A Preliminary Report on the Ephemeroptera, Plecoptera, and Trichoptera of Sleeping Bear Dunes National Lakeshore

By

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Abstract. A total of 117 species of mayflies, stoneflies, and caddisflies were collected from streams and lakes in Sleeping Bear Dunes National Lakeshore (SLBE) during 2014. Caddisflies provided the greatest number of species at 76, with mayflies contributing 35. Only six species of stoneflies were collected from SLBE. Several rare and new state record mayfly and caddisfly species were found in SLBE. EPT species richness was lower than expected for an area of this size, but limitations of stream size, narrow thermal regimes, and few heterotrophic streams are responsible rather than any anthropogenic disturbances. Additional sampling of lakes and interdunal swales is planned for June and July as is early spring sampling of flowing waters. Comparison of SLBE EPT richness to two measures of the regional species pool will take place after the 2015 sampling season.

Introduction

Sleeping Bear Dunes National Lakeshore is located in the northwest of the lower peninsula of Michigan in both Benzie and Leelanau counties, stretching in a discontinuous fashion from Beulah to west of Traverse City, Michigan. Its size is 71,189 acres. Prominent features of the park are moraines and outwash left by glaciers as recent as 12,000 years ago. Retreat of the glaciers and subsequent variability of the water level in Lake Michigan created many inland lakes, some with stream outlets to Lake Michigan (Vana-Miller 2002). The porosity of the materials in the moraines and dunes have created flowing water resources that usually arise from lakes or interdunal swales and quickly become relatively large (>5 m) in width. Abundant groundwater has a significant effect on the range of temperatures in several lakes and streams, allowing for a salmonid fishery to be maintained at least seasonally. A unique consequence of this glacial topography and porosity of materials is the near complete lack of small streams in the park.

One objective of the United States of America National Parks (parks) is to protect natural communities. To the best of their abilities managers, with the resources allotted to them, are to protect habitat for the continued existence of native species in as close to natural state as is practicable. It is often difficult to assess whether parks are meeting these goals. Priorities are many, resources are limited, and expertise is not always available. While vertebrate species abundance and community structure is well known for many parks, information on invertebrate fauna is generally poorly known. If regional species pools-an assemblage expectation-could be established, then comparison to current day samples could be made.

There is often little historical data available from which to recreate a regional pool for invertebrates. Published distributions suffer from a number of problems including incorrect identifications, the use of obsolete taxonomy, use of low taxonomic resolution (family and genus level identification), and the lack of vouchers that would be useful for verifying the identification of a specimen. In addition, published taxonomic checklists are often developed using states as boundaries, with little regard to finer regionalization of the data. What inhabits an entire state is not often applicable to what occurs in one part of it. Parks often do not have all of, or even a significant number of, the habitats that occur in a state. A better measure of the regional species pool is needed to determine if national park units are protecting invertebrates better than surrounding, unprotected areas.

Large specimen data sets would be desirable that would help to establish what represents a reasonable measure of the species pool available to parks. Accumulation of such a data set is difficult. Using current samples alone may not provide a historically accurate picture of what should be in the region. This is especially the case for the USA Midwest where the natural landscape has been extensively modified by agriculture, forestry, and urbanization. Finding undisturbed communities is nearly impossible; they are most prevalent inside larger protected areas such as national park holdings. This is a conundrum. How do we determine if parks are protecting communities, when there is so little information against which to compare?

Luckily, the Midwest region has a wealth of natural history museums that hold many millions of specimens. Many of these specimens were collected prior to, or coincident with, the worst of the changes in the Midwest, thus placing species where they no longer occur. The DeWalt laboratory was recently funded by the National Science Foundation (NSF) and the United States Fish and Wildlife Service (USFWS) to build a regional data set and predict pre-European settlement and future ranges for a large number of aquatic insects. This work has resulted in a 200,000 record specimen data set of point locations for three highly sensitive aquatic insects: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), collectively they are referred to as EPT taxa. The NSF has also dramatically increase funding and helped to develop standards for capturing of label data from museum specimens so that they may be used for a variety of research purposes, including rebuilding historical communities (iDigBio 2015). While the locations for these specimens may not be as densely distributed as we would like, the advent of sophisticated niche modeling (e.g., Maximum Entropy models, Elith et al. 2006) has helped to predict what other parts of the landscape species inhabited prior to rampant habitat destruction. Adding in future climate predictions helps in our understanding of patterns of range change due to changing climate patterns.

EPT are highly sensitive to changes in water and habitat quality and are used the world over as indicators of freshwater health (Barbour et al. 1999). These three orders have been extensively studied in the region (Burks 1953, Frison 1935, Ross 1944, Houghton 2012, Armitage et al. 2011, DeWalt et al. 1999, DeWalt et al. 2012, DeWalt & Grubbs 2011, Grubbs et al. 2012, Randolph & McCafferty 1998, Longridge & Hilsenhoff 1973 and many others) and a tremendous number of museum specimens exist. EPT specimen data have been used to build pre-European settlement distribution models at the USGS HUC12 drainage scale for 41 stoneflies in Illinois (Cao et al. 2013) and for 426 species of EPT across a seven state region of the Midwest (IA, IL, IN, MI, MN, OH, WI) (see Fig. 1 as an example). The predictions of watershed association may be used to build a regional species pool that is specific to any given national park unit in the region. Additionally, the 200,000 record dataset can be used as second source for species pool delineation, one that would have many more species that those that met minimum thresholds for model building.

The objectives of this study are to (1) conduct an inventory of the EPT present in Sleeping Bear Dunes National Lakeshore (SLBE) and (2) compare the assemblage to two measures of regional species pools: modeled species predictions and actual data points. Progress to this point has been limited to sampling EPT from several streams and two lakes in SLBE. All specimens related to 2014 sampling efforts have been identified, enumerated, and subjected to a preliminary analysis. Comparison to various estimates of a regional species pool will follow after additional sampling in SLBE during 2015. This report presents a partial inventory of EPT species for the 2014 season.

Methods

Sampling of EPT taxa began in May, 2014 and were collected on multiple occasions (Table 1). Species of EPT often succeed each other in development throughout the year, necessitating multiple visits. Collection of adults was prioritized since species level identification is most straightforward in this life stage. Historically, insect species have been described from adults, mainly males, leaving other life stages (females, nymphs, larvae, pupae) less likely to be identifiable. For this reason, immatures of many species were transported alive to Champaign for rearing to adulthood.

Sampling of Adults. Adult EPT are completely terrestrial. Because adults have distinct habitat preferences and behavior patterns, they were collected using a variety of methods. A beating sheet (canvas stretched between dowels) was one of the most useful sampling devises. The sheet was placed under emergent, riparian vegetation and adults dislodged using a stout rod. This method was especially useful when air temperatures were cool, limiting the flight of insects. During warmer conditions, an aerial sweepnet was used for sweeping adults from streamside vegetation. Insects were picked from nets and preserved in 95% EtOH. The number of insects kept per site/date event was limited to 10-15 where possible. Sometimes, multiple species of a given exemplar were present and since many species cannot be identified in the field, more specimens were taken.

Ultraviolet light traps are efficient in attracting adult EPT. This method was conducted when temperatures remained ≥20 C at night. Traps were set near the shore of streams or lakes where the area in front of them was open to water. Lights were turned on 15-30 min. before dark and remained on for 1.0-1.5 hrs. after dark. Generally, EPT ceased being drawn to light at about this time. Two types of traps were deployed: unattended and attended traps. Unattended traps consisted of small camping lights outfitted with ultraviolet emitting bulbs and a large plastic tray. The light and tray were set in a level location and the tray filled with 95% EtOH as preservative. Several of these traps could be set up and retrieved later in the evening. Attended lights were set up at the last location to be sampled for the night. Often a line was strung between trees, a white sheet placed over the line, and the light hung over the center. Plastic trays with alcohol were set below the sheet to capture insects that came to the light. Contents of trays were transferred to sample bottles at the end of the evening. Light traps often collected large numbers of individuals—this quantity cannot be tightly controlled. Lights gather insects from a relatively small area and the likelihood that they damage a population through is highly unlikely.

Sampling of Immatures. Immature EPT develop in water. These specimens were collected using a rectangular dipnet and handpicking from solid substrates. The need to maximize the number of species found necessitates a qualitative approach where many microhabitats and large amounts of sample debris are processed. The dipnet is the device of choice for this. It has a mesh bag stretched over a frame that captures insects and associated debris as the person sampling disturbs substrates (rocks, logs, finer sediment) by various means. Water currents in streams or sweeping of the net in lakes and marshes help to trap the insects in the net. Upon accumulation of a large amount of sample debris, specimens were sorted alive at streamside using a white plastic tray and stream water. Specimens were placed in a sample bottle with 95% EtOH as they were encountered. Some EPT were placed in cups with stream water for later rearing to obtain adult specimens. Sampling continued until no addition taxa were added. Researchers were careful not to take more than 10-15 specimens of a taxon during any one site/date collecting event. All non-target taxa were put back into the stream after sorting, with the exception of zebra mussels, which were destroyed upon discovery.

