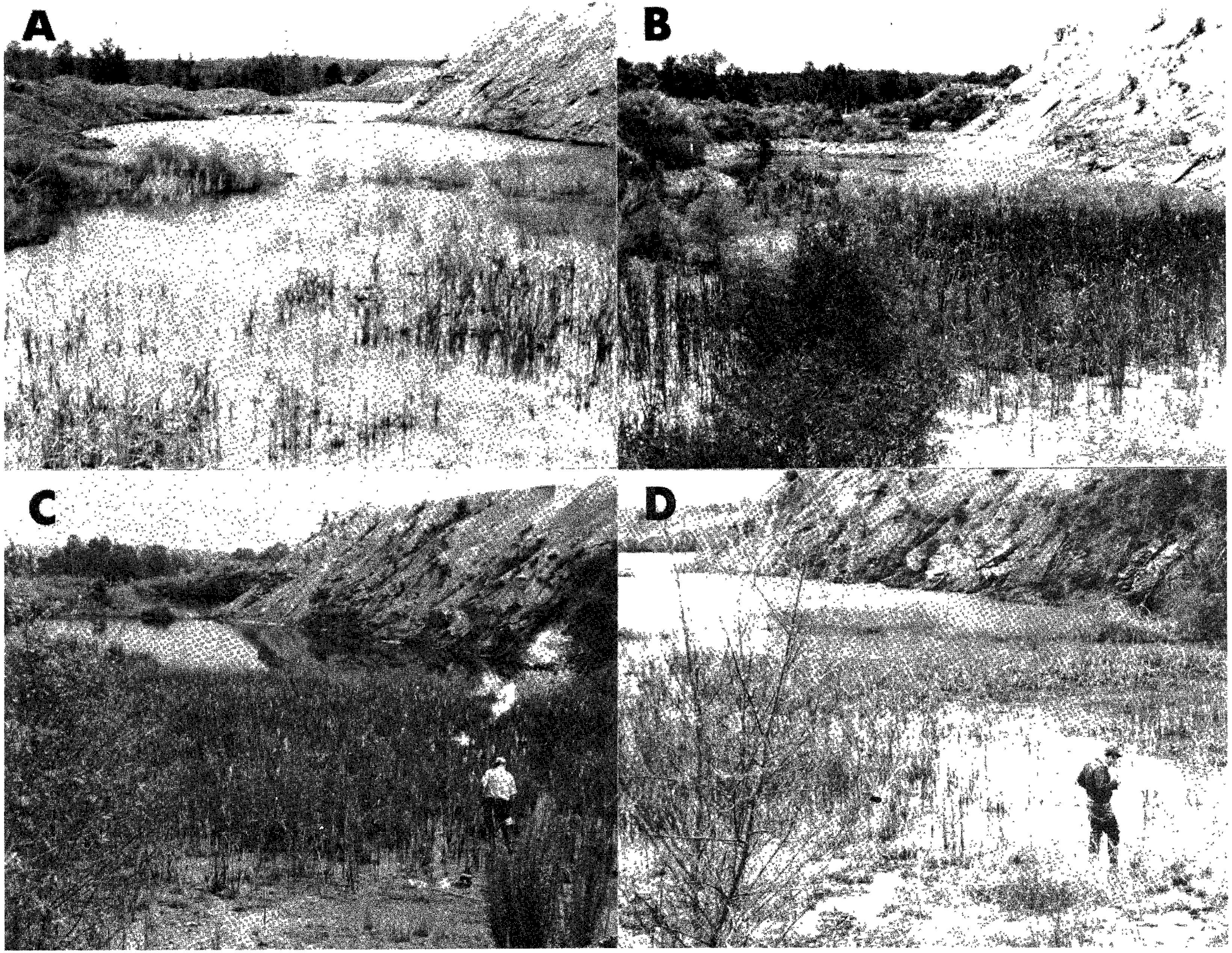

Figure 6. Example of 5- to 9-year-old pond surrounded by unclaimed spoil area. A. 5-year-old pond; B. 6-year-old pond; C. 7-year-old pond; D. 9-year-old pond.

Figure 7. Example of 10- to 14-year-old ponds showing unclaimed spoil area. A. 10-year-old pond; B. 11-year-old pond; C. 12-year-old pond; D. 14-year-old pond.

Figure 8. Eight-year-old pond showing dewatered marginal flat.

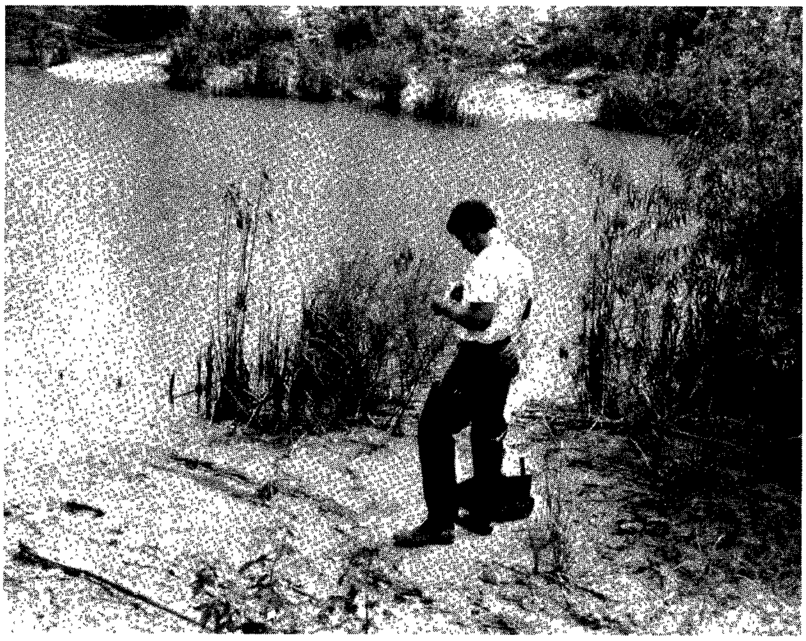

Figure 9. Thirteen-year-old pond showing alluvial outwash.

