

Optimizing Fishing Time: One vs. Two-Night Fyke Net Sets in Great Lakes Coastal Systems

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ABSTRACT. *Synoptic surveys of fish assemblages captured using fyke nets typically use a soak time of one night. We questioned whether enough information was gained from maintaining the nets for a second night to justify both the additional effort and the resulting reduction in sites sampled per field season. We compared fyke net catches from one-night and two-night sets at Great Lakes coastal margin ecosystems. Re-setting nets for a second night increased species richness by an average (\pm SE) of $12 \pm 0.06\%$. This translated to an average of 2.5 ± 0.25 additional species captured. Ordinations of the assemblage data revealed that one-night and two-night catches from the same site (catch pairs) were much more similar to each other than were catches from different sites: the Kendall's kappa concordance values between one-night catches and their two-night pairs measured along the first three ordination axes were 80%, 88%, and 87%, respectively. Catch pairs plotted more closely, Sorensen's distances were smaller, and assemblages were much more concordant than were pairs of catches randomly selected from different sites. Bootstrap analyses of catch species richness indicated that there was little difference between adding effort by increasing soak time versus adding effort by increasing the number of nets. Our data indicate that one- and two-night sets generally produce comparable assemblage data. For synoptic studies, the increase in statistical power gained by increasing the number of sites sampled will typically be more important than the moderate amount of additional information acquired by fishing sites for a second night.*

INDEX WORDS: *Great Lakes Environmental Indicators project, coastal wetlands, fish assemblages, sampling effort, study design, sampling methods.*

INTRODUCTION

Great Lakes coastal areas are utilized by many Great Lakes fishes (Jude and Pappas 1992, Minns *et al.* 1994). These habitats are also the areas most subject and sensitive to the effects of anthropogenic pressures of development and pollution. Recently, there has been increased interest in monitoring the coastal zones, both to determine their condition and

to provide baseline information against which to track anthropogenic impacts on coastal habitats and adjacent coastal watersheds (U.S. EPA 2003). The Great Lakes Environmental Indicators project (GLEI; <http://glei.nrri.umn.edu>), of which this research is part, was one of several research consortia created to assess anthropogenic stressor-biological response relationships and develop quantitative indicators of coastal environmental conditions. The research reported here focuses on aspects of sampling fish assemblages in the shallow coastal areas of the U.S. Great Lakes.

The standard methods of censusing fishes in open

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water areas (trawling, gill netting, hydroacoustics) are of limited use in shallow areas with complex habitat structure that characterizes coastal margins; furthermore, these methods can be destructive to fish. Seine netting is effective only when substrates are even and macrophytes are absent. Although electrofishing is effective (Weaver *et al.* 1993, Thoma 1999, Chow-Fraser *et al.* 2006), specialized equipment and training are required. Night-time electrofishing has been recommended (Thoma 1999), but it poses a significant logistical and safety challenge. Consequently, passive traps, cages, and nets are the alternative equipment of choice in wetlands and coastal margins. Fyke nets are often used to sample shallow-water fish assemblages even though this gear is selective for certain species (e.g., fish active in shallow waters; cover-seeking species; phytophilic taxa; Barthelmes and Doering 1996, Hubert 1996, Thoma 1999, Chow-Fraser *et al.* 2006). Despite their biases, fyke nets offer the advantages of being functional in moderately dense vegetation and areas laden with obstacles that would interfere with operation of trawls or seines. Furthermore, fyke nets result in much lower mortality than gill nets (Hubert 1996), and are more effective than minnow traps (Weaver *et al.* 1993).

There is limited available guidance on the fyke net effort required to representatively sample the fish assemblage, perhaps because the effort required varies greatly depending on habitat type, size of the targeted areas, and sampling goals (Thoma 1999, Chow-Fraser *et al.* 2006). Biodiversity surveys (e.g., Barthelmes and Doering 1996, Weaver *et al.* 1993, Fago 1998) attempt to capture all taxa in an area. This requires more intense sampling and assessment of more habitats than synoptic surveys. Synoptic surveys capture the most important aspects of a fish assemblage using consistent, unbiased methods in order to compare the common fish among a large number of sites. A common example is IBI-type sampling (e.g., Brazner and Beales 1997, Drake and Pereira 2002, Uzarski *et al.* 2005, Seilheimer and Chow-Fraser 2007). Thus, considerations incorporated in the design of synoptic studies include allocation of effort within versus among sampling locations and crew effort. Many agencies and groups performing synoptic surveys set fyke nets for a single night (e.g., Minnesota DNR 1993, Baker *et al.* 1997, Uzarski *et al.* 2005, Chow-Fraser *et al.* 2006). We wondered whether setting nets for a second night would significantly increase our information about fish assemblages of Great Lakes shallow coastal areas.