Laboratory Sorting and Identification. In the laboratory, specimens were identified to the lowest possible taxonomic level using current literature. Vouchers of each species were accessioned into the INHS Insect Collection (INHS-IC). This facility is a seven million specimen research collection housed at the University of Illinois that provides specimens for use by researchers and data that document in time and space the insect fauna of the Midwest and the world (http://wwx.inhs.illinois.edu/collections/insect). All data associated with these specimens are available at the INHS-IC database portal (http://inhsinsectcollection.speciesfile.org/InsectCollection.aspx).

SLBE project data were exported from the INHS-IC database in Excel format. All raw data, derived data, tables and figures associated with this report are provided as an Excel spreadsheet "Sleeping Bear EPT 2014.xls". Three primary worksheets are "Locations", providing detailed location information; "Field notes", capturing site/date/sample event data for each sample taken; and "Specimen records", providing raw sample data with species, their counts, and the catalog numbers linking specimen data to physical specimens in the INHS-IC. In addition, several tables and figures may be accessed from the spreadsheet.

Analysis of the completeness of sampling and prediction of EPT species richness was carried out using the EstimateS program (http://viceroy.eeb.uconn.edu/estimates/). A presence/absence data matrix was built using EPT species names (some unique genera as well) and field notebook numbers (Field#) as sample units. The matrix used in this analysis is contained with the spreadsheet as the "EstimateS data" worksheet. A tab delimited file of this matrix was submitted to EstimateS using default settings for estimating diversity. An "EstimateS output" worksheet is provided in the spreadsheet. To this worksheet, a cumulative increase in species/sample was added by the author. Chao 2 mean and its 95% upper and lower confidence intervals were presented as one measure of estimated EPT diversity at SLBE and was compared to the cumulative increase in EPT found in consecutive samples. In addition, an estimation of the number of rare species per sample was provided. Singletons, the number of species found in a single sample, and doubletons, the number of species found in two samples, were used as indices of rare species present in the sample.

Results

Locations Sampled. Twelve sites were sampled during 2014 (Table 1). Habitats sampled included streams, lakes, and one vernal pool. The vernal pool location produced no EPT specimens during the May visit, prompting the termination of sampling at that location.

EPT Species Sample Richness. A total of 3,158 specimens in 117 unique EPT taxa were sampled from SLBE aquatic resources during 2014 (Table 2). Samples were highly variable in the number of unique EPT taxa taken (Fig. 2). The two UV light trap samples from Loon and Mud lakes were more diverse than any stream samples. EstimateS, using the Chao2 model for richness estimation, suggested that at least 141 EPT taxa were present within SLBE (Fig. 3). The upper and lower 95% confidence intervals estimated between 130-167 EPT species. Observed, cumulative species richness climbed dramatically in June and continued to increase steadily during July samples. The largest jumps in species occurred with the use of ultraviolet light traps on Platte River, Loon Lake, and Mud Lake in July (Fig. 3).

Rare species, those found in one (singletons) or two (doubles) samples were high in number (Fig. 4). A total of 38 (32.5%) taxa were singletons, while 32 (27.4%) were found in two samples. With more samples, the number of singletons is predicted to continue to decline. Doubletons are predicted to increase with more samples.

EPT Species Richness By Locations. When samples were pooled by unique location, six sites were sampled with equivalent effort to allow for direct comparison (Fig. 5, Table 2). The richest waterbody was Platte River at El Dorado Landing. There, 54 EPT were recovered. The vast majority of these species were caddisflies (40 or 74%). Mayflies contributed 13 (24%) species, while stoneflies were poorly represented in the Platte River with a single species (2%). Three other stream locations were well sampled. Crystal River at the easternmost crossing of Crystal View Rd. was also rich at 37 EPT taxa, but the distribution of taxa was quite different from that of Platte River. Mayflies and caddisflies contributed the same number of species at 16 species (43%), but stoneflies (5 species, or 14%) were a much larger proportion of the total than in Platte River. Shalda Creek at Michigan Road and along MI-22 shared a similar number and composition of EPT species to that found in Crystal River.

Significant Findings. A total of 35 mayfly species were collected within 9 families. Three families provided 63% of mayfly species: Baetidae, or small minnow mayflies, with 9 species; Heptageniidae, or flat-headed mayflies, with 7 species; and Ephemerellidae, or spiny crawler mayflies, with 6 species. To date, only six species of stoneflies in four families have been recovered from SLBE. Perlidae, a family of generally large predatory stoneflies, contributed three species. Other families were represented by one species each. Caddisflies, by a factor of two, dominated in the number of species found with 76. Fourteen families were represented, three of which contributed more than 10 species: Hydropsychidae, or net-spinning caddisflies, contributed 12 species; Hydroptilidae, or micro-caddisflies, contributed 13 species; Leptoceridae, or long-horned caddisflies, contributed 22 species. Several EPT species found at SLBE were rare in the state or were new state records. To date, no species new to science have been discovered. Below is a discussion of the significant findings for individual species.

Ephemeroptera
Baetidae-small minnow mayflies
Acerpenna pygmaea (Hagen 1861). This species is common in the region but to date it has been reported from only three scattered locations in Michigan (Randolph & McCafferty 1998). It was rare in Shalda Creek and Crystal River, but abundant in the Platte River.

Labiobaetis propinquus (Walsh 1863). In Michigan, this species is known only from Houghton Co., but is common throughout the region (Randolph & McCafferty 1998). Sampling revealed that the species was relatively abundant in Shalda Creek and Crystal River, but rare in Platte River. It should be present in most running water locations in SLBE.

Neocloeon triangulifer (McDunnough 1931). This species has not been previously reported from the lower peninsula of Michigan. Single specimens were recovered from Crystal River, Platte River, and Shalda Creek. Randolph & McCafferty (1998) describe a disjunct distribution with records in Ohio and Indiana and then again in northern Wisconsin and in two counties east of Munising in the Upper Peninsula. Wisconsin lists it as a Species of Greatest Conservation Need (SGCN) (Anonymous 2015b) where it is known to occur infrequently across much of the state (Klubertanz in review). The species undergoes obligate parthenogenesis and populations are composed entirely of females (McCafferty et al. 2004, Funk et al. 2006). Jacobus & Wiersema (2014) recently placed the species into the genus *Neocloeon*.

Pseudocentroptiloides morihari Wiersema & McCafferty 1998. This is a new state record for Michigan. A single nymph was taken from Shalda Creek. The only regional records for the species are from four northern counties in Wisconsin (Klubertanz in review).

Baetiscidae-armored mayflies
Baetisca lacustris McDunnough 1932. Though it has never been reported from Michigan, it occurs in all surrounding states (Randolph & McCafferty 1998). Two specimens were collected from the Platte River.

Caenidae-small square-gill mayfly
Caenis punctata McDunnough 1931. This species has been reported from Marquette County in the Upper Peninsula of Michigan; no other records exist for the state (Randolph & McCafferty 1998). Wisconsin considers it an SGCN (Anonymous 2015b). Two individuals were collected from Platte River. The species is likely to be much more abundant than published records indicate.

Sparbarus maculatus (Berner 1946). This is a new state record for Michigan. A single specimen was taken from Crystal River. In the region it has been reported from northwestern Ohio (Randolph & McCafferty 1998) and from three northern Wisconsin counties (Sun & McCafferty 2008, Klubertanz in review). Wisconsin considers this species an SGCN (Anonymous 2015b).

Ephemerellidae-spiny crawler mayflies
Eurylophella cf. *minimella* (McDunnough 1924). The qualifier "cf." means confirmation should be sought through additional specimens and life stages. The nymphs from Crystal River were very small and key characters used in Funk & Sweeney (1994) are designed for older larvae. It may turn out that the larvae are merely young *E. bicolor* (Clemens 1913). Additional effort will be made to confirm this identification with more specimens and through rearing to the adult stage. *Eurylophella minimella* has been reported from Cheboygan County, Michigan and from Lake County, Ohio in the Midwest region (Randolph & McCafferty 1998).

Heptageniidae-flat-headed mayflies
Stenacron minnetonka (Daggy 1945). This is the first record of the species in Michigan. Throughout the region, this species is rare and probably declining. Regional records are available from Illinois, Indiana, Ohio and Kentucky (Randolph & McCafferty 1998).

