A BIOGEOGRAPHIC STUDY OF INTERMOUNTAIN LEECHES

Preliminary report, 1989

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PROLOGUE

This work began out of curiosity to determine what, besides fishes occurred in the isolated springs of the Great Basin. The initial pressure was the proposed basing of the MX missile in the Great Basin in which one-third on the springs were to be depleted. Examination of the literature revealed that most of the work was done before World War II. Big holes appeared in the present distributions of amphibians.

Thus initially I chose to inventory the springs for amphibians and mollusks, collecting the mollusks for deposit in Utah Museum of Natural History until interest and expertise could arise to the needs of identification. Dr. Shi-Kuei Wu at the Colorado Museum of Natural History expressed an interest and thus half of the mollusk were deposited in that museum. I express great appreciation to him for assisting in the classification and his interest. I was not going to collect leeches, even though Dr. Donald J. Klemm was very co-operative in the identification of some leeches in the mountains and Tule Valley. However the leeches kept appearing. Thus the second year leeches were collected. I am very greatful to Dr. Klemm for his co-operation, his interest and his patience. It has been a very excellent "mail-order" leech identification school. Likewise conversations with Dr. Donald R. Currey concerning the lake levels of the Bonneville Basin have been very rewarding. It was the beginning of explaining the present observations with the past. The publications of Dr. Dwight W. Taylor implied that 15,000 years was not sufficiently far back in time for many events had already happened during the Pliocene. To these scientist, I owe many thanks.

The next five years will include baited leech traps for those elusive leechs, examining Diamond, Long, Newark, and Big Smokey Basins, examining Sevier, Bear, and upper Humboldt Rivers, examine the desert pupfish habitats for southern influences, and continue to examine the high mountains.

Thus I submit these preliminary observations to inform the scientific world of the world of the leeches in the Intermountain region. I would appreciate any comments to readjust my thinking and planning during the next five years. I do see an end to the project, but many of the springs, lakes, valleys, rivers, and basins need rechecking and some regions have yet to be seen.

Peter Hovingh

TENTATIVE CONCLUSIONS

Two areas of relatively rich species abundance were found: 1) Ruby Marshes in the Lake Franklin basin and 2) Weber/Utah Lake (Provo and Spanish Fork Rivers) in eastern Bonneville drainage.

The Uinta Mountains, Wasatch Mountains-South Utah High Plateau, Ruby Mountains and Snake Range are characterized by 1) *Nephelopsis obscura*, 2) *Erpobdella punctata*, 3) *Helobdella stagnalis*, and 4) no leeches, respectively.

The Relict Dace Basins are characterized by *Erpobdella dubia*.

When one Pleistocene lake (Lake Maxey and Lake Gale) drained into the second Pleistocene lake (Lake Spring and Lake Franklin), the upper lake basin is presently depauperate with respect to leeches.

Leech fauna distribution is strongly affected by the last Pleistocene lake level elevation.

The scattered (disjunct) distribution of leeches suggest that the present distribution is a result of pre-Pleistocene populations which became isolated during the block-faulting period and survive the Pleistocene glacio-pluvial times and the subsequent desiccation events.

Intermountain region of western United States has been poorly examined for leeches. Beck (1954) identified four species of Glossiphoniidae (*Glossiphonia complanata*), *Helobdella stagnalis*, *Batracobdella picta*, and *Placobdella multilineata*), one species of Haemopidae (*Haemopis marmorata*), and three species of Erpobdellidae (*Erpobdella punctata*, *Erpobdella dubia*, and *Nephelopsis obscura*). The identity of *P. multilineata* is of questionable status with its range being eastern North America (Klemm, 1985). Most of the locations studied were in the central region of Utah (Utah and Wasatch Counties). The distribution of leeches in the intermountain region was summarized (Hovingh, 1986). The data presented in the present paper describes further distributions of leeches and relates the distribution to geographical and paleobiological events of the region. Limited ecological data is also provided.

METHODS

Water sources were examined by searching mud, under rocks, within plant roots, under logs and boards, and under any human disposed debris. The time at each source depended upon success of finding leeches, mollusks, or amphibians, and conversely, if a complex spring did not contain any specimens, more time was taken and several trips were taken to search and find specimens. Field trips occurred from April to September. Efforts were made to visit the water sources three times (not necessarily in one year): April and May, June and July, and August and September.

The paper refers to the number of sites within a given basin (see Table 2 and 3). This is a rather arbitrary number since many springs sometimes flow into a common pool and since some streams have a multitude of sites. The number of sites is inflated in these conditions. On the other hand, some large complex springs/wetlands covers several square kilometers and these are single sources often times. Yet the complexity of these sources reveal that mollusks and leeches are often within microhabitats within the greater spring/wetlands complex and these microhabitats could well be treated as sources and sites within their own right. The data presented likewise is not complete in some basins (Table 2).

Both leeches and mollusks were collected and placed on ice after collections. The mollusks were relaxed overnight with menthol crystals, fixed with 3 second exposure to boiling water, and preserved in 75% ethanol. Leeches were relaxed with dilute solutions of ethanol, fixed with 10% formalin overnight, and placed in 75% ethanol. Field preservation occurred if more than one night was spent on a trip. Leech nomenclature follows that of Sawyer (1986) and the leeches in this study are listed in Table 1.

Conductivity was measured with a YSI conductivity meter, Model 33. Hydrogen ion concentration (pH) was measured with a Cole-Parmer pH meter Model 5985-80 with calibrations with pH 7.0 and pH 10 standard solutions. Oxygen was determined with a Jenway oxygen meter Model 9070. Temperature was measured with each probe.

Gut contents were analyzed by removing all material from the entire length of the exposed gut (Barton and Metcalfe, 1986). This procedure detected mollusks and arthropods with oligochaetes and other soft animals being neglected. The alternative method of gut analysis, the serological analysis (Davies, et al., 1978) was not used. Although this second procedure has the potential to detect all animals, one has to know prior to the study what prey the leech consumed. Erpobdella punctata was observed feeding on a partially consumed horned lizard (Phrynosoma) brought to the wetlands by the harrier (Circus cyaneus). Antigens to the horned lizard would have to be prepared to detect this consumption by the leech.

The maps (Figure 1 and 2 and others) were adapted from Williams and Bedinger (1984) and from Mifflin and Wheat (1979). Figure 3 was used with permission of Raven Maps and Images, Medford, Oregon.

DESCRIPTION OF THE REGION

Most of the area belongs to the Basin and Range physiographic province and is land with no external drainages. The geology of the rocks is largely limestone and shale of Paleozoic origins with some regions of volcanic deposits. The basins and ranges run in a north-south direction. To the north of the Great Basin is the Columbia-Snake River Plains, To the east and south of the Great Basin is the Colorado River Basin. The Colorado River Basin, the Great Basin, and the Columbia-Snake River plains contain the salt-desert shrub (largely Chenopods) ecosystem and the sagebrush (Artemisa)- grass ecosystem in the low elevations. Figure 1 shows the present drainages and Pleistocene lake distribution of the Intermountain region. Figure 2 shows the basins of the Great Basin that have been investigated in this report. Figure 3 shows a map of Utah with its Uinta Mountains, Wasatch Mountains, and the high plateaus of southern Utah and the relationship between these features and the Bonneville and Colorado River Basin.

Numerous high ranges with peaks greater than 3000 m elevation above sea level occur within the region. The Uinta Mountains extend east from Colorado westward to the Wasatch Mountains just south of the Utah-Wyoming border. The Wasatch Mountains extend north-south in central Utah and drain entirely within the Bonneville Basin. South of the Wasatch Mountains are the high plateau region of southern Utah. The Ruby Mountains extend north-south in central Nevada and the Snake Range extends north-south along the Utah-Nevada border.

During Pleistocene times many of the present desiccated valleys contained large lakes. Figure 1 shows the distribution of the Pleistocene lakes in relation to the drainage basins and mountains. Lake Bonneville in western Utah was about the size of Lake Michigan. Its latest rise began some 30,000 years ago, rose to the Stansbury standstill (1373 m) by 22,000 years ago, reached the Bonneville levels (1552 m) some 16000 and again at 14500 years ago, broke the threshold into the Snake River and drained down to the Provo level (1446 m) 14000 years ago. Subsequently the lake desiccated with several minor shorelines established during the last 11, 000 years (Currey, et al., 1983 and Currey and Oviatt, 1985). During the last 11,000 years, the Great Basin has become the most arid region in North America with respect to precipitation and this aridity may not have ever occurred to such an extreme during Cenozoic period.

Many prior pluvial times have occurred throughout the last 600,000 years of the Pleistocene period. McCoy (1987) suggest that lake levels rose to 1420 m before 600,000 years ago, to 1428 m some 200,000 years ago, and to 1510 m 130,000 to 150,000 years ago. During this time the Bear River emptied into the Snake River drainage. Similar lake level increase occurred in the Lahontan Basin (Lao and Benson, 1988).

Including Lahontan Basin in western Nevada and Bonneville Basin in western Utah, the Great Basin contains some 81 basins which contained 53 pluvial lakes (Mifflin and Wheat, 1979). Table 2 describes the basins and lakes which occur in eastern Nevada and western Utah. The fish fauna affinities of these basins were thoroughly studied by Hubbs and Miller (1948) and Hubbs, Miller and Hubbs (1974). With the exception of several fishless basins, Hubbs and coworkers could assign the presently isolated basins to either the Lahontan, the Colorado River, or the Relict Dace basins and suggested pluvial connections during Pleistocene times. Although interbasin contact is readily assumed during the pluvial times, there are possibilities that aquatic connections occurred prior to the Pleistocene during the Pliocene or Miocene times and that block-faulting had already isolated the basins and their aquatic systems by the Pleistocene times.

Three types of water sources were examined. Springs within the desert shrub zone were either fissure springs, depressions valley springs or border springs (Bryan, 1919). The springs flow from their source and spread out through wetlands or form a small streamlet. Often terminal ponds (human made or natural) in the valley floor impound the water, causing some increase in salinity in water quality. These springs were often tapped for irrigation for pasture. Some springs in the mountains in the pinyon-juniper and higher elevations were also examined. The second type of water source were streams. Associated with streams were backwaters, partially abandoned channels, wetlands, springs and sometimes beaver ponds. The third type of aquatic sources were the high mountain lakes in the subalpine and alpine zones.

RESULTS

The species of leeches identified in the project area are listed in Table 1. Two species have previously been unknown in the Great Basin or the Colorado River drainage: *Haemopis grandis* which was previously identified only from Idaho in western North America west of the continental divide (Klemm, 1985) and *Helobdella fusca* which was previously unidentified west of the continental divide of North America (Klemm, 1985). This study is the first report of the family Erpobdellidae from Nevada. *Mooreobdella microstoma* listed in Table 1 and refered in other places in this report will require further taxonomic studies to confirm the identification and further collections and is thus presently considered uncertain.

In comparison to the table previously formulated (Hovingh, 1986), *Placobdella multilineata* (Moore, 1953) was removed from the Intermountain listing because 1) the report by Beck (1954) was far west of the current distribution (Klemm, 1985) and 2) *P. ornata* was found in the same region in this study. Only *Placobdella parasitica* (Say, 1824) has yet to be identified and is listed for Arizona and Nevada in western North America west of the continental divide (Klemm, 1985).

MONTANE DISTRIBUTION OF LEECHES. Figure 3 shows the geographic areas for Utah's mountains and basins. The distribution of Glossiphoniidae (Figure 4 and 5) and Erpobdellidae (Figure 6) are shown for the mountains of Utah.

