

Evaluating the Ecological Benefits and Risks of an Experimental Kidneyshell (*Ptychobranchus fasciolaris*) Reintroduction in Ontario

Todd J. Morris, Kelly A. McNichols-O'Rourke, Jason M. Barnucz, Karl A. Lamothe and Lauren E. Damphousse

Fisheries and Oceans Canada
Great Lakes Laboratory for Fisheries and Aquatic Sciences
867 Lakeshore Road
Burlington, ON
L7S 1A1

2026

**Canadian Manuscript Report of
Fisheries and Aquatic Sciences 3332**



Canadian Manuscript Report of Fisheries and Aquatic Sciences

Manuscript reports contain scientific and technical information that contributes to existing knowledge, but which deals with national or regional problems. Distribution is restricted to institutions or individuals located in particular regions of Canada. However, no restriction is placed on subject matter, and the series reflects the broad interests and policies of Fisheries and Oceans Canada, namely, fisheries and aquatic sciences.

Manuscript reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in the data base *Aquatic Sciences and Fisheries Abstracts*.

Manuscript reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page.

Numbers 1-900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 1426 - 1550 were issued as Department of Fisheries and Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Rapport manuscrit canadien des sciences halieutiques et aquatiques

Les rapports manuscrits contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui traitent de problèmes nationaux ou régionaux. La distribution en est limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques de Pêches et Océans Canada, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports manuscrits peuvent être cités comme des publications à part entière. Le titre exact figure au-dessus du résumé de chaque rapport. Les rapports manuscrits sont résumés dans la base de données *Résumés des sciences aquatiques et halieutiques*.

Les rapports manuscrits sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre.

Les numéros 1 à 900 de cette série ont été publiés à titre de Manuscrits (série biologique) de l'Office de biologie du Canada, et après le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés comme Manuscrits (série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros 901 à 1425 ont été publiés à titre de Rapports manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 sont parus à titre de Rapports manuscrits du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 1551.

Canadian Manuscript Report of
Fisheries and Aquatic Sciences 3332

2026

Evaluating the ecological benefits and risks of an experimental Kidneyshell
(*Ptychobranchnus fasciolaris*) reintroduction in Ontario

by

Todd J. Morris, Kelly A. McNichols-O'Rourke, Jason M. Barnucz, Karl A. Lamothe and
Lauren E. Damphousse

Ontario and Prairie Region
Fisheries and Oceans Canada
Great Lakes Laboratory for Fisheries and Aquatic Sciences
867 Lakeshore Road
Burlington, ON
L7S 1A1

© His Majesty the King in Right of Canada, as represented by the Minister of the Department of Fisheries and Oceans, 2026.

This work is licensed under the [Open Government Licence](#)

Cat. No. Fs97-4/3332E-PDF ISBN 978-0-662-32356-3 ISSN 1488-5387
<https://doi.org/10.60825/mefv-2j36>

Correct citation for this publication:

Morris, T.J., McNichols-O'Rourke, K.A., Barnucz, J.M., Lamothe, K.A. and Damphousse, L.E. 2026. Evaluating the ecological benefits and risks of an experimental Kidneyshell (*Ptychobranchnus fasciolaris*) reintroduction in Ontario. Can. Manuscr. Rep. Fish. Aquat. Sci. 3332: xii + 72 p. <https://doi.org/10.60825/mefv-2j36>

TABLE OF CONTENTS

| | |
|---|-----|
| GLOSSARY | xii |
| INTRODUCTION | 1 |
| 1) IDENTIFY OBJECTIVES FOR REINTRODUCTION | 4 |
| 2) ASSESS THE PROBABILITY OF ACHIEVING THE OBJECTIVES | 5 |
| 2.1) HISTORICAL EVIDENCE FOR KIDNEYSHELL OCCURRENCE IN SOUTHERN ONTARIO RIVERS | 6 |
| Thames River | 6 |
| Grand River..... | 7 |
| Welland River | 7 |
| 2.2) CURRENT STATUS AND LIKELIHOOD OF EXTIRPATION | 7 |
| Thames River | 8 |
| Grand River..... | 8 |
| Welland River | 8 |
| 2.3) SUITABILITY OF THE SYDENHAM RIVER AS A DONOR POPULATION | 9 |
| Donor Potential for the Thames River (including Medway Creek)..... | 10 |
| Donor Potential for the Grand River..... | 10 |
| Donor Potential for Welland River | 11 |
| 2.4) SELECTION OF THE RECIPIENT SYSTEM | 11 |
| 3) HABITAT SUITABILITY OF MEDWAY CREEK FOR KIDNEYSHELL | 12 |
| 3.1) DATA USED TO ASSESS HABITAT SUITABILITY | 12 |
| 3.2) AVAILABILITY OF PHYSICAL HABITAT | 12 |
| Host Fish Community in Sydenham River | 24 |
| Host Fish Community in Ausable River..... | 24 |
| 3.4) CAGE TRIALS | 26 |
| 3.5) POTENTIAL BIOTIC CONSTRAINTS | 27 |
| Interspecific Competition with Resident Unionids..... | 27 |
| Predation | 28 |
| 3.6) LIMITING FACTORS AND THREATS TO KIDNEYSHELL ESTABLISHMENT | 29 |
| 4) ASSESS THE PROBABILITY OF UNINTENDED CONSEQUENCES | 33 |
| 4.1) GENETIC AND HEALTH RISKS ASSOCIATED WITH A CAPTIVE-BRED DONOR POPULATION | 33 |
| Founder Effects and Genetic Drift..... | 33 |
| Inbreeding and Outbreeding Depression | 34 |
| Interspecific Hybridization | 34 |

| | |
|---|----|
| Artificial Selection (Domestication) | 35 |
| 4.2) ENVIRONMENTAL RISKS ASSOCIATED WITH A CAPTIVE-BRED DONOR POPULATION | 35 |
| Pathogen Introduction | 35 |
| Ecosystem-Level Consequences of Translocation in Medway Creek | 37 |
| Potential Impacts to the Donor Population (Sydenham River)..... | 38 |
| Invasive Species Introduction | 38 |
| 5) STRUCTURED EXPERT JUDGEMENT EXERCISE | 39 |
| Peer Review Meeting | 39 |
| Modified Mini-Delphi Results | 40 |
| Objectives and feasibility related factors influencing feasibility..... | 46 |
| 6) ASSESSMENT..... | 51 |
| Summary | 53 |
| ACKNOWLEDGEMENTS | 54 |
| REFERENCES CITED | 55 |

LIST OF TABLES

| | |
|--|----|
| Table 1. Summary of Kidneyshell information and population status across its distribution in southwestern, Ontario, Canada..... | 2 |
| Table 2. Mussel species found alive (Y) and as shells (SH) in the Upper Thames River (UTR) watershed and Medway Creek over time. Species at risk are highlighted (Government of Canada 2026). See Appendix 3 for scientific nomenclature (table modified from Gibson et al. 2025). | 18 |
| Table 3. Species detected, abundance, and species life-history strategies (LHS) at sites surveyed in the Medway Creek watershed in 2024. Species at risk are highlighted in grey. S = species found as shells or valves, Y = yes, N = no, UNK = unknown (table modified from Gibson et al. 2025). | 20 |
| Table 4. Summary of abundance (<i>n</i>) and relative abundance (RA; %) of Kidneyshell host fish species recorded across watershed locations (DFO unpublished data; UTRCA unpublished data)..... | 23 |
| Table 5. Pathogens screened as part of routine fish health monitoring at the OMNR White Lake Fish Culture Station..... | 37 |
| Table 6. Summary results of expert elicitation process. Included are the mean (median) lowest plausible probability (LPP), best guess probability (BGP), and highest plausible probability (HPP) for Questions 1-16. In addition, pooled mean (median) values of the equal-weight linear opinion pool are reported, along with hard union bounds (lowest LPP across participants–highest HPP across participants), and the 90 th percentile. N = number of participants that answered each question. | 44 |

LIST OF FIGURES

| | |
|--|----|
| Figure 1. All Kidneyshell (<i>Ptychobranchnus fasciolaris</i>) records (closed circles) and all sites surveyed (open circles) within the Canadian range of the species from 1882 to 2025 (Fisheries and Oceans Canada 2026). Map created by J. Colm (DFO). | 1 |
| Figure 2. Framework outlining the scientific considerations assessed in evaluating reintroduction as a recovery action for freshwater species listed under the <i>Species at Risk Act</i> (2002). Modified from Lamothe et al. (2023). | 4 |
| Figure 3. Visual estimates of percent substrate composition recorded at UMBO sites in the Sydenham River between 2022-2024, Medway Creek in 2025, and the Ausable River between 2018 and 2019. Sites included from the Sydenham and Ausable rivers were selected based on the presence of Kidneyshell (DFO unpublished data). | 14 |
| Figure 4. Mean substrate composition at UMBO sites in the Sydenham River between 2022-2024, Medway Creek in 2025, and the Ausable River between 2018 and 2019. Sites included from the Sydenham and Ausable rivers were selected based on the presence of Kidneyshell (DFO unpublished data). | 15 |
| Figure 5. Water quality parameters collected in the Sydenham River (SR), Medway Creek (MC), and the Ausable River (AR). Note: water clarity in Medway Creek exceeded the 0.60 m turbidity tube included as 0.60 m for visualization purposes. No data were available for the total dissolved solids (mg/L), or turbidity (FNU) in the Ausable River. | 16 |
| Figure 6. Sites sampled in the Medway Creek watershed in 2024, including new sites, previous timed-search sites, and sites where live Kidneyshell and/or shells have been detected. Map created by J. Colm (DFO). | 19 |
| Figure 7. Relative abundance (%) of Kidneyshell host fish species from Medway Creek (DFO unpublished data; UTRCA unpublished data). | 24 |
| Figure 8. Relative abundance (%) of Kidneyshell host fish species from the East Sydenham River (DFO unpublished data). | 25 |
| Figure 9. Relative abundance (%) of Kidneyshell host fish species from the Ausable River (DFO unpublished data). | 25 |
| Figure 10. von Bertalanffy growth curves for Kidneyshell collected from the Ausable River between 2012 and 2013 (red) ($n = 99$) and from propagated individuals housed at OMNR White Lake Fish Culture Station (black) ($n = 1050$). Ausable River data represent thin sections of individual shells and hatchery data represent repeated annual measurements made on individuals. | 27 |
| Figure 11. Provincial Water Quality Monitoring Network data by watershed (multiple stations) for chloride - including the Canadian Council of Ministers of the Environment | |

(CCME) guidelines for the protection of aquatic life (solid line at 120 mg/L for chronic exposure and dotted line at 640 mg/L for short-term exposure). Figure from Colm et al. (*In Press*)..... 30

Figure 12. Provincial Water Quality Monitoring Network data by waterbody (multiple stations) for total ammonia (mg/L). Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of aquatic life for ammonia vary with temperature and pH, but range from approximately 0.035–8.47 across the range of temperature and pH measured. Figure from Colm et al. (*In Press*)..... 31

Figure 13. Feasibility related questions divided by subcategory. Black and red points indicate the mean and median best guess probability across participants, respectively. The interval between the mean lowest plausible probability and mean highest plausible probability across participants is shown with a black line. Intervals were similarly calculated using the median values, show in red. Blue points indicate the pooled mean probabilities, and the blue intervals represent the 90% credible interval of the equal-weight linear opinion pool..... 41

Figure 14. Risk-related questions divided by subcategory. Black and red points indicate the mean and median best guess probability across participants, respectively. The interval between the mean lowest plausible probability and mean highest plausible probability across participants is shown with a black line. Intervals were similarly calculated using the median values, show in red. Blue points indicate the pooled mean probabilities, and the blue intervals represent the 90% credible interval of the equal-weight linear opinion pool..... 42

Figure 15. Expert participant scores for each question. Points indicate best guess probabilities and error bars indicate lowest to highest plausible probabilities. Each line represents an individual expert’s score. 43

Figure 16. Participant-specific (colours) PERT distributions for the Objectives related question, Question 1: What is the probability that establishing an additional population of Kidneyshell will increase the likelihood of survival or recovery of Kidneyshell in Canada? Black line indicates equal-weight linear opinion pool..... 46

Figure 17. Participant-specific (colours) PERT distributions for the population-related feasibility questions (Questions 2-5). Black lines indicate equal-weight linear opinion pools..... 47

Figure 18. Participant-specific (colours) PERT distributions for the habitat-related feasibility questions (Questions 6a-6d). Black lines indicate equal-weight linear opinion pools..... 48

Figure 19. Participant-specific (colours) PERT distributions for the community-related feasibility questions (Questions 7a, b). Black lines indicate equal-weight linear opinion pools..... 49

Figure 20. Participant-specific (colours) PERT distributions for the threat-related feasibility questions (Questions 8a, b). Black lines indicate equal-weight linear opinion pools..... 49

Figure 21. Participant-specific (colours) PERT distributions for the genetic-related risk questions (Questions 9-14). Black lines indicate equal-weight linear opinion pools..... 50

Figure 22. Participant-specific (colours) PERT distributions for the pathogen- and ecosystem-related risk questions (Questions 15,16). Black lines indicate equal-weight linear opinion pools. 51

LIST OF APPENDICES

| | |
|--|----|
| Appendix 1 Population, habitat, community, and threat considerations for evaluating the feasibility to reintroduce Kidneyshell in Canada. | 66 |
| Appendix 2. Ecological risk considerations associated with the translocation of Kidneyshell to Medway Creek. | 69 |
| Appendix 3. Scientific names for mussels. Nomenclature for mussels follows MolluscaBase eds. (2026) for scientific names and Williams et al. (2017) for common names. Species at risk, as of April 2026 are highlighted (Government of Canada 2026). | 70 |
| Appendix 4. Scientific names for fishes. Nomenclature for fishes follows Page et al. (2023)..... | 71 |
| Appendix 5. Names and affiliations of attendees at the April 8-9, 2026 peer review meeting. Meeting attendees were invited as experts on Kidneyshell, its habitat, and/or threats; as such, their opinions do not necessarily represent the opinions of their respective agencies..... | 72 |

ABSTRACT

Morris, T.J., McNichols-O'Rourke, K.A., Barnucz, J.M., Lamothe, K.A. and Dampousse, L.E. 2026. Evaluating the ecological benefits and risks of an experimental Kidneyshell (*Ptychobranchnus fasciolaris*) reintroduction in Ontario. Can. Manuscr. Rep. Fish. Aquat. Sci. 3332: xii + 72 p.
<https://doi.org/10.60825/mefv-2j36>

Reintroduction is recognized as an approach to support the persistence and recovery of species listed under the *Species at Risk Act* (SARA), but it has yet to be used for freshwater mussels in Canada. Kidneyshell (*Ptychobranchnus fasciolaris*) has experienced extensive contraction of its range in southern Ontario, with extirpation from several historically occupied river systems. A captive-reared cohort of Kidneyshell, propagated by the Ontario Ministry of Natural Resources at White Lake Fish Culture Station in 2015 from Sydenham River broodstock, now presents a time-sensitive opportunity for reintroduction rather than continued long-term maintenance in captivity. Recent advances in understanding of Kidneyshell population status, habitat requirements, and genetic composition, alongside national guidance for aquatic species reintroductions, enable an evaluation of reintroduction as a viable recovery action. Here, we applied a decision-support framework using a modified mini-Delphi expert elicitation approach to assess the likelihood of achieving the fundamental objective of improving survival or recovery of Kidneyshell in Canada through conservation translocation. An expert elicitation peer-review meeting was held April 8-9, 2026 to evaluate available information; assess the probability of achieving the fundamental and means objectives; and, identify and assess the probability of experiencing unintended consequences. Results from the expert-elicitation process indicated that reintroduction of Kidneyshell into its historical range within Medway Creek, a tributary of the Thames River, is likely to improve the survival and recovery of Kidneyshell in Canada. Suitable habitat and environmental conditions likely exist to support Kidneyshell within the waterbody and although threats still exist across the landscape, they are unlikely to limit establishment over the next ten years. Ecological risks were considered low, and it is not anticipated that reintroduction would lead to negative ecosystem level changes.

RÉSUMÉ

Morris, T.J., McNichols-O'Rourke, K.A., Barnucz, J.M., Lamothe, K.A. and Dampousse, L.E. 2026. Evaluating the ecological benefits and risks of an experimental Kidneyshell (*Ptychobranthus fasciolaris*) reintroduction in Ontario. Can. Manuscr. Rep. Fish. Aquat. Sci. 3332: xii + 72 p.
<https://doi.org/10.60825/mefv-2j36>

La réintroduction est reconnue comme une approche visant à favoriser la survie et le rétablissement des espèces inscrites en vertu de la Loi sur les espèces en péril (LEP), mais elle n'a pas encore été mise en œuvre pour les moules d'eau douce au Canada. Le Ptychobranche réniforme (*Ptychobranthus fasciolaris*) a vu son aire de répartition se réduire considérablement dans le sud de l'Ontario, et a disparu de plusieurs réseaux fluviaux qu'elle occupait autrefois. Une cohorte de moules à rein élevées en captivité, reproduite par le ministère des Ressources naturelles de l'Ontario à la station d'élevage de poissons de White Lake en 2015 à partir de géniteurs de la rivière Sydenham, offre aujourd'hui une occasion à saisir rapidement pour une réintroduction plutôt qu'un maintien à long terme en captivité. Les progrès récents dans la compréhension de l'état des populations de la palourde rénale, de ses besoins en matière d'habitat et de sa composition génétique, ainsi que les lignes directrices nationales relatives à la réintroduction d'espèces aquatiques, permettent d'évaluer la réintroduction comme une mesure de rétablissement viable. Nous avons ici appliqué un cadre d'aide à la décision utilisant une approche modifiée de consultation d'experts de type mini-Delphi afin d'évaluer la probabilité d'atteindre l'objectif fondamental consistant à améliorer la survie ou le rétablissement de la palourde rénale au Canada par le biais d'un transfert de conservation. Une réunion d'examen par les pairs a eu lieu les 8 et 9 avril 2026 afin d'évaluer les informations disponibles, d'estimer la probabilité d'atteindre les objectifs fondamentaux et intermédiaires, et d'identifier et d'évaluer la probabilité de conséquences imprévues. Les résultats du processus d'expertise ont indiqué que la réintroduction de la palourde rénale dans son aire de répartition historique au sein de Medway Creek, un affluent de la Thames River, est susceptible d'améliorer la survie et le rétablissement de cette espèce au Canada. Un habitat et des conditions environnementales propices sont susceptibles d'exister pour soutenir la présence de la palourde réniforme dans ce plan d'eau et, bien que des menaces persistent à l'échelle du paysage, elles ne devraient pas limiter son établissement au cours des dix prochaines années. Les risques écologiques ont été jugés faibles, et la réintroduction ne devrait pas entraîner de changements négatifs au niveau de l'écosystème.

GLOSSARY

Augmentation (or Supplementation): The intentional release of individuals into an existing population to increase population size, genetic diversity, or demographic stability (IUCN/SSC 2013).

Broodstock: Wild-caught individuals used as reproductive sources for captive propagation or breeding programs (Rytwinski et al. 2021).

Captive-reared (or Captive-propagated) individuals: Individuals produced through controlled breeding or rearing in a managed facility, rather than in the wild (VanTassel et al. 2021).

Conservation Translocation: The intentional movement of species in an effort to improve survival or recovery (IUCN/SSC 2013). It represents a long-term, experimental restoration strategy for species at risk of extinction.

Donor (or Source) Population: The source population from which individuals are collected for translocation, reintroduction, or captive propagation (Heinrichs et al. 2019; IUCN/SSC 2013).

Recipient Population (or Recipient System): The population or ecosystem into which individuals are released as part of a translocation, reintroduction, or augmentation effort (Sherman et al. 2025; Lamothe et al. 2023).

Reintroduction: The intentional release of a species into an area where it has been extirpated, with the goal of re-establishing a self-sustaining population (IUCN/SSC 2013).

INTRODUCTION

Kidneyshell (*Ptychobranchnus fasciolaris*) is a medium-sized freshwater mussel listed as Endangered under Canada's *Species at Risk Act* (SARA 2002) due to its extirpation from approximately 70% of its historical range (Fisheries and Oceans Canada 2013). This sharp decline is largely attributed to habitat degradation, changes in land use, pollution, and the introduction of invasive species like Zebra Mussel (*Dreissena polymorpha*). Once widespread across the Ohio River and lower Great Lakes basins, within Canada, the species now persists in only two isolated populations in Ontario: Ausable River and East Sydenham River. Historically, the species was also present in the Detroit River, Thames River, Grand River and Welland River systems (COSEWIC 2013; Colm and Morris 2025), as well as the waters of Lake Erie and Lake St. Clair (Figure 1; Table 1).

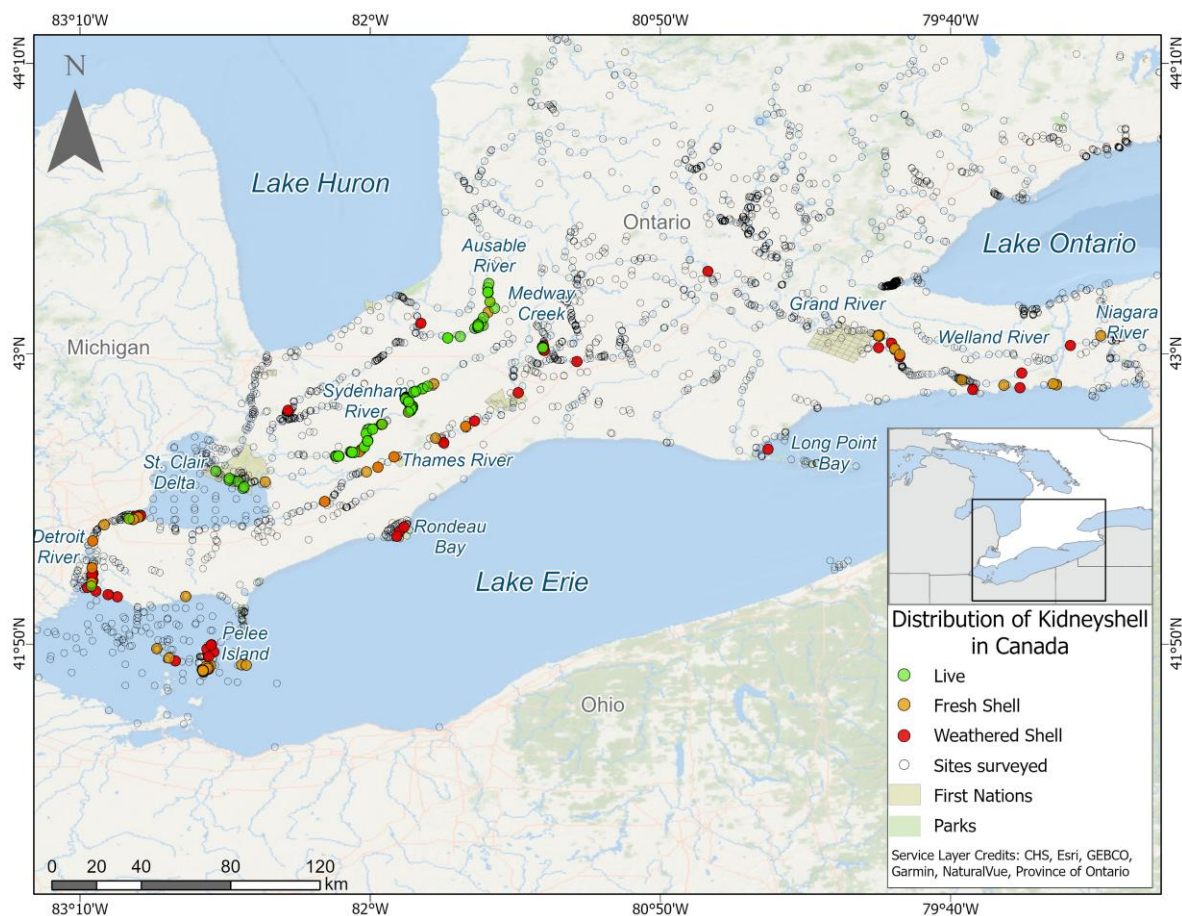


Figure 1. All Kidneyshell (*Ptychobranchnus fasciolaris*) records (closed circles) and all sites surveyed (open circles) within the Canadian range of the species from 1882 to 2025 (Fisheries and Oceans Canada 2026). Map created by J. Colm (DFO).

Table 1. Summary of Kidneyshell information and population status across its distribution in southwestern, Ontario, Canada.

| Population | First Collected | Last Collected Alive | Population Growth rate (λ) (Fung et al. 2025) | Population Status from Recovery Potential Assessment | Dreissenid Presence in occupied/formerly occupied reach |
|-------------------|------------------------|-------------------------------|---|---|--|
| Ausable River | 1994 | 2019 | 1.07 (95% CI: 1.02-1.13) | Fair | No |
| Sydenham River | 1963 | 2025 | 1.13 (95% CI: 1.11-1.15) | Good | No |
| Thames River | 1894 | 2008 (Medway Creek) | N/A | Presumed Extirpated | Yes – in main stem below Fanshawe Reservoir. Not in Medway Creek |
| Grand River | 1934 | No confirmed live collections | N/A | Extirpated | Yes – below Dunnville |
| Welland River | 1926 | No confirmed live collections | N/A | Extirpated | Yes |
| Lake St Clair | 1934 | 2003 | N/A | Presumed Extirpated | Yes |
| Detroit River | 1982 | 1998 | N/A | Extirpated | Yes |
| Lake Erie | 1885 | No confirmed live collections | N/A | Extirpated | Yes |

Conservation translocation approaches are commonly identified in species recovery strategies or management plans as potential methods for improving the survival or recovery of species listed under SARA (Swan et al. 2018; Lamothe and Drake 2019). The federal recovery strategy for Kidneyshell in Canada has a stated long-term goal to “...re-establish populations in historically occupied habitats, excluding areas where dreissenid mussels have now made habitats unsuitable” (Fisheries and Oceans Canada 2013, p. iv). While the continued persistence of dreissenids makes reintroduction or augmentation of lentic populations untenable at this time, opportunities exist to reintroduce extirpated riverine (lotic) populations in the historically occupied Thames, Grand, or Welland rivers and/or their tributaries.

Captive-reared Kidneyshell derived from Sydenham River broodstock produced in 2015 at White Lake Fish Culture Station by the Ontario Ministry of Natural Resources (OMNR) during efforts to develop freshwater mussel husbandry techniques in Canada presents an additional opportunity for reintroduction. These individuals are now approaching an age at which long-term maintenance in captivity may no longer be appropriate or beneficial. Rather than allowing these animals to perish in captivity, a conservation translocation represents an opportunity to contribute directly to recovery by attempting to re-establish a wild population within the species’ historical range.