Metretopodidae-cleft-footed minnow mayfly
Siphloplecton basale (Walker 1853). While this species is known from several locations in upper and lower Michigan, most of these records are old (Randolph & McCafferty 1998). Its usual habitat is sand-bottomed rivers, often large ones. Emergence of adults is in early spring before

many aquatic biologists start sampling. These two habits make the species difficult to collect and subject to speculation about its rarity. Consequently, it has been placed on the Michigan list of Species in Greatest Need of Conservation (SGNC) (Anonymous 2015a). Four nymphs were collected from one Shalda Creek location. It will be found at other locations in SBLE.

Trichoptera
Hydropsychidae-net-spinning caddisflies
Hydropsyche alhedra Ross 1939. This represents a new state record for Michigan. A single male specimen was taken from Shalda Creek. The species is common in small to medium sized streams in Minnesota (Houghton 2012).

Hydropsyche cf. *walkeri* Betten & Mosely 1940. This taxon requires confirmation with adult specimens. One larva was found in Shalda Creek. This species is known from historical records in eastern Ohio (Armitage et al. 2011) and from northeastern Minnesota (Houghton 2012).

Hydroptilidae-microcaddisflies
Hydroptila amoena Ross 1938. This species represents a new state record for Michigan. A single adult male was collected using an ultraviolet light trap from Loon Lake. The species is known regionally from Illinois, Indiana, Minnesota, Ohio, and Wisconsin (Armitage et al. 2011, Blickle 1979, Houghton 2012, Ross 1944, Waltz & McCafferty 1983).

Ithytrichia clavata Morton 1905. This is a new state record for Michigan. It was exceedingly abundant in lakes and in the Platte River. This species has a Holarctic distribution (Andersen & Kjarandsen 2002) and is generally found in more northern areas of North America (Blickle 1979). It has recently been reported from northeastern Minnesota (Houghton 2012) and northcentral Ohio (Armitage et al. 2011).

Oxyethira coercens Morton 1905. This species is a new state record for Michigan. It has been reported from most states bordering Michigan (Blickle 1979), though, it has not been reported from Ohio (Armitage et al. 2011) or from adjacent Canadian provinces.

Oxyethira grisea Betten 1934. This species too is a new state record. It was exceedingly abundant in Platte River and in Loon Lake. Regional literature records place it in Illinois and Indiana (Blickle 1979) and Ohio (Armitage et al. 2011).

Oxyethira michiganensis Mosely 1934. This species was originally described from Michigan with label data of "Michigan, U.S.A." (Mosely 1934). Leonard and Leonard (1949) reported no specimens in their checklist of caddisflies of Michigan. Blickle (1979) does not list the species from Michigan, presumably because of the lack of confirming specimens. Its presence in both Minnesota (Houghton 2012) and Ohio (Armitage et al. 2011) have been recently confirmed. A single specimen was collected from Loon Lake.

Oxyethira pallida (Banks 1904). This species in not know from Michigan (Leonard and Leonard 1949). Regionally it is known from Minnesota (Houghton 2012), Ohio (Armitage et al. 2011), and Illinois and Wisconsin (Blickle 1979). Four specimens were collected from Platte River and Loon Lake.

Oxyethira serrata Ross 1938. This species is known only from Roscommon County in Michigan prior to this point (Leonard & Leonard 1949). It is known regionally from Minnesota (Houghton 2012), Illinois (Ross 1944), and Wisconsin (Blickle 1979). Wisconsin lists this species as an SGCN (Anonymous 2015b). Five specimens were taken from Platte River and Loon Lake.

Leptoceridae-longhorned caddisflies
Ceraclea maculata (Banks 1899). This species is not known from Michigan, but is a common inhabitant of Minnesota (Houghton 2012) and Ohio (Armitage 2011). Four individuals were collected from Platte River at El Dorado.

Ceraclea transversa (Hagen 1861). This species has been reported from Crawford County, Michigan. It was abundant in Minnesota (Houghton 2012), throughout all but the northwest corner of Ohio (Armitage et al. 2011), and in the lower Illinois River basin of Illinois (DeWalt et al. 1999).

Oecetis ditissa Ross 1966. This species has not been reported from Michigan. It has been reported from Illinois, Indiana, and Ohio (Ross 1944, DeWalt et al. 1999, Armitage et al. 2011) and from Minnesota (Houghton 2012). One male specimen was collected from Mud Lake.

Limnephilidae-northern casemaking caddisflies
Anabolia sordida Hagen 1861. This species is not known from Michigan. It has been reported from Illinois (Ross 1944), Minnesota (Houghton 2012), and Wisconsin (Longridge & Hilsenhoff 1973). A female and larvae were taken from Mud Lake.

Grammotaulius sp. Five larvae were collected from Otter Creek. The most likely species would be *Grammotaulius interrogationis* (Zetterstedt 1840), which has only been reported in the region from an unspecified location in Minnesota (Houghton 2012). Given that the identification is based on larvae material, some uncertainty exists about the name associated with these specimens. If the identification stands, then this would be another state record for Michigan.

Molannidae-hoodcase making caddisflies
Molanna ulmerina Navas 1934. This species has not been previously reported from Michigan (Leonard & Leonard 1949). One male and two females were collected from a UV light trap set on Loon Lake. Houghton (2012) discussed a dubious record for Minnesota (Harris et al. 1991), but did not include it in his list of Minnesota caddisflies. Waltz & McCafferty (1983) reported it from northcentral Indiana. It has not been reported from Wisconsin (Longridge & Hilsenhoff 1973, Steven & Hilsenhoff 1984). Armitage et al. (2011) state that the species occurs in northeastern Ohio.

Polycentropodidae-trumpetnet caddisflies
Neureclipsis piersoni Frazer & Harris 1991. This species is a new state record and a large range extension from its type locality in northern Alabama and paratype locations in northwestern Georgia (Harris et al. 1991). A total of 10 adults were collected from Shalda Creek, Platte River, and Loon Lake locations. The species has not been reported from anywhere in the region and has been given a tentative global ranking of G1/G3 by NatureServe (2015). This species is similar to

the more common *N. crepuscularis* Banks 1914 and it is highly likely that many more locations between Alabama and Michigan will be discovered as new collections and museum specimens are examined.

Nyctiophylax serratus (Lago & Harris 1985). The presence of this species at SLBE is another state record for Michigan (Armitage & Hamilton 1990). One specimen was taken from a UV light trap set on Mud Lake. The species has not been collected from any other regional location and is another example of a northern Alabama/Georgia described species being present in Michigan.

Sericostomatidae-bushtailed casemaking caddisflies
Agarodes distinctus Ulmer 1905. Four female specimens were collected using UV lights at Loon and Mud lakes, representing the first record of the species in the state. Keth & Harris (2008) provided evidence of a large geographic disjunction consisting of areas bordering on and extending north of the Great Lakes, then in Georgia, South Carolina, and Tennessee. Wisconsin lists it as an SGNC (Anonymous 2015b). Regionally it has been reported from Minnesota (Houghton 2012) and Wisconsin (Longridge & Hilsenhoff 1973).

Discussion

Sleeping Bear Dunes National Lakeshore water resources are a unique mixture of aquatic resources, the glacial landscape and porous sand and gravel ensure near immediate percolation of surface water into the soil (Vana-Miller 2002). This groundwater is returned to the surface in lakes and swales, which in turn creates sizeable streams that flow into Lake Michigan. This abundant groundwater also creates a "summer cool", "winter warm" thermal regime. Platte River, the largest stream flowing through SBLE, is the only stream that enters from the east, far outside of the park boundary. It too, flows through a series of lakes before entering Lake Michigan. Streams flowing through large lakes dramatically change character, dropping their coarse organic materials and becoming more autotrophic due to phytoplankton inhabiting the lakes.

The diversity of EPT species in SLBE aquatic resources must be governed by this unique juxtaposition of topography, soil characteristics, presence of large lakes, stream size limitation, and narrower thermal regime. Though SLBE streams are generally of high water quality (Vana-Miller 2002), these limitations allow for far fewer EPT taxa in streams than are found east of SLBE where there are an abundance of stream sizes, substrate types, and thermal regimes. For instance, it would be expected that approximately 20 species of stoneflies would be found in an area of this size, when only six have been found to date. In addition, several mayfly species in the family Ephemerellidae were missing or were in low abundance in SLBE. Sand-inhabiting mayflies that usually live in heterotrophic sand streams were also missing, the lake robbing rivers of organic matter needed to support these sand species. Several caddisflies were missing as well, including the family Brachycentridae with at least one species being highly abundant in inland rivers. The type of habitat that is missing in SLBE, and that would be diverse, are the 1-5 m wide streams that have rich deposits of leaves and decaying wood in them and a mixture of thermal regimes. It is not likely that the lower EPT richness in SLBE streams is a function of potential declines in water quality, habitat quality, or high recreational traffic.