Uinta Mountains. The Uinta Mountains (Figure 3) contain a multitude of lakes, meadows, and streams. The western side of this east-west oriented range drains into the Bonneville Basin via the Weber and Provo Rivers. Just east of the Weber River headwaters on the north side of the range, a small portion of the Uinta Mountains drain via the Bear River into the Bonneville Basin. Formerly until 30,000 years ago the Bear River drained into the Snake River Basin until a lava flow blocked the river course and changed the direction of river flow (Taylor and Bright, 1987). The eastern and central portions of the Uinta Mountains drains into the Green River of the Colorado River Drainage Basin. During the last Pleistocene glaciation, all the lakes were covered by glaciers. Most of the high elevation region of the Uinta Mountains consists of Precambrian quartzite.

Three types of lakes occur in the Uinta Mountains. The typical drainage lakes with inlets and outlets are occupied by imported trout and are generally deplete of leech fauna. The semidrainage lakes (Pennak, 1968) are very plentiful and are typified by the presence of the yellow pond lily (*Nuphar*) and the tiger salamander (*Ambystoma tigrinum*). In a few locations on the north side of the range there are numerous seepage lakes or lakes that have no outlet and no drainage and are surrounded by a ring of dead (drowned) trees. On the east side bog lakes exist in which the aquatic portion lies within a grassland boggy area. Some of the bog lakes also contain *Nuphar*.

Both the seepage lakes (six lakes above 2800 m elevation) and the semidrainage lakes (eight lakes above 3000 m elevation) are commonly occupied by *Nephelopsis obscura* and to a much lesser extent by *Helobdella stagnalis* and *Glossiphonia complanata*. One bog lake containing *Nuphar* (Lily Pad Lake, elevation 2943 m) contained *Haemopis marmorata* and no *N. obscura*. All the examined semidrainage ponds contain abundant *N. obscura*.

Wasatch Mountains. The Wasatch Mountain range consists largely of Paleozoic limestone and shale and is typical of the Basin and Range mountains. This entire range drains into the Bonneville Basin. The few lakes between 2400 and 3000 m elevation that are found in the glaciated bowls have an entirely different character than the Uinta Mountain lakes with respect to macro-invertebrates and aquatic plant life. No semi-drainage lakes have been located in the Wasatch Mountains.

No *Nephelopsis obscura* have been found in the Wasatch Mountain lakes. *Erpobdella punctata* is a rare resident of the seepage lakes. *Glossiphonia complanata* and *Helobdella stagnalis* are also uncommon in these lakes. The rareness of *E. punctata* may be related to its life history in aquatic substrates and hence it is more difficult to observe. *Placobdella picta* was found in two seepage ponds.

Southern Utah High Plateaus. Much of this region consists of the Cretaceous and Tertiary formations of the Colorado Plateau and in some regions a transition zone exists between the Colorado Plateau and the Great Basin Paleozoic formations. Boulder Mountain contained numerous lakes above 3450 m elevation and leeches were absent in most of the lakes. Limited observations in the high plateau region imply leech occupants are similar to the Wasatch Mountain lakes with the rare occurrence of *Erpobdella punctata*, *Glossiphonia complanata*, *Helobdella stagnalis*, and *Placobdella picta*.

The Kaibab Plateau in northern Arizona is a continuation of the high plateau region. The Kaibab Plateau contains many lakes and ponds between 2100 and 2600 m elevation. These karst bog ponds contain very few leeches. One pond had *Helobdella stagnalis* and one pond (Fracas Lake) contained numerous *Haemopis marmorata*. Fracas Lake was similar to Lily Pad Lake in eastern Uinta Mountains in that it was a bog lake with *Nuphar*.

Snake Range. On the Nevada-Utah border (Figure 2) three lakes (3100 m elevation) were examined and contained no leeches.

Ruby Mountains. In central Nevada (Figure 2) seven lakes (2900 to 3100 m elevation) were examined. *Helobdella stagnalis* was commonly found in these lakes.

THE BASINS LEECH FAUNA. Bonneville Basin Transition Zone. A specialize region of relatively high leech abundance occurred in the Utah Lake Drainage (Provo and Spanish Fork Rivers) and the Weber River drainage above the Lake Bonneville level of 1552 m elevation (Table 3 and Figure 3). This region overlaps with the majority of locations in Beck's study (1954). *Erpobdella dubia* and *Erpobdella punctata* were common in this region. Low elevation of *Nephelopsis obscura* and its occurrence in streams (1757 m elevation) was unique in this study area. *E. dubia* in the Bonneville Basin was only found above the 1552 m elevation. The habitat diversity of springs, slow flowing streams, irrigation ditches, ponds, backwaters and wetland may contribute to the species diversity. Likewise this region was neither covered with glaciers nor flooded by Lake Bonneville and thus may represent a Pleistocene refugium. Lower elevations of the Provo and Weber Rivers may extend this rich transition zone into the Lake Bonneville domain.

A unique situation occurred in Spanish Fork River during 1983 when a huge landslide blocked the river and created Thistle Lake some 50 m deep. Today where 50 m of water occurred, one spring now contains *Erpobdella punctata*, *E. dubia*, and *Moorebdella microstoma*. This is the only location in this study which contained three species of Erpobdellidae.

Bonneville Basin. Bonneville Basin is largely depauperate with respect to leech fauna (Table 3, elevations below 1552 m). The investigations of three small streams (San Pitch River of the Sevier River drainage in southern Bonneville Basin and Dove Creek and Deep Creek, Idaho in northern Bonneville Basin) did not have the leech fauna of the Transition Zone of the Weber/Provo River drainages. The subbasins within the Bonneville Basin are largely unoccupied by leeches. One exception is in Snake Valley near Callao. This particular region consists of numerous springs, subterranean flows, pools, streams and wetlands below the Stansbury level (1320 m elevation). Although leech observations were rare, four species were found here: Haemopis grandis (Figure 7), Glossiphonia complanata (Figure 8), Helobdella stagnalis (Figure 9) and Erpobdella punctata(Figure 10). This contrast sharply with the remainder of Snake Valley with aquatic locations varying in elevation from 1320 m to 1700 m in which no leeches were found. Certainly further investigations are needed in Snake Valley.

Besides the addition of Haemopis grandis to the Bonneville Basin list, two other leeches were found below the Stansbury level at low elevations. Theromyzon rude was found in Pilot Valley (figure 4 and 8) and Haemopis marmorata was found west of Salt Lake City in a drainage ditch (Figure 7). Erpobdella punctata was also found in Tule Valley (Figure 10).

With Nephelopsis obscura commonly occurring in the Uinta Mountains, with Erpobdella punctata widely distributed in the Wasatch Mountains and Southern Utah High Plateaus, and with the rich leech fauna in the Transition Zone, the depauperate condition of leech species and numbers characterizes the Bonneville Basin below the Lake Bonneville levels of 1552 m elevation.

Relict Dace Basins. In central Nevada, three basins (Steptoe, Butte, and Ruby/Franklin) contain only one monotypic species of fish, the relict dace (Relictus solitarius). No other native fish lives in these basins and this genus is not found elsewhere. During Pleistocene times, Lake Gale in southern Butte Basin drained into Lake Franklin which occupied northern Butte Basin and Ruby and Franklin Basins. Steptoe Basin is separated by low divides from Butte Basin. Lake Waring occurred in northern Steptoe Basin, and in central and southern Steptoe Basin, extensive wetlands occurred.

The leech common to the Relict Dace basins is Erpobdella dubia. This leech is very common in the springs which occur above the Lake Waring high elevation level in Steptoe Basin and is very common in springs which lie below the Lake Franklin high elevation level in Butte and Ruby Basins (Table 3). Helobdella stagnalis commonly cohabits many of the same springs in northern Butte Valley, but is infrequent in Steptoe and southern

Butte Valley (lake Gale environs). Converse to the E. dubia distribution in the Relict Dace Basins, Haemopis marmorata and Erpobdella punctata occur in springs above the Lake Franklin high water elevation in Butte Valley whereas in Steptoe Basin, Haemopis marmorata and Erpobdella parva occur in springs below the Lake Waring high water elevation (Table 3). In the series of springs in northern Steptoe Basin (Big Springs), four leeches coexisted: H. stagnalis, H. marmorata, E. parva and Theromyzon rude. Erpobdella punctata has not been found in Steptoe Basin.

The springs below Lake Franklin high water elevation were relatively rich in leech abundance. Species abundance was very high in Ruby Valley (Table 2,3) and these observations may be related to the Pleistocene refugium, similar to the Weber/Provo river region of the Bonneville Basin. It is noted that Mooreobdella microstoma was found (pending further collection of species) in both these regions.

Colorado River Drainage Basin. The upper Strawberry River system which drains from the region east of the Spanish Fork and Provo River systems and drains to the Green River was extensively studied in 1988. This system (elevation 2312 to 2952 m) contains numerous abandoned river beds, backwaters, wetlands, springs, and ponds. Of the 23 sites (many visited up to four times during the summer), Helobdella stagnalis was found in seven sites, *Glossiphonia complanata* and *Erpobdella punctata* were found in four sites, and *Placobdella picta* and *Placobdella ornata* were found in one site. Species richness does not compare to the west side of the divide. Higher elevations may contribute to the difference found between the two drainages.

In Nevada, Railroad Basin and White/Muddy and Meadow Valley Washes are considered part of the Colorado River Basin sphere of influence because of the affinites of the fish found in these locations. Railroad Valley also contains Lahontan Basin influence based on fish. Based on the abundance of Leopard Frogs (*Rana pipiens*) in Spring Basin and Lake Basin and their presence in Meadow Valley Wash and their absence in the adjacent Steptoe Basin and Snake Basin (Bonneville Basin) except for human transplants , both Lake and Spring Basins can be postulated as belong to the Colorado River drainage sphere of influence. Both Lake and Spring Basins have had no native fish. The leopard frog could have migrated to the Spring and Lake Basins shortly after the pluvial period ended and before the desiccation of the region.

Placobdella ornata is found in both Spring Basin and Railroad Basin (Figure 8, 11) confirming the Colorado River drainage connection. Thus far, *P. ornata* has not been found in the Bonneville Basin.

DISJUNCT POPULATIONS. *Helobdella fusca*, *Haemopis grandis*, *Mooreobdella microstoma*, *Nephelopsis obscura*, and *Erpobdella parva* have widely discontinuous distributions. *N. obscura* (Figure 13) in Lake Basin could have arrived by the Colorado River drainage from the Uinta Mountains and Colorado. However these distribution patterns could be explained by widespread distribution during Pliocene times followed by extinctions during the pluvial times or the subsequent aridification of the region. *Haemopis grandis* is found in two locations: one in Snake Basin and one in Spring Basin (Figure 12). *Haemopis marmorata*, by contrast, is found in the basins and regions surrounding this limited *H. grandis* distribution. Competitive exclusion may have occurred here during the aridification of the region. *Helobdella fusca* was found in the Colorado River drainage (White River) and Clover Basin in northern Nevada (Figure 11). *Mooreobdella microstoma* was found in eastern Bonneville Basin and in the Ruby Basin (Figure 13). *Erpobdella parva* has been reported from Utah Lake (see Hovingh, 1986) and now in Steptoe Basin. *E. parva* may be a relict from Lake Waring and tending to occur in shallow lakes as the present Utah Lake. Furthermore the absence of *Erpobdella punctata* in Lake, Clover, Steptoe, and the Lake Gale regions of Butte Valley may likewise be significant. Thus the distributions in Figures 11, 12, and 13 may have different implications in leech paleobiology.