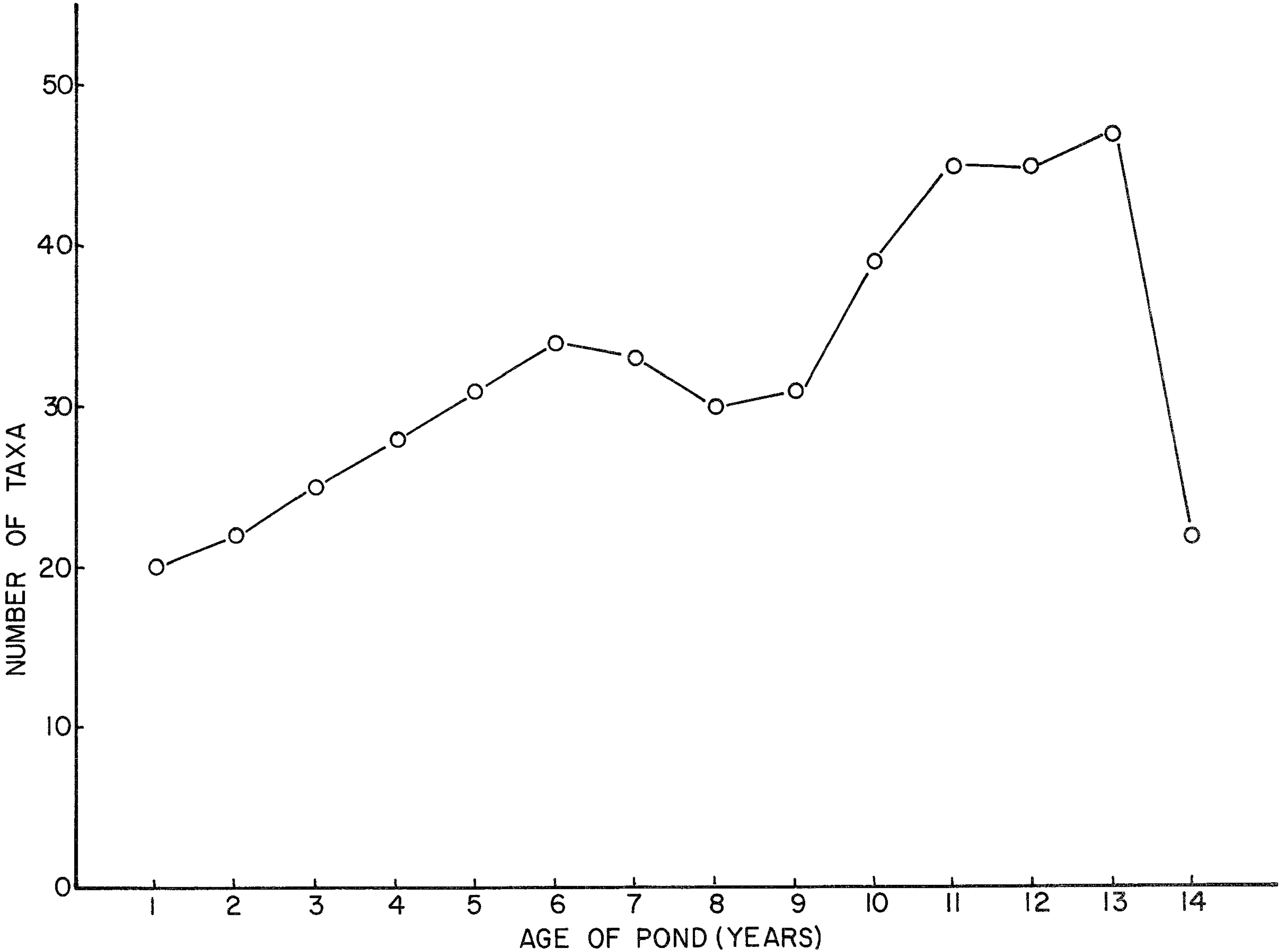

Figure 10. Number of plant taxa found in different age strip mine ponds.