Conversely, SLBE lakes are highly diverse and dominated by caddisflies. Most caddisflies that inhabit lakes are casemakers. They make tubular cases that provide camouflage and improve respiration by allowing larvae to undulate, creating a current of water past the body. Especially diverse were the micro- and longhorned caddisflies. Species in these families often consume algae from hard substrates or are predators of other invertebrates. The abundance of clear water allows for an autotrophic system that supports a wide range of caddisflies. In addition, large species of caddis were abundant whose larvae construct conspicuous stone or organic cases. These species can live in even hypoxic waters due to the respiratory features of their cases.

Despite these limitations, sampling produced 16 new state record EPT for Michigan and records of several rare species. The number of rare species is, in some ways, a reflection of the amount of sampling conducted in Michigan for EPT. A few early efforts to document the EPT fauna of Michigan were made (Leonard & Leonard 1949, Leonard & Leonard 1962), but these were not exhaustive studies and little follow-up was conducted (but see Grubbs & Bright 2001, Grubbs et al. 2012, Randolph & McCafferty 1998). Once extensive sampling has been conducted or reported (large amounts of EPT data now available from author), many of these species will be viewed as relatively common.

Sampling so far has concentrated on streams and a few lakes. It is highly likely that many more species (estimated 30-50 more) would be taken through additional lake sampling, and through sampling of interdunal swales. Swales associated with Shalda Creek, those near the junction of Peterson and Lasso roads, Good Harbor Creek swales, and those near the end of Boekeloo Rd. should yield many additional species. More work remains to be done documenting EPT in lakes, including Loon Lake, Otter Lake, North Bar Lake, Shell Lake, Bass Lake, and School Lake. Of course, the EPT fauna of Lake Michigan itself is poorly defined. Ultraviolet light trapping and some benthic sampling should improve our understanding of what occurs in the lake. The extra logistics needed to access shorelines and lakes of offshore islands negates assessment of their EPT at this time. Additional sampling of streams in early April, 2015 is needed to find all potential early emerging species.

After these additional sampling efforts, comparison to both modeled distributions and the large, regional EPT data set will be conducted. It will be interesting to know which species found regionally are not present in SLBE. It is likely that limitations imposed by species traits (Poff et al. 2006) and the small variation in stream size, thermal range, and energy source will be responsible for most differences found.

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Table 1. Locations sampled and dates visited to sample EPT at Sleeping Bear Dunes National Lake Shore during 2014. Location Code is unique and is used through report to identify exact location for waterbodies sampled.

Location Code	**County**	**Waterbody**	**Locality**	**Latitude**	**Longitude**	**May 9-10**	**June 13-14**	**July 26**	**Oct. 8**
61229	Benzie	Platte River	Platte River at MI-22	44.71194	-86.11977	X	X		
61671	Benzie	Otter Creek	5.5 km SSW Empire at Otter Creek Trlhd.	44.76168	-86.07412	X			
61672	Benzie	temporary pools	off Trails End Rd.	44.73317	-86.05625	X			
61673	Benzie	Otter Creek	at Trails End Rd.	44.73701	-86.06211	X			
61674	Leelanau	Shalda Creek	at Lake Michigan Rd.	44.94697	-85.88521	X	X	X	X
61675	Leelanau	Shalda Creek	8.5 km ENE Glen Arbor along MI-22	44.93372	-85.89075	X	X		
61676	Leelanau	Crystal River	1.9 km ENE Glen Arbor at Crystal View Rd.	44.90301	-85.96253	X	X	X	X
61677	Leelanau	Crystal River	1.1 km NE Glen Arbor at Crystal View Rd.	44.90329	-85.97446	X			
61678	Benzie	Platte River	2 km NW MI-22 along Lake Michigan Rd.	44.72735	-86.14989	X			
61734	Benzie	Platte River	at El Dorado canoe launch	44.72652	-86.14303		X	X	X
61735	Benzie	Mud Lake	150 m SE from fish weir gate	44.72005	-86.12907		X	X	
61737	Benzie	Loon Lake	at public access on east side	44.70908	-86.12646		X	X	

Table. 2. Ephemeroptera, Plecoptera, and Trichoptera (EPT taxa) recovered from Sleeping Bear Dunes National Lakeshore locations during 2014. Location Code following waterbody name is the same as used in locations in Table 1. Genera were added to richness measures if no species level identification was available for a given location.*Denotes new state record.

Genus	Species	Authority and Year of Description	Otter Cr. 61671	Otter Cr. 61673	Shalda Cr. 61674	Shalda Cr. 61675	Crystal R. E 61676	Crystal R. W 61677	Platte R. 61229	Platte R. 61678	Platte R. 61734	Loon L. 61737	Mud L. 61735	Total
Ephemeroptera-mayflies			Streams									Lakes		
Baetidae-small minnow mayflies														
Acerpenna	*pygmaea*	(Hagen 1861)	1	0	0	1	1	0	5	8	36	0	0	52
Baetis	*flavistriga*	McDunnough 1921	1	0	21	21	1	0	0	0	0	0	0	44
Baetis	*intercalaris*	McDunnough 1921	0	0	1	0	0	0	0	0	0	0	0	1
Baetis	*tricaudatus*	Dodds 1923	4	0	0	0	0	0	1	0	0	0	0	5
Callibaetis	*ferrugineus*	(Walsh 1862)	0	0	0	0	0	0	0	1	0	1	0	2
Callibaetis	sp.		0	0	0	0	0	4	0	0	0	0	0	4
Labiobaetis	*propinquus*	(Walsh 1863)	0	0	8	9	4	0	0	0	2	0	0	23
Neocloeon	*triangulifer*	(McDunnough 1931)	0	0	0	1	1	0	0	1	0	0	0	3
Procloeon	sp.		0	0	0	2	0	0	0	0	0	0	0	2
**Pseudocentroptiloides*	*morihari*	Wiersema & McCafferty 1998	0	0	1	0	0	0	0	0	0	0	0	1
Baetiscidae-armored mayflies														
**Baetisca*	*lacustris*	McDunnough 1932	0	0	0	0	0	0	2	0	0	0	0	2
Baetisca	*laurentina*	McDunnough 1932	0	0	0	0	3	7	6	8	3	5	0	32
Baetisca	sp.		0	0	0	0	0	0	2	0	0	0	0	2
Caenidae-small square-gilled mayflies														
Caenis	*amica*	Hagen 1861	0	0	0	0	0	0	0	0	2	0	0	2
Caenis	*latipennis*	Banks 1907	0	0	0	0	1	0	0	0	29	1	49	80
Caenis	*punctata*	McDunnough 1931	0	0	0	0	0	0	0	0	2	0	0	2
Caenis	sp.		4	0	0	0	0	0	1	5	0	0	0	10
**Sparbarus*	*maculatus*	(Berner 1946)	0	0	0	0	1	0	0	0	0	0	0	1
Ephemerellidae-spiny crawler mayfly														
Ephemerella	*invaria*	(Walker 1853)	0	0	0	0	0	0	5	4	0	0	0	9
Ephemerella	*subvaria*	McDunnough 1931	0	0	0	0	0	0	6	0	1	0	0	7
Ephemerella	sp.		0	0	0	0	0	0	9	0	0	0	0	9
Eurylophella	*bicolor*	(Clemens 1913)	0	0	0	1	4	0	0	0	0	0	0	5
Eurylophella	*lutulenta*	(Clemens 1913)	0	0	0	0	0	0	8	0	1	10	0	19