A national Canadian Science Advisory Secretariat (CSAS) process provided guidance on how to evaluate the potential ecological benefits and risks of conservation translocations (including reintroduction) to the survival or recovery of SARA-listed freshwater species and broader ecosystem components (Lamothe et al. 2023). The framework (Figure 2) is used here to assess the feasibility of achieving improved survival or recovery of Kidneyshell through an experimental reintroduction to a formerly occupied riverine ecosystem in southwestern Ontario. Information is summarized below for each of the first three major sections of the conservation translocation framework: 1) Identify objectives for reintroduction; 2) Assess the probability of achieving the objectives; and 3) Identify and assess the probability of unintended consequences (Figure 2). Element 4 of the framework (Compile and weigh the scientific evidence) is addressed through a series of questions which are presented in Appendices 1 and 2 and which were discussed in a peer-review meeting held virtually on April 8–9, 2026. Specifically, Appendix 1 provides a series of questions on population, habitat, community, and threat-related factors to structure an assessment of the feasibility of achieving reintroduction objectives. Appendix 2 provides questions related to the probability of experiencing unintended consequences during or following reintroduction efforts. This report and associated peer-review meeting will provide guidance for management regarding the use of reintroduction for Kidneyshell recovery.

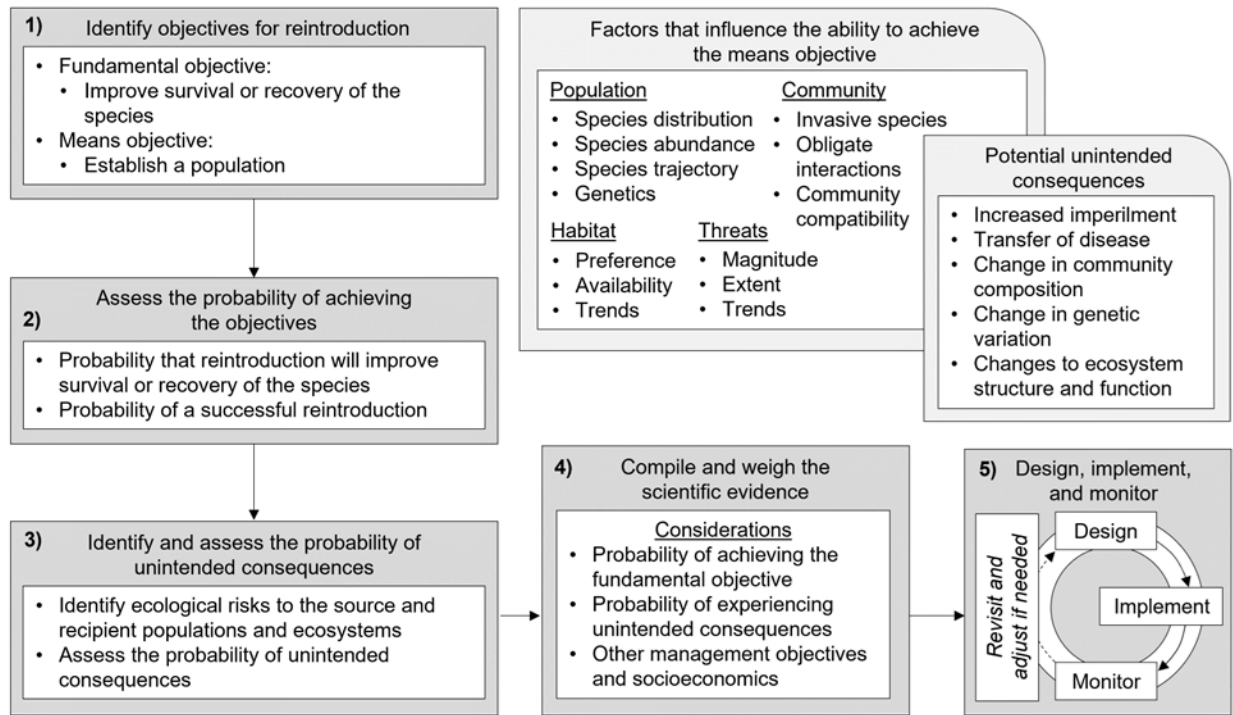


Figure 2. Framework outlining the scientific considerations assessed in evaluating reintroduction as a recovery action for freshwater species listed under the *Species at Risk Act* (2002). Modified from Lamothe et al. (2023).

1) IDENTIFY OBJECTIVES FOR REINTRODUCTION

The first step in considering a conservation translocation is to develop a problem statement and identify the fundamental and means objectives of performing the management action (Figure 2):

Problem statement: Kidneyshell is currently listed as Endangered under SARA and has been lost from approximately 70% of its historical range due to the combined impacts of 1) invasive species (i.e., Zebra Mussel) and 2) habitat loss from agricultural and urban land-use practices (Fisheries and Oceans Canada 2013). Relatively healthy populations remain in the Ausable and Sydenham rivers, while populations in the Detroit and Thames rivers, and lakes St. Clair and Erie are considered extirpated (Colm and Morris 2025). Although historical records of shell collections exist from both the Grand and Welland rivers, live Kidneyshell has never been collected from these systems. As such, the status of these potential populations was not evaluated by Colm and Morris (2025) (Table 1).

The federal recovery strategy for Kidneyshell in Canada identifies a long-term goal to “...re-establish populations in historically occupied habitats, excluding areas where *dreissenid* mussels have now made habitats unsuitable” via a short-term objective to

“(e)xamine the feasibility of relocations, reintroductions and the establishment of managed refuge sites” (Fisheries and Oceans Canada 2013, p. iv). Additionally, prior recovery actions for Kidneyshell in Canada have resulted in the availability of 779 individuals of the 2015 year-class (C. Wilson, OMNR, pers. comm. 2026). These individuals are available to be used for a conservation translocation in support of Kidneyshell recovery in Canada. However, there is uncertainty around the most appropriate recipient system for these individuals and the corresponding likelihood of success.

Fundamental objective: Improve the survival or recovery of Kidneyshell in Canada.

Means objective: As identified in the species recovery strategy (Fisheries and Oceans Canada 2013), the approach being considered to improve the survival or recovery of Kidneyshell in Canada is reintroduction to a formerly occupied location using the animals propagated by the OMNR.

Achieving the means objective requires first identifying potential recipient locations and then assessing the appropriateness of establishing a population in a recipient river using individuals derived from the Sydenham River. A decision to move forward, or not, with reintroduction follows an assessment of the suitability of a candidate recipient system including an assessment of the availability of physical and biological habitat, threats, and the risks of unintended consequences.

2) ASSESS THE PROBABILITY OF ACHIEVING THE OBJECTIVES

The next step is to assess the probability of achieving the objectives and consider the factors that may influence the ability to achieve those objectives (Figure 2). Recovery of at-risk species is often grounded in the principles of resiliency, redundancy, and representation (Shaffer and Stein 2000). Establishing an additional population for Kidneyshell can increase the species’ resilience by increasing capacity to withstand stochastic events, can increase its redundancy by redistributing risk across additional populations, and can improve representation by altering its ability to adapt to changing environmental conditions (Dunn et al. 2024).

In assessing the feasibility of reintroducing Eastern Sand Darter (*Ammocrypta pellucida*) to southern Ontario, Fisheries and Oceans Canada modelled the benefits of establishing an additional population (DFO 2025a). They determined that, depending upon condition of the new population (poor – good), establishment of a new population reduced the species’ extinction risk by 63 – 97% although the probability of persistence for each individual population remained uncertain. It is likely that similar benefits could be derived through the establishment of an additional Kidneyshell population. Furthermore, the quantitative criteria adopted from the International Union for Conservation of Nature (IUCN) and used by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) to assess the at-risk status of a species

places importance on the number of threat-based locations (IUCN 2012). Increasing the number of subpopulations of Kidneyshell in Canada will likely increase the number of locations, which may increase the chance of a COSEWIC reassessment at a lower risk level (Appendix 1, Question 1).

The following section examines the historical and current status of Kidneyshell populations in Canadian riverine systems and evaluates the suitability of potential recipient systems for the available captive-reared individuals. The evidence presented addresses the structured probability questions outlined in Appendix 1 (Questions 2–5), which consider historical occupancy, likelihood of persistence, donor population suitability, and identification of the optimal recipient system.

2.1) HISTORICAL EVIDENCE FOR KIDNEYSHELL OCCURRENCE IN SOUTHERN ONTARIO RIVERS

Kidneyshell was historically distributed across the Ohio River and lower Great Lakes basins. In Ontario, historical occurrence records indicate that the species was present in multiple southwestern Ontario systems, including the Ausable River, Lake St. Clair, Sydenham River, Thames River (and Medway Creek), Detroit River, Lake Erie, Grand River, Niagara River, and possibly the Welland River (Colm and Morris 2025) (Table 1, Figure 1). The invasion of dreissenids is identified as the primary driver of extirpation from the Great Lakes and connecting channels, including the St. Clair River, Detroit River, and Lake Erie systems. In contrast, a combination of intensive agricultural land-use, habitat modification, and impoundment is considered responsible for losses from large rivers such as the Grand and Thames (Colm and Morris 2025). As a result, contemporary opportunities for Kidneyshell recovery through reintroduction are most realistically confined to riverine environments where dreissenid impacts are limited, and habitat conditions remain suitable. The following subsections summarize historical evidence for occurrence in the three focal river systems.

Thames River

Kidneyshell has historically been found in the Thames River and its tributary Medway Creek (Figure 1). Shell records provide consistent evidence of historical occupancy for over 130 years. Documented shell material includes early collections from 1894 and 1933 in the lower river, followed by more recent records including 2005 (two shells downstream of Big Bend), 2011 (one fresh and one weathered shell near Tait's Corner), and the most recent observations in 2021 and 2022 (weathered valves near Thamesville) (Colm and Morris 2025). Within the upper Thames River watershed, a single weathered valve was found in the South Thames River in 2017; however, Medway Creek, a tributary of the North Thames River, represents the only location where live Kidneyshell have been confirmed in recent history and the only sites where collections of live Kidneyshell have ever been confirmed. Two live, old adults were

found in Medway Creek in 2004. Two additional individuals were found in 2006 and 2007 (one each year) and their presence was reconfirmed in 2008 (Colm and Morris 2025). Additional shells were collected in Medway Creek in 2024 and 2025, but no live individuals have been detected in the river since 2008 despite extensive search efforts (Gibson et al. 2025).

Grand River

Historical accounts of Kidneyshell in the Grand River are sporadic from 1934–1997, and while formal early surveys were limited, shell records persist along the main stem from Caledonia to the mouth at Port Maitland. Most recently, three shells were found near Caledonia in 2020 (Fisheries and Oceans Canada 2026). However, despite surveys at approximately 217 sites between 2001 and 2021, no live Kidneyshell was found (Goguen et al. 2023; Colm and Morris 2025). Fisheries and Oceans Canada has carried out repeated long-term monitoring of freshwater mussels in the Grand River over the last two decades as part of its Unionid Monitoring and Biodiversity Observation (UMBO) network monitoring program (Sheldon et al. 2020). During these monitoring efforts, nearly 1000 m² of river bottom has been sampled by hand in search of freshwater mussels with no indication of an extant population.

Welland River

Historical documentation of Kidneyshell in the Welland River (formerly Chippawa Creek) is more limited than the Grand and Thames rivers but nonetheless present (Figure 1). Records exist of at least 15 shells found prior to 1926, although their location near the river mouth raises questions about whether Kidneyshell was ever truly established within the Welland River itself (Colm and Morris 2025). A more recent shell discovered further upstream in the system adjacent to a feeder canal (an artificial connection between the lower Grand River and the Welland River) in 2015 may not represent *in situ* persistence and is more likely to have been deposited with fill material during construction or maintenance of the canals (Wright et al. 2017). While the evidence base is weaker than for the Grand or Thames rivers, the shell records support the inclusion of the Welland River within the historical Canadian range of Kidneyshell, but with higher uncertainty regarding the extent and structure of the former population.

2.2) CURRENT STATUS AND LIKELIHOOD OF EXTIRPATION

This section uses the historical evidence summarized above and the results of contemporary survey efforts to evaluate whether Kidneyshell is likely to persist in each candidate recipient system. For long-lived freshwater mussels, extirpation can be difficult to confirm, as individuals may persist for decades even after populations are no longer reproductively viable. As a result, populations may exist for extended periods as small, aging, and non-recruiting “ghost populations” before disappearing (Strayer et al. 2004; Campbell et al. 2008). Consequently, the continued absence of live individuals

across repeated surveys combined with the presence of only weathered or relict shell material is widely interpreted as strong evidence of functional extirpation for unionids (Campbell et al. 2008).

Thames River

Despite extensive survey effort throughout the main branches of the Thames River over the past several decades, no live Kidneyshell has been detected (Colm and Morris 2025). For example, LeBaron et al. (2023) surveyed 34 sites in the deepwater portions of the lower Thames River using a mussel brail and reported no detections. Similarly, community eDNA metabarcoding conducted across the North, South, and Middle Thames rivers in the upper watershed, as well as McGregor Creek in the lower watershed, also yielded no Kidneyshell detections (Coghlan et al. 2021). Although Medway Creek was not included in that study, Fisheries and Oceans Canada conducted targeted eDNA sampling in 2025 at two Medway Creek sites where live individuals had previously been detected (2004 and 2008). Six 1 L field replicates were collected at each site with each field replicate further divided into six lab replicates for analysis ($n = 72$). There were no positive Kidneyshell detections (DFO unpublished data).

Taken together, the consistent lack of detections across multiple survey methods and the absence of confirmed live records since 2008 indicates a low likelihood of a self-sustaining Kidneyshell population persisting in the Thames River.

Grand River

Targeted mussel surveys conducted throughout the Grand River between 2001 and 2021 have not detected any live Kidneyshell despite extensive spatial coverage and repeated sampling efforts (Minke-Martin et al. 2015; Goguen et al. 2023; Colm and Morris 2025). Community eDNA metabarcoding at two Grand River sites also failed to detect Kidneyshell (Coghlan et al. 2021). In addition, brail sampling conducted in deeper reaches near Brantford and at the river mouth yielded no detections (LeBaron et al. 2023). Given the absence of live individuals over more than two decades of intensive survey effort, the likelihood that Kidneyshell persists in the Grand River is considered very low.

Welland River

Evidence for historical Kidneyshell occurrence in the Welland River is limited to shell material, as no live individuals have been documented in any surveys. The most recent shell record from 2015 is of uncertain origin and may not reflect local persistence (Colm and Morris 2025). Community eDNA metabarcoding conducted at three Welland River sites—one on Coyle Creek and two on Oswego Creek—also yielded no Kidneyshell detections (Coghlan et al. 2021). It should be noted that these eDNA sampling locations

were situated upstream of historical shell records. Due to the absence of contemporary live detections and the high degree of channel modification in the system, the probability that a viable Kidneyshell population remains in the Welland River is considered very low.

2.3) SUITABILITY OF THE SYDENHAM RIVER AS A DONOR POPULATION

The next consideration for performing conservation translocation is the suitability of donor populations. In this case, the donor population is effectively predefined, as the Kidneyshell available for translocation are derived from broodstock collected from the Sydenham River in September 2015 as part of OMNR efforts to propagate and culture freshwater mussels (C. Wilson, OMNR, pers. comm. 2026). Some individuals were subsequently used during a genetic research project (VanTassel et al. 2021). Juveniles were propagated using Johnny Darter (*Etheostoma nigrum*) as a host species in October 2015 at the White Lake Fish Culture Station (C. Wilson, OMNR, pers. comm. 2026). No additional Kidneyshell propagation has been conducted since 2015, and there are currently no plans for future propagation experiments. Consequently, the current assessment evaluates only the suitability and risks associated with the use of Sydenham-derived (captive-reared) individuals, rather than comparing alternative donor sources.

The Sydenham River supports one of only two extant Canadian populations of Kidneyshell and represents the largest known population in the country. Modelling based on long-term quadrat sampling data estimated a minimum abundance of 6,949 individuals (95% CI: 5,371–9,059) in the Sydenham River, with a population growth rate of 1.13 over the period 1999–2022 (Fung et al. 2025). These metrics indicate a comparatively healthy and increasing population relative to other Canadian localities. Genetic analyses using microsatellite markers indicate that Kidneyshell exhibits low divergence among Ontario river populations, with lower divergence among rivers compared to other species and no evidence of population sub-structure (Galbraith et al. 2015; VanTassel et al. 2021). Like many unionids, Kidneyshell demonstrates some pattern of isolation-by-distance, although the overall amount of genetic diversity within the Great Lakes populations is low compared to the Ohio-Tennessee populations (Galbraith et al. 2015; VanTassel 2023). This pattern suggests substantial historical connectivity across the lower Great Lakes basin and supports the interpretation that extirpated populations in Lake Erie, Lake St. Clair, and their tributaries were not genetically distinct units, but part of a broad regional lineage (VanTassel et al. 2021).

VanTassel (2023) recommends that across watershed movements are only advisable when there is evidence of recent co-ancestry. Strict adherence to this advice would rule out the possibility of re-establishment of historically lost populations where genetic history is lacking (i.e., all extirpated rivers in southern Ontario). While recognizing that

movement of individuals from one watershed to another is not without risk, applying observed patterns of variability and accepted glacial history to the current landscape allows for an informed evaluation of potential risk.

Collectively, the demographic strength of the Sydenham River population and the relative genetic similarity among southern Ontario populations support the use of Sydenham-derived (including captive-reared) individuals as an appropriate and defensible donor source for Kidneyshell reintroduction within the Great Lakes region.

Donor Potential for the Thames River (including Medway Creek)

The Thames and Sydenham rivers are geographically proximate and historically supported overlapping unionid assemblages, including Kidneyshell (McNichols-O'Rourke et al. 2012; Colm and Morris 2025). Both systems occur within the lower Great Lakes basin and are part of the same source protection region, sharing broadly similar physiography, hydrology, land use, and aquatic habitat characteristics (SCRSPA 2008). Importantly, known Kidneyshell host fishes (i.e., darter species such as *Percina* and *Etheostoma* spp.) are widely distributed in both watersheds, reducing the likelihood of host limitation following release (Friends of Medway Creek 2009; COSEWIC 2013). Use of captive-reared individuals derived from Sydenham River broodstock further minimizes direct demographic impacts to the wild donor population while maintaining local genetic representation. VanTassel (2023) indicated that the Belle River population in Michigan population is the most similar to the Sydenham River. Both the Sydenham River and Belle River populations are part of the Lake St. Clair watershed, as is the Thames River. The Belle River is located approximately 20 km upstream from the outflow of the Sydenham River while the Thames River is located approximately 27 km downstream. Given the demonstrated retention of genetic diversity in the propagated cohort (VanTassel et al. 2021) and the comparatively strong status of the Sydenham River population (Fung et al. 2025), this donor–recipient pairing is considered ecologically and genetically defensible.

Donor Potential for the Grand River

The Grand River occurs within the lower Great Lakes basin and likely historically supported Kidneyshell as part of its southwestern Ontario distribution (McNichols-O'Rourke et al. 2012; Colm and Morris 2025). The Grand and Sydenham rivers are geographically proximate but differ in size. The Grand River is the largest watershed in southern Ontario, draining ~ 6,800 km² (GRCA 2026) whereas the Sydenham River drains 3,498 km² (SCRCA 2026). Despite historical mussel declines, the Grand River continues to support a diverse freshwater mussel assemblage and retains habitat characteristics typical of large river systems in southern Ontario, including sand–gravel substrates and riffle–run channel morphology (Goguen et al. 2023; Colm and Morris 2025). Known Kidneyshell host fishes are also widely distributed throughout the Grand

River watershed, suggesting that host availability is unlikely to constrain reintroduction success (Nikel et al. 2023). Genetic analyses indicate limited population structure among Ontario Kidneyshell populations, although isolation-by-distance has been demonstrated (Galbraith et al. 2015; VanTassel et al. 2021), suggesting substantial historical connectivity across southern Ontario river systems (VanTassel et al. 2021). The Grand River outflow is located approximately 400 km downstream from the outflow of the Sydenham River and is within the Lake Erie watershed. In combination with the strong demographic status of the Sydenham River population, this may support the use of Sydenham-derived (including captive-reared) individuals as an appropriate donor source for potential reintroduction to the Grand River.

Donor Potential for Welland River

The Welland River differs from the Sydenham River in having a greater degree of channel modification and flow alteration associated with navigation infrastructure and canalization. These factors likely contributed to historical population loss and may continue to constrain habitat suitability (Colm and Morris 2025). Nevertheless, the Welland River system within the lower Great Lakes basin retains sand–gravel substrates and fish assemblages typical of Kidneyshell habitat (Colm and Morris 2025). Although evidence for a former Welland River population is more limited than for the Thames or Grand rivers, the Welland system is located within the broader Great Lakes drainage. As with other Ontario rivers, genetic analyses suggest weak population structuring across the region (VanTassel et al. 2021) functioning as isolation-by-distance. The Welland River outflow is located approximately 470 km downstream of the Sydenham River outflow but is within the Lake Ontario watershed. Use of Sydenham-derived (captive-reared) individuals likely represents a less defensible donor option should reintroduction to the Welland River be considered.

2.4) SELECTION OF THE RECIPIENT SYSTEM

Based on the synthesis of historical occurrence, likelihood of extirpation, and donor population suitability presented above, the Thames River, specifically Medway Creek, has been preliminarily identified as the most appropriate focal system for further evaluation of Kidneyshell reintroduction. The Thames River is the only extirpated population where live individuals have been historically collected, allowing the confirmation of an extant population in Medway Creek within the last two decades. The Thames River also represents the nearest extirpated population to the donor population in the Sydenham River. Accordingly, subsequent sections of this assessment focus specifically on Medway Creek as the proposed recipient system for reintroduction, and evaluates risks, limitations, and ecosystem-level implications within this context.

3) HABITAT SUITABILITY OF MEDWAY CREEK FOR KIDNEY SHELL

This section examines habitat suitability within Medway Creek, specifically considering substrate and water-quality conditions, existing mussel assemblage, indicator species, host fish availability, community interactions, and potential limiting threats to determine whether the system can support establishment and persistence of Kidneyshell (Appendix 1, Questions 6a-8b). Detailed nomenclature used throughout this section for mussels and fishes can be found in appendices 3 and 4, respectively.

3.1) DATA USED TO ASSESS HABITAT SUITABILITY

Data to support section 3.1 were collected through quantitative excavation sampling (UMBO network) or semi-quantitative timed-search sampling. Briefly, data collected at UMBO sites include a single collection of water quality parameters per site. Water-quality parameters include: water temperature (°C), conductivity (µs/cm), total dissolved solids (mg/L), optical dissolved oxygen (mg/L), salinity (psu), turbidity (FNU), and pH. Substrate composition was visually estimated following excavation of 75 1m² quadrats over a 375 m² area (for detailed UMBO methods see Sheldon et al. 2020). Substrate classes assigned were bedrock, boulder (>250 mm in diameter), cobble (65–250 mm), gravel (2–65 mm), sand (grainy, 0.06–2 mm), silt (floury, <0.06 mm), clay, muck (soft organic material), and detritus (plant matter) (modified from Stanfield 2010). Habitat data available from timed-search surveys include water quality parameters collected once at each site using an EXO2 multiparameter YSI and water clarity using a turbidity tube [see Gibson et al. (2025) for detailed methods].

Fish community data were compiled for Medway Creek, the Sydenham River, and the Ausable River to evaluate host fish availability in section 3.2. The fish data were collected between 2002 and 2025 across numerous sites using a range of sampling designs and methods which reflected specific study objectives. Collectively, the data provided a broad spatial coverage of Kidneyshell host fishes and facilitated comparisons of host fish relative abundance between watersheds.

3.2) AVAILABILITY OF PHYSICAL HABITAT

Extant populations of Kidneyshell can be found in the Ausable River (Lake Huron) and the Sydenham River (Lake St. Clair) and as such, critical habitat has been identified in both systems. In the East Sydenham River, this includes a 120 km reach from west of Cairngorm to Dresden. In the Ausable River, critical habitat is limited to a ~70 km reach from Crediton Rd. to downstream of Centre Rd. (Fisheries and Oceans Canada 2013). Using information collected from UMBO network within these critical habitat reaches, Fung et al. (2025) found that the minimum area for population viability (MAPV) of Kidneyshell in the Sydenham and Ausable rivers was ~10 ha (95% CI: 0.62-109) and ~108 ha (95% CI 4.7-5, 100), respectively. Both populations are believed to be healthy

and reproducing, with the Ausable River considered stable and the Sydenham River population increasing (Colm and Morris 2025; Fung et al. 2025).

Critical habitat has also been identified in the Thames River watershed and includes a 55 km stretch from Tate Corners to downstream of Thamesville in the lower subwatershed and a 3 km stretch from Sunningdale Rd. to downstream of Fanshawe Park Rd. in Medway Creek, which is in the upper subwatershed. The suspected historical Kidneyshell distribution within Medway Creek is ~ 3.5 km, most of which is included in the currently identified critical habitat. With an average creek width of 16 m within this reach, the amount of available habitat is ~ 5.85 ha. If this is extended to the confluence of the North Thames River, which is ~ 8 km in length with an average width of 17 m, there is ~ 13.5 ha of available habitat. Although the total area of available habitat in both the Sydenham and Ausable rivers are larger than that of Medway Creek, the amount of available habitat within Medway Creek is within the 95% confidence intervals of MAPV.

Kidneyshell is known to prefer substrates composed of stable, coarse gravel and sand (Metcalf-Smith et al. 2005). Using information collected during excavation at UMBO network sites, Fung et al. (2025) determined that Kidneyshell abundance in the Sydenham and Ausable rivers increased with increasing proportions of sand and gravel substrates, thus indicating that sand and gravel are important substrate components for this species. Kidneyshell was detected at 10 UMBO sites surveyed in the East Sydenham River between 2022-2024 (DFO unpublished data) and five in the Ausable River between 2018-2019 (ABCA unpublished data). In the Sydenham River, mean percent cover of gravel and sand (\pm standard error) within all quadrats at UMBO sites where Kidneyshell occurred was $32.46\% \pm 0.59$ and $21.52\% \pm 0.49$, respectively. In the Ausable River, percent cover of gravel was $43.66\% \pm 0.91$ and $20.74\% \pm 0.68$ for sand. Substrate composition was estimated at two UMBO sites in Medway Creek within the formerly occupied reach during the 2025 field season and was composed of $42.00\% \pm 0.93$ gravel, $30.00\% \pm 1.12$ cobble, and $18.00\% \pm 0.80$ sand (DFO unpublished data). Cobble was the third most abundant substrate in the Sydenham and Ausable rivers, characterizing $18.33\% \pm 0.51$ and $19.87\% \pm 0.99$ of the substrate, respectively (Figure 3).

