Species at Risk Act
Recovery Strategy Report Series

Report on the Progress of Recovery Strategy Implementation for the Round Hickorynut (*Obovaria subrotunda*) and Kidneyshell (*Ptychobranchus fasciolaris*) in Canada for the Period 2018 to 2023

Round Hickorynut and Kidneyshell

2025

Canada

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For copies of the progress report, or for additional information on species at risk, including Committee on the Status of Endangered Wildlife in Canada (COSEWIC) status reports and other related documents, please visit the Species at Risk Public Registry.

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« Rapport sur les progrès de la mise en oeuvre de la stratégie de rétablissement de l'obovarie ronde (*Obovaria subrotunda*) et du ptychobranche réniforme (*Ptychobranchus fasciolaris*) au Canada pour la période allant de 2018 à 2023. »

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Preface

The *Species at Risk Act* (S.C. 2002, c.29) (SARA), requires reporting on the implementation of the recovery strategy for a species at risk (via a progress report), and the progress towards meeting its objectives within 5 years of the date when the final recovery strategy was placed on the Species at Risk Public Registry, and every subsequent 5 years, until the recovery strategy is no longer required under SARA or the species' recovery is no longer feasible. This reporting must be done by the competent Minister.

The Minister of Fisheries is the competent minister under SARA for the Round Hickorynut and Kidneyshell and has prepared this progress report.

Reporting on the progress of recovery strategy implementation requires reporting on the collective efforts of the competent minister(s), provincial and territorial governments and all other parties involved in conducting activities that contribute to the species' recovery. Recovery strategies identify broad strategies and approaches that will provide the best chance of recovering species at risk. Some of the identified strategies and approaches are sequential to the progress or completion of others and not all may be undertaken or show significant progress during the timeframe of a report on the progress of recovery strategy implementation (progress report).

As stated in the preamble to SARA, success in the recovery of species at risk depends on the commitment and cooperation of many different groups that will be involved in implementing the directions set out in the recovery strategy and will not be achieved by Fisheries and Oceans Canada or any other jurisdiction alone. The cost of conserving species at risk is shared amongst different constituencies. All Canadians are invited to join in supporting and implementing the recovery strategy for the benefit of the Round Hickorynut and Kidneyshell and Canadian society as a whole.

Acknowledgments

This progress report was prepared by Fisheries and Oceans Canada (DFO). To the extent possible, this progress report has been prepared with inputs from DFO Science and the Ontario Ministry of Natural Resources and the Ontario Ministry of Environment, Conservation and Parks. DFO would also like to express its appreciation to all individuals and organizations who have contributed to the recovery of the Round Hickorynut and Kidneyshell.

Executive summary

The Round Hickorynut (*Obovaria subrotunda*) and the Kidneyshell (*Ptychobranchus fasciolaris*) were both listed as endangered under the *Species at Risk Act* (SARA) in 2005. The "Recovery Strategy for the Round Hickorynut (*Obovaria subrotunda*) and the Kidneyshell (*Ptychobranchus fasciolaris*) in Canada" was finalized and published on the Species at Risk Public Registry in 2006. An updated "Recovery Strategy for the Round Hickorynut (*Obovaria subrotunda*) and Kidneyshell (*Ptychobranchus fasciolaris*) in Canada" was finalized and published on the Species at Risk Public Registry in 2013.

The main threats identified for the Round Hickorynut and the Kidneyshell include invasive species (for example, dreissenid mussels and Round Goby [*Neogobius melanostomus*]), siltation and sedimentation, physical habitat loss, and reduced water quality.

The population and distribution objectives for the Round Hickorynut and the Kidneyshell are to return/maintain self-sustaining populations in the following locations:

1. St. Clair River delta and East Sydenham River (Round Hickorynut and Kidneyshell)
2. Ausable River and Thames River, including Medway Creek (Kidneyshell)

The "Report on the Progress of Recovery Strategy Implementation for the Round Hickorynut and the Kidneyshell in Canada for the Period 2018 to 2023" (progress report) summarizes progress that Fisheries and Oceans Canada (DFO), Environment and Climate Change Canada, the province of Ontario, conservation authorities, academic institutions, other stakeholders and other jurisdictions have made towards implementing the recovery strategy and achieving its objectives. During this time period, progress has been made in surveying current and historical locations, completing a variety of stewardship projects in the watersheds where the Round Hickorynut and Kidneyshell reside, engaging landowners and the general public in recovery activities, and improving understanding of their environmental requirements and the nature and scale of the threats that they face.

Surveys have continued to detect Kidneyshell within the Sydenham and Ausable rivers, while they were absent from a survey of Medway Creek (a Thames River tributary). Only 1 Round Hickorynut was detected in the Sydenham River, while no sampling occurred in St. Clair River delta in Canadian waters. Additionally, many Round Hickorynut and Kidneyshell historic locations were sampled during the 2018 to 2023 time-frame; no live specimens were found in the Detroit (on both the United States. and Canadian sides of the river), Grand, or Thames rivers.

Taken together, these ongoing and/or completed activities indicate that progress is being made towards the population and distribution objectives for Kidneyshell for some populations in Canada; however, additional recovery measures related to the feasibility of reintroductions are needed to achieve the population and distribution objectives for Round Hickorynut and Kidneyshell, for the Lake St. Clair delta and Medway Creek populations. Future surveys at index stations in the Sydenham River and St. Clair River delta will increase confidence in understanding the status of the Round Hickorynut in Canada. A number of areas still exist where further information is required to better understand the scope and scale of threats impacting both species. For example, the impact of land use patterns on these 2 species is largely extrapolated from studies in different locations with different species; hence, more targeted research may be necessary. With a continual improvement in the understanding of

threats and population status, recovery activities can continue to be directed to areas of greatest need.

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1 Introduction

The “Report on the Progress of Recovery Strategy Implementation for the Round Hickorynut and Kidneyshell in Canada for the Period 2018 to 2023” outlines the progress made towards meeting the objectives listed in the “Recovery Strategy for the Round Hickorynut (*Obovaria subrotunda*) and the Kidneyshell (*Ptychobranchus fasciolaris*) in Canada” during the indicated time period[1] and is part of a series of documents for these species that are linked and should be taken into consideration together; including the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessment and status reports on the Round Hickorynut (COSEWIC 2003b; COSEWIC 2013b) and Kidneyshell (COSEWIC 2003a; COSEWIC 2013a), a recovery strategy (DFO 2013)[2], and previous progress reports (DFO 2012 and DFO 2022).