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Eurylophella	cf. *minimella*	(McDunnough 1931)	0	0	0	0	15	1	0	0	0	0	0	16
Eurylophella	*temporalis*	(McDunnough 1924)	0	0	0	3	0	0	1	29	0	0	0	33
Eurylophella	sp.		0	0	0	0	0	0	13	0	0	0	0	13
Ephemeridae-burrowing mayfly														
Ephemera	sp.		0	0	0	0	0	0	0	0	0	1	0	1
Hexagenia	*limbata*	(Serville 1829)	0	0	0	0	0	0	0	0	0	1	0	1
Heptageniidae-flat-headed mayfly														
Leucrocuta	*hebe*	(McDunnough 1924)	0	0	27	0	0	0	0	0	0	0	0	27
Leucrocuta	sp.		0	0	2	0	0	0	0	0	0	0	0	2
Maccaffertium	*exiguum*	(Traver 1933)	0	0	8	10	4	0	0	0	10	0	0	32
Maccaffertium	*terminatum*	(Walsh 1862)	0	0	3	6	2	0	0	0	15	0	0	26
Maccaffertium	*vicarium*	(Walker 1853)	4	3	10	5	6	1	3	0	0	0	0	32
Maccaffertium	sp.		0	0	0	0	4	0	0	0	0	0	0	4
Stenacron	*interpunctatum*	(Say 1839)	4	0	3	2	7	0	8	2	10	0	0	36
**Stenacron*	*minnetonka*	(Daggy 1945)	0	0	0	0	0	0	0	1	0	0	0	1
Stenacron	sp.		0	0	0	0	0	0	0	0	0	2	0	2
Stenonema	*femoratum*	(Say 1823)	0	0	0	0	0	0	7	5	2	7	0	21
Leptohyphidae-triangle-gill mayfly														
Tricorythodes	sp.		0	0	0	0	1	0	0	0	7	0	0	8
Leptophlebiidae-prong-gilled mayfly														
Leptophlebia	*cupida*	(Say 1823)	0	0	0	0	0	1	0	0	0	0	0	1
Leptophlebia	sp.		0	0	0	0	1	0	6	3	0	0	0	10
Paraleptophlebia	sp.		0	0	0	2	0	0	0	0	0	0	0	2
Metretopodidae-cleft-footed minnow mayfly														
Siphloplecton	*basale*	(Walker 1853)	0	0	0	4	0	0	0	0	0	0	0	4
Siphlonuridae-primitive minnow mayfly														
Siphlonurus	*quebecensis*	(Provancher 1878)	0	0	0	0	1	0	0	0	0	0	0	1
Siphlonurus	sp.		0	0	0	0	2	0	0	0	0	0	0	2
Plecoptera-stoneflies														
Nemouridae-forest flies														
Prostoia	*completa*	(Walker 1852)	0	0	0	1	62	27	0	0	0	0	0	90

Genus	Species	Authority and Year of Description	Otter Cr. 61671	Otter Cr. 61673	Shalda Cr. 61674	Shalda Cr. 61675	Crystal R. E 61676	Crystal R. W 61677	Platte R. 61229	Platte R. 61678	Platte R. 61734	Loon L. 61737	Mud L. 61735	Total
Perlidae-summer predatory stoneflies														
Acroneuria	*lycorias*	(Newman 1839)	0	0	2	3	22	0	0	0	0	0	0	27
Paragnetina	*media*	(Walker 1852)	0	0	8	1	2	0	0	0	0	0	0	11
Perlesta	*ephelida*	Grubbs & DeWalt 2012	0	0	0	2	10	0	0	1	41	0	0	54
Perlesta	sp.		0	0	0	0	0	1	0	0	0	0	0	1
Perlodidae-spring predatory stoneflies														
Isoperla	*frisoni*	Illies 1966	0	0	0	1	13	0	0	0	0	0	0	14
Taeniopterygidae-large winter stoneflies														
Taeniopteryx	*parvula*	Banks 1918	0	0	0	0	0	1	0	0	0	0	0	1
Trichoptera														
Glossosomatidae-saddlecase caddisflies														
Glossosoma	*nigrior*	Banks 1911	0	0	16	0	0	0	0	0	0	0	0	16
Helicopsychidae-snailcase caddisflies														
Helicopsyche	*borealis*	Hagen 1861	10	0	3	1	0	0	0	0	1	0	2	17
Hydropsychidae-net-spinning caddisfly														
Cheumatopsyche	*analis*	Banks 1903	0	0	1	2	0	0	0	0	6	0	0	9
Cheumatopsyche	*campyla*	Ross 1938	0	0	0	0	1	0	2	0	88	6	7	104
Cheumatopsyche	*gracilis*	Banks 1899	0	0	0	0	5	0	0	0	0	0	0	5
Cheumatopsyche	*oxa*	Ross 1938	0	0	0	3	9	0	0	0	0	0	0	12
Cheumatopsyche	sp.		7	3	7	6	11	1	40	13	17	88	10	203
**Hydropsyche*	*alhedra*	Ross 1939	0	0	1	0	0	0	0	0	0	0	0	1
Hydropsyche	*betteni*	Ross 1938	12	10	12	7	14	1	0	0	0	0	0	56
Hydropsyche	*morosa*	Hagen 1861	0	0	0	0	0	0	17	0	1	1	0	19
Hydropsyche	*bronta*	Ross 1938	0	0	6	0	1	0	0	0	0	0	0	7
Hydropsyche	*morosa* group		0	0	16	0	11	0	4	0	0	0	0	31
Hydropsyche	*simulans*	Ross 1938	0	0	0	0	0	0	2	2	33	0	3	40
Hydropsyche	*slossonae*	Banks 1905	3	0	0	0	0	0	0	0	0	0	0	3
Hydropsyche	*sparna*	Ross 1938	0	0	4	1	0	0	0	0	0	0	1	6
**?Hydropsyche*	cf. *walkeri*	Betten & Mosely 1940	0	0	1	0	0	0	0	0	0	0	0	1
Hydropsyche	sp.		0	0	3	0	4	0	0	0	0	0	0	7

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Hydroptilidae-micro-caddisflies														
Agraylea	*multipunctata*	J Curtis 1834	0	0	0	0	0	0	0	0	0	3	91	94
**Hydroptila*	*amoena*	Ross 1938	0	0	0	0	0	0	0	0	0	2	0	2
Hydroptila	*hamata*	Morton 1905	0	0	0	0	0	0	1	0	12	49	2	64
Hydroptila	*waubesiana*	Betten 1934	0	0	0	0	0	0	0	0	1	1	0	2
Hydroptila	sp.		0	0	0	0	0	0	0	0	7	0	0	7
Ithytrichia	*clavata*	Morton 1905	0	0	0	0	0	0	0	0	75	125	14	214
Ithytrichia	sp.		0	0	0	0	0	0	0	0	4	0	0	4
Orthotrichia	*aegerfasciella*	(Chambers 1873)	0	0	0	0	0	0	0	0	0	33	3	36
**Oxyethira*	*coercens*	Morton 1905	0	0	0	0	0	0	0	0	2	3	0	5
Oxyethira	*forcipata*	Mosely 1934	0	0	0	0	0	0	0	0	0	1	0	1
Oxyethira	*grisea*	Betten 1934	0	0	0	0	0	0	0	0	56	49	0	105
Oxyethira	*michiganensis*	Mosely 1934	0	0	0	0	0	0	0	0	0	1	0	1
**Oxyethira*	*pallida*	Banks 1904	0	0	0	0	0	0	0	0	1	3	0	4
Oxyethira	*serrata*	Ross 1938	0	0	0	0	0	0	0	0	4	1	0	5
Oxyethira	*zeronia*	Ross 1941	0	0	0	0	0	0	0	0	0	18	0	18
Oxyethira	sp.		0	0	0	0	0	0	0	0	0	21	3	24
Lepidostomatidae-lepidostomatid case making caddisflies														
Lepidostoma	*togatum*	Hagen 1861	0	0	0	0	1	0	0	0	0	0	0	1
Lepidostoma	sp.		0	0	0	0	2	0	0	0	0	0	0	2
Leptoceridae														
Ceraclea	*alagma*	Ross 1938	0	0	0	0	0	0	0	0	9	25	9	43
Ceraclea	*cancellata*	Betten 1934	0	0	0	0	0	0	0	0	0	0	1	1
Ceraclea	*diluta*	Hagen 1861	0	0	0	0	0	0	0	0	0	1	4	5
**Ceraclea*	*maculata*	Banks 1899	0	0	0	0	0	0	0	0	4	0	0	4
Ceraclea	*tarsipunctata*	Vorhies 1909	0	0	0	0	0	0	0	0	1	15	1	17
Ceraclea	*transversa*	Hagen 1861	0	0	0	0	0	0	0	0	6	15	0	21
Ceraclea	sp.		0	0	0	0	0	0	0	0	5	0	0	5
Leptocerus	*americanus*	Banks 1899	0	0	0	0	0	0	0	0	3	15	5	23
Mystacides	*interjectus*	Banks 1914	0	0	0	0	0	0	0	0	24	120	60	204
Mystacides	*sepulchralis*	Walker 1852	0	0	0	0	3	0	9	0	2	50	0	64

