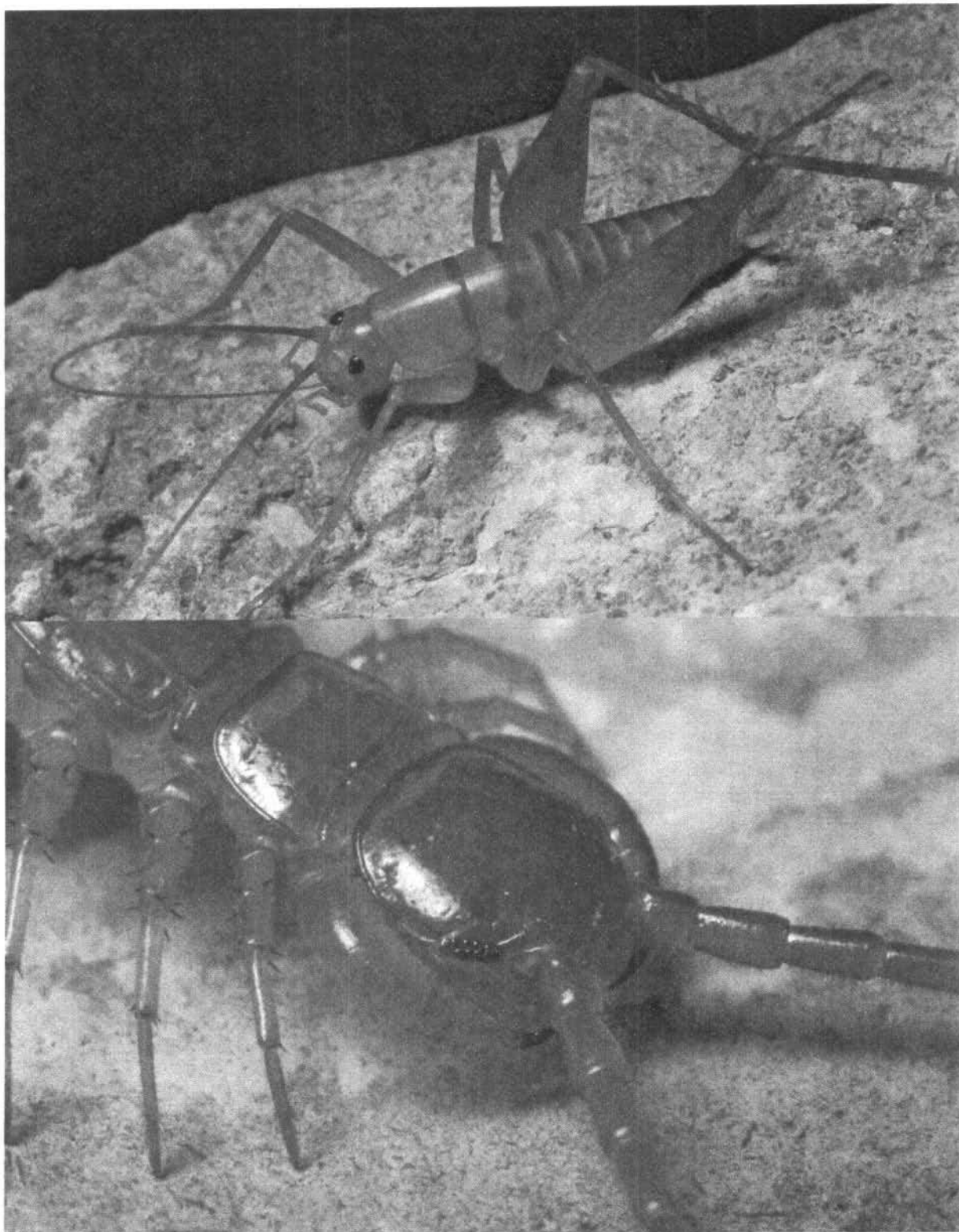




MACROINVERTEBRATES OF TIMPANOGOS CAVE,
TIMPANOGOS CAVE NATIONAL MONUMENT, UTAH
Final Report 2003

MACROINVERTEBRATES OF TIMPANOGOS CAVE, TIMPANOGOS CAVE NATIONAL MONUMENT, UTAH

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INTRODUCTION

The following final report follows the relevant headings and format of the Cooperative Agreement # CA 1248-00-009 between the National Park Service and Brigham Young University (BYU).

BACKGROUND

Parts of the Timpanogos Cave system were discovered by Europeans as early as 1887. Martin Hansen found an opening in the fall of that year which led to the grotto system now known as "Hansen's Cave". Discovery of other openings to nearby caves followed through the years (Trimble 1983). The entrance to Hansen's Cave now serves as the tour entrance to the entire developed Timpanogos Cave system. This entrance is located on the side of the mountain at 2039 msl in American Fork Canyon. A variety of invertebrates have been noted in the past and collections have been made, but no comprehensive inventory exists for these caves.

This macroinvertebrate inventory of Timpanogos Cave (known herein as TICA, Timpanogos Cave System, or "the cave") is one component of a suite of biological inventories being conducted within the Northern Colorado Plateau Network (NCPN) as part of a new national emphasis on inventory and monitoring within the National Park Service (NPS). Although most biological inventories associated with the Inventory and Monitoring Program have focused on vertebrates and vascular plants, there was an urgent need to conduct baseline inventory of macroinvertebrate taxa living in the Timpanogos Cave system. The biota of Timpanogos Cave is virtually unknown, and macroinvertebrates were believed to be a key element of the cave's fauna. Baseline data are required to assess the composition of the cave's macroinvertebrate community as well as potential impacts of cave-management activities. This survey can lead to an assessment of monitoring needs, as they relate to living organisms in the cave.

Biological inventory goals for NCPN parks are to provide: (1) complete bibliographies of studies pertinent to biological inventory of network parks; (2) detailed summaries of biological survey and natural history specimen data for the network parks; (3) species lists for each taxonomic group; (4) relative abundance estimates for selected species of concern; (5) spatially located data for species of interest or concern; (6) spatial data on sampling site locations; (7) pertinent herbarium and museum and photo voucher databases; and (8) recommendations for further inventory and long-term monitoring within the network.

Little formal, published work has been done in Utah on the invertebrates of cave systems. Packard (1877) visited Clinton's Cave on the shores of the Great Salt Lake as part of the Hayden Expedition. He recorded several species of invertebrates as occurring in this cave and discussed their relevance to discussions about "natural selection" and "survival of the fittest" which were clearly hot topics in the day. Carpenter (1968) reported

on the occurrence of six species of invertebrate animals in Logan Cave, Utah, as part of a brief progress report from a few visits to that cave. Huebner and Vinson (2004) reported on a wide assortment of aquatic animals collected from Logan Cave and nearby spring outflows in the Bear River Mountain Range of northern Utah. They found only six taxa from Logan Cave: Trombidiform mites, Collembola, Diplura, mayfly nymphs (Ephemeroptera: Ameletidae: *Ameletus* sp.), winter stonefly nymphs (Plecoptera: Capniidae), green stonefly nymphs (Plecoptera: Chloroperlidae: *Sweltsa* sp.), and blind amphipods (Crustacea: Amphipoda: *Stygobromus* hubbsi group. Peck (1981) produced the most extensive list of cave invertebrates for Utah sites. The caves he sampled from in the Uinta Mountains of northeastern Utah. We found no formally published lists of the invertebrates of Timpanogos Cave during our literature searches. Jay Swofford, of Friends of Oregon Caves, has been very helpful in providing bibliographic citations for cave faunas of North America. He provided us with an electronic copy of Roth (2001). In searching through Wolf's monumental *Animalium Cavernarum Catalogus* (1934, 1937, 1938), the only Utah caves listed are Clinton's Cave (Beim Hotel, Lake Point) and Hohle bei (Salt Lake City). Few cave faunas have been published for Utah and surrounding states but Drost & Blinn's 1997 list of the fauna of Roaring Springs Cave, Grand Canyon, Arizona is one notable exception. Unpublished reports of faunas for numerous caves exist and are scattered. Of particular note, however, are the trapping lists of Crawford (1994 and 1996) which are a useful recent compendia of work in western caves, particularly for Oregon Caves. He provided evidence of good success in traps baited with cheese, but gave no details of deployment. Another report useful as a guide for western cave invertebrates is the report of Ubick (2001). In that report he summarizes knowledge of invertebrates from Cave Gulch, California and many comments are useful in other contexts.

In brief, little macroinvertebrate faunal work has been done in Utah and the taxonomy of the cave inhabitants is very poorly known. We seek to remedy this situation for Timpanogos Cave, at least, with this report and subsequent publication.

OBJECTIVE

The overall objective of this project is to provide managers of Timpanogos Cave National Monument with a baseline inventory of macroinvertebrates found in major habitats of Timpanogos Cave.

METHODS

We used a suite of methods to inventory the macroinvertebrates of Timpanogos Cave. Specific sampling methods, locations, and timing were each approved by TICA staff following an on-site cave visit by BYU investigators (Figs. 1-4). Procedures for cave access as well as roles and responsibilities of TICA staff were agreed upon during the initial site visit by BYU investigators. Investigators from BYU were accompanied by Timpanogos Cave personnel on each visit. From the cave staff, Cami Pulham and Jason Mateljak were frequent participants as was Becky Peterson. Jon Jasper accompanied us from time to time as his schedule allowed. BYU personnel making visits to the cave included Julie Guptill, Riley Nelson, Shawn Clark, Richard Baumann, Adam Frischknecht, Andrew Olsen, and Grant Stucki.

Collection by Traps. The primary method for conducting this inventory was the collection of macroinvertebrate specimens with a variety of traps. Specimens were trapped and collected from the entrance, twilight zone, and deep cave regions. Samples were sought

from standardized unbaited traps, select baited traps, and by visual inspection (and collection) monthly from April through September 2003. These traps humanely killed the specimens for detailed viewing and identification back at the laboratory. Some of the traps collected live specimens, but a killing solution was necessary in most cases. We initially used 70% ethanol as the preservative in the traps but after one trapping session this was abandoned because cave personnel could smell it and were concerned about the impact this might have on the experience of the visiting public. The fluid medium for subsequent sessions was a concentrated salt solution. Excess fluid from the traps was disposed of outside the caves. Reasonable care was anticipated and taken to avoid overcollecting of sensitive or rare cave fauna. We anticipated, for example, that if a particular trap were to be attracting too many specimens of taxa judged by the investigator to be of concern, the trap would be modified to reduce its effectiveness. This was not necessary. The apparent trapping success was low enough that we did not put in place modifications to decrease effectiveness. Despite the continuing lack of knowledge regarding which taxa are of concern, our initial survey gave no indication that trap limitation was necessary. In brief, we believe that the number of traps we employed had no significant impact on the total population numbers of target taxa. We add, however, that our trapping protocol was not designed to particularly address this issue. We initially used a diversity of baits in small, enclosed traps. These baits included such items that have proven useful in other studies, such as overripe bananas, oatmeal, Limburger cheese, rolled newspapers, and bunches of green twigs. None of these initial baiting attempts seemed to produce more trapped individuals than simple interceptor traps, such as pitfalls. The baited traps had the pronounced disadvantage of quickly molding and ruining the few specimens they captured. So after initial trapping episodes we settled on unbaited pitfall and pan traps as our preferred passive inventorying methodology.

