Lake Erie Protection Fund Grant – SG 390-10 Final Reporting
Protecting mussel habitat on Lake Erie's coast

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August 4, 2011

Abstract SG 390-10
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The primary goal of the research project funded by SG 390-10 was to test the importance of flooded river mouths, also called freshwater estuaries as refugia for freshwater mussels in the Lake Erie watershed. Each estuary was surveyed at multiple sites and four person hours per site using mussel rakes designed for work in soft substrate. With on exception where a stream mouths suffered from extensive human impacts, mussels occurred in these estuaries and invasive dreissenid mussels were rare to absent. A group or community of species could be ascribed to this flooded river mouth habitat, which included several typical fast growing "pond" species: *Pyganodon grandis*, *Utterbackia imbecillis*, and *Toxolasma parvum*, plus *Lasmigona complanata* and *Leptodea fragilis*, which often live in slower moving river water, but not ponds, perhaps due to host fish limitations in ponds. *Uniomerus tetralasmus* occurred in one stream, and while a pond species, it is rare in Ohio and listed as State Threatened. Two large river species also occurred, which possess thick shells and large protuberances (postules or warts) that adapt them for life in soft, silty substrates. These are *Quadrula quadrula*, which was almost ubiquitous, and *Obliquaria reflexa*, a state threatened species. Although the state endangered species, *Ligumia nasuta* once was common in the lake, we did not find it other than as old shells in one smaller stream. Thus, while mussel diversity is not high in these flooded river mouths, each has provided a small refugia for mussels close to Lake Erie.

Technical Report:

This report presents the results and recommendations following completion of a project on "Protecting mussel habitat on Lake Erie's coast" (SG 390-10) by Robert Krebs and Trevor Prescott of the Dept. of Biological, Geological and Environmental Sciences at Cleveland State University. The objectives of this project were as follows: to promote diversity of native flora and fauna by examining new sites for rare mussel communities and species in Lake Erie's nearshore, estuaries and wetlands and to identify how such communities correlate with the presence of shoreline modifications, especially with the lay of rip rap and presence of marinas.

The primary goal was to test for the presence of mussels in flooded stream mouths along Lake Erie. Many of these areas are used to develop small commercial marinas and/or private boat docks. Secondarily, we continued to examine coastline for the presence of fresh shells that are indicative of mussel populations in the lakes nearshore. During Summer, 2010, we discovered mussel populations in seven of eight new streams examined that were not known to currently receive protection and we confirmed mussel populations in several other streams as a comparison of our technical methods. Within each stream, two to four surveys were made depending on stream size and the number of discrete access points, and each survey was made for four person hours (generally two individuals searching over a 2 hour period). We designed collection rakes (see photo) especially for surveying in the soft substrates characteristic of flooded stream mouths, and they enabled detection of young mussels and small species (i.e., lilliput, *Toxolasma parvum*, which is believed to be underreported in the region due to its small size).

The streams chosen for sampling varied from fairly small with very low flows from the drowned stream mouths to several of moderate order: Cedar Creek: Turtle Creek and Toussaint Creek in the western basin, Yellow Swale, South Creek, Raccoon Creek, and Plum Brook as tributaries of Sandusky Bay, Old Woman Creek, Cranberry Creek, and Chappel Creek in the central basin, and we added a sites in the lower Cuyahoga River below Independence, OH, and the Chagrin River at Eastlake, OH, that were not originally listed in the proposal to fill in information farther east. With the exception of Old Woman Creek, records of mussels were either spotty or completely unknown where we surveyed, and most predictions based on stream size were for few if any mussels to be present.

We found mussels in all but one stream studied (Chapel Creek) although several others were so degraded that populations are mere remnants of the past. Collections included nine species found living in these habitats (Table 1 & 2): *Amblema plicata* (Threeridge), *Lasmigona complanata* (White heelsplitter) *Leptodea fragilis* (Fragile Papershell), *Obliquaria reflexa* (Threehorn Wartyback), *Pyganodon grandis* (Giant Floater), *Quadrula quadrula* (Mapleleaf), *Toxolasma parvum* (Lilliput), *Uniomerus tetralasmus* (Pondhorn), and *Utterbackia imbecillis* (Paper Pondshell). Shells of several others suggested their possible presence: *Potamilus alatus* (Pink Heelsplitter), *Strophitus undulatus* (Creeper), *Quadrula pustulosa* (Pimpleback) and *Ligumia nasuta* (Eastern Pondmussel). Three horn Wartyback and the Pondhorn are state listed as Ohio Threatened, while the Eastern Pondmussel is Ohio Endangered. These mussels were

found upstream but within th estuaries. Generally habitat right at the mouths could not be tested due to the presence of marinas and restrictions against surveying in these private lands, i.e., owners cited safety issues if they felt they were responsible for giving us permission to work near where boats navigate.