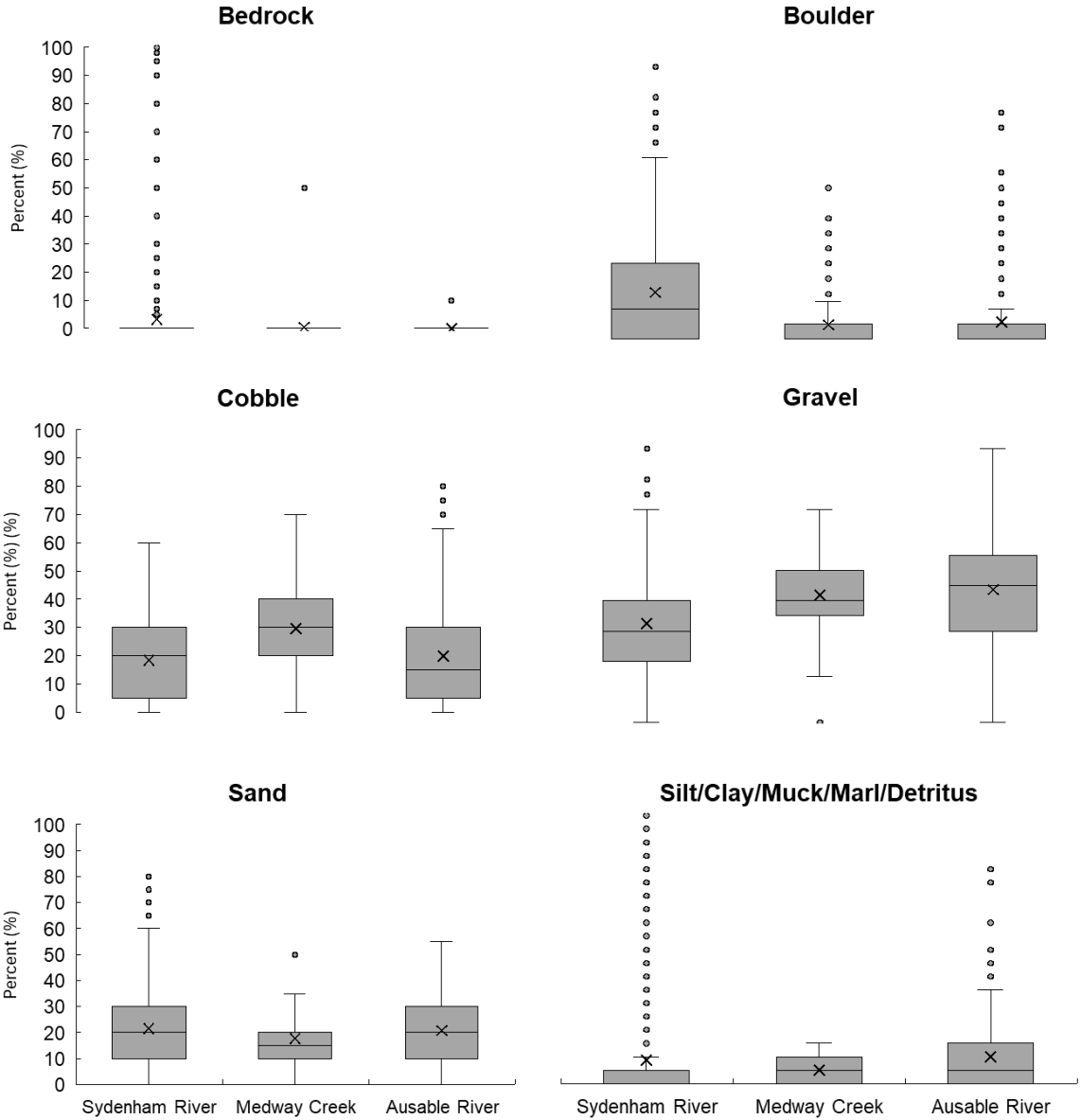


Figure 3. Visual estimates of percent substrate composition recorded at UMBO sites in the Sydenham River between 2022-2024, Medway Creek in 2025, and the Ausable River between 2018 and 2019. Sites included from the Sydenham and Ausable rivers were selected based on the presence of Kidneyshell (DFO unpublished data).

Horn’s index of niche similarity (Krebs 1999) was used to compare substrate composition between the three waterbodies based on the UMBO substrate data (Figure 4). Horn’s Index ranges from 0 to 1, where 0 indicates no overlap, and 1 indicates complete overlap. Zaret and Rand (1971) suggest that anything ≥ 0.60 represents significant overlap. Based on the UMBO sampling data, both the Sydenham River and Medway Creek ($R_0 = 0.91$), and the Ausable River and Medway Creek ($R_0 = 0.97$), demonstrate high overlap with respect to substrate. This indicates that substrate in

Medway Creek would support the presence of Kidneyshell given that the composition is very similar to sites where Kidneyshell currently exist in both the Sydenham and Ausable rivers.

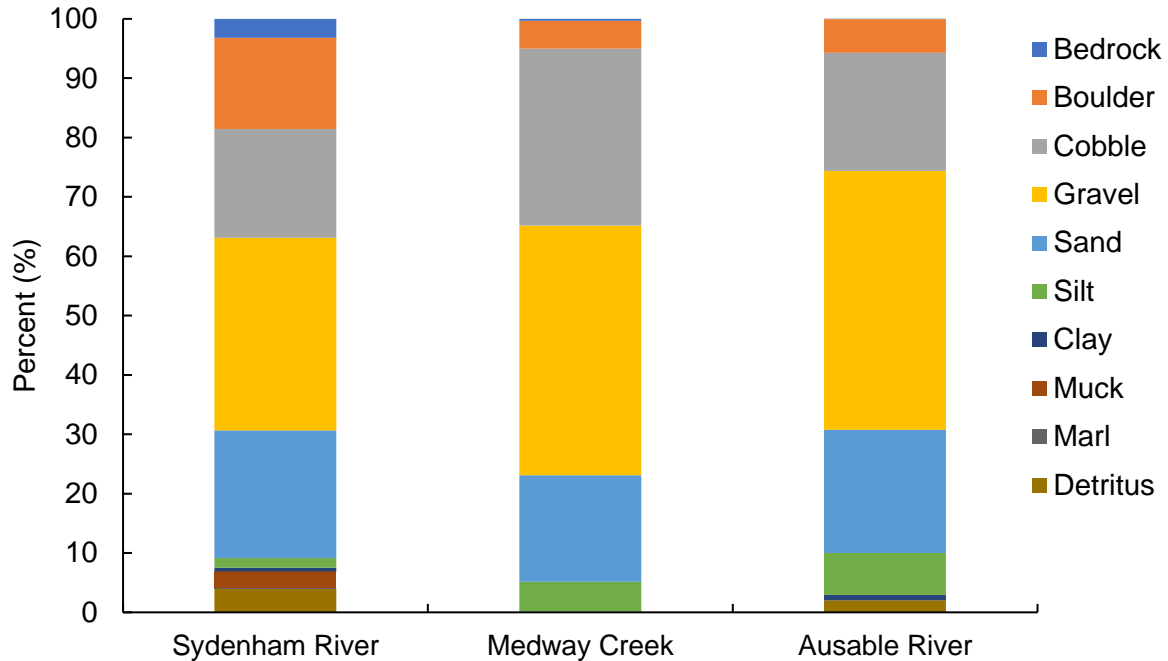


Figure 4. Mean substrate composition at UMBO sites in the Sydenham River between 2022-2024, Medway Creek in 2025, and the Ausable River between 2018 and 2019. Sites included from the Sydenham and Ausable rivers were selected based on the presence of Kidneyshell (DFO unpublished data).

Water-quality parameters were also compared among the three water bodies. These site-level parameters were collected once between 2017–2022 at each of 14 sites that support Kidneyshell in the Sydenham River. Water-quality data were also collected at eight sites within the suspected historical range of Kidneyshell in Medway Creek in 2024. Additionally, in 2017, water-quality parameters were collected at 14 sites during targeted fish surveys in the Ausable River within the known distribution of Kidneyshell (Lamothe et al. 2025). Data presented here represent a snapshot of abiotic conditions and do not capture the full range of variability through time. While not collected for the purpose of quantitatively describing Kidneyshell habitat, they provide a means of coarsely comparing abiotic conditions in Medway Creek with conditions in the two rivers where Kidneyshell persists in Canada. Although not all parameters were available for all sites/dates, most showed overlap among the three systems (water temperature, conductivity, total dissolved solids, salinity and pH; Figure 5). Medway Creek appeared to have higher dissolved oxygen concentration and was less turbid (higher water clarity and lower turbidity) than the Sydenham and Ausable rivers.

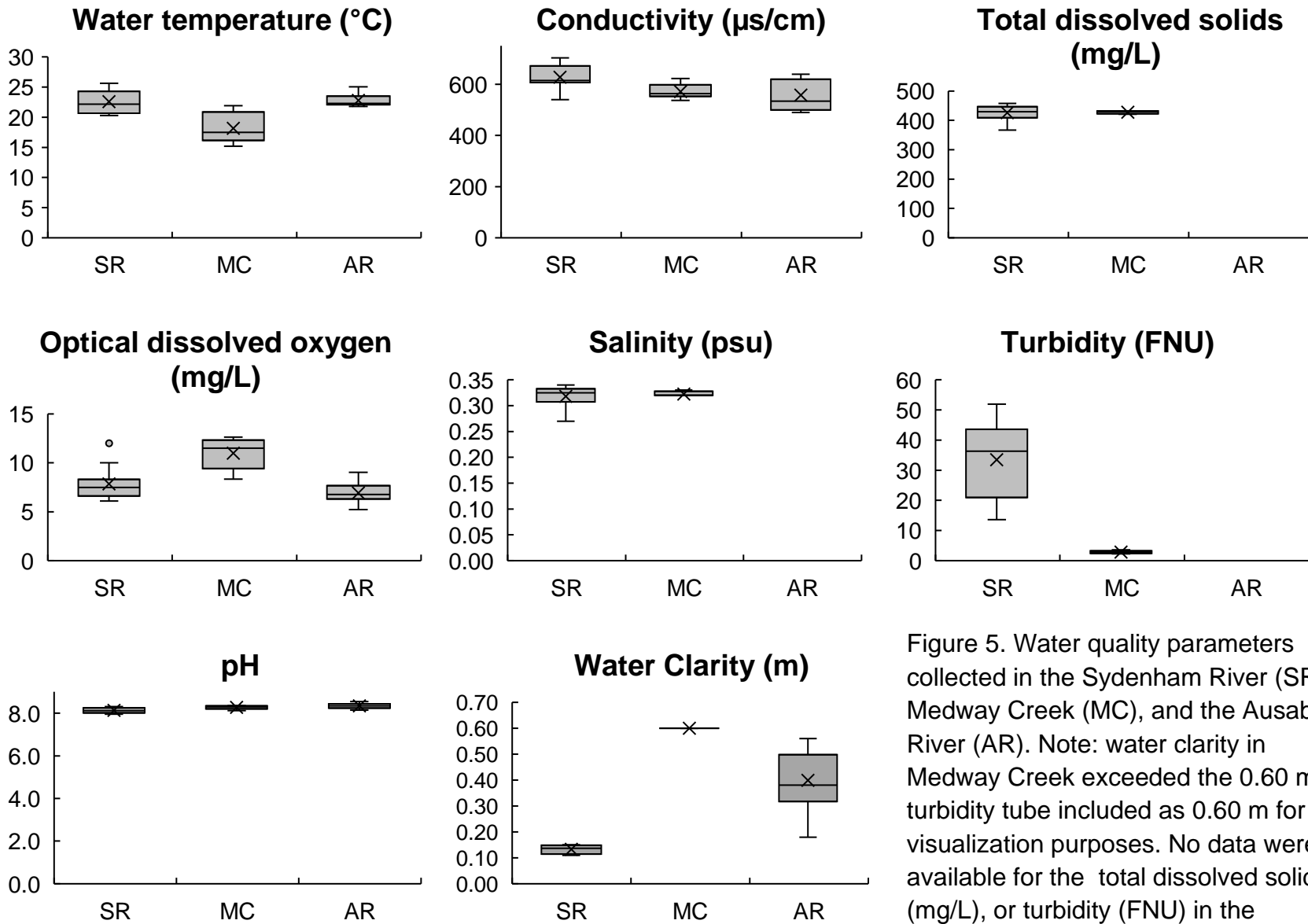


Figure 5. Water quality parameters collected in the Sydenham River (SR), Medway Creek (MC), and the Ausable River (AR). Note: water clarity in Medway Creek exceeded the 0.60 m turbidity tube included as 0.60 m for visualization purposes. No data were available for the total dissolved solids (mg/L), or turbidity (FNU) in the Ausable River.

A higher dissolved oxygen concentration is considered beneficial for most aquatic organisms and many freshwater mussel species (Sparks and Strayer 1998; Csábrági et al. 2019; Bird et al. 2022), including Kidneyshell (Colm and Morris 2025). Water clarity in Medway Creek exceeded the 0.60 m turbidity tube at all sites surveyed in 2024 and had a mean (\pm standard error) of 0.13 ± 0.010 m and 0.39 ± 0.04 m in the Sydenham and Ausable rivers, respectively. Mean turbidity in Medway Creek was 2.85 ± 0.16 FNU, lower than that of the Sydenham River, which was 33.49 ± 3.86 FNU. No turbidity data in FNU units were available for comparison in the Ausable River; however, the river is known to be turbid (DFO 2020; Lamothe et al. 2025). Although water clarity is higher and turbidity lower in Medway Creek compared to the Sydenham and Ausable rivers, the establishment of Kidneyshell during a reintroduction is not likely to be limited by these parameters as the species is known to occur in clear water systems within the US portion of its North American distribution. LaValley (2022) found Kidneyshell in the Maple, Portage, Clinton and Huron rivers as well as Davis Creek (Tributary of the Huron R.) in Michigan, and reported turbidity categorically as low to medium based on underwater visibility (low = > 10 m and medium = 2-5 m) (D. Woolnough, Central Michigan University, pers. comm. 2026). These values are well beyond the water clarity values observed in the Sydenham and Ausable rivers. In addition, many of the host species are tolerant of a range of turbidity levels (Eakins 2026). Kidneyshell use a host infection strategy involving conglutinates that mimic benthic macroinvertebrates which elicits a predatory response from its host (Watters 1999). Clear water may facilitate this interaction.

In addition to the overlap in substrate composition and similarities in most measured water condition variables, the continued presence of a strong mussel assemblage in Medway Creek provides further indication that Medway Creek is likely able to support a Kidneyshell reintroduction. Freshwater mussels were first surveyed in Medway Creek in 1935 (Gibson et al., 2025) (Table 2) but have also been documented at archaeological sites throughout the Deshkan Ziibi (Thames River) watershed, including the Lawson Site, an early sixteenth-century Indigenous village situated adjacent to Medway Creek near Snake Creek (Museum of Ontario Archaeology, pers. comm. 2026). By 2023, a total of 15 species had been identified in the system, including three that are currently listed under SARA: Rainbow (*Cambarunio iris*; Special Concern), Wavyrayed Lampmussel (*Lampsilis fasciola*; Special Concern), and Kidneyshell (last seen alive in 2008; Endangered). In 2024, DFO conducted mussel surveys at 15 sites throughout Medway Creek (Figure 6, Gibson et al. 2025). Using a semi-quantitative 4.5 hour timed-search method, a total of 14 extant species were detected (Table 3). Species exhibiting all three life-history strategies – opportunistic, equilibrium, and periodic – as described by Haag (2012) were represented (Table 3).

Table 2. Mussel species found alive (Y) and as shells (SH) in the Upper Thames River (UTR) watershed and Medway Creek over time. Species at risk are highlighted (Government of Canada 2026). See Appendix 3 for scientific nomenclature (table modified from Gibson et al. 2025).

| Common Name | UTR | Medway Creek | | | | | |
|-------------------------------|-----------|--------------|-----------|-----------|-----------|-----------|-----------|
| | | 1935 | 1994-1995 | 2001-2010 | 2011-2023 | 2024 | 2025 |
| Black Sandshell | Y | - | - | - | - | - | - |
| Creek Heelsplitter | Y | - | Y | Y | Y | Y | SH |
| Creeper | Y | - | Y | Y | Y | Y | Y |
| Cylindrical Papershell | Y | - | - | Y | - | Y | - |
| Deertoe | Y | - | - | - | - | - | - |
| Elktoe | Y | - | Y | Y | - | Y | - |
| Fatmucket | Y | - | Y | - | - | - | - |
| Fawnsfoot | Y | - | - | - | - | - | - |
| Flutedshell | Y | SH | Y | Y | Y | Y | Y |
| Fragile Papershell | Y | - | - | - | - | - | - |
| Giant Floater | Y | - | Y | Y | Y | Y | Y |
| Kidneyshell | Y | - | - | Y | - | SH | SH |
| Mapleleaf | Y | - | - | - | - | - | - |
| Mucket | Y | - | SH | Y | Y | Y | Y |
| Pimpleback | Y | - | - | - | - | - | - |
| Pink Heelsplitter | Y | - | - | - | - | - | - |
| Plain Pocketbook | Y | - | Y | Y | - | Y | Y |
| Purple Wartyback | Y | - | - | - | - | - | - |
| Rainbow | Y | SH | Y | Y | Y | Y | Y |
| Rayed Bean | Y | - | - | - | - | - | - |
| Round Pigtoe | Y | - | - | - | - | - | - |
| Salamander Mussel | SH | - | - | - | - | - | - |
| Slippershell | Y | SH | - | - | Y | Y | - |
| Spike | Y | SH | Y | Y | Y | Y | Y |
| Threehorn Wartyback | Y | - | - | - | - | - | - |
| Threeridge | Y | - | - | - | - | - | - |
| Wabash Pigtoe | Y | - | SH | Y | Y | Y | Y |
| Wavyrayed Lampmussel | Y | - | - | Y | Y | Y | Y |
| White Heelsplitter | Y | - | - | - | - | Y | - |
| Live Species Richness | 28 | 0 | 9 | 13 | 10 | 14 | 9 |
| Total Species Richness | 29 | 4 | 11 | 13 | 10 | 15 | 11 |

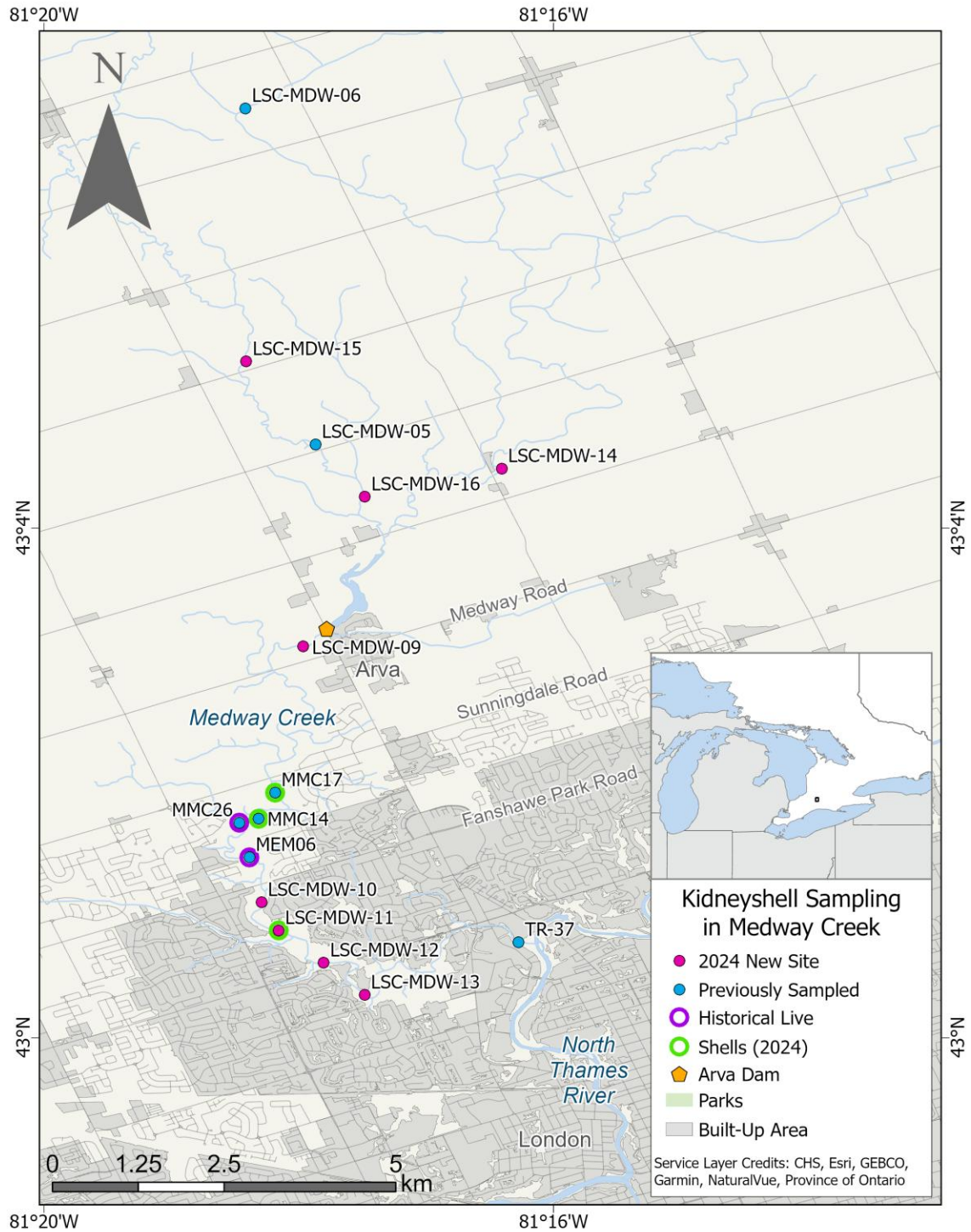


Figure 6. Sites sampled in the Medway Creek watershed in 2024, including new sites, previous timed-search sites, and sites where live Kidneyshell and/or shells have been detected. Map created by J. Colm (DFO).

Table 3. Species detected, abundance, and species life-history strategies (LHS) at sites surveyed in the Medway Creek watershed in 2024. Species at risk are highlighted in grey. S = species found as shells or valves, Y = yes, N = no, UNK = unknown (table modified from Gibson et al. 2025).

| Common Name | LHS* | LSC-MDW-06 | LSC-MDW-14 | LSC-MDW-15 | LSC-MDW-05 | LSC-MDW-16 | LSC-MDW-09 | MMC17 | MMC14 |
|--|----------------|------------|------------|------------|------------|------------|------------|-----------|-----------|
| Elktoe | P | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Creek Heelsplitter | O | 0 | 0 | 1 | 0 | 0 | S | 0 | 0 |
| Creeper | P | 0 | 36 | 1 | 0 | 0 | 2 | 1 | 2 |
| Cylindrical Papershell | UNK | S | 3 | 5 | S | 0 | 0 | 0 | 0 |
| Flutedshell | O | 0 | 0 | 1 | 0 | 0 | 6 | 1 | 1 |
| Giant Floater | O | 2 | 33 | 49 | 4 | 1 | 10 | 19 | 28 |
| Kidneyshell | P ¹ | 0 | 0 | 0 | 0 | 0 | 0 | S | S |
| Mucket | E | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 5 |
| Plain Pocketbook | P | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 6 |
| Rainbow | P | 0 | 0 | 0 | 41 | 2 | S | S | S |
| Slippershell | P | 0 | 0 | 3 | 0 | 0 | 0 | 0 | S |
| Spike | E | 0 | 0 | 48 | 60 | S | S | 13 | 14 |
| Wabash Pigtoe | E | 0 | 0 | 0 | S | 0 | S | 6 | 3 |
| Wavyrayed Lampmussel | P | 0 | 0 | 0 | 0 | 0 | S | 8 | 3 |
| White Heelsplitter | O | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total Abundance | | 2 | 72 | 108 | 105 | 3 | 21 | 59 | 62 |
| Live Species Richness | | 1 | 3 | 7 | 3 | 2 | 4 | 9 | 8 |
| Kidneyshell Historical Distribution | | N | N | N | N | N | N | Y | Y |

*E = equilibrium, O = opportunistic, P = periodic (Haag 2012)

¹Differs from Haag (2012) due to the use of a larger sample size (Fung et al. 2025).

Table 3. Continued.

| Common Name | LHS* | MMC26 | MEM06 | LSC-MDW-10 | LSC-MDW-11 | LSC-MDW-12 | LSC-MDW-13 | TR-37 | Total |
|--|----------------|------------|------------|------------|------------|------------|------------|----------|-------------|
| Elktoe | P | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 4 |
| Creek Heelsplitter | O | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |
| Creeper | P | 69 | 15 | 7 | 7 | 2 | 0 | 0 | 142 |
| Cylindrical Papershell | UNK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |
| Flutedshell | O | 28 | 12 | 12 | 2 | 1 | 0 | 1 | 65 |
| Giant Floater | O | 113 | 170 | 49 | 36 | 14 | 1 | 2 | 531 |
| Kidneyshell | P ¹ | 0 | 0 | 0 | S | 0 | 0 | 0 | S |
| Mucket | E | 24 | 16 | 51 | 23 | 1 | 0 | 1 | 127 |
| Plain Pocketbook | P | 11 | 12 | 7 | 4 | 5 | 2 | 2 | 56 |
| Rainbow | P | 0 | 7 | 5 | 1 | 0 | 0 | 0 | 56 |
| Slippershell | P | 0 | S | 0 | 0 | 0 | 0 | 0 | 3 |
| Spike | E | 77 | 55 | 59 | 58 | 2 | 0 | 1 | 387 |
| Wabash Pigtoe | E | 44 | 16 | 29 | 11 | 1 | 0 | 1 | 111 |
| Wavyrayed Lampmussel | P | 8 | 2 | 3 | 0 | 3 | 0 | 0 | 27 |
| White Heelsplitter | O | 2 | 4 | 6 | 2 | 1 | 0 | 0 | 15 |
| Total Abundance | | 377 | 309 | 230 | 144 | 30 | 4 | 8 | 1534 |
| Live Species Richness | | 10 | 10 | 12 | 9 | 9 | 3 | 6 | 14 |
| Kidneyshell Historical Distribution | | Y | Y | Y | Y | N | N | N | |

*E = equilibrium, O = opportunistic, P = periodic (Haag 2012)

¹Differs from Haag (2012) due to the use of a larger sample size (Fung et al. 2025).

This indicates that Medway Creek supports species that are not only tolerant to changes, but also those that occur in stable, productive habitats (Haag 2012).

