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A Survey of the Mussels (Pelecypoda: Unionoidia: Unionacea) of Twelvepole Creek, West Virginia with a Study of Commensal Algae Found on Selected Mussels

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A SURVEY OF THE MUSSELS (PELECYPODA: UNIONOIDIA: UNIONACEA) OF TWELVEPOLE CREEK, WEST VIRGINIA WITH A STUDY OF COMMENSAL ALGAE FOUND ON SELECTED MUSSELS

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ABSTRACT

A survey of the Unionacea of Twelvepole Creek, West Virginia was conducted coupled with a qualitative study of commensal algae found on selected mussel species. The naiads and the algae were both found to have diverse populations. Naiads collected during the survey were represented by 23 species, 16 genera and 2 families. *Corbicula fluminea* was found to be confined largely to the main branch of Twelvepole, with no individuals being collected from the East or West Forks and only limited collections near the mouth of Beechfork Creek. *Lampsilis radiata luteola* and *L. ventricosa* were found to have the greatest distribution, being represented at nearly all of the study sites.

The algae were cultured from shell scrapings of three species of mussels, *Lampsilis ventricosa*, *Quadrula p. pustulosa* and *Corbicula fluminea*. Sixty-seven species of algae were identified. The trophic level was evaluated by using Nygaard's Trophic Indices and indicated an organically enriched stream.

In addition to the mussel survey and algal study, the known fishes of Twelvepole Creek were compared to the mussel species collected. Only *Elliptio c. crassidens* and *Quadrula quadrula* were found to occur in areas where their known host fishes have not been collected.

CHAPTER I

INTRODUCTION

Twelvepole Creek forms the major drainage basin for Wayne County and parts of Cabell and Lincoln Counties, West Virginia. The majority of the stream consists of riffle areas and deep pools interspersed with long, shallow stretches of sandy bottomed streambed. Four dams are located in the drainage, two stone dams and two United States Army Corps of Engineer impoundments.

Freshwater mussels of the superfamily Unionaceae, also referred to as naiads and freshwater clams, constitute a substantial portion of the macrobenthic population of the Twelvepole drainage. Previous survey work in West Virginia has largely neglected the southwestern counties. The only previous records found were a survey done by Bates (1971) and several collections from Beechfork Creek housed in the Marshall University Malacological Collections.

Since various types of algae are utilized by naiads as food (Epifanio, 1979; Fuller, 1974; Purchon, 1968; Wilbur and Yonge, 1966), a qualitative study was made at one survey site to see what species were present. Bates looked at the phytoplankton in Twelvepole in 1971 and found the number of individuals to be high, but the diversity was low. The samples in this study were taken from the periostracum of several mussels. Although algal growth has been documented on several marine mussels (Purchon, 1968; Wilbur and Yonge, 1966), no similar works were found concerning naiads.

Major objectives of this research were: (1) to report the representative species of naiads present in the Twelvepole Creek drainage and (2) to investigate the phytoplankton which make use of the naiads as a substrate. An additional objective was to correlate the representative species of naiads with known host fish which are present in Twelvepole Creek.

CHAPTER II

LITERATURE REVIEW

Mussels

Since the most abundant unionacean fauna in the world is in North America, numerous studies have been compiled on their taxonomy and distribution. Studies concerning commensalism between freshwater mussels and algae were not found. Permanent symbiotic relationships between algae and marine mussels of the superfamily Cardiacea (Wilbur and Yonge, 1967) and the genus Hippopus (Purchon, 1968) have been studied extensively. Works dealing with the specific fish host or hosts required by each species of mussel are limited and the lists incomplete.

Only one previous survey of naiads and phytoplankton has been done. Bates (1971) chose a survey site on the West Fork of Twelvepole which produced no mussels. The phytoplankton samples from this site proved to be low in diversity, but high in numbers.

Neighboring areas have been shown to have good populations of naiads. The Ohio River was surveyed, from the Greenup Locks in Kentucky to Pittsburgh, Pennsylvania by Taylor in 1981, and produced 35 species. Twenty-one species were found in Tygarts Creek in northeastern Kentucky (Taylor, 1981). Although a number of mussel surveys have been done in Ohio, the single best source of mussel distribution in that state is by La Rocque (1967) which lists 107 species and subspecies of unionid mussels.

The previously mentioned study by Bates (1971) included the entire State of West Virginia. Bates reported relatively low numbers of naiads from all of the streams surveyed. More recent works, however, have shown at least some of the streams have a greater diversity than previously reported. Taylor and Hughart (1981) collected 19 species of mussels from the Elk River. Thirteen species of mussels were collected from the Kanawha River, but only from the portion of the river above the industrialized city of Charleston (Morris and Taylor, 1978).

Algae

Although symbiotic relationships between algae and naiads may exist, no papers were found which alluded to such relationships. Permanent symbiotic relationships are well documented for algae and representatives of the superfamily Cardiacea. Members of this superfamily are marine and located in the Indo-Pacific and tropical areas (Wilbur and Yonge, 1967). A study by Kawaguti (1950) reported algae in the mantle, gills and other superficial tissues in Corculum cardissa (L.), which resulted in shell modifications.

The greatest shell modification to accommodate symbiosis with algae is observed in the Tridacnidae of the Indo-Pacific coral reefs. In these animals the foot and byssus are located midventrally, while the siphons have been extended over the dorsal surface. Great numbers of zooxanthellae are located in the siphons and in the blood cells of the blood sinuses. These intensely pigmented siphons remain exposed unless subjected to direct sunlight (Wilbur and Yonge, 1966). Hyaline organs are present which direct the sunlight into the inner tissues of the clam (Purchon, 1968). Having this independent food source plus the ability to feed as a filter feeder probably has contributed to the large size of these clams. <u>Tridacna derasa</u> was the largest bivalve ever recorded (Purchon, 1968). Symbiosis with algae is also found in <u>Hippopus</u>, the Horseshoe Clam, but to a lesser degree than that found in the Tridacnidae (Purchon, 1968).

<u>Life Cycle of Mussels</u>

<u>Corbicula fluminea</u> is known to be monecious (Gardner et al., 1976), as are some naiads, notably <u>Anodonta</u> (Wilbur and Yonge, 1966), but most of the naiads are dioecious. An intermediate host is required by most unionids, usually a particular species of fish. Some mussels parasitize several species of fishes, while others are dependent on one species (Fuller, 1978; Gardner et al., 1976; Pennak, 1978). One naiad, <u>Simpsoniconcha ambigua</u>, is known to use <u>Necturus</u>, the mud puppy, as an intermediate host (Pennak, 1978).

Glochidia, the mussel form which attaches to the intermediate host, are expelled through the excurrent siphon of the females in most naiads (Fuller, 1974). They then attach to the superficial tissues of the host fish for about 10 to 30 days. If a glochidium inadvertently attaches to the wrong host, it detaches voluntarily after a short period. During this parasitic phase most of the organ systems present in the adults are formed. Following encystment, the young mussel drops from the host and matures on the bottom (Pennak, 1978). Since the glochidia are not free swimming and no free-swimming larval stage exists in naiads, the hosts play a major role in dispersing the mussel populations and in range extension (Fuller, 1974).

CHAPTER III

TAXONOMY AND DISTRIBUTION

North American naiads are classified into two families, 46 genera and 227 species (Burch, 1975). The taxonomic classification is based on the internal soft anatomy of gravid females and shell characteristics. There were few taxonomic studies done on mussels during the early 1900's. Ortmann, however, completed two, one in 1911 and a second in 1919.