ECOLOGICAL NOTES ON BASIN LEECH SOURCES. In an attempt to understand the basin springs and in particular, why some basins contain Erpobdella punctata and other contain Erpobdella dubia, conductivity, oxygen, pH and temperature were measured in early season (April and May) and late season (July and August). Analysis from both times gave remarkable agreement, indicating that the spring water quality was constant (Table 4). Plant growth however is highly variable with little growth in spring, extensive beds of aquatic vegetation (watercress) during the summer, and dead vegetation in early winter. In general, the springs were low conductivity, low in oxygen (except in the presence of algal growth) and were alkaline pH (Table 5).

The gut contents of Erpobdellidae from these same sources were examined in early season and late season (Table 6). The Lake Basin Nephelopsis obscura show different food preference than the Uinta Mountain populations. Dipterans were common to both populations, but in the Lake Basin amphipods (not found in the Uinta Mountain semidrainage lakes) and ostracods were selected. Erpobdella parva showed a preference for ostracods and amphipods. Erpobdella dubia preyed on ostracods and amphipods and the spring snail (Hydrobiidae). Thus Erpobdellidae were consuming the obvious macro-invertebrates in these water sources.

Leech co-occupants were examined (Table 7). All aquatic sources with three or more species of leeches were analysed. Fourteen sources were identified and compared to three sources from British Columbia. Of the seventeen sources, 13 sources contained *Helobdella stagnalis* and *Erpobdella punctata* and eight sources contained *Glossiphonia complanata*. These three species were found in six Bonneville Basin and Colorado River Basin sources and made up most of the multiple-species co-occupants. Two aquatic sources in the study area contained two or three Erpobdellidae, whereas two out of three sources in British Columbia contained *Nephelopsis obscura* and *Erpobdella punctata* together, an event not occurring in the Intermountain study area. The entire region contrasts sharply with the midwestern United States where 13 leeches cohabit two ponds in Minnesota (Peterson, 1983).

DISCUSSION

Two limitations of any biogeographical study hampers the interpretation of results. The first limitation is knowing how complete is the sampling. *Haemopis marmorata* in Lake Basin and Steptoe Basin were readily observed in numerous trips. *Nephelopsis obscura*, *Erpobdella parva* and *Erpobdella dubia* were also repeatedly observed. Where *Helobdella stagnalis* and *Theromyzon rude* were common, repeated sampling took place. Conversely, *Glossiphonia complanata*, *Placobdella ornata*, *Haemopis* and *Erpobdella punctata* were irregularly observed on repeat trips. Consequently the distribution of these latter species could be greater than described herein. Two locations, Callao in Snake Basin and Tule Basin fissure springs were very unpredictable. In Tule Valley I did extensive monitoring of the wetlands in 1981. In 13 times throughout the year (every month) I had 8 observations of _Erpobdella punctata_ in 5 different springs. From 1982 to 1988, 16 trips were taken and 2 observations of _E. punctata_ were noted in 2 springs. Of the ten observations, 9 were from March through May and one was in August. Thus one could readily miss some leeches in some springs.

A second limitation is the assessment of passive transport by other agents (human, birds, insects, wind). This biogeographical study of aquatic fauna in the Great Basin assumes that distributions are the result of previous aquatic connections. Hubbs and Miller (1948) and Miller, et al., (1974) were successful in explaining the fish distribution in the Great Basin by studying possible pluvial connections between the present isolated fish populations in different basins. If fish did not occur, then no hypothesis could be advanced.

In this study both leeches, mollusks, and amphibians were noted. Although it is easier to invoke wind and birds for the transport of leeches and mollusk than for fish and amphibians (even today it is popular to suggest that amphibian and fish eggs can travel on ducks feet), it is more aesthetically pleasing to continue with the study of ancient aquatic habitat connections (Taylor, 1985 and 1988). With respect to both mollusks and leeches, there is very little positive evidence of mollusks and leeches being found on either birds (Roscoe, 1955) or aquatic insects (Owens, 1962) in flight (see also reviews by Rees, 1965 and Boag, 1986 for mollusks and Sawyer, 1986 for leeches).

Two examples of analysis of passive dispersal by waterfowl in the Great Basin are represented by Skull Valley were Roscoe (1955) made his observation and by Tule Valley. Within Skull Valley, the distribution of mollusk (there are no leeches or amphibians except for the spadefoot (Scaphiopus intermontanus) which does not utilize the mollusk-containing water sources) is not uniform even though waterfowl and shorebirds utilize all the springs/wetlands. Figure 14 shows the layout of the springs, the distribution of the mollusks and the conductivity of the springs. If passive movement by waterfowl and shorebirds was a common event, then all the springs would contain Physa, Lymnaea, Sphaeriidae, Gyraulus and two species of Hydrobiidae. One spring (Eight Mile Spring) is 12 kilometers from the nearest water source (unnamed spring) and contains no mollusks. These water sources have been manipulated by human during the last 100 years such that irrigation ditches connect the central mollusk containing springs and many of these areas contain reservoirs which the waterfowl inhabit. Water analysis (Hood and Waddell, 1968) shows differences ir is salinity. Yet this could only explain that one species of mollusks is found in Tiempe Springs. The last highest lake level (1264 m) allowed exotic fish and waterfowl to utilize the south portion of the Great Salt Lake (salinity approximate to sea water). These springs are all above this level. Some 10,500 years ago the lake reached the Gilbert level of 1275 m. Again these springs are above that level. Thus, in spite of waterfowl and shorebirds readily utilizing these springs, the mollusk distribution varies from no mollusk in one spring to grouped distribution in other springs. Some 11,000 years has not made these springs uniform with respect to mollusk. These molluscan observations extend to each isolated valley in the Bonneville Basin.

The second example is the special case of Tule Valley. During Lake Bonnevile Provo level (1446 m) era, Tule Valley was an arm of Lake Bonneville with a shallow connection. This allowed for the concentration of salts in this arm (while Lake Bonneville was freshwater) to the extent that the salinity was greater than sea water. After desiccation numerous salt flats remain with a series of fissure fault springs arising in the middle of the valley. These springs contain the relict population of spotted frog (Rana pretiosa) and Erpobdella punctata and no living mollusks (although there is an abundance of semifossil shells laying about the valley floor and in the salt flats) nor native fish. Two springs (1681 and 2393 m) in Tule Valley drainage of the House Range contain a Succineidae and a Hydrobiidae. The nearest adjacent springs to the Tule Valley springs are Fish Springs (48 km north) and Twin Spring in Snake Valley (33 km west). Both Fish Springs and Twin Springs contain an abundant molluscan fauna (Taylor, 1986) and all three areas contain an abundant waterfowl and shorebirds fauna. The conductivity of the springs (Tule Valley, 2900; Fish Springs, 3100; and Twin Springs, 1000) would not make a difference in the interpretation. *Helisoma* from the Uinta Mountains was maintained in aquaria, one with water from Twin Springs and one with water from Tule Valley. Survival in this limited experiment was equivalent. Thus in some 13000 years no passive distribution of mollusk has occurred between these basin. One can invoke passive distribution by birds (Rees, 1965 and Boag, 1986) but it does not apply to the Great Basin arid region.

With respect to passive dispersal of leeches, Davies, et al. (1982) examined the possibilities with two sanguivorous species (*Theromyzon rude* and *Placobdella papillifera*) and *Helobdella stagnalis* and *Nephelopsis obscura*. Both the sanguivorous leeches could be transport to a second water source by ducks. *Helobdella stagnalis* was not transported and only coccoons of *N. obscura* on aquatic plants fed to well-fed ducks survived the transport. To assess passive transport in the Great Basin, one must show 1)the leech is common, 2) the passive transport vector is common, and 3) that leech distribution can not be accounted for by survival in ephemeral water sources in the mud.

Two cosmopolitan species, Helobdella stagnalis (Sawyer, 1986) and the bivalve Pisidium casertanum (Taylor, 1988) have wide distribution in the Palearctic and Nearctic regions of the northern hemisphere. Both these species are widely distribution in the Intermountain region. Such wide distribution can best be explained by long-term survival and adaptibility to a wide range of ecological habitats and that such species may have lived within the region since the Tertiary. With both western Great Basin (Lake Lahontan) and eastern Great Basin (Lake Bonneville) thought to have drained to the Pacific in pre-Pleistocene times (Taylor ang Bright, 1987 and Taylor, 1985), the leech distribution may reflect such archaic aquatic connections. There have been postulations of connections, not continuous but serial over time, with aquatic systems in the north (Columbia-Snake River and Mississippi River (Taylor, 1988) and in the east between the Colorado River System and the continental drainages east of the divide. Such routes are postulated to explain fish distribution (Behnke, 1981).

In arid regions in the Great Basin and the Colorado River Basin, not much habitat is suitable for aquatic species unless they are specially adapted. In the Great Basin, the mountain streams are flushed during spring snow melt and with the summer storms and dry other times of the year. The basin ponds are filled with water during wet years and turn to mud flats, baked clay and saline flats during the dry seasons. The basin springs in arid regions contain a constant aquatic habitat within all this variability. In the absence of fish, the predatory Erpobdellidae and Haemopidae are the top of the food chain. They can survive in adjacent mud banks and in wetlands were moisture is only as low as the roots of the vegetation.

The distribution in the Intermountain region is unique in that very few species occur within this region and that within a single aquatic source, only rarely do two members of the same family of Erpobdellidae and Haemopidae occur together. Is this explainable by the small size of the aquatic source, by competitive exclusion, or by paleobiological distribution and subsequent extinctions? If paleobiological distribution is a major factor, the present sporadic distribution patterns probably reflectpre-pluvial distributions. The environments during the glacio-pluvial period suggest that subalpine forest occurred at elevations between 1660 and 2340 m (Wells, 1983) in the Bonneville Basin. Lake Bonneville, in particular, and other pluvial lakes (Spring, Waring, and Franklin) impacted the leech populations either positively (Franklin) or negatively (Bonneville). During the desiccation in the last 13,000 years, the leeches have not moved rapidly to the new aquatic sources of springs and streams. The region occupied by former Lake Bonneville is essentially barren of leeches. This contrasts sharply with Lake Franklin and the Provo/Weber River region which may have been highly suitable for leeches during the glacio-pluvial period.

Thus one can envision a widespread distribution of leeches representing the species of the Neartic across the Intermountain region. In the Great Basin, the distribution relied on ancient drainages including the Colorado River system. Block-faulting isolated the populations within basins. Both the pluvial period of some 600,000 years and the desiccation period of the last 13,000 years caused local exterminations and the present distributions.

Previously (Hovingh, 1986) a list of leeches from western Colorado (from Herrman, 1970), Utah and Nevada indicated a decline in the number of species in an east-west direction. This decline can now be attributed to the lack of fieldwork in the Intermountain Region and the Great Basin in particular. Table 8 shows the north-south distribution of leeches from British Columbia to Arizona (all west of the continental divide). If the paleobiological aspects accounts for leeches in the Great Basin, this list of leeches from Idaho and British Columbia could indicate that more species may be found in the Great Basin. Since Arizona is largly within the Colorado River Basin, more leeches should be identified in Arizona, especially within the northern region. It is of interest that whereas both British Columbia and the Uinta Mountains were covered by glaciers some 20,000 years ago, that so few leeches reached the Uinta Mountain lakes whereas British Columbia has extensive populations. This might be explained by abundant numbers of leeches in adjacent Idaho which shares the Columbia River with British Columbia and a lack of these numbers in the Colorado River basin and the Bonneville Basin adjunct to the Uinta Mountains.

Taylor and Bright (1987) noted that whereas fish were uniformly distributed within the Bonnevile Basin, mollusks were not uniformly distributed. The mollusk formed two populations, that of the Sevier drainage and that of the Bear River drainage. Thus in some 8000 years of Lake Bonneville history, mollusk distribution did not become uniform. It is too early to determine if leech distribution will partition within the Bonneville Basin. An indication that the western portion (with Haemopis grandis) and the eastern portion (with H. marmorata) might suggest such a partition.