We used a variety of traps to accumulate specimens. During test visits we deployed pitfall traps, malaise traps, newspaper traps, funnel traps baited with banana, funnel traps baited with limburger cheese, and stick bundle traps. The most effective traps were the simple pitfall traps. The malaise trap was very effective in the areas outside the cave but not too effective in Furnace Cave where it was deployed. However, this trap did collect the only specimens of anobiid beetles collected during the survey. We suggest a modification of malaise traps for future inventories to include much smaller versions that can be hidden from the public. Although we detected no adverse reaction from the public, we were hampered slightly in the locations we could choose to deploy the traps. Smaller traps could be put in more locations and hence perhaps more efficient locations for gathering insects and other arthropods. The traps baited with cheese, bananas, newspaper and oatmeal were not as effective in trapping specimens and required more effort than we deemed useful to search for specimens in the trap. Specimens found in these traps were all found in the unbaited pitfall traps as well. This time required to separate specimens from bait was better used for opportunistic collecting. Alternatively, baits which attracted but did not cover the specimens could be deployed. We used 70% ethanol as a trapping preservative on the first trapping episode. The smell of the alcohol was judged distractive by the cave personnel and eliminated after the first visit. A salt solution was used in its place, Antifreeze was proposed but never used for this purpose. We placed a solution of approximately 2.5% salt water (100 ml NaCl in 4000 ml water) with a drop of dishwashing detergent in each pitfall trap to temporarily preserve the specimens between trap checking episodes. This was an effective preservative and avoided what we judged to be more

invasive preservatives. When the traps were changed the contents were transferred to 70% ethanol.

To be sensitive to the cave biota and park visitors, small, unobtrusive traps were placed in concealed spaces. Initial trials determined that many traps were necessary in all habitats because of low trapping success. We deployed approximately 80 plastic cup traps (of approximately 250 ml size with a mouth opening diameter of approximately 8 cm). These cups were scattered in clusters through the three main cave areas. Individual traps were numbered to allow for repeated comparisons throughout the field season. We found that there were plenty of unobtrusive, hidden locations to deploy these traps and suggest that even more be used in future sampling and monitoring efforts. Multiple traps allowed greater chance of trapping success and will allow for rough estimates of population size along the light gradient. Again, we suggest that no baited traps be used in the caves. They weren't noticeably more effective than the unbaited cups.

Our unobtrusive traps yielded no negative comments from the resource management staff of the cave. No adverse comments were communicated to us by the public or the cave staff. The success rate of capturing invertebrates in the traps was low (Table 3) when compared to similar traps used elsewhere outside the cave, but yielded a good diversity of specimens. We never caught large numbers of individuals in any particular traps but indeed invertebrates were trapped throughout the cave system. Because the traps are unobtrusive and no evidence of overtrapping of sensitive species is indicated, we suggest increasing the number of pitfall traps in Hansen Cave and Middle Cave in future surveys. All portions of the cave system, including entrance, twilight zone, and deep cave regions yielded at least some specimens.

Surveys by Visual Inspection. In addition to collection by trapping, the inventory was supplemented with opportunistic collections of specimens and visual inspection surveys. These visual searches were not time-constrained and thus not readily quantifiable but rather were used as a supplement to the trapping protocols used for quantitative and semiquantitative estimates of populations size given by traps. Visual searches were especially useful in smaller, and solid rock habitats where traps were not as relevant.

Our opportunistic collecting yielded fewer specimens than we had expected yet were probably more effective than traps on a unit effort basis. This being said, some taxa such as flies of the family Heleomyzidae and moths of the family Alucitidae were collected only using this qualitative technique. We suggest further opportunistic collecting at the entrances, in deep sections throughout the cave, and on or near formations. Such efforts should surely continue in the future.

Photographs. High-quality digital photographs using strobes for lighting were taken of the particular habitats sampled. Select specimens taken from traps were also photographed. Specimens from traps were chosen based on completeness of parts and our being able to manipulate them into positions useful for illustrating each species and key characteristics. Photographs of living specimens were taken of as many specimens as were available during on-site visits. We have assembled a nice assortment of photographs that accompany this report and will be of value in future scientific studies in the cave. Additionally these photographs can be effectively used in future publications interpreting the cave for visitors. We anticipated that some taxa would probably not be photographed alive because they will have been seen only as dead specimens in traps. This was indeed the case in two instances: a beautiful large daddy long leg arachnid (Opilionida) was seen

alive only once and attempts at photography were unsuccessful. It disappeared into a crack near the Middle Cave door before it could be photographed or caught. We did, however, collect significant chelicerate parts of this species elsewhere in the cave and a young individual was taken in a pitfall trap. The second instance was that of the mycetophilid fly *Boletina* sp., which is almost certainly a new species! This fly was a dominant in traps in both adult and larval forms, yet we were not able to collect living specimens. We plan to visit the cave again in 2004 to capture live specimens of these two species.

Several species from the cave were photographed in their habitat throughout sections of the cave system during the opportunistic collecting. This yielded excellent photographs of species in the field. We supplemented these *in situ* photographs with photomicroscopic images of preserved specimens in the laboratory.

Raw data have been archived in the researchers' individual files and literature collections. These data are available to the general scientific community on personal request.

Julie Guptill, Allison Bingham, and Scott Rynearson have entered the collecting information into a database designed by and with the cooperation of Margaret Beers of the National Park Service. The database contains records of numbered traps at all the locations within the Timpanogos Cave systems. Information about these locations and its type of habitat are described. Specimens found in the traps or by opportunistic collecting have been counted and identified to the lowest taxonomic level possible. Identifications to levels beyond our particular taxonomic expertise have been sent to the appropriate experts in the United States and Canada. We await the return of these specimens, which have been appropriately labeled and cross-referenced to allow quick incorporation into the main database. Photo voucher labels have been associated with all specimens of which photographs have been taken. All specimens are stored in 70% ethanol, with the exception of a single staphylinid beetle (*Phlaeapterus cavicollis* Fauvel) that was dried and pointed for close examination and identification.

Habitat and guild classification

Barr (1963) provided a classification of cavernicoles and their habitats. We use Ubick's (2001) summary of this system. This classification is a continuum between organisms that are cave obligates to those that are surface creatures accidentally trapped in the caves. Because knowledge of the life histories of most invertebrates are unknown, using these categories is somewhat arbitrary. We have usually used more common terms for these categories in this report, but they are useful in communications with cave specialists and are thus listed below.

Troglobite, an obligate cave dweller. Troglobites show much anatomical modification for life underground. The most common manifestations are loss of pigment, extremely long appendages, loss of extreme body sculpture, and loss of vision.

Phreatobite, obligate cavernicoles inhabiting underground water sources.

Troglophile, a facultative cave dweller. These organisms can complete their life cycles in caves, but often can do so in surface habitats as well. In some cases they may show some of the anatomical expressions of troglobites, but usually to a lesser degree.

Trogloxene, a cave visitor or that is unable to complete its life cycle in the cave. They show no modification for cave life.

Epigaeal, a surface dweller. These are organisms from the upper world accidentally trapped below ground.

TIMING OF SURVEYS AND FIELD SCHEDULE

Timing of surveys:

On any particular visit our searches generally began mid-morning. We made conscientious efforts to avoid unnecessary disruption of visitor activities. Personal surveys of the cave were confined from about 9:30 am to 3:30 pm. We noted no adverse reactions from the public during our surveys. On the contrary, the public was often interested in the survey. We were asked questions regarding the natural history of the invertebrates we were collecting at the invitation of interpretive cave staff members.

Field schedule:

The cave was visited at least monthly from April to September. A typical initial visit included placing traps then searching for individual specimens in likely habitats. Photographs of live specimens were taken at this time. A follow-up visit would include emptying specimens from the traps and preserving them for transport back to the laboratory. The bulk of the time in this project was spent curating and identifying specimens back in the laboratory. This was reflected in the personnel budget. Additional time was required to prepare shipments to send to taxonomic experts. We originally planned that investigators would return for an initial follow-up visit after leaving the traps open for two days. Our concern was that too many specimens might accumulate in the traps if a longer interval was chosen. This was not the case (Table 1). The traps were left open and accumulating specimens for longer periods of time, usually about a week but often for longer. Members of the cave's resource management team were very helpful in monitoring and emptying the traps. This provided for xxx duplicated collections during the six-month interval.

We made double the number of visits to the cave that was initially proposed in the contract and will continue with visits in 2004. A summary of collecting efforts and the taxa encountered is given in Table 2. Personnel from BYU were changing traps and searching opportunistically (qualitatively) for cave fauna on each of those dates.

We visited locations throughout the Timpanogos Cave System (Fig. 1) that in general consists of Hansen, Middle, and Timpanogos Caves (Figs. 2-4). These localities are summarized in Table 3. An effective trapping interval (based on good preservation of the specimens trapped) of one week was determined. Future trapping protocols can make use of this interval. The phenology of individual taxa is given in Table 2. The most effective trapping interval was judged, from the biological sampling point of view, to be between one and two weeks. This allowed enough time for a notable number of specimens to be collected in the traps. At an extended interval specimens do not preserve as well, although we noticed no extreme decomposition in salt solution traps left for more than three weeks. They do, however, become more fragile, making removal from the traps much more difficult and the quality of specimens lessens. We never judged our trapping to be eliminating too many invertebrates from the cave. We judged that our trapping was not

so biologically intrusive to be harming the populations in the cave. We would hope to continue with more trapping during the 2004 field season.

DOCUMENTATION AND DATA MANAGEMENT

Acquisition and management of inventory data, voucher specimens, and photographs was an extremely important part of this project. We present this information in an attached database file compatible with Microsoft Access. We summarize other information in tables and figures in this report.

Inventory Data.

Prior to the initiation of fieldwork, BYU investigators, particularly Riley Nelson and Julie Guptill worked together with the NCPN Data Manager, Margaret Beers, to identify and coordinate BYU and NCPN data management needs associated with this project. The database tools designed by Margaret Beers and implemented by Julie Guptill were effective and were regularly modified, as more exacting needs for the data were determined. The summary database associated with this report is named: timp cave invert 2003.mdb

Specimens. Voucher specimens are an important means of documenting species presence in parks. All specimens will be managed and curated following NPS servicewide protocols, and the disposition and cataloging of all specimens (including those deposited in collections of the M.L. Bean Life Science Museum at BYU and those distributed to cooperating taxonomic authorities) were coordinated with the NPS collections curator at Timpanogos Cave National Monument, Cami Pulham. Specimens collected as part of this project will be affixed with National Park Service issue specimen tags containing information on species, collector, date of collection, collection site and NPS record number. Specimen data as required in electronic format per product specifications section found later in this document have been attached as computer file: timp cave invert 2003.mdb.