In addition to simply surveying for mussels, water samples were collected and water chemistry analysis was run by Dr. David Klarer of the OWCNERR (Table 3). These water samples were collected after a period of little rain to assess conditions of the stream mouths as opposed to the content of likely runoff. No obvious problems in water chemistry were detected, although one stream, Cranberry Creek, had very high phosphate levels, which correlated with observation of manure/fertilizer piles upstream noted after completion of the surveys. Visual assessments suggest that habitat at these streams depends on the land owners within the watersheds and that few regulations limit the actions of people who own this land. The most obvious concern is with Chapel Creek, the one site mussels were not observed. Dr. Klarer (pers. comm.) reported to us extensive modification by the religious group in possession of much of this stream and all of the area around its mouth. That owner even altered they outflow some years ago to provide a more protected harbor.

The effects of stream mouth alteration in Chapel Creek can be contrasted with changes that likely occurred in the much larger Chagrin River that empties into Lake Erie at Eastlake, Ohio. In that river, the mouth was also moved west some 100 meters creating a small island joined only by a sand bar beach popular with local residents. The new mouth is regularly dredged for the passing of personal watercraft. The mussels reported in the lower Chagrin River were predominantly found in the wetlands behind the sandbar at the old mouth, and these populations today are probably remnants of a larger community present before isolation. Even with rakes, young mussels were not found.

Where mussels were found, across our surveys, abundance remains much higher along Lake Erie's western basin than in points farther east. Published research and unpublished surveys continue to identify Crane Creek in the Ottawa National Wildlife Refuge to possess one of the most abundant and diverse communities of freshwater mussels along Lake Erie's southern shores, and that stream can serve as a model for what populations can be in natural areas. However, mussels do occur in unprotected lands and the following summary pertains to our observations of populations persisting in the absence of management or protection. Summaries by stream follow.

Lake Erie's Western Basin

Toussaint Creek

Surrounding types of land use varied from recovering riparian zone, to residential and agricultural. This river was wider than most others surveyed and the current was often very slow making the Toussaint appear like a typical flooded river mouth for several miles upstream. Within the stream, patches of aquatic vegetation such as water

lotus were present. Different sites along this river had substrates that varied in degree of instability and softness. Overall, the substrate ranged from very soft mud that was approximately 1 foot deep, to much more stable and less muddy, but still soft, and occasional patches of sand mixed with gravel. The water depth ranged from 2 feet to 6 feet deep.

Toussaint Creek has a diverse and abundant mussel community. The mouth is regulated by the Davis-Besse Nuclear Powerplant, but numerous small marinas line the shores of the flooded river mouth. In some localities, the Ottawa National Wildlife Refuge has obtained property, for example the marsh at Gaeth Kurdy (Crail et al., 2011). The lower reaches appear to be filling in as we surveyed in 5-6 feet of water within site of the entrance to the lake, which may lead to requests for dredging in the near future. The course substrates composing this bar in the center of the river is the habitat and collection locality for the state threatened, Threehorn Wartyback we found. Surveys were extended to near the top of the Lake Erie-influenced zone, and we found mussels present high in this area, but abundance dropped off greatly from surveys closer to the mouth

A variety of live and voucher specimens were found in the Toussaint; 7 species were found alive and 9 were found as voucher specimens. The dominate species found were species more commonly found in soft substrates and included *Quadrula quadrula* (32). *Utterbackia inbecillis* (9), and *Obliquaria reflexa* (6).

Cedar Creek

The riparian zone around Cedar creek was small. Generally the riparian zone would stretch from about only 10 to 30 feet away from the banks of the creek, which were very incised. This stream was also very narrow. Outside of the small riparian zone lay agricultural fields. Within the stream, there were plenty examples of coarse particulate organic matter (CPOM) and much allochthonous input, such as downed trees and garbage. The substrate mainly consisted of hard packed clay and mud, along with cobble. Cedar creek's depth when surveyed ranged from 2 feet to 5 feet deep.

Few mussels were present and the stream seemed degraded by erosion of the banks. A couple of White Heelsplitters occurred well upstream from the mouth and this species is very pollution tolerant. The presence of shells of the Eastern Pondmussel suggested better conditions in the past, and that finding spurred an intensive but unsuccessful search for a live individual. There seems little left of his stream's mussel community. We could not get in near the mouth due to a narrow and very active marina present there.

Turtle Creek

This stream's surroundings can be categorized as mainly agricultural. Any riparian zone present was very thin, made up of mostly shrubs and a few trees, and relatively young. However, this stream's channel width was very wide, and much more so than other streams of this size surveyed (South Creek probably is second; Toussaint Creek is a larger stream), and the flow was slow. Turtle creek looked like a typical flooded river mouth. The substrate at Turtle creek was also very soft, and unstable. Turtle creek and Toussaint Creek were very similar in their stream characteristics as well as the species of unionids found within.