In 2025, two sites within Medway Creek were added to the UMBO network: one at MEM06, a site that previously had live Kidneyshell in 2004 and LSC-MDW-11, which represents the most downstream site where evidence of Kidneyshell (shell) has been found (Figure 6). These were chosen as they represent the middle and downstream end of what is the suspected historical distribution of the species in Medway Creek. Despite this intensive survey effort, no evidence of live Kidneyshell was found throughout the surveys completed in 2024 and 2025; however, Plain Pocketbook was observed at all sites within Medway Creek that were formerly occupied by Kidneyshell but does not occur upstream of these areas (Table 3). This is important as Metcalfe-Smith et al. (2007) found a positive association of Kidneyshell with Plain Pocketbook during UMBO surveys in the Sydenham River. With respect to other macroinvertebrate indicators, Eveleens et al. (2023) identified indicator taxa (Psephenidae, Empididae, Simuliidae, Leptohiphidae, Isonychiidae, Leptophlebiidae, Corydalidae and Hydrachnidia) for the presence of Kidneyshell within the Sydenham River. The first four families listed have been observed at sites within the historically occupied Kidneyshell reach in Medway Creek. In addition, the macroinvertebrate families that Eveleens et al. (2023) found to be significant indicators of Kidneyshell absence in the Sydenham River (Corixidae and Physidae) have not been observed in Medway Creek within the historical Kidneyshell distribution (UTRCA unpublished data).

Apart from Kidneyshell, the mussel assemblage present in Medway Creek appears intact and has seen minimal change over time (Table 2). The watershed supports 14 extant species, which represents 50% of the known, extant species from the upper Thames River watershed. Based on the assessment of habitat characteristics, presence of indicator macroinvertebrates, and the presence of an intact mussel assemblage, it appears that Medway Creek has suitable biotic and abiotic habitat conditions to support a Kidneyshell reintroduction.

3.3) KIDNEYSHELL HOST FISH REQUIREMENTS

Kidneyshell reproduction depends on successful attachment of glochidia to appropriate host fish species. Potential host fishes for Kidneyshell include Blackside Darter, Fantail Darter, Greenside Darter, Johnny Darter, Logperch, and Brook Stickleback (Colm and Morris 2025; COSEWIC 2013). The relative abundance (RA; %) of Kidneyshell host fish species was calculated separately for Medway Creek, East Sydenham River, and Ausable River. Fish community survey data considered for RA analyses were compiled from watershed-specific fish community surveys conducted by multiple sources. RA was calculated by dividing the total number of individual host fishes across all surveyed sites (n), by the total number of fish captured across the same surveyed sites (N) and

multiplying by 100. This metric represents the proportional contribution of each host fish species to the overall fish assemblage across all surveyed sites considered.

Host Fish Community in Medway Creek

Fish community sampling has occurred periodically between 2002 and 2025 in the Medway Creek watershed by DFO (DFO 2026) and Upper Thames River Conservation Authority (UTRCA) across 21 sampling sites (Table 4; DFO unpublished data; UTRCA unpublished data). All historical fish sampling sites considered for this review were located within Medway Creek and its tributaries between the Arva Dam (Arva, Ontario) and Western Rd. (London, Ontario). DFO fish community data was collected across 8 sites between 2002 and 2025 using a combination of single pass backpack electrofishing ($n = 1$; 2002) and repeated sampling with a 9 m bag seine ($n = 5$, 2011; $n = 2$, 2025). All UTRCA sites ($n = 10$) were sampled using a single pass backpack electrofishing unit with a mean effort of 1081 seconds per site. The combined relative abundance of Kidneyshell host fish species represented 15.4% of the total fish community. Host fish species recorded in Medway Creek included Greenside Darter (7.09%), Johnny Darter 5.29%), Brook Stickleback (1.89%), Fantail Darter (0.97%), Logperch (0.15%), and Blackside Darter (0.05%) (Table 4, Figure 7).

Table 4. Summary of abundance (n) and relative abundance (RA; %) of Kidneyshell host fish species recorded across watershed locations (DFO unpublished data; UTRCA unpublished data).

| Host Species | Medway Creek | | East Sydenham River | | Ausable River | |
|-------------------|--------------|--------------|---------------------|--------------|---------------|--------------|
| | n | RA | n | RA | n | RA |
| Blackside Darter | 1 | 0.05 | 134 | 4.36 | 40 | 2.11 |
| Brook Stickleback | 39 | 1.89 | 0 | 0 | 0 | 0 |
| Fantail Darter | 20 | 0.97 | 68 | 2.21 | 0 | 0 |
| Greenside Darter | 146 | 7.09 | 364 | 11.86 | 88 | 4.65 |
| Johnny Darter | 109 | 5.29 | 2 | 0.07 | 62 | 3.28 |
| Logperch | 3 | 0.15 | 7 | 0.23 | 7 | 0.37 |
| Total | 318 | 15.44 | 575 | 18.73 | 1737 | 10.41 |

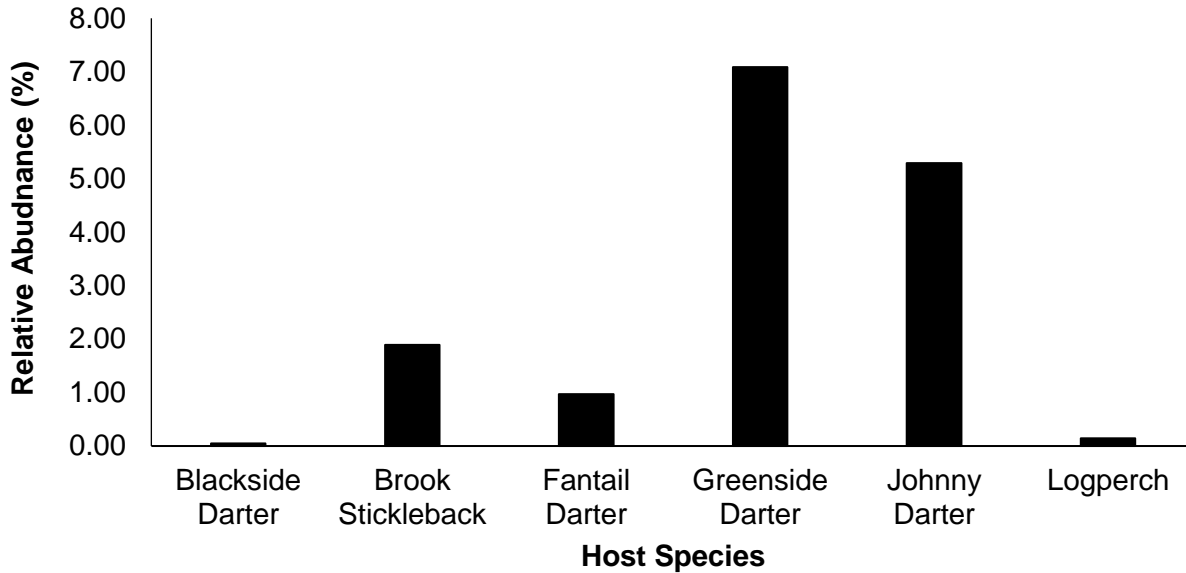


Figure 7. Relative abundance (%) of Kidneyshell host fish species from Medway Creek (DFO unpublished data; UTRCA unpublished data).

Host Fish Community in Sydenham River

UMBO fish community sampling occurred in the East Sydenham River watershed between 2022 and 2024 across 10 sites (Table 4, Figure 8) (DFO unpublished data). All sites were surveyed using a depletion design with three consecutive hauls conducted in a downstream direction using a 9 m bag seine. The combined relative abundance of host fish species represented 18.73% of the total fish community in the East Sydenham River where Kidneyshell occur. Host species recorded in the East Sydenham River included Greenside Darter (11.86%), Blackside Darter (4.36%), Fantail Darter (2.21%), Logperch (0.23%), and Johnny Darter (0.07%) (Table 4, Figure 8).

Host Fish Community in Ausable River

Fish community sampling data from the Ausable River was available from two survey years (2007 and 2017) (Lamothe et al. 2025). Sites considered for this review were restricted to sites within the known distribution of Kidneyshell. Sites surveyed in 2007 ($n = 8$) were surveyed using a 9 m bag seine. Sites surveyed in 2017 ($n = 14$) were surveyed using a combination of a 9 m bag seine ($n = 2$) and a 6 m straight seine ($n = 12$), depending on the habitats sampled. For both survey years, sites were sampled using a depletion design with three hauls performed in a downstream direction (Table 4, Figure 9, DFO unpublished data). The combined relative abundance of host fish species represented 10.41% of the total fish community in the Ausable River. Host species recorded in the Ausable River included Greenside Darter (4.65%), Johnny Darter (3.28%), Blackside Darter (2.11%), and Logperch (0.37%) (Table 4, Figure 9).

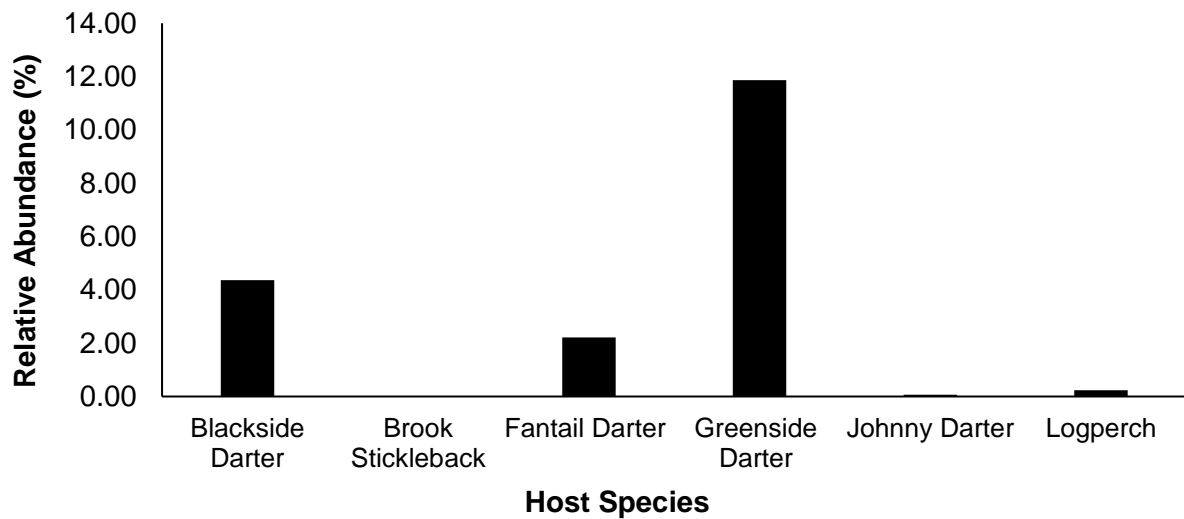


Figure 8. Relative abundance (%) of Kidneyshell host fish species from the East Sydenham River (DFO unpublished data).

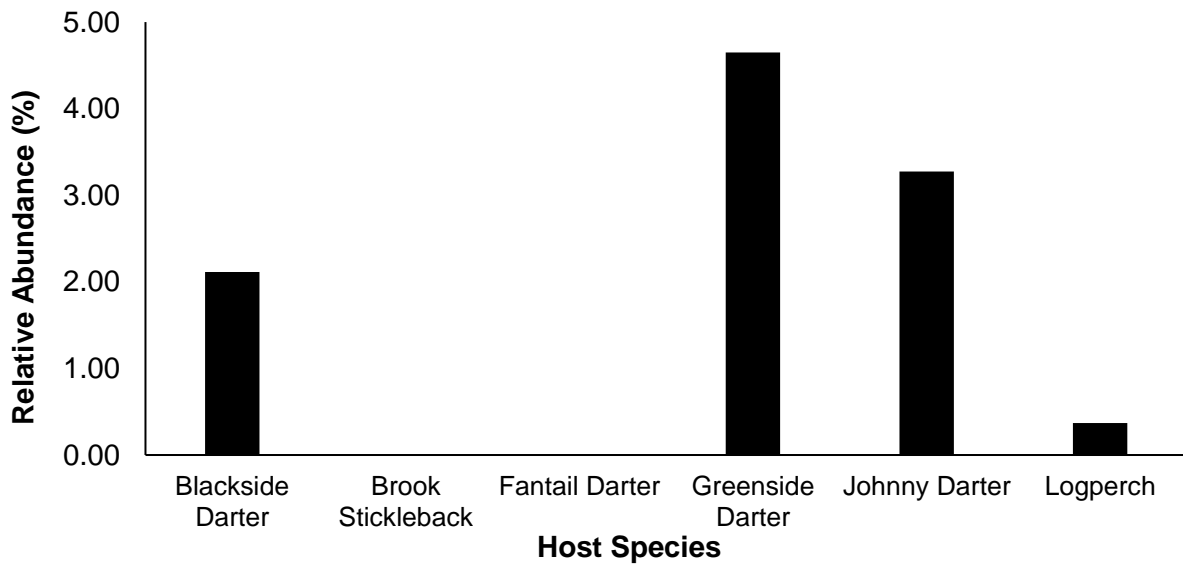


Figure 9. Relative abundance (%) of Kidneyshell host fish species from the Ausable River (DFO unpublished data).

3.4) CAGE TRIALS

Cage trials were initiated in July 2025 to assess the short-term suitability of Medway Creek as a recipient system for Kidneyshell. On July 2, 2025, six modified rodent traps [810 mm x 260 mm x 325 mm; mesh size of 25 mm (below substrate) and 18 mm (above)] were installed at two sites in Medway Creek (three cages at each of MMC26 and MEM06), where an experimental reintroduction could occur (Figure 6). The creek bottom was excavated to a depth of 5–10 cm, and each cage was installed and then backfilled with the removed substrate to ensure that animals within the cages had sufficient substrate to burrow. Ten Kidneyshell from the captive-reared stock were added to each cage. Each individual was measured (maximum length; mm), weighed (wet weight; g), and PIT tagged prior to placement inside the cage. Cages were anchored in place using rebar. Cages remained in place from July 2 – October 23, 2025, and were checked weekly to ensure they remained anchored in location. Individual Kidneyshell were not handled over the duration of the cage trial.

All 60 Kidneyshell were recovered alive at the end of the trial period. All individuals except one demonstrated measurable growth over the trial period with a mean length increase of 3.4 mm (SD=0.73) equivalent to a mean increase of 6.5% from the starting size. Based on growth curves developed for wild collected Kidneyshell from the Ausable River (based on 99 shells collected in 2012 and 2013; DFO unpublished data) and for the captive-reared animals (based on annual shell measurements of 60-180 individuals/year; OMNR unpublished data data), growth during the trial exceeded predictions (Figure 10).

Wild Ausable River Kidneyshell are expected to grow approximately 2.0 mm (2.3%) in their 10th year while the captive-reared animals under hatchery conditions were predicted to grow only 1.7 mm (3.6%) over the 2025 growing season.

In addition to recording growth over the trial period, each animal was assessed for gravidity after collection. Twenty of 60 (33%) individuals were gravid after being retrieved from the field. The proportion of the non-gravid individuals that were male vs non-gravid females could not be determined as Kidneyshell are not sexually dimorphic. Prior work on Kidneyshell in southern Ontario suggests spawning occurs around late June/early July (DFO unpublished data); periods that correspond to the movement of the captive-reared Kidneyshell into the cages. As a result, it was not possible to determine whether the 2025 spawn event occurred while the caged animals were still in the hatchery or whether it occurred in Medway Creek. In October 2025, Kidneyshell

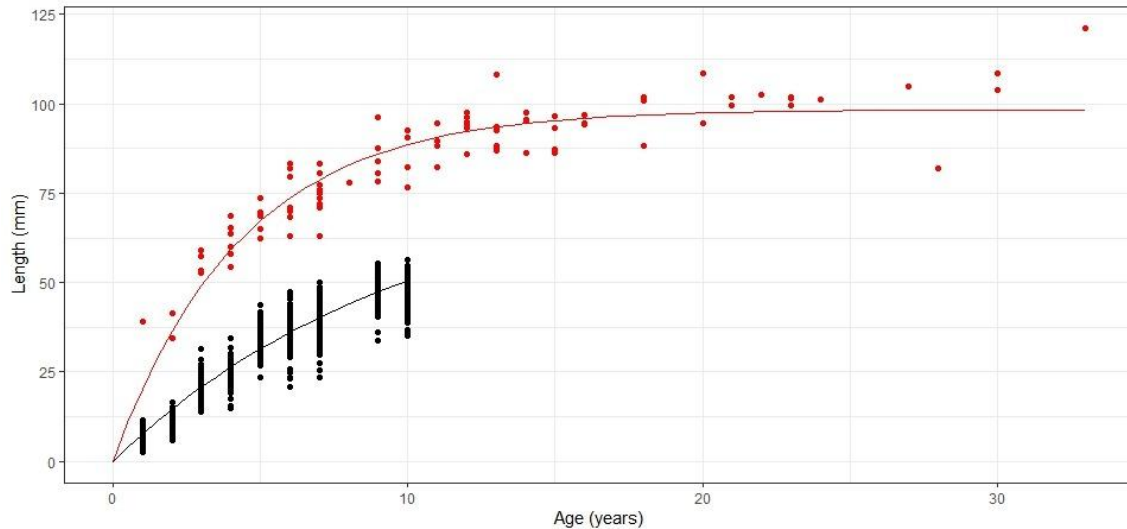


Figure 10. von Bertalanffy growth curves for Kidneyshell collected from the Ausable River between 2012 and 2013 (red) ($n = 99$) and from propagated individuals housed at OMNR White Lake Fish Culture Station (black) ($n = 1050$). Ausable River data represent thin sections of individual shells and hatchery data represent repeated annual measurements made on individuals.

maintained at the OMNR White Lake Fish Culture Station were checked for gravidity and 49% (159 individuals were gravid out of the 324 that were checked) of captive-reared animals were found to be gravid. Two gravid individuals were tested for viability using the ASTM (2006) standard, and viability was calculated at 85%. Therefore, it is clear that spawning occurs in the hatchery; however, even if the caged animals had spawned prior to movement to Medway Creek, the cage study shows that many were able to maintain those broods during their time in the field further suggesting favourable conditions.

3.5) POTENTIAL BIOTIC CONSTRAINTS

Interspecific Competition with Resident Unionids

The possibility exists that interspecific competition may influence the establishment success of translocated freshwater mussels if introduced individuals experience limitations in access to space, food resources, or suitable host fishes (Vaughn et al. 2008). However, such effects are rarely demonstrated under natural conditions (Vaughn and Hakenkamp 2001). Rather, available evidence suggests that interspecific competition is not a primary regulator of population dynamics in most freshwater mussel communities. Unionid distributions are more strongly structured by habitat conditions and host fish availability than by direct competitive interactions among species and between individuals (Vaughn and Hakenkamp 2001; Pandolfo et al. 2016; Haag 2012). Multiple mussel species commonly coexist within the same habitat patches under

natural conditions without evidence of competitive exclusion or strong resource limitation (Haag 2012).

The resident mussel assemblage in Medway Creek includes species that have been documented co-occurring with Kidneyshell in other southern Ontario rivers, indicating that ecological overlap between Kidneyshell and the existing community is historically common (Gibson et al. 2025; Goguen et al. 2022; McNichols-O'Rourke and Morris 2024). This suggests that introduced individuals are unlikely to experience novel or unusually intense competitive pressure relative to conditions in extant populations. In addition, reintroduction densities will be selected conservatively to avoid creating unusually high local mussel densities. By maintaining translocation numbers within the range of contemporary unionid abundance in Medway Creek, the likelihood that competition will limit Kidneyshell establishment is expected to be low (Cope et al. 2003).

Predation

Predation is a natural process within freshwater mussel communities and may influence survival at different life stages. A variety of predators have been documented feeding on unionids, including muskrat, fishes, turtles, and crayfish (Vaughn 2018; Clark et al. 2022; Hicks et al. 2025). Muskrats are among the most well-documented predators of freshwater mussels and can consume large numbers of individuals in localized areas, often leaving characteristic shell middens along riverbanks (Sousa et al. 2019).

Predation by fishes and other aquatic organisms may also occur, particularly on juvenile mussels (Clark et al. 2022) but is less often observed. Additionally, predation in unionid communities is often selective, with predators such as muskrats exhibiting preferences based on prey size, shape, and handling efficiency. Studies have shown that elongated or laterally compressed mussel species tend to be underrepresented in predator middens relative to their availability, likely due to increased difficulty of extraction from the substrate and lower energetic efficiency during handling. Kidneyshell, which exhibits a relatively elongated shell morphology, has been identified as a species that is often avoided in predation studies, suggesting that shell form may confer some degree of resistance to predation (Owen et al. 2011).

At present, there is no evidence of unusually high predation pressure within Medway Creek, nor indications that predation is currently limiting the persistence of the resident mussel assemblage. While some level of predation on reintroduced individuals is expected to occur, as with all native mussel species, the available evidence suggests that Kidneyshell is unlikely to be disproportionately vulnerable relative to co-occurring species. Therefore, it is not expected to be a predominant limiting factor affecting the establishment or persistence of a reintroduced Kidneyshell population.

3.6) LIMITING FACTORS AND THREATS TO KIDNEYSHELL ESTABLISHMENT

The primary factor limiting the success of many conservation translocation efforts is the failure to reduce or alleviate the original factor that led to the species' loss (Bubac et al. 2019). The factor(s) that historically contributed to the decline and extirpation of Kidneyshell from Medway Creek are not fully understood, and therefore it cannot be stated with certainty that all historic threats have been eliminated. The overall threat level for Kidneyshell in Canada was assessed as low in the Recovery Potential Assessment (RPA) (DFO 2025b). Pollution from agricultural and domestic and urban wastewater, invasive species (Round Goby (*Neogobius melanostomus*) and Dreissenid mussels), and the effects of climate change (frequency and severity of droughts and extreme temperatures) were identified as the major threats.

Although the RPA for Kidneyshell did not explicitly include Medway Creek (it only assessed extant populations), it is likely that the main threats are similar to those within the Thames River watershed given the close geographic proximity. Dreissenid mussels have been present in the Thames River in low density for over two decades and are well established within Fanshawe Reservoir on the North Thames River just upstream of the confluence with Medway Creek (Morris and Edwards 2007). Native mussels infested with Zebra Mussel are regularly encountered in the main branches of the Thames River; however, infestations are typically low (e.g., 1-2 zm/mussel) and well below the thresholds where risks to unionids are typically encountered (100-200 zm/mussel) (Schloesser et al. 1996). Round Goby have been observed in the lower Thames River since at least 2003 (Poos et al. 2010); however, they have never been observed upstream of Tait's Bridge (DFO unpublished data). While it remains unclear whether Flathead Catfish (*Pylodictus olivaris*) are native to the Great Lakes basin, it is a species that appears to be expanding its range upstream in the Thames River (Illes et al. 2019). Medway Creek may not represent ideal Flathead Catfish habitat; however, its presence in the Thames River watershed has the potential to alter the distribution and abundance of host species for Kidneyshell through competition and predation.

The Upper Thames River watershed, including Medway Creek, is situated in a highly developed and predominantly agricultural landscape, and surface water quality remains under ongoing pressure from nutrient inputs, bacteria, and land-use change (UTRCA 2022). Watershed report cards indicate that overall surface water quality grades across the Upper Thames range from C to D, with modest improvements observed over the past two decades (UTRCA 2022). The RPAs completed for Kidneyshell in 2023 (DFO 2025b) and for Northern Riffleshell, Snuffbox, Rayed Bean, and Salamander Mussel in 2025 (DFO *In Press*) included threats assessments for the Sydenham and Ausable rivers and the latter included the upper Thames River watershed. Pollution in the form of agricultural and forestry effluents and domestic and urban wastewater, including specific

ammonia and chloride details, were included as relevant low or medium threats for species at risk mussels in these systems. As such, a high-level overview of chloride and ammonia concentrations in these watersheds over time was summarized by Colm et al. (*In Press*) using data from the Provincial Water Quality Monitoring Network (PWQMN; Government of Ontario 2012-2026) (Figure 11). The Canadian Council of Ministers of the Environment (CCME) guidelines suggest that long- and short-term chloride exposure should not exceed 120 mg/L and 640 mg/L, respectively, to protect aquatic life in freshwater environments (CCME 2011). The long-term exposure guideline was established to protect freshwater organisms during continuous exposure periods and the short-term guideline (based on exposure periods of 24 to 96 hours) was developed "...to protect most species against lethality during severe but transient events..." (CCME 2010, p. 1). None of the available chloride measurements exceeded the short-term guideline (Figure 11); however, seasonal pulses may not be well reflected in these point-in-time measurements. Some records have exceeded the long-term guideline in these systems since the 1970s (Figure 11), including many within the North Thames River watershed.

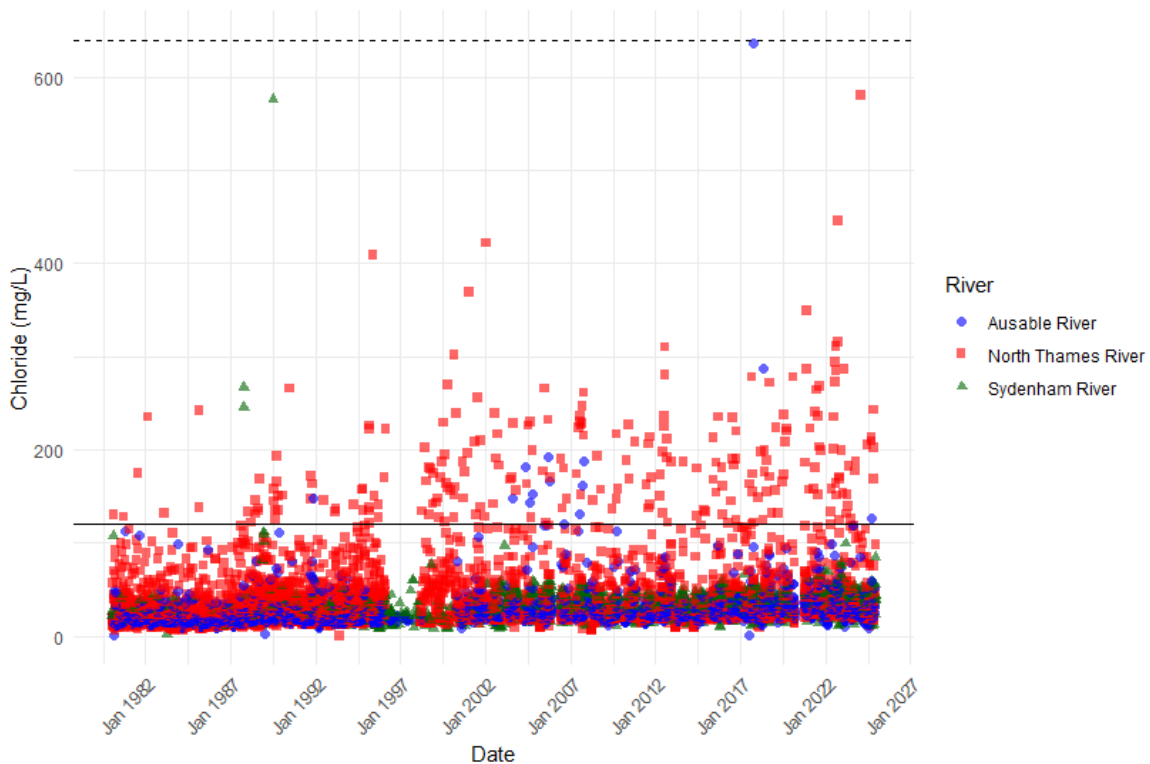


Figure 11. Provincial Water Quality Monitoring Network data by watershed (multiple stations) for chloride - including the Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of aquatic life (solid line at 120 mg/L for chronic exposure and dotted line at 640 mg/L for short-term exposure). Figure from Colm et al. (*In Press*).