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Nectopsyche	*diarina*	Ross 1944	0	0	1	0	0	0	0	0	1	9	10	21
Nectopsyche	sp.		0	0	0	0	0	0	0	0	2	15	0	17
Oecetis	*avara*	Banks 1895	0	0	0	1	0	0	0	0	23	23	3	50
Oecetis	*cinerascens*	Hagen 1861	0	0	0	0	0	0	0	0	0	11	10	21
**Oecetis*	*ditissa*	Ross 1966	0	0	0	0	0	0	0	0	0	0	1	1
Oecetis	*inconspicua*	Walker 1852	0	0	0	0	0	0	0	0	4	81	18	103
Oecetis	*osteni*	Milne 1934	0	0	0	0	0	0	0	0	0	1	0	1
Oecetis	*persimilis*	Banks 1907	0	0	0	0	0	0	0	0	0	12	0	12
Oecetis	sp.		0	0	2	2	0	0	0	0	1	0	5	10
Setodes	*oligius*	Ross 1938	0	0	0	0	0	0	0	0	40	22	3	65
Triaenodes	*aba*	Milne 1935	0	0	0	0	0	0	0	0	0	1	0	1
Triaenodes	*dipsius*	Ross 1938	0	0	0	0	0	0	0	0	8	0	0	8
Triaenodes	*ignitus*	Walker 1852	0	0	0	0	0	0	0	0	2	0	0	2
Triaenodes	*injustus*	Hagen 1861	0	0	0	0	0	0	0	0	8	30	25	63
Triaenodes	*tardus*	Milne 1934	0	0	0	0	0	0	0	0	1	8	1	10
Triaenodes	sp.		0	0	1	0	0	0	0	0	1	0	0	2
Limnephilidae-northern casemaking caddisflies														
Anabolia	*bimaculata*	Walker 1852	0	0	0	0	0	0	0	0	0	4	1	5
Anabolia	*consocia*	(Walker 1852)	0	0	0	0	0	0	0	0	3	1	0	4
**Anabolia*	*sordida*	Hagen 1861	0	0	0	0	0	0	0	0	0	0	3	3
Anabolia	sp.		0	0	0	1	0	0	0	0	0	1	0	2
Grammotaulius	sp.		5	0	0	0	0	0	0	0	0	0	0	5
Platycentropus	*radiatus*	Say 1824	1	0	0	2	0	1	0	0	0	0	0	4
Platycentropus	sp.		0	0	0	2	1	2	0	0	2	0	4	11
Pycnopsyche	guttifera	Walker 1852	0	0	2	0	3	0	0	0	3	0	0	8
Pycnopsyche	lepida	Hagen 1861	0	0	0	0	0	0	0	0	2	0	0	2
Pycnopsyche	sp.		1	1	2	2	1	0	1	1	2	2	0	13

Genus	Species	Authority and Year of Description	Otter Cr. 61671	Otter Cr. 61673	Shalda Cr. 61674	Shalda Cr. 61675	Crystal R. E 61676	Crystal R. W 61677	Platte R. 61229	Platte R. 61678	Platte R. 61734	Loon L. 61737	Mud L. 61735	Total
Molannidae-hoodcase making caddisflies														
Molanna	*tryphena*	Betten 1934	0	0	0	3	2	0	0	0	0	0	0	5
**Molanna*	*ulmerina*	Navas 1934	0	0	0	0	0	0	0	0	0	3	0	3
Molanna	*uniophila*	Vorhies 1909	0	0	0	0	0	0	0	0	1	1	0	2
Molanna	sp.		0	2	1	1	2	0	0	0	0	1	0	7
Philopotamidae-fingernet caddisfly														
Chimarra	*aterrima*	Hagen 1861	0	0	12	2	0	0	0	0	0	0	0	14
Chimarra	*feria*	Ross 1941	0	0	4	0	0	0	0	0	0	0	0	4
Chimarra	*obscura*	Walker 1852	0	7	14	14	23	0	0	1	21	0	0	80
Chimarra	sp.		0	0	12	0	0	0	0	0	0	0	0	12
Phryganeidae-giant case caddisflies														
Ptilostomis	*angustipennis*	Hagen 1873	0	0	0	0	0	0	0	0	0	1	0	1
Ptilostomis	*ocellifera*	Walker 1852	0	0	0	1	0	0	0	0	2	3	4	10
Ptilostomis	*postica*	Walker 1852	0	0	0	0	0	0	0	0	0	1	0	1
Ptilostomis	sp.		0	1	0	1	0	2	0	1	2	0	0	7
Polycentropodidae-trumpetnet caddisflies														
Holocentropus	*interruptus*	Banks 1914	0	0	0	0	0	0	0	0	0	0	2	2
Neureclipsis	*crepuscularis*	(Walker 1852)	0	0	0	4	0	0	4	0	9	4	5	26
**Neureclipsis*	*piersoni*	Frazer & Harris 1991	0	0	1	1	0	0	1	0	2	5	0	10
Neureclipsis	sp.		0	0	0	5	3	1	9	4	12	16	0	50
Nyctiophylax	*affinis*	(Banks 1897)	0	0	0	0	0	0	0	0	0	0	1	1
**Nyctiophylax*	*serratus*	(Lago & Harris 1985)	0	0	0	0	0	0	0	0	0	0	1	1
Nyctiophylax	sp.		0	0	0	0	0	0	0	0	3	0	40	43
Plectrocnemia	*cinerea*	Hagen 1861	0	0	0	0	1	0	0	0	2	50	9	62
Plectrocnemia	sp.		0	0	0	0	1	0	0	0	0	0	0	1
Polycentropus	sp.		0	0	0	1	0	0	0	0	6	0	0	7
Psychomyiidae-nettube caddisflies														
Lype	*diversa*	Banks 1914	0	0	3	12	6	0	0	0	2	0	0	23
Psychomyia	*flavida*	Hagen 1861	0	0	13	0	0	0	0	0	0	0	0	13
Sericostomatidae-bushtailed casemaking caddisflies														
**Agarodes*	*distinctus*	Ulmer 1905	0	0	0	0	0	0	0	0	0	3	1	4

Uenoidae-uenoid stonecase makers																
Neophylax	*oligius*	Ross 1938		0	0	2	0	20	0	0	0	0	0	0	22	
			Total Specimens	57	27	234	150	293	51	173	90	688	983	412	3158	%
			Ephemeroptera	6	1	9	13	16	5	13	11	13	8	1	35	29.9
			Plecoptera	0	0	2	5	5	3	0	1	1	0	0	6	5.1
			Trichoptera	7	6	20	16	16	5	9	6	40	45	33	76	65.0
			EPT Taxa	13	7	31	34	37	13	22	18	54	53	34	117	100

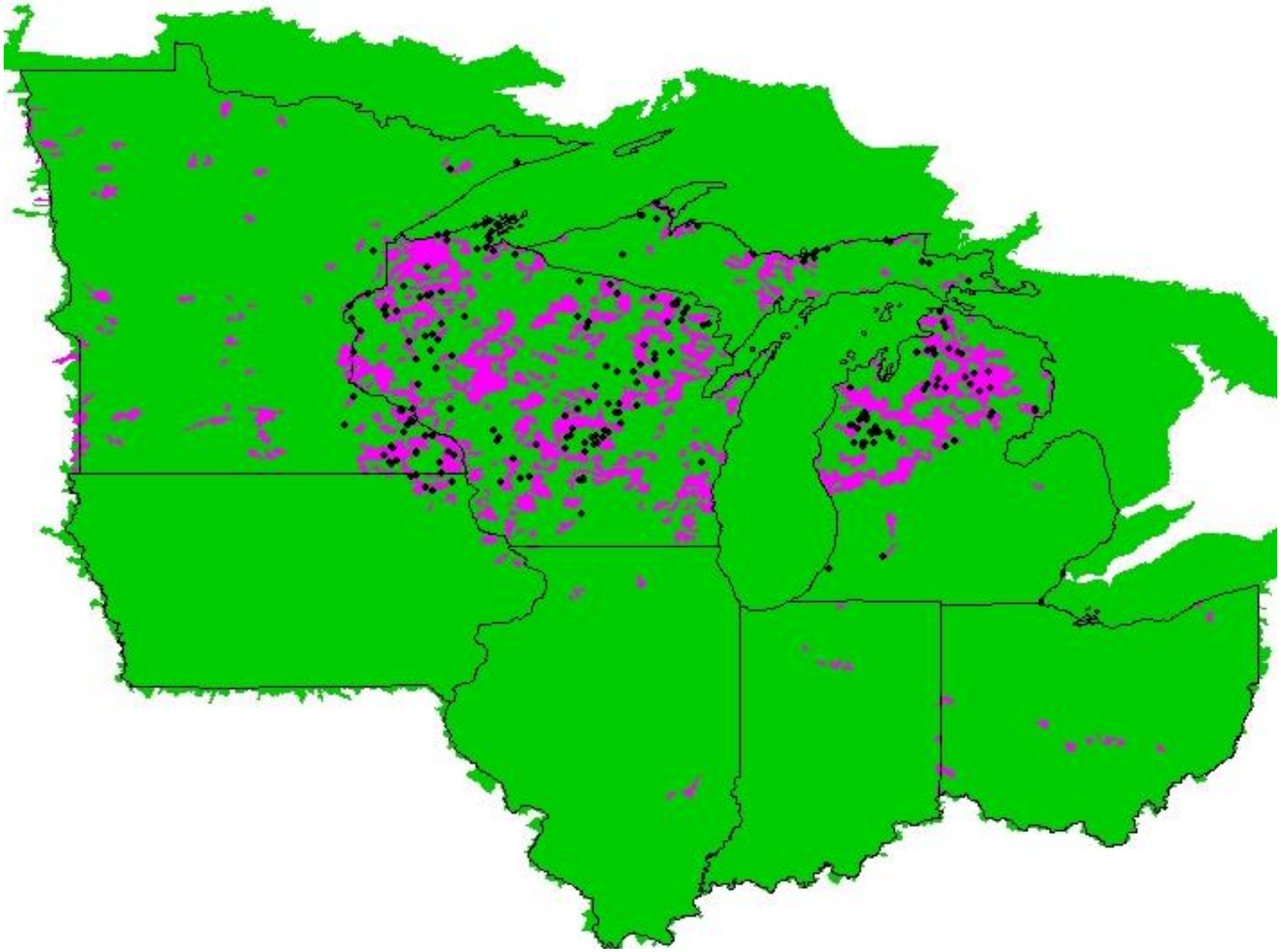

Fig. 1. Maximum Entropy presettlement distribution for *Brachycentrus americanus* (Banks 1899) (Trichoptera) in a seven state Midwest, USA region.