Turtle Creek also possesses an active marina at the mouth, but only a hundred yards downstream, the flooded area opens into a wide wetland with emergent vegetation. The substrate was amorphous, and the water deep. The habitat seems to support this low diversity community near Lake Erie despite human impacts. *Quadrula quadrula* was the found the most often in Turtle creek, followed by *Pyganodon grandis*. *Leptodea fragilis* and *Toxolasma parvum*, which were found in low numbers, 2 and 1 respectively.

Sandusky Bay region

Several small streams enter Muddy Creek and subsequently Sandusky Bay, and each is inhabited by mussels. As such, these streams near their mouths fall within the lands protected by Winous Point's, Muddy Creek Marsh Conservancy, but not far upstream farmland and thin riparian zones may restrict habitat.

Yellow Swale:

This stream, along with South Creek, has a larger established riparian zone consisting of older, larger trees and a variety of other plants. Primarily fields of agriculture and wild low vegetation lay outside the riparian zone, followed by residential property. Yellow Swale's bankful width was not as wide as Turtle or Toussaint but it was not a small incised stream. Flow in this river was also slow 2-3 miles from Muddy Creek, where Yellow Swale still looked like a typical flooded river mouth influenced by lake water levels. The substrate was soft, but not as soft as Toussaint or Turtle, as more sand was present in the substrate. The water depth ranged from 2 feet to 5 feet where we surveyed. Yellow Swale also possessed thick in-stream vegetation downstream.

Giant Floaters were by far the most prevalent species found. *Pyganodon grandis* fit this stream because of the low flow rate and the substrate: slow and soft but sandy. The substrate and other characteristics seemed to form a good place for common, perhaps generalist species such as Giant Floater and Lilliput mussels, rather than soft substrate specific species such as *Quadrula quadrula*. Notably, one live *Uniomerus tetralasmus* (Pondhorn) was found, along with several voucher specimens (shells of fresh dead).

This stream like others in the area tends to fill in near the mouth, creating a wetland blocking boat navigation with the lake, or in this case the flooded moth of the Sandusky River. Farmland upstream likely impacts nutrient loads, but no marina is present.

South Creek

This stream had an established, healthy riparian zone downstream with residential areas outside of the riparian zone. The substrate in-stream was muddy and soft, but again less silt (perhaps 50/50 sand/mud), and was similar to the substrate in Yellow Swale. Upstream (south of bridge for access) the stream was surrounded with herbaceous vegetation, cattails, reeds, and tall grass.

Giant Floaters were the prevalent species in South creek (37 live 31 fresh dead), followed by *Leptodea fragilis* (12 alive, 5 dead). Many of the *Pyganodon grandis* were found in the upstream, sandy portion of the stream. Some *Quadrula quadrula* were found

downstream in the softer, more unstable sediment along with other species, despite appearing like a wide, shallow ditch.

We later discovered the mouth to be very shallow where it enters muddy creek, but possibly open all the way upstream to survey sites.

Raccoon creek

This stream was similar to Cedar creek: incised banks, thick canopy cover, narrow bankfull width, cobble and hard packed mud substrate, abundant allochthonous input in the form of CPOM and anthropogenic waste. This stream was surrounded by riparian zone, residential areas, and eventually marsh land towards the mouth. Unionids were found in only one spot near the route 6 bridge, in a sandy area of deposition (70/30 mud/sand), similar to results for Cedar Creek. Raccoon Creek also matched Cedar Creek for an erosion influenced stream that is now deep and filled in with decaying vegetation. Although the stream enters the Pickering State Bird Refuge Downstream, degradation from farm runoff seems to have severely impacted the stream above this preserve.

Several species were found in the one small area of deposition: *Lasmigona complanata, Pyganodon grandis,* and as fresh dead, *Strophitus undulatus*. Also like Cedar creek, the most prevalent species found here was the pollution tolerant *Lasmigona complanata*. Although the water in each of the areas where unionids were found in Cedar and Raccoon was shallow, it appears that the large *L. complanata* can survive is the substrate is soft enough to allow movement within sites.

Plum Brook:

Surveys in lower Plum Brook encompassed areas that are part of the Erie Co. metroparks. This stream was wide and slow moving, much like South creek, and Yellow Swale. Lower Plum Brook is surrounded by a large, thick riparian zone with residential properties outside of the riparian zone. This stream appeared to be a high quality, healthy, flooded river mouth, or estuary. Plum Brook also has an abundant amount of aquatic vegetation throughout the stream and this vegetation becomes increasingly thicker downstream. Plum Brook varied in substrate types: hard compact mud, soft vegetation covered mud, and soft mud free of vegetation.