All of the freshwater bivalves collected in the Twelvepole drainage are included in the following major taxonomic divisions:

Phylum: Mollusca
  Class: Pelecypoda
    Order: Unionoidia
      Superfamily: Unionaceae
        Family: Unionidae
        Family: Corbiculidae (*Corbicula fluminea*)

The general United States distribution for most of these mussels is mainly in the Mississippi drainage system. The exotic Asian clam, *Corbicula fluminea*, however, has immigrated into nearly all of the major drainage systems in the United States. It was first reported in the United States in the Columbia River in 1938 (Gardner et al., 1976). *Corbicula* was later found on the San Francisco Peninsula (Carleton, 1973), in the Tennessee River (Sinclair and Ingram, 1961), in lower Florida (Clench, 1970), in the Atlantic drainage (Fuller and Powell, 1973), in central Arizona (Rinne, 1974), in the upper Mississippi River

(Eckblad, 1975), in the Altamaha River, Georgia (Gardner et al., 1976), in the New River (Rogers, 1977) and in eastern Texas (Pool and McCulloug, 1979). The presence of <u>Corbicula</u> in the Ohio River, near Paduach, Kentucky, was first documented in 1957 (Sinclair and Ingram, 1961).

Mud River Jay + McCoy

CHAPTER IV

STUDY AREA

Twelvepole Creek was named in 1784 by surveyors locating the Captain John Savage land grant. The mouth of the creek was twelve poles or rods across thus the name. Three streams actually compose what is known as Twelvepole Creek: the East Fork of Twelvepole, the West Fork of Twelvepole and the main branch of Twelvepole (Krebs et al., 1913).

The East Fork of Twelvepole begins in northern Mingo County and merges 1.61 kilometers south of Wayne, West Virginia with the West Fork of Twelvepole. Eighteen and fifty-two hundredths kilometers of stream are in Mingo County, 2.42 kilometers of stream are in Lincoln County and 35.42 kilometers are in Wayne County for a total length of 56.35 kilometers. East Fork drops 271.34 meters in the first 1932 kilometers and 54.88 meters in the remaining 37.03 kilometers (Krebs et al., 1913). East Lynn Dam impounds East Fork near the town of East Lynn, West Virginia. The United States Army Corps of Engineer dam was completed in 1973 (Johnson, 1977).

The West Fork of Twelvepole also begins in northern Mingo County in the Guyan Mountains. West Fork runs for 24.15 kilometers through Mingo County, a corner of Lincoln County and 57.96 kilometers through Wayne County for a total length of 83.72 kilometers. There is a 236.53 meter fall in the first 24.15 kilometers and a 79.25 meter fall in the last 57.96 kilometers. The overall gradient average is 1.36 meters per kilometer.

Twelvepole Creek is formed 1.62 kilometers south of Wayne, West Virginia and flows 49.91 kilometers to its confluence with the Ohio River near Ceredo, West Virginia. The stream gradient is 1.37 meters, dropping in elevation from 211.84 meters to 169.16 meters. This gradient is greater than that of either the Big Sandy River or the Guyandot River (Krebs et al., 1913). Two stone dams exist along Twelvepole Creek, one at the community of Dickson and one at Wayne.

A major tributary of Twelvepole Creek is Beechfork Creek. Beechfork Creek has its headwaters in the Stonewall District of Wayne County and flows for 45.89 kilometers to merge with Twelvepole near Lavalette, West Virginia. The creek has a 178.31 meters fall from its headwaters to the mouth, with the greatest drop being 105.16 meters in the first 3.22 kilometers (Krebs et al., 1913). An impoundment was completed on this stream in 1976 by the United States Army Corps of Engineers (Johnson, 1977).

The following study sites were chosen for this investigation (Figures 2 and 3):

Site 1: Located 548.64 meters below the mouth of Bob's in Twelvepole Creek. Mud and sand bars. Bordered by a dairy farm.

Site 2: Located 228.6 meters below the mouth of Bob's Branch in Twelvepole Creek. Extensive network of sand bars. Bordered by a dairy farm.

Site 3: Located 274.32 meters below the mouth of Buffalo Creek in Twelvepole Creek. Riffle area. Near a housing subdivision and a heavily traveled bridge.

Site 4: Located 182.88 meters below the mouth of Haney's Branch. Sand and gravel bar. Bordered on one side by several residences.

Site 5: Located 365.76 meters upstream from the mouth of Haney's Branch. Sand gravel bar. Bordered by cornfields and woods.

Site 6: Located 457.2 meters downstream from the bridge on State Route 75 at Malcolm's Lane, in Twelvepole Creek. Extensive sand bars. Bordered by several residences.

Site 7: Located at Shoal's bridge on Route 75 in Twelvepole Creek. Riffle area with both gravel and large rocks. Bordered by several residences and farm fields.

Site 8: Located in the mouth of Beechfork Creek. On sand bars. Bordered by several residences and woods.

Site 9: Located 1371.6 meters above mouth of Beechfork Creek in Beechfork Creek. Sand Bars. Bordered by small farms and residences.

Site 10: Located 640.08 meters below Mays Chapel in Beechfork Creek. Sand and gravel bars. Bordered by farms and residences.

Site 11: Located 640.08 meters below the Beechfork Dam spillway in Beechfork Creek. Sand bar. Wooded banks.

Site 12: Located 274.32 meters below the mouth of Lynn Creek in Twelvepole Creek. Gravel bar followed sandy shallows. Bordered by scattered residences and woods.

Site 13: Located 1097.28 meters below Dickson Dam in Twelvepole Creek. Gravel bar. Bordered by scattered residences and woods.

Site 14: Located below Dickson Dam. Large rocks and gravel bars. Bordered by scattered residences.

Site 15: Located 548.64 meters below the Police Farm on Route 75 in Twelvepole Creek. Sand and gravel bar. Scattered residences and small farms.

Site 16: Located behind the Police Farm on Route 75 in Twelvepole Creek. Sand and gravel bar. Bordered by scattered residences and small farms.

Site 17: Located 2194.56 meters below Wayne High School in Twelvepole Creek. Sand and gravel bar. Bordered by scattered residences.

Site 18: Located 914.4 meters below Wayne High School in Twelvepole Creek. Sandy mud bottomed shallows followed by a large gravel bar. Bordered by a single residence and large corn and hay field.

Site 19: Located 2.82 kilometers above the mouth of the West Fork. Sand and gravel bar. Small farms and residences border the stream.

Site 20: Located 1.62 kilometers below Echo in the West Fork. Gravel bar. Small farms and residences border the site.

Site 21: Located 0.81 kilometers below Echo in West Fork. Gravel bar. Bordered by small farms and residences.

Site 22: Located at Joel's Branch Bridge in West Fork. Sand and gravel bars. Woods and small farms border the site.

Site 23: Located 91.44 meters above Twelvepole Valley Church in the West Fork. Sand and gravel bar. Bordered by several residences.

Site 24: Located 0.60 kilometers below Drift Branch, near Genoa, in the West Fork. Sand and gravel bar. Bordered by scattered residences and woods.