Section 2 of the progress report provides an overview of key information on the threats to the species, population and distribution objectives for achieving its recovery, approaches to meeting the objectives, and performance indicators to measure the progress of recovery. For more details, readers should refer back to the recovery strategy. Section 3 reports on the progress made towards the activities identified in the recovery strategy, to support achieving the population and distribution objectives. Section 4 summarizes the progress towards achieving the population and distribution objectives.

2 Background

2.1 COSEWIC assessment summary and threats to the species and their critical habitat

The listing of the Round Hickorynut and Kidneyshell under SARA in 2005 led to the development and publication of the Recovery Strategy for the Round Hickorynut (*Obovaria subrotunda*) and Kidneyshell (*Ptychobranchus fasciolaris*) in Canada in 2006, with an updated version published in 2013. The recovery strategies are consistent with the information provided in the COSEWIC status reports (COSEWIC 2003a, 2003b), and the COSEWIC summary information is included in section I.1 of the recovery strategy.

In 2013, COSEWIC re-examined and confirmed the status of the Round Hickorynut (COSEWIC 2013b) and Kidneyshell (COSEWIC 2013a) as endangered.

[1] The previous progress report covered the time period of 2013 to 2018; this progress period begins in May 2018 and ends in May 2023.
[2] The 2013 recovery strategy replaced the original 2006 recovery strategy for these species.

Round Hickorynut

Assessment summary: May 2013

Common name

Round Hickorynut

Scientific name

Obovaria subrotunda

Status

Endangered

Reason for designation

The Canadian population of this species has declined by 75 to 95% over the last 10 years, with an estimated 99% decline over the last 30 years. Populations in the Grand and Thames rivers are extirpated and populations in the Sydenham River and Lake St. Clair have declined to very low levels. Losses and declines are due to the combined effects of pollution from agriculture and residential runoff, and the impacts of invasive species like the Zebra Mussel.

Occurrence

Ontario

COSEWIC status history
Designated endangered in May 2003. Its status was re-examined and confirmed in May 2013.

Kidneyshell

Assessment summary: May 2013

Common name
Kidneyshell

Scientific name
Ptychobranchus fasciolaris

Status
Endangered

Reason for designation
By 2001, this species had been lost from about 70% of its historical range in Canada due to the impacts of the Zebra Mussel and habitat loss from land use practices. It is now restricted to the East Sydenham and Ausable rivers, Lake St. Clair delta, and Medway Creek of the Thames River. The population in Lake St. Clair is close to extirpation. Both Ausable and East Sydenham river populations appear to be reproducing, but populations in Medway Creek and Lake St. Clair are not reproducing. Populations are threatened by pollution from agriculture, urban and road runoff sources, and invasive species (dreissenids and Round Goby).

Occurrence
Ontario

COSEWIC status history
Designated endangered in May 2003. Its status was re-examined and confirmed in May 2013.

The recovery strategy identifies the threats to survival and recovery of the Round Hickorynut and Kidneyshell, and threats to their critical habitat.

Section I.10 of the recovery strategy provides information on the threats to the species' survival and recovery. These threats include invasive species (for example, dreissenid mussels and Round Goby [*Neogobius melanostomus*]), siltation and sedimentation, physical habitat loss, and reduced water quality.

Critical habitat for the Round Hickorynut and Kidneyshell has been identified, to the extent possible, in section II.7 of the recovery strategy. The recovery strategy also provides examples of activities that are likely to result in the destruction of critical habitat (that is, threats to critical habitat). The list of activities provided in table 10 of the recovery strategy is neither exhaustive nor exclusive, and their inclusion has been guided by the relevant threats to habitat described in the recovery strategy. For more details on the activities likely to result in the destruction of critical habitat, consult the recovery strategy.

2.2 Distribution

Between 2018 and 2023, only 1 live Round Hickorynut was detected in the Sydenham River (figure 1). The St. Clair River delta was not sampled for unionids in Canadian waters during the 2018 to 2023 time-period and the species has not been detected in other areas where it historically occurred (for example, Lake Erie, and the Thames, Detroit, Grand, and Upper Niagara river watersheds). Kidneyshell continues to be detected in the Ausable and Sydenham rivers (figure 2) and 1 fresh valve was found in the Grand River (figure 3). No detections of Kidneyshell were recorded from the St. Clair River Delta, Lake Erie, or the Detroit, Thames, Welland, and Upper Niagara river watersheds where the species historically occurred.

