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Monitoring lake populations of Eastern Sand Darter (*Ammocrypta pellucida*): a comparison of two seines

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ABSTRACT

For many imperiled fishes in the Laurentian Great Lakes basin, detection protocols and population monitoring programs are lacking. In this study, we used a repeat-sampling approach to compare the effectiveness of two seines (bag and beach) to detect and characterize the abundance of lake-dwelling populations of Eastern Sand Darter (*Ammocrypta pellucida*); a threatened species in Canada. Compared to the bag seine, the larger beach seine collected a greater number of Eastern Sand Darter and detected the species at more sampling sites. Model-averaged estimates of detection probability were also greater for the beach seine ($p = 0.72$) than bag seine ($p = 0.48$). A decline in catch over repeated seine hauls occurred at less than a third of the sample units. Mean capture probabilities were 0.41 in units sampled by beach seine, and 0.37 in units sampled by bag seine, when depletion occurred. Sizes of Eastern Sand Darter collected by each seine were significantly different, with fewer small (<40 mm total length) individuals found in bag seine hauls. Power analyses indicate that data collected with either seine are expected to detect changes in local distribution of 50% or greater. Power to detect future changes in Eastern Sand Darter abundance of 50% or greater is predicted to be higher for the beach seine, and to increase with the number of seine hauls at a site. Catch differences between seines are interpreted to reflect the greater area sampled by the larger beach seine.

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Sampling; monitoring; endangered species; detection probability; power analysis

Introduction

The Eastern Sand Darter (*Ammocrypta pellucida*) is a small, benthic fish with translucent flesh and an elongate body, almost round in cross-section (Scott 1955). Its occurrence is strongly associated with unsilted sand substrates of streams and rivers, and sandy shoals in lakes (Scott and Crossman 1973; Daniels 1993; O'Brien and Facey 2008). Eastern Sand Darter populations are in decline throughout its North American range, likely in response to habitat degradation associated with agricultural and urban development, the impoundment of free-flowing riverine habitats, and competition with invasive fishes (COSEWIC 2009; Poesch et al. 2010). The species has been assessed as Threatened in Canada (COSEWIC 2016) and Vulnerable in North America (Jelks et al. 2008). In the province of Ontario (Canada), its distribution was formerly considered to be limited to riverine and Laurentian Great Lakes habitats in the southwestern part of the province. Within this part of the species' range, distribution patterns, habitat associations, population genetic structure and

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demographics, and sampling strategies have all been studied (Drake et al. 2008; Finch et al. 2013; Dextrase et al. 2014a, 2014b; Ginson et al. 2015).

In the spring of 2013, Eastern Sand Darter was collected from West Lake, Ontario (a small lake connected to eastern Lake Ontario; Reid and Dextrase 2014). Prior to this record, the known range of this imperiled species consisted of two disjunct elements in eastern North America separated by about 500 km (Figure 1). The southwestern element includes the Ohio River basin and the lower Laurentian Great Lakes drainage and the northeastern element includes St. Lawrence River and Lac Champlain drainages (Scott and Crossman 1973; Lee et al. 1980). The new occurrence is in the middle of these two distributional elements. The discovery of Eastern Sand Darter in West Lake suggests that there may be additional undiscovered populations in the drainages of Lake Ontario and Upper St. Lawrence River in the province of Ontario and New York state (USA). Accordingly, targeted surveys of areas with suitable Eastern Sand Darter habitat have been identified as a priority management action in this region (MNRF 2015).