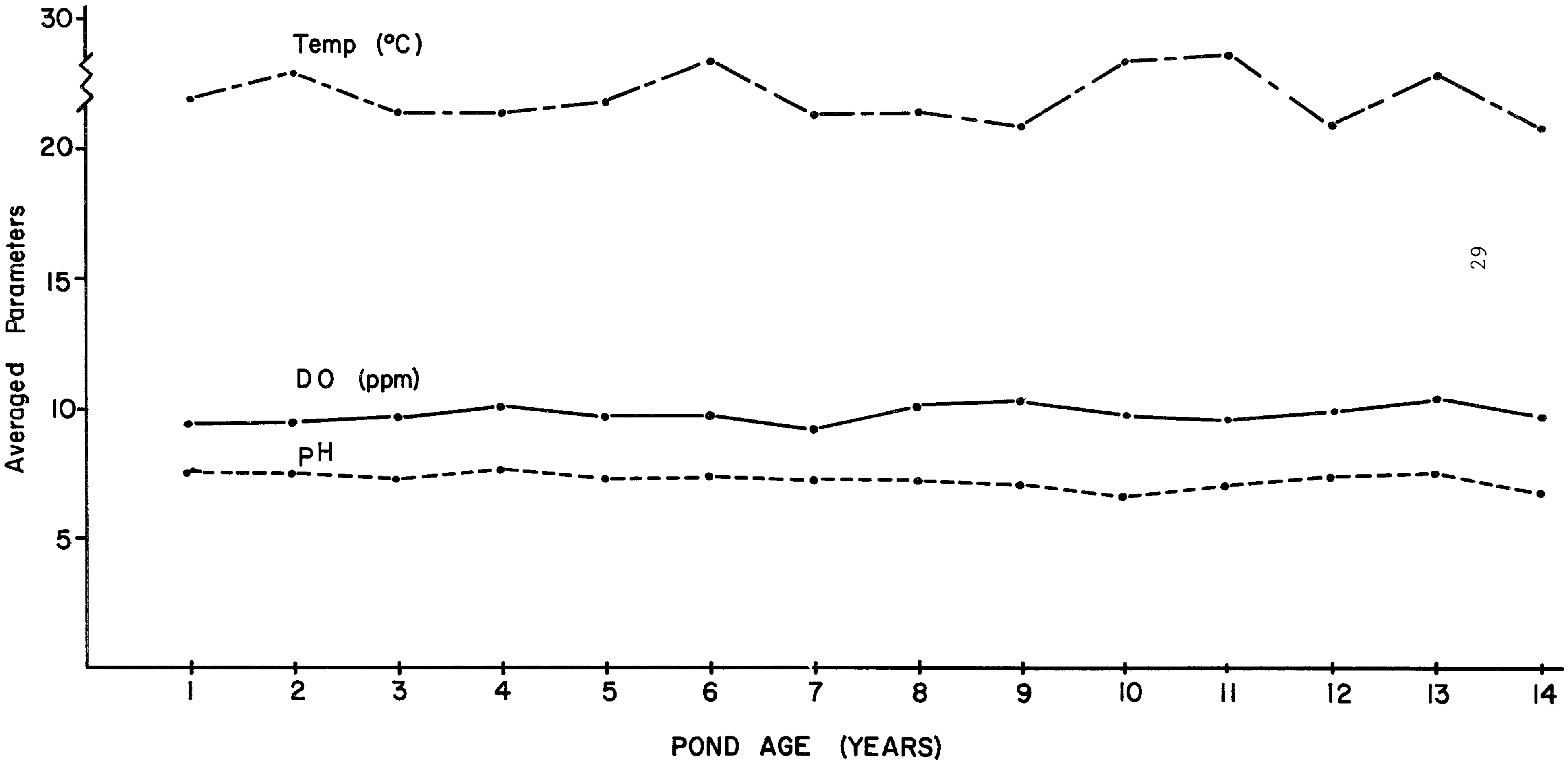

Figure 11. Seasonal averages of pH, dissolved oxygen, and temperature in strip mine ponds, April-October 1976-1980.

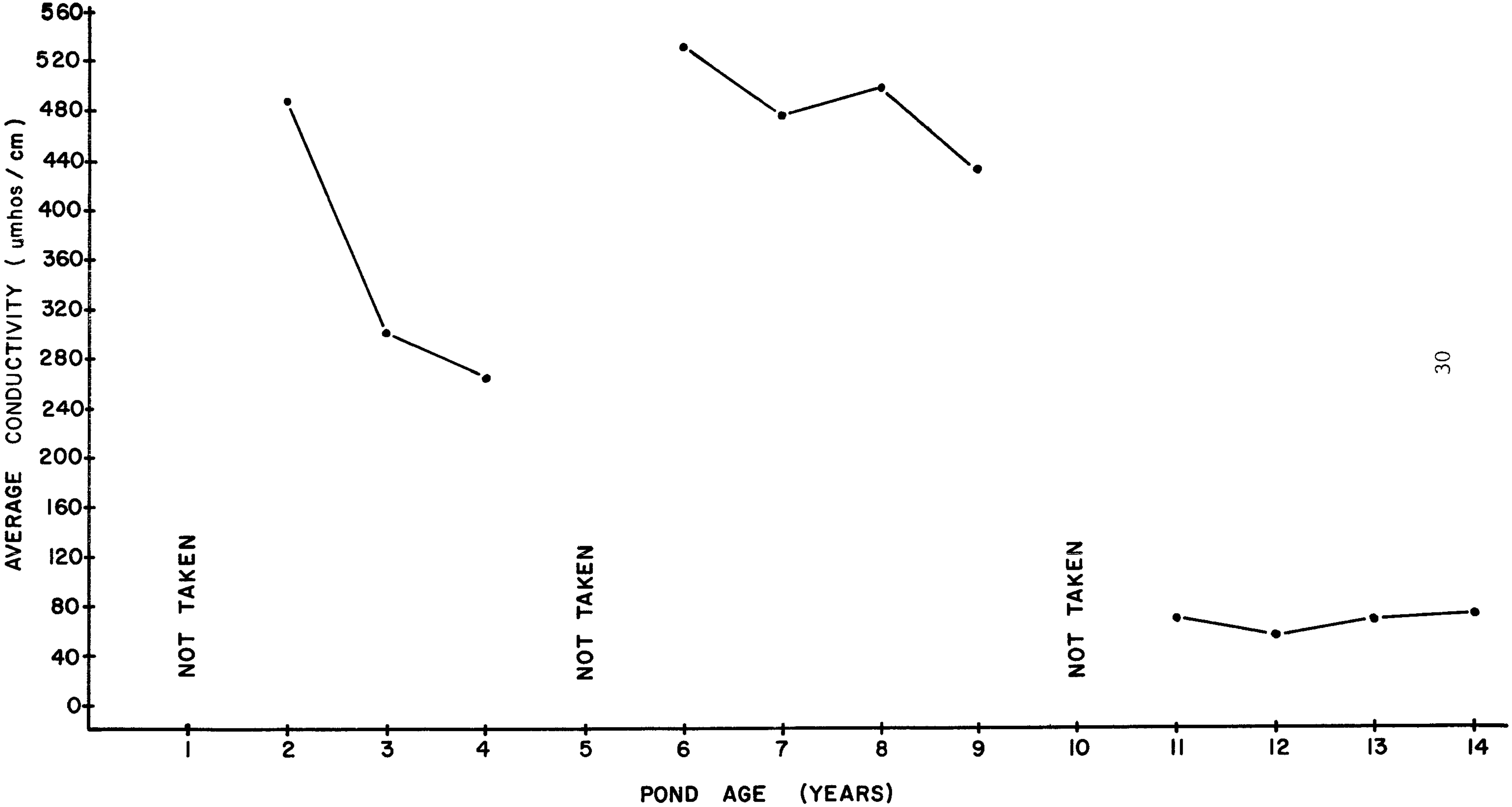

Figure 12. Seasonal averages of conductivity in coal strip mine ponds, April-October 1976-1980.

Figure 13. Water level fluctuations in the nine coal strip mine study ponds for the 1979 growing season.