Whereas fish (Hubb and Miller, 1948) and mollusk (Taylor, 1985) are highly endemic with the Intermountain region, leeches have no endemic species within this region with the possible exception of Erpobdella montezuma in Arizona. Whereas mollusc are undifferentiated from Pliocene and earlier (Taylor, 1985), fish are though to have differentiated in the Pliocene or in the Pleistocene (Behnke, 1981). Thus each group of species contributes different information on biogeography, an observation that Taylor (1985, 1988) has noted repeatedly.

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TABLE 1. LIST OF LEECHES IN THE INTERMOUNTAIN REGION OF UTAH AND NEVADA AND ADJACENT REGIONS OF THE GREAT BASIN.

Glossiphoniidae

Theromyzon rude(Baird, 1863)

Glossiphonia complanata (Linnaeus, 1758)

Helobdella stagnalis (Linnaeus, 1758)

Helobdella fusca (Castle, 1900)

Placobdella (Batracobdella) picta (Verrill, 1872)

Placobdella ornata (Verrill, 1872)

Haemopidae

Haemopis marmorata (Say, 1824)

Haemopis grandis (Verrill, 1874)

Erpobdellidae

Nephelopsis obscura (Verrill, 1872)

Erpobdella punctata (Leidy, 1870)

Erpobdella (Dina) dubia (Moore and Meyer, 1951)

Erpobdella (Dina) parva (Moore, 1912)

Mooreobdella microstoma (Moore, 1901)

TABLE 2. Characterization of numerous basins with respect to Pleistoce Lakes, aquatic sources and leeches

Basin	Basin size Km^2 *	Pleistocene Lake Depth (m)*	Pleistocene Lake Size (km^2)*	Percent lake	# Sites	# Sites 1000 km^2 basin	# Sites with leeches	# Leech species
Bonneville	139,860	274	51,645	37	224	1.6**	34 (15%)	10
Spring-Spring	2,867	42	603	21	12	4.2	3 (25%)	5
Maxey(1)	1,425	39	210	15	9	6.3	0	0
Lake	1,360	21	52	4	6	4.3**	3 (50%)	3
Steptoe/Antelope	9,293	59	1,527	16	60	6.5	11 (18%)	5
Railroad	12,147	20	971	8	21	1.7**	2 (10%)	2
Clover	2,639	29	912	35	16	6.2	2 (13%)	2
Butte/Gale (2)	1,870	27	411	22	5	2.6**	2 (40%)	1
Ruby/Franklin	3,315	39	1,251	38	20	6.1**	14 (70%)	7

* Data derived from Mifflin and Wheat (1979)

** Number of sites could increase with future investigations

(1) Lake Maxey drained into Lake Spring

(2) Lake Gale drained into Lake Franklin

TABLE 3. DISTRIBUTION OF LEECHES IN NUMEROUS DRAINAGES AS PARTITIONED BY PLEISTOCENE LAKE LEVELS AND MOUNTAIN ELEVATIONS

	Number of Sites	# Sites with leeches	H. stagnalis	H. fusca	G. complanata	P. picta	P. ornata	T. rude	H. marmorata	H. grandis	N. obscura	E. punctata	E. dubia	E. parva	M. microstoma
Bonneville Basin															
above 2500 m	12	9	3		2	2					4	3			
1552-2500 m 1/	57	3	2									1	2		
1552-2500 m 2/	22	13	2		3						3	6	4		1
1446-1552 m	42	2										2			
1373-1446 m	31	0													
below 1373 m	60	8	4		1			1	1	1		4			
Colorado Basin															
above 2500 m	45	19	7		5	2			2		5	4			
1800-2500 m	20	5	4		3		1					2			
below 1800 m	2	1		1											
Railroad															
above 1485 m	11	0													
below 1485 m	10	2					1	1				2			
Lake															
above 1825 m	1	0													
below 1825 m	5	3	2						2		1				
Spring															
above 1760	8	0													
below 1760	13	3	2				1	1		1		2			
Butte (Gale)															
above 1906 m	5	2	2												
below 1906 m	0	0													
Ruby/Franklin															
above 1850 m	6	3	1						1			2			
below 1850 m	14	11	8		2			1					9		1
Clover															
above 1730 m	12	0													
below 1730 m	4	2		1					1						
Steptoe															
above 2100 m	8	0													
1762-2100 m	48	10	3					1					8		
below 1762 m	4	1	1					1	1					1	
Lahontan															
above 2500m	7	3	3												
1800-2500 m	3	0													
below 1800m	10	0													
Fraser River Basin		7	2		2				5		4	3			

1/ Sources in Bonneville Basin exclude those in Footnote 2.

2/ Sources in the Weber, Provo and Spanish Fork drainages of the Bonneville Basin

TABLE 4. ANALYSIS OF LEECH-OCCUPIED SPRINGS FOR CONDUCTIVITY, pH, OXYGEN, AND TEMPERATURE

LOCATION	DATE	CONDUCTIVITY	OXYGEN	pH	
(B 5-19) 36ac, Pilot Valley	Aug.19	380 @ 18 C	6.4 @ 15.9 C	7.66 @ 15.8 C	
South Patterson Spring	May 4	370 @ 16.5 C	4.6 @ 14.5 C	6.80 @ 14.7 C	
(36/66) 22c Steptoe Valley	Aug. 19	315 @ 24 C	3.1 @ 17.7 C	7.64 @ 18.1 C	open H_2
Big Spring	April 18	260 @ 13.5 C	7.6 @ 14.2 C	8.35 @ 15.5 C	
	Aug 19	330 @ 22 C	2.5 @ 17.0 C	7.51 @ 15.5 C	roots
	April 18	270 @ 13.0 C	4.9 @ 14.0 C	7.87 @ 14.3 C	
(26/67) 31aa, Steptoe Valley	Aug. 19	240 @ 21.5 C	5.0 @ 18.7 C	7.6 @ 18.4 C	Lookout
(25/66) 11a, Steptoe Valley	Aug. 19	275 @ 19 C	1.2 @ 15.0 C	7.82 @ 15.2 C	
Flat Spring	April 19	250 @ 13 C	6.5 @ 13.5 C	7.90 @ 13.6 C	
(28/63) 36a Steptoe Valley	Aug. 19	205 @ 15 C	7.0 @ 11.6 C	7.75 @ 11.6 C	
Thompson Spring	April 19	230 @ 10 C	8.1 @ 11.3 C	7.88 @ 11.9 C	
(28/63) 36c Steptoe Valley	Aug. 19	250 @ 14 C	7.0 @13.7 C	7.83 @ 13.7 C	
Currie Gardens	April 19	240 @ 11 C	7.6 @ 13.6 C	7.77 @ 14.2 C	
(29/63) 35a Steptoe Valley	Aug. 20	300 @ 20 C	3.7 @ 20.8 C	7.69 @ 20.9 C	source
	April 19,	290 @ 18 C	4.9 @ 20.8 C	7.49 @ 21	
	Aug 20	300 @ 21 C	4.3 @ 21 C	7.48 @ 21.1 C	stream
(19/63) 33cb Steptoe Valley	Aug 20	290 @ 15 C	4.3 @ 12.9 C	7.49 @ 12.8 C	spring
	Aug 20	330 @ 16 C	3.5 @ 13.7 C	7.74 @ 13.3 C	reservo
	May 4	290 @ 10 C	7.5 @ 10.3 C	7.31 @ 10.6 C	reservo
(9/65) 24 #1 Lake Valley	Aug 20	280 @ 19.5 C	1.9 @ 17.2 C	7.69 @ 17.6 C	
(9/65) 24 #2 Lake Valley	Aug 20	295 @ 21 C	5.1 @ 18.6 C	7.35 @ 18.5 C	
(18/66) 24 Spring Valley	Aug 20	95 @ 16 C	12.4 @ 18.4 C	9.54 @ 18.6 C	spring
	May 3	90 @ 15 C	17.4 @ 20.4 C	10.2 @ 19.7 C	algae
	Aug 20	95 @ 16 C	5.5 @ 16.6 C	7.9 @ 14.1 C	outlet
(18/66) 12 Spring Valley	Aug 20	65 @ 16 C	4.5 @ 13.6 C	6.53 @ 14.7 C	
	May 3	50 @ 15 C	7.9 @ 13.4 C	6.6 @ 13.0 C	
(C 10-17) 36 #1 Snake Valley	Aug 21	820 @ 27 C	5.7 @ 19.9 C	7.53 @ 23.5 C	
	May 3	500 @ 17 C	7.8 @ 17.2 C	7.65 @ 17.4 C	
(C 10-17) 36 #2 Snake Valley	Aug 21	300 @ 17.C	3.7 @ 15.7 C	7.60 @ 15.5 C	
	May 3	315 @ 19 C	7.2 @ 16.5 C	8.3 @ 15.9 C	
(C 10-17) 36 #3 Snake Valley	Aug 21	320 @ 20 C	13.4 @ 17.1 C	9.50 @ 19.6 C	
	May 3	310 @ 16 C	12.2 @ 19.4 C	9.68 @ 16.7 C	anserir
	May 3		27.8 @ 15.8 C	9.74 @ 13.2 C	algae
(C 17-15) 10aab Tule Valley	Aug 21	1600 @ 29 C	1.6 @ 28.3 C	7.40 @ 28.0 C	source
	May 2	1550 @ 27 C	1.4 @ 18.5 C	7.60 @ 28.8 C	
	Aug 21	1600 @ 27.5 C	4.9 @ 27.5 C	7.83 @ 17.3 C	"C"
	May 2	1450 @ 24 C	6.1 @ 25 C	8.22 @ 23.9 C	

TABLE 5. SUMMARY OF ANALYSIS OF LEECH-OCCUPIED SPRINGS

CHEMICAL PARAMETERS OF SELECTED GREAT BASIN SPRINGS

VALLEY	NUMBER OF SPRINGS	CONDUCTIVITY umhos/ cm	OXYGEN ppm	pH
STEPTOE	7	205-300	1.2 - 8.1	7.3 - 7.9
LAKE	2	280	1.9 - 5.1	7.5
SPRING	2	50-95	4.5 -17.4	6.5 -10.2
SNAKE	3	310-820	3.7 -27.8	7.5 - 9.7
TULE	1	1450-1600	1.4 - 6.1	7.4 - 8.2

TABLE 6. Analysis of Erpobdellidae gut contents. The date of collection is followed by the number of leeches examined at that date.

ANALYSIS OF ERPOBDELLIDAE PREY

NUMBER OF PREY PER LEECH

	Nephelopsis obscura						*E. punctata*		*E. parva*		*E. dubia*	
	Uinta Mountains				Lake Basin							
Date-number:	7/80-61	9/80-27	7/87-3	9/87-1	7/87-7	8/87-4	5/87-3	8/87-9	4/87-5	8/87-5	4/87-12	8/87-31
PREY												
OSTRACODA	-	-	-	-	-	1.8	-	-	-	0.8	0.1	5.0
AMPHIPODA	-	-	-	-	0.3	0.3	-	0.3	0.2	0.8	0.3	0.7
CLADOCERA	1.9	10.2	-	-	-	-	-	-	-	-	-	0.2
DIPTERA	1.4	2.8	3.3	1.0	0.3	1.5	-	-	-	-	-	-
OTHER INSECTS	0.2	0.2	-	-	-	-	0.7	0.1	0.2	0.2	-	0.2
HYDROBIIDAE	-	-	-	-	-	-	-	-	-	-	0.1	0.7
UNKNOWN	-	-	-	-	0.1	0.5	-	-	0.2	-	-	0.2

TABLE 7. Characterization of water sources by the multiple number (more than three) leech species.