Specimen curation and identification progressed more slowly than anticipated. Some specimens sent out for identifications have not as yet returned from scattered taxonomic authorities. As these detailed specific identifications return from these cooperators, information will be updated in the electronic database (timp cave invert 2003.x.mdb) and forwarded to Cami Pulham and Margaret Beers for use by managers and administrators. We summarize the rank abundance plot of all taxa in Fig. 5.

Specimens were collected through the field season, but showed a bimodal distribution in early and late summer (Fig. 6). This indicates that trapping and monitoring should be continuous in the future because the animals are appearing and populations peaking at different times throughout the field season.

Additional support for a monitoring program which includes trapping throughout the season is given in Fig. 7. This species-effort analysis does not seem to be reaching an asymptote, indicating that additional species are encountered right up to the end of our trapping efforts. Several plateaus are reached, for example at 20, 250, 325, and 425 traps, but the good fit (R^2 of the power curve equals 0.9148) points towards additional species being encountered had trapping continued. Future trapping should continue into the late fall (and perhaps into winter) to see if the cold of winter flattens the species encounter curve. Note, however, that the plateau seen on this curve can consist of very large numbers of traps with no newly observed encountered. For example near the 200 trap

effort level a run of over 100 traps without newly observed species occurred. Had we assumed (as might have been reasonable) that this was a real plateau indicating all species in the cave had been encountered, about half of the species diversity of the cave would have been unsampled! A conclusion from this analysis is that a large number of traps is necessary in an appropriate monitoring program for Timpanogos Cave, even if species richness is the only desirable attribute for which one is managing the biota.

Hansen Cave was by far the most productive in number of taxa encountered and number of specimens obtained (Table 4). The taxa encountered in each of the caves is given in Table 5. Hansen Cave produced the richest assemblages of species in the system, yet each of the other caves added unique species to the faunal list.

The complete list of taxa collected by both the quantitative pitfall trapping and the qualitative visual inspection protocols is given in Table 6. We also make an hypothesis for each of the taxa as to whether it is an obligate or facultative cave dweller (troglobite or troglophile). The number of specimens of each of the taxa gives a rough measure of relative abundance in the system. No attempt was made at estimating the biomass of each constituent taxon.

TAXONOMIC TREATMENTS

Arthropods dominate, by far, the invertebrate fauna of the Timpanogos Cave system. Of the 31 species encountered in the caves, only one (segmented worms, Annelida) was not an Arthropod. This agrees with the preponderance of species of Arthropods in terrestrial systems world-wide (Wilson 1999) and in caves in particular (alluded to in Roth 2001). In this section we will summarize the taxonomic status and biological information for each of the taxa encountered in the Timpanogos Cave system.

Phylum Annelida

Annelids, segmented worms, are coelomate animals with their body divided along their length into a series of ring-like segments. They consist of over 17,000 species world-wide, most of which are Polychaeta and live in marine ecosystems. Oligochaeta includes the familiar earthworms and many species in freshwater (Brusca & Brusca 1990). A few oligochaetes were collected in and around traps in the cave. They were highly pigmented earthworms which at least superficially resembled those outside the cave. They are most probably in the family Lumbricidae but exact determination awaits higher taxonomic authority.

Phylum Arthropoda

This is by far the largest group of organisms on earth, whether measured by number of described species (over 1 million) or biomass. In terrestrial ecosystems they are particularly species rich and abundant. They are recognized by having an exoskeleton composed of chitin (a polysaccharide polymer of sugar subunits) which allows for the uniquely articulated joints from which they derive their phylum name. Arthropods include many groups including four which are familiar to most people: Insecta or Hexapoda (insects), Chelicerata (Arachnida: spiders, mites, and relatives) Myriapoda (millipedes and centipedes), and Crustaceans (isopods, amphipods, shrimp, crayfish, and crabs) so apparent in most any ecosystem on earth. Caves are well-known to harbor rich arthropod faunas, many species of which are highly modified to live only in cavernicolous situations. They are the dominant animals living in the Timpanogos Cave system. We encountered 30 species of arthropods during our survey. For convenience in the discussion which follows

we will refer to these four groups as "Classes", although the taxonomic hierarchy for these groups is much more complicated than this and the "true" acceptable classification is debated heavily among scientists specializing in phylogenetic systematics. Each of the four groups is probably paraphyletic, an undesirable taxonomic system in which some but not all of the species included in the group are descendants of a common ancestor. The Myriapods and Crustaceans are the most clearly paraphyletic but these names are a useful shorthand until details of this problem are worked out in an overarching phylogeny which is broadly accepted by biologists (Wheeler et al. 2002; Nelson 2002).

Of the four major groups listed above we encountered three. Crustaceans were surprisingly absent from our traps and searches. Isopods and amphipods are common in wet caves elsewhere with substantial running water. Amphipods (undescribed *Stygobromus* spp.) have been reported in Utah caves (Peck 1981; Huebner & Vinson 2004) and groundwater spring outfalls (an indication of caves). Timpanogos Cave lacks this specific habitat, but a careful survey of springs in the area may very well produce specimens in the future. The common ground dwelling isopods known as pill bugs, potato bugs, and roly polys were not collected in the cave, although they are numerous in trap samples elsewhere in American Fork Canyon.

Class Myriapoda. Both Chilopoda (centipedes) and Diplopoda (millipedes) were collected in the cave. Centipedes are predatory arthropods with many segmented bodies, most segments of which bear one pair of running legs. In addition they have an enlarged pair of anterior legs immediately posterior to the head which are modified for injecting venom in their prey (and perceived predators!). Centipedes are quite common in the cave in what appears to be a single reddish brown species reaching up to 3 cm in length. These specimens were sent to the North American authority on the group, Dr. Rowland Shelley, of the North Carolina Museum of Natural Sciences in Raleigh, North Carolina. He identified them as belonging to the Order Lithobiomorpha, but could not identify them to species. He replied that the taxonomic state of this group is in chaos, with many described and probably many undescribed species awaiting description, but no experts for the Lithobiomorpha have emerged willing to revise this difficult, yet common and interesting group. The species in the cave at least superficially resembles common centipedes seen elsewhere, but clearly more taxonomic work is necessary in the future. Millipedes were encountered in traps and during hand collecting. We tentatively have identified some of them as the Order Chordeumida. Others, based on fragments were clearly not Chordeumida, but anatomical parts necessary for ordinal classification were lacking.

Class Chelicerata. This class contains the familiar Arachnida in as diverse body forms as spiders, mites, scorpions, and harvestmen. The less familiar chelicerates include the marine horseshoe crabs and the extinct sea scorpions, which, of course, are not present in the cave. The arachnids are generally separated from the somewhat similar insects by having more legs (typically eight in arachnids) and fewer major body segments (two, the cephalothorax and abdomen in arachnids). They can be reliably separated from the other three classes with which we are dealing in that they lack antennae. At least six species have been collected during our visits to Timpanogos Cave: one unidentified mite (Order Acari); one unidentified pseudoscorpion; three spiders (Order Araneae); and one harvestman (Order Opilionida, or alternatively Phalangida, also known as daddy long-legs). We used the keys in Kaston (1953) and Roth (1985) for spider identifications. With a quick search of name usage on a variety of websites there seems to be a great deal of synonymous names used. As part of future studies these specimens need to be viewed by an expert taxonomist of Araneae.

Two of the spider species we found are in the cobweb spider family, so named for their irregularly and perhaps diagnostically disorganized webs, the family Theridiidae. This family also includes the infamous and venomous to humans black widow spider. No black widows were encountered in the cave, but may very well inhabit crevices near the openings. The bite of the cobweb spiders we encountered, *Ctenium* sp. and *Lithyphantes* sp. (some species are actually known as *Steatoda*) are not known to be dangerous for humans. Theridiids are common in the cave and seem to be more common the closer you get to entrances. We suspect that several other theridiids will be found in the cave. The strikingly more apparent and robust Amaurobiidae, the hackledmesh weavers are found near entrances in the cave. Large specimens of *Callobius nevadensis* (Simon) are readily recognizable by their reddish brown cephalothorax and legs with a grayish abdomen. In smaller specimens, probably immatures, the legs and cephalothorax are more yellow.

The pseudoscorpion we collected in the cave has elongate appendages, so is probably a cave-adapted form (troglobite). We caught only a single individual despite all our searching and trapping efforts.

The most exciting arachnid in Timpanogos Cave, from our biodiversity point of view, is an elusive harvestman (Opilionida). On our first visit to the cave on 20 May 2004, Riley Nelson found the chelicerae and front part of the dead body of a specimen perched on a small stalagmite in the Big Room of Middle Cave. The mouthparts were astounding for their length, compared to most other chelicerates, formed as pincers on the end of a rather long leg homologue. Few groups of Arthropods have chelate (pincer-like) mouthparts, so by the process of elimination we determined it to be an opilionid. We sent photographs of this specimen to a world authority on harvestmen, Darrell Ubick of the California Academy of Sciences in San Francisco, California. He quickly confirmed our determination and suggested that it might be the genus *Taracus*. Comparing the salient features of the specimen in the key of Roewer (1914) support this identification, but we would need a more complete specimen for identification (Levi & Levi 1968). On each subsequent visit we searched for these harvestmen to no avail until our last visit of the season. We did collect one immature specimen in a pitfall trap. On 2 October 2003 several of us saw a large harvestman near the door into Middle Cave. While preparing to photograph it, we were disappointed as we watched it walk into an undetected crack. At that time Cami Pulham said she had seen these regularly in the past at a variety of locations in the cave. Our hope for 2004 is that we can find whole, adult specimens of this interesting, but as yet unidentified species. Two important references for identifying Opilionida from caves are Roewer 1914 and 1923.

Class Insecta. Insects are readily identifiable as adults by having three pairs of legs and the body divided into three major sections: head, thorax, and abdomen. We follow the ordinal classification of Nelson (2002) in this report, which is conservative in recognizing the Orders in the paraphyletic "Apterygota" as insects rather than part of Hexapoda. We collected representatives of six orders of insects in Timpanogos Cave: Collembola, Orthoptera, Coleoptera, Diptera, Lepidoptera, and Hymenoptera. Diptera were by far the most species rich group, with nine species caught in the cave. They also contributed the largest number of specimens (Fig. 5). Orthoptera, the putative single species of *Ceuthophilus*, however, probably contributed more total biomass.