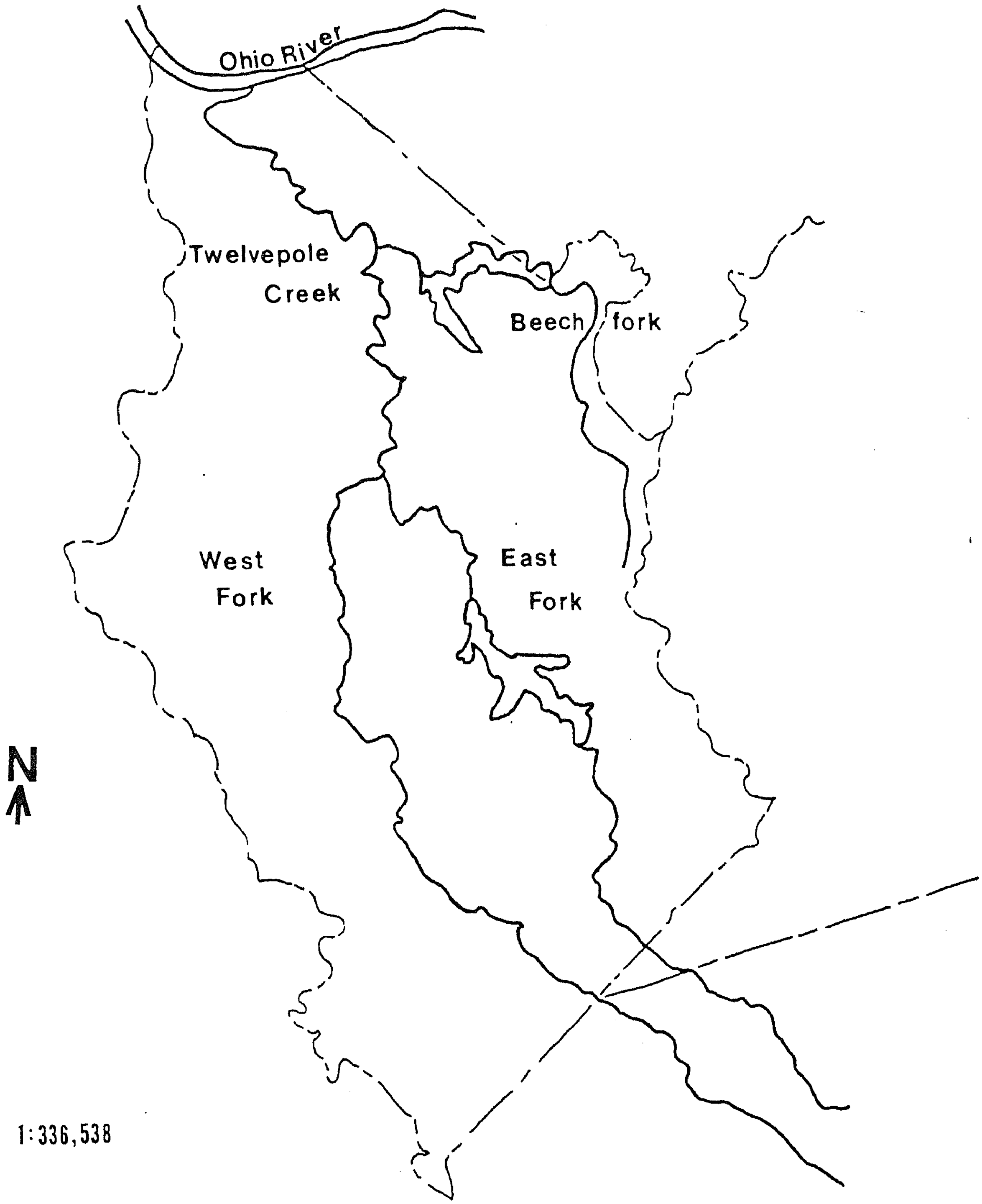
Site 25: Located at Fleming in the West Fork. Sand and gravel bar. Bordered by scattered residences and abandon farm fields.

Site 26: Located at Radnor Bridge in the West Fork. Gravel bars. Bordered by a dirt road and several residences.

Site 27: Located at Ferguson in the West Fork. The area contained many large rocks and was at the base of an abandoned Norfolk and Western Railroad bridge. Bordered by woods and farm fields.

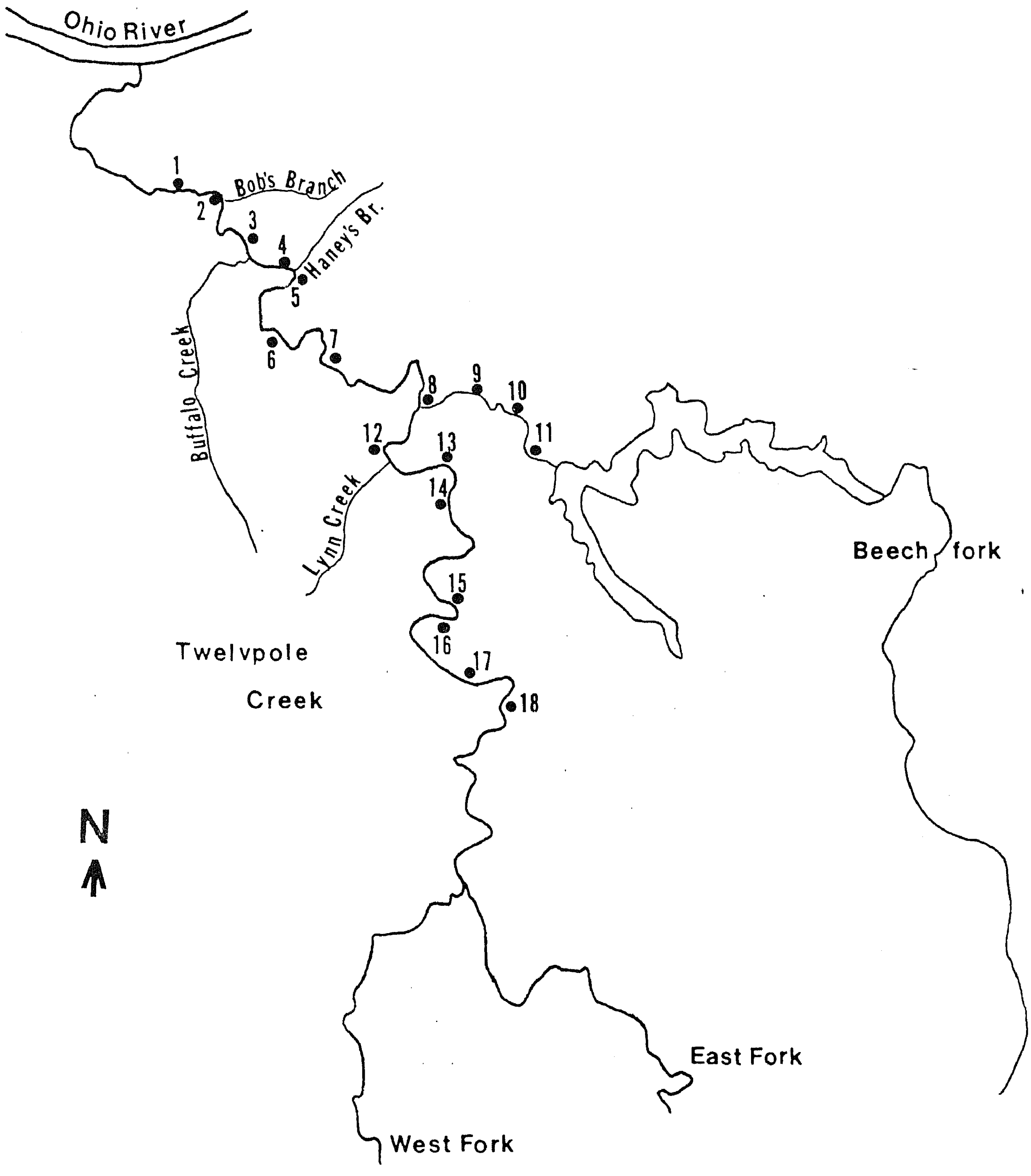
Site 28: Located 1.61 kilometers above Moses Branch in the West Fork. Sand and gravel bar. Bordered by several residences.