	H. stagnalis	H. fusca	G. complanata	P. picta	P. ornata	T. rude	H. marmorata	H. grandis	N. obscura	E. punctata	E. dubia	E. parva	M. microstoma
Bonneville Basin													
Bloods Lake, 2934	+		+							+			
Provo dr. 2825	+			+						+			
Thistle, 1600										+	+		+
Callao,1320	+		+					+		+			
Colorado Basin													
Posy Lake,2646	+		+	+						+			
Strawberry,2525	+		+							+			
Strawberry,2312	+		+		+					+			
Strawberry R,2312	+		+							+			
Railroad													
Bullwacker,1452					+	+				+			
Lake													
Wambolt,1810	+						+		+				
Spring1/12,1710	+				+					+			
Spring13/24,1710	+							+		+			
Ruby 2b,1830			+								+		+
Steptoe,1739	+					+	+					+	
Fraser River dr.													
Chubb lake	+						+		+	+			
Moose Lake	+								+	+			
neChilko Lake			+				+		+				

Table 8. North-south distribution by province and state from British Columbia to Arizona. The data is derived from Klemm (1985), Herrman (1970), Sawyer (1986) and this paper. The <u>Mooreobdella microstoma</u> listing for the Great Basin needs confirmation.

	British Columbia	Idaho	Utah-Nevada Great Basin	Utah-Colorado Colorado River Basin	Arizona
Actinobdella inequiannulata	+	+			
Alboglossiphonia heteroclita	+				
Actinobdella phalera		+			
Placobdella picta	+	+	+	+	
Glossiphonia complanata	+	+	+	+	
Helobdella elongata		+			
Helobdella fusca			+		
Marvinmeyeria lucida	+				
Helobdella stagnalis	+	+	+	+	+
Placobdella montifera	+				
Placobdella ornata	+	+		+	
Placobdella parasitica			+		+
Theromyzon tessulatum	+				
Theromyzon rude	+	+	+	+	
Myzobdella lugubris		+			+
Piscicoloa punctata	+				
Piscicola salmositica	+				
Piscicola milneri	+				
Haemopis grandis		+	+		
Haemopis kingi					+
Haemopis marmorata	+	+	+	+	+
Erpobdella anoculata	+				
Erpobdella parva		+	+	+	
Erpobdella dubia		+	+	+	
Erpobdella punctata	+	+	+	+	
Erpobdella montezuma					+
Mooreobdella fervida	+	+			
Mooreobdella microstoma		+	(+)		
Nephelopsis obscura	+	+	+	+	
TOTAL	18	17	13	10	6

FIGURE 1. A map of the Intermountain region showing the distribution of the states, the present major drainages, and Pleistocene lakes.

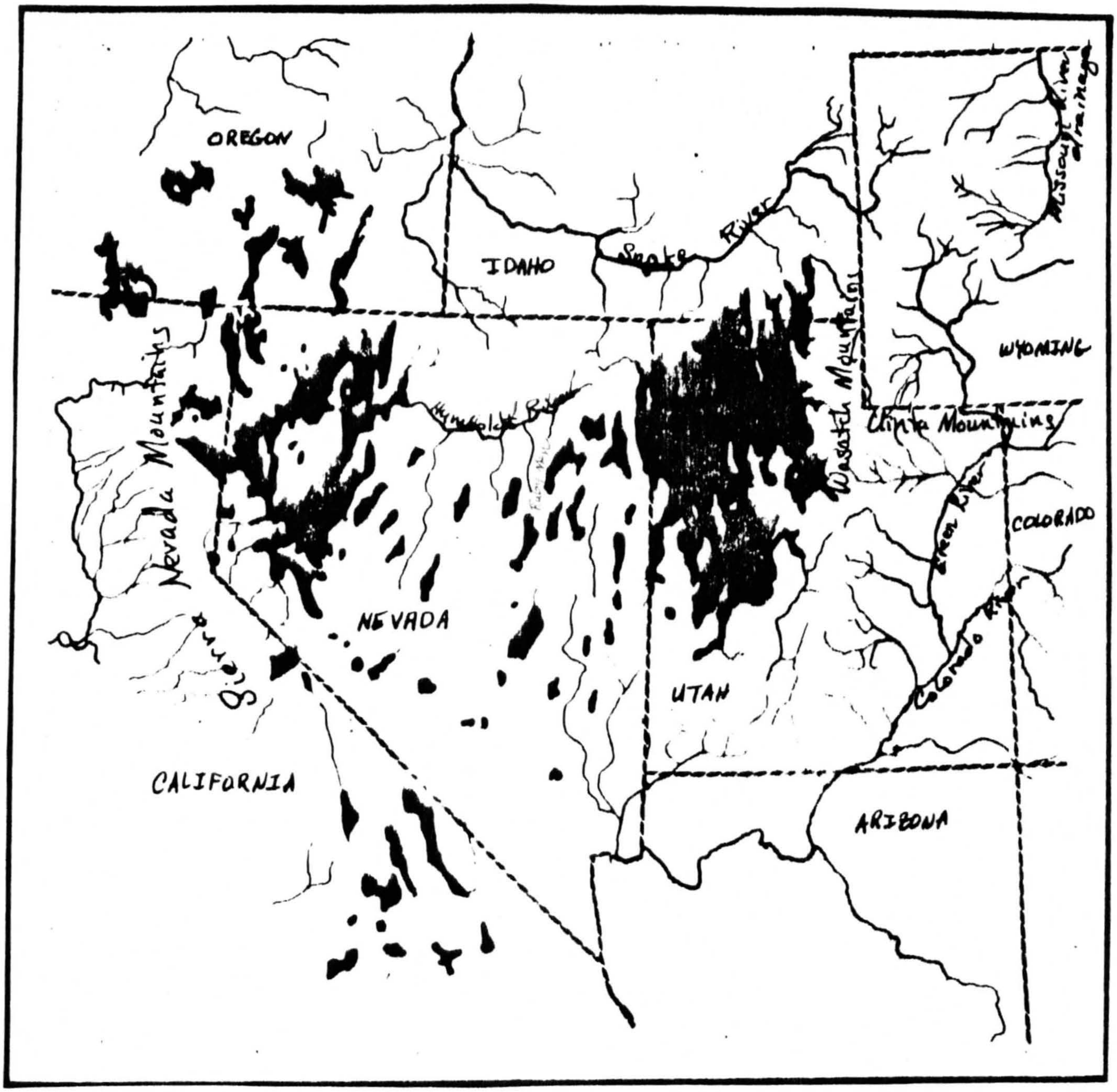
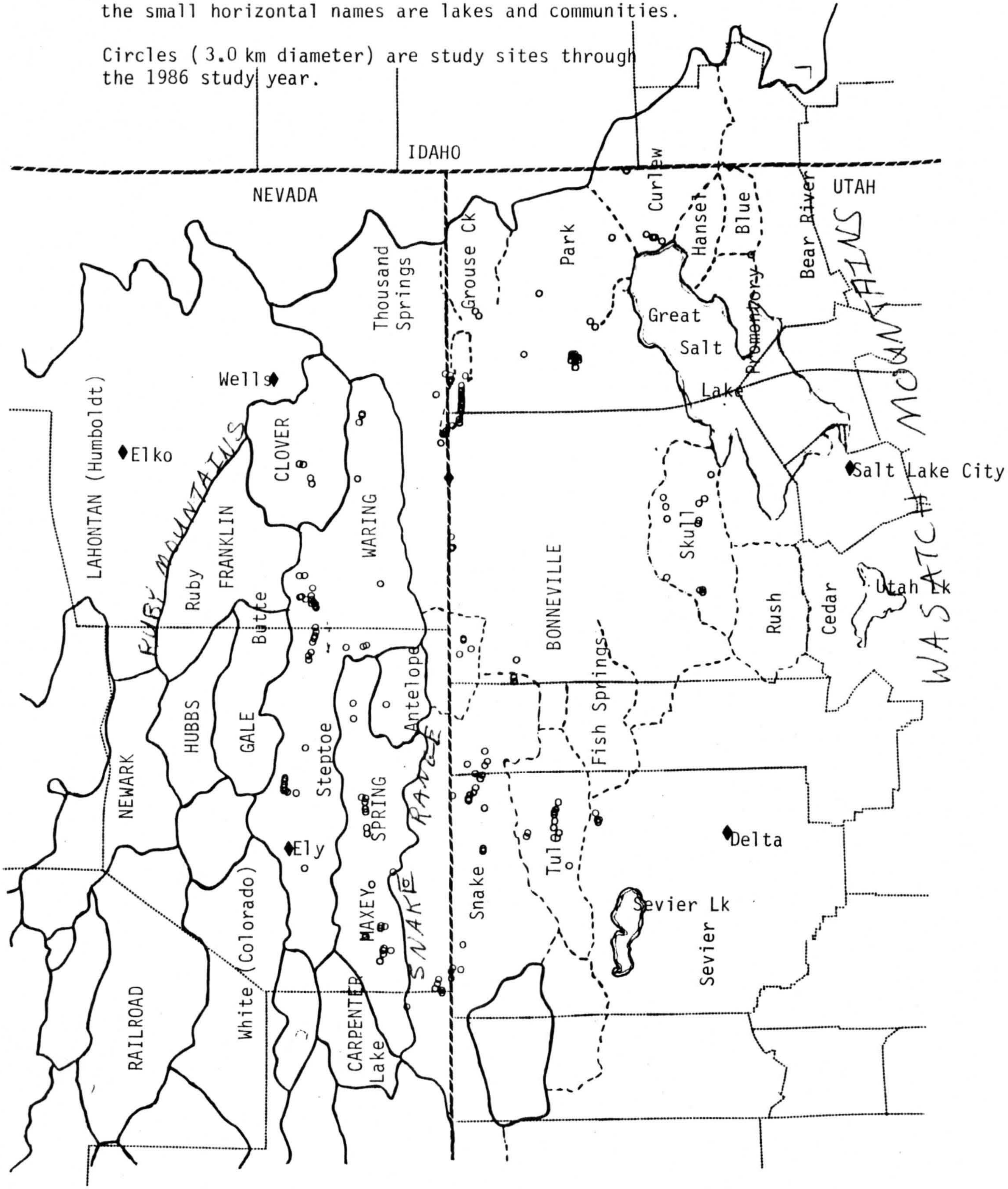


FIGURE 2. Map showing the basins of western Utah and eastern Nevada. The vertical large names are Pleistocene lake names, the vertical small names are the basin names, the hand-written names are the mountains, and the small horizontal names are lakes and communities.

Circles (3.0 km diameter) are study sites through the 1986 study year.