We compared results of one- versus two-night fyke net deployments in Great Lakes coastal areas, and addressed the implications on the fish assemblage data as well as the logistical trade-offs of these two levels of effort. Our primary question is: does a two-night fyke net soak time provide significantly more information about fish assemblages than a one-night soak time? If so, what are the impacts on the cost of data acquisition and on the total number of sites that can be sampled in a field season?

METHODS

Sampling

Fish were sampled along the U.S. coastline of the five Great Lakes in wetlands, embayments, and at high-energy shorelines with anthropogenic disturbance ranging from least affected by human activity to highly modified. Site selection rationale and methodology for the GLEI project has been described in detail elsewhere (Danz *et al.* 2005). Sample sites were classified into five hydrogeomorphic types including three types of Great Lakes coastal wetlands: protected ($n = 10$), riverine ($n = 14$), and open coastal ($n = 12$) (after Keough *et al.* 1999), embayments (shoreline indentations whose depth was greater than the width at the mouth, having less than two sub-embayments, and a size between 1 km² and 20 km²; $n = 6$), and high-energy shorelines (unvegetated, unprotected areas exposed to the open lake, such as sand and rock beaches; $n = 7$).

This analysis is based on 49 sites at which nets were set for two consecutive nights and at which net effort on the first night was equal to net effort on the second night (i.e., the same number of nets fished at a site without incident on both nights). Sampling was conducted from mid-June through mid-September, 2002 and 2003, to avoid most of the spawning migrations. At each site, four large fyke nets and four small fyke nets were set. Large fyke nets had a 7.5 m lead approximately 0.9 m deep with two 3 m long and 0.9 m deep wings, two 0.9 × 1.2 m rectangular frames and five 0.75 m diameter hoops; mesh size was 12 mm on the net, but 4 mm on wings and leads. Small fyke nets had a 7.5 m lead approximately 0.45 m deep with two 3 m long and 0.45 m deep wings, two 0.45 × 0.75 m rectangular frames and five 0.45 m diameter hoops; mesh size was 4 mm.

In wetlands, and in embayments where shoreline slope was shallow, nets were set as arrays, with two

fyke nets of the same size set lead-to-lead and parallel to shore or along similar depth contours. At high-energy sites with steep shorelines, nets were set individually and perpendicular to the shoreline and depth contours. In either case, four large and four small nets were set for two consecutive nights at each site. Wings were attached to the initial frame at a 45 degree angle for parallel sets; there were no wings on perpendicular sets. Nets or arrays were set to sample the two most dominant shoreline land-use types found at a site, or to sample as much of the site area as possible when the land use was homogeneous. Nets or arrays were set as pairs, with a large and a small net or array set near each other whenever possible. This allowed each land-use type to be sampled by both a large and a small net or array. Small nets were set in 0.25 to 0.5 m water depths; large nets were set in water 0.5 to 1 m deep.

Nets were held in place using fence posts driven 30–60 cm into the substrate, anchored using rocks, or a combination of bracing fence posts with rocks. Nets were not set when wave energy at exposed sites was high. Collections made from collapsed nets or nets with large holes were not included in the dataset. Nets were checked daily; fish were identified, counted, and released a minimum of 500 m away from the net set area. Nets were re-set for the second night in the same location at all sites.

Statistical Analyses

Fish recovered from all nets were summed to yield a total catch per site per night. Catch data were not transformed, and all fish that could be identified to species, including uncommon species, were used in the analyses. The first night's catch (night one) was compared to the total catch (night one plus night two). (Hereafter, the night-one catch and the total catch at a site are referred to as "catch pairs").

We performed three types of analyses to assess the additional information gained by the second night's set. First, we determined whether the first night's set produced an unbiased estimate of taxonomic richness at a site. Second, we ascertained whether the duration of sampling influenced interpretations of assemblage composition using ordination approaches (PC-ORD version 4.36, McCune and Mefford 1999). Last, we quantified the differences in short- versus longer-duration sampling on assemblage composition at each site by extracting the Sorenson (Bray-Curtis) multivariate distances between catch pairs from the ordination output and

comparing distances between catch pairs versus statistical distances among sites.