Order Collembola. The springtails are a significant part of the fauna of Timpanogos Cave. Four families of these diminutive insects, usually less than 2 mm in length, can be found in the cave. Two families, the Isotomidae and Tomoceridae were collected throughout the trapping season (Table 1) while Hypogastruridae and Entomobryidae

became more prevalent at the season's end. The genus *Tomocerus* is notable in being large for the order (up to 5 mm) and a common component of cave faunas around the world, with considerable discussion on how many species are in the genus, including a number of highly endemic forms. *Tomocerus plumbea* (Linnaeus) variety *alba* was recorded in the first published cave fauna of Utah (Packard 1877). Since that time numerous species have been described in the genus (including Folsom 1913, discussing taxonomic problems that had already arisen at the turn of the 20th Century. . .) so identification to the species level was not attempted. Because *Tomocerus* spp. appear on lists of species of conservation concern elsewhere (Lewis et al. 2003), a detailed attempt at identification of this springtail should be made and an assessment of its distribution made.

Order Coleoptera. Beetles are the most species rich group of animals on earth with over 350,000 described species worldwide (Hallan 2004). Many species of beetles, perhaps most, have not been described. But the diversity of beetles in Timpanogos Cave is not particularly great. We found five species in the cave in four different families (Table 1). None of them seem to be cave specialists (troglobites), although the Anobiidae were found associated with a packrat (*Neotoma* sp.) midden and *Catops* sp. (and other members of the family Leiodidae) have been found in various caves elsewhere (Peck 1973, 1978, 1982). One staphylinid beetle collected deep in the cave and was identified to the species level, *Phlaeopterus cavicollis* (Fauvel), is not thought to be a cave specialist (Thayer, Margaret, pers. communication). The other staphylinid species await attention from a specialist.

Order Diptera. Flies, especially small, dainty ones, are the most commonly collected invertebrates in the cave. They are also the richest in number of species. The culicid, a mosquito of the genus *Culiseta* is a common fly outside the cave and probably only incidentally found in the cave.

The three genera of Heleomyzidae, which resemble dusky, yellowish house flies, were hand collected near the cave openings. All three genera (*Aecothea*, *Amoebalaria*, and *Eccoptomera*) have been reported as living in mammal burrows (Gill & Peterson 1987), with the larvae probably feeding on dung (Ferrar 1987). A careful search in the pack rat middens in the cave may turn up the larvae of these interesting flies. The genus *Suillia* is commonly collected elsewhere in the canyon and on a separate note, some Europeans follow these flies to discover where truffles, a fungal delicacy can be found (Janvier 1963)

Two species of fungus gnats were caught in the cave. One species of the large and delicate fungus gnat (Mycetophilidae: *Boletina* sp.) is common in the cave. It is breeding deep in the cave as we found several specimens of larvae there on separate occasions. This genus consists of at least 36 species in North America with many others undescribed (Richard Vockeroth, pers. communication). We have collected specimens of the genus elsewhere on the Wasatch Front which are much smaller and darker than the beautiful specimens found in the cave. It is quite reasonable to assume that this is an undescribed species limited to the cave, as it has longer appendages than most members of the genus. We currently have specimens in the hands of Dr. Vockeroth, the world-reknowned taxonomic expert for these flies and await his specific determination. Most members of the family feed on fungus as immatures with some adults visiting flowers. *Boletina* differs in having some species recorded as feeding on Hepaticae (Plantae: Bryophyta: liverworts). At least some species are predatory on smaller arthropods (Vockeroth 1981). A number of species in the family seem to be limited to caves, the most spectacular of which (*Arachnocampa luminosa* (Skuse), among others) have light producing organs, seemingly

to attract prey to their sticky webs they suspend from grotto ceilings in New Zealand and Australia (Broadley & Stringer 2001). These caves, incidentally, attract many tourists to view the spectacle. We encourage further research into the biology of this species to determine its biology and whether or not it is limited only to the Timpanogos Cave system.

A second species, *Cordyla* sp. was also collected several times in the cave. It is lighter than specimens in this genus that we collect elsewhere in Utah. This small genus is in need of revision and the material from the cave will be incorporated into a project on the genus which we are initiating. Specimens of this genus were also collected in the malaise trap outside the Timpanogos Cave entrance, which indicates that they may not be obligate cave dwellers. They were collected with a wide variety of other mycetophilids, none of the others of which were collected in the caves. No *Boletina* were collected in the malaise trap.

Mycetophilids are the second most abundant organism we collected during this survey, outnumbered by the Sciaridae (Fig. 5).

The most abundant taxon caught in the cave was the family Sciaridae. A single genus of the dark fungus gnat family was collected in the cave. *Corynoptera* sp. is part of a genus with only six species described from North America (Steffan 1981). Members of the genus were last revised by Petzey (1918), as part of *Neosciara*. The specimens at hand key to *lobosa* Petzey, but not cleanly. This species is known from the type locality in British Columbia, Canada. We have labeled the specimens as "near" *lobosa*. It is quite reasonable to assume that this is an undescribed species because little work has been done with this family in this part of the world. There are currently no active North American workers specializing in this family, and only two elsewhere (Europe). We will probably use this opportunity to summarize information on this species and perhaps describe it after looking at the type specimens of other related species in the genus. This species definitely requires taxonomic attention because its status as a species of potentially limited range and thus conservation concern needs exploration. This species is abundant in the cave, the most commonly encountered arthropod during this survey. Of particular interest is a specimen, probably of this species, imbedded in a flow curtain formation in a passageway in Middle Cave. The malaise trap outside the entrance to Timpanogos Cave caught many representatives of several genera of this family, but none in the genus *Corynoptera*.

Several female specimens of small dung flies, family Sphaeroceridae, were collected in the cave. Males are necessary for generic identification and will be particularly sought in the future. As their name implies they are attracted to and feed on dung (as well as a wide variety of other decaying organic matter). A diversity of species in the family occur outside the cave, often in abundance, but none were collected in the exterior malaise traps near the cave.

Winter crane flies, the family Trichoceridae, are common inhabitants of caverns, mine shafts, cellars, hollow trees, and similar darkened places (Alexander 1981). We collected several specimens of the genus *Trichocera* in our traps and by hand. They also occur rather commonly in shady areas outside the cave, including during the coldest months of winter.

Order Lepidoptera. Moths and butterflies are in the top four most species rich orders of described insects on earth, yet we encountered few in the cave. The six-plume moth (Alucitidae: *Alucita hexadactyla* Linnaeus) was abundant in the cave just inside the Hansen Cave entrance. This attractive species was most likely introduced from Europe and is readily collected outside the cave. It feeds, as caterpillars, on honeysuckles, *Lonicera* spp., and probably on a variety of green plants (Covell 1984), and thus is not an

obligate cave dweller. Remains of a second, unidentifiable species, were also collected in the cave.

Order Hymenoptera. Bees, wasps, and ants form a substantial part of the biodiversity of the plant, but only a single specimen of Ichneumonidae was collected during this survey. It was collected in Lunch Bench Cave and is probably not a cave obligate.

Photographs.

Photographic documentation has been an important component of this project. High-quality digital photographs of sampled habitats, selected specimens (including significant finds), and field crews conducting inventory work were required and have been labeled according to specifications provided below in the products section.

We have produced excellent digital photographs of the invertebrates and habitats in the cave. We have documented many of the participants in this survey. All photographs have been properly associated with locality information and updated with taxonomic specificity when determinations made by taxonomic experts have arrived. File information is attached as electronic captions with each of the photographs. These captions can be accessed using the File> File Information path in Adobe Photoshop CS®, similar access can be made in a wide variety of graphics programs. The individual photographs are included on an accompanying compact disk (CD) as JPEG (Joint Pictures Expert Group) files manipulated in Adobe Photoshop CS® and which can be accessed by a wide variety of graphics programs on multiple computer platforms and operating systems. We have also included on the CD a somewhat informal Microsoft PowerPoint® presentation given at the meetings of the Utah Chapter of the Wildlife Society in February 2004 using the file name: *Timp Cave Wildlife Soc show.ppt*.

Data Management and Reports. An appropriate proportion (approx. 10-15 %) of the total funding for this project has been set aside for data management, analysis and report preparation. The NCPN data manager, Margaret Beers, worked together with BYU investigators to ensure that all NCPN and investigator specific data management needs were identified and coordinated. Thomas O' Dell, as Inventory & Monitoring Coordinator for the National Park Service - Northern Colorado Plateau Network, was effective as liaison to effect delivery of contracted reports. The efforts of these two persons were greatly appreciated.

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Table 1. Effectiveness of pitfall traps in the Timpanogos Cave system, 2003.

Pitfall Trap Effectiveness	
Number of pitfall traps	91
Number of specimens trapped	207
Duration of trapping (days)	135
Average number of specimens per trap per day	0.017

Table 2. Seasonal occurrence of macroinvertebrates in caves of the Timpanogos Cave system, Utah, 2003. In order to determine which taxa were collected during which weeks, several rules were followed. Due to access and logistic constraints, trapped specimens were harvested at different intervals including weekly, bi-weekly, and tri-weekly in some cases. The exact day that the specimen entered a trap is unknown. Thus the best phenological precision available is the interval between trap start dates and trap harvesting dates. Blackened boxes indicate intervals in which a specific taxon was collected from any trap, vertical line patterns indicate hand-collected specimens, checkered patterns indicate the taxon was both trapped and hand-collected.

						May		June				July				August				September					
Phylum	Class	Order	Family	Genus	Species	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24	31	7	14	21	28
1	Annelida	Oligochaeta	Lumbricidae																						
2	Arthropoda	Myriapoda	Diplopoda: Choreauidae																						
3	Arthropoda	Myriapoda	Chilopoda: Lithobiomorpha																						
4	Arthropoda	Chelicerata	Pseudoscorpiones																						
5	Arthropoda	Chelicerata	Acari																						
6	Arthropoda	Chelicerata	Araneae	Amaurobiidae	Callobius nevadensis																				
7	Arthropoda	Chelicerata	Araneae	Theridiidae	Ctenium?																				
8	Arthropoda	Chelicerata	Araneae	Theridiidae	Lithyphantes																				
9	Arthropoda	Chelicerata	Opilionida																						
10	Arthropoda	Insecta	Collembola	Entomobryidae																					
11	Arthropoda	Insecta	Collembola	Hypogastruridae																					
12	Arthropoda	Insecta	Collembola	Isotomidae																					
13	Arthropoda	Insecta	Collembola	Tomoceridae	Tomocerus																				
14	Arthropoda	Insecta	Orthoptera	Rhaphidophoridae	Ceuthophilus																				
15	Arthropoda	Insecta	Coleoptera	Anobiidae																					
16	Arthropoda	Insecta	Coleoptera	Carabidae																					
17	Arthropoda	Insecta	Coleoptera	Staphylinidae	Phlaeopterus cavicollis																				
18	Arthropoda	Insecta	Coleoptera	Staphylinidae	Genus 1, black																				
19	Arthropoda	Insecta	Coleoptera	Staphylinidae	Genus 2, brown																				
20	Arthropoda	Insecta	Coleoptera	Leiodidae	Catops																				
21	Arthropoda	Insecta	Diptera	Culicidae	Culiseta																				
22	Arthropoda	Insecta	Diptera	Heleomyzidae	Aecothea																				
23	Arthropoda	Insecta	Diptera	Heleomyzidae	Amoebalaria																				
24	Arthropoda	Insecta	Diptera	Heleomyzidae	Eccoptomera																				
25	Arthropoda	Insecta	Diptera	Mycetophilidae	Boletina																				
26	Arthropoda	Insecta	Diptera	Mycetophilidae	Cordyla																				
27	Arthropoda	Insecta	Diptera	Sciaridae	Corynoptera																				
28	Arthropoda	Insecta	Diptera	Sphaeroceridae	Genus 1																				
29	Arthropoda	Insecta	Diptera	Trichoceridae	Trichocera																				
30	Arthropoda	Insecta	Lepidoptera	Alucitidae	Alucita hexadactyla																				
31	Arthropoda	Insecta	Lepidoptera	Family 1	Genus 1																				

Table 3. Summary of locations in the Timpanogos Cave system visited by members of the macroinvertebrate sampling team and major collecting activity at those sites.