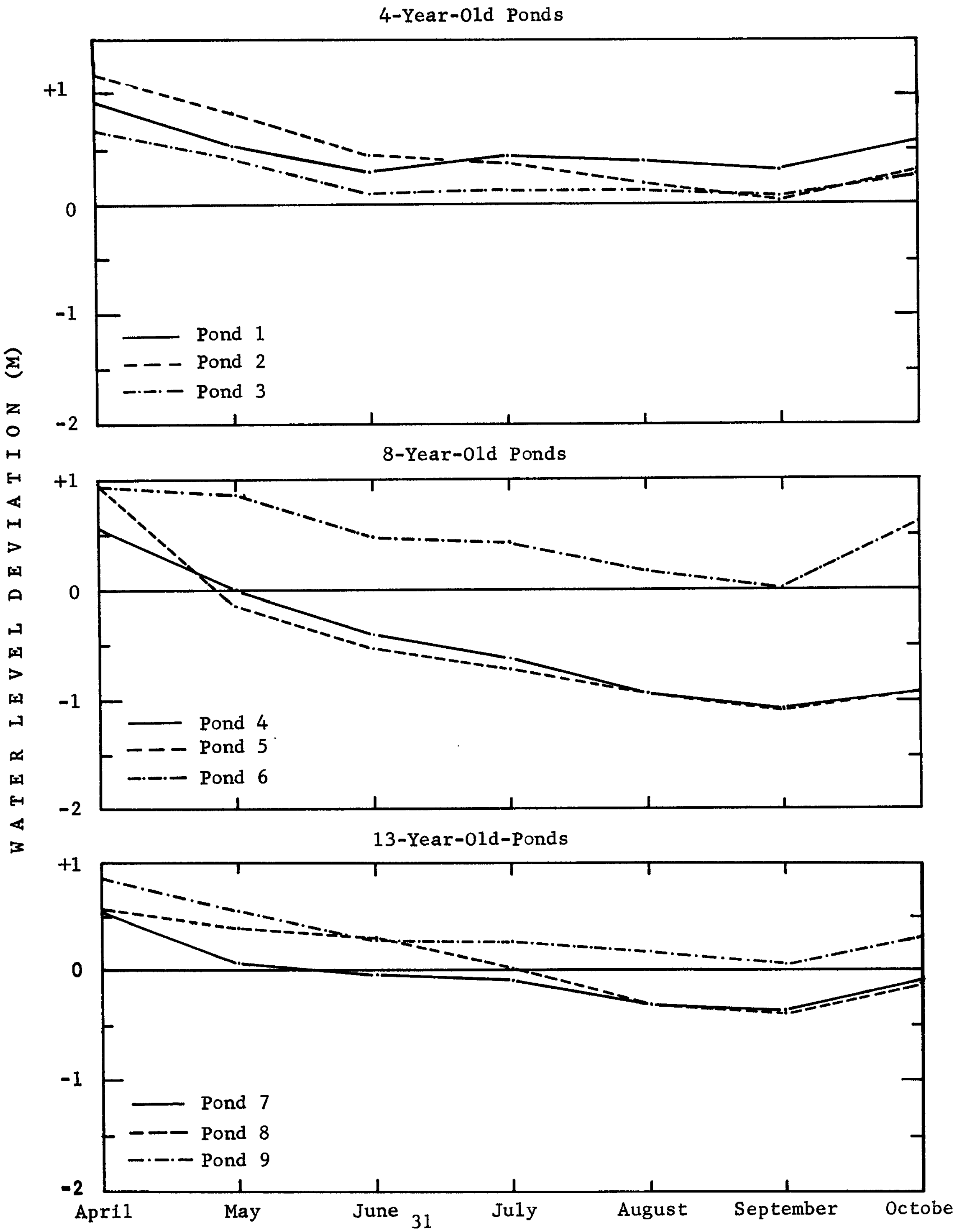

TABLE 1. SUMMARY OF MOSQUITO PRODUCTION, BASED ON AVERAGE NUMBER OF LARVAE PER DIP IN COAL STRIP MINE PONDS IN MARION COUNTY, ALABAMA, APRIL - OCTOBER 1976-1980

1976

Species	April Pond age (yrs)			May Pond age (yrs)			June Pond age (yrs)			July Pond age (yrs)			August Pond age (yrs)			September Pond age (yrs)			October Pond age (yrs)			Total Pond age (yrs)		
	1[a]	5[a]	10[a]	1	5	10	1	5	10	1	5	10	1	5	10	1	5	10	1	5	10	1	5	10
Anopheles crucians	-	0.00	0.00	-	0.00	0.00	-	0.03	0.00	-	0.17	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.03	0.00
Anopheles punctipennis	-	0.07	0.04	-	0.04	0.04	-	0.20	0.13	-	0.81	0.43	-	0.04	0.00	-	0.01	0.17	-	0.00	0.00	-	0.17	0.13
Anopheles quadrimaculatus	-	0.00	0.00	-	0.02	0.00	-	0.14	0.02	-	0.48	0.30	-	0.04	0.00	-	0.09	0.02	-	0.00	0.00	-	0.11	0.06
Culex erraticus	-	0.00	0.00	-	0.01	0.01	-	0.02	0.07	-	1.43	1.92	-	0.08	0.00	-	0.92	0.66	-	0.00	0.00	-	0.31	0.46
Culex restuans	-	0.02	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.01	0.00
Culex territans	-	0.01	0.00	-	0.00	0.00	-	0.00	0.07	-	1.94	0.00	-	0.00	0.24	-	0.01	0.01	-	0.00	0.00	-	0.26	0.03
Uranotaenia sapphirina	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.02	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.01	0.00

1977

Species	April Pond age (yrs)			May Pond age (yrs)			June Pond age (yrs)			July Pond age (yrs)			August Pond age (yrs)			September Pond age (yrs)			October Pond age (yrs)			Total Pond age (yrs)		
	2[a]	6[a]	11[a]	2	6	11	2	6	11	2	6	11	2	6	11	2	6	11	2	6	11	2	6	11
Anopheles crucians	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Anopheles punctipennis	0.00	0.04	0.02	0.00	0.37	0.01	0.00	0.07	0.22	0.00	0.06	0.08	0.05	0.04	0.15	0.00	0.20	0.42	0.00	0.39	0.59	0.01	0.20	0.21
Anopheles quadrimaculatus	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.07	0.28	0.00	0.13	0.30	0.00	0.00	0.01	0.00	0.40	0.11	0.00	0.00	0.00	0.00	0.06	0.08
Culex erraticus	0.00	0.00	0.00	0.00	0.06	0.01	0.00	2.04	0.97	0.00	0.69	2.00	0.00	12.20	2.56	0.02	1.77	0.56	0.00	0.01	0.06	0.01	1.45	0.71
Culex territans	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.00	0.21	0.00	0.00	0.00	0.01	0.00	0.08

