Reinforcement of American eel *Anguilla rostrata* populations in eastern Lake Ontario tributaries, Ontario, Canada

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SUMMARY

A dramatic decline in American eel *Anguilla rostrata* abundance led to the species being assessed as Endangered in Ontario (Canada) and the closure of fisheries. As part of efforts to recover populations, four million eels (glass eels and elvers) were released over a five year period into the upper St. Lawrence River and Lake Ontario. A large-scale electrofishing survey of eastern Lake Ontario tributaries was undertaken to assess the distribution and survival of the released eels. Four hundred and seventy-six eels were collected from 37 sites along seven watercourses. Eels were well-distributed along five rivers close to the release site. By contrast, distribution along the two largest rivers surveyed was restricted to a few kilometres upstream of Lake Ontario because of multiple impassable dams. The average length of eels caught in these two rivers was 40 mm shorter than eels in other watercourses. Eels were not detected in five smaller and colder creeks further west.

BACKGROUND

American eel *Anguilla rostrata* is a formerly common migratory fish species found in freshwater and coastal habitats of eastern North America (MacGregor *et al.* 2009).In the province of Ontario (Canada), a dramatic decline in the number of American eel over the past two decades led to closures of commercial and recreational fisheries (Mathers & Stewart 2009). The species has been assessed as Endangered in the province of Ontario, and Threatened in Canada (OMNR 2006, COSEWIC 2012). The decline has been attributed to both regional (fishing, pollution and dams) and global (declines in oceanic productivity) factors (COSEWIC 2006).

As part of conservation efforts to recover populations, young eels (glass eels and elvers) were translocated from the Atlantic coast to the upper St. Lawrence River and Lake Ontario between 2006 and 2010 (Threader *et al.* 2010). The goal was to reinforce the American eel population in these formerly productive rearing habitats, where populations of naturally recruiting eels were now small or absent (Pratt & Threader 2011). Glass eels and elvers have previously been transferred to enhance fisheries (Knights & White 1997), but translocations to increase the number of out-migrating silver-stage eels is a relatively new strategy (Verreault *et al.* 2009). The likely effects of the current ecological condition of the upper St. Lawrence River and Lake Ontario and the use of an earlier life-stage than naturally migrates into these habitats were unknown.

The success of recovery efforts will be evaluated based on desired outcomes, such as high post-release survival, the production of large and predominately female eels, and successful spawning migrations to the Sargasso Sea. To date, monitoring efforts undertaken by Fisheries and Oceans Canada and Ontario Power Generation within Lake Ontario and the upper St. Lawrence River have found that: (1) translocated eels have had high survival rates over the first five years, with all stocking year-classes present in 2011; (2) growth of individual eels has been rapid; (3) initially, a large proportion (50%) of eels were male; and (4) out-migrations of small, silvering eels have occurred (Verreault *et al.* 2010, Pratt & Threader 2011).

Tributaries flowing into eastern Lake Ontario historically provided a substantial area of habitat to maturing eels (MacGregor *et al.* 2009, MacGregor *et al.* 2013). However, these watersheds are now fragmented by old mill, low flow augmentation, flood control, navigation and hydro-power generation dams. Over the past century, sightings of eels in these rivers became increasingly rare with no reports of eel capture after the 1980s (MacGregor *et al.* 2013). Furthermore, recent electrofishing surveys of these watersheds did not detect American eel (Reid *et al.* 2005, Reid 2006, Stanfield & Kilgour 2006). The accessibility and productivity of these habitats to translocated eels was therefore unknown (Greig *et al.* 2006). The objectives of this study were to: (1) characterise the distribution of translocated eel along Lake Ontario tributaries, and (2) assess the effect of dams on upstream dispersal.

ACTION

Four million eels (glass and elver stages) were released over five years (2006–2010) at two locations: Deseronto, Bay of Quinte (44°11’41”N, 77°02’51”W) and Mallorytown Landing, St. Lawrence River (44°27’12”N, 75°51’30”W) (Pratt & Threader 2011). Between 142,033 and 2,001,561 eels were released annually. Elvers were only released in 2006. Target densities were set based on the amount of lake-habitat shallower than 10 m (estimated to be 2600 km^2). Eels were obtained from the commercial glass eel fishery in Nova Scotia and New Brunswick. The average length of released eels each year ranged from 56.5 mm to 60.9 mm.