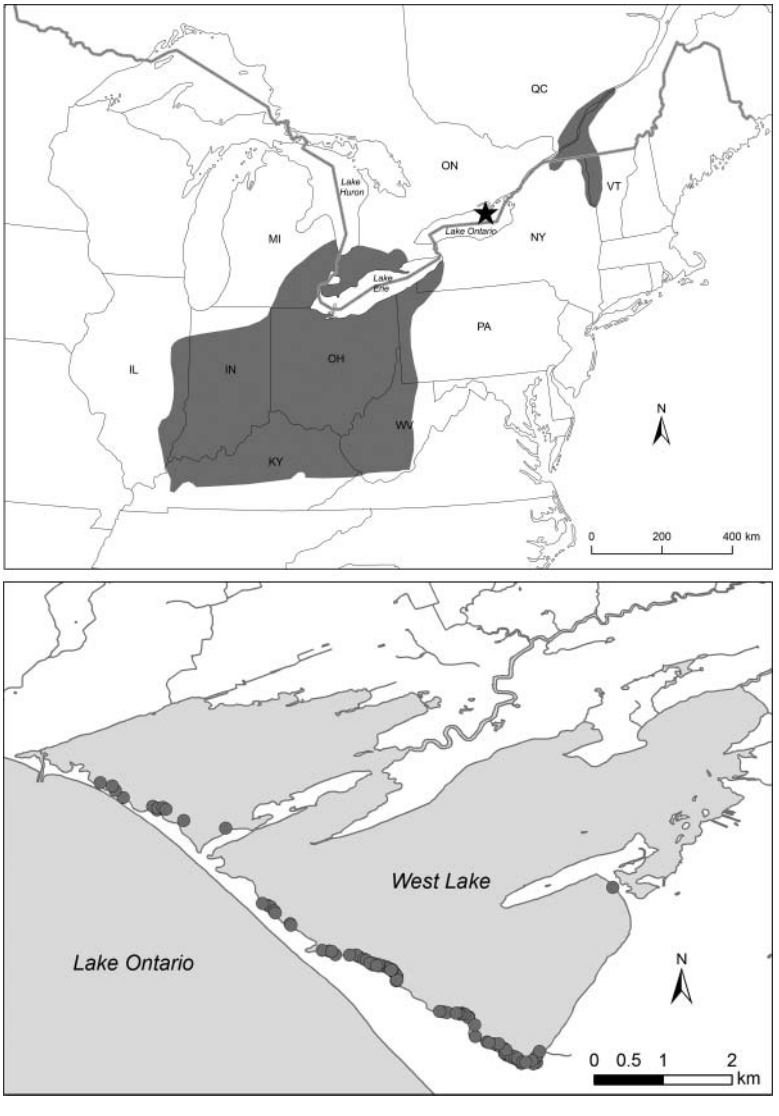

Figure 1. Global range of Eastern Sand Darter (gray shaded area; modified from Page and Burr (1991)) and location of West Lake population (black star) (upper panel) and sampling sites within West Lake (lower panel).

For many fishes at risk in the Laurentian Great Lakes basin, standardized species detection protocols and population monitoring programs are lacking. Sampling protocols for imperiled fishes need to provide accurate, precise, and cost-effective information (Poos et al. 2007) and pilot studies are useful for testing sampling designs before full-scale implementation (Hughes and Peck 2008). In North America, the seine is a commonly used gear to collect fishes from a diversity of standing and flowing waters (Bonar et al. 2009). The gear is widely used to support research and monitoring for small-bodied imperiled fishes and fish-hosts of imperiled mussels in southern Ontario (Mandrak et al. 2006; Poos et al. 2007). In this study, we used a removal (repeat)-sampling approach (MacKenzie et al. 2002) to compare the effectiveness of two seines to monitor the distribution and abundance of lake populations of Eastern Sand Darter. The bag seine and larger beach seine have both been used to collect darters of conservation concern from wadeable, sandy habitats in the Laurentian Great Lakes basin (Reid and Mandrak 2008; Dextrase et al. 2014b). Performance of the two seines was compared based on the following criteria: (i) probability of species detection, (ii) capture probability, (iii) ability to characterize spatial variation in distribution and abundance, (iv) size-selectivity, and (v) power to detect future changes in distribution and abundance.

Methods

Field sampling

Sampling was undertaken in the late summer/early fall of 2013 (September 16–19) and 2014 (August 27–September 18). Fishes were seined from 69 sites widely distributed along 5 km of shallow (<1.4 m deep), sandy habitat along the southwest and north shores of West Lake (Figure 1). Most habitats were adjacent to a barrier sand dune formation in a provincially protected area (Sandbanks Provincial Park) that separates West Lake (43°56′11″N, 77°17′00″W) from Lake Ontario. Mean water temperature during sampling was 18.4°C (standard deviation, SD = 2.7). Sites were divided into two sampling units (a 20 m long unit and a 10 m long unit). Unit lengths were defined based on the minimum distance required to properly deploy each seine. The length of the unit sampled with the bag seine was based on past Eastern Sand Darter research in Ontario rivers (Drake et al. 2008; Finch et al. 2013; Dextrase et al. 2014b). Sites were separated by a minimum of 20 m.

The 20 m unit was sampled with five repeated hauls of a beach seine. The beach seine had the following dimensions: 15.2 m in length × 2.4 m high with a 2.4 × 2.4 × 2.4 m bag; and each wing measured 6.4 m in length. The mesh in the wings was 6.4 mm in diameter and the mesh in the bag was 3.2 mm in diameter. The 10 m unit was sampled with five repeated hauls of a bag seine. The bag seine had the following dimensions: 9.1 m in length × 1.8 m high with a 1.8 × 1.8 × 1.8 m bag; and each wing measured 3.65 m in length. The mesh in the wings was 4.8 mm in diameter and the mesh in the bag was 3.2 mm in diameter. Along the lead lines of both seines, 50 g weights were attached at 30 cm intervals. For each haul, the seine was pulled in a direction parallel to the shoreline and fishes were removed from the bag at the end of the sampling unit. Successive hauls were pulled in opposite directions over the same habitat area. At least 5 min elapsed between successive hauls. Over the course of each sampling day, the placement of 10 and 20 m long units in each site alternated.