The long-term guideline is based on exposure over a > 7 day period (CCME 2011) and because PWQMN data are not continuously recorded, it is impossible to determine whether these results accurately represent chronic chloride exposure.

The CCME guideline for un-ionized ammonia to protect aquatic life in freshwater is 0.019 mg/L (CCME 2010); however, ammonia toxicity varies greatly depending on the pH and water temperature of the system. Specific guidelines were calculated using equations from the CCME (2010) and data from the PWQMN, that included total ammonia (ammonia + ammonium (mg/L)), pH, and temperature for each of the Ausable and North Thames river watersheds, and the East Sydenham River (Figure 12). Since the mid 1990s, there has been a reduction in the number of extreme measurements (e.g., above 1 mg/L total ammonia) observed in the North Thames River watershed; however, many remain above the water quality guideline for the protection of aquatic life in all three systems (CCME 2010).

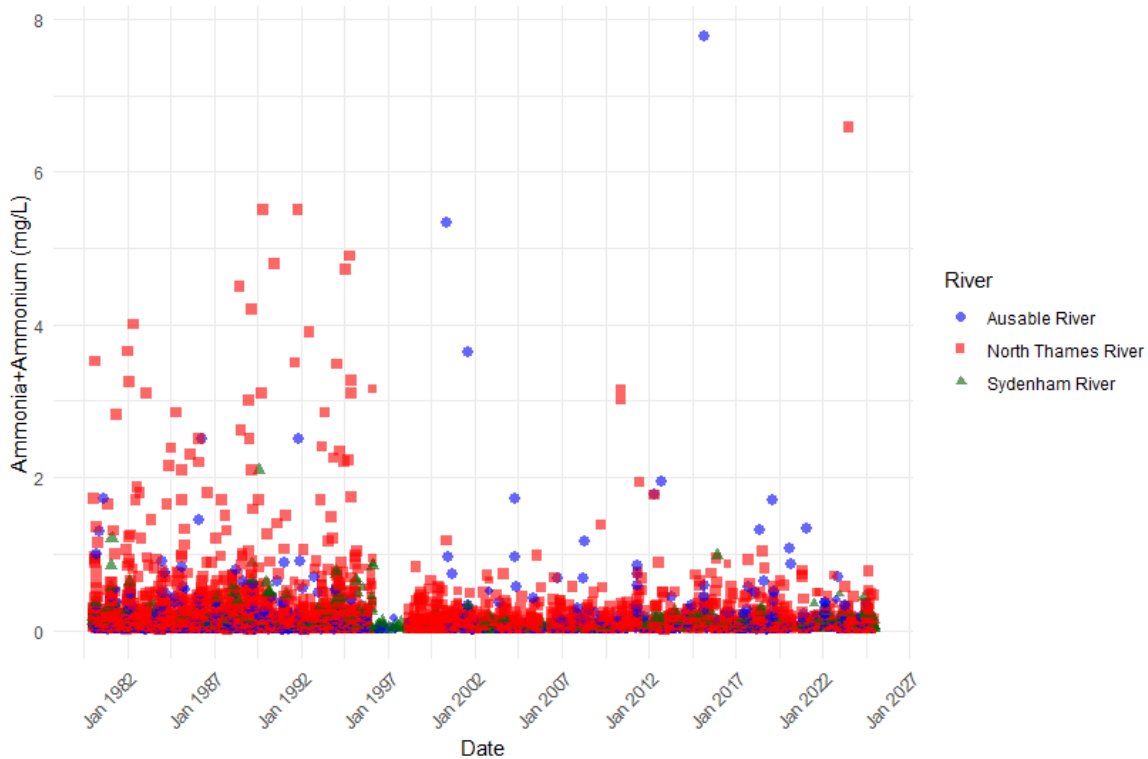


Figure 12. Provincial Water Quality Monitoring Network data by waterbody (multiple stations) for total ammonia (mg/L). Canadian Council of Ministers of the Environment (CCME) guidelines for the protection of aquatic life for ammonia vary with temperature and pH, but range from approximately 0.035–8.47 across the range of temperature and pH measured. Figure from Colm et al. (*In Press*).

Recent observations suggest that hydrological dynamics within Medway Creek may be changing in response to ongoing land-use change and development pressure within the watershed. Local conservation authority staff have noted that Medway Creek may be becoming increasingly “flashy,” potentially associated with drainage modifications, removal of large beaver dams, and intensification of urban development (E. Carroll, C. Ramsey and B. Gallagher, UTRCA, pers. comm. 2026). Increased hydrological variability may influence habitat stability, sediment transport, and recruitment success for freshwater mussels, although quantitative analyses of these trends are currently limited. Lastly, the Thames River watershed is experiencing increasing development pressure, particularly in the Arva area immediately north of the City of London. Proposed and ongoing residential development, including large subdivision projects, will introduce additional stormwater management infrastructure, including stormwater management ponds (E. Carroll, UTRCA, pers. comm. 2026). These ponds are designed to regulate flow and improve water quality; however, they may also influence thermal regimes, sediment delivery, and hydrological timing within receiving systems. While the specific characteristics of individual stormwater management devices within the Thames River watershed have not been quantified here, their presence represents a potential pathway for altered flow regimes and, in some cases, the introduction or movement of aquatic invasive species (AIS) if not properly managed.

During their early life stages, freshwater mussels are highly sensitive to waterborne contaminants, including metals and increased salinity, with acute responses observed at concentrations detected in some freshwater systems (Gillis et al. 2008; Gillis 2011). However, some freshwater mussel species, including Kidneyshell, employ a reproductive strategy in which glochidia are packaged into conglomerates prior to release. These structures are thought to enhance host infection success by mimicking prey items but may also provide a degree of protection from environmental stressors. Experimental evidence indicates that glochidia encased within conglomerates are less sensitive to waterborne contaminants than free glochidia, with significantly higher tolerance observed in toxicity trials (Gillis et al. 2008). This suggests that the conglomerate matrix may act as a partial barrier, reducing direct exposure to contaminants. However, this protective effect is likely temporary and context-dependent, as glochidia must ultimately be released and successfully attach to a host fish to complete development.

Collectively, these findings suggest that water-quality stressors such as nutrient enrichment, contaminant inputs, and altered hydrological regimes—already present within the Medway Creek watershed—may influence translocation success not through direct adult mortality, but through impacts on reproduction and juvenile recruitment. Although the extent to which these factors will influence Kidneyshell establishment is

uncertain, they represent ongoing and potentially increasing pressures within the watershed that should be considered in the context of long-term habitat stability and water quality.

Despite these ongoing stressors, recent targeted surveys indicate that Medway Creek currently supports a moderately abundant and diverse freshwater mussel assemblage, with 14 species detected across 15 sites, including two species at risk (Gibson et al. 2025). Sites with historical Kidneyshell records were characterized by intact riparian buffers (>30 m), which have been shown to be important for maintaining mussel habitat (Lu et al. 2024; Gibson et al. 2025). This reach is currently defined as critical habitat under SARA (2002) for Kidneyshell and includes portions of critical habitat for Black Redhorse (*Moxostoma duquesnei*; Fisheries and Oceans Canada 2022a) and Silver Shiner (*Notropis photogenis*; Fisheries and Oceans Canada 2022b). In addition, the area has been defined as the Medway Valley Heritage Forest Environmentally Significant Area by the City of London (UTRCA 2024).

4) ASSESS THE PROBABILITY OF UNINTENDED CONSEQUENCES

This section addresses the probability of unintended consequences associated with the proposed reintroduction (Questions 9–16, Appendix 2). The evaluation includes genetic risks to the newly established population, pathogen introduction risk, and potential ecosystem-level effects.

4.1) GENETIC AND HEALTH RISKS ASSOCIATED WITH A CAPTIVE-BRED DONOR POPULATION

Captive breeding and propagation programs are widely used as conservation tools for imperiled freshwater fishes and mussels, but they can be associated with genetic and health risks if not carefully designed and managed (Rytwinski et al. 2021). Key genetic risks relevant to the proposed Kidneyshell reintroduction include founder effects and genetic drift, inbreeding or outbreeding depression, and artificial selection (domestication) (Hoftyzer et al. 2008; Rytwinski et al. 2021; Howe et al. 2024).

Founder Effects and Genetic Drift

Founder effects occur when a new population is established from a small number of individuals, potentially resulting in reduced genetic diversity and biased representation of the source population. Genetic drift refers to the random change in the allele frequency of a particular gene in a population. This risk is of particular concern in captive populations where broodstock numbers are limited and initial population sizes are small (Rytwinski et al. 2021). Hoftyzer et al. (2008) suggest these can be minimized by using glochidia from a large number of females and by maximizing the initial population size.

In the case of Kidneyshell, donor individuals arose from an OMNR program designed to develop freshwater mussel husbandry capacity in Canada. Previously, individuals from the donor population were used as part of a doctoral level research program specifically designed to answer the question “how many females are required to maintain genetic diversity in a captive bred population?”. VanTassel et al. (2021) demonstrated that captive-propagated individuals derived from as few as seven gravid females from the Sydenham River retained levels of allelic richness and heterozygosity comparable to the wild population. Population genetic analyses revealed low genetic differentiation between captive-reared and wild individuals, and structure analyses supported the presence of a single genetic population. There is strong evidence that the pattern of multiple paternity observed in wild mussel populations greatly enhances genetic diversity of broods and allows for the maintenance of genetic diversity in propagation programs that use wild broodstock (Wacker et al. 2019). Together, these results indicate that broodstock collection and propagation would likely not result in a genetic bottleneck or substantial loss of diversity. The risk of founder effects associated with the propagated cohort is considered low. Genetic drift, although common in small, isolated populations and likely already acting on the Sydenham and Ausable populations, is unlikely to have negative short-term (e.g., 10 years) impacts following a reintroduction.

Inbreeding and Outbreeding Depression

Inbreeding depression can occur when related individuals reproduce, leading to reduced fitness, while outbreeding depression may arise when genetically divergent populations are crossed, potentially disrupting locally adapted gene complexes (Rytwinski et al. 2021).

For Kidneyshell, the risk of outbreeding depression is considered negligible because the species is likely extirpated from the system and no resident Kidneyshell population remains with which introduced individuals could interbreed. As a result, there is no risk of genetic incompatibility between donor and recipient populations. The risk of inbreeding depression is therefore related to the genetic structure of the captive-propagated cohort itself. VanTassel et al. (2021) found no evidence of elevated inbreeding coefficients or reduced genetic diversity in captive-reared individuals relative to the wild Sydenham River population. Genetic diversity metrics, including allelic richness and heterozygosity, were comparable between captive and wild groups, indicating that broodstock selection and propagation methods did not result in inbreeding within the cohort.

Interspecific Hybridization

Interspecific hybridization has been documented in freshwater mussels, but it appears to be largely restricted to closely related taxa within the same genus. Genetic studies

have identified hybridization among species of *Pyganodon* (Cyr et al. 2007) and between closely related *Lampsilis* species in areas of secondary contact (Porto-Hannes et al. 2021). In both cases, hybridization occurred among phylogenetically proximate species with overlapping distributions. The freshwater mussel assemblage currently present in Medway Creek and the broader Upper Thames River watershed includes representatives of multiple genera (e.g., *Lampsilis*, *Ligumia*, *Cambarunio*, *Pyganodon*, *Quadrula*, *Fusconaia*), but no other species of *Ptychobranhus* (Table 2; Appendix 3). Molecular phylogenetic analyses demonstrate that *Ptychobranhus* represents a distinct monophyletic lineage within *Lampsilini* (Roe 2013). Given the absence of congeneric species in Medway Creek and the phylogenetic distinctiveness of Kidneyshell relative to co-occurring taxa, the probability of interspecific hybridization following reintroduction is considered very low.

Artificial Selection (Domestication)

Domestication is a form of human-mediated selection caused by the relaxation of natural selection under hatchery conditions (Howe et al. 2024). While this within-captivity selection may sometimes be deliberate (e.g., milk production in dairy cattle; Flori et al. 2009) it can potentially lead to maladapted progeny if the purpose is for eventual release to the wild as part of a recovery program (Blouin et al. 2021). Minimizing the amount of time individuals are held in captivity can reduce the effects of domestication (Hoftyzer et al. 2008), although negative effects can still be observed after only a few generations in captivity (Howe et al. 2024).

The Sydenham River Kidneyshell available for translocation were bred in the wild and, although they have lived in captivity for 10 years, still represent the first generation in captivity. Harmful domestication selection during rearing cannot be ruled out, but odds of its occurrence are likely low.

4.2) ENVIRONMENTAL RISKS ASSOCIATED WITH A CAPTIVE-BRED DONOR POPULATION

Pathogen Introduction

The introduction of pathogens is a recognized risk associated with captive breeding and translocation programs, particularly when individuals are moved between systems or exposed to novel environments (Hoftyzer et al. 2008; Rytwinski et al. 2021). Although habitat degradation and fragmentation have historically been emphasized as primary drivers of freshwater mussel declines, increasing attention has been directed toward the potential role of infectious agents in population health and mortality events (Haag 2019; Waller and Cope 2019; Brian et al. 2021; Brian and Aldridge 2023). A recent synthesis of unionid pathology highlights that freshwater mussels host a diversity of viruses, bacteria, fungi, and parasites, but that few infectious agents have been conclusively

linked to large-scale mortality in wild populations (Knowles et al. 2023). In many cases, infectious agents appear to be opportunistic or associated with environmental stress rather than primary causes of decline (Carella et al. 2016). Nevertheless, as propagation and reintroduction efforts expand, disease surveillance and biosecurity are increasingly recognized as important components of conservation planning (Haag and Williams 2014).

Several factors reduce the likelihood of pathogen introduction from Kidneyshell reintroductions. All captive-reared individuals have been maintained at the White Lake Fish Culture Station (Sharbot Lake, Ontario) since 2015 with the exception of 60 individuals removed for the cage trials in 2025. These individuals were returned to the Aquatic Life Research Facility at the Canada Centre for Inland Waters in Burlington, Ontario in October 2025 where they will remain until release. The OMNR facility at Sharbot Lake is supplied with cold, lake-fed source water, conditions which are expected to reduce stressors associated with eutrophication, which have been linked to increased disease risk in nutrient-enriched systems (Sinclair et al. 2023). The facility operates under provincial biosecurity and fish health best management practices designed to minimize the introduction, amplification, and transfer of pathogens within and beyond hatchery settings (OMNRF 2015a; 2015b). These protocols emphasize separation of cohorts, equipment disinfection, movement controls, sanitation, stress reduction, and monitoring for abnormal mortality or clinical signs consistent with disease. While these guidelines were developed primarily for fish culture, the underlying principles of pathogen containment, stress minimization, and sanitary control are directly applicable to freshwater mussel propagation and reduce the likelihood of inadvertent pathogen spread.

In addition to these protocols, the facility conducts annual, facility-level fish health monitoring in collaboration with the Animal Health Laboratory at the University of Guelph, including external examinations, necropsy, and histopathology. Routine screening includes a suite of bacterial and viral pathogens commonly associated with disease in freshwater aquaculture (Table 5). Except for occasional, low-level occurrences of bacterial gill disease and columnaris, no significant disease outbreaks or abnormal mortality events have been identified during the period in which Kidneyshell have been cultured at the facility (C. Wilson, MNR, pers. comm. 2026). Furthermore, the mussel culture system has remained hydrologically isolated from fish production systems, eliminating a potential pathway for cross-contamination between fish and unionid cohorts.

The Kidneyshell cohort has been reared under stable environmental conditions, with no reported unusual mortality events or disease outbreaks. The mussels are one of only

two unionid species maintained at the facility, the other being Wavyrayed Lampmussel propagated from Ontario donor stock, further limiting the risk of exposure to non-local or inter-jurisdictional pathogens. Because propagation has occurred entirely within Ontario, no cross-border transfers have occurred, thereby maintaining alignment with provincial biosecurity frameworks and reducing the likelihood of introducing novel pathogens. While fish health monitoring programs are not specifically designed to detect unionid pathogens, the absence of disease events and the controlled rearing conditions provide strong indirect evidence that pathogen-related risks associated with reintroduction are low.

Table 5. Pathogens screened as part of routine fish health monitoring at the OMNR White Lake Fish Culture Station.

| Category | Pathogen | Associated Disease |
|-----------------|--|---|
| Bacteriology | <i>Aeromonas salmonicida</i> | Furunculosis |
| | <i>Yersinia ruckeri</i> | Enteric redmouth disease (ERM) |
| | <i>Flavobacterium branchiophilum</i> | Bacterial gill disease (BGD) |
| | <i>Flavobacterium columnare</i> | Columnaris disease |
| | <i>Renibacterium salmoninarum</i> | Bacterial kidney disease (BKD) |
| Virology (qPCR) | Infectious Pancreatic Necrosis Virus (IPNV) | Infectious pancreatic necrosis (IPN) |
| | Infectious Salmon Anemia Virus (ISAv) | Infectious salmon anemia (ISA) |
| | Viral Hemorrhagic Septicemia Virus (VHSV) | Viral hemorrhagic septicemia (VHS) |
| | Infectious Hematopoietic Necrosis Virus (IHNV) | Infectious hematopoietic necrosis (IHN) |

Ecosystem-Level Consequences of Translocation in Medway Creek

When discussing the reintroduction of a species, any potential risks to the existing ecosystem must be considered. Potential risks could include disruption of existing species interactions, alteration of benthic habitat structure, or indirect effects on resident invertebrate or fish communities (IUCN/SSC 2013).

At present, there is no empirical evidence to suggest that the introduction of a native freshwater mussel species would result in harmful ecosystem-level effects. Reviews of freshwater mussel propagation, augmentation, and reintroduction indicate that the primary ecological risks to recipient systems are genetic or disease-related, rather than competitive or community disruptive (McMurray and Roe 2017). Freshwater mussels are naturally occurring components of river ecosystems, and Kidneyshell historically occurred within the Medway Creek watershed (Colm and Morris 2025). As such, reintroduction does not represent the addition of a novel functional group or exotic

ecological role. Because translocation densities will be selected to remain within the range of contemporary unionid abundance, the introduction is not expected to cause substantial changes in benthic biomass, filtration capacity, or nutrient fluxes that could destabilize existing ecosystem processes (Cope et al. 2003). Furthermore, as a unionid, Kidneyshell does not exhibit behaviours or life-history traits associated with invasive or disruptive species, and there is no evidence from other case studies of unionid introductions to indicate that its presence negatively affects co-occurring taxa (Jourdan et al. 2019; Haag 2012; Colm and Morris 2025).

Potential Impacts to the Donor Population (Sydenham River)

Broodstock individuals have already been collected and the propagated cohort required for introduction is currently maintained in captivity at White Lake Fish Culture Station. As such, no additional collections from the wild donor population are required for the proposed reintroduction, and no further direct demographic impacts are anticipated. At the time of broodstock collection, potential risks to the donor population included localized reductions in adult abundance, disruption of population size structure, and the removal of genetically valuable individuals (VanTassel et al. 2021). Broodstock collection involved seven gravid females from the East Sydenham River, all of which were returned alive to the river following glochidial extraction, resulting in no permanent removal of adult individuals from the population (VanTassel et al. 2021). The collection of such a small number of individuals from a large and demographically robust population served to further minimize these risks (DFO 2025b; Colm and Morris 2025).

Invasive Species Introduction

The probability of unintentionally introducing AIS during Kidneyshell translocation is considered very low. The captive-reared Kidneyshell have been maintained for over 10 years at the OMNR White Lake Fish Culture Station under controlled, lake-fed water conditions. Routine provincial fish health monitoring is conducted across all Ontario hatcheries, and although these protocols are designed primarily for fish, the underlying measures substantially reduce the likelihood of maintaining or transferring AIS from hatchery systems to receiving natural waters. Staff at the fish culture station confirm that mussel culture units have not experienced signs of invasive species contamination over more than a decade of rearing Kidneyshell at the facility (C. Wilson, OMNR, pers. comm. 2026). Risk of AIS introduction during the physical transfer process can be minimized by incorporating protocols that utilize clean containers to reduce the transfer of hatchery water to the receiving system. These approaches align with established biosecurity principles for preventing the spread of *Dreissenid* mussels, and other aquatic invasive species, which emphasize avoiding movement of source water between systems (CFIA 2026). During translocation the Kidneyshell will be transferred from the White Lake Fish Culture Station in holding tanks and then transferred into

clean transport containers before being placed directly into Medway Creek at pre-determined release sites. This will ensure no hatchery water enters the recipient system directly. Collectively, the operating procedures at OMNR White Lake Fish Culture Station, and the use of clean transfer methods will greatly reduce the probability of introducing AIS to Medway Creek during the translocation.

5) STRUCTURED EXPERT JUDGEMENT EXERCISE

The information presented in this document informed a structured expert-elicitation process among subject-matter experts, rightsholders, and stakeholders regarding the feasibility and advisability of proceeding with a Kidneyshell reintroduction in southern Ontario. An expert elicitation exercise based on a modified mini-Delphi approach (Lamothe 2026) was used to systematically evaluate the available evidence and to elicit independent judgements on the likelihood of achieving the fundamental and means objectives, as well as potential conservation benefits, ecological risks, and unintended consequences of a potential reintroduction. Participants were asked to provide probability estimates for each of the structured questions outlined in Appendices 1 and 2, including risks related to genetic processes, pathogen introduction, ecosystem-level consequences, and potential impacts to the Sydenham River donor population. These individual probability assessments were compiled and discussed iteratively to identify areas of agreement, uncertainty, and knowledge gaps. The resulting synthesis will inform an overall evaluation of whether the likelihood of unintended consequences is acceptably low relative to the anticipated conservation benefits of reintroduction. Documentation of the deliberations and resulting recommendations will provide a transparent and evidence-based rationale to guide subsequent management decisions.

Peer Review Meeting

A virtual peer-review meeting was held April 8-9, 2026 to weigh the scientific evidence presented above; to assess the probability of achieving the fundamental and means objectives; and to identify and assess the probability of experiencing unintended consequences (Figure 2) (Lamothe et al. 2023). Participants were invited to review the background materials prior to the meeting and to provide any additional information they deemed appropriate for discussion during the meeting. Twenty-one experts attended all or part of the meeting and participated in the expert-elicitation exercise following a modified mini-Delphi approach (Appendix 5) (Lamothe 2026).

Details of the expert elicitation procedures can be found in Lamothe (2026). Briefly, experts were provided an overview of the information relating to each of the questions in appendices 1 and 2 and asked to provide their best guess probability, as well as their lowest plausible and highest plausible probabilities ranging from 0 (no likelihood) to 1 (absolute likelihood) for each question. The lowest and highest plausible probabilities

were treated as hard bounds, indicating that experts judged the true probability to be unlikely to fall outside this interval. Prior to answering each question, opportunity was provided for discussion and clarification among participants. Questions were scored anonymously and after each question was scored, a summary of answers was provided to the group. Summaries included point plots visualizing each participant's answer, along with plots of participant answers converted to PERT (Program Evaluation and Review Technique) distributions with a linear mixed opinion pool summary curve. PERT distributions provide a convenient approach to translate elicited minimum, most-likely, and maximum values into a smooth probability distribution. Mathematically, it is equivalent to a Beta distribution rescaled to the elicited interval, with the mode equal to the participant's best guess (Lamothe 2026). Further, an equal-weight linear opinion pool was calculated for each question to combine expert opinions into a group-level estimate. This approach combines multiple probability distributions into a single group-level distribution by averaging them directly, treating each distribution as an equally valid expression of uncertainty.

After participants were presented with the results, they were given the opportunity to seek further clarification on the question and discuss results with the group. Following this discussion, participants were then given the opportunity to revise their scores. After the second round of scoring, scores were considered final.

Modified Mini-Delphi Results

Between 18 and 21 experts answered each question from appendices 1 and 2. There were no questions that had a completely unanimous response (Figures 13, 14) suggesting some level of uncertainty with respect to each evaluated factor. Figure 13 summarizes the responses of experts to the feasibility-related questions (Questions 1-8b), including questions related to the objectives, populations, habitats, communities, and threats. Black and red points indicate the mean and median best guess probability across participants, respectively. Error bars around those points represent the mean (and median) lowest and highest plausible probabilities across participants. The blue point represents the pooled mean value from the equal-weight linear opinion pool with 90% credible intervals. In the same manner, Figure 14 summarizes the responses of experts to risk-related questions (Questions 9-16), divided by subcategory. Figure 15 provides the raw scores of each participant for each question asked, where the error bars represent the lowest to highest plausible probabilities, and the points represent the best guess probabilities.