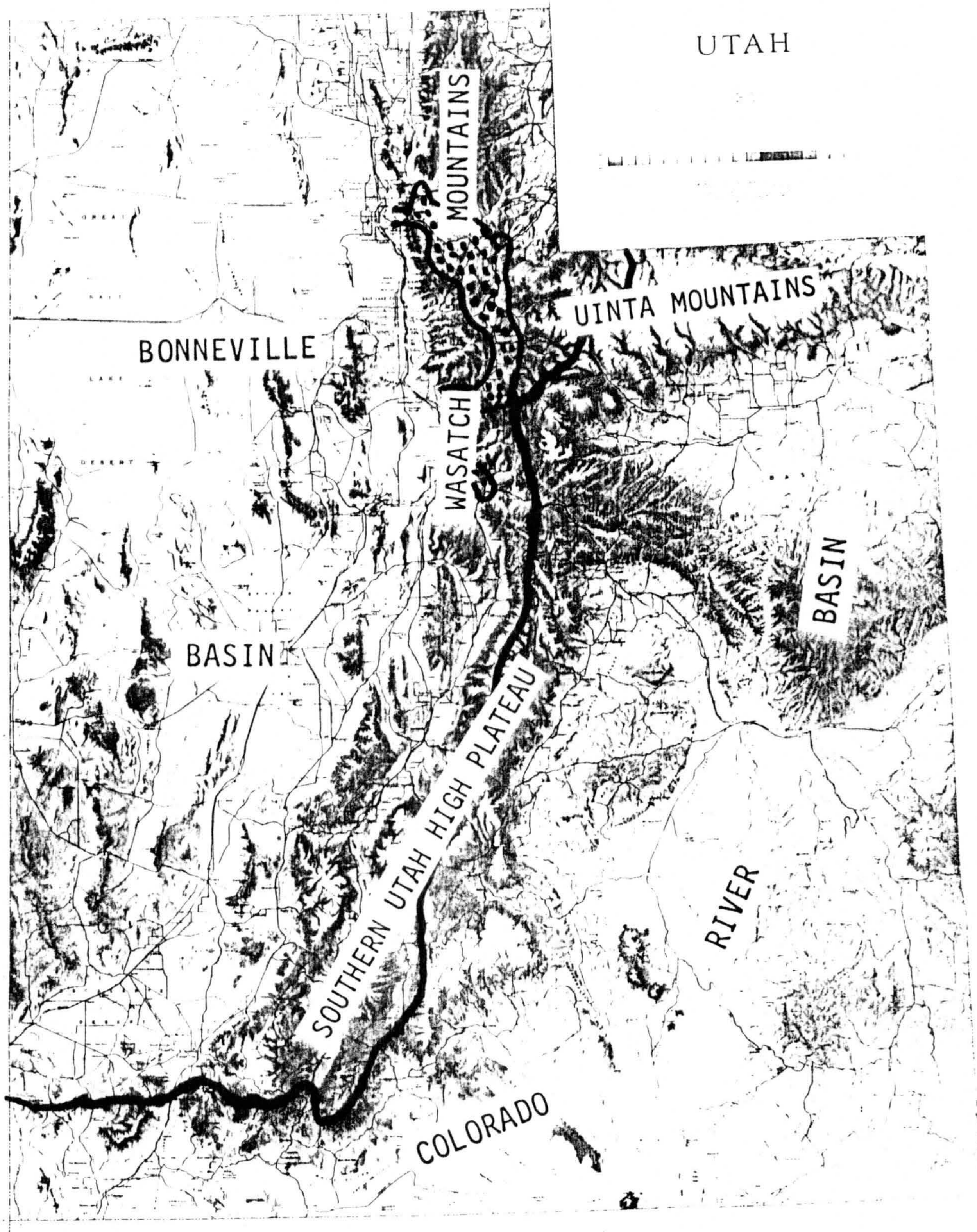


FIGURE 3. A map showing the state of Utah with respect to the Bonneville and Colorado River Drainage Basins and in respect the the Uinta Mountains, the Wasatch Mountains, and the Southern Utah High Plateau. The dotted region is the Weber,Provo, and Spanish Fork region with its special leech fauna.

Figure 4. Distribution of four Glossiphoniidae species in Utah.

Figure 5. Distribution of <u>Helobdella</u> <u>stagnalis</u> in Utah

Figure 6. Distribution of four species of Erpobdellidae in Utah. The number associated with the letters indicates the number of sites at that location in which the particular leech was found.

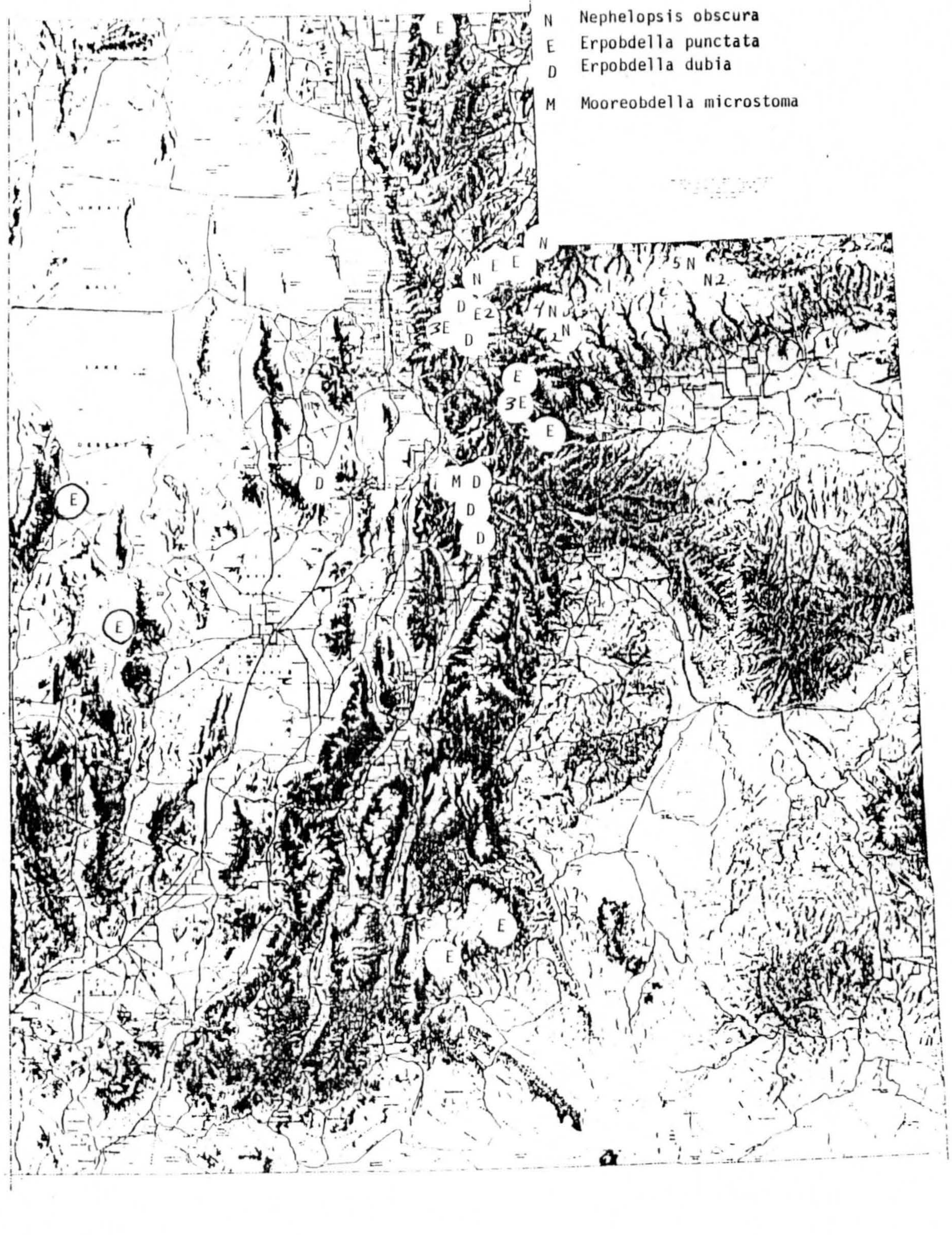


Figure 7. Distribution of <u>Haemopis grandis</u> and <u>Haemopis marmorata</u> in the Great Basin.

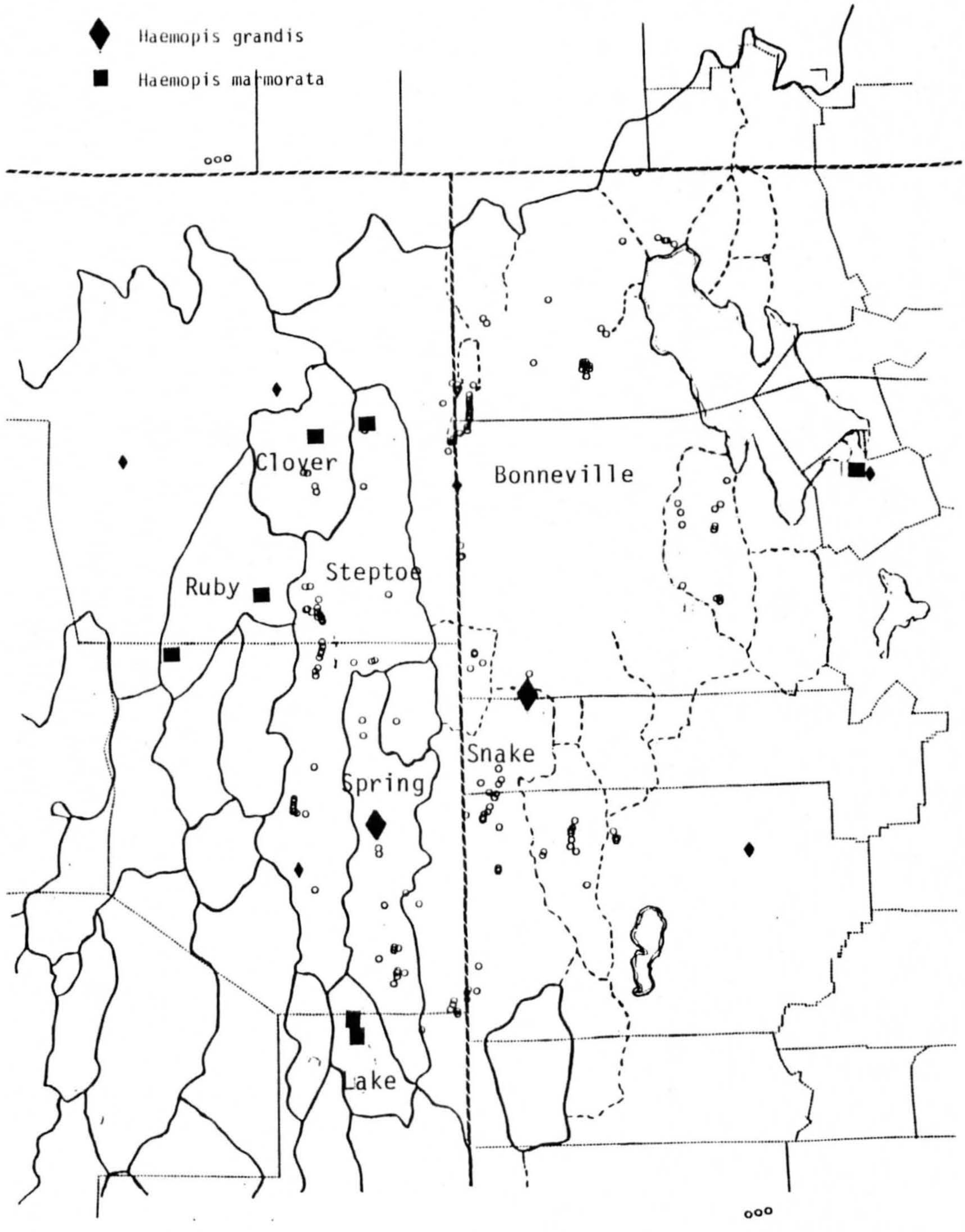


Figure 8. Distribution of three species of Glossiphoniidae in eastern Great Basin.