Eastern Sand Darter caught in each haul were enumerated separately and measured for total length (TL) (mm). Numbers of other small benthic fishes were also enumerated by haul. All fishes were released after processing. On average, the beach seine (mean = 37 min, SE = 6.9) took 10 minutes longer than the bag seine (mean = 27 min, SE = 4.4) to sample a single unit. At each sample unit, water depth was measured and percent composition of the substrate (i.e. fines, sand, or gravel) was visually assessed.

Data analysis

Site occupancy models that incorporate imperfect detection were developed based on the detection histories from repeat surveys at each site using the multinomial likelihood function of MacKenzie

et al. (2002, 2006) that jointly considers the probability of occupancy (ψ) and detection probability (p). Through the use of a logit link function, ψ and p for Eastern Sand Darter were modelled as a function of environmental covariates and survey covariates. For each seine, a candidate set of 16 models was assessed using depth, percent sand, and year as occupancy covariates; and, year and removal in previous seine hauls as detection covariates. Continuous occupancy covariates (depth and percent sand) were standardized prior to analysis by subtracting the mean value and dividing by the standard deviation (Legendre and Legendre 1998). All occupancy modelling was conducted with the software program PRESENCE 9.8 (Hines 2006, http://www.mbrpwrc.usgs.gov/software/presence.html).

Candidate models were compared with an information-theoretic approach using Akaike's Information Criterion (AIC) corrected for small sample size (AICc) (Anderson and Burnham 2002). The number of sites was used as the sample size. Quasi-AIC corrected for small sample size (QAICc) was used in cases where there was overdispersion in the data ($\hat{c} > 1$). Goodness of fit of occupancy models within each candidate set was assessed using the Pearson chi-square statistic and the parametric bootstrap test of MacKenzie and Bailey (2004) by performing 10,000 bootstraps on the most parameter-rich (most global) model.

Spatial patterns of Eastern Sand Darter distribution associated with each seine were characterized by calculating the Index of Dispersion (an index of spatial clustering, Krebs 1989) and testing for spatial autocorrelation. The Index of Dispersion is expected to equal 1 when individuals are randomly distributed across the sampling area and greater than 1 when the distribution of individuals is clumped. The association between species presence (and counts) and the geographic distance separating each sampling unit was tested using the Mantel test (999 permutations; Fortin and Dale 2005). Distance matrices were constructed using Jaccard (presence) and Euclidian (count) distance measures. Spatial analyses were completed using PASSaGE 2.0 (Rosenberg and Anderson 2011).

The ability of sampling gears to characterize populations is dependent on the proportion of the total number of individuals present that are captured in a sample (catchability; Rosenberger and Dunham 2005) and whether individuals vulnerable to capture are representative of the overall population (e.g. size-selectivity; Mahon 1980). Sampling events were assessed based on: (i) whether a decline in catch was observed with successive passes (i.e. depletion); and (ii) capture probability. Differences in frequency of successful depletion between seines were tested using Fisher's Exact Test. Differences between bag- and beach seine total catch (all five hauls pooled and standardized to a 10 m sample unit) were tested using the Wilcoxon rank-sum test. Capture probability (P) was estimated using multiple-haul data and the maximum likelihood weighted method (Carle and Strub 1978). P was calculated using Removal Sampling software (version 2.0; Seaby and Henderson 2007). Graphic inspection of length frequency distributions and the Kolmogorov-Smirnov (K–S) test were used to assess differences in the size of Eastern Sand Darter captured (Zar 1984).

A prospective power analysis was also undertaken to evaluate whether seining could reliably detect future declines in species distributions. Using p and ψ, power estimates were calculated for each species using an Excel-based sample size/power calculator (OccPower.xlsx). The power to detect differences in species occupancy between two independent, single-season surveys is calculated using a closed-form estimator (equation 3 in Guillera-Arroita and Lahoz-Monfort 2012). Power (based on the critical region of a two-tailed test) is a function of the initial occupancy estimate (ψ), proportional change in occupancy between surveys (R), species detection probability (p), number of replicate surveys (K), and number of sites surveyed (S). The likelihood of detecting a change in occupancy between surveys improves as parameter values increase. Prospective power analysis was done to evaluate whether single or multiple-haul (three and five hauls) catch data could detect relatively large (>30%) changes in relative abundance in the lake. Using sample means and standard deviations (SD), power estimates were calculated using an Excel-based sample size/power calculator (Gerow 2007; available from www.statsalive.com). For both power analyses, rate of declines (30%, 50%, and 70%) were based on COSEWIC quantitative assessment criteria (www.cosewic.gc.ca). Type I error rates of 0.05 and 0.1 were adopted.