One hundred fifty-four sites along 13 Lake Ontario tributaries were sampled once during September-October 2010

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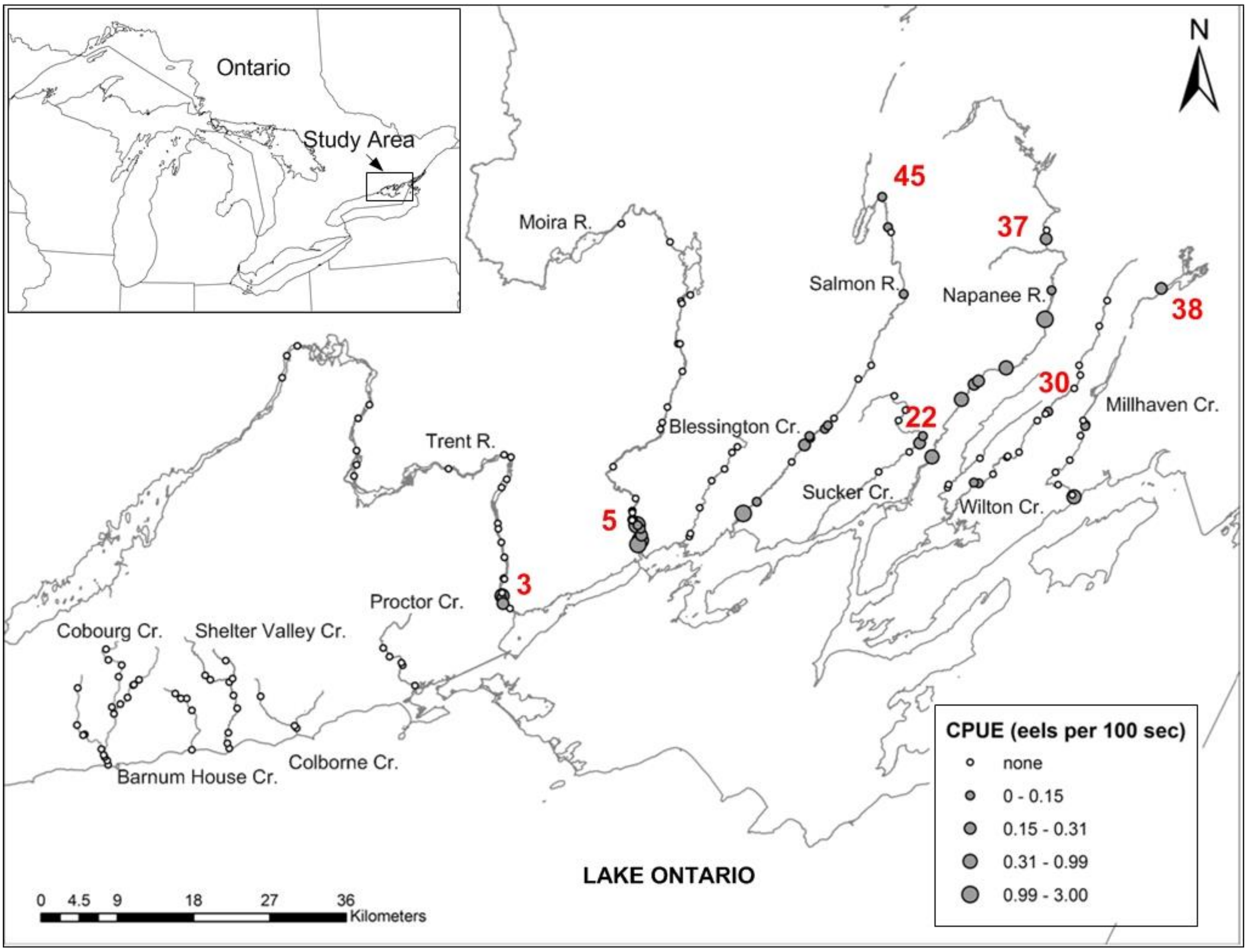

Figure 1. Location of sampling sites, and distribution and catch-per-unit effort (CPUE) of American eel. Figures represent maximum distance of eel capture upstream of Lake Ontario for each watercourse. Location of study area within the Laurentian Great Lakes basin is provided by inset map.

or June-October 2011 (Figure 1). There was a wide range of water temperatures, flow rates and bed material characteristics across sampling sites (Reid *et al.* 2005, Table 1). Individual sampling sites were placed within randomly selected river segments, with the number of sites along each tributary weighted relative to its length. River segments were identified using the Ontario Ministry of Natural Resources Aquatic Landscape Inventory Software (Stanfield & Kuyvenhoven 2002). Thirty-eight percent of selected sites were not surveyed, either because they were not wadeable or permission to access private property was not granted. Additional sites were selected to ensure that at least one site was sampled between each pair of dams, and to replace sites that could not be sampled.