Fig. 1. Map of Study Area



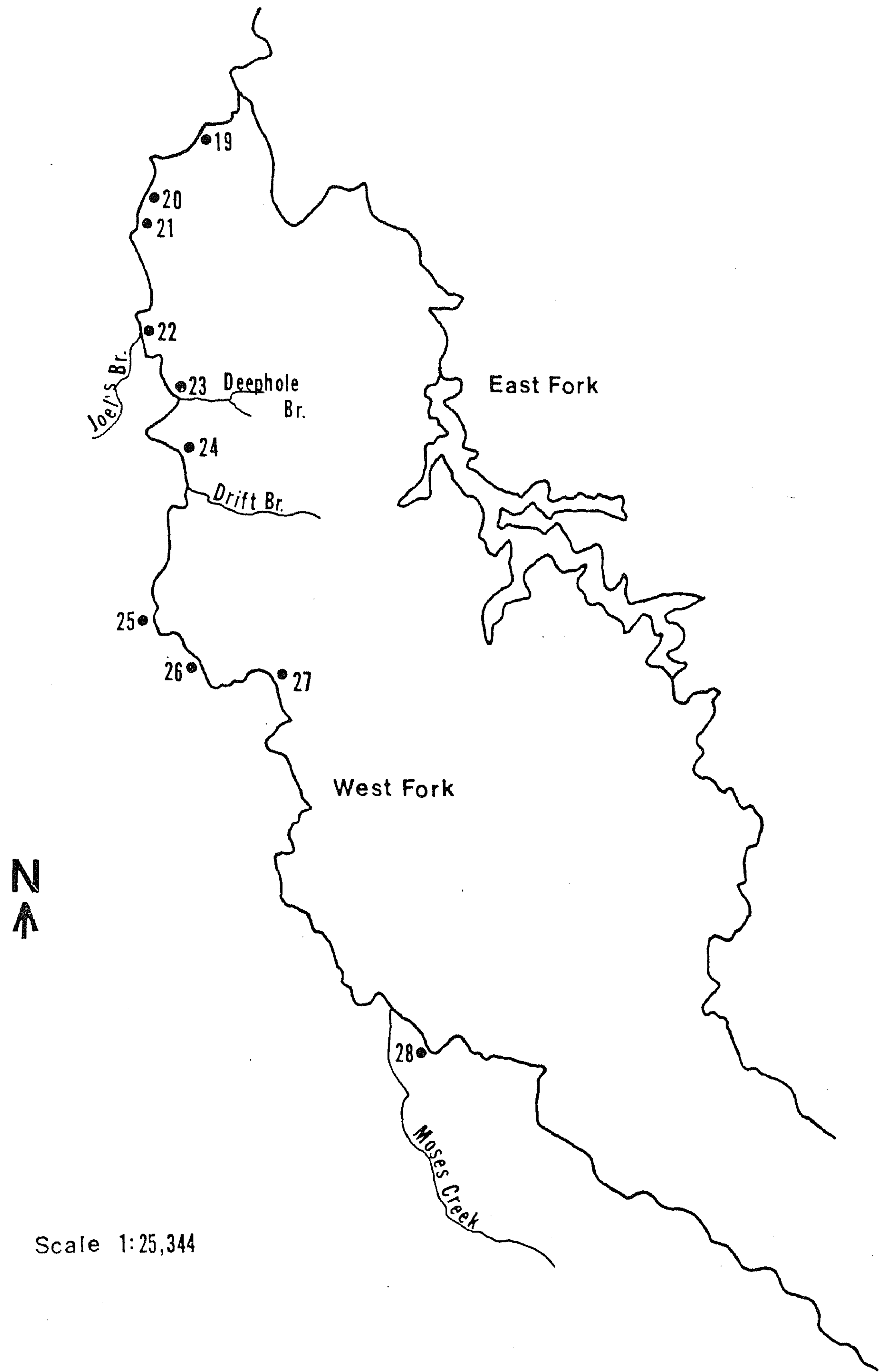
Scale 1:336,538

Fig. 2. Map of Study Area Depicting Stations 1–18



Scale 1:25,344

Fig. 3. Map of Study Area Depicting Stations 19-28



19
20
21
22
Joel's Br.
23
Deephole Br.
24
Drift Br.
25
26
27
East Fork
West Fork
28
Moses Creek
N
Scale 1:25,344

CHAPTER V

MATERIALS AND METHODS

Mussel Survey

Collections of the shell remains of naiads were made largely by handpicking along sand bars and in shallows. Handpicking has been shown to be a superior method of collecting both subfossils and live naiads in stream shallows and areas where debris hinder other collection methods (Mathiak, 1979; Starrett, 1971 and Taylor, 1980).

At several locations, while searching the stream bank, fresh piles of naiad shells were discovered. Apparently these were left by predators of the mussels and contributed specimens from areas which might have otherwise appeared nonproductive due to water depth.

In order to make collections when the water was too cold for handpicking, a collecting tool was made from a potato rake, similar to the collecting fork used by Mathiak (1979). The tines of the rake were covered with half-inch square hardware cloth. Samples were taken by scooping up the streambed at prospective sites with the rake. Gravel and most other debris filtered through the hardware cloth and out of the way. The rake also proved useful in sampling pools that were too deep to handpick and where the water was not clear enough to view the bottom. In addition, the rake was found to be invaluable as an aid while negotiating slippery streambeds and determining water depth while wading in turbid water.

Several attempts at brailing the main branch of Twelvepole Creek were unsuccessful. The brail, a pipe fitted with trailing treble hooks, was drawn along the creek bed as a means of catching live mussels. Brailing was inhibited largely by the nature of the stream with its combination of riffles, deep pools and long stretches of sandy bottomed shallows. At locations where the water depth was sufficient for the use of a powerboat, the trash on the stream bottom continually fouled the brail.

Where water depth allowed, a sixteen foot fiberglass canoe was used to survey the stream. The ease of handling the canoe made it valuable in surveying the various habitats found along Twelvepole. The last five and one-half miles of Twelvepole were surveyed using a sixteen foot bass boat powered by a fifty horsepower outboard motor.

The specimens were bagged and tagged in the field prior to being returned to the laboratory. In the laboratory, each of the specimens was thoroughly cleaned. Information identifying each specimen and its collection site was recorded in the Marshall University Malacological Collection catalog. A specimen number from the catalog was inscribed on the nacre (inner surface) of each specimen with India ink. The specimens were then coated with a thin layer of shellac to act as a preservative. In addition to the specimens placed in the Marshall University Malacological Collection, voucher specimens have been accessioned to the Ohio State University Museum of Zoology.

Algae Study

The algae were cultured from scrapings made from the periostracum of three species of mussels: *Lampsilis ventricosa* (Barnes), *Quadrula pustulosa pustulosa* (Lea) and *Corbicula fluminea* Muller. The scrapings were made with a flamed scalpel and transferred to liquid media or agar plates using sterile technique.

Algae were cultured on both green media (Miller et al., 1978) and blue-green media (Kratz and Myers, 1960 after Zehnder and Gorham, 1960). The cultures were grown on liquid and agar media at both 25 C and 35 C.

Identifications of the algae were based on Patrick and Reimer (1966), Whitford and Schumacher (1973) and Palmer (1977). A killing and fixing solution was made by adding 10 gms of iodine, 20 gms of potassium iodine and 20 mls of glacial acetic acid to 200 mls of water (Prescott, 1964). The fixing solution was also used as a starch indicator when the presence of starch was required for identification. A Whipple micrometer was used to make measurements of specimens.