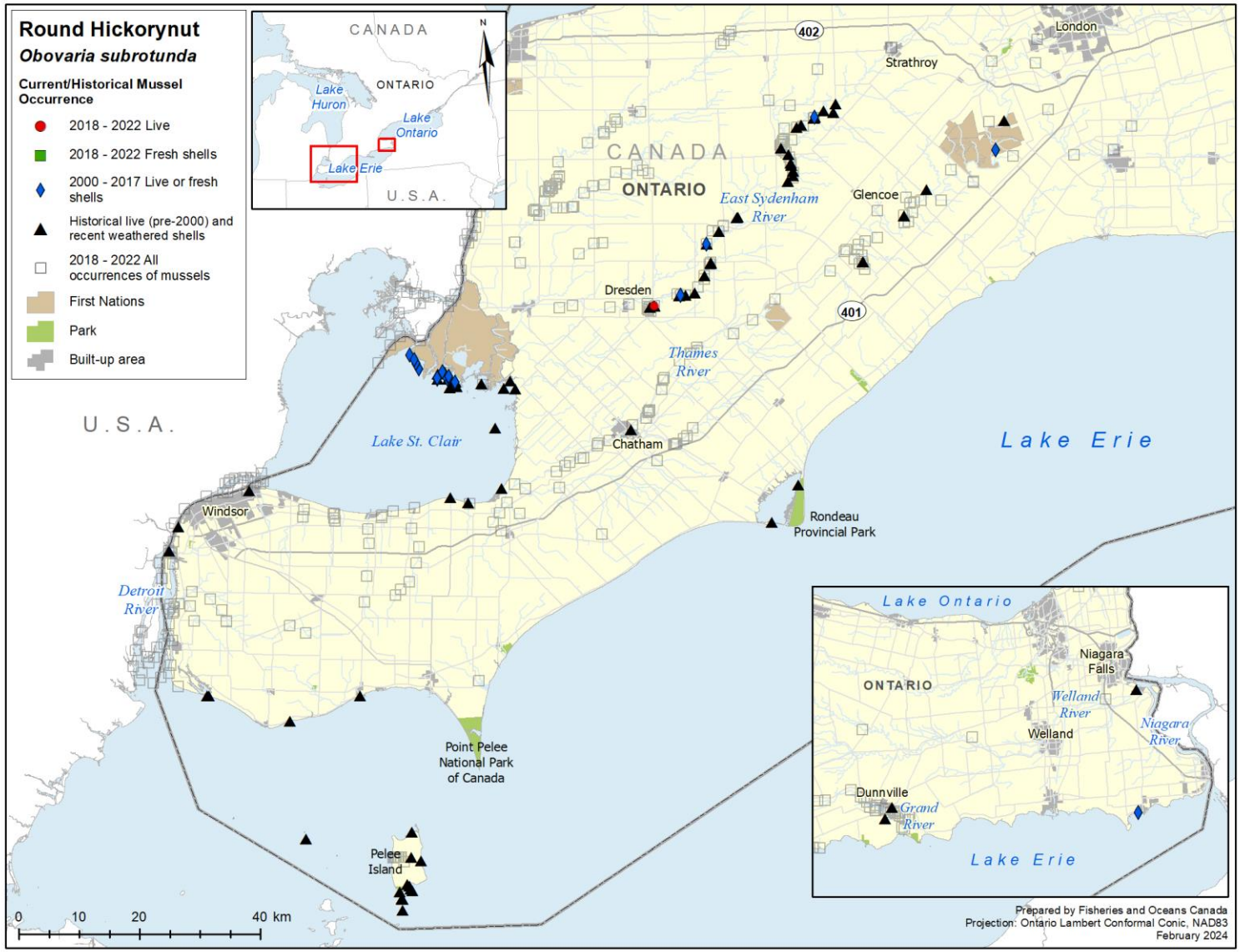

Figure 1. Historical and recent detections and relevant sampling of Round Hickorynut in southwestern Ontario. Empty squares depict all sites where mussels were found from 2018 to 2022, including incidental catches.

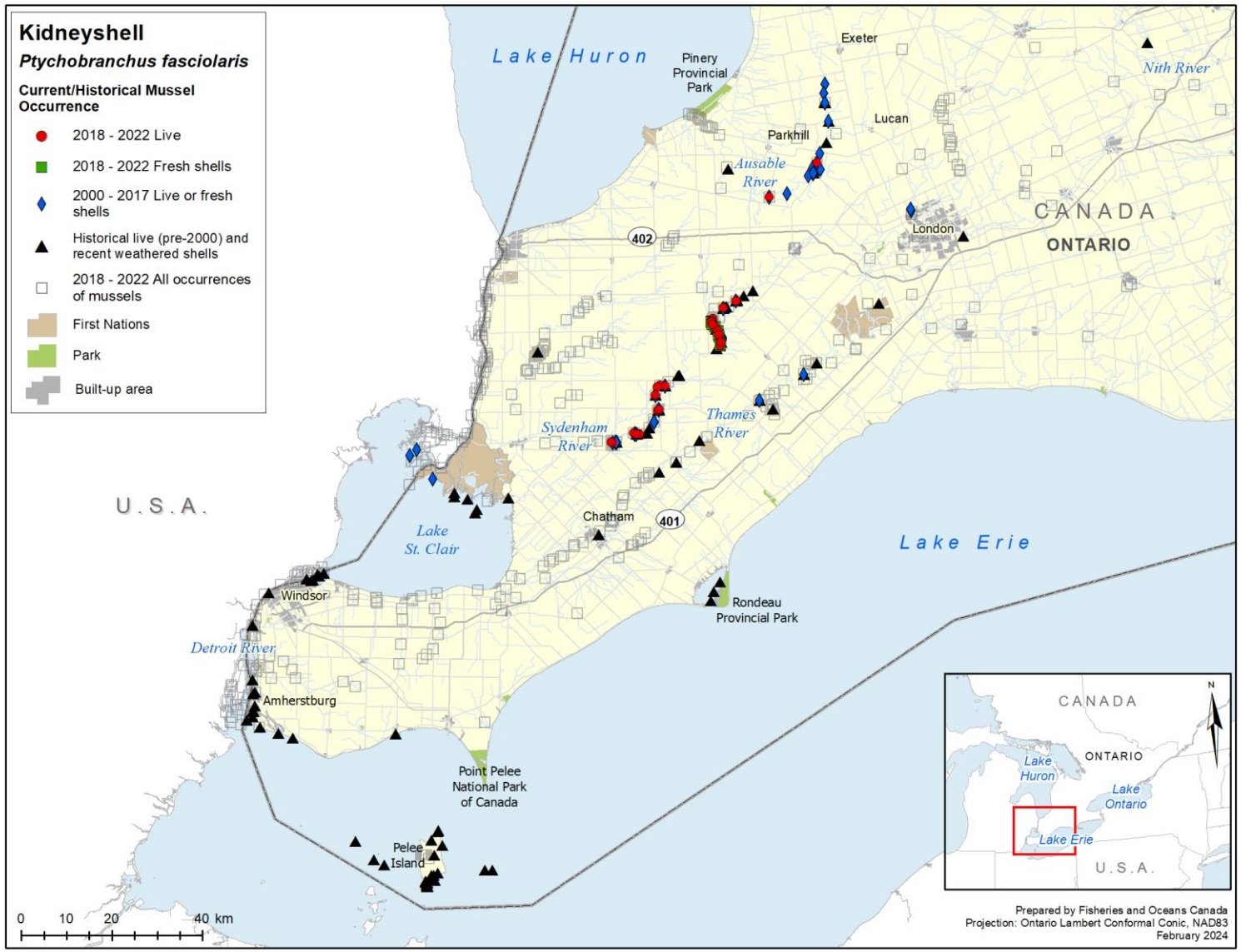

Figure 2. Historical and recent detections and relevant sampling of Kidneyshell in southwestern Ontario. Empty squares depict all sites where mussels were found from 2018 to 2022, including incidental catches.