Locations Visited	Trap Numbers	Trap Cluster	Additional Activity
Lunch Bench Cave		A	Qualitative
Root Cave		B	Qualitative
Hansen Cave Furnace Room		C	Malaise Trap
Hansen Cave Catwalk Room	13-16	D	Qualitative
Hansen Cave 7up Rock	1-3	E	Qualitative
Hansen Cave Calcite Graveyard	4-9	F	Qualitative
Hansen Cave Pack Rat Nest	10-12	G	Qualitative
Hansen Tank Room Lookout	34, 36, 37	H	Qualitative
Hansen Tank Room Boulder	32, 33, 35	I	Qualitative
Hansen Cave Gully Descent with Rope	38-39	J	Qualitative
Hansen Lake Organ	40-41	K	Qualitative
Hansen Lake	42-44	L	Qualitative
Middle Cave Pump Room	17-22	M	Qualitative
Ladder Ledge over Big Room	23-26	N	Qualitative
Big Room Electrical Box	27-31	O	Qualitative
Cavern of Sleep	45-47	P	Qualitative
Lower Passage Trail	48-67	Q	Qualitative
Dinosaur Head	68-70	R	Qualitative
Fault	71-72	S	Qualitative
13 Stitch	73	T	Qualitative
St Bernard Bridge	74-76	U	Qualitative
Red Dirt Crawls	77-80	V	Qualitative
Timpanogos Soda Pop Pit	81-84	W	Qualitative
Timpanogos Cave Entrance		X	Qualitative
Timpanogos Cave Entrance/Exit		Y	Malaise Trap

Table 4. Number of individuals and richness of invertebrates collected in pitfall traps in clusters in each of the major caves of the Timpanogos Cave system, 2003.

Cave with trap cluster	Cluster Location	Trap Cluster letter	Number of Taxa Collected	Number of specimens
Hansen Cave	Catwalk Room	D	14	102
Hansen Cave	Seven Up Rock	E	4	17
Hansen Cave	Calcite Graveyard	F	2	2
Hansen Cave	Pack Rat Nest	G	3	10
Hansen Cave	Tank Room Lookout	H	2	9
Hansen Cave	Tank Room Boulder	I	2	3
Hansen Cave	Gully descent with rope	J	2	2
Hansen Cave	Lake organ	K	0	0
Hansen Cave	Lake	L	1	1
Middle Cave	Pump Room	M	1	2
Middle Cave	Ladder ledge over Big Room	N	3	7
Middle Cave	Electrical Box	O	4	5
Timpanogos Cave	Cavern of Sleep	P	1	1
Timpanogos Cave	Lower Passage Trail	Q	2	11
Timpanogos Cave	Dinosaur Head	R	0	0
Timpanogos Cave	Fault	S	0	0
Timpanogos Cave	13 Stitch	T	1	1
Timpanogos Cave	Saint Bernard Bridge	U	0	0
Timpanogos Cave	Red Dirt Crawls	V	4	1
Timpanogos Cave	Soda Pop Pit	W	4	20
				194

Grand total of taxa for these three caves: 29

Table 6. Classification of all taxa encountered in the Timpanogos Cave system, Utah, 2003.

	Phylum	Class	Order	Family	Genus	Species	Number of individuals	Habitat Guild
1	Annelida	Oligochaeta		Lumbricidae			6	facultative
2	Arthropoda	Myriapoda	Diplopoda: Choreumida				3	facultative
3	Arthropoda	Myriapoda	Diplopoda: Order #2				2	facultative
4	Arthropoda	Myriapoda	Chilopoda: Lithobiomorpha				4	facultative
5	Arthropoda	Chelicerata	Pseudoscorpiones				1	obligate
6	Arthropoda	Chelicerata	Acari				2	unknown
7	Arthropoda	Chelicerata	Araneae	Amaurobiidae	<i>Callobius</i>	<i>nevadensis</i>	5	facultative
8	Arthropoda	Chelicerata	Araneae	Theridiidae	<i>Robertus</i>		6	facultative
9	Arthropoda	Chelicerata	Araneae	Theridiidae	<i>Lithyphantes</i>		1	facultative
10	Arthropoda	Chelicerata	Opiliona				1	obligate
11	Arthropoda	Insecta	Collembola	Entomobryidae			36	unknown
12	Arthropoda	Insecta	Collembola	Hypogastruridae			5	unknown
13	Arthropoda	Insecta	Collembola	Isotomidae			21	unknown
14	Arthropoda	Insecta	Collembola	Tomoceridae	<i>Tomocerus</i>		42	obligate
15	Arthropoda	Insecta	Orthoptera	Rhaphidophoridae	<i>Ceuthophilus</i>		35	obligate
16	Arthropoda	Insecta	Coleoptera	Anobiidae	<i>Ptinus</i>		7	facultative
17	Arthropoda	Insecta	Coleoptera	Carabidae			1	facultative
18	Arthropoda	Insecta	Coleoptera	Staphylinidae	<i>Phlaeopterus</i>	<i>cavicolis</i>	1	facultative
19	Arthropoda	Insecta	Coleoptera	Staphylinidae	Genus 1, black		3	facultative
20	Arthropoda	Insecta	Coleoptera	Staphylinidae	Genus 2, brown		1	facultative
21	Arthropoda	Insecta	Coleoptera	Leiodidae	<i>Catops</i>		1	unknown
22	Arthropoda	Insecta	Diptera	Culicidae	<i>Culiseta</i>		2	facultative
23	Arthropoda	Insecta	Diptera	Heleomyzidae	<i>Aecothea</i>		6	facultative
24	Arthropoda	Insecta	Diptera	Heleomyzidae	<i>Amoebalaria</i>		1	facultative
25	Arthropoda	Insecta	Diptera	Heleomyzidae	<i>Eccoptomera</i>		1	facultative
26	Arthropoda	Insecta	Diptera	Mycetophilidae	<i>Boletina</i>		61	obligate
27	Arthropoda	Insecta	Diptera	Mycetophilidae	<i>Cordyla</i>		4	facultative
28	Arthropoda	Insecta	Diptera	Sciaridae	<i>Corynoptera</i>		89	obligate
29	Arthropoda	Insecta	Diptera	Sphaeroceridae	Genus 1		3	facultative
30	Arthropoda	Insecta	Diptera	Trichoceridae	<i>Trichocera</i>		7	facultative
31	Arthropoda	Insecta	Lepidoptera	Alucitidae	<i>Alucita</i>	<i>hexadactyla</i>	15	facultative
32	Arthropoda	Insecta	Lepidoptera	Family 1	Genus 1		1	facultative
33	Arthropoda	Insecta	Hymenoptera	Ichneumonidae			1	facultative
							375	Total

Fig. 1. Timpanogos Cave system, Utah during invertebrate sampling, 2003.

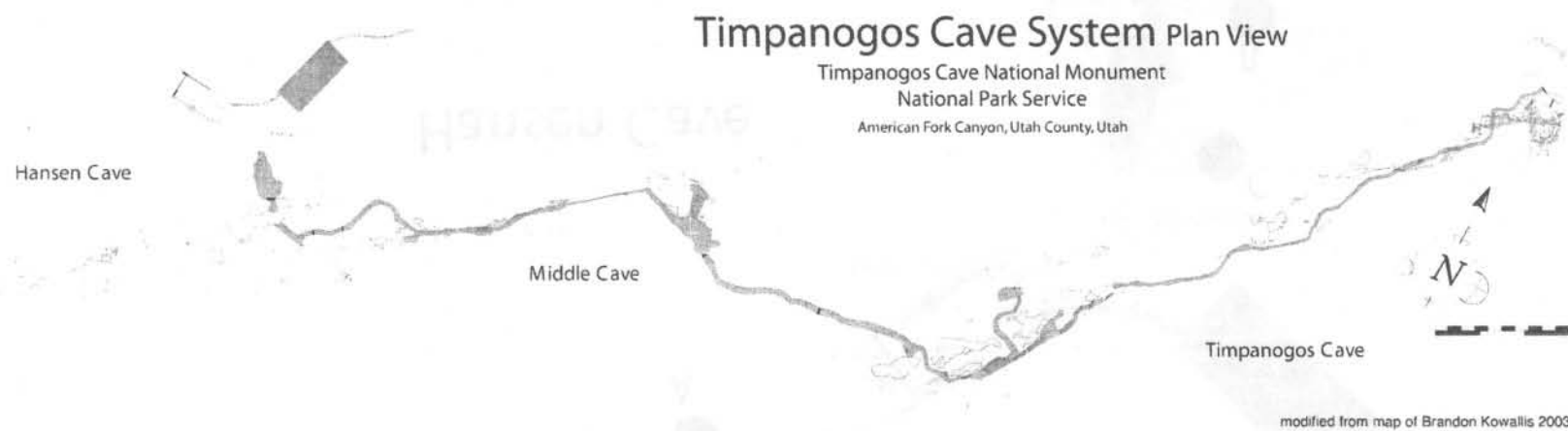


Fig. 2. Trap cluster locations in Timpanogos Cave system, Utah during invertebrate sampling, 2003. See Table 2 for details of traps at each lettered location.