CHAPTER VI

RESULTS AND DISCUSSION

Molluscan Fauna

The mussel fauna collected in this study is represented by 23 species, 16 genera and two families (Table 1). Lampsilis radiata luteola had the most extensive range being represented at 21 of the 28 collection sites.

No species dominated the entire drainage. For example, at Site 18 there were nine species represented with Corbicula fluminea and Obovaria subrotunda clearly dominating the site. However, Corbicula fluminea was not collected at any of the sites farther upstream and, while common at the downstream sites, it was most dominant at Site 18. Obovaria subrotunda was represented at nine of the 28 sites, but only at Site 18 was it clearly a dominant species.

While not abundant, members of the Amblemini were represented in both Twelvepole and the West Fork. Amblema p. plicata was found at only three sites, with its best population at Site 15. Fusconia flava was rare in Twelvepole, as was F. m. maculata, but was represented at four of the ten sites on the West Fork. Quadrula quadrula was collected only at two widely separated sites. Quadrula p. pustulosa was common in the lower half of Twelvepole Creek, but not found above Site 7. Tritogonia verrucosa was only moderately common in Twelvepole below the Dickson Dam and rare above it.

The only Pleurobemini represented in the study was Elliptio c. crassidens. Site 7 was the only location where Elliptio c. crassidens was collected. No live specimens were observed. The collected specimen appeared to be several years old.

The most common of the Anodontini were Strophitus u. undulatus and Lasmigona costata. Anodonta cataracta, A. imbecillus, Anodontoides ferussacianus and Simpsonaias ambigua were each represented at three stations and by several live specimens.

Members of the Lampsilini were the dominant group. Lampsilis radiata luteola, L. ventricosa and Obovaria subrotunda comprised three of the four species collected on the East Fork. All three species were abundant in Twelvepole with the lampsilids the most common. Villosa fabalis and Potamilus alatus were collected only at single sites as single specimens. Leptodea fragilis, also rare, was represented at two sites exclusively. Villosa lienosa lienosa was collected only from three consecutive sites in the area between the Dickson and Wayne Dams.

Corbicula fluminea was abundant throughout Twelvepole, but nonexistent above the Wayne Dam. No specimens of this species were found on the East or West Forks. The Asiatic clam has migrated a limited distance of approximately 500 yards into Beechfork Creek.

Beechfork Creek was dominated by Lampsilis radiata luteola. Anodonta imbecillus and Anodonta cataracta were unique to this stream. The creek was turbid on all of the collection visits.

Twenty-three species of naiads were collected from the Twelvepole drainage. Of the 23 species, 21 species were collected from Twelvepole Creek. Six species were found represented in Beechfork Creek. The West Fork molluscan fauna consisted of only four species. No collections were made from the East Fork, although on one visit some shell fragments were observed.

Algal Study

Sixty-seven species of algae were cultured from scrapings of mussel shells. The algae were found to culture well on the media, with the blue-greens growing better at the higher temperature. Greens and blue-greens were found on both media used. Species of *Lyngbya* and *Oscillatoria* did extremely well on the green media. *Anacystis cyanea* generally dominated the blue-green media.

Of the five experimental mussel shells only one subfossil, *Lampsilis ventricosa*, was used. This shell produced the only species of desmid cultured, *Closterium acutum*. Of the 31 species of algae cultured from this specimen, 19 were found only on the subfossil (Tables 4 and 12).

Seventeen species of algae were found on the two specimens of *Corbicula fluminea*. Eight of the 17 species were unique to the Asiatic clam (Tables 4 and 12). These specimens were collected in rather than on the substrate.

Anacystis cyanea was found on all of the shells scraped. Representatives of *Microspora*, *Ankistrodesmus*, *Scenedesmus* and *Zygonema* were present on all of the shells except *Corbicula fluminea* (Table 12).

The number of taxa found on the mussels varied with the specimen (Tables 4 and 12). *Corbicula fluminea* was found to serve as a substrate for the lowest number of algal taxa. Scrapings from *Quadrula p. pustulosa* yielded the largest number of diatoms. This specimen was covered more extensively by sediment than the other individuals collected for this study.

Of the 38 genera of algae cultured, 18 genera are known to produce pungent odors when abundant (Table 8). Musty and septic odors were particularly prominent along many areas of Twelvepole. At several locations, algae were observed blooming in large numbers.

According to the Nygaard's trophic indices, Twelvepole Creek is clearly eutrophic. Of the six indices used, five show strong eutrophication. The Euglenophyte Index of 0.12 was in an overlap between the values given for oligotrophic and eutrophic states. A value of 29 for the Compound Index is four points above the values given for eutrophism, 1.2-2.5, clearly pointing to the enriched level of the creek (Table 5).

In addition to Nygaard's Indices showing a high level of eutrophication, 14 of the species found are known to be common to organically enriched areas (Table 6). Eight of the algae found, however, are common to clean water areas (Table 7).

The algae found in Twelvepole have the capability of causing a variety of water use problems, in addition to odors (Palmer, 1977) (Table 9). Problems could be caused in the two impoundments in the Twelvepole drainage by algae which produce slime, corrode concrete, corrode steel or cause water coloration. Six of the genera found in Twelvepole are difficult to erradicate from water supplies should they become established and two of those six are natural water softeners. Anacystis, which was found on all of the mussel specimens, can cause a variety of problems, among those are its toxicity to humans and livestock.

Some of the algae identified from Twelvepole are indicators of oil pollution (Table 11). Twelve genera of the algae are oil indicators out of a list of 22 (Palmer, 1977). No oil refineries or oil storage facilities are located on the stream, but gas wells are scattered throughout the drainage basin. Another possible source of oil is from the numerous junked automobiles located in and on the banks of the Twelvepole drainage.

Fish Host-Mussel Distribution

Known fish hosts of the mussels found in Twelvepole Creek were generally consistent with the distribution of the mussels (Table 3). An exception was *Quadrula quadrula* found at Site 18 whose only known host, *Pylodictus olivaris*, has not been documented above the Dickson Dam. The only other exception was *Elliptio c. crassidens*, which was collected only at Site 7 as a subfossil. *Elliptio c. crassidens*' known host is *Alosa chrysochloris* which has only been collected near the mouth of Twelvepole Creek.

CHAPTER VII

CONCLUSIONS

1. Twelvepole Creek has a well diversified mussel population of 23 species present in the drainage.

2. Twelvepole Creek has a diversified algal flora of at least 67 taxa, but one which clearly indicates an organically enriched stream.

3. The West Fork appears to be lacking something necessary to support a good mussel population, as suitable habitats and host species of fish are present.

4. No naiads were collected from the East Fork. There is no apparent reason for the nonexistence of mussels, as suitable habitats are available, as well as host species of fish.

5. Four of the mussel species were found to be extremely rare in the Twelvepole drainage.

   a. *Elliptio c. crassidens* is probably extinct in the drainage, but due to its normal habitat it would be doubtful if it ever existed in large numbers.

   b. *Anodonta cataracta* and *Anodonta imbecillis* exist, in the Twelvepole drainage, exclusively as a small population in Beechfork Creek.

   c. *Anodontoides ferussacianus* is present in Twelvepole Creek in small numbers. Only one subfossil of this species was collected.

6. *Quadrula quadrula* exists only occasionally in the stream as two widely separated collections were made.

7. *Lampsilis r. luteola* and *L. ventricosa* were the most abundant species in the Twelvepole drainage.