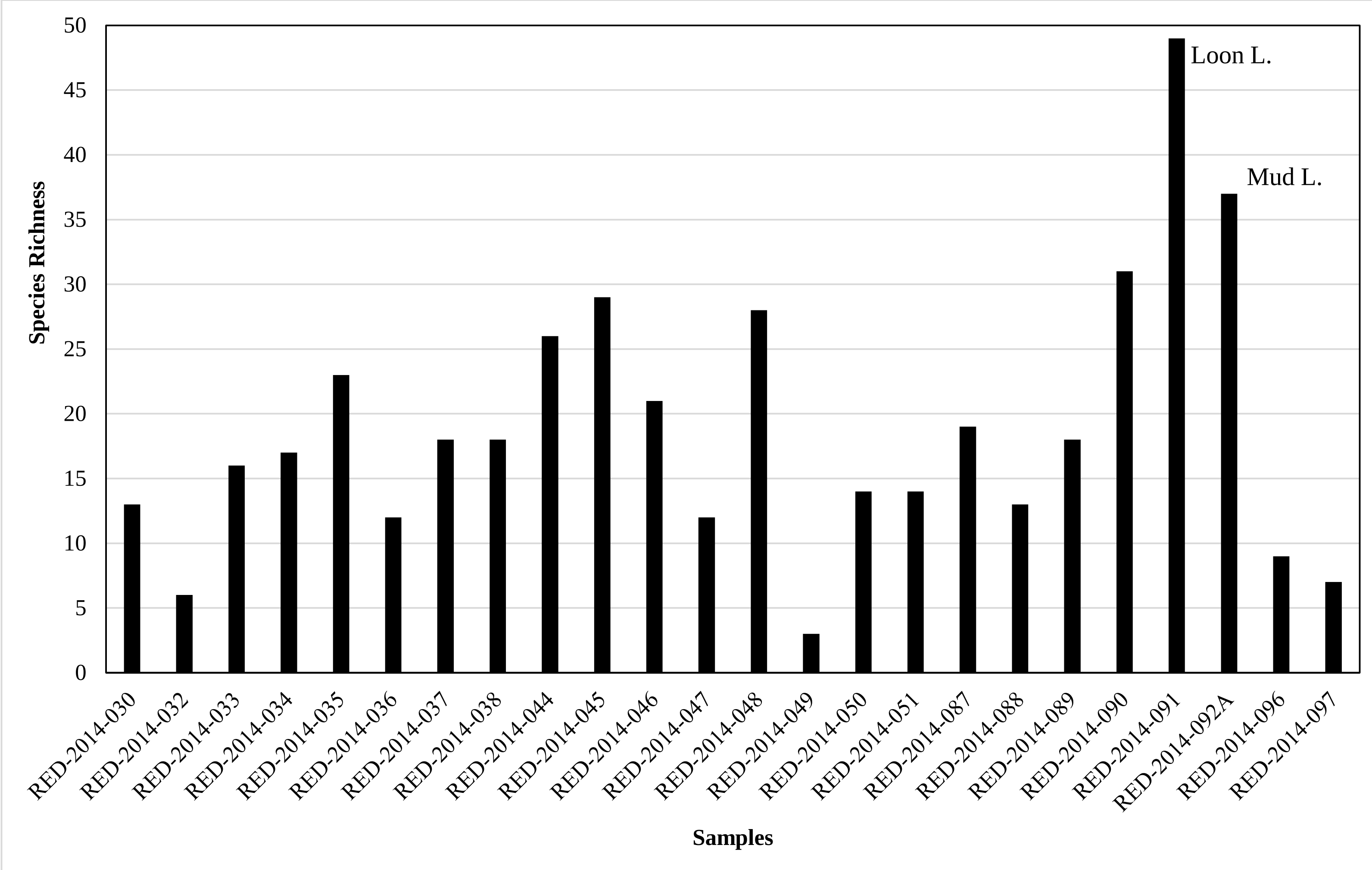

Fig. 2. EPT species richness by sample from Sleeping Bear Dunes National Lakeshore. Codes on X axis are field notebook numbers for consecutive site/date collection events.

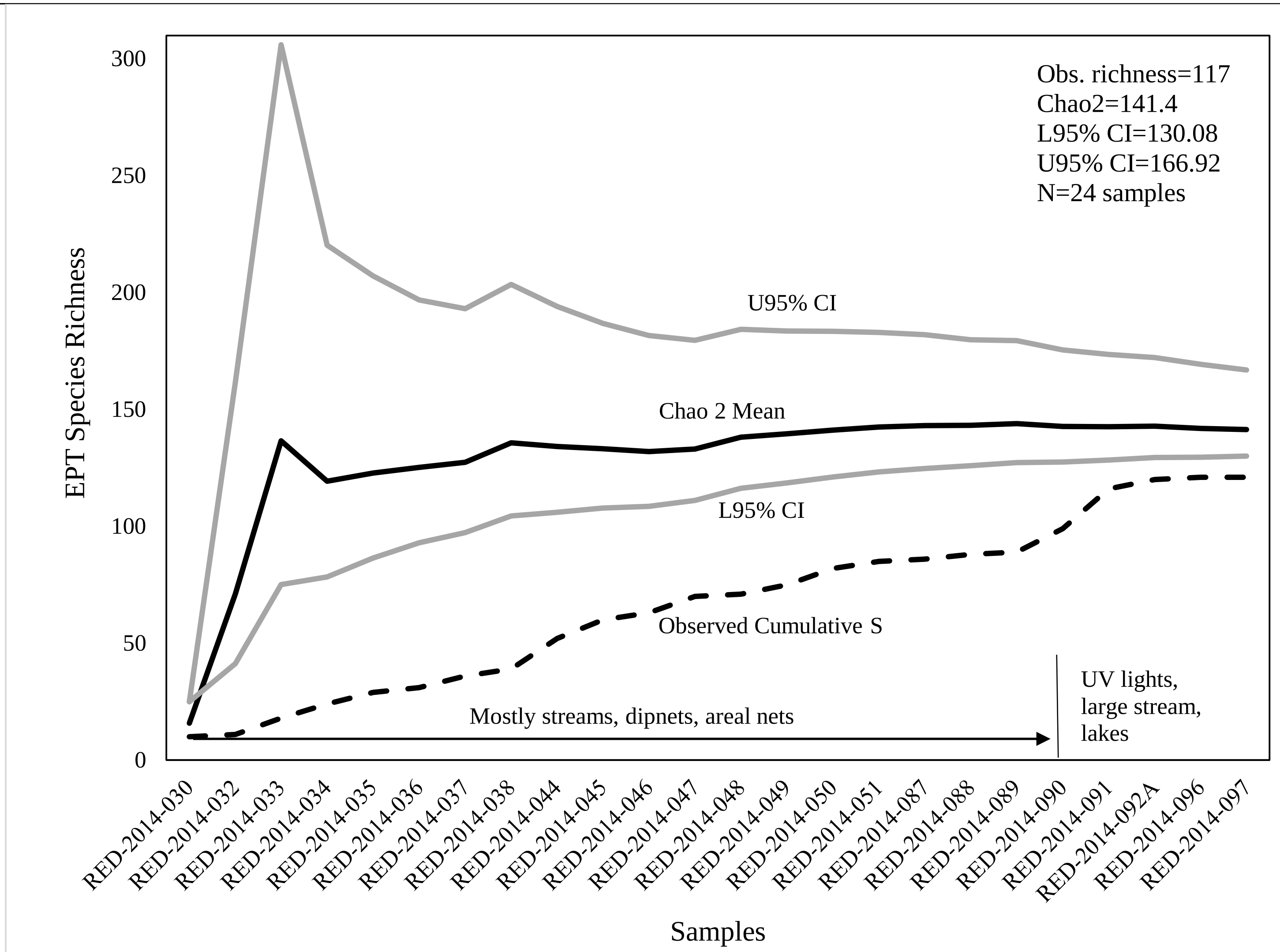

Fig. 3. EstimateS EPT species richness estimates based on samples from Sleeping Bear Dunes National Lakeshore. Codes on X axis are field notebook numbers for consecutive site/date collection events.