A transect-based electrofishing strategy was adopted to detect American eel (Reid 2011). At 136 wadeable sites, sampling was carried out with a backpack electrofishing unit and one or two netters (Pulsed DC settings: 200-300 V, 50–60 Hz, 4–6 ms). Forty 10 x 1 m transects were systematically distributed at each site. Transect sets were placed parallel to banks at 10 m intervals, with transects within each set separated by 2 m across the channel. Due to large differences in channel width and availability of wadeable habitat, the configuration of transects varied between sites. Average electrofishing effort along each transect was 60 s. In addition to backpack electrofishing surveys, 18 non-wadeable sites along the Trent River were sampled with a single-anode, boat-mounted electrofishing unit. At each site, eight randomly-placed 50 m long shoreline transects were sampled. Average electrofishing effort along each of these transects was 90 s. Eels captured from each transect were held in separate buckets until processed. The probability of detecting eel when they are present at wadeable sites was estimated to be > 0.95 (Reid 2011), but was unknown for non-wadeable sites.

Length was used to distinguish translocated individuals from natural recruits. American eel that naturally migrate into Lake Ontario are on average between 3-5 years old, and prior to 2006 the average length of eels naturally migrating into Lake Ontario through the eel ladder at the Moses Saunders dam was 460 mm (95% confidence interval: 6 mm) (Marcogleise & Cassellman 2009). Given the small size of translocated eel in this study, a threshold length of 325 mm was used, with all eels shorter than this assumed to have been released at the site (Pratt & Threader 2011).

Seventy-one dams were identified along the sampled reaches. Upstream passability for eel was scored between 0 (free passage) and 5 (impassable) based on the following factors: drop height (m), profile (slope), roughness of downstream face, favourability of banks, and existence of an alternate passage route (Steinbach 2006). For each dam, the passability score is a weighted combination of individual scores associated with each factor. Nine dams were not assessed, as permission to access the private land where they were located could not be obtained.

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Table 1. Characteristics of sampled watercourses, showing presence of eels, number of dams and average (and range) channel width, water temperature and upstream dam passability scores.

Watercourse	Channel width (m)	Water temperature (°C)	Number of dams[a]	Upstream passability[b]	Eels present?
Barnum House Creek	4.1 (3.0 - 6.0)	13.0 (10.0 - 14.5)	1 (1)	3	No
Blessington Creek	5.6 (3.0-8.0)	21.3 (18.4-26.3)	2 (1)	0	No
Cobourg Creek	6.8 (2.0-14.0)	13.0 (10.5-17.8)	3 (2)	4.0 (3 – 5)	No
Colborne Creek	5.7 (5.0-6.0)	13.2 (11.8-14.6)	2 (1)	3.0 (3)	No
Millhaven Creek	11.9 (9.5-15.7)	27.3 (14.0-30.9)	7 (6)	3.0 (1 – 5)	Yes
Moira River	53.7 (15.0-83.6)	21.3 (9.1-27.5)	14 (13)	3.4 (0 - 5)	Yes
Napanee River	26.5 (12.3-38.0)	22.8 (12.1-26.1)	6 (6)	1.7 (0 – 4)	Yes
Proctor Creek	4.6 (3.0-6.0)	13.6 (1.0-14.2)	0	-	No
Salmon River	24.7 (7.0-57.0)	24.0 (9.8-28.0)	13 (11)	1.4 (0 – 4)	Yes
Shelter Valley Creek	7.9 (4.0-16.0)	15.0 (13.5-17.5)	3 (3)	3.0 (2 – 4)	No
Sucker Creek	6.7 (1.0-14.0)	23.3 (16.7-29.7)	1 (1)	0	Yes
Trent River	215.0 (75-630)	24.6 (22.8-25.9)	17 (17)	4.9 (4 – 5)	Yes
Wilton Creek	7.6 (4.2-16.6)	21.9 (17.0-25.5)	2 (0)	n/a	Yes

[a] number of dams assessed in parentheses
[b] 0 = free passage, 5 = impassable.

CONSEQUENCES

Four hundred and seventy-six eels were collected by backpack electrofisher from 37 sites along Sucker, Millhaven and Wilton creeks, and Moira, Napanee, Salmon and Trent rivers. No eels were captured in the other six tributaries (Figure 1). Only two eels were captured from boat-electrofishing surveys of the Trent River. Seventy-four percent of eels were collected from the Moira (n = 217) and Napanee (n = 134) rivers. The number of eels collected from each occupied site ranged from 1-77 (median = 3), and the number of transects with eels ranged from 1-33 (median = 3). Eels were collected from only a single transect at 27% of occupied sites. Average eel total length was 181 mm (standard error: 2.9) and only 3% of eels were large enough to potentially be natural recruits (Figure 2). These large eels were found in Millhaven and Wilton creeks, and the Napanee and Salmon rivers. Trent and Moira river eels were small, and were on average 40 mm shorter than eels in other watercourses (Figure 2).