Species richness

The potential for species richness bias was evaluated by plotting the night- one catch versus the total catch and using linear regression to compare the resulting slope to a slope of one. Next, we investigated the relative contribution to species richness from the number of nets versus the duration of net sets. We could not make direct comparisons of observed richness per site because of unequal numbers of nets and sampling duration across sites. To deal with the unequal sampling effort across sites, we used a SAS bootstrapping routine to obtain a sampling distribution of richness from repeated random draws of nets at sites, with replacement (SAS Version 9.1. 2002. SAS Institute Inc. Cary, NC). We performed separate random draws for high-energy sites because these nets were set singly, whereas nets at the other site types were set as arrays. A few sites had to be excluded from this analysis due to mixed orientation of sets (nets set as both arrays and parallel sets) or nonstandard net sets for the site type (e.g., nets set as arrays at a high-energy site). Consequently, 5 high-energy sites and 39 wetland and embayment sites were included in the bootstrap analysis (the full set of 49 sites was used for all other analyses). For each high-energy site, the bootstrap run generated 500 draws each of 1, 2, 3, and 4 net pairs (a pair is one large and one small net). Species richness was tallied for each net for the night-one and total catches, and the means and standard errors were calculated and plotted for each net pair draw (of one to four pairs) by night (one or total) combination. Similarly, for wetland and embayment sites, the bootstrap run generated 500 draws each of one and two array pairs (an array pair consists of one large and one small array). Again, species richness was tallied for each array for the night-one and total catches. Means and standard errors were calculated and plotted for each array pair draw (of one to two array pairs) by night (one or total) combination.

Assemblage composition

Relationships among multivariate samples are often ascertained by reducing the dimensionality of the data through ordination analyses. A successful analysis preserves the ordinal relationship (statistical distance) among samples while describing their

position with respect to a smaller number of compound variables that are combinations of the original variables (McCune and Grace 2002). To determine if the ordination of the fish assemblage structures differed strongly between the single-night catch dataset and the total catch (two-night) data set, we performed nonmetric multidimensional scaling (NMS) ordination analyses using PC-ORD for Windows (Version 4.36, McCune and Mefford 1999) on an untransformed dataset consisting of the night-one catch and the total catch for each site. Default settings were used for the analysis, and choices included use of Sorensen's distance measure with a default setting of a three-axis solution and starting coordinates based on a Bray-Curtis ordination. On the two-dimensional ordination plot of the two axes which captured the most variability, we drew lines (vectors) to connect each night-one sample with its total catch counterpart. The expectation was that the closer the members of a pair of points, the greater the concordance between a one-night sample and the total catch. There is complete concordance between the catch pair members if the order of the samples representing night-one catches along each ordination axis perfectly matches the order of the total catch samples. We assessed this by calculating Kendall's kappa (coefficient of concordance; Landis and Koch 1977) for the ordination scores of night-one catches and the total catch samples along each of the three axes derived from NMS analysis.

We also summarized the relative three-dimensional concordance between species collected in night-one and total catch sample pairs using the Sorensen (Bray-Curtis) distance from the NMS ordination distance matrix (the ordination uses ranked distances; thus, concordance is effectively based on comparing the relative abundances between catch pairs). We compared overall concordance between the catch pair distances relative to the distances among sites (all other catches). Relative concordance can be expressed as: concordance = $(1 - \text{mean Sorensen distance}) * 100\%$. This value will therefore range between 0 and 100%, with 100% indicating complete concordance (all point pairs plot on top of each other in the ordination, indicating an exact match of species and abundances) and 0% indicating complete lack of concordance, with all point pairs sharing no species plotting at the maximum possible distance in the ordination matrix. We calculated relative concordance separately for catch pairs and for all other catches, and compared the values.