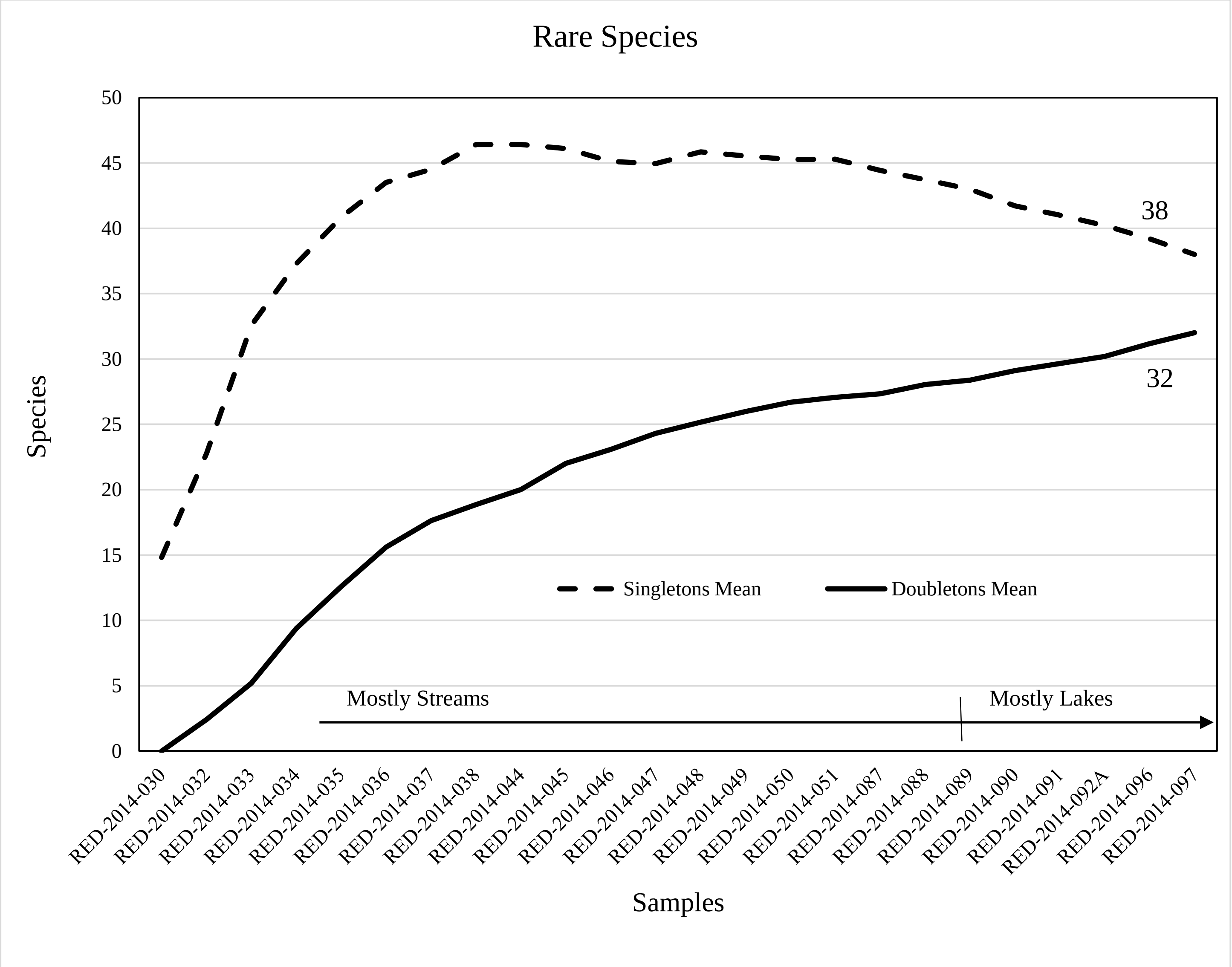

Fig. 4. EstimateS EPT rare species richness estimates based on samples from Sleeping Bear Dunes National Lakeshore. Codes on X axis are field notebook numbers for consecutive site/date collection events.

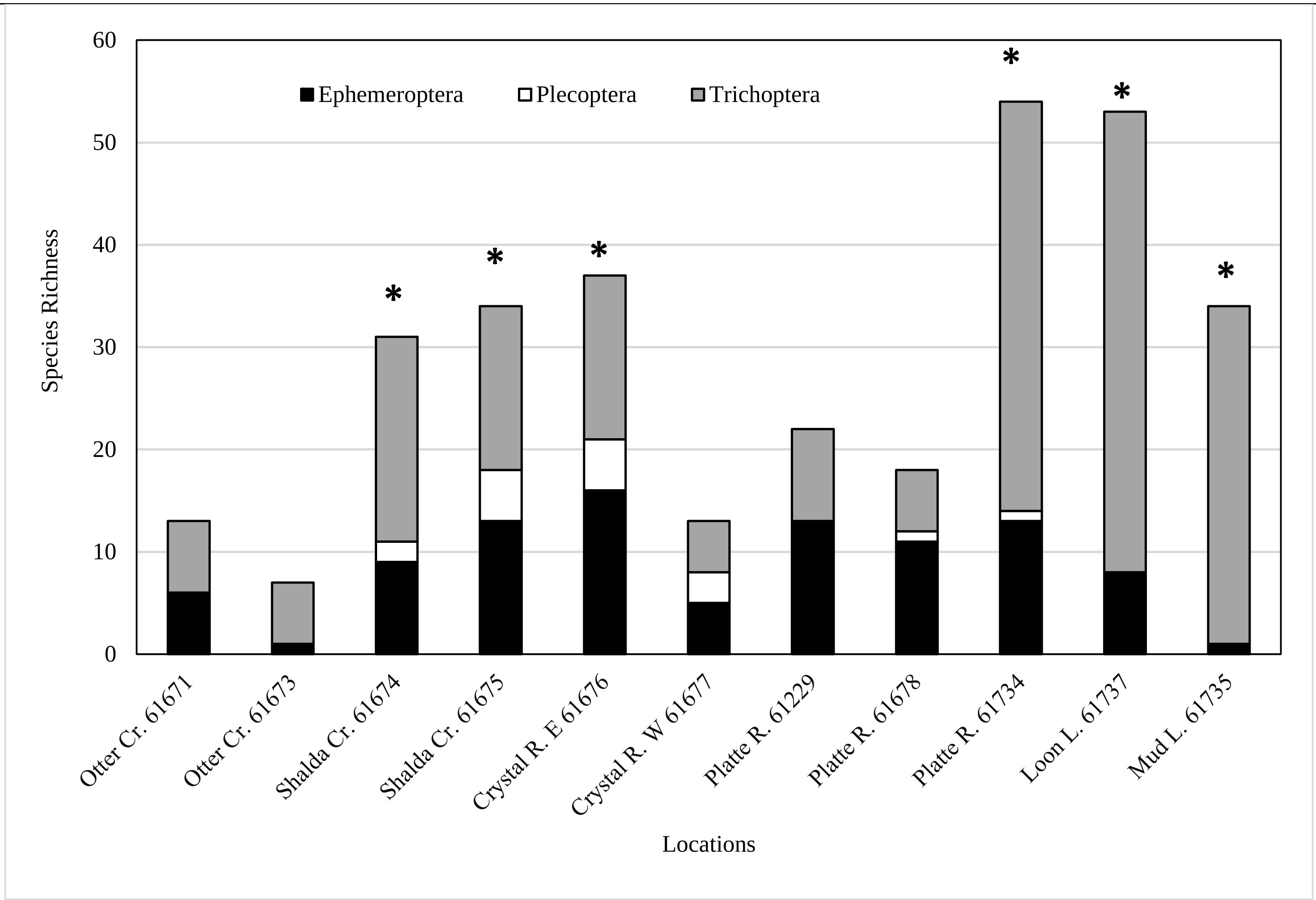

Fig. 5. Observed EPT species richness for unique locations in Sleeping Bear Dunes National Lakeshore. Labels on X axis are waterbody names. Five digit numbers following them are location codes found in Excel worksheet named "Locations".