Eels were widely distributed along the Napanee and Salmon rivers, but restricted to the lower reaches of the Moira and Trent rivers (Figures 1 and 3). None of the dams along the Napanee and Salmon rivers were assessed as impassable, and many were old and decaying, providing a rough surface for small eels to climb, and routes through (cracks and holes) and around structures. However, a series of dams classified as impassable were present along both the lower Moira and Trent rivers. These dams were of a newer construction, with high, steep faces of smooth material (concrete or steel gates) that extended out onto the river banks.

Eels were not detected in watercourses to the west of the Trent River (Barnhum House, Cobourg, Colborne, Proctor and Shelter Valley creeks). These creeks were colder and narrower than watercourses where translocated eel were found (Table 1).

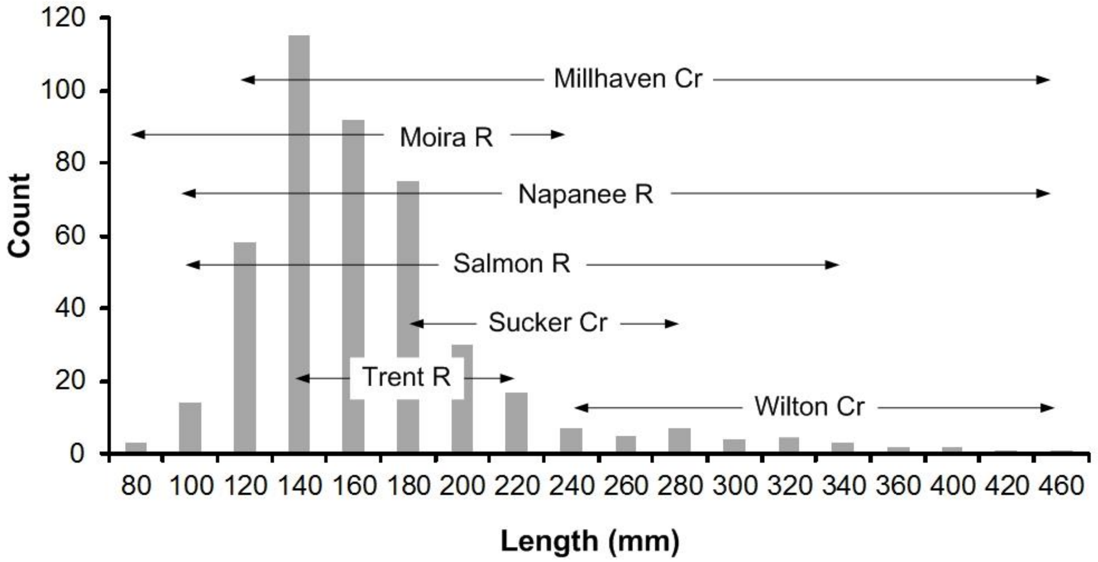

Figure 2. Length distribution of American eel captured from Lake Ontario tributaries and range for each watercourse. A 325 mm length threshold was used to distinguish translocated individuals from natural recruits.