Table 1. Comparison of bag seine and beach seine catch statistics for four small, benthic fishes species collected from 69 West Lake sites.

	Eastern Sand Darter		Johnny Darter		Logperch		Round Goby	
	Bag	Beach	Bag	Beach	Bag	Beach	Bag	Beach
Mean (SE) catch	3.1 (0.90)	6.6 (1.3)	2.7 (0.49)	4.2 (0.65)	11.5 (2.11)	18.0 (3.0)	11.8 (2.88)	31.0 (5.5)
Frequency of occcurrence[a] (%)	46	65	49	62	74	88	59	84
Index of dispersion	17.8	39.9	16.9	14.9	26.9	76	48.4	150.4
Frequency of depletion[b]	25	33	15	27	22	16	15	14
Mean (SE) capture probability	0.37 (0.03)	0.41 (0.03)	0.64 (0.06)	0.42 (0.03)	0.59 (0.06)	0.56 (0.04)	0.55 (0.05)	0.43 (0.05)

[a]percent of all sites sampled.
[b]percent of sites where the species was collected and a successive decline in catch was observed.

Results

More than 11,000 individuals representing seven benthic fishes (Brown Bullhead *Ameiurus nebulosus*, Eastern Sand Darter, Iowa Darter *Etheostoma exile*, Johnny Darter *Etheostoma nigrum*, Logperch *Percina caprodes*, Round Goby *Neogobius melanostomus,* and Tadpole Madtom *Noturus gyrinus*) were seined from West Lake. Catches were dominated by Eastern Sand Darter (11.0% of all individuals), Johnny Darter (7.3%), Logperch (31.5%), and Round Goby (49.7%). The invasive Round Goby was often caught from the same sampling unit as individual darter species (bag seine: 57%–85% of sites where a darter species was detected; beach seine: 68%–96%).

Eastern Sand Darter was collected from relatively deep (bag seine: mean = 0.59 m, range = 0.33–0.91; beach seine: mean = 0.56, range = 0.24–0.88), sandy (bag seine: mean = 98.6%, range = 80–100; beach seine: mean = 97.7%, range = 70–100) sites. Variation in the number of Eastern Sand Darter detected among sample units was highly correlated between seines (Spearman rank correlation, r_s: 0.82; $p < 0.001$), and the distribution of individuals clumped (Index of Dispersion >1, Table 1). The distribution and number of individuals detected were not spatially auto-correlated ($p < 0.001$).

Site occupancy and detection probability

The beach seine detected Eastern Sand Darter at a greater proportion of sites (naïve occupancy = 0.65) than the bag seine (naïve occupancy = 0.46; Table 1). Eastern Sand Darter was detected by both seines at 83% of paired sample units. When detected with the beach seine, Eastern Sand Darter was collected during the first haul at 72% of sample units. The first haul with the bag seine collected Eastern Sand Darter at 66% of detected sample units. Detections by the bag seine and beach seine represented 17 of 32 and 20 of 32 possible detection histories, respectively. No detections at a site (00000) and detections across all five hauls (11111) were the most common detection histories for both gear types. The bag seine had a higher proportion of sites without detections and a lower proportion of sites with five detections. Detection histories representing four detections per site were more frequent with the beach seine than the bag seine (Figure 2).

Detection probability with the beach seine (p: model-averaged estimate = 0.72; SE = 0.051) was greater than bag seine (p: model-averaged estimate = 0.48; SE = 0.075). For both seines, the influence of Removal on p was not well supported and its coefficient was positive, opposite to the hypothesized relationship (i.e. previous removal of Eastern Sand Darter will increase detection probability; Tables 2 and 3). Therefore, Removal was not considered as a detection covariate in either candidate set of models. For the beach seine, null models of constant detection were generally better supported than when Year was considered as a detection covariate (combined model weight [cmw] for Year was only 0.39). The coefficient for Year was positive, implying that the beach seine had an improved

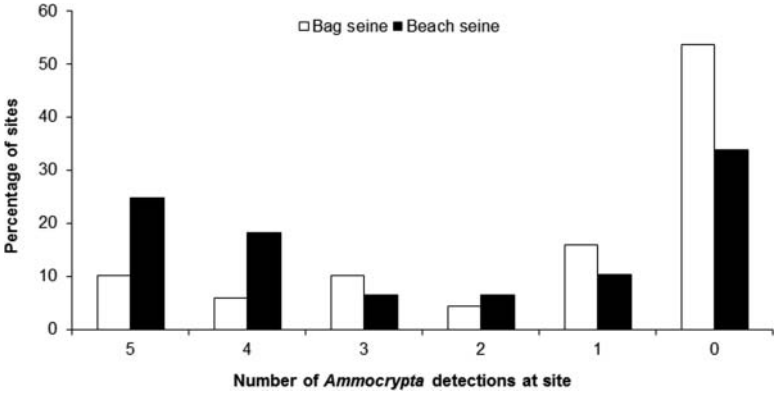

Figure 2. Comparison of the number of Eastern Sand Darter detections per site by gear type in West Lake (2013–2014).