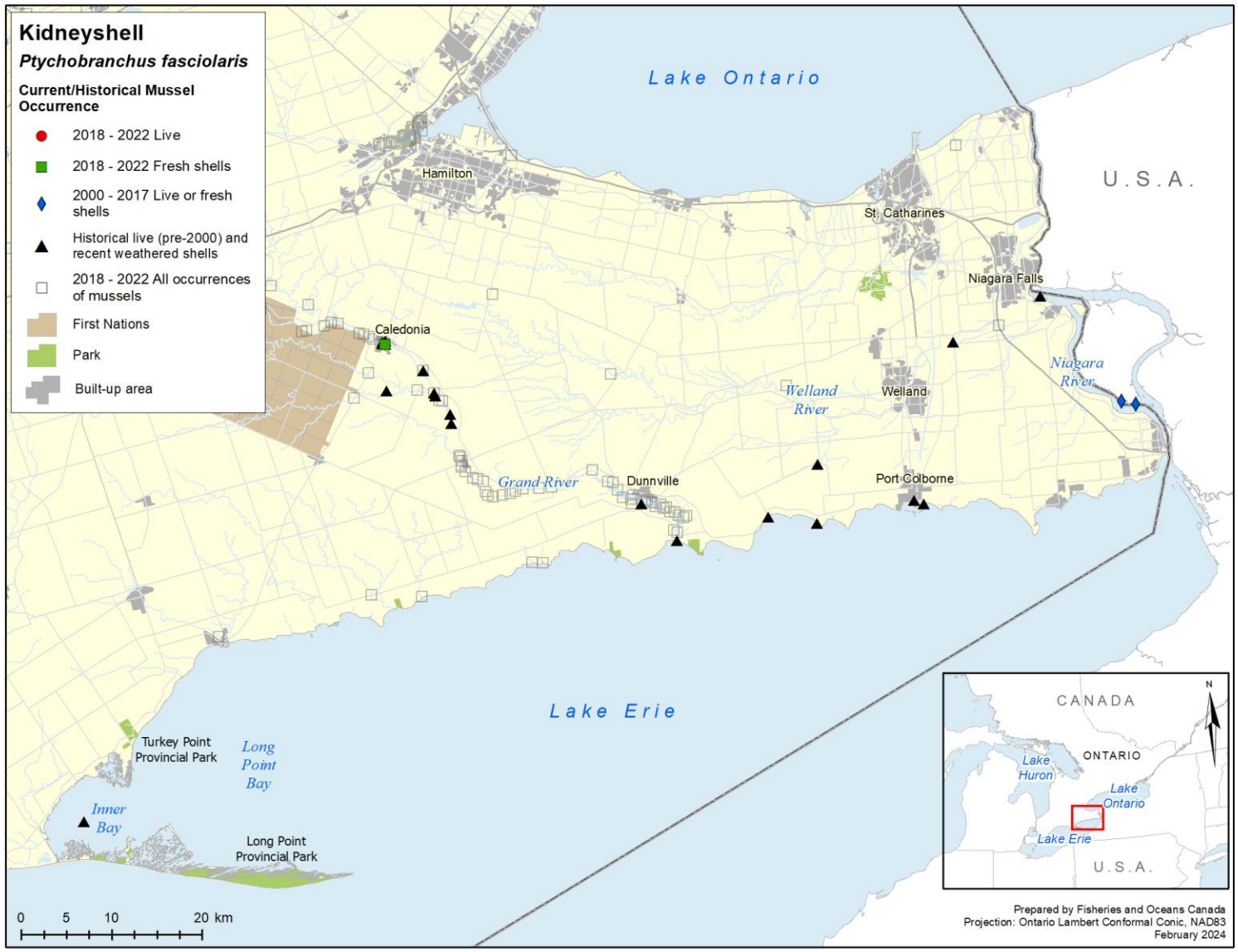

Figure 3. Historical detections, recent weathered shells and relevant sampling of Kidneyshell in eastern Lake Erie tributaries. Empty squares depict all sites where mussels were found from 2018 to 2022, including incidental catches.

2.3 Recovery

This section summarizes the information found in the recovery strategy on the population and distribution objectives that are necessary for the recovery of the Round Hickorynut and Kidneyshell, and on the performance indicators that provide a way to define and measure progress towards achieving the population and distribution objectives.

Section II.2 of the recovery strategy identified the following population and distribution objectives, and short-term (5 year) recovery objectives that are necessary for the recovery of the species. The population and distribution objectives are to return/maintain self-sustaining populations in the following locations:

1. St. Clair River delta and East Sydenham River (Round Hickorynut and Kidneyshell)
2. Ausable River and Thames River, including Medway Creek (Kidneyshell)

The recovery strategy did not include performance indicators; however, short-term recovery objectives towards achieving the population and distribution objectives were included:

i. determine extent, abundance, and population demographics of existing populations
ii. determine host fishes and their distributions and abundances
iii. define key habitat requirements to identify critical habitat
iv. establish a long-term monitoring program for Round Hickorynut and Kidneyshell populations, their hosts, and the habitat of both
v. identify threats, evaluate their relative importance, and implement remedial actions to minimize their impacts
vi. examine the feasibility of relocations, reintroductions, and the establishment of managed refuge sites
vii. increase awareness about the distribution, threats, and recovery of these species

The progress towards achieving population and distribution objectives will be informed by fulfillment of the short-term recovery objectives.

3 Progress towards recovery

The recovery strategy for the Round Hickorynut and Kidneyshell (DFO 2013) divides the recovery effort into 4 broad strategies: 1) research and monitoring, 2) management, 3) stewardship, and 4) awareness. Progress in carrying out these broad strategies is reported in section 3.1. Section 3.2 reports on the activities identified in the schedule of studies to identify critical habitat. Section 3.3 reports on the progress in meeting the recovery objectives and other commitments (for example, action plan and critical habitat order) identified in the recovery strategy and information obtained through implementing the recovery strategy.

3.1 Activities supporting recovery

Table 1 provides information on the implementation of activities undertaken to address the approaches and broad strategies identified in the recovery planning table of the recovery strategy.