Plum Brook was the site of a cesium spill about 30 years ago (reference), and more live specimens were found than voucher specimens, suggesting that Plum Brook's unionid fauna are recovering. The recovering population could be further evidence that flooded river mouths and estuaries are/can act as refugia for unionid mussels when protected.

Most unionids were found in the soft, vegetation free areas of the stream. Areas of thick vegetation were not surveyed as they restricted use of the mussel rakes. Species found included 2 generalists: *P. grandis* and *T. parvum*. *Leptodea fragilis* was also found, and may be more common in sites closer to the lake (its host fish is freshwater drum, a common lake fish that tends not to move easily above stream barriers).

Lake Erie's Central Basin

In this region few communities of any kind are known. Nearby, Old Woman Creek, which is a protected preserve, has up to six species, but only Giant Floaters and Paper Pondshell (*Utterbackia imbecillis*) were ever reported in many numbers. Sheldon Marsh likewise has four, but in low abundance (Crail et al., 2011).

Chapel Creek:

Chapel creek was the only stream where no unionids were found alive nor were shells found. The riparian zone, if present, was very thin. R residential property lined the banks of the creek. Downstream the stream ran adjacent to a parking lot and recreation area. Commonly, there was very little to no buffer zone to absorb and process run-off.

In-stream, Chapel Creek was unique in terms of depth and substrate. The depth varied greatly from several inches to 6 feet within a small distance (50 feet). The substrate was mixture of hard packed cobble, mud and a flaky orange sediment that did not appear natural. The stream mouth had been previously moved. Due to the substrate, the history of disturbance, and the current land use surrounding Chapel Creek it is not surprising that no specimens were found, and recovery is not expected. This stream may typify human destruction of habitat.

Cranberry Creek

Within this stream, we were able to survey very close to the lake. Surveys were done on the south side of route 6 before the stream is culverted, and then runs through a marina. Also, land fill was observed being dumped into this creek. Surrounding types of land use were residential and agricultural fields upstream, and the marina around the mouth of the river. This stream's substrate is a semi-compact mud. This stream was thin, but still wider than Raccoon or Cedar. Also, Cranberry's banks were not heavily incised.

Much of the collected fauna from Cranberry were very young unionds that were mostly *P. grandis, L. complanata or perhaps L. fragilis*. Due to the small size of the juvenile individuals collected, identification was difficult. A concern is that these species may be present only because of the proximity of the survey area to the lake, and that the habitat is not supportive of a mussel community.

Of importance to the Central Basin is the possible contribution of larger rivers. The Chagrin was mentioned above, and we added a couple sites in the lower Cuyahoga River below Independence, OH. We collaborate with the Sewer District for access, and small numbers of mussels are appearing downstream, approaching the shipping channel. We are also awaiting some results from a dredge project conducted out from the mouth of the river.

Coastal assessment

Assessment of fresh shells along beaches was extended to support recent published results by Crail et al.(2011), in particular near Turtle Creek, and a residential area called Reno Beach (Fig. 1). Contrasts of shells show clear variation from the species present in the small streams. Thus the evidence strongly supports that some of the fast-

growing species, like Fragile Papershell and Giant Floater live in Lake Erie despite the presence of dreissenid mussels. Live animals were not found in the period of the present project, but that omission suggests only that the extant Lake Erie populations extend beyond the shallow nearshore. The surveyed areas tended to have packed sand and clay with coarse ridging, suggestive of the effects of wave action. Such a substrate composition would provide little support for mussels, and may act as a sink habitat where mussels drop off from fish, but are periodically washed ashore in storms. The source populations must therefore be farther out, as Fragile Papershell, for one, is a minor component of the flooded river mouth populations, but it is simply abundant as very recently deceased animals along shore. Some of these shells still contain mussel tissue. Other species also are found washed ashore, including Threehorn Wartyback, Mapleleaf, and Threeridge (*Amblema plicata*) but in much lower numbers.

Although this present technical report pertains to work performed between April, 2010 and June 30, 2011. The project continues. Perhaps the most exciting component of the LEPF award is that it contributed to the evidence of mussel recolonization, strengthening a successful grant application to the Federal Great Lake Recovery Initiative, which now is bringing mussel researchers together from multiple universities and agencies in the region to fully survey the region for refugia and to assess habitat models to improve conditions for sustaining mussel communities. Specifically, the small award provided data of much greater numbers of small refugia throughout the region, and enabled a graduate student (Trevor Prescott) to progress well on a Master of Science Thesis at Cleveland State University. Trevor led the survey work in the stream mouths and now continues on a habitat assessment of these areas using GIS and Remote Sensing technology. An example of such assessments is provided for Old Woman Creek (Fig. 3), and these will be produced for each of the small streams listed here. This aspect of the project should be completed by the end of the 2011 calendar year, supported by an assistantship to Trevor from Cleveland State University.