Table 2. Model-averaged parameter estimates, 95% confidence limits and relative variable importance (combined model weights) for West Lake Eastern Sand Darter site occupancy models developed based on beach seine surveys.

Parameter	Estimate (SE)	95% CL_{lower}	95% CL_{upper}	Combined model weight
Detection				
p	0.722 (0.051)	0.612	0.811	—
Intercept	0.77 (0.38)	0.03	1.51	—
Year	0.20 (0.37)	−0.53	0.93	0.39
Occupancy				
ψ	0.664 (0.112)	0.424	0.841	—
Intercept	0.85 (0.53)	−0.19	1.90	—
Depth	0.18 (0.35)	−0.51	0.87	0.39
Year	−0.30 (0.65)	−1.58	0.99	0.35
Sand	0.07 (0.22)	−0.37	0.50	0.28

Note: ψ = probability of site occupancy.

probability of detecting Eastern Sand Darter in 2014 (Table 2). For the bag seine, Year was an important detection covariate (cmw of 0.97); all models with empirical support had Year as a detection covariate. The coefficient for Year was negative implying lower detection probability in 2014 (Table 3).

The model-average estimate of site occupancy when sampling Eastern Sand Darter with the beach seine (*p*: model-averaged estimate = 0.664) was also greater than the bag seine (*p*: model-averaged estimate = 0.529). Reflective of the higher detection probability, model-based adjustment of the naïve occupancy estimate was much less for the beach seine than bag seine. There was limited separation between any of the beach seine occupancy candidate models (maximum ΔQAICc of 4.77)

Table 3. Model-averaged parameter estimates, 95% confidence limits and relative variable importance (combined model weights) for West Lakes Eastern Sand Darter site occupancy models developed based on bag seine surveys.

Parameter	Estimate (SE)	95% CL_{lower}	95% CL_{upper}	Combined model weight
Detection				
P	0.478 (0.075)	0.336	0.623	—
Intercept	0.58 (0.26)	0.07	1.09	—
Year	−1.51 (0.62)	−2.72	−0.30	0.97
Occupancy				
ψ	0.529 (0.137)	0.277	0.768	—
Intercept	0.56 (0.55)	−0.51	1.63	—
Depth	0.98 (0.61)	−0.20	2.17	0.89
Year	−0.91 (1.02)	−2.90	1.09	0.58
Sand	0.03 (0.18)	−0.32	0.37	0.24

Note: ψ = probability of site occupancy.

Table 4. Model selection procedure for Eastern Sand Darter site occupancy in West Lake based on surveys with the beach seine, 2013–2014 (n = 77, $\hat{c}$ = 2.34, p = 0.0007; naïve occupancy = 0.662).

Model	QAICc	ΔQAICc	AIC weight (w)	Number of parameters	−2*LL
ψ(.),p(.)*	174.02	0	0.1864	3	399.95
ψ(.),p(year)	174.88	0.86	0.1212	4	396.69
ψ(depth),p(.)	175.31	1.29	0.0978	4	397.72
ψ(year),p(.)	175.64	1.62	0.0829	4	398.50
ψ(sand),p(.)	175.88	1.86	0.0735	4	399.08
ψ(depth + year),p(.)	175.90	1.88	0.0728	5	393.65
ψ(depth),p(year)	176.25	2.23	0.0611	5	394.50
ψ(year),p(year)	176.54	2.52	0.0529	5	395.19
ψ(sand),p(year)	176.81	2.79	0.0462	5	395.82
ψ(depth + year),p(year)	176.88	2.86	0.0446	6	390.38
ψ(depth + sand),p(.)	177.11	3.09	0.0398	5	396.55
ψ(sand + year),p(.)	177.59	3.57	0.0313	5	397.68
ψ(depth + sand + year),p(.)	177.74	3.72	0.0290	6	392.43
ψ(depth + sand),p(year)	178.12	4.10	0.0240	6	393.34
ψ(sand + year),p(year)	178.55	4.53	0.0194	6	394.36
ψ(depth + sand + year),p(year)	178.79	4.77	0.0172	7	389.16

*null model for constant probabilities of occupancy (ψ) and detection (p) across sites.

and the null model of constant occupancy and constant detection had the most empirical support (Table 4). None of the occupancy covariates were well supported (cmw <0.40) and the associated confidence limits for coefficients included 0. Depth was the most influential occupancy covariate (cmw of 0.89) when sampling with the bag seine and was positively related to occupancy (Table 5). Year was also supported in additive models (cmw of 0.58) and had a negative coefficient suggesting lower probability of occupancy in 2014. Confidence limits for the coefficients of all covariates included 0.