Table 1. Details of activities supporting the recovery of the Round Hickorynut (RH) and Kidneyshell (KS) from 2018 to 2023.

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3] [4]
Research reproduction: Identify spawning periods of RH and KS. Determine length of encystment period on host in nature.	Research and monitoring	Smodis (2022) found allochrony[5] of peak glochidia[6] abundances among unionid species in the Sydenham River. Kidneyshell glochidia were found in higher abundance during nocturnal and crepuscular activity periods. Additionally, peak glochidia abundance coincided with the reported diel[7] activity pattern of host fish. No research has been conducted during the reporting period regarding the life history of Round Hickorynut.	i, iii	Component of fish host declines	**DFO**, **AI**
Research host fishes: Confirm the host fish species for the RH and KS.	Research and monitoring	Shepard et al. (2021)[8] examined host fish associations and the life history of the RH in 2 United States (U.S.) river drainages (Kentucky). Their results suggest that Eastern Sand Darters (*Ammocrypta pellucida*) are primary hosts for RH, but that observed differences in host use may indicate phylogenetic divergence between the populations.	ii, v	Host fishes declines	**U.S. government departments**

[3] Participant full names: Academic Institutions (AI), Conservation Authorities (CAs), which include the Ausable Bayfield (ABCA), Grand River (GRCA), Lower Thames Valley (LTVCA), St. Clair Region (SCRCA), and Upper Thames Region (UTRCA) conservation authorities, Environment and Climate Change Canada (ECCC), Environmental Non-Governmental Organizations (ENGO), Fisheries and Oceans Canada (DFO), Ontario Ministry of the Environment, Conservation and Parks (OMECP), Ontario Ministry of Natural Resources (OMNR), Ontario Soil and Crop Improvement Association (OSCIA), U.S. Geological Survey (USGS), and Walpole Island First Nation (WIFN).
[4] Lead participant(s) is/are listed on top and in bold; other participants are listed alphabetically. Not all activities have specific participants identified.
[5] Differences in timing of glochidia release by mussel species.
[6] Parasitic larvae form of mussels.
[7] 24 hour cyclic pattern, including daytime, nighttime and twilight periods (dawn and dusk).
[8] The activity described was not conducted specifically to address measures prescribed in the recovery strategy. This activity was conducted for other species and/or by other organizations. It was included in this report because it is relevant to the recovery objectives of RH and KS.

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3 4]
		Furthermore, they contend that their findings support categorizing RH as a periodic life-history strategist. No work has been conducted for KS in the last 5 years; however, earlier work described in the last progress report (DFO 2022) identifies several potential host fishes.			
Surveys host fishes: Determine the distribution, abundance, and health of the host species at sites where RH and KS currently occur.	Research and monitoring	Fish community assessments continue to be undertaken at unionid index stations (that is, the Ausable and Sydenham rivers), which provide insight on the availability of RH and KS host fishes. In addition, DFO and OMNR fish sampling was conducted in a number of other areas within the historical range of the RH and KS (for example, Thames River, Detroit River, Grand River, coastal Lake Erie) using a variety of gear types such as electrofishers, and seine and fyke nets. Conservation Authorities (for example, ABCA, LTVCA, SCRCA) continue to undertake fish sampling in projects unrelated to mussel research within sites that are relevant to RH and KS. Information collected from these surveys is important in determining if host fish availability limits reestablishment potential at these locations.	ii, v	Host fishes declines	**DFO**, **CAs**, **OMNR**
Research critical habitat: Determine the habitat requirements for all life-stages, particularly for juveniles.	Research and monitoring	Water quality parameters and other habitat characteristics continue to be recorded during unionid surveys (for example, Goguen et al. 2022). Ultimately, this information will improve understanding of unionid environmental requirements, and aid in refining critical habitat determination for RH and KS. Daniel et al. (2018)[9] investigated habitat suitability for 11 unionids, including KS. KS was negatively associated with high intensity urban land use, and stream discharge. Laboratory experiments conducted on 3 coexisting unionids (including KS) collected from the Sydenham River indicate resource partitioning is occurring based on	iii	Knowledge gaps	**AI**, **DFO**, OMNR, OMECP

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3] [4]
		feeding differences observed between the species (Tran and Ackerman 2019). Lum (2020) found juvenile unionids were less widely dispersed in the Sydenham River compared to adults. Juveniles appeared to be more influenced by shear stress, suggesting this stage may be particularly sensitive to alterations that impact hydraulic forces. Eveleens et al. (2023) surveyed portions of the Sydenham River with the goal of ascertaining possible associations between unionids and benthic macroinvertebrates. Positive associations were found between KS and the presence of Ephemeroptera (Families: *Isonychiidae*, *Leptophlebiidae, Leptohyphidae*), Coleoptera (Family: *Psephenidae*), Diptera (Families: *Empididae, Simuliidae*), Megaloptera (Family: *Corydalidae*), and Trombidiformes (Family: *Hydrachnidia*), while a negative association with Hemiptera (Family: *Corixidae*), and Mollusca (Family: *Physidae*) was recorded. Consequently, the relationship between unionids and benthic macroinvertebrates may aid in the identification of suitable unionid habitat. Moore et al. (2021)[9] classified unionids (including RH and KS) based on generic life-history traits (that is, equilibrium, opportunistic, and periodic), which will aid in the identification of representative species for risk assessment, and on determining relative threats to the species. Lu (2023) examined the effectiveness of riparian buffer at conserving mussel habitats. Intact buffer sites had fewer fine sediments, higher hydraulic conductivity and higher habitat quality (lower ammonia, higher dissolved oxygen, more diatoms and chlorophytes). The study indicates that riparian buffers can be effective at maintaining mussel			

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3] [4]
		habitats, contingent on the fact that they are large enough to prevent excess fine sediment. Conclusions on juvenile mussel habitat could not be drawn due to low observations. Furthermore, research on contaminants and turbidity (see below) continues to shed light on unionid susceptibility to deleterious water quality conditions.			
Research and surveys critical habitat: Prepare a distribution map of areas of suitable habitat (currently occupied and unoccupied).	Research and monitoring	No further investigations have occurred.	iii, vi	All threats	
Research managed refuge sites: Investigate the feasibility of establishing actively managed refuge sites in the St. Clair River delta.	Research and monitoring	No further investigations have occurred.	vi	Invasive species	
Monitoring mussel and fish host populations: Continue to monitor the current stations and establish a network of	Research and monitoring	**Current locations:** **Index Stations:** Monitoring stations relevant to the RH and KS have been established within Lake St. Clair (St. Clair River delta), and the Ausable, Sydenham, and Thames rivers. Sampling is conducted over time to track changes in the abundance of unionids, measure environmental variables, and undertake fish community assessments that provide information regarding the	i, iv	Host fishes declines	**DFO**, **CAs, OMNR**, AI, OMECP WIFN