1978

Species	April Pond age (yrs)			May Pond age (yrs)			June Pond age (yrs)			July Pond age (yrs)			August Pond age (yrs)			September Pond age (yrs)			October Pond age (yrs)			Total Pond age (yrs)		
	3[a]	7[a]	12[a]	3	7	12	3	7	12	3	7	12	3	7	12	3	7	12	3	7	12	3	7	12
Anopheles crucians	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.01	0.01
Anopheles punctipennis	0.00	0.00	0.10	0.00	0.01	0.06	0.00	0.12	0.00	0.00	0.18	0.30	0.00	0.14	0.26	0.00	0.07	0.23	0.00	0.40	0.65	0.00	0.09	0.22
Anopheles quadrimaculatus	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.03	0.05	0.00	0.23	0.56	0.00	0.04	0.33	0.00	0.09	0.14	0.00	0.20	0.02	0.00	0.07	0.16
Culex erraticus	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.12	0.06	0.00	1.61	0.30	0.11	1.99	1.38	0.04	5.96	7.57	0.00	0.10	0.61	0.07	1.15	1.11
Culex restuans	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Culex territans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Psorophora columbiae	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00

1979

Species	April Pond age (yrs)			May Pond age (yrs)			June Pond age (yrs)			July Pond age (yrs)			August Pond age (yrs)			September Pond age (yrs)			October Pond age (yrs)			Total Pond age (yrs)		
	4[a]	8[a]	13[a]	4	8	13	4	8	13	4	8	13	4	8	13	4	8	13	4	8	13	4	8	13
Anopheles crucians	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.13	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.01
Anopheles punctipennis	0.09	0.19	0.04	0.00	0.26	0.54	0.02	0.16	0.27	0.00	0.26	0.12	0.02	0.04	0.04	0.00	0.00	0.15	0.02	0.56	0.83	0.02	0.21	0.29
Anopheles quadrimaculatus	0.00	0.05	0.00	0.00	0.13	0.13	0.00	0.10	0.12	0.00	0.35	0.14	0.00	0.04	0.09	0.00	0.00	0.03	0.00	0.08	0.07	0.00	0.13	0.08
Culex erraticus	0.00	0.04	0.00	0.00	0.00	0.01	0.17	1.17	0.06	0.77	2.89	0.49	2.22	1.47	0.31	2.25	1.68	1.50	0.02	0.00	0.25	0.81	1.29	0.47
Culex restuans	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00
Culex territans	0.00	0.05	0.00	0.00	0.01	0.23	0.00	0.00	0.18	0.00	0.20	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.28

1980

Species	April Pond age (yrs)			May Pond age (yrs)			June Pond age (yrs)			July Pond age (yrs)			August Pond age (yrs)			September Pond age (yrs)			October Pond age (yrs)			Total Pond age (yrs)		
		9[a]	14[a]		9	14		9	14		9	14		9	14		9	14		9	14		9	14
Anopheles crucians	-	0.00	0.00	-	0.00	0.00	-	0.02	0.02	-	0.02	0.00	-	0.00	0.00	-	0.00	0.01	-	0.00	0.01	-	0.01	0.01
Anopheles punctipennis	-	0.02	0.00	-	0.02	0.01	-	0.12	0.23	-	0.08	0.13	-	0.05	0.05	-	0.06	0.66	-	0.10	0.52	-	0.06	0.20
Anopheles quadrimaculatus	-	0.00	0.00	-	0.00	0.04	-	0.02	0.07	-	0.02	0.04	-	0.05	0.05	-	0.03	0.11	-	0.00	0.01	-	0.02	0.05
Culex erraticus	-	0.00	0.00	-	0.00	0.01	-	0.24	0.21	-	0.90	0.66	-	1.09	0.77	-	2.25	3.58	-	0.00	0.02	-	0.66	0.66
Culex restuans	-	0.00	0.03	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	0.01
Culex territans	-	0.00	0.00	-	0.00	0.01	-	0.00	0.08	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	0.01

[a]Average of three ponds.

TABLE 2. SPECIES AND NUMBER OF FLOODWATER MOSQUITO OVA COLLECTED FROM SOIL SAMPLES TAKEN IN COAL STRIP MINE PONDS, RANGING IN AGE FROM ONE TO FOURTEEN YEARS, MARION COUNTY, ALABAMA -- 1976-1980

	From ponds aged years[a]													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Samples taken	22	15	25	20	53	39	32	29	38	42	40	46	32	37
Samples positive for mosquito ova	0	0	0	0	3	3	0	2	1	14	10	5	5	0
Percent positive samples	0.0	0.0	0.0	0.0	5.7	7.7	0.0	6.9	2.6	33.3	25.00	10.9	15.6	0.0
Aedes sollicitans ova	0	0	0	0	1	0	0	0	0	2	0	0	0	0
Aedes sticticus ova	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Aedes trivittatus ova	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Aedes vexans ova	0	0	0	0	3	13	0	2	0	98	39	6	2	0
Psorophora columbiae ova	0	0	0	0	0	0	0	0	1	0	0	2	0	0
Psorophora cyanescens ova	0	0	0	0	0	0	0	0	0	0	0	1	0	0

a. Average of 3 replicates

TABLE 3. INSECT TAXA TAKEN FROM VARIOUS AGES OF COAL STRIP MINE PONDS IN MARION COUNTY, ALABAMA--APRIL - OCTOBER 1976, 1980[a]

Species composition	Age of Pond (Years)													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
EPHEMEROPTERA														
Baetidae														
Callibaetis	I	C	I	I	C	C	C	I	A	I	I	I	A	C
Cloeon					I				I					
Caenidae														
Caenis			I	A			C	A	A		I		I	A
Ephemeridae														
Hexagenia munda elegans		C	C	I	A	C	I	C	A	A	A	A	C	C
ODONATA														
Aeshnidae														
Anax junius					I	C		I	I		C	I	C	A
Anax longipes		I			I	I				I	I	I	C	C
Basiaeschna janata						I		I						
Coenagrionidae		I							I					
Anomalagrion hastatum		I			I	I	I	I	I		I			
Argia apicalis								I	I					
Argia fumipennis				I		I	I	I	C	I	I	I	I	C
Argia sedula									I					
Argia sp.			I				I							
Enallagma aspersum		I	I		C	C			I	C	C	C	A	A
Enallagma basidens				C		I	A	A	A		I		C	A
Enallagma civile			I		I		I		I					A
Enallagma divagans													I	
Enallagma doubledayi						I								
Enallagma signatum					I			I	A					
Enallagma sp.		C	C				C		C			C	C	A
Ischnura posita			C		C		C	C	C	I	I	C	I	A
Corduliidae														
Tetragoneuria cynosura						I		C	C		C		C	I
Gomphidae														
Dromogomphus spinosus	I	C			I	I	C	I	C					
Gomphus exilis	C	C	A	C	C	C	C	A	A	A	C	C	C	A
Lestidae														
Archilestes grandis											I			
Lestes congener														I
Lestes disjunctus						I	I			I		I	C	C
Libellulidae							I						I	
Celithemis elisa				I		A		C	A		I	I	C	A
Erythemis simplicicollis				I					C	I		I	I	I