RESULTS AND DISCUSSION

Species Richness Comparisons

A total of 85 species was collected from 49 sites. Richness ranged from 5 to 25 species, with a mean \pm SE of 11 ± 0.55 species for a one-night set and 13.5 ± 0.69 species for the total two-night set. On average, fyke nets set in wetlands and embayments for two nights captured 14.1 ± 0.7 species while 9.7 ± 1.0 species were captured at high-energy sites. The five dominant species at open coastal wetlands were *Notropis hudsonius* Clinton (spottail shiner), *Ambloplites rupestris* Rafinesque (rock bass), *Dorosoma cepedianum* Lesueur (gizzard shad), *Lepomis macrochirus* Rafinesque (bluegill), and *Notropis atherinoides* Rafinesque (emerald shiner). At protected wetlands, the dominant species were *L. macrochirus*, *Ameiurus melas* Rafinesque (black bullhead), *Cyprinus carpio* Linnaeus (common carp), *Lepomis gibbosus* Linnaeus (pumpkinseed), and *Semotilus atromaculatus* Mitchell (creek chub). Riverine wetlands contained *L. macrochirus*, *Pimephales notatus* Rafinesque (bluntnose minnow), *A. rupestris*, *N. hudsonius*, and *Perca flavescens* Mitchell (yellow perch). *Ambloplites rupestris*, *A. melas*, *Ictalurus punctatus* Rafinesque (channel catfish), *Micropterus dolomieu* Lacepède (smallmouth bass), and *Catostomus commersonii* Lacepède (white sucker) were dominant in embayments. Dominant species at high-energy sites included *N. hudsonius*, *P. flavescens*, *L. gibbosus*, *C. commersonii*, and *N. atherinoides*. Together, these species accounted for 71% by abundance of all fish captured. More detailed analyses of these data are in preparation, and the datasets will be available on a U.S. EPA-sponsored website (linked via <http://glei.nrrri.umn.edu>) in 2008 or from the authors on request.

Species richness from night-one versus total richness was analyzed using linear regression (Fig. 1). The slope of the relationship was $1.19 \pm \text{SE } 0.06$, which is significantly greater than 1.0 ($p = 0.003$; SAS version 9.1), indicating that the second night's catch added 1.19 times more species to richness values, and that the first night's set on average captured 84% ($= 1/1.19$) of the total number of species observed. There was no evidence of nonlinearity, indicating that the night-one relative richness estimates were unbiased across the range of richnesses. On average, 2.5 additional species were added per site by the second night's catch (range 0–8). Although wetland sites generally had higher species richness than high-energy sites, the mean number of

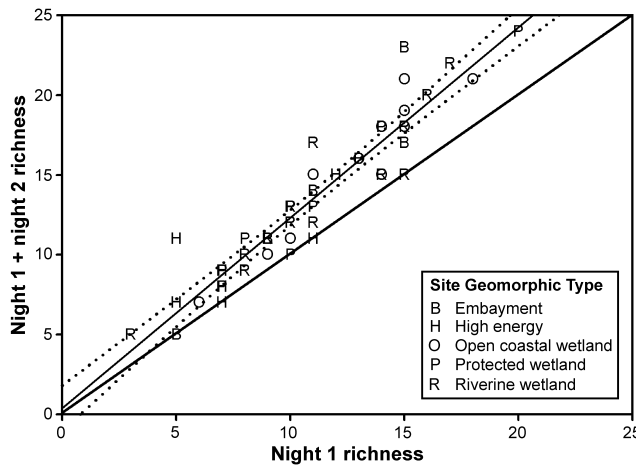


FIG. 1. Scatterplot of night 1 vs. nights 1 + 2 (total) fish species richness using fyke nets set at the same location for either one or two nights. Shown are the 1:1 line and the linear regression line (slope = 1.19) with 95% confidence limits.

additional species gained by adding a second night's set did not differ among the five geomorphic types (ANOVA, $F = 0.48$, $p = 0.74$).

Our bootstrapped estimates of fish species richness indicate that net soak time made little difference in the number of species gained. In general, doubling soak time (number of nights) increased estimated species richness by an average of $1.87 \pm \text{SE } 0.06$, whereas doubling the number of nets increased species richness by an average of $1.39 \pm \text{SE}$

TABLE 1. Mean fish species richness (with standard error in parentheses) from bootstrapping of random draws of fish catches from fyke net pairs or fyke array pairs set for one night or two consecutive nights. HE indicates a high-energy site in which nets were set perpendicular to shore. L-L indicates nets set as arrays in a lead-to-lead fashion (see methods). Each net or array pair consists of one large and one small fyke net or array.