Thus the goals of the proposal were met.

We extended surveys of mussels along Lake Erie's coastline and found multiple populations near the mouths of several of the smaller creeks and streams that flow into the lake, and support that a few species sustain populations in the lake. Unquestionably, mussel abundance and diversity correlates with reduced human impacts. Because riparian zones are not extensive, the wider, shallow streams dominated by areas of deposition possessed many more species and total mussels than did streams with narrow banks cut into the hard clay. Narrow streams will be impacted much more by rapid runoff. Potentially rates of run-off associated with agriculture may therefore be the most important factor in flooded stream mouths; this analysis is continuing using remote sensing data. The impact of dredging at stream mouths for small marinas may not have a great impact and may help to keep streams open to the lake.

A second important characteristic to investigate is how mussels are impacted by shoreline manipulation to reduce erosion. We did not find mussels close to shore, although shells of a few species (mainly Fragile Papershell) are commonly washed ashore. Therefore, coastal manipulation to reduce erosion may not have a direct affect on

mussels. Whether sediment creation from erosion would benefit mussels out in the lake is not readily testable, and certainly not in the scope of the present project. Therefore we have no evidence to suggest changing present policy with respect to creation of shoreline structures. More may become known as studies of Lake Erie's populations

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Outputs:

This present work was presented at the Biannual meeting of the Freshwater Mollusk Conservation Society in April, 2011. As data collection was only completed in June, 2011, writing and analysis are in the early stages. We still plan to provide an updated edition on the mussel chapter of Old Woman Creek and the surrounding watersheds as part of the Atlas under production by the OWCNERR. Our studies of flooded stream mouths along Lake Erie provide new data for almost all of the streams we entered, and we conducted the first designed survey of this habitat type. These results are being prepared for the Journal of Great Lakes Research. This project will allow Trevor Prescott to produce a Masters Thesis, also in progress. Longer term, this work clearly adds to an assessment of the whole lake and contribute as a base to ongoing genetical studies of divergence among rivers within a large-lake system that are 2-4 years down the pipe-line.

Table 1. Mussels found alive and as freshly spent (dead) shells within the survey region or Lake erie and Sandusky Bay.

Site Name	County	Species Name	Live	Dead
Cedar Creek	Lucas	Lasmigona complanata	2	1
		Lasmigona compressa	0	1
		Leptodea fragilis	1	1
		Ligumia nasuta	0	5
		Pyganodon grandis	0	12
		Toxolasma parvum	0	3
Chagrin River	Lake	Lampsilis siliquoidea	0	2
		Potamilus alatus	0	1
		Ptychobranchus fasciolaris	0	1
		Pyganodon grandis	8	1
		Toxolasma parvum	0	3
		Utterbackia imbecillis	2	1
Cranberry Creek	Erie	Lasmigona complanata	5	1
		Pyganodon grandis	9	2
		Quadrula Quadrula	1	0
		Toxolasma parvum	1	1
Cuyahoga (Lower)	Cuyahoga	Lasmigona complanata	0	1
		Leptodea fragilis	0	1
		Potamilus alatus	0	11
		Pyganodon grandis	0	4
Old Woman Creek	Erie	Leptodea fragilis	0	3
		Pyganodon grandis	3	11
		Quadrula quadrula	2	1
		Toxolasma parvum	1	1
		Utterbackia imbecillis	0	2
Plum Brook	Erie	Leptodea fragilis	7	0
		Pyganodon grandis	11	0
		Toxolasma parvum	13	3
		Utterbackia imbecillis	2	0
Reno Beach	Lucas	Amblema plicata	0	1
		Elliptio dilatata	0	1
		Fusconaia flava	0	10
		Lampsilis siliquoidea	0	54
		Leptodea fragilis	0	15
Raccoon Creek	Sandusky	*Lasmigona complanata*	10	2
		Pyganodon grandis	3	3
		Strophitus undulatus	0	3
Sheldon March (beach)	Erie	*Lampsilis siliquoidea*	0	1
		Leptodea fragilis	0	2
		Pyganodon grandis	0	25
		Utterbackia imbecillis	0	1