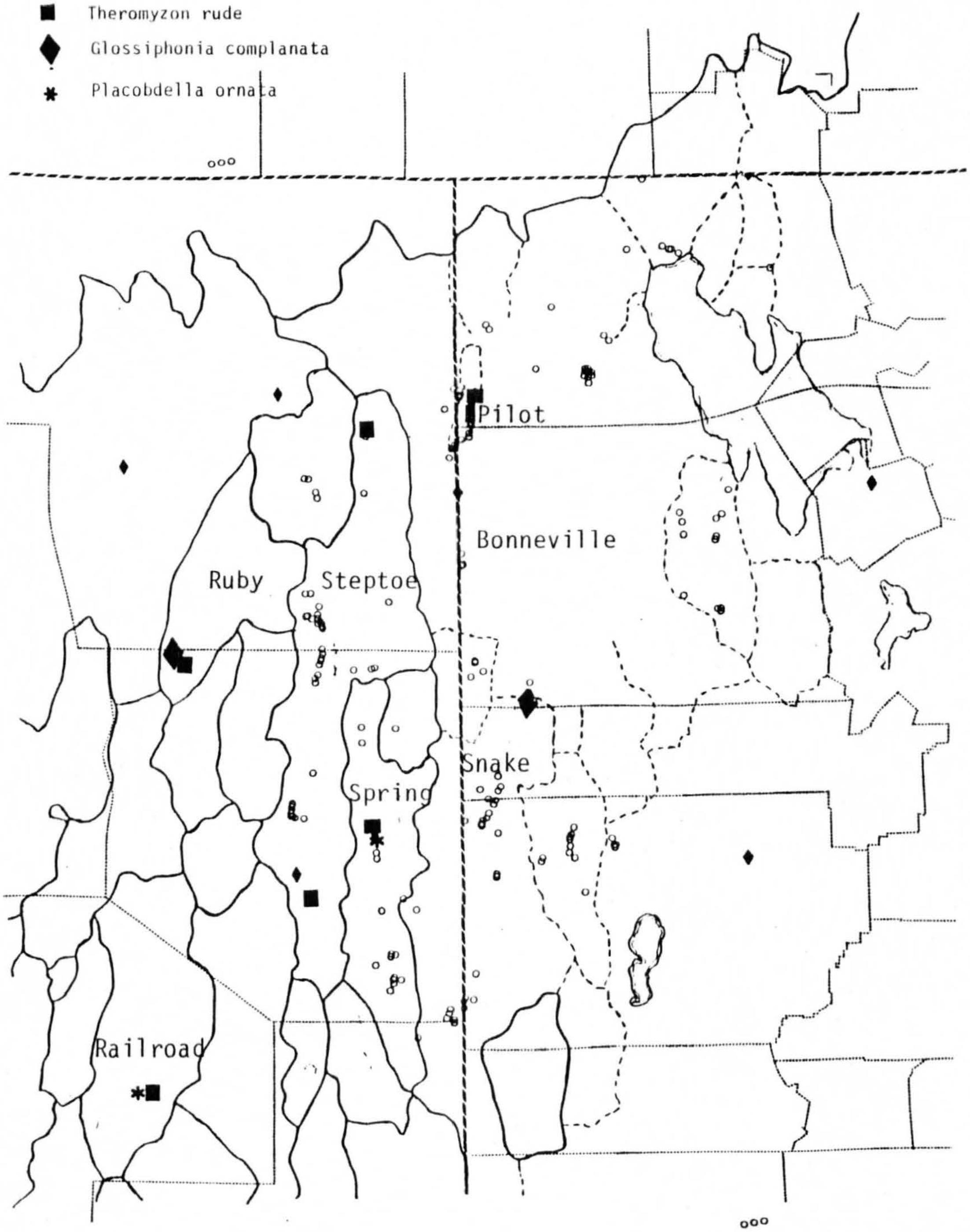


Figure 9. Distribution of Helobdella (Glossiphoniidae) in the Great Basin.

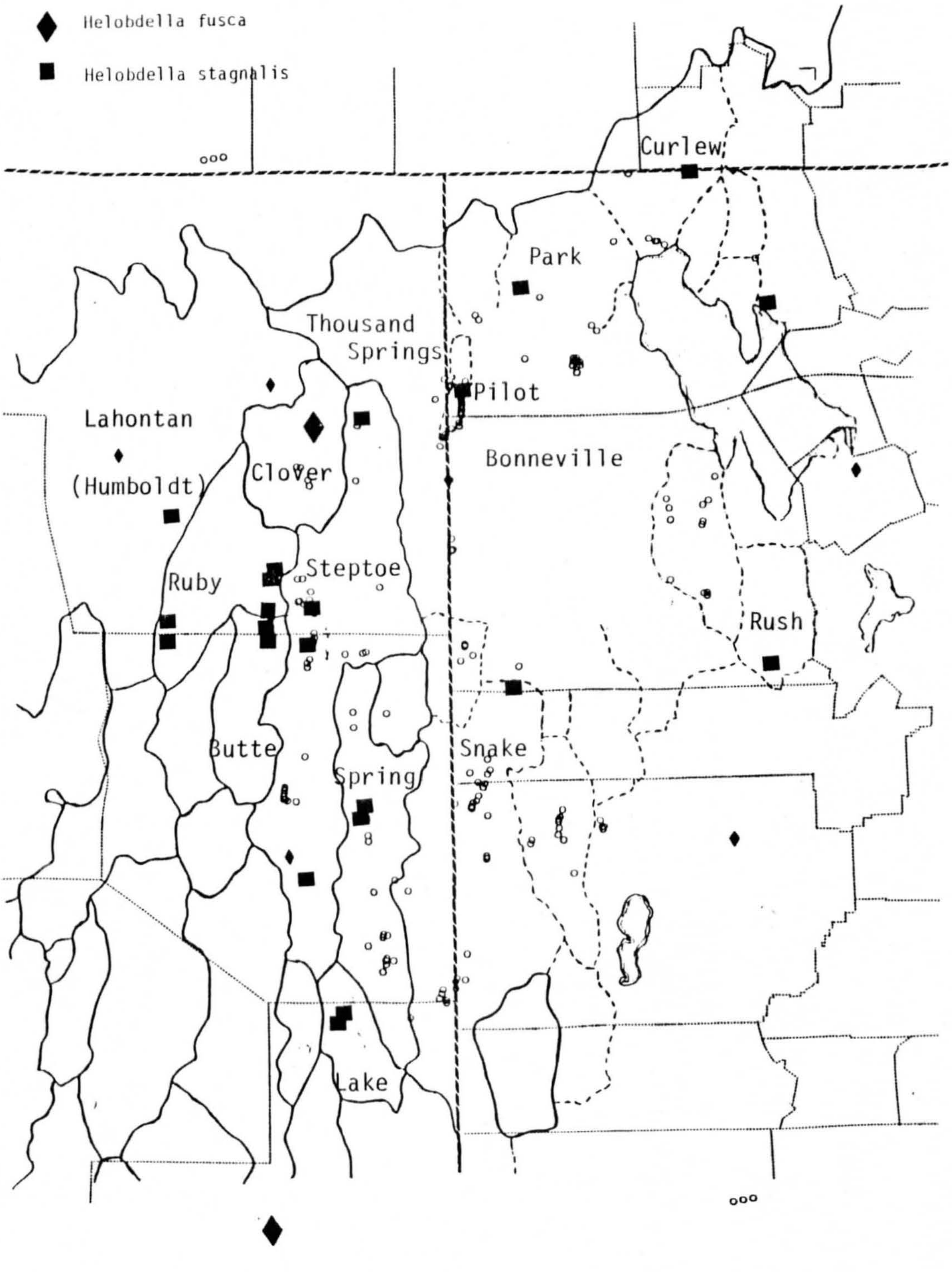


Figure 10. Distribution of Erpobdellidae in eastern Great Basin.

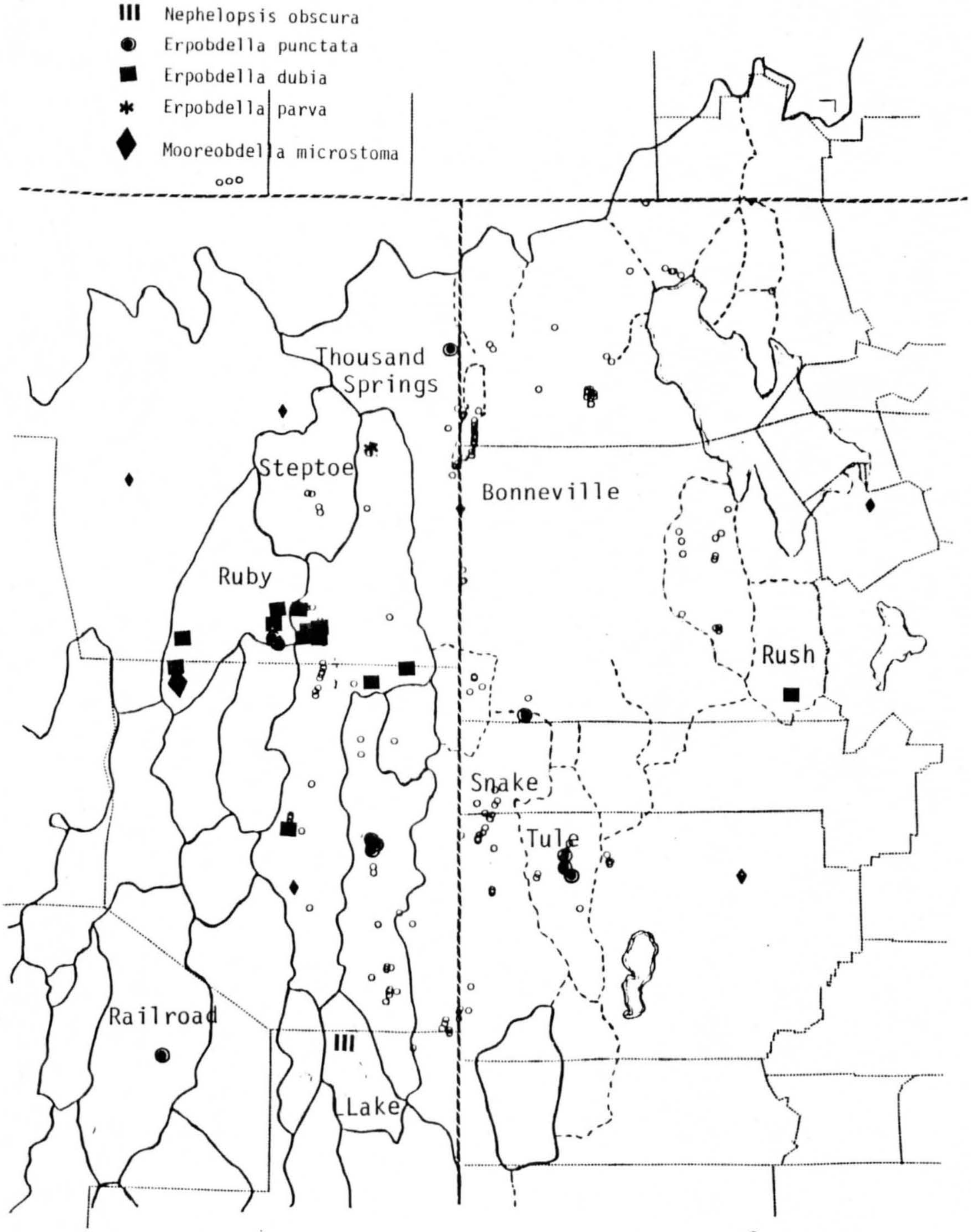


Figure 11. Distribution of Placobdella ornata and Helobdella fusca in Nevada and Utah.