	Mean richness	
	1 night	2 nights
HE 1 net pair	4.17 (1.02)	5.99 (0.84)
HE 2 net pairs	5.73 (1.23)	7.81 (1.01)
HE 3 net pairs	6.54 (1.29)	8.76 (1.10)
HE 4 net pairs	6.99 (1.29)	9.38 (1.16)
L-L 1 array pair	10.56 (0.40)	11.91 (0.53)
L-L 2 array pairs	11.62 (0.47)	13.0 (0.61)

0.04 (Table 1). Thus, hypothetically doubling the soak time from one to two nights added only marginally more species than did hypothetically doubling the number of nets for either high-energy or wetland and embayment sites (Fig. 2). This is similar to the findings of other studies, which have shown that the cumulative numbers of species captured by trap nets and fyke nets increases with increasing soak time, even though proportionately fewer additional individuals are caught each night (Hamley and Howley 1985), as is typical of most collecting efforts (Scheiner 2004).

In theory, adding more nets should increase the ability to sample more habitat types, particularly in wetlands, potentially adding more species. Our data only marginally support this expectation. However, our results may be an artifact of our randomization process, because the pool of species from which samples were drawn represented only the one additional location actually sampled within a wetland or embayment site. In practice, added nets could sample additional habitats that were not sampled in our study, which could capture species unique to those habitats. Nevertheless, these results suggest either that a single night's set captured most of the fish species present in the sampled habitats or that acquiring significantly more additional information about fish assemblages at sites requires a substantial increase in effort per site and may require the addition of other gear types.

Whole Assemblage Comparisons

The first three axes of the NMS ordination accounted for 50% of the variability in the data; the three-dimensional solution was statistically significant ($p = 0.01$), with a final stress of 19.4, indicating that the solution provided significantly more reduction in stress than expected by chance (McCune and Grace 2002). Four of the five sites that plotted most positively on axis 3 are high-energy sites in the northern Great Lakes (Fig. 3). Manuscripts currently in preparation will further explore the patterns in the fish assemblage data. Catch pairs typically fell quite close together in ordination space (Fig. 3; catch pairs connected by lines to produce vectors), partly because the total catch encompassed the night-one catch. Nine catch pairs (18%) had distances greater than one standard deviation from the mean distance among catch pairs; thus, the night-one catch and the total catch were most different for these nine pairs. These nine sites included all geomorphic types and had no obvious unusual

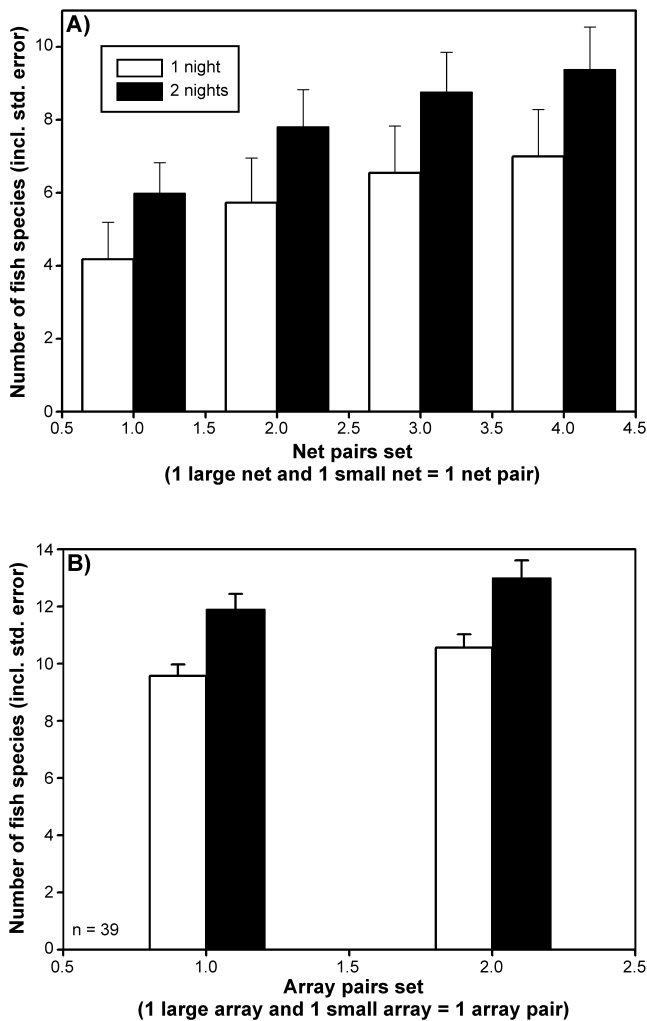


FIG. 2. Additional fish species added by individual pairs of fyke nets set perpendicular to shore at five high-energy sites (A) or as arrays in a lead-to-lead fashion at 39 wetlands and embayment sites (B). Datasets were generated in a bootstrap fashion by randomly drawing 500 catches from the suite of net catches at each site using SAS. Species richness was computed for each net or array for 1 and 2 night sets, then the mean and standard error of the richness for each net pair \times night combination were calculated.