South Creek	Sandusky	*Lampsilis siliquoidea*	0	1
		Lasmigona complanata	3	2
		Leptodea fragilis	12	5
		Pyganodon grandis	37	31
		Quadrula quadrula	5	0
		Toxolasma parvum	0	5
		Utterbackia imbecillis	0	7
Toussaint River	Ottawa	*Amblema plicata*	1	2
		Leptodea fragilis	1	1
		Obliquaria reflexa	6	5
		Potamilus alatus	0	2
		Pyganodon grandis	3	12
		Quadrula quadrula	32	13
		Strophitus undulatus	0	1
		Toxolasma parvum	2	2
		Utterbackia imbecillis	9	1
Turtle Creek (estuary)	Ottawa	*Leptodea fragilis*	2	9
		Potamilus alatus	0	2
		Pyganodon grandis	14	18
		Quadrula pustulosa	0	1
		Quadrula quadrula	42	10
		Toxolasma parvum	1	0
Turtle Creek (beach)	Ottawa	*Leptodea fragilis*	0	48
		Pyganodon grandis	0	1
		Quadrula quadrula	0	1
Yellow Swale	Sandusky	*Lasmigona complanata*	1	4
		Pyganodon grandis	27	77
		Quadrula quadrula	1	0
		Toxolasma parvum	5	19
		Utterbackia imbecillis	0	2
		Uniomerus tetralasmus	1	3

Table 2. Latitude and longitude taken at the stream access points for each of the small stream surveyed and the mussels collected per 1 person hour unit effort (CPUE). CPUE values are for the entire stream. Results are separated based on animal collected alive, shells, and total records. Where two survey points are indicated, the first point is upstream, the 2nd downstream.

Stream Name	Latitude	Longitude	Live CPUE	Shells CPUE	Total CPUE
Cedar	41 38' 2.5”	83 18' 3.7”	0.38	2.88	3.25
Turtle	41 36' 16”	83 9' 11.7”	4.92	3.33	8.25
Toussaint	41 34' 44.1”	83 8' 42.3”	4.50	3.25	7.75
	41 34' 59.3”	83 5' 29.9”			
Yellow	41 25' 18.8”	83 2' 4.6”	2.92	7.92	10.83
	41 25' 20.1”	83 2' 3.6”			
South	41 24' 52.5”	83 0' 30.2”	4.75	4.17	8.92
	41 24' 54.3”	83 0' 16.5”			
Raccoon	41 24' 28.4”	82 58' 55.7”	3.25	2.00	5.25
Plum Brook	41 25' 29.5	82 38' 23.8”	4.13	0.38	4.50
Cranberry	41 22' 51.8”	82 28' 20.8	4.00	1.00	5.00
Chapel	41 23' 30.5”	82 26' 22.6”	0.00	0.00	0.00

Table 3. Water chemistry analysis of10 flooded stream mouths along the southern coasts of Lake Erie and Sandusky Bay.

Site	SPECIFIC COND	Chloride	TURBIDITY	ALK-tot	NH_3-N AMMONIA	NO_2-N NITRITE	N_3+N_2 (NO_3-N)	NITRATE	SILICATE	Sulfate	SRP PO4	P-dis	P	Ca	Mg	Na	K	Fe-tot
	µmhos/cm	(ppm)	(JTU)	(ppm)	(ppm)	(ppb)	(ppm)	(ppm)	(ppm)	(ppm)	(ppb)	(ppb)	(ppb)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
Cedar Creek-1	814	107.3	17.7	185.0	0.003	2.0	0.040	0.038	7.561	66.2	55.5	67	109	66.10	21.33	63.95	4.43	0.38
Cedar Creek-2	816	107.3	18	184.1	0.002	2.0	0.039	0.037	7.606	65.4	56.5	67	102	64.63	20.82	62.75	4.36	0.36
Turtle Creek	516	32.3	92.4	161.9	0.086	5.8	0.023	0.017	3.213	56.7	113.9	123	312	56.48	20.52	15.24	3.87	2.01
Toussant River-1	768	74.4	68.2	190.4	0.044	5.2	0.023	0.018	2.425	98.1	132.8	140	265	73.45	27.69	35.16	7.71	1.28
Toussant River-2	768	74.4	68.3	190.4	0.044	5.2	0.020	0.015	2.425	99.4	133.1	142	258	74.02	27.57	35.54	7.90	1.46
Yellow Swale	626	39.6	55.1	206.4	0.133	2.8	0.008	0.005	5.329	60.0	83.1	99	137	69.30	21.52	22.68	6.20	1.17
South Creek-1	1817	50.9	51.3	206.4	0.000	0.5	0.000	0.000	3.372	804.6	26.1	39	233	323.37	66.47	32.83	5.26	1.02
South Creek-2	1822	50.9	51.7	207.7	0.000	0.5	0.000	0.000	3.336	804.6	26.1	42	154	323.13	65.61	32.83	5.14	1.15
Raccoon Creek	2104	116.4	21.6	187.1	0.009	22.9	6.745	6.722	1.238	786.4	78.9	95	145	276.93	33.82	167.04	21.09	0.46
Plum Brook-1	509	61.1	21	117.7	0.005	0.8	0.023	0.022	0.264	40.0	34.5	46	127	46.03	14.71	33.00	3.28	0.53
Plum Brook-2	511	61.1	20.8	117.3	0.007	0.8	0.013	0.012	0.269	38.9	34.6	46	126	45.81	14.65	33.37	3.42	0.56
Old Woman Creek	516	64.3	30.5	132.8	0.000	0.6	0.000	0.000	2.096	26.4	2.7	18	112	42.87	13.05	38.72	4.68	0.77
Cranberry Creek-1	489	35.5	17.7	119.8	0.009	29.5	4.222	4.193	0.446	41.0	925	1490	1504	48.16	14.82	17.73	11.15	0.38
Cranberry Creek-2	490	35.5	17.6	120.2	0.010	30.0	4.326	4.296	0.446	39.6	815	1480	1539	48.11	14.80	17.50	11.13	0.34
Chappel Creek	569	62.9	23.3	150.1	0.000	1.2	0.083	0.082	0.786	35.9	15.3	29	89	53.50	13.69	35.83	5.12	0.62