TABLE 3 (Continued)

Species composition	Age of Ponds (Years) 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Ladona deplanta									C					
Libellula cyanea							I	I	C	I			I	C
Libellula sp.					I				I			I		I
Pachydiplax longipennis	I		I		I		C		I					
Pantala flavescens	I	C	I	C			I				C	C	I	I
Pantala hymenaea								I						
Perithemis tenera								I	I				I	
Plathemis lydia										I				
Sympetrum vicinum											I		I	
Tramea carolina													I	
Tramea sp.					I		C		I			I	I	A
Macromiidae														
Didymops transversa		C	I		I	C	C	C	I		C	I	C	
ORTHOPTERA														
Tridactylidae														
Tridactylus						I								
HEIMPTERA														
Belostomatidae														
Belostoma					I	I	I	I	I	I				
Lethocerus														I
Corixidae			I									I	I	
Hesperocorixa		I							A		I	I	A	
Sigara		I	I	C		I			I	I	C	C	C	I
GALASTOCORIDAE														
Gelastocoris													I	
Gerridae					I			I	I					I
Gerris		I	I	I	C	I	I	I	I		I	I		C
Limnoporus canaliculatus									I					C
Neogerris hesione					C	I		I	I		I		I	I
Rheumatobates					I	I						I		
Trepobates			I	A	I	A	A	A	A	A	A	A	A	A
Hydrometridae														
Hydrometra		I	I		I			I	I		I	I	I	I
Mesoveliidae									C					C
Mesovelia			C		C	I	C	C		I	I	I	I	
Naucoridae														
Pelocoris					I	I	I	C	I	C	I		I	C
Nepidae														
Ranatra	I	I	I	I	C		I		I		C	C	C	A
Notonectidae														
Buenoa	I	A	I	I	C			I		A	A	A	C	A
Notonecta	A	A	I	C	A	I			I	C	C	C	C	A
Veliidae														
Microvelia			I		I		A	I		I				

TABLE 3 (Continued)

Species composition	Age of Ponds (Years)													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
TRICHOPTERA														
Leptoceridae														
Oecetis								I	I					I
Triaenodes									I					
Phryganeidae														
Agrypnia														I
Polycentropodidae														
Polycentropus			I	C		C	C	A	C				I	I
COLEOPTERA														
Chrysomelidae														
Donacia														I
Dytiscidae														
Agabus disintegratus			I		I				I	I		I		I
Agabus (larvae)					I									
Bidessus									I					
Copelatus glyphicus									I	I				
Coptotomus interrogatus		C	I	I	C		I			I	C	A	A	A
Cybister													I	C
Deronectes												I		
Hydroporinae (genus unidentified)												I		
Hydroporus rufilabris									I	C	I	I		I
Hydroporus undulatus	I	I			A	A			I	C	I	I	C	C
Hydroporus sp.							I							I
Hygrotus		I		I										
Laccophilus maculosus	A	A	C	C	A	C	I	I	I	C	A	A	A	A
Laccophilus proximus					I								I	C
Thermonectus		I											C	C
Elmidae							I							
Dubiraphia														I
Gyrinidae														
Dineutus	A	A	A	C	C	A	A	C	I	A	A	A	A	A
Gyrinus		C	I			I			I		I	I	I	I
Haliplidae														
Peltodytes						C	C	I	I	I	I	I	I	I
Helodidae														
Cyphon									C					
Hydrophilidae								C	I					I
Berosus infuscatus	I				I		I		I					C
Berosus nr. *aculeatus*			I	I	C	A	I	C	C	C	C	C	C	C
Berosus (larvae)									I				I	I
Berosus (sp #3)									I					
Cymbiodyta blanchardi										I				
Enochrus									C					I
Helochares maculicollis								I	I	I				

TABLE 3 (Continued)

Species composition	Age of Ponds (Years) 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Helophorus								I			I		I	
Hydrochus									I					
Paracymus (subcupreus group)									C	I	I			
Tropisternus lateralis		I		I	C	I	I	I		I	I	C	C	A
Tropisternus (sp. #2)													I	
Tropisternus (sp. #3)									I					I
Tropisternus sp.									I					I
Noteridae														
Hydrocanthus							I							
Suphisellus														I
MEGALOPTERA														
Sialidae														
Sialis	I	I	C	C	C	C	A	A	A		C	A	C	A
DIPTERA														
Ceratopogonidae			C				C					I		
Palpomyia	C	A	A	A	A	A	A	A	A	A	I	C	A	A
Chaoboridae														
Chaoborus			I								I	I		I
Corethrella						I								
Eucorethra						I			I					I
Chironomidae			I	I			C					C		
Ablabesmyia annulata									i		i			
Ablabesmyia sp.	I	A	A	A	I	A	A	A	A	I	A	A	A	A
Chironomus		I	C	I	I	A	A	A	A	C	A	A	A	A
Cladotanytarsus	I	C	A	I		I	I	I	I		I	C	I	I
Coelotanypus							I					A		
Conchapelopia									I					
Corynoneura														I
Clinotanypus			I	I			I	C	A	I	C	C	C	A
Cricotopus remus					I							I		
Cricotopus sp.		C	C			I	I	I	I		I	I		
Cryptochironomus fulvus	I	C	I	I		I	I	A	C		I	I	I	I
Cryptochironomus sp.	I	C	I			I	I				I	I		
Cryptocladopelma									I		C		C	A
Cryptotendipes sp.1		I		I					I		I			
Cryptotendipes sp.2				I		I		I			I		I	
Dicrotendipes			I			I	A	I	C	I	I	C	C	I
Einfeldia											C	I		
Encochironomus nigricans	I	C	C	C	C	C	A	A	C	C		C	A	C