characteristics such as habitat types, land uses surrounding the site, or the amount of human usage of the site. However, changing weather features such as strong wind or notable waves on one of the days may have been responsible for these differences. The same lack of unusual or distinguishing features held true for sites with the most similar catch pairs.

Catch pairs plot so closely together for most sites (Fig. 3) that ordinations based on night-one catch alone and total catch alone have very similar interpretations (ordinations not shown). There was strong and highly significant ($p < 0.0001$) concordance between the order of the night-one catch data points and the corresponding total catch points, with Kendall's kappa values of 0.81, 0.88, and 0.87 for NMS axes 1, 2, and 3, respectively. Kendall's kappa values greater than 0.75 are considered to represent excellent concordance (Landis and Koch 1977). Vectors connecting only two catch pairs intersected (Fig. 3). The lack of intersecting vectors corroborates that relationships among sites changed very little between the night-one and the total catch data.

Another way to investigate catch pair similarity versus among site similarity is to extract Sorensen (Bray-Curtis) distances from the ordination output. Sorensen distances generated by the ordination software provided a matrix of the distance in ordination space between all point pairs (in this case, catches). These distances range between 0 (points plot exactly on top of each other) and one (points are as far apart as possible in ordination space). Sorensen distances between catch pairs (night-one versus total catch) were quite short, only $0.338 \pm \text{SE } 0.024$ and contrasted greatly with distances among any catch (0.915 ± 0.0014 for nets at other sites), indicating that catch pairs were much closer to each other in ordination space than were catches taken at random. To test the degree to which catch pairs corresponded to each other in ordination space relative to catches among sites, we used Sorensen distances between catches to measure mean concordance between catch pairs and mean concordance between all other catches (see methods). On average, catch pairs were 66% concordant whereas catches at different sites were only 9% concordant. This indicates that, as a group, catch pairs were much closer to each other in ordination space than were catches among sites to each other as a group. Thus, we conclude that a single night's catch captures the majority of the assemblage composition pattern from a two-night sampling regime as determined by ordination.

Taken together, the multivariate similarity and high ordinal concordance of catch pairs plotted within the ordination, the low number of intersecting catch pair vectors, and the relatively high index of concordance of catch pairs in ordination space, indicates that one-night and two-night sampling ef-