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3] [4]
permanent monitoring stations throughout the distributions of the RH and KS.		availability of host fishes. In 2018, 4 additional sites were added to the pre-existing 12 index stations throughout the Thames River (see Sheldon et al. 2020). **Ausable River:** Quadrat surveys conducted by the ABCA in 2018 and 2019, uncovered KS at 5 separate index stations (number of KS found per station: 212, 23, 17, 13, and 1) within the Ausable River system. As a part of a genetic study, 12 KS were uncovered at 1 station within the Ausable River in 2019 (VanTassel et al. 2021). **Sydenham River (east branch):** Results of surveys that occurred in 2015 and 2017 (and mentioned in the previous progress report) in the Sydenham River have recently been published (Wright et al. 2020; Goguen et al. 2022). In 2022, 58 KS were detected through qualitative surveys at 4 locations, while additional quadrat surveys conducted by DFO yielded 218 specimens at 4 sites. Furthermore, projects that occur outside the purview of routine index station monitoring sometimes detect RH and KS. In the course of operating DFO's unionid identification workshops, RH and KS are occasionally detected, for example: 50 KS and 1 RH were found in 2018 at 1 index station. DFO personnel conducted timed-search surveys targeting the Salamander Mussel (*Simpsonaias ambigua*) in the Sydenham River in 2018 and 2019. These surveys led to the detection of 2 KS at 2 sites in 2018, while 4 sites yielded 1 KS each in 2019. Surveys were conducted by University of Guelph personnel at 1 Sydenham River index station. They uncovered 4 KS in both 2018 and 2019. In 2020 and 2021, the SCRCA completed quadrat and timed-search surveys in the Sydenham River. In 2020, 8			

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3] [4]
		sites were surveyed, resulting in 12 KS found during timed-search surveys, while 13 KS were found during quadrat surveys (Paterson 2020). Additionally, 44 KS were found at 5 sites during timed-search surveys, while 4 of these sites yielded 19 KS during quadrat surveys in 2021 (Snetsinger 2021). The surveys were conducted by the SCRCA to fulfill recovery measures of the Sydenham River action plan. In 2020, 2 sites in the Sydenham River yielded 16 KS during timed-search and quadrat sampling conducted by the University of Windsor to evaluate species at risk mussel habitat restoration (Eveleens 2021). In 2022, 1 site yielded 5 KS during quadrat sampling for a Masters thesis studying the harmonization of datasets among and within organizations to advance the conservation of species at risk mussels and accelerate on the ground restoration efforts (Willsie 2023). **Brail Sampling:** Brail sampling was piloted in 2019 by OMNR and DFO in the Grand River; however, no RH or KS were found among the 48 sites. In 2022, a mussel brail was used by OMNR to survey deeper, non-wadable habitats in the Ausable, Sydenham, and Thames rivers with 23, 37, and 34 sites sampled, respectively (LeBaron et al. 2023). This led to the capture of 1 live KS in the East Sydenham River; no RH were detected. **Historical locations:** In 2018, SCRCA discovered 1 weathered KS valve in Bear Creek, which is the first record of KS in the North Sydenham watershed. A 2019 unionid survey of the Detroit River failed to detect live RH or KS, although weathered shells of both species were found (Keretz et al. 2021). No evidence of the presence of RH was detected in			

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3 4]
		the Grand River; however, 1 fresh KS valve and 2 weathered KS shells were found during a 2020 mussel relocation. A 2021 unionid survey of the Grand and Thames rivers uncovered shells/valves of both RH and KS in the Thames River (Goguen et al. 2023). In 2021, a unionid survey of the St. Clair River and delta failed to detect live RH or KS; however, on the U.S. side of the river, weathered shells of KS were detected at 1 historical site and 2 sites more than 12 km upstream. Sampling in 2022 discovered 1 weathered valve in the Thames River. A single site in Medway Creek (Thames River tributary) was surveyed but no KS were detected. **Sampling Techniques:** Unionid sampling techniques, including eDNA, continue to be tested and refined and may be a consideration for establishment of permanent monitoring sites (Reid et al. 2018; Klymus et al. 2020[9]; Coghlan et al. 2021; Marshall et al. 2022[9]; Dokai et al. 2023[9]). Additionally, the Government of Ontario published a survey protocol for sampling unionids in Ontario wetlands (OMNR 2018).			
Monitoring habitat: Establish permanent monitoring sites for tracking changes in habitat.	Research and monitoring	Habitat monitoring is performed in conjunction with routine index station monitoring within Lake St. Clair (St. Clair River delta), and the Ausable, Sydenham, and Thames rivers. Quantitative mussel sampling conducted at these locations is paired with assessments of habitat conditions, including water velocity, depth, degree of siltation, aquatic macrophyte presence/absence, algal growth, degree of shading, and streambed/substrate composition. Furthermore, the Provincial Water Quality Monitoring Network (PWQMN) measures water quality in rivers and streams across Ontario (PWQMN 2023). Parameters measured include total and dissolved nutrients, metals, conductivity, turbidity, and chloride. Stations exist within	iv, v	All threats	**DFO**, **CAs**, **OMNR,** AI, Cramer Fish Sciences, OMECP, Stantec Consulting Ltd., USFWS, USGS