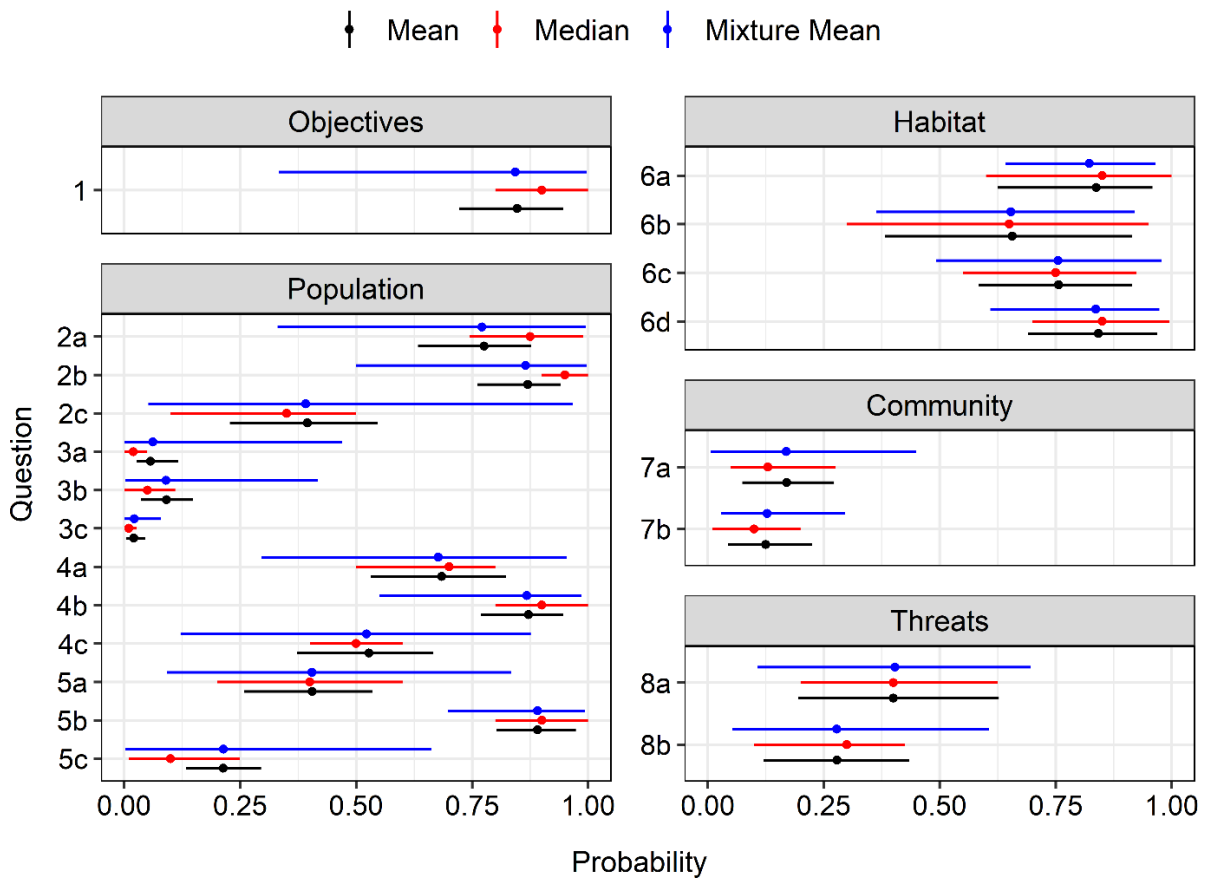


Figure 13. Feasibility related questions divided by subcategory. Black and red points indicate the mean and median best guess probability across participants, respectively. The interval between the mean lowest plausible probability and mean highest plausible probability across participants is shown with a black line. Intervals were similarly calculated using the median values, show in red. Blue points indicate the pooled mean probabilities, and the blue intervals represent the 90% credible interval of the equal-weight linear opinion pool.

Table 6 presents summary information of the raw participant scores and for the equal-weight linear opinion pools. Figures 16-22 provide the PERT distributions fit to each participant for each question. In the next section, we describe the results to each question including the objectives and feasibility related questions, and risk-related questions.

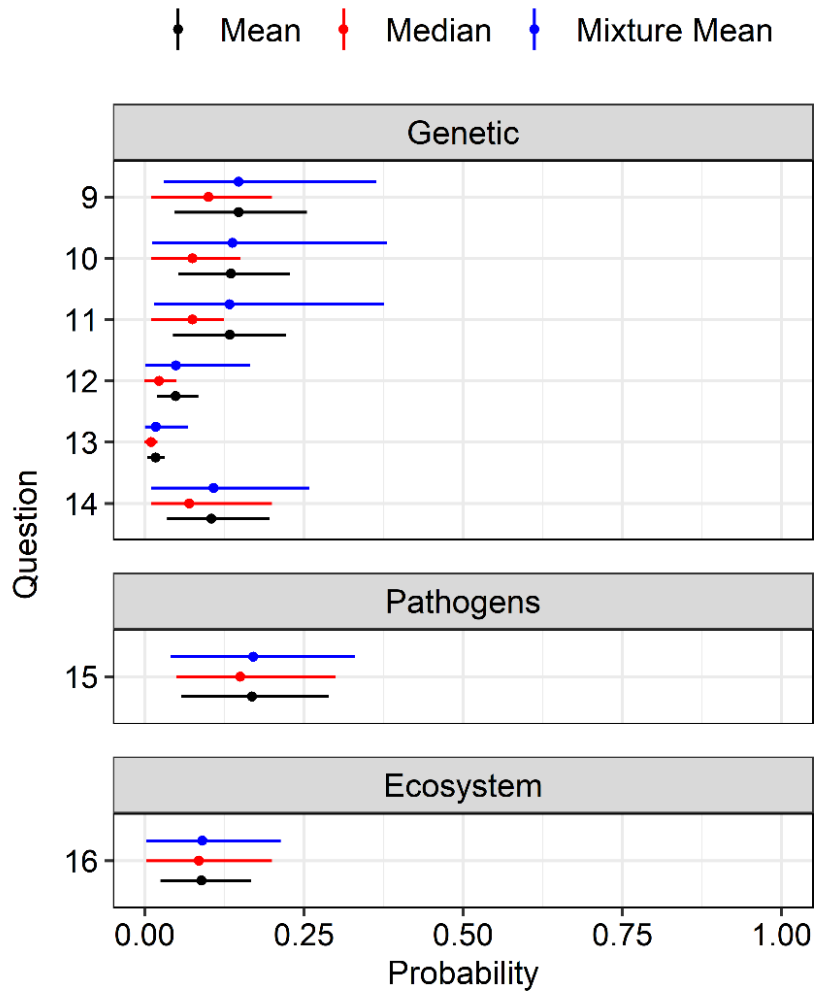


Figure 14. Risk-related questions divided by subcategory. Black and red points indicate the mean and median best guess probability across participants, respectively. The interval between the mean lowest plausible probability and mean highest plausible probability across participants is shown with a black line. Intervals were similarly calculated using the median values, show in red. Blue points indicate the pooled mean probabilities, and the blue intervals represent the 90% credible interval of the equal-weight linear opinion pool.

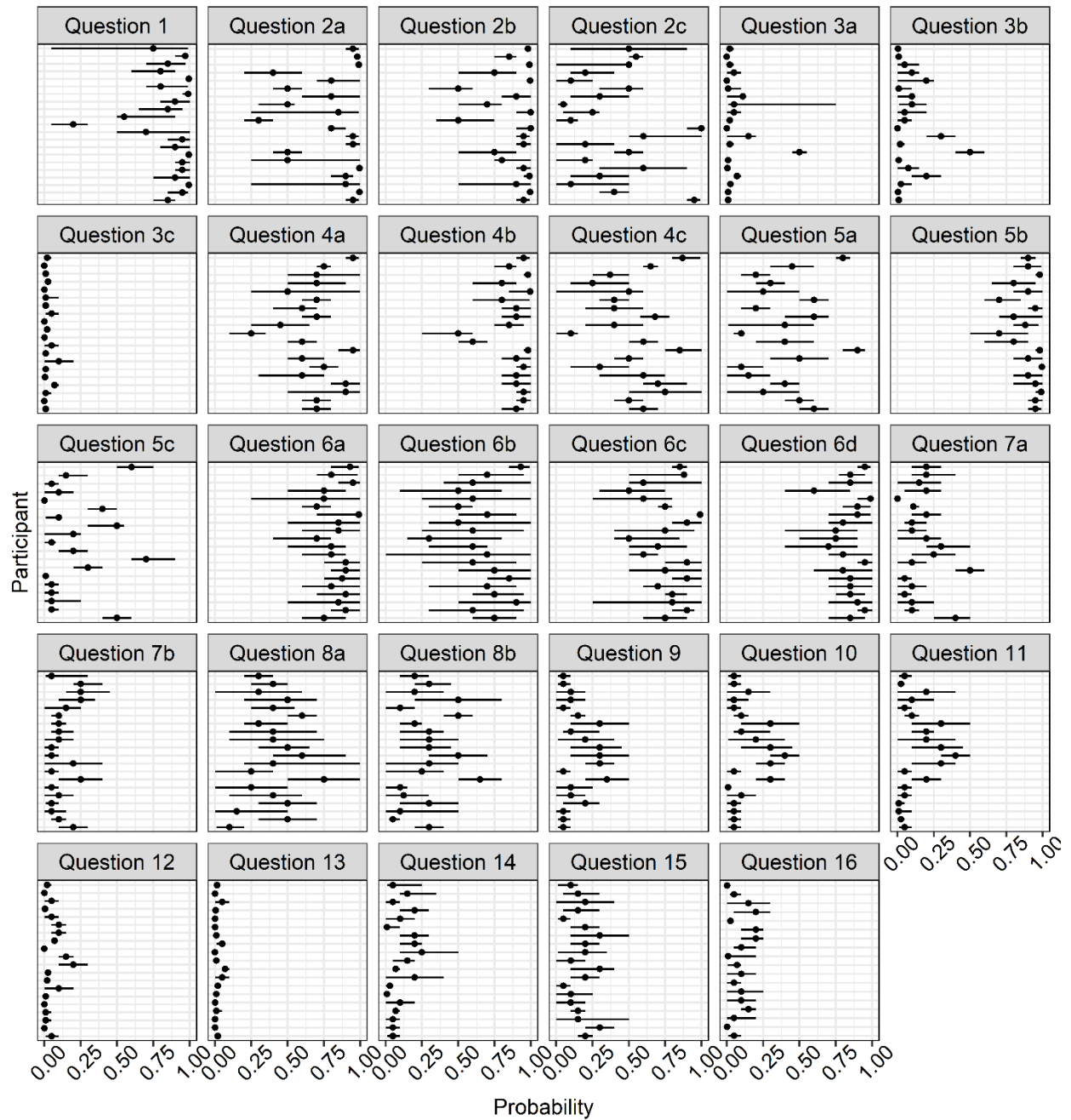


Figure 15. Expert participant scores for each question. Points indicate best guess probabilities and error bars indicate lowest to highest plausible probabilities. Each line represents an individual expert's score.

Table 6. Summary results of expert elicitation process. Included are the mean (median) lowest plausible probability (LPP), best guess probability (BGP), and highest plausible probability (HPP) for Questions 1-16. In addition, pooled mean (median) values of the equal-weight linear opinion pool are reported, along with hard union bounds (lowest LPP across participants–highest HPP across participants), and the 90th percentile. N = number of participants that answered each question.

| Quest. No. | N | LPP | BGP | HPP | Pooled Mean (Median) | Hard Union Bounds | 90th percentile |
|-------------------|----------|-------------|-------------|-------------|-----------------------------|--------------------------|-----------------------------------|
| 1 | 21 | 0.72 (0.80) | 0.85 (0.90) | 0.95 (1.00) | 0.84 (0.91) | 0.05–1.00 | 0.33–1.00 |
| 2a | 20 | 0.63 (0.75) | 0.78 (0.88) | 0.88 (0.99) | 0.77 (0.86) | 0.20–1.00 | 0.33–1.00 |
| 2b | 20 | 0.76 (0.90) | 0.87 (0.95) | 0.94 (1.00) | 0.87 (0.94) | 0.30–1.00 | 0.50–1.00 |
| 2c | 20 | 0.23 (0.10) | 0.39 (0.35) | 0.55 (0.50) | 0.39 (0.36) | 0.00–1.00 | 0.05–0.97 |
| 3a | 20 | 0.03 (0.00) | 0.06 (0.02) | 0.12 (0.05) | 0.06 (0.02) | 0.00–0.75 | 0.00–0.47 |
| 3b | 20 | 0.04 (0.00) | 0.09 (0.05) | 0.15 (0.11) | 0.09 (0.04) | 0.00–0.60 | 0.00–0.42 |
| 3c | 20 | 0.00 (0.00) | 0.02 (0.01) | 0.05 (0.03) | 0.02 (0.01) | 0.00–0.20 | 0.00–0.08 |
| 4a | 19 | 0.53 (0.50) | 0.68 (0.70) | 0.82 (0.80) | 0.68 (0.69) | 0.10–1.00 | 0.30–0.95 |
| 4b | 19 | 0.77 (0.80) | 0.87 (0.90) | 0.95 (1.00) | 0.87 (0.91) | 0.25–1.00 | 0.55–0.99 |
| 4c | 19 | 0.37 (0.40) | 0.53 (0.50) | 0.67 (0.60) | 0.52 (0.52) | 0.00–1.00 | 0.12–0.88 |
| 5a | 19 | 0.26 (0.20) | 0.41 (0.40) | 0.54 (0.60) | 0.40 (0.39) | 0.00–0.95 | 0.09–0.83 |
| 5b | 19 | 0.80 (0.80) | 0.89 (0.90) | 0.97 (1.00) | 0.89 (0.92) | 0.50–1.00 | 0.70–0.99 |
| 5c | 19 | 0.13 (0.01) | 0.21 (0.10) | 0.30 (0.25) | 0.21 (0.12) | 0.00–0.90 | 0.00–0.66 |
| 6a | 20 | 0.63 (0.60) | 0.84 (0.85) | 0.96 (1.00) | 0.82 (0.84) | 0.25–1.00 | 0.64–0.96 |
| 6b | 20 | 0.38 (0.30) | 0.66 (0.65) | 0.91 (0.95) | 0.65 (0.66) | 0.00–1.00 | 0.36–0.92 |
| 6c | 20 | 0.58 (0.55) | 0.76 (0.75) | 0.91 (0.93) | 0.76 (0.77) | 0.25–1.00 | 0.49–0.98 |
| 6d | 20 | 0.69 (0.70) | 0.84 (0.85) | 0.97 (0.99) | 0.84 (0.85) | 0.40–1.00 | 0.61–0.97 |
| 7a | 20 | 0.08 (0.05) | 0.17 (0.13) | 0.27 (0.28) | 0.17 (0.14) | 0.00–0.60 | 0.01–0.45 |
| 7b | 20 | 0.04 (0.01) | 0.13 (0.10) | 0.23 (0.20) | 0.13 (0.10) | 0.00–0.45 | 0.03–0.30 |
| 8a | 20 | 0.20 (0.20) | 0.40 (0.40) | 0.63 (0.63) | 0.40 (0.40) | 0.00–1.00 | 0.11–0.70 |
| 8b | 20 | 0.12 (0.10) | 0.28 (0.30) | 0.44 (0.43) | 0.28 (0.26) | 0.00–0.80 | 0.05–0.61 |
| 9 | 20 | 0.05 (0.01) | 0.15 (0.10) | 0.26 (0.20) | 0.15 (0.11) | 0.00–0.50 | 0.03–0.36 |
| 10 | 20 | 0.05 (0.01) | 0.14 (0.08) | 0.23 (0.15) | 0.14 (0.08) | 0.00–0.50 | 0.01–0.38 |
| 11 | 20 | 0.04 (0.01) | 0.13 (0.08) | 0.22 (0.13) | 0.13 (0.08) | 0.00–0.50 | 0.01–0.38 |

| Quest. No. | N | LPP | BGP | HPP | Pooled Mean (Median) | Hard Union Bounds | 90th percentile |
|-------------------|----------|-------------|-------------|-------------|-----------------------------|--------------------------|-----------------------------------|
| 12 | 20 | 0.02 (0.00) | 0.05 (0.02) | 0.08 (0.05) | 0.05 (0.03) | 0.00–0.30 | 0.00–0.17 |
| 13 | 19 | 0.00 (0.00) | 0.02 (0.01) | 0.03 (0.02) | 0.02 (0.01) | 0.00–0.1.00 | 0.00–0.07 |
| 14 | 19 | 0.04 (0.01) | 0.10 (0.07) | 0.20 (0.20) | 0.11 (0.08) | 0–0.5 | 0.01–0.26 |
| 15 | 19 | 0.06 (0.05) | 0.17 (0.15) | 0.29 (0.30) | 0.17 (0.17) | 0–0.5 | 0.04–0.33 |
| 16 | 18 | 0.02 (0.00) | 0.09 (0.09) | 0.17 (0.20) | 0.09 (0.07) | 0–0.3 | 0.00–0.21 |

Objectives and feasibility related factors influencing feasibility

Participants were first asked, “What is the probability that establishing an additional population of Kidneyshell will increase the likelihood of survival or recovery of Kidneyshell in Canada?” (Figure 16). In general, responses indicated that the probability was high, with mean and median best guess probabilities (BGPs) above 0.80 (Table 6). However, participant specific PERT distributions (Figure 16; Table 6) and the relatively large credible interval in Figure 13 indicates that there was some uncertainty across participants. Specifically, one person had significant uncertainty about the true probability, with an uncertainty interval of nearly 100%, while another participant felt that the probability was less than 0.25 (Figure 15).

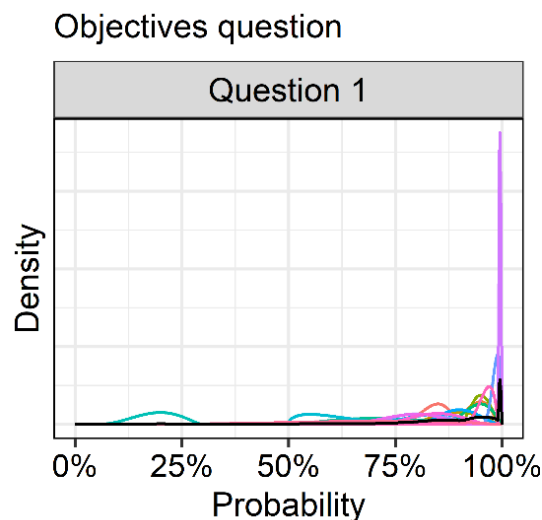


Figure 16. Participant-specific (colours) PERT distributions for the Objectives related question, Question 1: What is the probability that establishing an additional population of Kidneyshell will increase the likelihood of survival or recovery of Kidneyshell in Canada? Black line indicates equal-weight linear opinion pool.

Most of the responses for the population-related feasibility questions were anchored near 0% or 100% (Figure 17). Question 2 asked participants to estimate the probability that the a) Grand, b) Thames, and c) Welland rivers historically supported a self-sustaining Kidneyshell population. Generally, participants showed high confidence of a historical population in the Grand and Thames rivers, with much lower confidence for the Welland River (Figure 17); mean and median best guess probability was less than 50% for the Welland River across participants (Figure 13). Nevertheless, there were two experts that were very confident (high probability, low uncertainty) that the Welland River historically supported Kidneyshell (Figure 15). Question 3 then asked participants to estimate the probability that the a) Grand, b) Thames, and c) Welland rivers still support a self-sustaining Kidneyshell population. Although a few participants indicated uncertainty for the Thames River (Figure 15), there was general alignment that these

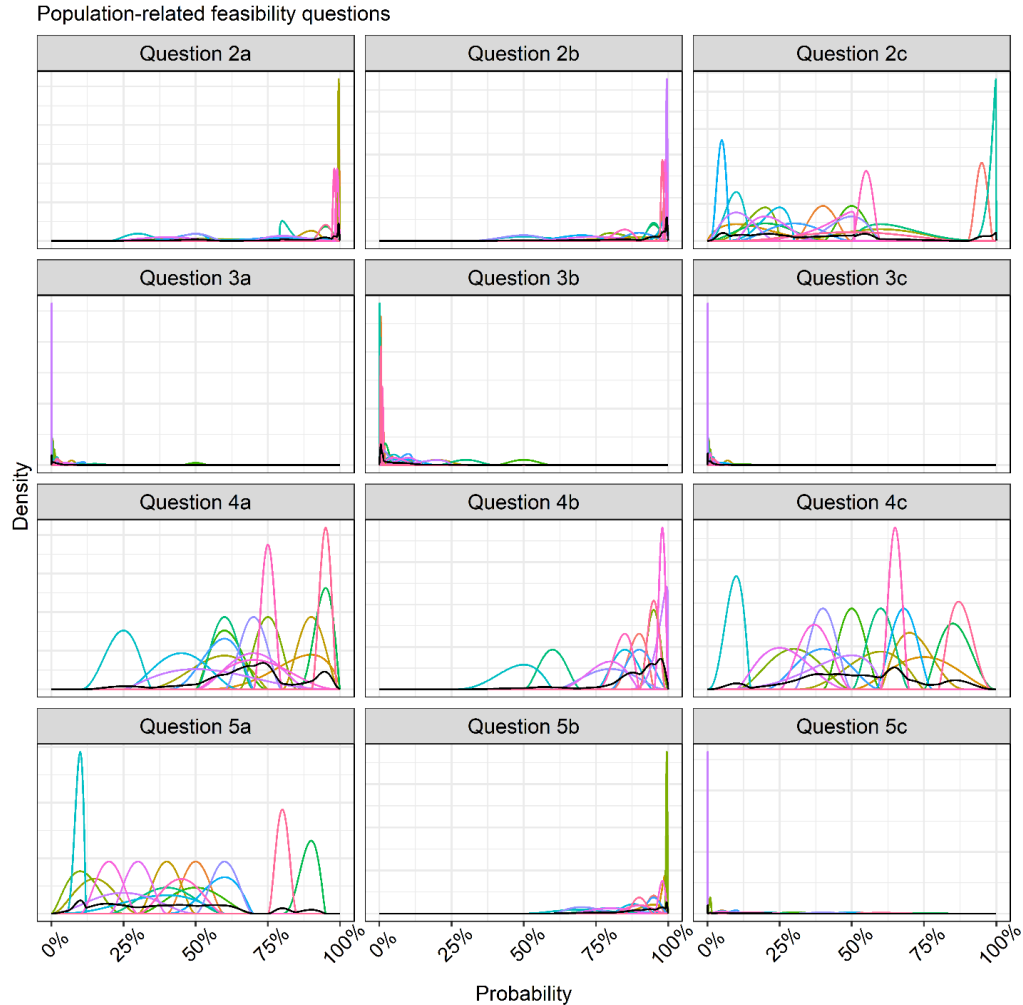


Figure 17. Participant-specific (colours) PERT distributions for the population-related feasibility questions (Questions 2-5). Black lines indicate equal-weight linear opinion pools.

three rivers no longer support a Kidneyshell population (Figures 13,17). There was much greater uncertainty among participants when asked whether the Sydenham River is an appropriate donor population (Question 4) for supporting reintroduction efforts in the a) Grand, b) Thames, and c) Welland rivers (Figures 13,15,17), particularly for the Grand and Welland. Although the mean and median BGP for the Thames River (4b) was above 0.87, the range between the lowest to highest plausible probabilities across participants for both the Grand and Welland rivers were nearly 100% (Table 6), while the range for the Thames River was 0.25–1.00 (Table 6). Finally, for Question 5, participants were asked the probability that the a) Grand, b) Thames, and c) Welland rivers were optimal recipient systems for release of the Sydenham River broodstock animals. There was low uncertainty among participants that the Sydenham River broodstock was well-positioned to act as a source population to support a reintroduction

to the Thames River, and not the Welland River (Figures 13, 17). Participants were uncertain whether the broodstock was appropriate for the Grand River (Figures 15, 17).

Figure 18 displays the results of the habitat-related feasibility questions. Across questions, participants generally felt that there was a) suitable substrate, b) suitable abiotic habitat, c) sufficient habitat, and d) appropriate host fishes present (Figures 13, 18; Table 6). There was high confidence that competition would not prevent the establishment of Kidneyshell in Medway Creek (Figure 19, Question 7a), with participants also indicating a low probability of predation preventing establishment, albeit with more uncertainty (Figure 19, Question 7b).

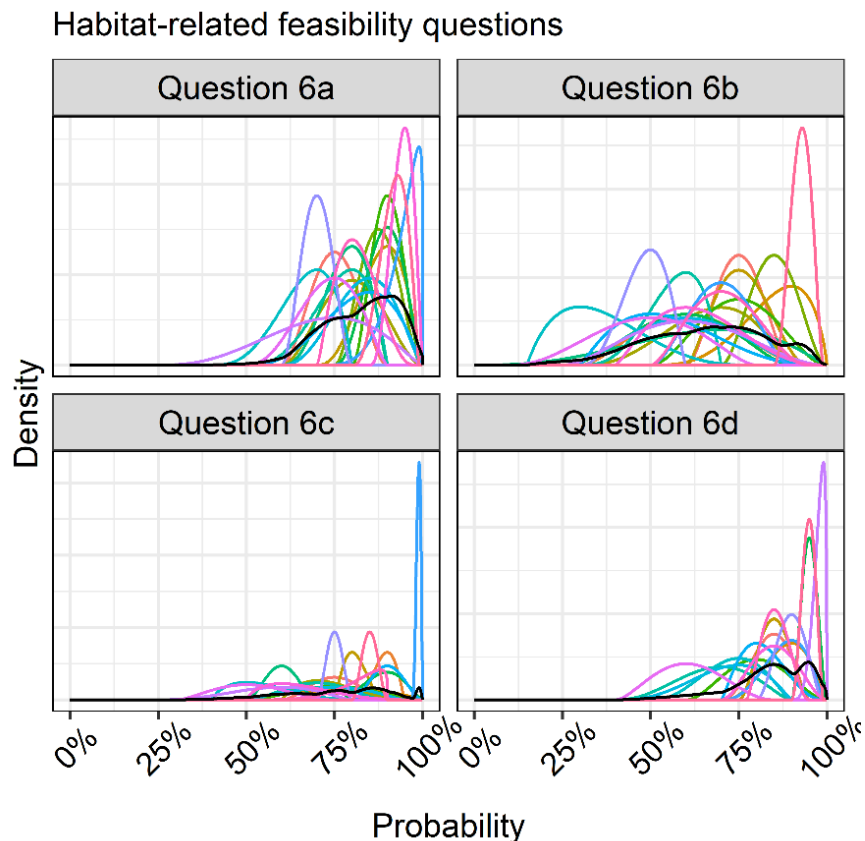


Figure 18. Participant-specific (colours) PERT distributions for the habitat-related feasibility questions (Questions 6a-6d). Black lines indicate equal-weight linear opinion pools.

Community-related feasibility questions

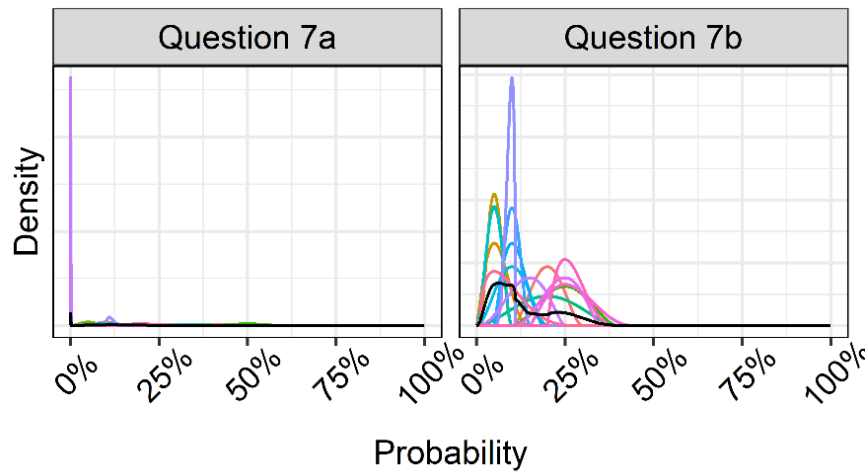


Figure 19. Participant-specific (colours) PERT distributions for the community-related feasibility questions (Questions 7a, b). Black lines indicate equal-weight linear opinion pools.