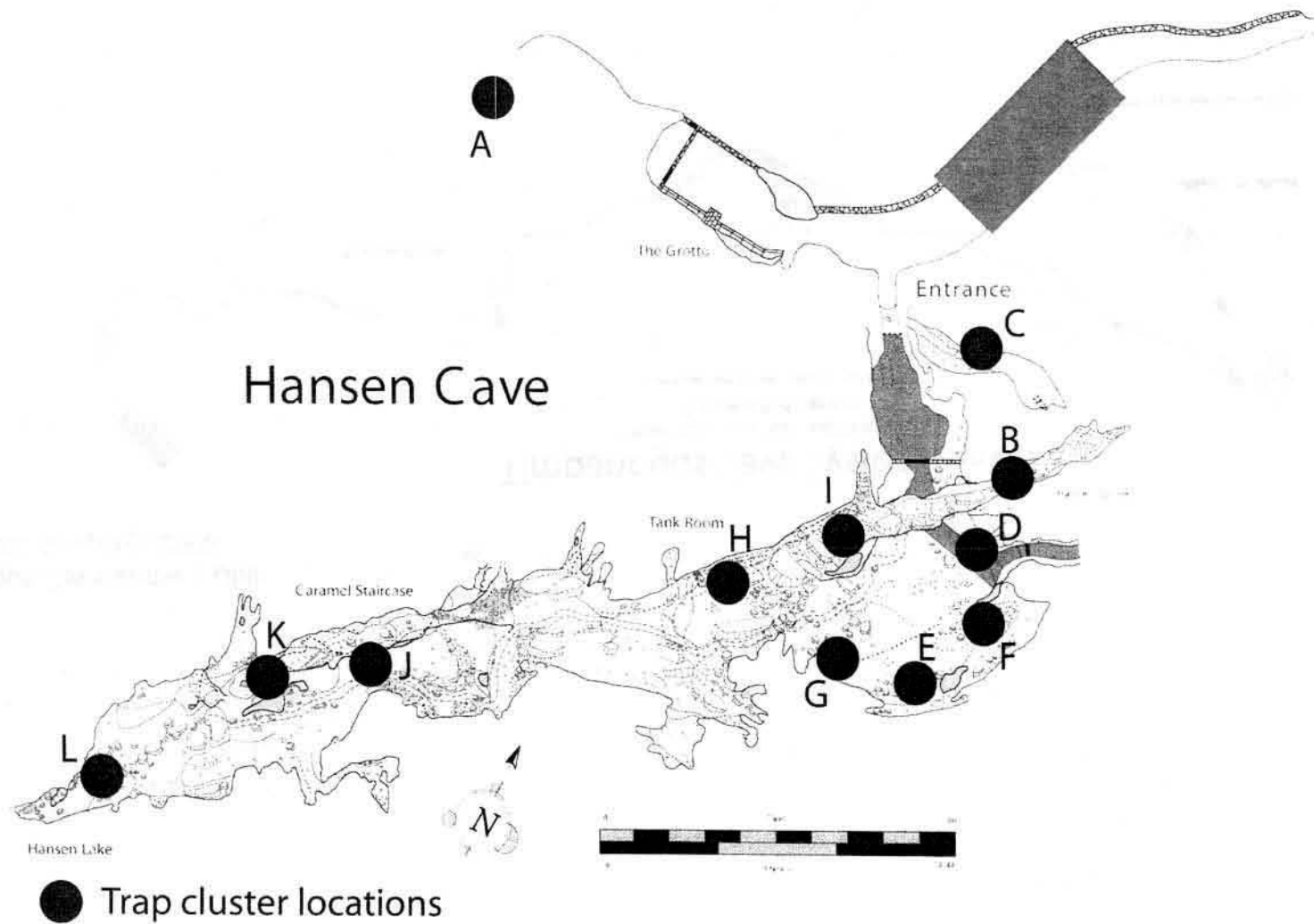
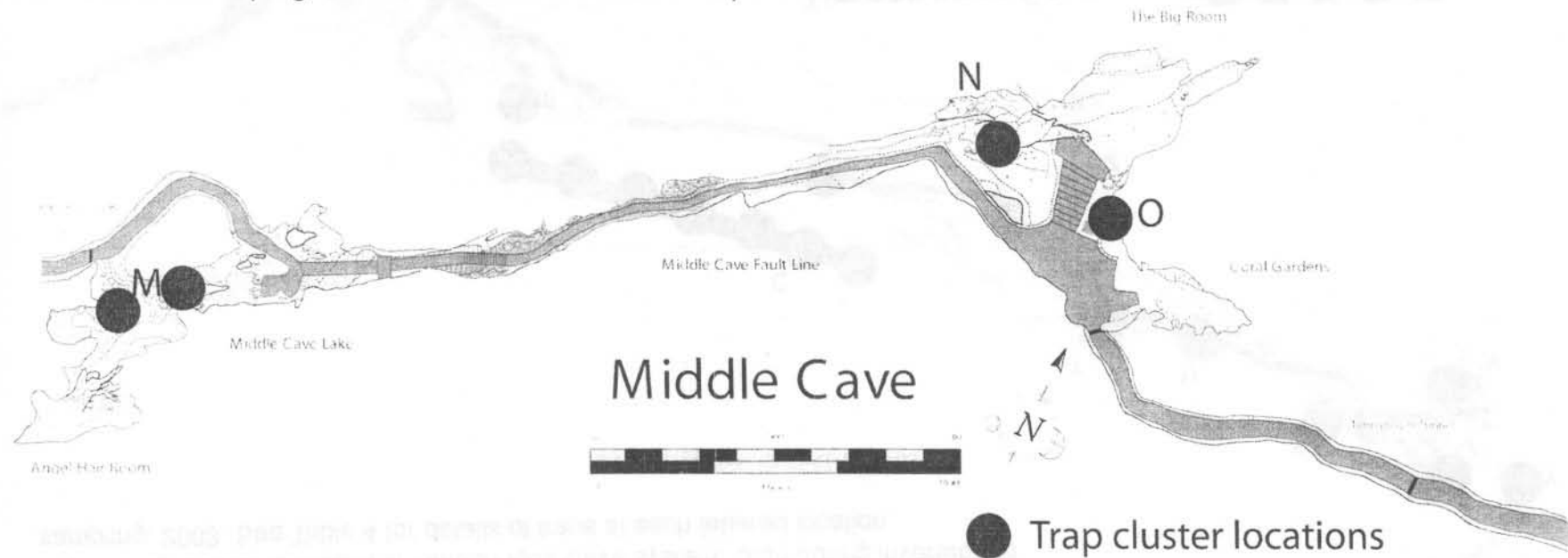
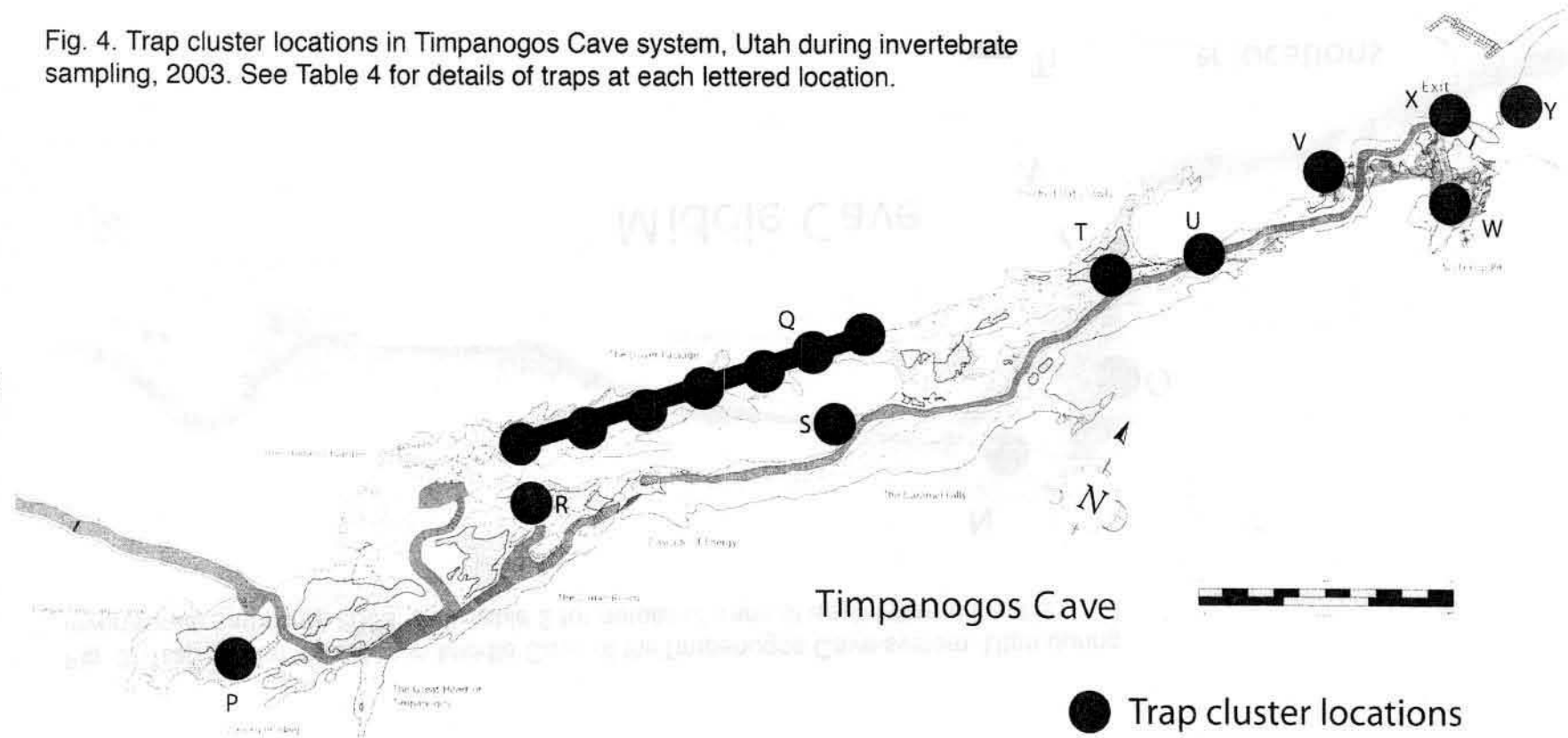


Fig. 3. Trap cluster locations in Middle Cave of the Timpanogos Cave system, Utah during invertebrate sampling, 2003. See Table 2 for details of traps at each lettered location.