Abundance

The beach seine consistently captured more Eastern Sand Darter than the bag seine (Figure 3). More than twice as many individuals were collected from units sampled with the beach seine than bag seine (Table 1) (Wilcoxon test: $p < 0.001$). Overall, there was a general pattern of decline in beach seine catch with each successive haul (Figure 3). The number of fish captured in the bag seine only decreased between the first and second haul and then leveled off. There was no significant difference between seine types in the frequency of samples with a decline in catch suitable for capture

Table 5. Model selection procedure for Eastern Sand Darter site occupancy in West Lake based on surveys with the bag seine, 2013–2014 (n = 69, $\hat{c}$ = 1.46, p = 0.05; naïve occupancy = 0.464).

Model	QAICc	ΔQAICc	AIC weight (w)	Number of parameters	−2*LL
ψ(depth + year),p(year)	210.60	0	0.3894	6	287.17
ψ(depth),p(year)	211.34	0.74	0.2690	5	291.74
ψ(depth + sand + year),p(year)	212.83	2.23	0.1277	7	286.81
ψ(depth + sand),p(year)	213.71	3.11	0.0822	6	291.69
ψ(.),p(year)	214.69	4.09	0.0504	4	300.01
ψ(year),p(year)	215.94	5.34	0.0270	5	298.44
ψ(depth + year),p(.)	216.79	6.19	0.0176	5	299.68
ψ(sand),p(year)	217.02	6.42	0.0157	5	300.01
ψ(sand + year),p(year)	218.33	7.73	0.0082	6	298.43
ψ(depth + sand + year),p(.)	218.84	8.24	0.0063	6	299.16
ψ(depth),p(.)	220.95	10.35	0.0022	4	309.12
ψ(year),p(.)	221.83	11.23	0.0014	4	310.40
ψ(.),p(.)*	221.97	11.37	0.0013	3	313.89
ψ(depth + sand),p(.)	223.05	12.45	0.0008	5	308.80
ψ(sand + year),p(.)	224.14	13.54	0.0004	5	310.38
ψ(sand),p(.)	224.19	13.59	0.0004	4	313.84

*null model for constant probabilities of occupancy and detection across sites.

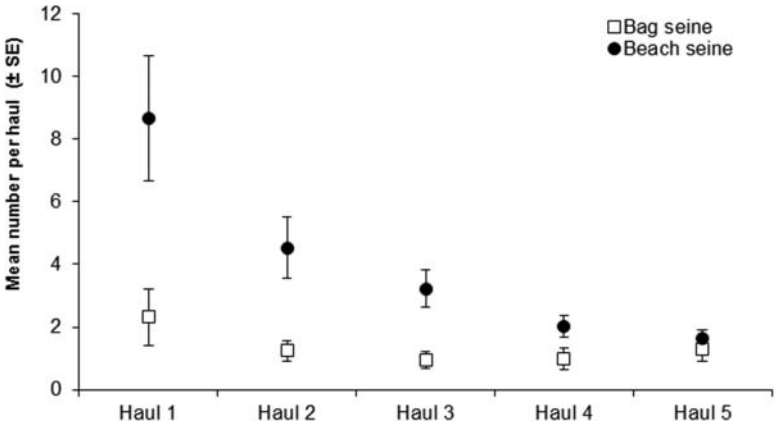

Figure 3. Comparison of the mean number of Eastern Sand Darter captured in successive hauls by two seines, at sites with detections in West Lake.

probability estimation (Exact test; $p = 0.47$). Regardless of seine type, capture probability could only be estimated for less than a third of sample units (Table 1). Mean capture probabilities were 0.41 in units sampled by beach seine, and 0.37 in units sampled by bag seine, when depletion occurred. Capture probability estimates were not significantly different between gear types (Mann–Whitney Test; $U = 43.5$, $p = 0.17$).

Size-selectivity

Size distributions of Eastern Sand Darter collected by each seine type were significantly different ($D = 0.56$; $p < 0.001$) (Figure 4). Individuals captured with the bag seine were longer; although the largest individual was collected with the beach seine (Bag seine: median TL = 48 mm, range: 23–66; Beach seine: median TL = 45 mm, range: 20–69). A greater representation of young-of-the-year (<42 mmTL) individuals was present in beach seine collections. For both seines, the length of individuals captured was similar across successive hauls (Figure 4). Eastern Sand Darter length distributions differed between years ($D = 0.75$; $p < 0.001$). Median TL was 48 mm (range: 23–69) in 2013, and 35 mm (range: 20–61) in 2014.