8. Corbicula fluminea has not expanded its range into either the East or West Forks. The Asiatic clam has only migrated into the mouth of Beechfork Creek.
9. Corbicula fluminea has a well established population in Twelvepole Creek except for the first few miles of stream.
10. If Twelvepole Creek was to be used as a human water source, there are many problem-causing algae present which would have to be dealt with.
11. Anacystis cyanea was found growing on all of the species used in this study.
12. The only desmid cultured was found on the only subfossil used in the study.
13. The mussels serve as a good substrate for many freshwater algae.
14. The mussels may be passively gardening the algae as some of the marine species do. Extensive gut analyses would need to be done in conjunction with cultures of shell scrapings to confirm this.
15. Because of the diversification of the mussel fauna and algal flora, Twelvepole Creek can be considered a healthy stream despite the evident organic enrichment.
16. Despite the diversity of the algal flora and naiad fauna on the main branch of Twelvepole, the stream should be monitored, since the East Fork supports no mussels and the West Fork supports only a scattered population of four species. In addition, Bates (1971) stated that the algal sample he examined from the West Fork was of a low diversity.

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APPENDIX

Table 1. The Unionacea of Twelvepole Creek.

Unionacea
  Unionidae
    Ambleminae
      Amblemini

Amblema plicata plicata (Say, 1817)
Fusconaia flava (Rafinesque, 1820)
Fusconaia maculata maculata (Rafinesque, 1820)
Quadrula quadrula (Rafinesque, 1820)
Quadrula pustulosa pustulosa (Lea, 1831)
Tritogonia verrucosa (Rafinesque, 1820)

Unioninae
  Pleurobemini

Elliptio crassidens crassidens (Lamark, 1819)

Anodontini

Anodonta cataracta (Say, 1817)
Anodonta grandis grandis (Say, 1829)
Anodonta imbecillis (Say, 1829)
Anodontoides ferussacianus (Lea, 1834)
Lasmigonia complanta (Barnes, 1823)
Lasmigonia costata (Rafinesque, 1820)
Simpsonaias ambigua (Say, 1825)
Strophitus undulatus undulatus (Say, 1817)

Lampsilini

Lampsilis radiata luteola (Lamark, 1819)
Lampsilis ventricosa (Barnes, 1823)
Leptodea fragilis (Rafinesque, 1820)
Obovaria subrotunda (Rafinesque, 1820)
Potamilus alatus (Say, 1817)
Villosa lienosa lienosa (Conrad, 1834)
Villosa fabalis (Lea, 1831)

Corbiculidae

Corbicula fluminea (Muller, 1774)

Table 2. Abundance and Distribution of Twelvepole Mussels (R = Rare, M = Moderately Common, C = Very Common).

Species	Site 1	2	3	4	5	6	7	8	9	10
Amblema p. plicata (M)										
Fusconaia flava (M)						X				
Fusconaia m. maculata (M)										
Quadrula quadrula (R)			X							
Quadrula p. pustulosa (M)	X		X	X	X		X			
Tritogonia verrucosa (M)							X			
Elliptio c. crassidens (R)							X			
Anodonta cataracta (R)										
Anodonta g. grandis (R)						X	X			
Anodonta imbecillis (R)										
Anodontoides ferussacianus (R)										
Lasmigonia complanta (R)										
Lasmigonia costata (M)							X			
Strophitus u. undulatus (M)										
Simpsonaias ambigua (R)										
Lampsilis radiata luteola (C)		X			X		X	X	X	X
Lampsilis ventricosa (C)		X		X	X	X	X		X	
Leptodea fragilis (R)						X				
Obovaria subrotunda (C)							X			
Potamilus alatus (R)										
Villosa fabalis (R)										
Villosa lienosa lienosa (R)										
Corbicula fluminea (C)	X		X	X	X	X	X	X		

Table 2 continued.

Species	Site								
	11	12	13	14	15	16	17	18	19
<u>Amblema</u> <u>p</u>. <u>plicata</u> (M)		X			X			X	
<u>Fusconaia</u> <u>flava</u> (M)			X						
<u>Fusconaia</u> <u>m</u>. <u>maculata</u> (M)						X			
<u>Quadrula</u> <u>quadrula</u> (R)								X	
<u>Quadrula</u> <u>p</u>. <u>pustulosa</u> (M)			X	X					
<u>Tritogonia</u> <u>verrucosa</u> (M)		X	X	X	X		X		
<u>Elliptio</u> <u>c</u>. <u>crassidens</u> (R)									
<u>Anodonta</u> <u>cataracta</u> (R)	X								
<u>Anodonta</u> <u>g</u>. <u>grandis</u> (R)	X								
<u>Anodonta</u> <u>imbecillis</u> (R)	X								
<u>Anodontoides</u> <u>ferussacians</u> (R)					X				
<u>Lasmigonia</u> <u>complanta</u> (R)		X							
<u>Lasmigonia</u> <u>costata</u> (M)			X	X		X	X		
<u>Strophitus</u> <u>u</u>. <u>undulatus</u> (M)			X	X			X	X	
<u>Simpsonaias</u> <u>ambigua</u> (R)								X	
<u>Lampsilis</u> <u>radiata</u> <u>luteola</u> (C)		X	X	X	X	X	X	X	X
<u>Lampsilis</u> <u>ventricosa</u> (C)		X	X			X	X		
<u>Leptodea</u> <u>fragilis</u> (R)			X						
<u>Obovaria</u> <u>subrotunda</u> (C)					X	X	X	X	X
<u>Potamilus</u> <u>alatus</u> (R)		X							
<u>Villosa</u> <u>fabalis</u> (R)								X	
<u>Villosa</u> <u>lienosa</u> <u>lienosa</u> (R)						X	X	X	
<u>Corbicula</u> <u>fluminea</u> (C)							X	X	

Table 2 concluded.

Species	Site								
	20	21	22	23	24	25	26	27	28
Amblema p. plicata (M)									
Fusconaia flava (M)	X					X	X	X	
Fusconaia m. maculata (M)									
Quadrula quadrula (R)									
Quadrula p. pustulosa (M)									
Tritogonia verrucosa (M)									
Elliptio c. crassidens (R)									
Anodonta cataracta (R)									
Anodonta g. grandis (R)									
Anodonta imbecillis (R)									
Anodontoides ferussacians (R)									
Lasmigonia complanta (R)									
Lasmigonia costata (M)									
Strophitus u. undulatus (M)									
Simpsonaias ambigua (R)									
Lampsilis radiata luteola (C)	X	X	X	X	X	X	X		
Lampsilis ventricosa (C)			X	X					X
Leptodea fragilis (R)									
Obovaria subrotunda (C)			X	X			X		
Potamilus alatus (R)									
Villosa fabalis (R)									
Villosa lienosa lienosa (R)									
Corbicula fluminea (C)									

Table 3. A List of the Mussels of the Twelvepole Drainage and Known Host Fishes Found in that Drainage (from Fuller, 1974 and Hardman et al., 1981).

Amblema plicata

Ictaluridae

Ictalurus punctatus (Rafinesque)

Pylodictus olivaris (Rafinesque)

Centrarchidae

Ambloplites rupestris (Rafinesque)

Lepomis cyanellus Rafinesque

Lepomis macrochirus Rafinesque

Micropterus salmoides (Lacepede)

Pomoxis annularis Rafinesque

Pomoxis nigromaculatus (Lesueur)

Percidae

Stizostedion canadense (Smith)

Anodonta grandis grandis

Clupidae

Alosa chrysochloris (Rafinesque)

Dorosoma cepedianum (Lesueur)

Cyprinidae

Cyrpinus carpio Linnaeus

Notemigonus crysolencas (Mitchill)

Ictaluridae

Ictalurus natalis (Lesueur)

Table 3 continued.