There was high uncertainty observed for Question 8 about whether a) agriculture or urban wastewater, and b) invasive species would prevent the establishment of Kidneyshell in Medway Creek over the next 10 years (Figure 20). On average, participants felt that there was less than a 50% chance (Table 6) but were uncertain due to the incomplete knowledge around why Kidneyshell was originally extirpated, among other considerations (e.g., continuing development within the watershed).

Threat-related feasibility questions

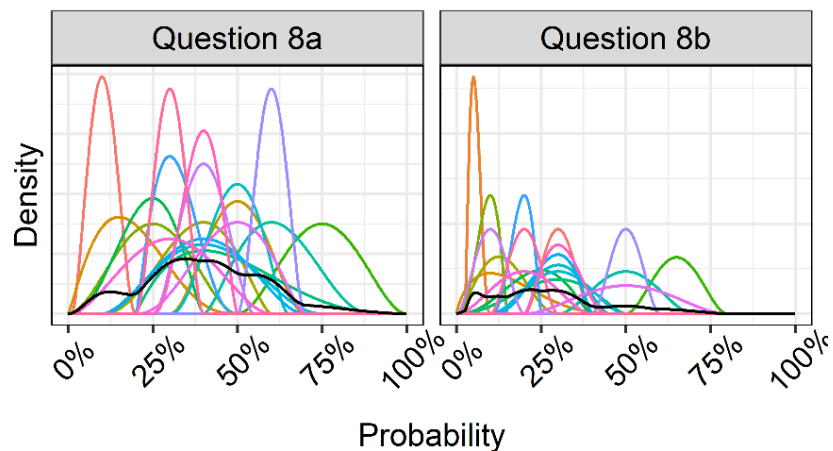


Figure 20. Participant-specific (colours) PERT distributions for the threat-related feasibility questions (Questions 8a, b). Black lines indicate equal-weight linear opinion pools.

Figure 21 presents the results of the genetic-related questions. In general, participants felt that there was a low probability of founder effects occurring in Medway Creek (Question 9), genetic drift over the next 10 years (Question 10), inbreeding depression within the next 10 years (Question 11), outbreeding depression with a pre-existing population (Question 12), interspecific hybridization in the recipient location (Question 13), or artificial selection experienced under human care (Question 14; Figure 21). Finally, participants felt there was a relatively low probability of pathogen transfer during the translocation process (17%; Table 6; Question 15) or negative ecosystem-level effects (<10%) resulting from the reintroduction of Kidneyshell to Medway Creek (Question 16; Figure 22).

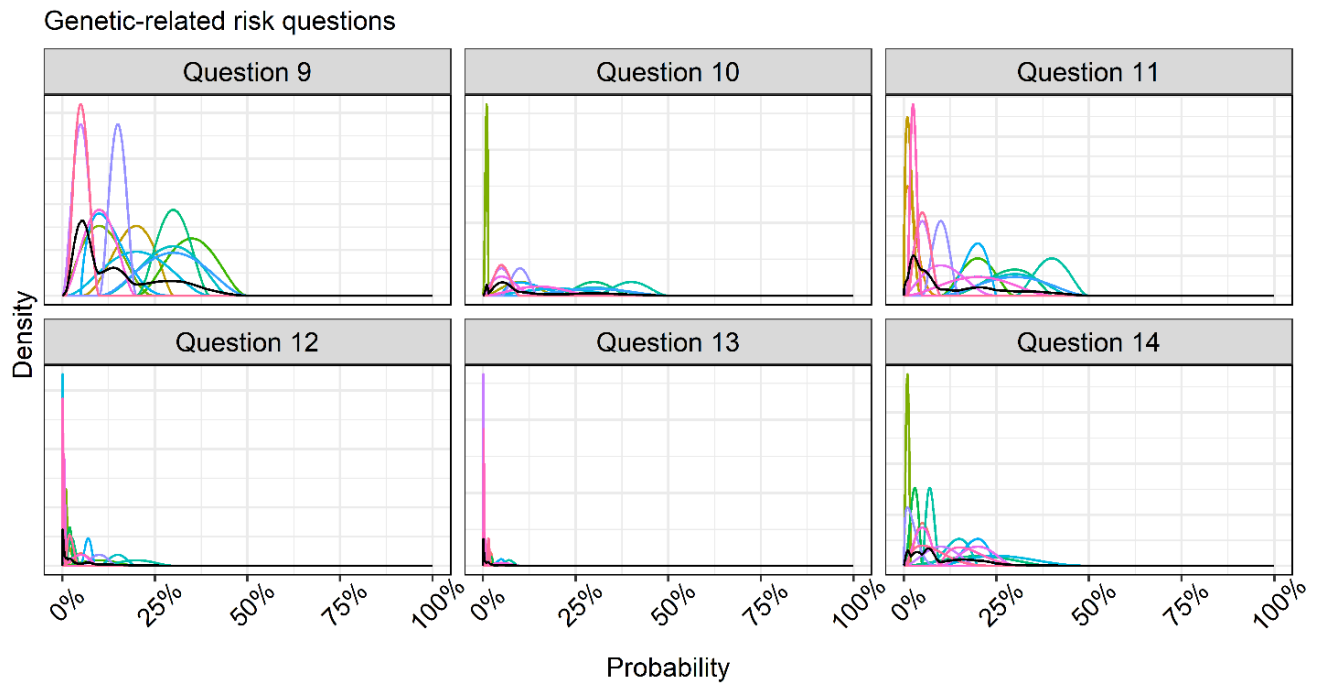


Figure 21. Participant-specific (colours) PERT distributions for the genetic-related risk questions (Questions 9-14). Black lines indicate equal-weight linear opinion pools.

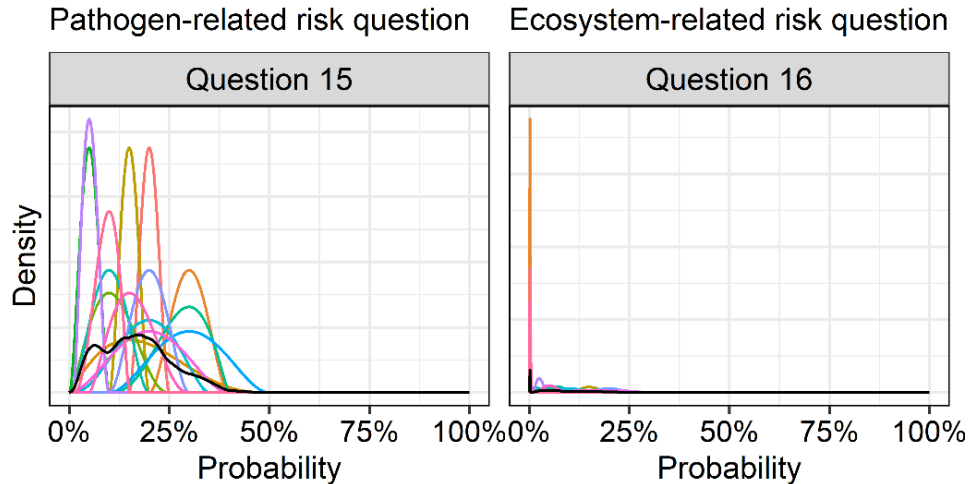


Figure 22. Participant-specific (colours) PERT distributions for the pathogen- and ecosystem-related risk questions (Questions 15,16). Black lines indicate equal-weight linear opinion pools.

6) ASSESSMENT

Recovery of Kidneyshell in Canada is unlikely to happen without direct intervention to re-establish historical populations. Large areas of historical habitat have been lost following the invasion of dreissenid mussels, and although remaining populations in the Ausable and Sydenham rivers are relatively healthy and appear to be growing (Colm and Morris 2025; Fung et al. 2025), they are likely too isolated to allow natural recolonization of historically occupied rivers. The federal recovery strategy for Kidneyshell states a long-term goal to “...re-establish populations in historically occupied habitats, excluding areas where dreissenid mussels have now made habitats unsuitable” via a short-term objective to “(e)xamine the feasibility of relocations, reintroductions and the establishment of managed refuge sites” (Fisheries and Oceans Canada 2013, p. iv). Participants at the peer-review meeting generally agreed that achieving the means objective of re-establishing an historical population through conservation translocation would lead to increased resiliency, redundancy, and representation, thereby increasing the likelihood of meeting the fundamental objective of improving survival and recovery of Kidneyshell in Canada.

Recovery actions undertaken in 2015 by the OMNR, in response to research and monitoring approaches described and recommended in the federal recovery strategy, resulted in the availability of approximately 779 individual Kidneyshell propagated from Sydenham River broodstock that can be used in a conservation translocation (C. Wilson, OMNR, pers. comm. 2026). Meeting attendees were presented with three potential recipient waterbodies to receive the propagated individuals: Grand River, Medway Creek (Thames River), and Welland River. These three systems were selected

based on evidence of historical populations and the continued presence of habitat that has not been made unsuitable by dreissenid mussels as necessitated in the recovery strategy goal. While attendees felt strongly that the Grand River and Medway Creek likely contained historically self-sustaining Kidneyshell populations, they felt uncertain that the same could be said for the Welland River (Figure 17). There was strong agreement that self-sustaining populations do not currently exist in any of these three systems (Figure 17). There was also strong support that the Sydenham River individuals would be a good genetic match for the Grand River and Medway Creek and that Medway Creek was the optimal target system for a reintroduction.

The historically occupied reach within Medway Creek consists of an ~ 3.5 km long stretch between Sunningdale Rd. and Western Rd. in London, Ontario. This reach is currently defined as critical habitat under SARA (2002) for Kidneyshell along with Silver Shiner and Black Redhorse. In addition, the area has been defined as the Medway Valley Heritage Forest Environmentally Significant Area by the City of London. Hence, this 3.5 km stretch of river is the anticipated location for future reintroductions.

The probability of achieving the means objective or experiencing unintended consequences was a well-discussed topic at the peer-review meeting. Attendees indicated a high probability that suitable substrate likely exists and that host fishes are present to facilitate juvenile development (Figure 18). However, there was greater uncertainty regarding the availability of other abiotic habitat due to limited data within this system. The observed presence of a diverse mussel assemblage including positive indicator species like Plain Pocketbook and the presence (Psephenidae, Empididae, Simulidae, Leptohyphidae) or absence (Corixidae, Physidae) of other benthic invertebrate indicator taxa (Metcalf-Smith et al. 2007; Eveleens et al. 2023; Gibson et al. 2025) contributed to the belief that habitat within Medway Creek is likely able to support Kidneyshell.

Interspecific competition and predation were seen as unlikely to prevent the establishment of Kidneyshell in Medway Creek within the next 10 years (Figure 19).

Several meeting participants expressed concerns that the cause of the historical extirpation of Kidneyshell in Medway Creek has not been identified. Kidneyshell was last recorded in Medway Creek in 2008 as a pair of mature, likely senescent, individuals approaching the maximum age recorded in Canada (33 years). This suggests that the last confirmed reproduction in the system may have occurred in the 1980s. Freshwater mussel monitoring was not conducted in Medway Creek, or elsewhere in Ontario, during this time. However, this timeframe roughly coincides with a period of elevated nutrient inputs (e.g., ammonia) (Figure 12). Although nutrient inputs remain elevated, reductions

in peak levels (e.g., above 1 mg/L total ammonia) have been observed in the North Thames River watershed over the last 20 years. The current threat landscape in Medway Creek is broadly similar to other southwestern Ontario watersheds where overall threats to mussels are considered low, and recent UMBO monitoring shows increasing mussel populations (van der Lee et al 2026). While the portion of Medway Creek where Kidneyshell may be reintroduced is not expected to see further development in the next decade, upstream areas are anticipated to experience further conversion of agricultural land to housing with associated stormwater management. In light of these considerations, meeting attendees expressed greater uncertainty regarding the likelihood of threats to limit establishment in the next 10 years, although this outcome was still considered unlikely (Figure 20).

VanTassel et al. (2021) demonstrate that the propagated cohort closely matches the genetic composition of the Sydenham River wild population which alleviated concerns regarding potential founder effects, and risks of inbreeding and outbreeding depression were considered highly unlikely (Figure 21). Genetic drift, although common in small, isolated populations and likely already acting on the Sydenham and Ausable populations, is unlikely to have negative short-term (e.g., 10 years) impacts following a reintroduction. Negative effects of domestication selection during maintenance in the hatchery were also considered unlikely. Biosecurity practices in place at the White Lake Fish Culture Station during the holding period led meeting attendees to consider the introduction of pathogens or diseases during reintroduction unlikely. Finally, meeting attendees felt that reintroduction of Kidneyshell into historical habitat in Medway Creek would be unlikely to lead to negative ecosystem level changes.

Summary

Reintroduction of Kidneyshell into its historical range within Medway Creek is likely to improve the survival and recovery of Kidneyshell in Canada. Suitable habitat and environmental conditions likely exist to support Kidneyshell within the creek and although threats still exist across the landscape, they are unlikely to limit establishment over the next decade. Protections afforded through critical habitat designations and the location within the Medway Valley Heritage Forest Environmentally Significant Area should further ameliorate threats. Ecological risks are considered low, and no negative ecosystem level changes are anticipated with this reintroduction.

ACKNOWLEDGEMENTS

We are grateful to all individuals who attended the peer-review meeting and provided thoughtful and constructive feedback on the meeting materials both before and during the meeting. We would like to thank OMNR's White Lake Fish Culture Station staff for their propagation efforts and their flexibility and helpfulness during Kidneyshell processing visits. Thanks to E. Carroll (UTRCA) for field assistance and data sharing. M. Gibson, L. Collinson, N. Elliott-Friesen, L. Dutheil, E. Collins, and E. MacLennan-Nobrega were an invaluable part of the field team during 2024 and 2025. We thank J. Colm (DFO) for map and figure development. Funding for this project was provided by Fisheries and Oceans Canada's Species at Risk program.

REFERENCES CITED

- ASTM (American Society of Testing Materials). 2013. Standard guide for conducting laboratory toxicity tests with freshwater mussels ASTM-E2455-06. ASTM International, West Conshohocken, PA.
- Bird, C.T., Kaller, M.D., Pasco, T.E., and Kelso, W.E. 2022. microhabitat and landscape drivers of richness and abundance of freshwater mussels (Unionida: Unionidae) in a coastal plain river. *Appl. Sci.* **12(20)**, 10300. <https://doi.org/10.3390/app122010300>
- Blouin, M.S., Wrey, M.C., Bollmann, S.R., Skaar, J.C., Twibell, R.G., and Fuentes, C. 2021. Offspring of first-generation hatchery steelhead trout (*Oncorhynchus mykiss*) grow faster in the hatchery than offspring of wild fish, but survive worse in the wild: Possible mechanisms for inadvertent domestication and fitness loss in hatchery salmon. *PLoS ONE* **16(12)**: e0257407. <https://doi.org/10.1371/journal.pone.0257407>
- Brian, J.I., and Aldridge, D.C. 2023. Enigmatic freshwater mussel declines could be explained by the biodiversity-disease relationship. *J. Appl. Ecol.* **60**: 1771–1777. <https://doi.org/10.1111/1365-2664.14479>
- Brian, J.I., Ollard, I.S., and Aldridge, D.C. 2021. Don't move a mussel? Parasite and disease risk in conservation action. *Conserv. Lett.* 2021: 14:e12799. <https://doi.org/10.1111/conl.12799>
- Bubac, C.M., Johnson, A.C., Fox, J.A., and Cullingham, C.I. 2019. Conservation translocation and post-release monitoring: Identifying trends in failures, biases, and challenges from around the world. *Biol. Conserv.* **238**: 108239. <https://doi.org/10.1016/j.biocon.2019.108239>
- Campbell, D.C., Johnson, P.D., Williams, J.D., Rindsberg, A.K., Serb, J.M., Small, K.K., and Lydeard, C. 2008. Identification of “extinct” freshwater mussel species using DNA barcoding. *Mol. Ecol. Resour.* **8(4)**: 711–724. <https://doi.org/10.1111/j.1755-0998.2008.02108.x>
- CFIA (Canadian Food Inspection Agency). 2026. Aquatic animal biosecurity. Available at: <https://inspection.canada.ca/en/animal-health/aquatic-animals/aquatic-animal-biosecurity> [accessed 2026-03-01].
- Carella, F., Villari, G., Maio, N., and De Vico, G. 2016. Disease and disorders of freshwater unionid mussels: A brief overview of recent studies. *Front. Physiol* **7**: 489. <https://doi.org/10.3389/fphys.2016.00489>
- CCME. 2011. Canadian Water quality guidelines for the protection of aquatic life: Chloride. Canadian Environmental Quality Guidelines. Available from [Canadian](#)

[Water Quality Guidelines for the Protection of Aquatic Life - Chloride](#) [assessed 24 April 2026].

- CCME. 2010. Canadian water quality guidelines for the protection of aquatic life: Ammonia. Canadian environmental quality guidelines. Available from <https://ccme.ca/en/res/ammonia-en-canadian-water-quality-guidelines-for-the-protection-of-aquatic-life.pdf> [assessed 24 April 2026].
- Clark, K.H., Iwanowicz, D.D., Iwanowicz, L.R., Mueller, S.J., Wisor, J.M., Bradshaw-Wilson, C., Schill, W.B., Stauffer, J.R., and Boyer, E.W. 2022. Freshwater unionid mussels threatened by predation of Round Goby (*Neogobius melanostomus*). *Sci. Rep.* **12**(1), Article 12859. <https://doi.org/10.1038/s41598-022-16385-y>
- Coghlan, S.A., Currier, C.A., Freeland, J., Morris, T.J., and Wilson, C.C. 2021. Community eDNA metabarcoding as a detection tool for documenting freshwater mussel (Unionidae) species assemblages. *Environ. DNA* **3**:1172–1191. <https://doi.org/10.1002/edn3.239>
- Colm, J.E., and Morris, T.J. 2025. Information in Support of a Recovery Potential Assessment for Kidneyshell (*Ptychobranthus fasciolaris*). DFO Can. Sci. Advis. Sec. Res. Doc. 2025/040. v + 65 p.
- Colm, J.E., van der Lee, A.S., and Morris, T.J. *In Press*. Information in support of a Recovery Potential Assessment of Northern Riffleshell (*Epioblasma rangiana*), Snuffbox (*Epioblasma triquetra*), Rayed Bean (*Paetulunio fabalis*), and Salamander Mussel (*Simpsonaias ambigua*) in Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2025/nnn. iv + xx p.
- Cope, W.G., Hove, M.C., Waller, D.L., Hornbach, D.J., Bartsch, M R., Cunningham, L.A., Dunn, H.L., and Kapuscinski, A.R. 2003. Evaluation of relocation of unionid mussels to in situ refugia. *Molluscan Stud.* **69**(1): 27–34. <https://doi.org/10.1093/mollus/69.1.27>
- COSEWIC. 2013. COSEWIC status appraisal summary on the Kidneyshell *Ptychobranthus fasciolaris* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xxvi pp. Available from www.registrelep-sararegistry.gc.ca/default_e.cfm [accessed 20 January 2026].
- Csábrágia, A., Molnára, S., Tanosa, P., Kovácsb, J., Molnárc, M., Szabóá, I., and Hatvani, I.G. 2019. Estimation of dissolved oxygen in riverine ecosystems: Comparison of differently optimized neural networks. *Ecol. Eng.* **138**: 298-309. <https://doi.org/10.1016/j.ecoleng.2019.07.023>
- Cyr, F., Paquet, A., Martel, A.L., and Angers, B. 2007. Cryptic lineages and hybridization in freshwater mussels of the genus *Pyganodon* (Unionidae) in

- northeastern North America. *Can. J. Zool.* **85**(12): 1216–1227.
<https://doi.org/10.1139/Z07-104>
- DFO. 2020. Action plan for the Ausable River in Canada: An Ecosystem Approach. *Species at Risk Act* Action Plan Series. Fisheries and Oceans Canada, Ottawa. v + 44 pp.
- DFO. 2025a. Evaluating the ecological benefits, risks, and feasibility of reintroduction for Eastern Sand Darter (*Ammocrypta pellucida*) in Ontario. DFO Can. Sci. Advis. Sec. Res. Doc. 2025/023.
- DFO. 2025b. Recovery potential assessment for Kidneyshell (*Ptychobranchnus fasciolaris*). DFO Can. Sci. Advis. Sec. Res. Doc. 2025/033.
- DFO. 2026. [Great Lakes Fish Biodiversity Database - ongoing](#). Version published January 2026. Great Lakes Laboratory for Fisheries and Aquatic Sciences, Fisheries and Oceans Canada, Burlington, ON.
- Dunn, C.G., Schumann, D.A., Colvin, M.E., Sleezer, L.J., Wagner, W., Jones-Ferrand, D.T., Rivenbank, E., McRae, S., and Evans, K. 2024. Using resiliency, redundancy, and representation in a Bayesian belief network to assess imperilment of riverine fishes. *Ecosphere* **15**: e4738. <https://doi.org/10.1002/ecs2.4738>
- Eakins, R.J. 2025. Ontario Freshwater Fishes Life History Database. Version 5.36. Online database. Available from <https://www.ontariofishes.ca> [accessed 10 February 2026].
- Eveleens, R.A., Morris, T.J. Woolnough, D.A., and Febria, C.M. 2023. One informs the other: Unionid species at risk and benthic macroinvertebrate community biomonitoring reveal complementarity in support of watershed-scale restoration. *FACETS* **8**:1-13. <https://www.facetsjournal.com/doi/pdf/10.1139/facets-2022-0207>
- Fisheries and Oceans Canada. 2013. Recovery strategy for the Round Hickorynut (*Obovaria subrotunda*) and the Kidneyshell (*Ptychobranchnus fasciolaris*) in Canada. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada. Ottawa. vi + 70 pp.
- Fisheries and Oceans Canada. 2022a. Recovery strategy and action plan for the Black Redhorse (*Moxostoma duquesnei*) in Canada. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. vi + 63 pp.
- Fisheries and Oceans Canada. 2022b. Recovery strategy and action Plan for the Silver Shiner (*Notropis photogenis*) in Canada. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. vi + 51 p.

- Fisheries and Oceans Canada. 2026. "DFO_CFMD" [Feature class]. Internal Enterprise GIS Geodatabase (SDE). Canadian Freshwater Mussel Distribution. [accessed 3 February 2026].
- Flori, L., Fritz, S., Jaffrézic, F., Boussaha, M., Gut, I., Heath, S., Foulley, J.-L., and Gautier, M. 2009. The genome response to artificial selection: A case study in dairy cattle. *PLoS One* **4**(8): e6595. <https://doi.org/10.1371/journal.pone.0006595>
- Friends of Medway Creek. 2009. Medway Creek community-based enhancement strategy. Prepared with the Upper Thames River Conservation Authority and the London Community Foundation. <https://thamesriver.on.ca/wp-content/uploads/MedwayCBES-report.pdf> [accessed 20 January 2026].
- Fung, S.R., van der Lee, A.S., and Koops, M.A. 2025. Recovery potential modelling of Kidneyshell (*Ptychobranhus fasciolaris*) in Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2025/041. v + 41 p.
- Galbraith, H.S., Zanatta, D.T., and Wilson, C.C. 2015. Comparative analysis of riverscape genetic structure in rare, threatened and common freshwater mussels. *Conserv. Genet.* **16**: 847-857. <https://doi.org/10.1007/s10592-015-0705-5>
- Gibson, M.P., McNichols-O'Rourke, K.A., and Morris, T.J. 2025. Freshwater mussel (Unionidae) timed-search surveys in Medway Creek: the search for *Ptychobranhus fasciolaris* (Kidneyshell). *Can. Manuscr. Rep. Fish. Aquat. Sci.* 3304: vii + 39 p. <https://doi.org/10.60825/chmq-cz47>
- Gillis, P.L. 2011. Assessing the toxicity of sodium chloride to the glochidia of freshwater mussels: Implications for salinization of surface waters. *Environ. Pollut.* **159**: 1702-1708. <https://doi.org/10.1016/j.envpol.2011.02.032>
- Gillis, P.L., Mitchell, R.J., Schwalb, A.N., McNichols, K.A., Mackie, G.L., Wood, C.M., and Ackerman, J.D. 2008. Sensitivity of the glochidia (larvae) of freshwater mussels to copper: Assessing the effect of water hardness and dissolved organic carbon on the sensitivity of endangered species. *Aquat. Toxicol.* **88**: 137-142. <https://doi.org/10.1016/j.aquatox.2008.04.003>
- Goguen, M.N., McNichols-O'Rourke, K.A., and Morris, T.J. 2022. Freshwater mussel surveys in the Sydenham River Nature Reserve, Ontario, 2017. *Can. Data Rep. Fish. Aquat. Sci.* 1351: vi + 17 p.
- Goguen, M.N., McNichols-O'Rourke, K.A., and Morris, T.J. 2023. Freshwater mussel timed-search surveys at historically sampled sites in the Grand River and Thames River watersheds, Ontario, 2021. *Can. Data Rep. Fish. Aquat. Sci.* 1352: v + 23 p. <https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/41100682.pdf>
- Government of Canada. 2026. Species at Risk Public Registry. Available from

<https://species-registry.canada.ca/indexen.html#/species/taxonomyId=9&sortBy=commonNameSort&sortDirection=asc¤tPage=5&pageSize=10> [accessed 3 February 2026].