Power analysis

For both seines, the power to detect changes in distribution of 50% or greater is predicted to be high (Table 6). The power to detect future changes in abundance is predicted to be higher for the beach seine, and to increase with the number of seine hauls at a site (Table 6). However, the power to detect small (30%) changes is not expected to be high for either seine, regardless of the number of hauls (one, three, or five).

Discussion

An important step in the development of inventory and monitoring programs for imperiled fishes is the selection and validation of sampling gear. Results from our study indicate that despite requiring more sampling time, the beach seine is more effective at detecting Eastern Sand Darter and capturing small (<40 mmTL) individuals in the lake environment than the bag seine. Otherwise, capture efficiency and the power to detect future changes in population status are similar.

As is becoming more widely recognized when sampling freshwater fishes, the detection of Eastern Sand Darter from lake habitats by seine was imperfect. Probabilities for both seines are well above

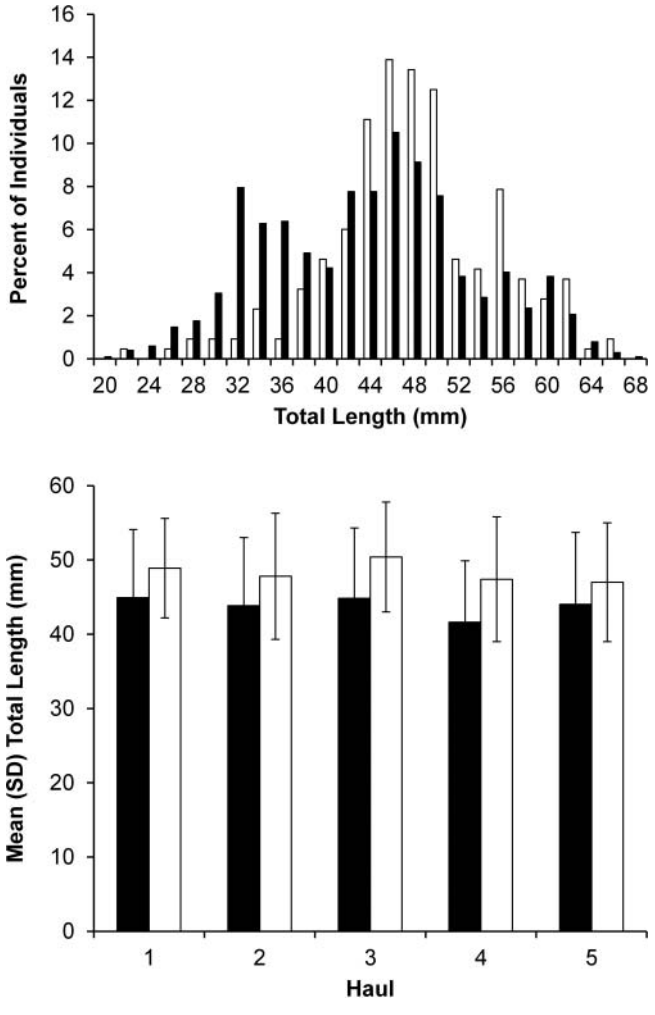

Figure 4. Comparison of the lengths of Eastern Sand Darter collected from West Lake using a bag seine (white) and beach seine (black) (upper panel) and among successive seine hauls (lower panel).

Table 6. Prospective power analyses using seine catch data for the detection of declines in Eastern Sand Darter abundance. Rates of declines are based on COSEWIC quantitative assessment criteria (www.cosewic.gc.ca). Estimates of power ≥80 (Cohen 1988; Peterman 1990) are considered 'high' and provided in bold.

		Bag seine		Beach seine	
Number of hauls	Percent decline	$\alpha = 0.05$	$\alpha = 0.1$	$\alpha = 0.05$	$\alpha = 0.1$
CPUE					
1	30	23	35	42	56
	50	44	60	77	**87**
	70	63	76	**93**	**97**
3	30	31	45	53	67
	50	61	74	**89**	**94**
	70	**81**	**90**	**98**	**99**
5	30	36	51	57	71
	50	69	**81**	**92**	**96**
	70	**88**	**94**	**99**	**100**
Occupancy					
5	30	44	57	67	77
	50	**88**	**93**	**98**	**99**
	70	**99**	**99**	**99**	**99**

Note: Type I error rate = α.