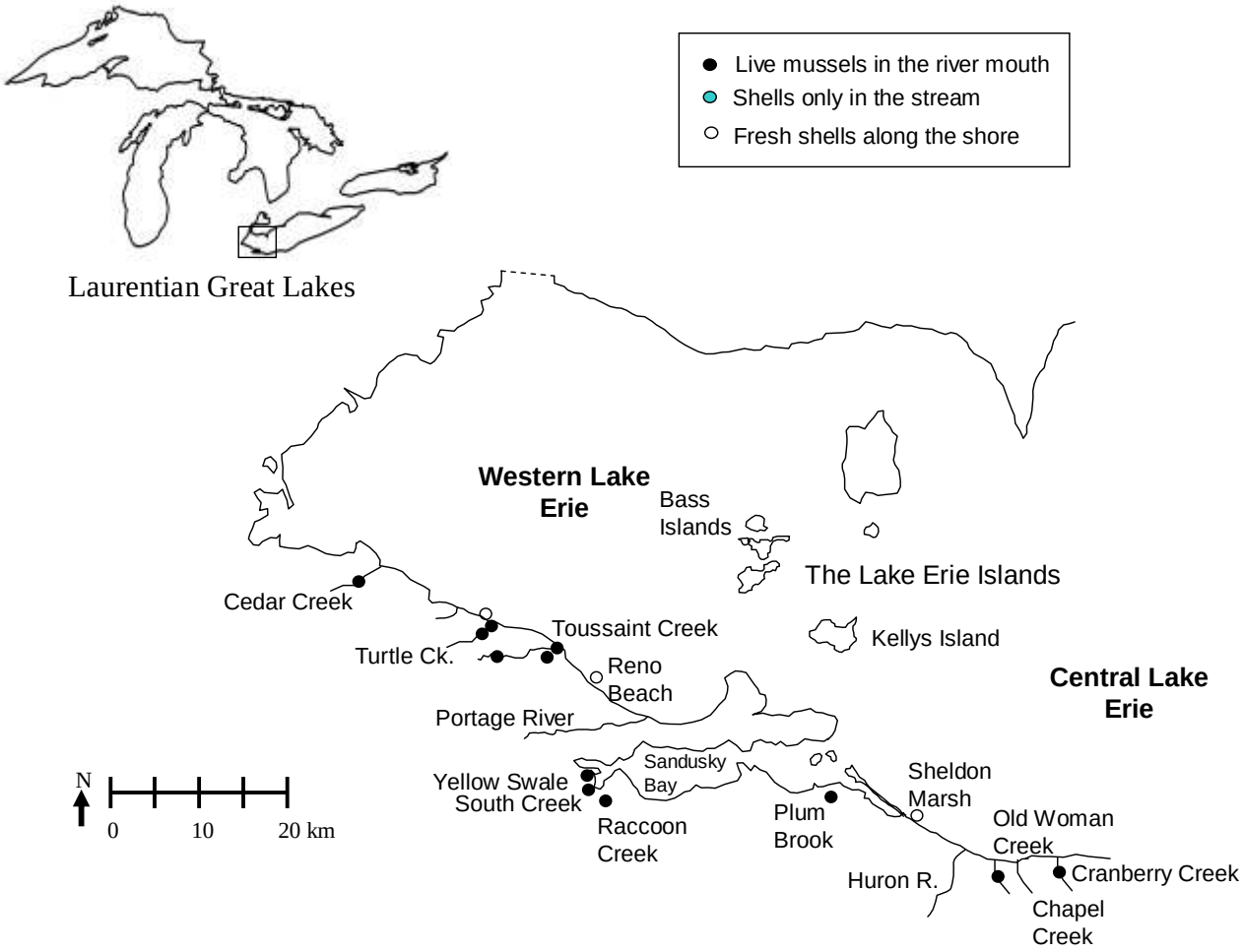

Fig. Survey site locations for the small stream estuary habitat surveyed. Filled circles denote approximate geographic areas for surveys although multiple sites were examined in each stream; some were sufficiently close o be encompassed by the single point indicated. Stream access was the primary factor limiting the scale of the investigation. The Cuyahoga and Chagrin Rivers are approximately 50 miles east of the border of this figure.