Anodonta grandis grandis (continued)

Centrarchidae

Ambloplites rupestris (Rafinesque)

Lepomis cyanellus Rafinesque

Lepomis macrochirus Rafinesque

Lepomis megalotis Rafinesque

Micropterus salmoides (Lacepede)

Pomoxis annularis Rafinesque

Pomoxis nigromaculatus (Lesueur)

Percidae

Etheostoma nigrum Rafinesque

Sciaenidae

Aplodinotus grunniens Rafinesque

Anodonta imbecillus

Cyprinidae

Semotilus atromaculatus (Mitchill)

Centrarchidae

Lepomis cyanellus Rafinesque

Anodonta cataracta

Cyprinidae

Cyprinus carpio Linnaeus

Elliptio crassidens

Clupidae

Alosa chrysochloris (Rafinesque)

Table 3 continued.

Fusconia flava

Centrarchidae

Lepomis macrochirus Rafinesque

Pomoxis annularis Rafinesque

Pomoxis nigromaculatus (Lesueur)

Fusconia maculata

unknown

Lampsilis radiata luteola

Centrarchidae

Ambloplites rupestris (Rafinesque)

Lepomis macrochirus Rafinesque

Micropterus dolomieui Lacepede

Micropterus salmoides (Lacepede)

Pomoxis annularis Rafinesque

Pomoxis nigromaculatus (Lesueur)

Lampsilis ventricosa

Centrarchidae

Lepomis macrochirus Rafinesque

Micropterus dolomieui Lacepede

Micropterus salmoides (Lacepede)

Pomoxis annularis Rafinesque

Lasmigona complanta

Cyprinidae

Cyprinus carpio Linnaeus

Table 3 continued.

Lasmigona complanta (continued)

  Centrarchidae

    Lepomis cyanellus Rafinesque

    Micropterus salmoides (Lacepede)

    Pomoxis annularis Rafinesque

Lasmigona costata

  Cyprinidae

    Cyprinus carpio Linnaeus

Leptodea fragilis

  Sciaenidae

    Aplodinotus grunniens Rafinesque

Obovaria subrotunda

  unknown

Potamilus alatus

  unknown

Quadrula pustulosa

  Ictaluridae

    Ictalurus melas (Rafinesque)

    Ictalurus punctatus (Rafinesque)

    Pylodictus olivaris (Rafinesque)

  Centrarchidae

    Pomoxis annularis Rafinesque

Quadrula quadrula

  Ictaluridae

    Pylodictus olivaris (Rafinesque)

Table 3 concluded.

<u>Simpsonaias ambigua</u>

Necturidae

<u>Necturus maculosus</u>

<u>Strophitus undulatus undulatus</u>

Cyprinidae

<u>Semotilus atromaculatus</u> (Mitchill)

Centrarchidae

<u>Lepomis cyanellus</u> Rafinesque

<u>Micropterus salmoides</u> (Lacepede)

<u>Tritogonia verrucosa</u>

unknown

<u>Villosa fabalis</u>

unknown

<u>Villosa lienosa</u>

unknown

Table 4. Comparison of Algae Taxa Found on Selected Mussels in Twelvepole Creek.

Mussels	Number of Taxa Represented		
	Blue-green	Green	Diatoms
*Lampsilis ventricosa**	7	23	1
Lampsilis ventricosa	2	9	8
Quadrula pustulosa pustulosa	6	10	13
Corbicula fluminea	4	2	3
Corbicula fluminea	4	4	3

*subfossil

Table 5. Enrichment Level of Twelvepole Creek - Nygaard's Index (Hiatt et al., 1977).

Index	Calculation	Trophic Level*
Myxophycean	$\frac{\text{Myxophyceae}}{\text{Desmideae}}$	15 = E
Chlorophycean	$\frac{\text{Chlorococcales}}{\text{Desmideae}}$	10 = E
Diatom	$\frac{\text{Centric Diatoms}}{\text{Pennate Diatoms}}$	0.5 = E
Euglenophyte	$\frac{\text{Euglenophyte}}{\text{Myxophyceae + Chlorococcales}}$	0.12 = O-E
Compound	$\frac{\text{Myxophyceae + Chlorococcales + Centric Diatoms + Euglenophyta}}{\text{Desmideae}}$	29 = E

*Eutrophic (E); Oligotrophic (O)

Table 6. Algae of Twelvepole Creek Common to Organically Enriched Areas.

Blue-green Algae (Myxophyceae)

Oscillatoria chlorina
O. lauterbornii
O. princeps
O. putrida

Green Algae (Nonmotile Chlorophyceae)

Ankistrodesmus falcatus
Chlorella pyrenoidosa
C. vulgaris
Scenedesmus quadricauda

Diatoms (Bacillariophyceae)

Melosira varians
Navicula sp.
Navicula crytocephala exilis

Flagellates (Euglenophyceae, Volvocales of Chlorophyceae, others)

Euglena sp.
Euglena agilis
Pandorina sp.

Table 7. Clean Water Algae of Twelvepole Creek.

Blue-Green Algae (Myxophyceae)

None

Green Algae (Nonmotile Chlorophyceae)

Ankistrodesmus falcatus acicularis
Bulbochaete mirabilis
Cladophora sp.
Vaucheria sp.

Red Algae (Rhodophyceae)

None

Diatoms (Bacillariophyeae)

Meridion circularia
Pinnularia sp.
Synedra sp.

Flagellates (Chrysophyceae, Cryptophyceae, Euglenophyceae and Volvocales of Chlorophyceae)

Euglena sp.

Table 8. Odor Causing Algae of Twelvepole Creek.

Algae Genera	Odor Based on Abundance	
	Moderate	Abundant
Anacystis	Grassy	Septic
Chlamydomonas	Musty, Grassy	Fishy, Septic
Chlorella	. . . .	Musty
Cladophora	. . . .	Septic
Closterium	. . . .	Grassy
Euglena	. . . .	Fishy
Fragilaria	Geranium	Musty
Hydrodictyon	. . . .	Septic
Melosira	Geranium	Musty
Meridion	. . . .	Spicy
Nostoc	Musty	Septic
Oscillatoria	Grassy	Musty, Spicy
Pandorina	. . . .	Fishy
Scenedesmus	. . . .	Grassy
Synedra	Grassy	Musty
Tribonema	. . . .	Fishy
Ulothrix	. . . .	Grassy
Volvox	Fishy	Fishy

Table 9. Algae of Twelvepole Creek That Cause Problems in Water Supplies.

Slime-producing

- Anacystis
- Cymbella
- Oscillatoria

Water Coloration

- Anacystis
- Chlamydomonas
- Chlorella

Concrete Corrosion

- Anacystis
- Euglena

Steel Corrosion

- Oscillatoria

Persistent in Water Supplies

- Anacystis
- Chlorella
- Closterium
- Euglena
- Scenedesmus
- Synedra

Natural Water Softener

- Scenedesmus
- Synedra

Toxic

- Anacystis

Table 10. Algae of Twelvepole Creek That Are Water Source Indicators.