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3] [4]
		the distribution of the RH and KS in the Ausable, Sydenham, and Thames rivers.			
Research threats: Identify and evaluate threats to all life-stages (including toxic contaminants).	Research and monitoring	The Canadian Freshwater Species at Risk Research Network (SARNET) was formed in 2017 to deliver and inform research programs aimed at addressing research gaps for a variety of aquatic species at risk (see Castañeda et al. 2021). DFO provided financial support to SARNET from 2017 to 2019. This collaborative government–academic research network advanced scientific research in the support of recovery of RH and KS, among other species. **Invasive species:** The consumption of unionids by Round Goby was documented in the French Creek watershed, Pennsylvania (Bradshaw-Wilson et al. 2019[9]; Clark et al. 2022[9]). However, despite being present in the watershed, KS were not found in the stomach contents when DNA barcoding was used (Clark et al. 2022)[9]. KS may still be consumed by Round Goby during the juvenile phase. McAllister et al. (2022) suggests that Round Goby has negatively affected the relative abundance of several darter species, including Blackside Darter (*Percina maculata*) a putative host fish for KS, in the Ausable River. The findings show that Round Goby relative abundance is highest near the Great Lakes but sharply decreases further upstream. In the Ausable River, it appears that Round Goby and KS distributions do not currently overlap, as KS is found further upstream in the Middle and Upper Ausable. Alternatively, Round Goby, KS and RH distribution overlaps in the Sydenham and Thames rivers. DFO conducted targeted surveys for Northern Madtom (*Noturus stigmosus*) in the East Sydenham River between Dresden and Dawn Mills in 2019 and found that Round Goby were the most frequently occurring species (97% of	v	All threats	**DFO**, **AI**, **CAs**, **ECCC**, OMNR

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3] [4]
		sites) and was among the most abundant species captured (Barnucz and Drake 2021). Lamothe et al. (2020) described sampling of benthic fishes in the lower Thames River in 2012, 2013, 2015, and 2016, using Missouri and Siamese trawls. Round Goby was detected at 35% of sites in the Thames River with a probability of detection of 0.833 (Lamothe et al. 2020). **Habitat alteration:** Hornbach et al. (2019)[9] investigated potential impacts of agricultural land use on unionids in the Minnesota River basin. A negative relationship between agricultural land use and unionid diversity and abundance was detected. Furthermore, Hornbach et al. (2021)[9] measured growth and glycogen levels in unionids from 2 small river basins containing different levels of agricultural activity. Higher levels of agricultural land use appeared to have a negative effect on unionid abundance and diversity, but a positive effect on growth and glycogen levels was also detected. Goldsmith et al. (2020)[9] conducted a literature review summarizing sediment-based impacts on unionids, including sediment thresholds which caused significant declines in population performance. Luck and Ackerman (2022) used a multi-stressor approach to investigate how changes in turbidity, water temperature, and velocity affect clearance rates and oxygen consumption rates in the Fatmucket (*Lampsilis siliquoidea*). Although their results demonstrated a complex interaction of measured factors, temperature appeared to play a particularly significant role in defining feeding success, which may have significance in relation to projected climate change scenarios. **Contaminants:** Research on the effect of granular Bayluscide, which is applied for control of invasive Sea			

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3] [4]
		Lamprey (*Petromyzon marinus*), on freshwater mussels has been initiated. In a laboratory setting, KS experienced approximately 54% mortality when individuals were exposed to 3.2% granular Bayluscide for 8 hours; however, the spatial overlap of KS with application sites is currently thought to be low (Newton et al. 2017; Andrews et al. 2021). Using a simulation model, Smyth and Drake (2021) found that there was a relatively high median mortality risk for KS, and 5% of the time the mortality risk was extremely high in the Sydenham River. In addition to grappling with causes of enigmatic[9] unionid declines, Haag (2019)[9] focused on specific concerns, such as contaminants. Although RH and KS have not been specifically evaluated, recent evidence suggests that chemical contaminants (derived from agricultural and road run-off, municipal wastewater, firefighting water additives, and industrial effluents) are negatively affecting unionid mussels (Archambault et al. 2018; Jorge et al. 2018; Graetz 2019; Haag et al. 2019; André and Gagné 2020; Salerno et al. 2020; Woolnough et al. 2020; Kleinert et al. 2021; Hayward et al. 2022; Millar et al. 2022; Rzodkiewicz et al. 2022; Roznere et al. 2023). Potential consequences of road salt applications to unionids continue to be investigated (Wang et al. 2018a[9], 2018b[9]; Gillis et al. 2021a, 2021b; Burton et al. 2023). Additionally, Gillis et al. (2021a) measured the toxicity of de-icing products to Wavyrayed Lampmussel (*L. fasciola*) glochidia, and found that the beet juice-based products currently in use may pose more of a threat to early life stage unionids than traditional products (for example, road salt).			

[9] No clear causes and other components of the aquatic communities appear unaffected.

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3] [4]
		Bringolf et al. (2022)[9] investigated the relative risks of major ions, which may result from activities including oil and gas extraction, mineral mining, irrigation, industrial effluents, and road de-icing, to freshwater mussels to inform water quality guidelines in both the U.S. and Canada. The findings were consistent with previous research that revealed that glochidia are sensitive to these major ions. Bringolf et al. (2022)[9] also examined the relationship between water hardness and chloride toxicity and found that toxicity generally decreased as water hardness increased. Another potential threat to freshwater mussels is microplastics, although little research has been conducted to determine the extent to which they might impact freshwater mussels. Microplastics have been confirmed in Flutedshell (*Lasmigona costata*) in the Grand River (Wardlaw and Prosser 2020). In addition, a study in the Grand River is underway examining microplastics in caged and wild-caught mussels downstream of wastewater treatment plants, which aims to provide insight to how wastewater treatment plants act as a source of microplastics and bioaccumulation of microplastics in mussels (Robson 2023). **Climate change and severe weather:** Fogelman et al. (2023)[9] conducted a review of lethal thermal tolerances for freshwater mussels within North America. Although the lethal thermal tolerances for RH and KS remain unknown, Fogelman et al. (2023)[9] found an overall grand mean lethal thermal tolerance of 34.6°C for acute exposures and 32.0°C for medium-chronic exposures across all species tested. In general, glochidia had a lower lethal thermal tolerance than juveniles or adults of the same species.			