TABLE 3 (Continued)

Species composition	Age of Ponds (Years) 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Goeldichironomus holoprasinus		I												
Glyptotendipes								I						
Harnischia		I	I											
Kiefferulus dux													I	
Labrundinia johannseni														I
Labrundinia neopilosella								I	I				I	
Labrundinia virescens									I					I
Larsia									C				I	C
Lauterborniella														I
Micropsectra				C			C	C	I				I	
Microtendipes						I		I	I					I
Nilothauma								I						
Pagastiella		I		I	I	I	I	I	I				I	C
Parachironomus									I					
Paralauterborniella									I					I
Paratendipes							I	I				I	I	I
Polypedilum	I	A	A	A	I	A	A	A	A	I	A	A	A	A
Procladius	I	A	A	A	A	A	A	A	A	A	A	A	A	A
Psectrocladius				I				I	C				I	
Pseudochironomus								I	I				I	
Rheotanytarsus			I	I			I					I		
Smittia				I										
Stictochironomus	I	A	A	C			A	I	A			C	C	C
Tanypus											I	I		I
Tanytarsus	I	I	C	C	I	C	A	C	A			A	C	C
Orthocladiinae (genus #1 unidentified)	I	I	I	I			I	C	C			A	I	C
Orthocladiinae (genus #2 unidentified)			I				I							
Orthocladiinae (genus #3 unidentified)			I											
Xenochironomus			I											
Stratiomyidae														
Eulalia						I		I	I					
Tabanidae														
Chrysops			I		I		I	I	I	I	I	C	I	C
Tabanus						I		I						
Tipulidae														
Gonomyia		I						I						
Helius														I
Tipula	I									I				

TABLE 3 (Continued)

Species composition	Age of Ponds (Years)													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
COLLEMBOLA														
Isotomidae									I					
Isotomurus												I		
Sminthuridae														
Sminthurides									I					
HIRUDINEA														I
LUMBRICULIDA														
Lumbriculidae						I	I	C	A			I	C	I
TRICLADIDA														
Planariidae														I
Cura formanii														
Number of Insect Taxa	25	44	54	45	47	54	63	68	97	42	58	66	77	92

[a] The presence and degree of abundance of the taxa in the ponds are indicated by the following scale:
I = 1 to 5, infrequent
C = 6 to 19, common
A = 20 and above, abundant

TABLE 4. LIST OF VASCULAR PLANT SPECIES AND MACROSCOPIC ALGAE ASSOCIATED WITH STRIP MINE PONDS OF VARIOUS AGES IN MARION COUNTY, ALABAMA[a]

Plant taxon and habitat zonation	Age category of ponds[b]													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Submersed														
Chara sp.				1		1		1	4			1	1	1
Potamogeton diversifolius		1	6	5	5	5	7	8	3	2	3	3	3	4
Potamogeton pusillus		1		1			2	4	5					3
Emergent														
Eleocharis acicularis											1			3
Eleocharis engelmannii											1	1		
Eleocharis obtusa			3	1	2	2	5	6	6	5	5	8	8	8
Juncus acuminatus					1	2		1	1	7	8	6	7	1
Juncus debilis							1	1	1					
Juncus diffusissimus								1	1					
Juncus tenuis													1	
Scirpus cyperinus			1	3	3	3	3	5	4	9	9	9	9	9
Sparganium americanum					1	1								
Typha latifolia	7	7	6	6	9	9	9	7	5	7	7	7	7	1
Wetland														
Acer rubrum						1					1	1	4	5
Aster pilosus	1	1	1	6	4	1	7	7		4	5	2	4	
Bidens frondosa			2	5	6	9	9	9	6	6	9	8	9	4
Cyperus odoratus			3	2										
Echinochloa crusgalli	1	1	8	6	3	3	3			4	3	2	2	
Eclipta alba					2	2	2							
Eupatorium coelestinum											2	1	1	
Eupatorium perfoliatum												1	2	
Fimbristylis autumnalis							1	1	2	1	1	1		
Hypericum mutilum										1	1	1	2	
Liquidambar styraciflua													1	
Ludwigia alternifolia					3	3	3	4	4	3	3	4		
Mikania scandens										3	3	3	3	2
Panicum agrostoides									3				1	
Panicum dichotomiflorum	2	3	6	8	8	8	9	7	1	3	3	5	3	
Panicum microcarpon	2				2		1			1	3		5	
Panicum spretum												1	3	
Panicum verrucosum										1	1	1	1	

TABLE 4 (continued)

Plant taxon and habitat zonation	Age category of ponds[b]													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Panicum sp.		1				1								
Paspalum boscianum										3	3	2	1	
Pluchea camphorata			1		3	3	4	4	3	2	2	3	3	2
Polygonum hydropiperoides				1					1			1	1	
Polygonum lapthifolium	2	2	6		1	1	3							
Polygonum pensylvanicum	5	5	6	1	1	1			1	1	1			
Polygonum punctatum					1	1	2			2	2	1		
Populus deltoides	1	1	3	5					1					
Salix nigra	6	3	5	8	9	9	9	9	9	9	9	8	9	8
Spiranthes cernua													2	
Terrestrial														
Ambrosia artemisifolia			2	1	3	3	2		3	5	5	2		
Andropogon virginicus	5	5	4	8	5	5	5	5	2	6	6	6	6	1
Aristida dichotoma	1	1								3	3	4	4	
Aristida oligolantha			1											
Cassia fasciculata				2										
Cassia nicitans					3	3	3	3	4	3	3	4	2	1
Chenopodium album					1	1					1			
Chenopodium ambrosioides	3	3	1	1										
Desmodium perplexum										1	1			
Digitaria ischaemum	1	1	5	4	2	2	7	8	7	4	4	3	2	
Diodia teres	1	1		2	5	5	4	4	6	7	7	3	6	1
Diospyros virginiana					1	1	1	2					1	1
Erechtites hieracifolia	3	3						3		6	6	1	5	
Erianthus alopecuroides												1	1	2
Eupatorium compositifolium					2	2	1		2	6	4	1	4	1
Eupatorium hyssopifolium								2						
Eupatorium serotinum			1	2	7	7	6	7	7	2	2	5	4	1
Eupatorium sessilifolium												1		
Iva annua	2	2	8	8			1	2	3	2	2	1	1	
Lespedeza cuneata				2	5	5	7	7	2	7	8	6	5	1
Lespedeza hirta									1	1	1			
Lespedeza striata	7	7	8	3	3		1	1	2	5	2	6		
Lobelia puberula										2	2	2	2	
Lonicera japonica												1	1	
Oxalis sp.										1	1	1		
Panicum anceps													1	
Panicum lanuginosum								1				3	2	
Paspalum dilatatum							1							
Phytolacca americana	6	6	1				3		3			1		
Pinus taeda													3	
Pinus virginiana	1	1												
Plantago aristata	1	1												