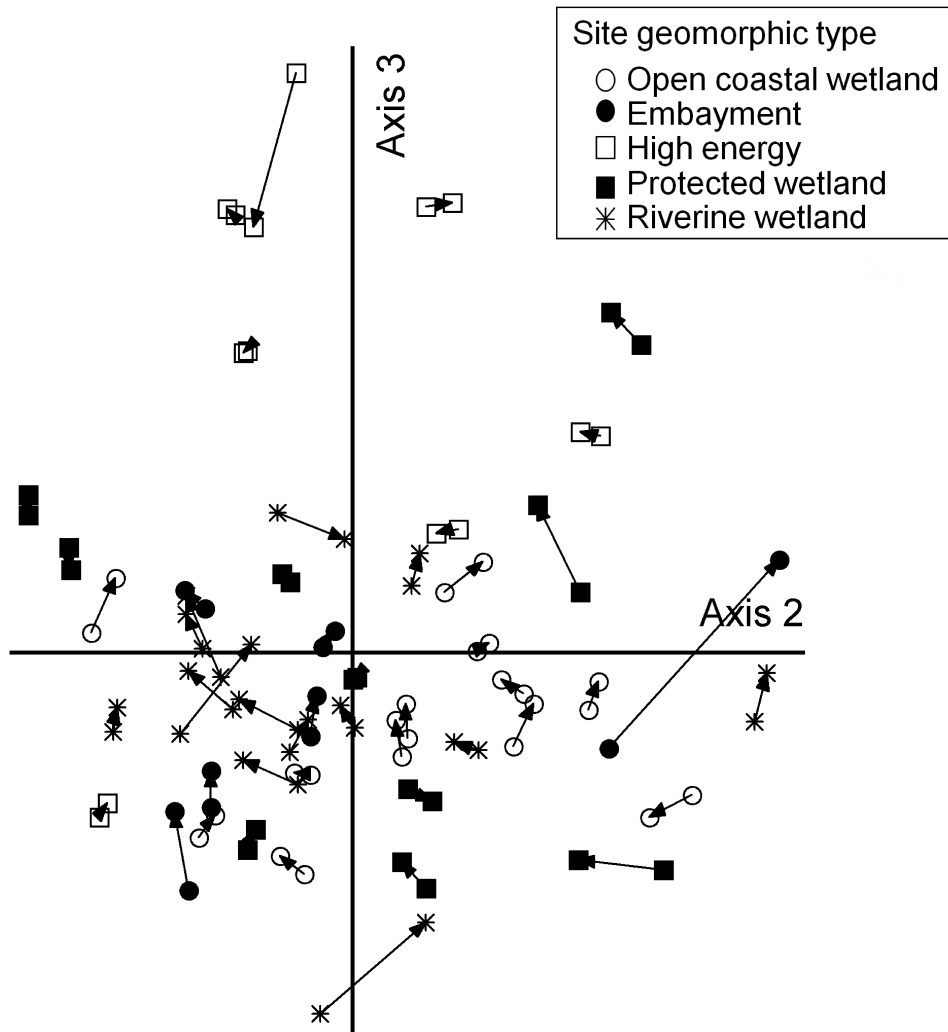


FIG. 3. An NMS ordination of catch pairs, which are fyke nets set for either 1 or 2 nights at the same site; each catch pair represents one unique site. Catch pairs are connected by lines with arrows; the first night's catch is the tail of the arrow, and the total 2-night catch is the tip of the arrow for each site. Arrows are not visible for some catch pairs that plot very close together. The two axes capturing the most variability are shown (17% for axis 2, 21% for axis 3; axis 1 captured 12% of the variability).

forts produce comparable estimates of fish assemblage composition among our sites.

Although longer fyke net soak times catch more species, often much longer soak times are needed to catch species that are either uncommon or not easily captured by trap-type nets. Barthelmes and Doering (1996) report that 20 to 60 nights of fyke net sets were required to catch the full complement of 11–12 species in a small lake (25 ha) in samples taken each of two consecutive springs. However, 45–58% of the total species richness was caught on

the first night, with that percentage reaching only 54–75% by the second or third night. Additional species were added singly and very gradually over the next 20–60 nights (Barthelmes and Doering 1996). Tanner and Brazner (2001) found that 73% of species were caught on the first night with fyke nets set for 4 consecutive nights in Great Lakes coastal wetlands.

We conclude that single-night fyke net sets produce representative and relatively unbiased species assemblage data for sites (given the inherent selec-

tivity of fyke nets). We agree with Hanowski and co-authors (2007, this volume) and many others who have shown that for ecological assessment synoptic sampling, sampling more sites increases the power of a study more than does improving the precision of sampling at fewer sites.

SUMMARY

Synoptic sampling programs often are designed for sampling a large number of sites in a limited amount of time, providing data on the core fish assemblage using consistent, unbiased methods so that the common fish can be compared among a large number of sites. The goals and methods of such programs differ greatly from those that seek to find nearly all taxa, or to accurately sample uncommon taxa. For synoptic-type designs, setting fyke nets for two consecutive nights instead of a single night, as is typical of such surveys, resulted in the capture of 12% more species at a site (2.5 additional fish species averaged over the entire dataset). Species assemblages from the night-one catch and the total combined catch at sites were similar: these catch pairs plotted in similar locations and concordantly on unconstrained ordinations and overall were much closer to each other in ordination space than were net catches randomly paired between sites. Bootstrapping analyses showed that doubling the number of net sets at one time (i.e., increasing the number of locations sampled within a site) was no more effective at capturing additional species than simply re-setting the same number of nets in the same location for an additional night. And neither additional effort greatly increased our information about the fish assemblage at sites or improved our ability to compare sites. Where a synoptic program depends on sampling a large number of sites in a limited amount of time, we conclude that the potential benefits of adding a second night's effort do not yield enough additional information to justify potentially reducing the number of sites that could be sampled in a field season. It is better to sample more sites for one night than fewer sites for two nights.

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