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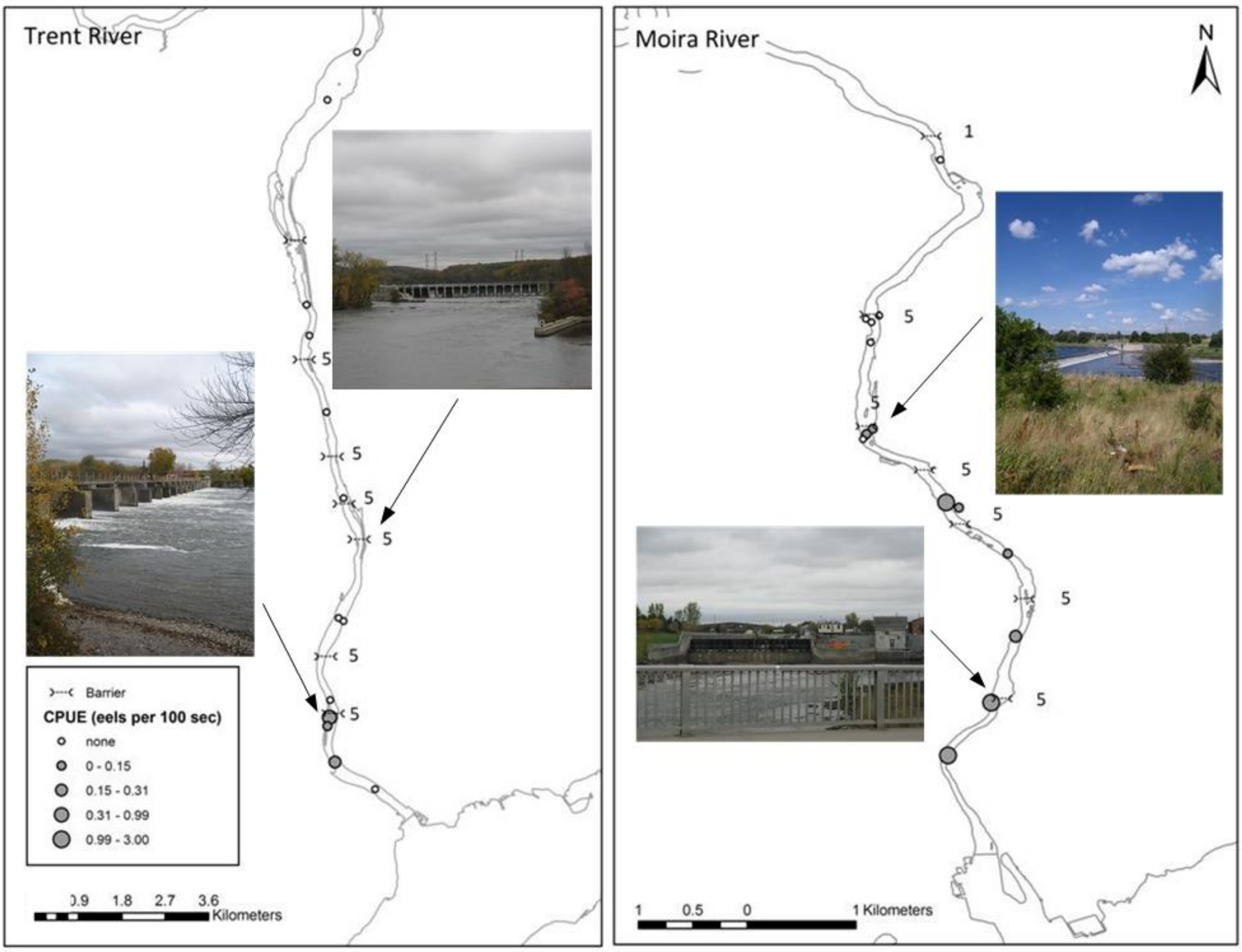

Figure 3. Distribution (catch-per-unit effort (CPUE)) of American eel and impassable dams (class 5) along the Moira and Trent River

DISCUSSION

The number of eels released into the upper St. Lawrence River and Lake Ontario was based on the assumption that 2,600 km^2 of eel habitat was available (Greig *et al.* 2006). Our survey indicates that a comparatively small amount of additional habitat (approximately 4 km^2) was being used by translocated eels in eastern Lake Ontario tributaries. This finding was corroborated by fish collection data from electrofishing surveys of 902 stream and river sites west of the Trent River (conducted by Fisheries and Oceans Canada,Ontario Federation of Anglers and Hunters, and Conservation Ontario). Between 2009 and 2011, only four small eels were collected. Together, these results indicate that few translocated eels have dispersed into tributaries west of the Trent River and migration has largely been local. However, we estimate that impassable dams along the lower Moira and Trent rivers prevent eels from accessing more than 760 km^2 of historical river and lake habitats. If future efforts to reinforce American eel populations are to include these historically important habitats, upstream passage needs to be improved, for example by eel ladders. Alternatively stocking should occur in areas upstream less affected by passability issues.

Along the lower Moira River, eels were collected from sites between the first five impassable dams (Figure 2). One of the impassable dams is a hydro-electric facility that was not fully operational in 2010. Partially-open gates would have provided an upstream passage route. Steinbach (2006) states that the upstream passability assessment key is best suited for identifying partially passable or almost impassable dams, and so it may not accurately identify completely impassable dams. Tremblay *et al.* (2011) recommend that passability assessments are completed during the expected eel migration period (mid-June to mid-October in the St. Lawrence River system). In our study area, this timeframe generally corresponds with the period of lower flows. However, for potentially impassable dams, the accuracy of our assessments might have been improved by repeating assessments when higher flows could provide alternate passage routes.

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