the minimum value ($p > 0.3$) recommended for occupancy-based studies and the likelihood of species detection with a beach seine is considered high with an estimate of $p = 0.72$ (MacKenzie et al. 2006). Detection probabilities for both seines were also similar to estimates calculated for bag seine surveys of southern Ontario rivers for Eastern Sand Darter (p range: 0.41–0.71, Dextrase et al. 2014a), and another Ontario fish of conservation concern, Blackstripe Topminnow (*Fundulus notatus*; $p = 0.51$, Reid and Hogg 2014). The probability of detecting a species is related to the local abundance and the probability of individual capture, both of which may be influenced by habitat (Bayley and Peterson 2001). For Eastern Sand Darter, Dextrase et al. (2014a) reported large differences in seining detection probability between two rivers with contrasting population sizes, and a negative relationship between substrate size and seining detection probability. In West Lake, year was identified as an important sampling covariate, with a contrasting influence on the effectiveness of each seine. This covariate likely reflects the greater abundance of smaller fish in 2014 compared to 2013, and the greater efficiency of the beach seine to capture smaller fish than the bag seine. Unlike other littoral lake habitats (Pierce et al. 1990), features that can cause the seine net to roll off the bottom (e.g. dense aquatic macrophyte beds) or snag (e.g. rocks or logs) were absent from the sandy West Lake habitats, and therefore did not affect sampling. The lower detection probability associated with the bag seine produced a site occupancy estimate that was much higher than naïve occupancy when compared to the beach seine, where the estimated and naïve occupancy were similar.

In North American rivers, Eastern Sand Darter habitat use and distribution have been linked to physical habitat characters, especially the availability of sand and fine gravel substrates (Daniels 1993; O'Brien and Facey 2008; Dextrase et al. 2014b). In West Lake, there was a lack of a strong relationship between site occupancy and environmental covariates. This result likely reflects the design of the gear comparison study which focused sampling on locations with suitable habitat conditions. Habitats considered less suitable for Eastern Sand Darter (e.g. sites with abundant aquatic macrophyte cover) were not sampled. Larger sites are more likely to be occupied than smaller sites. In comparison to the bag seine, Eastern Sand Darter was collected from 20% more sites by beach seining. As increasing the amount of habitat sampled at a site has been found to have a positive effect on occupancy estimates for other aquatic taxa (Rodtka et al. 2015; Reid 2016), this result is likely largely driven by the differences in the sizes of the sites sampled by the beach (site length: 20 m) and bag seines (site length: 10 m).

For many imperiled fishes in Canada, there is a lack of information on population sizes, and trends (Staton et al. 2003; Venturelli et al. 2010). Repeated standardized sampling is needed to determine population status and trajectory, and to evaluate conservation actions. Previous attempts to generate removal-based population density estimates for imperiled Canadian fishes with a bag seine have had varying levels of success (Poos et al. 2012; Finch et al. 2013; Reid and Hogg 2014; Neufeld et al. 2016). In our study, removal-based sampling of Eastern Sand Darter with either seine was not a reliable strategy to generate site-level density estimates. At Thames River (Ontario) sites, Finch et al. (2013) also reported limited success estimating Eastern Sand Darter densities with the removal method. At more than half of the West Lake sampling units where Eastern Sand Darter were collected, a consistent decline in catch with successive hauls (i.e. depletion) was not achieved. Accurate estimates from removal studies also rely on catches much larger (i.e. 200 individuals) than we encountered at West Lake sites (White et al. 1982). Our observation of a low capture efficiency of the seine for Eastern Sand Darter is consistent with results for small, benthic fishes in other studies (Lyons 1986; Pierce et al. 1990; Poos et al. 2007; Neufeld et al. 2016), and for the other three benthic fish species collected from West Lake. As an alternative to population monitoring with density estimates, we found pooled catches from successive hauls with either seine to be relatively precise, and likely sufficient to detect future declines in abundance of 50% or greater.

The collection of young-of-the-year (YOY) individuals is important for characterizing trends in Eastern Sand Darter recruitment, estimating growth rate, and understanding the habitat requirements of all life-stages. The bag seine design used in this study was previously effective in collecting large numbers of YOY (20–37 mmTL) from the Thames River (Drake et al. 2008; Finch et al. 2013).

Although not absent from bag seine hauls, a substantially greater number of small (<40 mmTL) Eastern Sand Darter were collected from West Lake with the beach seine despite the fact that this gear had wings with a larger diameter mesh size (6.4 mm) than the bag seine (4.8 mm). The greater efficiency of the beach seine in capturing YOY can possibly be explained by the larger size of the 3.2 mm diameter fine-mesh bag when compared to the bag seine. The length of the fine-mesh bag in contact with the bottom in the beach seine (2.4 m) was 33% longer than in the bag seine (1.8 m) which may have prevented fewer YOY from escaping.

The results of our study suggest that the larger beach seine would be a preferred gear where the sampling objective is to identify occurrences and occupied sites for Eastern Sand Darter in lacustrine environments. This gear could be deployed with fewer repeated surveys per site, maximizing the number of sites that could be visited. The beach seine is also more effective at detecting YOY Eastern Sand Darter than the bag seine. Either gear type could be used if the sampling objective is to detect changes in abundance at occupied sites.

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