26



Rank Abundance

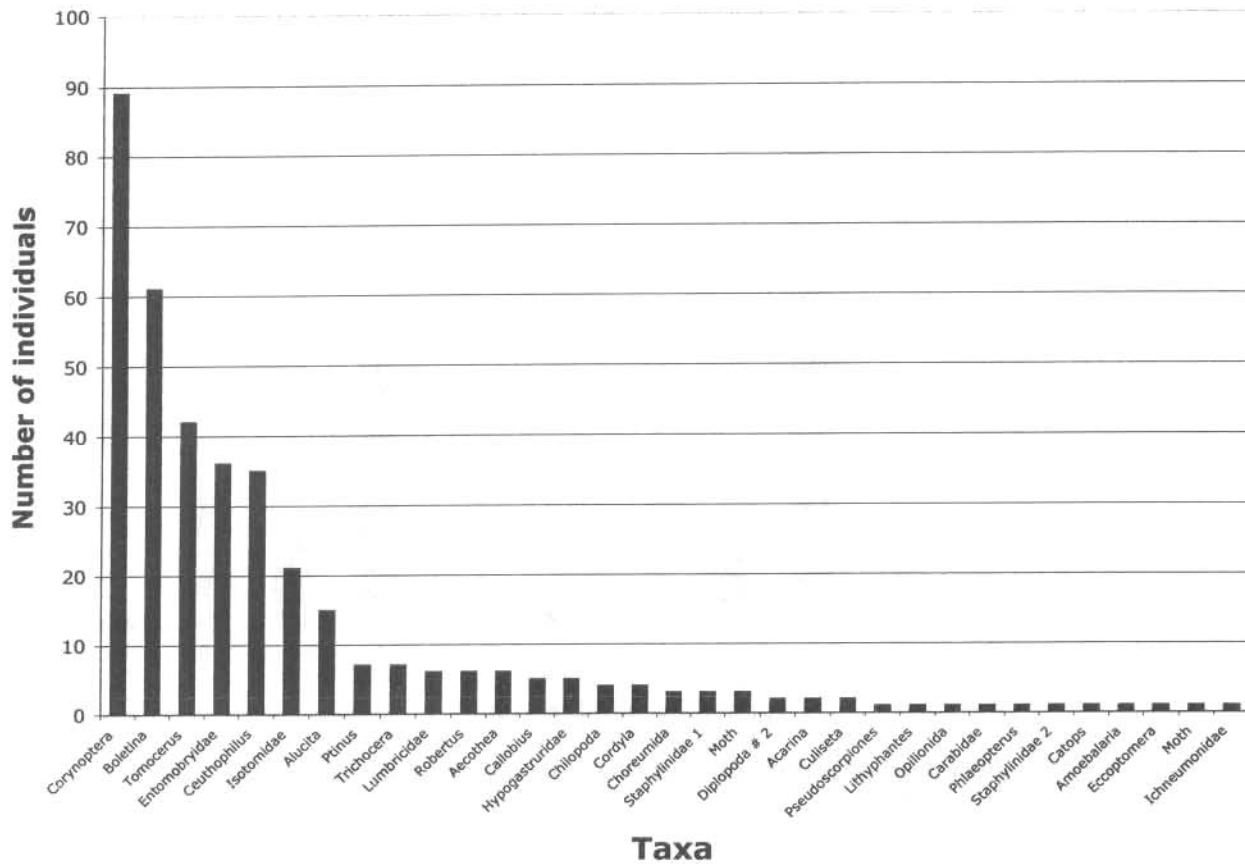


Fig. 5. Taxon rank abundance plot of macroinvertebrates collected from the Timpanogos Cave system, Timpanogos Cave National Monument, Utah, 2003. See Table 6 for classification of all taxa.

Seasonal Distribution of Specimens in Timpanogos Cave

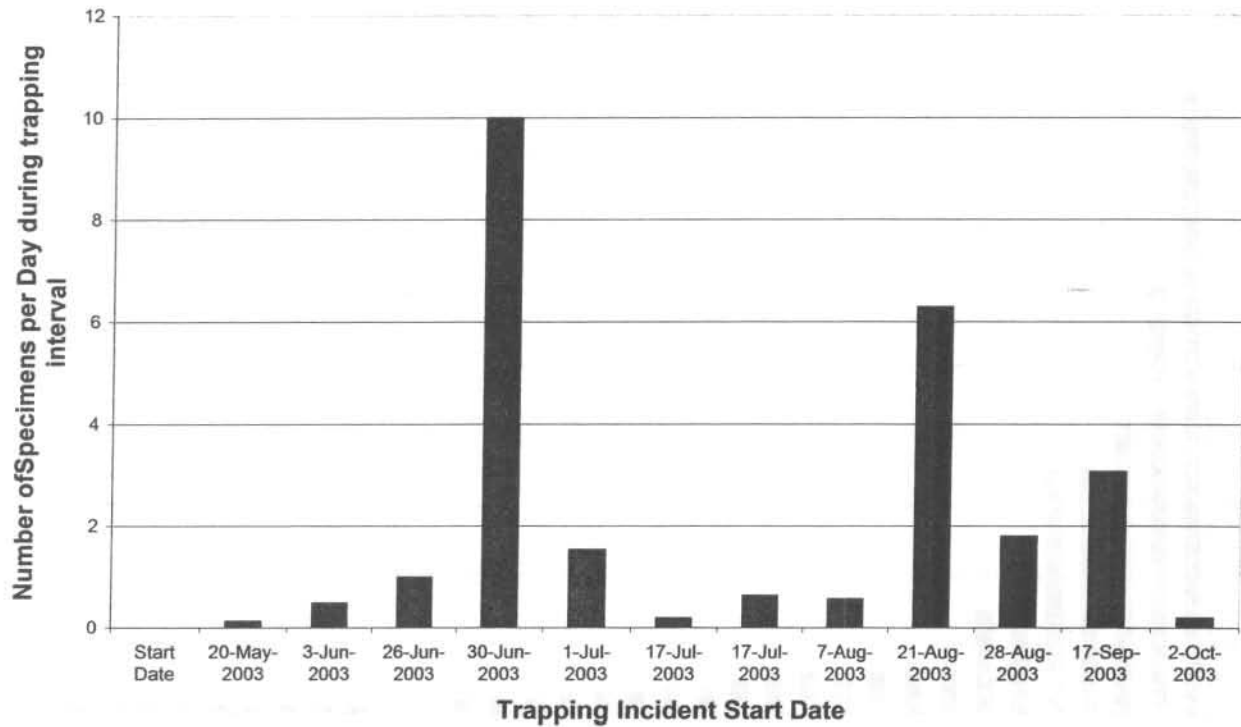


Fig. 6. Trapping efficiency and population phenology in caves at Timpanogos Cave National Monument, Utah, 2003.