Hardwater Lake With Outlet	Present in Twelvepole
Blue-green Algae	Yes
Diatoms	Yes
Green Flagellates	
Pandorina	Yes
Volvox	Yes
Softwater Lake With Outlet	
Desmids	Yes
Diatoms	Yes
Acid Bog Lake	
Desmids	Yes
Anacystis thermalis major	No
Batrachospermum	No
Hapalosiphon pumilus	No
Microspora	Yes
Oedogonium	Yes
Scytonema ocellatum	No

Table 11. Oil Indicating Algae of Twelvepole Creek.

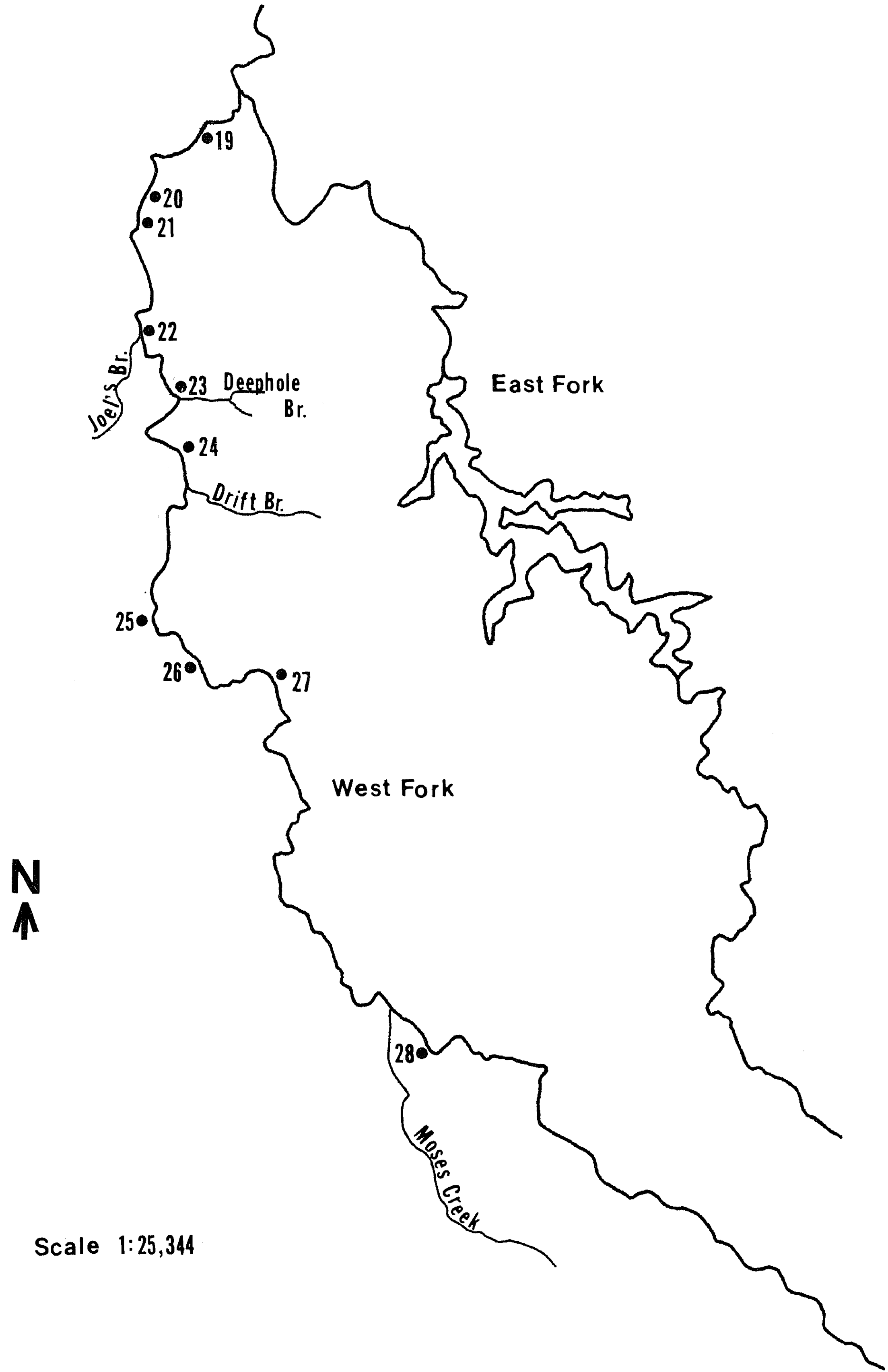
Ankistrodesmus
Chlamydomonas
Closterium
Euglena
Fragilaria
Lyngbya
Melosira varians
Meridion
Navicula radiosa
Oscillatoria
Scenedesmus
Tabellaria

Table 12. Algae of Twelvepole Creek and Their Mussel Host(s). Key to Columns: 1. Alga name; 2. Group (BG = Blue-green, G = Green, D = Diatom, De = Desmids, Fl = Flagellate); 3. *Lampsilis ventricosa* (subfossil); 4. *Lampsilis ventricosa*; 5. *Quadrula p. pustulosa*; 6. *Corbicula fluminea*; 7. *Corbicula fluminea*.

1	2	3	4	5	6	7
Anacystis cyanea	BG	X	X	X	X	X
A. montana	BG					X
Ankistrodesmus convulutus	G	X				
A. falcatus	G		X	X		
A. f. acicularis	G	X	X			
Aphamotheca castagnii	BG				X	
Bulbochaete mirabilis	G	X				
Chlorella ellipsoides	G	X				
C. pyrenoidosa	G	X				
C. vulgaris	G	X	X	X		X
Chlamydomonas fenestrata	G	X				
Cladophora sp.	G	X				
Closterium acutum	De	X				
Cymbella ventricosa	D		X	X		
Euglena sp.	Fl			X		
E. agilis	Fl	X			X	
Eutreptia viridis	Fl		X			
Fragillaria sp.	D			X		
F. virescens	D		X	X		
Gyrosigma	D		X			
Hydrodictyon reticulatum	G					X
Lyngbya aeruginea caerula	BG			X		
L. digeuti	BG		X			
L. putealis	BG	X				
Melosira varians	D	X				

Table 12 continued.

1	2	3	4	5	6	7
Meridion circularia	D		X			
Microspora amoena	G	X	X	X		
M. floccosa	G	X	X	X		
M. quadrata	G			X		
M. tumidula	G	X				
M. willeana	G			X		
M. wittrocki	G	X				
Mongeotia parvula	G	X				
Navicula sp.	D		X		X	
N. cryptocephala exilis	D					X
N. keeleyi	D			X		
N. pupila	D			X		
N. radiosa	D			X		
N. r. tenella	D			X		
Nitzschia parvula	D			X		
Nostoc carneum	BG	X				X
N. pruniforme	BG					X
Oedogonium suecium	G	X				
Oscillatoria sp.	BG	X			X	
O. chlorina	BG	X		X		
O. lautebornii	BG			X		
O. ornata	BG	X		X		
O. princeps	BG	X				
O. putrida	BG			X		
Pandorina sp.	G	X				
Pinnularia sp.	D		X		X	
P. brebissonii	D		X			
Planktosphaeria gelatinosa	G	X				
Scenedesmus bijuga	G	X	X	X		
S. quadricauda	G	X				



Scale 1:25,344

Table 12 concluded.

1	2	3	4	5	6	7
Spirulina sp.	BG				X	
Stauroneis obtusa	D			X		
Suirella brightwelli	D			X		
Synedra sp.	D			X	X	X
S. minuscula	D		X	X		X
Tabellaria fenestrata	D			X		
Tribonema affine	G		X	X		
Ulothrix variabilis	G	X				
Vaucheria sp.	G	X				X
Volvox aureus	Fl				X	X
Zygonema sp.	G		X	X		
Z. sterile	G	X				