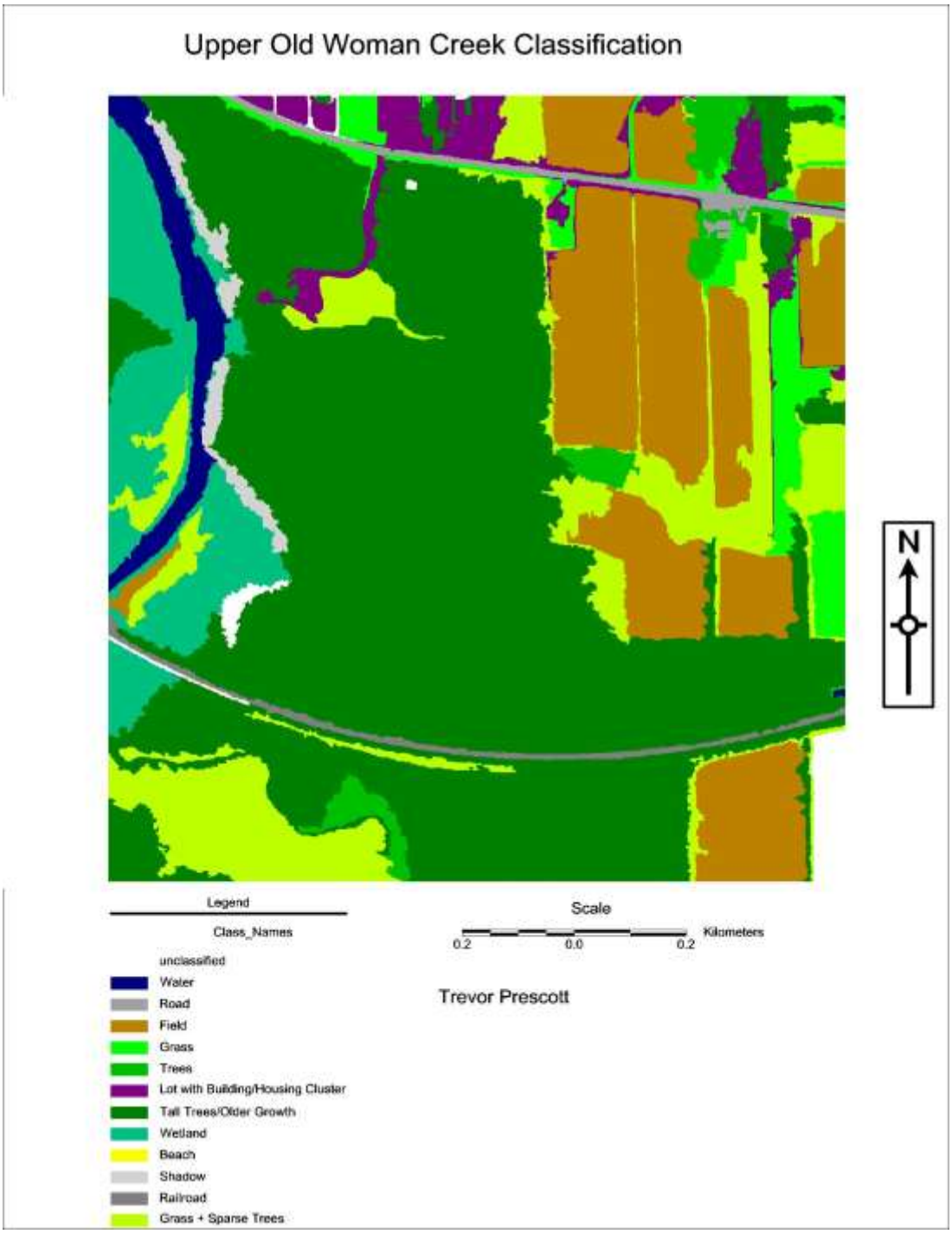

Fig. 2. An example of work in progress across the region to assess the landscape around the small estuaries. Shown is a section of Old Woman Creek where a combination of Lidar imaging and aerial photographs enable characterization of habitat, and importantly, identification of the stream channels with the surrounding shallow marshes and wetlands.