- Government of Ontario. 2012-2026. Provincial (Stream) Water Quality Monitoring Network. © King's Printer for Ontario, 2012–25. Available from <https://data.ontario.ca/dataset/provincial-stream-water-quality-monitoring-network> [accessed 2025-01-13].
- GRCA (Grand River Conservation Authority). 2026. Our Watershed. Available from <https://www.grandriver.ca/our-watershed/> [accessed 12 March 2026].
- Haag, W.R., 2012. North American freshwater mussels: natural history, ecology, and conservation. Cambridge University Press.
- Haag, W.R., 2019. Reassessing enigmatic mussel declines in the United States. *Freshwater Mollusk Biology and Conservation* **22**: 43-60. <https://doi.org/10.31931/fmbc.v22i2.2019.43-60>
- Haag, W.R., and Williams, J.D. 2014. Biodiversity on the brink: an assessment of conservation strategies for North American freshwater mussels. *Hydrobiologia* **735**(1): 45–60. <https://doi.org/10.1007/s10750-013-1524-7>
- Heinrichs, J.A., McKinnon, D.T., Aldridge, C.L., and Moehrensclager, A. 2019. Optimizing the use of endangered species in multi-population collection, captive breeding and release programs. *Glob. Ecol. Conserv.* **17** Article e00558. <https://doi.org/10.1016/j.gecco.2019.e00558>
- Hicks, B.V., Engman, A.C., Da Silva Neto, J.G., Carey, C.S., Jett, J.J., and Dinkins, G.R. 2025. Assessing muskrat predation on a freshwater mussel assemblage in a southeastern United States river. *Food Webs* **44** Article e00407. <https://doi.org/10.1016/j.fooweb.2025.e00407>
- Hoftyzer, E., Ackerman, J.D., Morris, T.J., and Mackie, G.L. 2008. Genetic and environmental implications of reintroducing laboratory-raised unionid mussels to the wild. *Can. J. Fish. Aquat. Sci.* **65**(6): 1217-1229. [https://doi-org.ledproxy2.uwindsor.ca/10.1139/F08-024](https://doi.org.ledproxy2.uwindsor.ca/10.1139/F08-024)
- Howe, N.S., Hale, M.C., Waters, C.D., Schaal, S.M., Shedd, K.R., and Larson, W.A. 2024. Genomic evidence for domestication selection in three hatchery populations of Chinook salmon, *Oncorhynchus tshawytscha*. *Evol. Appl.* **17**: e13656. <https://doi.org/10.1111/eva.13656>
- Illes, C., J.E. Colm, N.E. Mandrak, and D.M. Marson. 2019. Flathead Catfish (*Pylodictis olivaris*) reproduction in Canada. *Can. Field-Nat.* **133**(4): 372–380. <https://doi.org/10.22621/cfn.v133i4.2323>

- IUCN. 2012. IUCN Red List Categories and Criteria: Version 3.1. Second edition. Gland, Switzerland and Cambridge, UK: IUCN. iv + 32pp.
- IUCN/SSC. 2013. Guidelines for Reintroductions and Other Conservation Translocations. Version 1.0. Gland, Switzerland: IUCN Species Survival Commission, viii + 57 pp.
- Jourdan, J., Plath, M., Tonkin, J.D., Ceylan, M., Dumeier, A.C., Gellert, G., Graf, W., Hawkins, C.P., Kiel, E., Lorenz, A.W., Matthaei, C.D., Verdonschot, P.F.M., Verdonschot, R.C.M., and Haase, P. 2019. Reintroduction of freshwater macroinvertebrates: challenges and opportunities. *Biol. Rev. Camb. Philos. Soc.* **94**(2): 368–387. <https://doi.org/10.1111/brv.12458>
- Knowles, S., Dennis, M., McElwain, A., Leis, E., and Richard, J. 2023. Pathology and infectious agents of unionid mussels: A primer for pathologists in disease surveillance and investigation of mortality events. *Vet. Pathol.* **60**(5), 510–528. <https://doi.org/10.1177/03009858231171666>
- Krebs, C.J. 1999. *Ecological Methodology*. Second Edition. Benjamin/Cummings, Menlo Park, CA.
- Lamothe, K.A. 2026. Implementing a three-step expert-elicitation approach to inform ecological decision-making. *Can. Manuscr. Rep. Fish. Aquat. Sci.* 3333: vi + 33 p.
- Lamothe, K.A., and Drake, D.A.R. 2019. Moving repatriation efforts forward for imperilled Canadian freshwater fishes. *Can. J. Fish. Aquat. Sci.* 76:1914-1921. 10.1139/cjfas-2018-0295.
- Lamothe, K.A., Dextrase, A.J., Barnucz, J., Gáspárdy, R.C., Jean, K., and Drake, D.A.R. 2025. Summary of targeted sampling for Eastern Sand Darter (*Ammocrypta pellucida*) in the Ausable River, Ontario: 2007 and 2017. *Can. Data. Rep. Fish. Aquat. Sci.* 3309: vi + 24 p.
- Lamothe, K.A., Morris, T.J., and Drake, D.A.R. 2023. Decision support framework for the conservation translocation of SARA-listed freshwater fishes and mussels. *DFO Can. Sci. Advis. Sec. Res. Doc.* 2022/064. vii + 83 p.
- LaValley, S.M. 2022. An assessment of federally endangered Snuffbox (*Epioblasma triquetra*) populations in Michigan, USA. Master of Science in Conservation Biology, Central Michigan University. 82 p.
- LeBaron, A., Hassal, E., and Reid, S.M. 2023. Results from freshwater mussel bait sampling in non-wadeable habitats of four southwestern Ontario rivers. *Can. Data. Rep. Fish. Aquat. Sci.* 1377: viii + 74 p.

- Lu, A., Morris, T.J., and Ackerman, J. D. 2024. The relationship between riparian vegetation buffer size and unionid mussel habitats. *Sci. Total Environ.* **956** <https://doi.org/10.1016/j.scitotenv.2024.177121>.
- McMurray, S.E., and Roe, K.J. 2017. Perspectives on the controlled propagation, augmentation, and reintroduction of freshwater mussels (Mollusca: Bivalvia: Unionoida). *Freshwater Mollusk Biology and Conservation* **20**(1): 1–12. <https://doi.org/10.31931/fmbc.v20i1.2017.1-12>
- McNichols-O'Rourke, K.A. and Morris, T.J. 2024. 2012–2015 Unionid Monitoring and Biodiversity Observation (UMBO) Network assessment in the Sydenham River watershed, Ontario. *Can. Data. Rep. Fish. Aquat. Sci.* 1413: ix + 50 p.
- McNichols-O'Rourke, K.A., Robinson, A. and Morris, T.J. 2012. Summary of freshwater mussel timed search surveys in southwestern Ontario in 2010 and 2011. *Can. Manuscr. Rep. Fish. Aquat. Sci.* 3009: vi + 42 p.
- Metcalfe-Smith, J.L., MacKenzie, A., Carmichael, I., and McGoldrick, D. 2005. Photo field guide to the freshwater mussels of Ontario. St. Thomas Field Naturalist Club Inc. St. Thomas, ON, Canada.
- Metcalfe-Smith, J.L., McGoldrick, D.J., Zanatta, D.T., and Grapentine, L.C. 2007. Development of a monitoring program for tracking the recovery of endangered freshwater mussels in the Sydenham River, Ontario. Prepared for the Sydenham River Recovery Team, the Interdepartmental Recovery Fund and Fisheries and Oceans Canada. WSTD Contribution No. 07-510. Environment Canada, Water Science and Technology Directorate. https://publications.gc.ca/collections/collection_2019/eccc/En83-9-07-510-eng.pdf
- Minke-Martin, V., McNichols-O'Rourke, K.A., and Morris, T.J. 2015. Initial application of the half-hectare unionid survey method in wetland habitats of the Laurentian Great Lakes, southern Ontario. *Can. Manuscr. Rep. Fish. Aquat. Sci.* 3069: vi + 36 p.
- MolluscaBase eds. 2026. MolluscaBase. Available from <https://www.molluscabase.org/> [accessed 20 April 2026].
- Morris, T. J. and Edwards, A. 2007. Freshwater mussel communities of the Thames River, Ontario: 2004-2005. *Can. Manuscr. Rep. Fish. Aquat. Sci.* 2810: v + 30pp.
- Nikel, K.E., Tetreault, G.R., Marjan, P., Hicks, K.A., Fuzzen, M.L. M., Srikanthan, N.,

- McCann, E.K., Dhiyebi, H., Bragg, L.M., Law, P., Celmer-Repin, D., Kleywegt, S., Cunningham, J., Clark, T., McMaster, M.E., and Servos, M.R. 2023. Wild fish responses to wastewater treatment plant upgrades in the Grand River, Ontario. *Aquat. Toxicol.* **255**: 106375. <https://doi.org/10.1016/j.aquatox.2022.106375>
- OMNRF (Ontario Ministry of Natural Resources and Forestry). 2015a. Biosecurity Protocols. Fish Culture Technical Bulletin 2015-06. Best Management Practices Series. Ontario Ministry of Natural Resources and Forestry, Fish Culture Section, Peterborough, Ontario. 12 p.
- OMNRF (Ontario Ministry of Natural Resources and Forestry). 2015b. Disease Prevention in the Fish Culture Facility. Fish Culture Technical Bulletin 2015-06. Best Management Practices Series. Ontario Ministry of Natural Resources and Forestry, Fish Culture Section, Peterborough, Ontario. 5 p.
- Owen, C.T., McGregor, M.A., Cobbs, G.A., and Alexander Jr., J.E. 2011. Muskrat predation on a diverse unionid mussel community: impacts of prey species composition, size and shape. *Freshw. Biol.* **56**: 554-567. <https://doi.org/10.1111/j.1365-2427.2010.02523>
- Page, L.M., Bemis, K.E., Dowling, T.E., Espinosa-Pérez, H.S., Findley, L.T., Gilbert, C.R., Hartel, K.E., Lea, R.N., Mandrak, N.E., Neighbors, M.A., Schmitter-Soto, J.J., and Walker Jr., H.J. 2023. Common and Scientific Names of Fishes from the United States, Canada, and Mexico. 8th edition. American Fisheries Society, Special Publication 37, Bethesda, Maryland.
- Pandolfo, T.J., Kwak, T.J., Cope, W.G., Heise, R.J., Nichols, R.B., and Pacifici, K. 2016. Species traits and catchment-scale habitat factors influence the occurrence of freshwater mussel populations and assemblages. *Freshw. Biol.* **61**(10): 1671–1684. <https://doi.org/10.1111/fwb.12807>
- Poos, M., Dextrase, A.J., Schwalb, A.N., and Ackerman, J.D. 2010. Secondary invasion of the Round Goby into high diversity Great Lakes tributaries and species at risk hotspots. *Biol. Invasions.* **12**(5): 1269–1284 <https://doi.org/10.1007/s10530-009-9545-x>
- Porto-Hannes, I., Burlakova, L.E., Zanatta, D.T., and Lasker, H.R. 2021. Boundaries and hybridization in a secondary contact zone between freshwater mussel species (Family:Unionidae). *Heredity* **126**(6): 955–973. <https://doi.org/10.1038/s41437-021-00424-x>
- Roe, K. J. 2013. Phylogenetic Analysis of the Freshwater Mussel Genus *Ptychobranchus* (Bivalvia: Unionidae). *Am. Malacol. Bull.* **31**(2), 257–265. <https://doi.org/10.4003/006.031.0205>

- Rytwinski, T.L., L.A., Donaldson, L.A., Taylor, J.J., Smith, A., Drake, D.A.R., Martel, A.L., Geist, J., Morris, T.J., George, A.L., Dextrase, A.J., Bennett, J.R., and Cooke, S.J. 2021. What evidence exists for evaluating the effectiveness of conservation-oriented captive breeding and release programs for imperilled freshwater fishes and mussels? *Can. J. Fish. Aquat. Sci.* **78**: 1332-1346.
<https://doi.org/10.1139/cjfas-2020-0331>
- Schloesser, D.W., Nalepa, T.F., and Mackie G.L. 1996. Zebra Mussel infestation of unionid bivalves (Unionidae) in North America. *Am. Zool.* **36**: 300-310.
<http://digitalcommons.unl.edu/usdeptcommercepub/368>
- SCRCA (St. Clair Region Conservation Authority). 2026. The Sydenham River watershed. Available from <https://www.sydenhamriver.on.ca/introducing-spri/> [accessed 12 March 2026].
- SCRSPA (St. Clair Region Source Protection Authority). 2008. Thames–Sydenham and Region Watershed Characterization Summary Report. Prepared for the Ontario Drinking Water Source Protection Program, Government of Ontario.
https://www.sourcewaterprotection.on.ca/wp-content/uploads/sp_plan3/SupDocs/WCR/SCLair_Characterization_Report/StClair-Summary.pdf [accessed 21 January 2026].
- Shaffer, M.L., and Stein, M.A. 2000. “Safeguarding Our Precious Heritage.” In *Precious Heritage: The Status of Biodiversity in the United States*, edited by B. A. Stein, L. S. Kutner, and J. S. Adams, 301–321. New York: Oxford University Press.
- Sheldon, M.N., McNichols-O’Rourke, K.A., and Morris, T.J. 2020. Summary of initial surveys at index stations for long-term monitoring of freshwater mussels in southwestern Ontario between 2007 and 2018. *Can. Manuscr. Rep. Fish. Aquat. Sci.* 3203: vii + 85 p.
- Sherman, J., Menon, V., Kock, R., King, T., Luz, S., Ashraf N.V.K., Soorae, P., and Moehrensclager, A. 2025. Guidelines on responsible translocation of displaced organisms. Gland, Switzerland: IUCN.
- Sinclair, J.S., Fraker, M.E., Hood, J.M., Reavie, E.D., and Ludsin, S.A. 2023. Eutrophication, water quality, and fisheries: A wicked management problem with insights from a century of change in Lake Erie. *Ecol. Soc.* **28**(3): 10.
<https://doi.org/10.5751/ES-14371-280310>
- Sparks, B.L. and Stayer, D.L. 1998. Effects of low dissolved oxygen on juvenile *Elliptio complanata* (Bivalvia:Unionidae). *J. N. Am. Benthol. Soc.* **17**(1): 129-134.
- Stanfield, L. 2010. Ontario stream assessment protocol. Version 8. Fisheries Policy Section. Ontario Ministry of Natural Resources. Peterborough, Ontario, Canada.

Available from <https://docs.ontario.ca/documents/2575/226871.pdf> [accessed 02 February 2026].

- Sousa, R., Nogueira, J.G., Ferreira, A., Carvalho, F., Lopes-Lima, M., Varandas, S., and Teixeira, A. 2019. A tale of shells and claws: The signal crayfish as a threat to the pearl mussel *Margaritifera margaritifera* in Europe. *Sci. Total Environ.* **665**: 329–337. <https://doi.org/10.1016/j.scitotenv.2019.02.094>
- Strayer, D.L., Downing, J.A., Haag, W.R., King, T.L., Layzer, J.B., Newton, T.J., and Nichols, S.J. 2004. Changing perspectives on Pearly Mussels, North America's most imperiled animals. *Bioscience* **54**(5): 429–439. [https://doi.org/10.1641/0006-3568\(2004\)054\[0429:CPOPMN\]2.0.CO;2](https://doi.org/10.1641/0006-3568(2004)054[0429:CPOPMN]2.0.CO;2)
- Swan, K.D., Lloyd, N.A., and Moehrensclager, A. 2018. Projecting further increases in conservation translocations: A Canadian case study. *Biol. Conserv.* **228**: 175–182.
- UTRCA (Upper Thames River Conservation Authority). 2022. 2022 Upper Thames River Watershed Report Cards, Upper Thames River Conservation Authority, 2022. Available from https://thamesriver.on.ca/wp-content/uploads/RC_Medway.pdf [accessed 4 February 2026].
- UTRCA (Upper Thames River Conservation Authority). 2024. Medway Valley Heritage Forest Environmentally Significant Area. Available from <https://thamesriver.on.ca/wp-content/uploads/2024-MedwayESA-brochure.pdf> [accessed 22 April 2026].
- van der Lee, A.S., Gibson, M.P., McNichols-O'Rourke, K., Jean, K.J., Koops, M.A., and Morris, T.J., 2026. Abundance trends within the freshwater mussel assemblages of seven major southwestern Ontario rivers. *Canadian Journal of Fisheries and Aquatic Sciences*. Just-IN <https://doi.org/10.1139/cjfas-2025-0429>
- VanTassel. N.M. 2023. Conservation, genomics, and evolution of Lampmussels and Kidneyshells. PhD. Dissertation. Central Michigan University, Mount Pleasant, Michigan, USA. 186 pp.
- VanTassel, N.M., Morris, T.J., Wilson, C.J., and Zanatta, D.T. 2021. Genetic diversity maintained in comparison of captive-propagated and wild populations of *Lampsilis fasciola* and *Ptychobranhus fasciolaris* (Bivalvia: Unionidae)¹. *Can. J. Fish. Aquat. Sci.* **78**(9): 1312–1320. <https://doi.org.ledproxy2.uwindsor.ca/10.1139/cjfas-2020-0373>
- Vaughn, C.C., and Hakenkamp, C.C. 2001. The functional role of burrowing bivalves in freshwater ecosystems. *Freshw. Biol.* **46**(11): 1431–1446. <https://doi.org/10.1046/j.1365-2427.2001.00771.x>

- Vaughn, C.C., Nichols, S.J., and Spooner, D.E. 2008. Community and foodweb ecology of freshwater mussels. *J. N. Am. Benthol. Soc.* **27**(2): 409–423. <https://doi.org/10.1899/07-058.1>
- Vaughn, C.C. (2018). Ecosystem services provided by freshwater mussels. *Hydrobiologia* **810**(1), 15–27. <https://doi.org/10.1007/s10750-017-3139-x>
- Wacker, A., Larsen, B.M., Jakobsen, P. and Karlsson, S. 2019. Multiple paternity promotes genetic diversity in captive breeding of a freshwater mussel. *Glob. Ecol. Conserv.* **17**: e00564 <https://doi.org/10.1016/j.gecco.2019.e00564>.
- Waller, D.L., and Cope, W.G. 2019. The Status of Mussel Health Assessment and a Path Forward. *Freshwater Mollusk Biology and Conservation* **22**: 26-42. <https://doi.org/10.31931/fmbc.v22i2.2019.26-42>
- Watters, G.T. 1999. Morphology of the conglutinate of the kidneyshell freshwater mussel, *Ptychobranchnus fasciolaris*. *Invertebr. Biol.* **118**: 289-295.
- Williams, J.D., Bogan, A.E., Butler, R.S., Cummings, K.S., Garner, J.T., Harris, J.L., Johnson, N.A., and Watters, G.T. 2017. A revised list of the freshwater mussels (Mollusca: Bivalvia: Unionida) of the United States and Canada. *Freshwater Mollusk Biology and Conservation* **20**(2): 33–58. <https://doi.org/10.31931/fmbc.v20i2.2017.33-58>
- Wilson, C. 2026. Fish health and hatchery biosecurity notes provided via personal communication (February 2026). Ontario Ministry of Natural Resources and Forestry, Fish Culture Section.
- Wright, K.A., McNichols-O'Rourke, K.A., Sheldon, M.N. and Morris, T.J. 2017. Freshwater mussel surveys of the Welland River watershed: 2014-16. *Can. Manuscr. Rep. Fish. Aquat. Sci.* 3115: v + 28 p.
- Zaret, T.M. and Rand, A.S. 1971. Competition in Tropical Stream Fishes: Support for the Competitive Exclusion Principle. *Ecology* **52**(2):336-342. <https://www.jstor.org/stable/1934593>

Appendix 1 Population, habitat, community, and threat considerations for evaluating the feasibility to reintroduce Kidneyshell in Canada.

| No. | Category | Location | Question |
|------------|-----------------|-----------------|--|
| 1 | Objectives | Ontario | What is the probability that establishing an additional population of Kidneyshell will increase the likelihood of survival or recovery of Kidneyshell in Canada? |
| 2a | Population | Grand River | What is the probability the Grand River historically supported a self-sustaining Kidneyshell population? |
| 2b | Population | Thames River | What is the probability the Thames River historically supported a self-sustaining Kidneyshell population? |
| 2c | Population | Welland River | What is the probability the Welland River historically supported a self-sustaining Kidneyshell population? |
| 3a | Population | Grand River | What is the probability that the river still supports a Kidneyshell population? |
| 3b | Population | Thames River | What is the probability that the river still supports a Kidneyshell population? |
| 3c | Population | Welland River | What is the probability that the river still supports a Kidneyshell population? |
| 4a | Population | Grand River | What is the probability that the Sydenham River is an appropriate donor population for this system? |
| 4b | Population | Thames River | What is the probability that the Sydenham River is an appropriate donor population for this system? |
| 4c | Population | Welland River | What is the probability that the Sydenham River is an appropriate donor population for this system? |
| 5a | Population | Grand River | What is the probability that this river is the optimal recipient |

| | | | |
|----|------------|---------------|--|
| | | | system for release of the Sydenham River broodstock animals? |
| 5b | Population | Thames River | What is the probability that this river is the optimal recipient system for release of the Sydenham River broodstock animals? |
| 5c | Population | Welland River | What is the probability that this river is the optimal recipient system for release of the Sydenham River broodstock animals? |
| 6a | Habitat | Medway Creek | What is the probability that suitable substrate exists to support the presence of Kidneyshell? |
| 6b | Habitat | Medway Creek | What is the probability that suitable abiotic habitat exists to support the presence of Kidneyshell? |
| 6c | Habitat | Medway Creek | What is the probability that there is sufficient habitat to support a diverse mussel assemblage including Kidneyshell? |
| 6d | Habitat | Medway Creek | What is the probability that fish hosts are present, and in sufficient abundance, to support Kidneyshell reproduction? |
| 7a | Community | Medway Creek | What is the probability that interspecific competition will prevent the establishment of Kidneyshell over the next 10 years? |
| 7b | Community | Medway Creek | What is the probability that predation will prevent the establishment of Kidneyshell over the next 10 years? |
| 8a | Threats | Medway Creek | What is the probability that agriculture or urban wastewater will prevent establishment of Kidneyshell over the next 10 years? |
| 8b | Threats | Medway Creek | What is the probability that invasive species will prevent the |

| | | | |
|--|--|--|---|
| | | | establishment of Kidneyshell over the next 10 years? |
|--|--|--|---|

Appendix 2. Ecological risk considerations associated with the translocation of Kidneyshell to Medway Creek.

| No. | Category | Question |
|------------|-----------------|---|
| 9 | Genetic | What is the probability of a founder effect occurring within a newly established Medway Creek Kidneyshell population over the next 10 years? |
| 10 | Genetic | What is the probability of genetic drift occurring within a newly established Medway Creek Kidneyshell population over the next 10 years? |
| 11 | Genetic | What is the probability of observing inbreeding depression within a newly established Medway Creek Kidneyshell population over the next 10 years? |
| 12 | Genetic | What is the probability of observing outbreeding depression within a pre-existing Medway Creek Kidneyshell population following the introduction of Sydenham River derived stock? |
| 13 | Genetic | What is the probability of interspecific hybridization in recipient location? |
| 14 | Genetic | What is the probability that captive-reared individuals have undergone artificial selection in captivity that will limit establishment in the wild? |
| 15 | Pathogens | What is the probability of introducing pathogens during the translocation process? |
| 16 | Ecosystem | What is the probability that there will be ecosystem level changes following a reintroduction? |

Appendix 3. Scientific names for mussels. Nomenclature for mussels follows MolluscaBase eds. (2026) for scientific names and Williams et al. (2017) for common names. Species at risk, as of April 2026 are highlighted (Government of Canada 2026).

| Common Name | Scientific Name |
|------------------------|------------------------------------|
| Black Sandshell | <i>Ligumia recta</i> * |
| Creek Heelsplitter | <i>Lasmigona compressa</i> |
| Creeper | <i>Strophitus undulatus</i> |
| Cylindrical Papershell | <i>Anodontooides ferussacianus</i> |
| Deertoe | <i>Truncilla truncata</i> |
| Elktoe | <i>Alasmidonta marginata</i> |
| Fatmucket | <i>Lampsilis siliquoidea</i> * |
| Fawnsfoot | <i>Truncilla donaciformis</i> |
| Flutedshell | <i>Lasmigona costata</i> |
| Fragile Papershell | <i>Potamilus fragilis</i> |
| Giant Floater | <i>Pyganodon grandis</i> |
| Kidneyshell | <i>Ptychobranhus fasciolaris</i> |
| Mapleleaf | <i>Quadrula quadrula</i> |
| Mucket | <i>Ortmanniana ligamentina</i> |
| Pimpleback | <i>Pustulosa pustulosa</i> |
| Pink Heelsplitter | <i>Potamilus alatus</i> |
| Plain Pocketbook | <i>Lampsilis cardium</i> * |
| Purple Wartyback | <i>Cyclonaias tuberculata</i> |
| Rainbow | <i>Cambarunio iris</i> *† |
| Rayed Bean | <i>Paetulunio fabalis</i> * |
| Round Pigtoe | <i>Pleurobema sintoxia</i> |
| Salamander Mussel | <i>Simpsonaias ambigua</i> |
| Slippershell | <i>Sulcularia viridis</i> |
| Spike | <i>Eurynia dilatata</i> |
| Threehorn Wartyback | <i>Obliquaria reflexa</i> |
| Threeridge | <i>Amblema plicata</i> |
| Wabash Pigtoe | <i>Fusconaia flava</i> |
| Wavyrayed Lampmussel | <i>Lampsilis fasciola</i> * |
| White Heelsplitter | <i>Pterosyna complanata</i> |

*Sexually dimorphic species

†Species currently listed under SARA and formerly known as: *Villosa iris*

Appendix 4. Scientific names for fishes. Nomenclature for fishes follows Page et al. (2023).

| Common Name | Scientific Name |
|--------------------|-------------------------------|
| Blackside Darter | <i>Percina maculata</i> |
| Brook Stickleback | <i>Culaea inconstans</i> |
| Fantail Darter | <i>Etheostoma flabellare</i> |
| Greenside Darter | <i>Etheostoma blennioides</i> |
| Johnny Darter | <i>Etheostoma nigrum</i> |
| Logperch | <i>Percina caprodes</i> |

Appendix 5. Names and affiliations of attendees at the April 8-9, 2026 peer review meeting. Meeting attendees were invited as experts on Kidneyshell, its habitat, and/or threats; as such, their opinions do not necessarily represent the opinions of their respective agencies.

| Name | Affiliation |
|--------------------------|---|
| Dr. Todd Morris (Chair) | DFO – Science |
| Kelly McNichols-O’Rourke | DFO – Science |
| Jason Barnucz | DFO – Science |
| Lauren Damphousse | University of Windsor |
| Amanda Conway | DFO – FFHPP |
| Anita LeBaron | Ontario Ministry of the Environment, Conservation and Parks |
| Dr. Catherine Febria | University of Windsor |
| Christopher Wilson | Ontario Ministry of Natural Resources, (OMNR) |
| Dominique Rumball | University of Toronto |
| Erin Carroll | Upper Thames River Conservation Authority |
| Dr. Isabel Porto-Hannes | University at Buffalo |
| Jessica Epp-Martindale | DFO – Species at Risk |
| Cambell McKay | Chippewas of the Thames First Nation |
| Julia Colm | DFO – Science |
| Dr. Karl Lamothe | DFO – Science |
| Mandy Gibson | University of Toronto |
| Dr. Nichelle Van Tassel | South Carolina Department of Natural Resources |
| Dr. Patty Gillis | ECCC |
| Dr. Scott Reid | OMNR |
| Sydney Todd (rapporteur) | DFO – Science |
| Vicki McKay | Lower Thames Valley Conservation Authority |
| Kari Jean | Ausable-Bayfield Conservation Authority |
| Craig Paterson | St. Clair Region Conservation Authority |