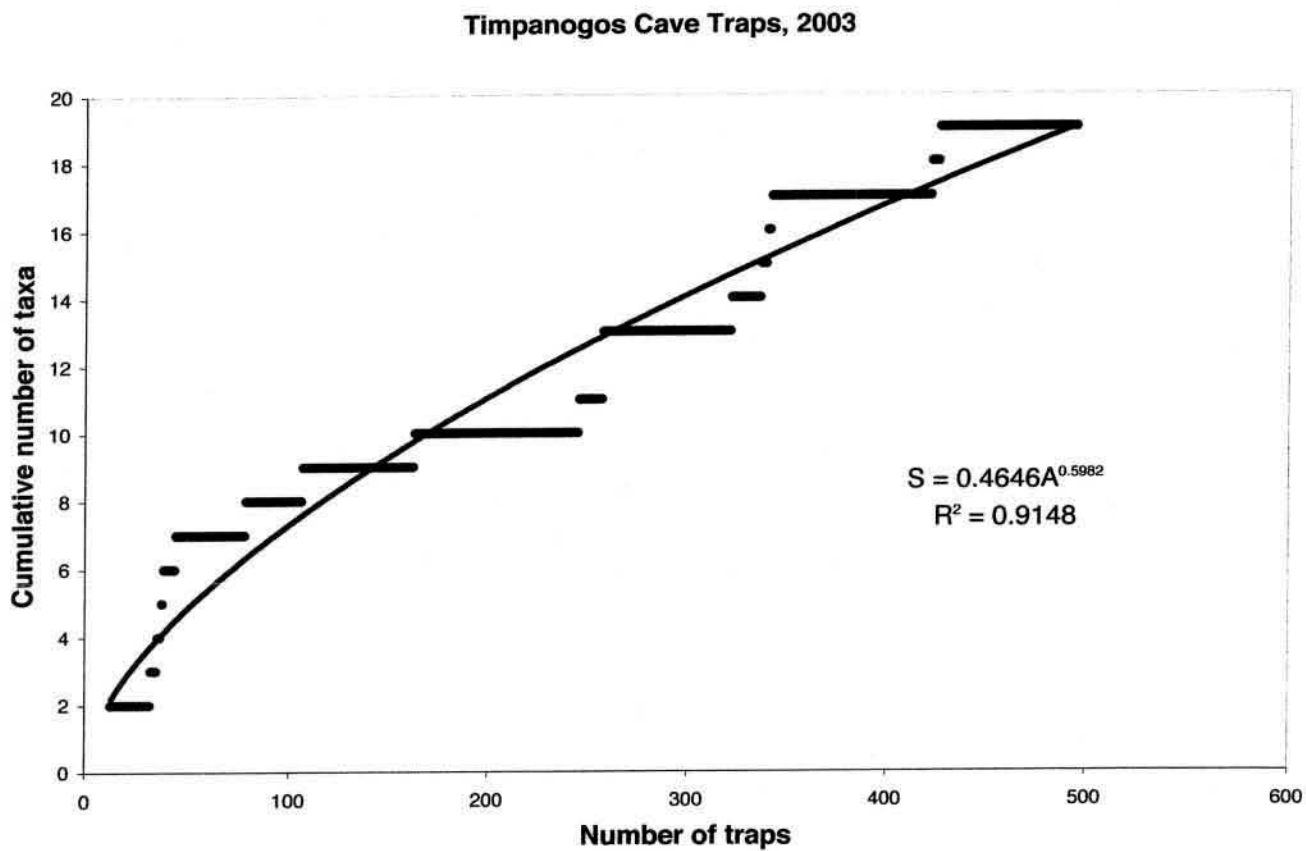


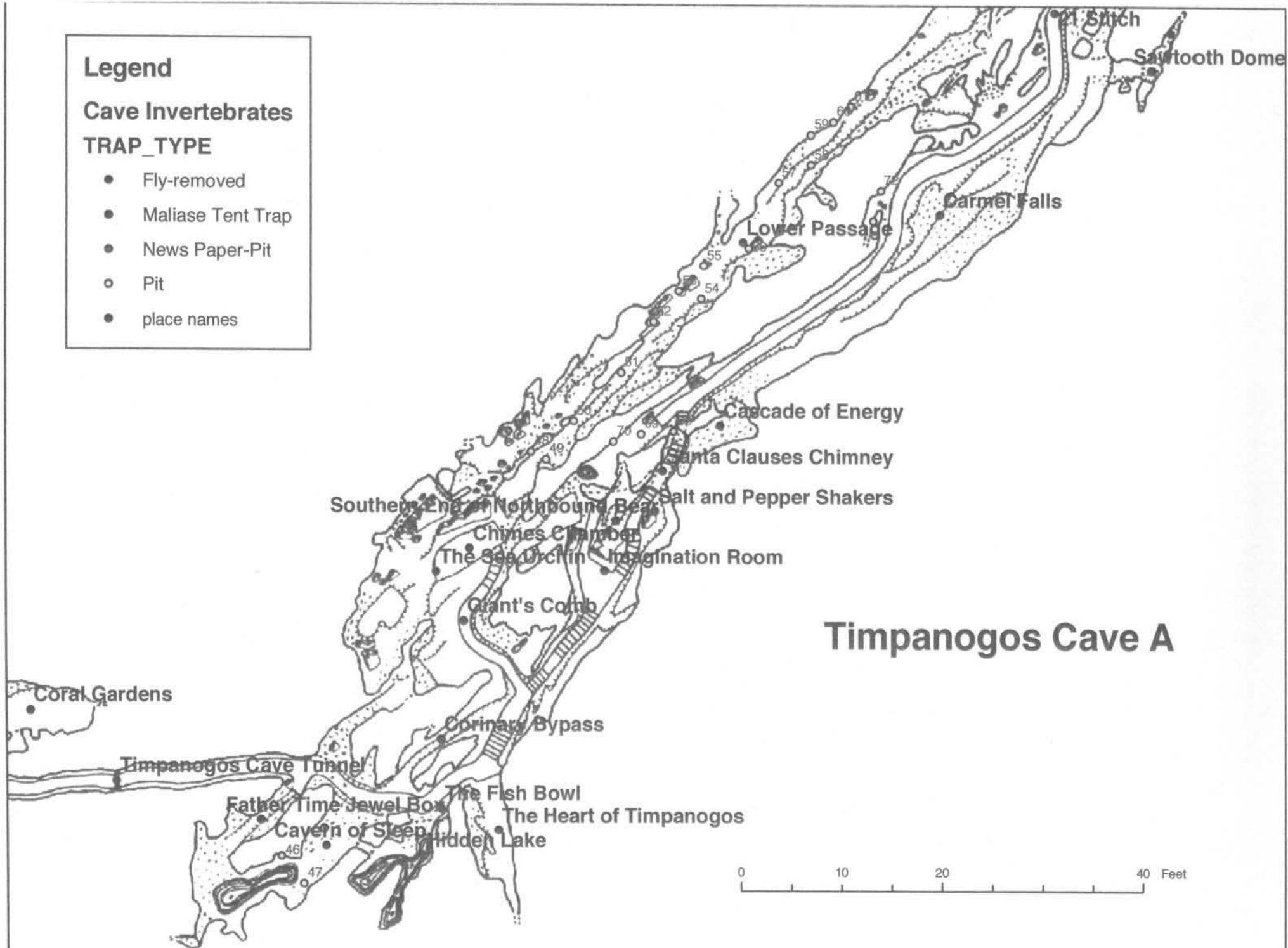
Fig. 7. Species-effort curve for pitfall traps in caves of Timpanogos Cave National Monument, Utah, summer 2003. The power curve ($S=cA^z$) is fit using the algorithm in Microsoft Excel Mac version X. Note climbing curve with numerous plateaus.

Legend

Cave Invertebrates

TRAP_TYPE

- Fly-removed
- Maliase Tent Trap
- News Paper-Pit
- Pit
- place names

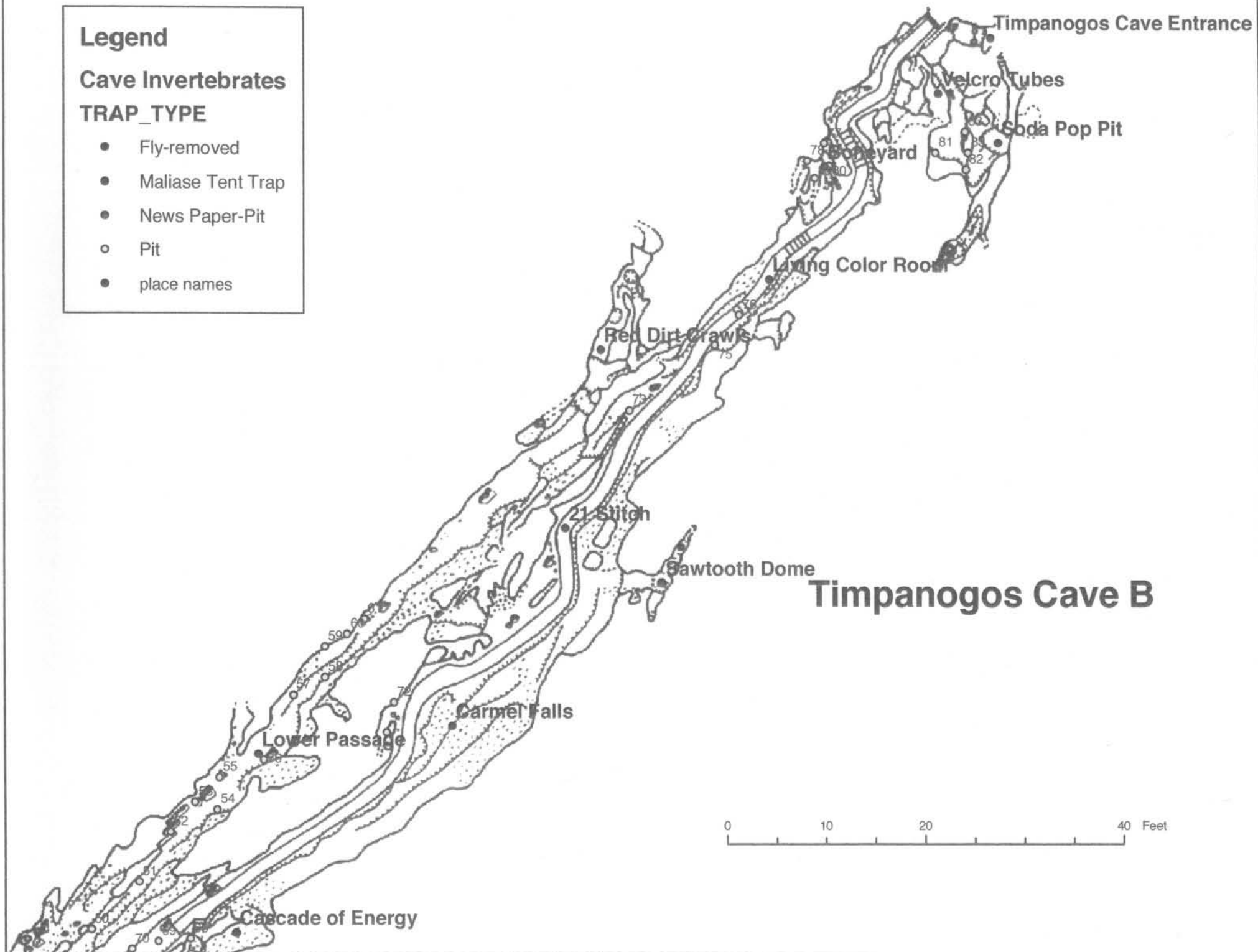


Legend

Cave Invertebrates

TRAP_TYPE

- Fly-removed
- Maliase Tent Trap
- News Paper-Pit
- Pit
- place names



•Comfort Station

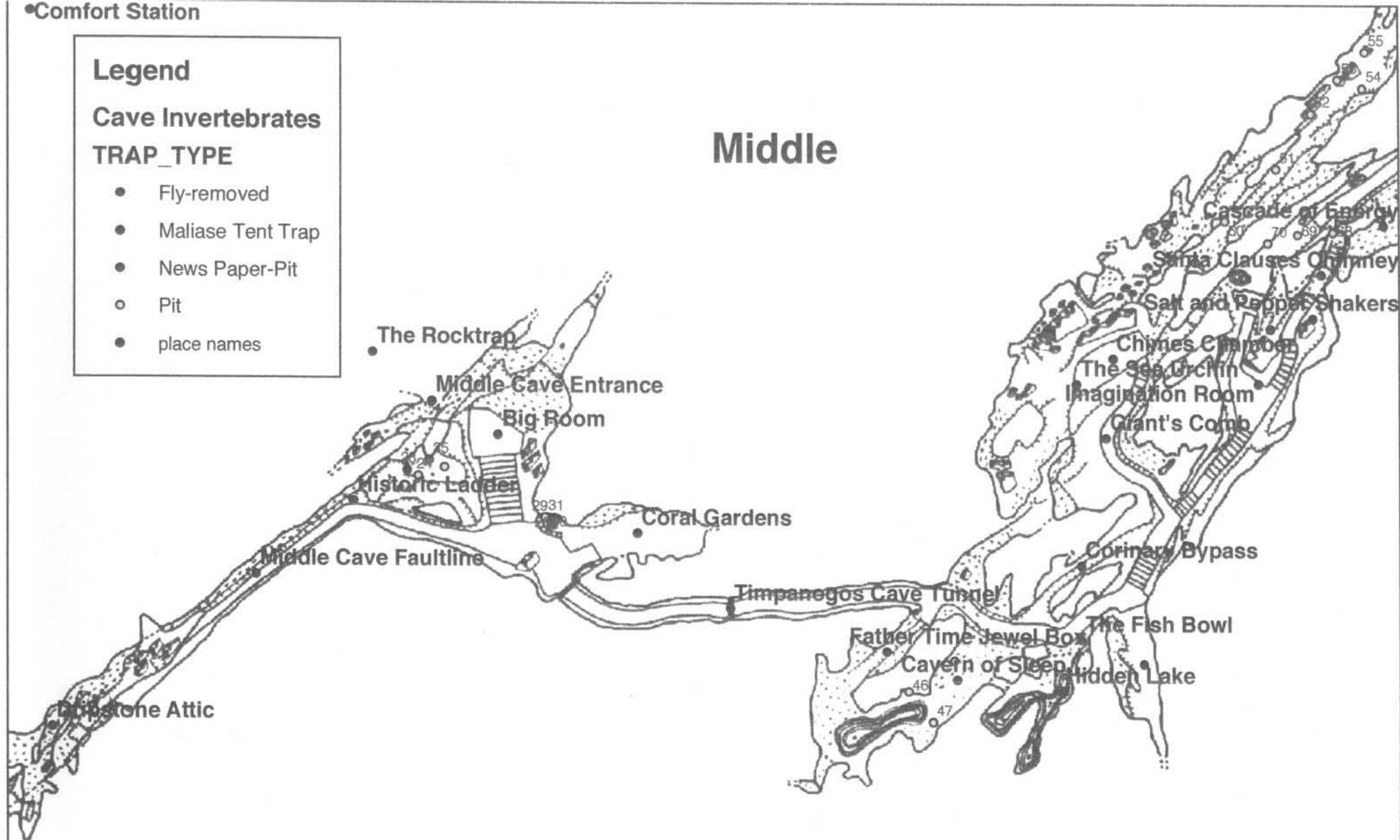
Legend

Cave Invertebrates

TRAP_TYPE

- Fly-removed
- Maliase Tent Trap
- News Paper-Pit
- Pit
- place names

Middle



0 10 20 40 Feet

Legend

Cave Invertebrates

TRAP_TYPE

- Fly-removed
- Maliase Tent Trap
- News Paper-Pit
- Pit
- place names