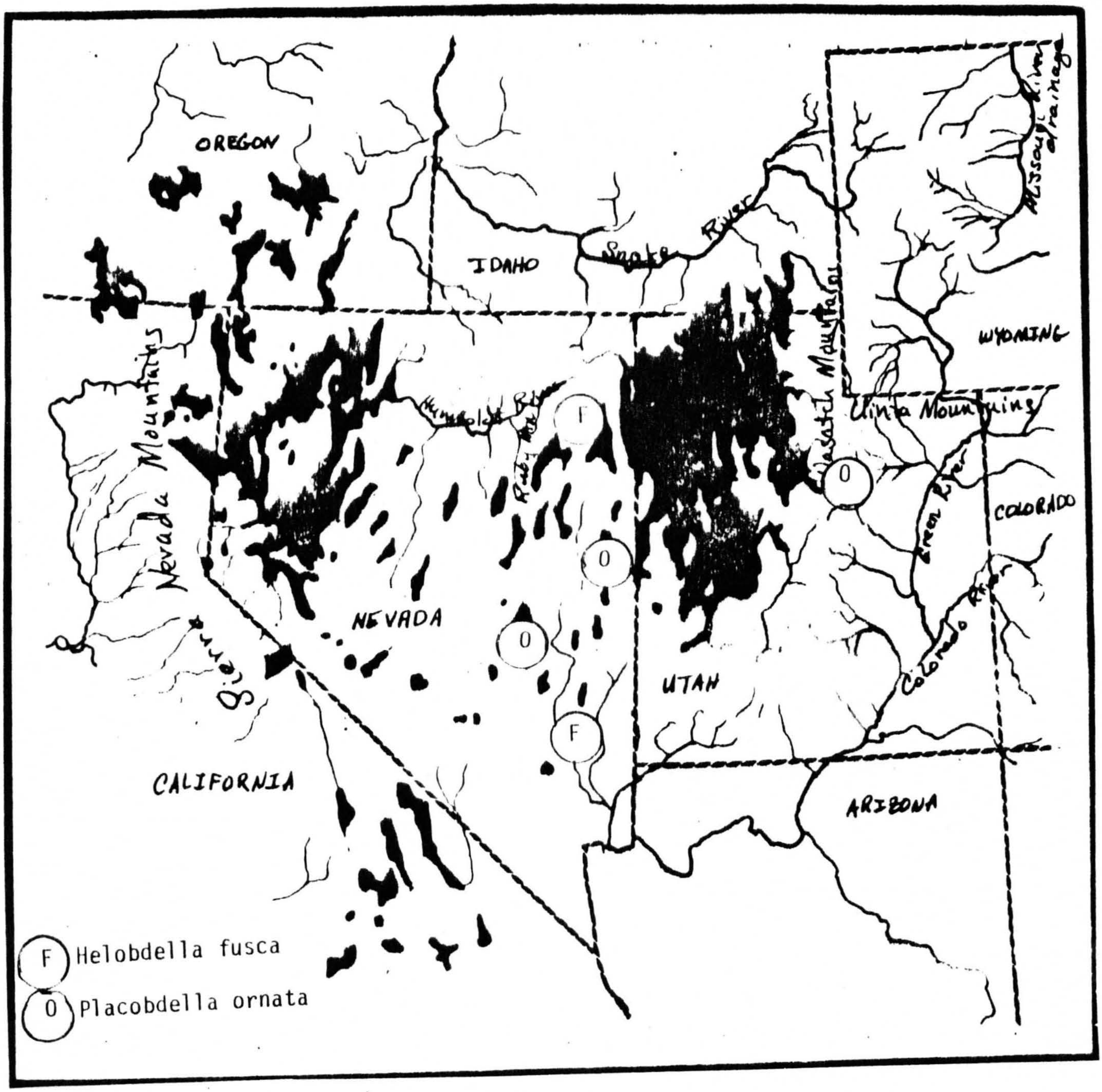


Figure 12. Distribution of Haemopis marmorata and Haemopis grandis in the Intermountain region.

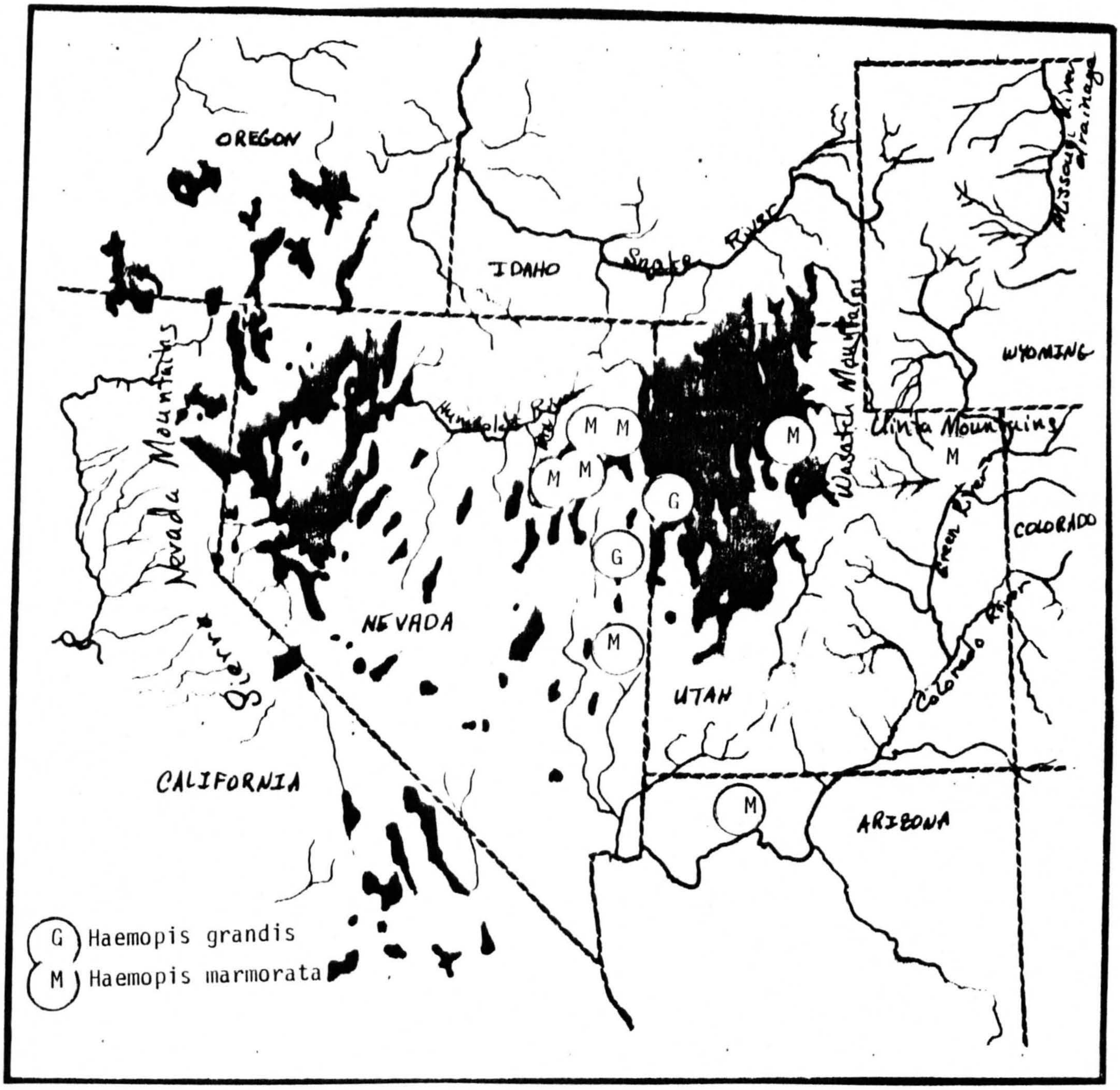


Figure 13. Distribution of Nephelopsis obscura, Erpobdella parva, and Mooreobdella microstoma (to be confirmed)

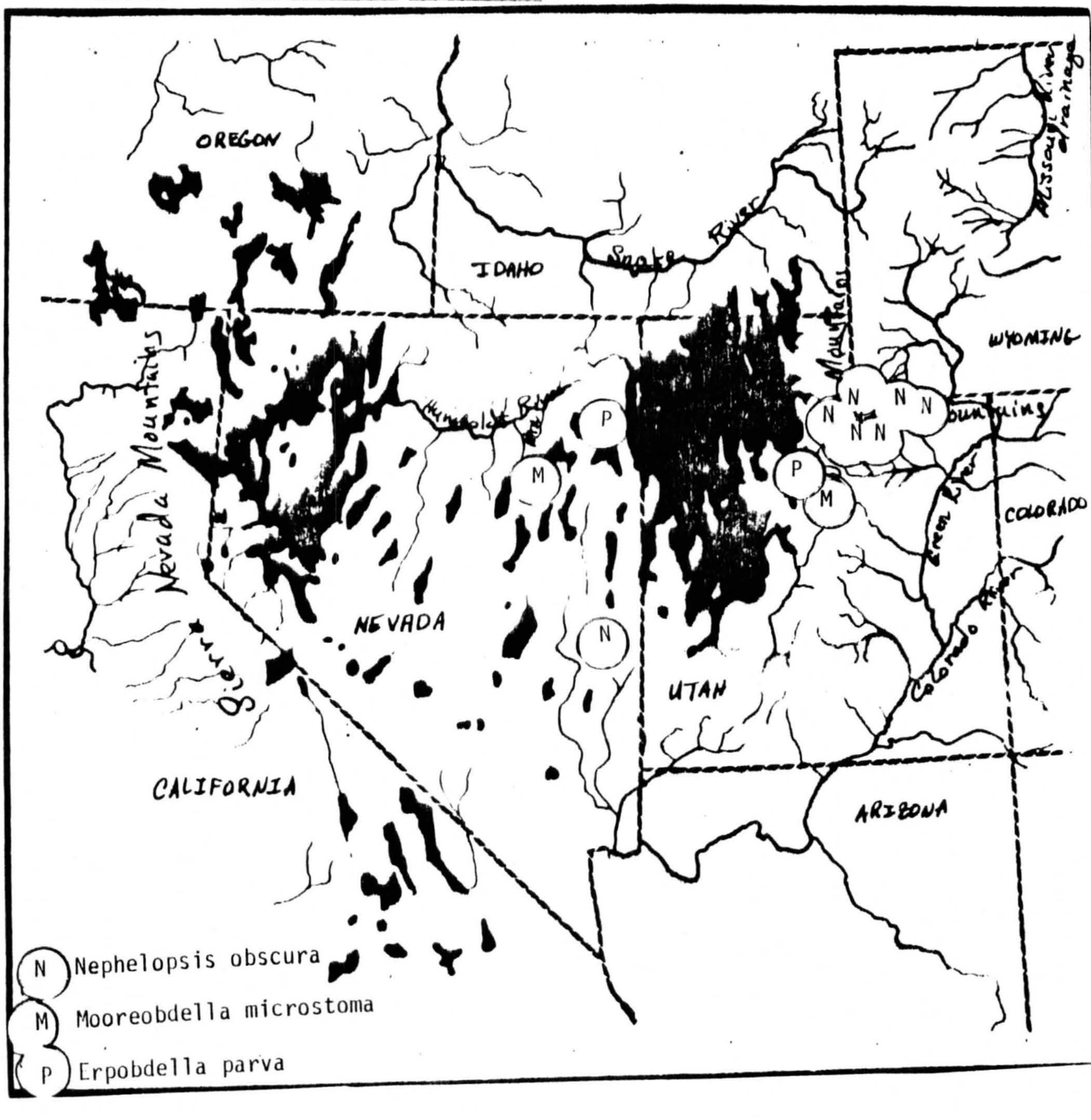


Figure 14. Map of Skull Valley, Bonneville Basin, showing the springs. The number in parenthesis is conductivity of the water. The mollusk fround in springs are listed below each spring. Squares represent townships (9.5 km). Willow Springs is the location of the area in Roscoe (1955) report. Adapted from Hood and Waddell (1968).