TABLE 4 (continued)

Plant taxon and habitat zonation	Age category of ponds[b]													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Polypremum procumbens										1	1	1	1	
Pyrrhopappus carolinianus				1		1					1			
Rubus sp.					1	1	2		2				2	
Setaria geniculata					1	1				1	1			
Smilax rotundifolia													1	
Solidago sp.			1	2			1	6				1	3	
Xanthium strumarium			1	1		1				1	1			
Number of Taxa	20	22	25	28	31	34	33	30	31	39	45	45	47	22

a. Each number represents the number of sampling stations from which a species was present out of nine total stations.

b. Each age category (e.g., 1-year-old ponds) contain three ponds, each of which contain three sampling stations.

TABLE 5. Results of Monthly Monitoring in Five Consecutive Years Of Four Physical Parameters of Nine Coal Strip Mine Ponds in Marion County, Alabama. April to October 1976-1980.

Pond age (y)	April	May	June	July	Aug.	Sept.	Oct.	Seasonal Range
	Average monthly pH							
1	7.3	7.5	7.4	8.1	8.1	7.5	7.4	6.4 - 8.7
2	7.7	8.1	7.4	7.3	7.6	7.4	7.6	6.2 - 8.5
3	6.7	7.2	6.7	6.8	8.3	8.0	7.8	6.0 - 8.6
4	7.6	7.5	7.4	8.0	8.2	7.7	7.5	7.0 - 8.6
5	7.2	7.4	7.2	7.4	6.6	7.6	7.6	5.7 - 8.9
6	7.2	7.4	7.9	7.3	7.1	7.1	7.6	5.7 - 8.9
7	6.7	6.3	6.8	6.7	7.4	8.0	8.0	5.8 - 9.0
8	7.0	7.2	-	7.2	7.6	6.5	7.1	5.3 - 9.0
9	7.0	7.1	7.0	7.2	7.2	7.5	6.5	5.8 - 8.0
10	6.8	6.9	6.7	6.7	7.1	6.3	6.6	5.9 - 8.2
11	7.1	6.7	7.0	7.0	6.2	6.2	7.3	5.0 - 8.3
12	6.6	7.0	6.3	7.1	7.2	8.0	7.3	5.3 - 8.6
13	6.5	6.7	7.1	7.5	7.8	7.4	7.2	5.6 - 9.2
14	6.8	7.0	6.9	7.8	6.9	7.8	5.9	5.5 - 9.2
	Average monthly DO (ppm)							
1	9.9	10.1	9.5	8.8	9.3	9.2	12.0	8.1 - 12.2
2	10.5	9.7	8.7	8.1	8.8	9.3	11.1	7.6 - 12.4
3	10.0	9.7	9.3	8.2	8.9	10.4	11.1	7.6 - 13.8
4	-	10.6	9.1	9.4	10.0	9.7	11.8	8.2 - 12.2
5	10.3	9.6	10.1	8.1	10.0	10.2	12.2	6.4 - 14.1
6	10.5	10.1	10.3	8.1	9.6	9.2	10.3	7.4 - 11.8
7	9.6	9.5	8.6	8.6	8.9	10.4	10.1	4.1 - 12.6
8	-	10.1	8.3	9.5	10.4	10.6	11.1	7.2 - 12.2
9	10.7	8.8	10.0	9.3	9.6	11.1	11.4	7.0 - 13.8
10	9.6	10.5	9.1	8.3	8.3	7.4	11.7	6.0 - 12.6
11	9.7	9.3	8.7	8.5	8.6	8.7	10.8	7.2 - 11.7
12	9.1	9.8	8.9	8.9	9.1	9.3	11.3	7.4 - 12.4
13	-	10.2	10.2	8.8	10.4	10.1	11.0	7.8 - 13.3
14	10.6	9.0	9.2	8.7	8.4	9.1	10.2	6.2 - 11.2
	Average monthly temperature (^{o}C)							
1	23	23	28	30	29	26	12	9 - 31
2	23	27	30	29	32	25	16	13 - 33
3	20	21	23	29	27	26	16	14 - 30
4	22	21	23	30	26	26	18	17 - 33
5	19	27	28	33	29	26	14	13 - 42
6	24	27	30	31	32	27	17	17 - 33
7	21	20	26	26	25	26	15	10 - 30
8	20	23	21	30	24	26	17	15 - 33
9	12	22	27	24	26	28	18	12 - 30
10	26	23	28	28	29	26	13	8 - 31
11	27	27	31	31	29	28	18	15 - 34
12	18	21	22	28	24	26	15	12 - 29
13	21	23	21	30	24	26	17	15 - 33
14	12	22	27	25	26	28	17	11 - 30
	Average monthly conductivity (μmhos/cm)							
1	-	-	-	-	-	-	-	
2	-	-	496.7	553.9	593.3	487.8	294.5	150 - 1000
3	283.8	275.0	298.0	349.4	367.8	269.0	307.8	27 - 700
4	205.0	229.4	285.0	313.1	309.6	305.0	221.9	100 - 700
5	-	-	-	-	-	-	-	
6	-	-	641.7	602.2	580.0	487.5	359.5	195 - 1400
7	513.8	350.6	531.7	550.0	546.7	392.2	450.6	27 - 1150
8	363.9	502.2	553.9	556.7	566.7	531.1	343.9	125 - 1150
9	286.6	449.4	542.2	387.8	500.6	511.7	338.3	85 - 1150
10	-	-	-	-	-	-	-	
11	-	-	85.2	78.9	76.1	60.0	48.9	20 - 160
12	54.4	57.5	49.4	67.2	62.2	69.9	56.7	15 - 170
13	57.8	68.9	73.8	82.2	74.8	71.1	53.3	10 - 200
14	56.1	75.0	83.9	62.2	81.1	87.8	68.3	5 - 205