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3] [4]
Research conservation genetics: Compare the within and among population genetic variability of Canadian populations and determine if populations show genetic structure by comparing variability between populations in Canadian and U.S. waterways.	Research and monitoring	VanTassel et al. (2021) compared genetic variation of wild versus captive-propagated unionids, including KS. For KS, genetic differences between wild and captive-reared specimens were not detected, suggesting that captive reared specimens could be a viable option for reintroductions. No investigations into the population structure of RH have been undertaken at this time.	vi	Knowledge gaps	**AI**, DFO, OMNR, USGS
Capacity building: Continue to promote and enhance expertise in freshwater mussel identification/ biology and provide for the transfer of knowledge.	Management	During the time period of this report, the Fish Culture Section of OMNR has developed expertise in unionid culture, including the propagation and rearing of KS (Loftus and Wilson 2018; Wilson et al. 2021). Furthermore, a protocol is being finalized for mussel propagation, rearing techniques, and broodstock development (Wilson pers. comm. 2023). Captive rearing may be useful to provide specimens for research needs considering wild-caught individuals of listed species such as KS are endangered. DFO, in partnership with SCRCA, has continued to conduct a hands-on freshwater mussel identification course that is offered to government, non-government organizations, Indigenous peoples, and the general public. Similarly, the LTVCA has coordinated (with training provided by DFO) freshwater mussel identification workshops, which were designed to encourage the	i-vi	All threats	**DFO, OMNR, CAs**, Toronto Zoo

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3] [4]
		participation of Indigenous communities. In 2020, DFO staff provided unionid identification training to Conservation and Protection fishery officers. Additionally, the Clam Counter app (Toronto Zoo) continues to be promoted and refined.			
Cooperation ecosystem recovery strategies: Work with existing ecosystem recovery teams to implement recovery actions.	Management	DFO continues to partner with CAs and stakeholders, principally through the Habitat Stewardship Program (HSP). The Action Plan for the Ausable River in Canada: An Ecosystem Approach (DFO 2018a) has a focus on KS, while the Action Plan for the Sydenham River in Canada: An Ecosystem Approach (DFO 2018b) contains measures to support the recovery of RH and KS. To oversee the implementation of these action plans, the Ausable River and Sydenham River recovery teams were formed, and are made up of DFO, CAs, provincial departments, and academic partners.	v, vi	All threats	**DFO**, **CAs**, AI, OMECP, OMNR
Municipal planning: Encourage municipal planning authorities to consider critical habitat in official plans.	Management	Municipal public works and planning departments have been included in aquatic species at risk outreach activities conducted by DFO. For example, DFO has provided a review of new species at risk Critical Habitat Orders, and a refresher on DFO's integrated project review process. Additionally, DFO has developed and distributed aquatic species at risk official plan guidance for municipalities (that is, Regional Planning Commissioners of Ontario) to incorporate into municipal official plan updates.	v	Urbanization, water quality, water quantity, impoundments	**DFO**
Reduction of chloride loading: Encourage municipalities to adapt Best Management Practices (BMPs)	Management	The Government of Canada developed the Code of Practice for the Environmental Management of Road Salts in 2004. The code assists municipal and provincial road organizations to reduce harm to the environment. Elgin County developed a salt management plan in 2020, which includes actions to protect salt-vulnerable areas.	v	Water quality	**ECCC**, **DFO**, **CAs**

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3] [4]
to reduce the use of road salt.					
Drainage: Work with drainage supervisors, engineers, and contractors to limit the effects of drainage activities on mussel habitat.	Management	DFO provides species at risk-specific guidance regarding proposed drainage activities on an ongoing basis. Furthermore, DFO has delivered presentations to drainage supervisors and engineers that identify issues and threats to species at risk, including the RH and KS, which may arise as a result of drainage activities such as cleanouts. Mitigation measures and BMPs are communicated through these presentations.	v	Water quality, siltation, water quantity	**DFO**
Baitfish: Work with the baitfish industry to reduce the impacts of commercial baitfishing on host species. Update baitfish guide to include information on the mussel lifecycle and note potential host fishes and time frames when encystment is likely to occur.	Management	The Government of Ontario developed the Ontario's Sustainable Bait Management Strategy, 2020, which describes a new approach in managing baitfish and leeches so the ecological risks associated with the use and movement of bait are reduced. Commercial bait harvesters and dealers will be required to take a standardized training course designed to increase harvester and dealer awareness of non-target species, including invasive species and species at risk, and to identify actions to prevent their spread. DFO updated the baitfish primer in 2018 to include links to the national aquatic species at risk maps for areas to avoid during baitfish collection. Information was added on the mussel life cycle and the connection of potential mussel population declines if large numbers of baitfish are removed. In addition, an app called Baitfish Primer was created and is available for free download from the Apple App Store and the Google Play Store.	v	Host fishes declines	**OMNR**, **DFO**
Wastewater treatment plants and stormwater management facilities: Verify	Management	No progress has been made regarding this measure.	v	Water quality, water quantity, impoundments	

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3] [4]
that wastewater treatment plants are functioning up to specifications and encourage upgrading where appropriate. Review stormwater management facilities for quantity and quality control in new developments, and retro-fit existing development where possible.					
Riparian buffers: Establish riparian buffer zones in areas of high erosion potential by encouraging naturalization or planting of native species.	Stewardship	Federal funding is available annually through the Aboriginal Fund for Species at Risk (AFSAR) and the Habitat Stewardship Program (HSP). HSP funding is provided by DFO[10] to fund projects submitted by Canadians that contribute directly to the recovery of species at risk, while AFSAR funding supports the development of Indigenous capacity to participate actively in the implementation of SARA. Starting in 2018, the Canada Nature Fund for Aquatic Species at Risk (CNFASAR) was initiated, with the aim of supporting the recovery and protection of aquatic species at risk. Similarly, the OMECP administers the Species at Risk Stewardship Program (SARSP)[11], which provides money	v	Water quality, siltation, water quantity	**DFO**, **CAs**, **OMECP**, ENGO

[10] HSP funding was provided by DFO through ECCC in 2018.
[11] Formerly known as Species at Risk Stewardship Fund (SARSF) and administered by OMNR.

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3] [4]
		for stewardship activities similar to what is described for HSP-funded projects. Collectively, funded activities facilitate the implementation of conservation measures, such as BMPs associated with water quality improvements, and sediment loading and reduction (for example, planting of riparian buffers). Many important stewardship projects that established riparian areas benefitting RH and KS have been undertaken through these various federal and provincial funding programs. The ABCA has implemented elements of the Ausable River Recovery Strategy through the Ausable River Action Plan Implementation. Habitat improvement projects were completed in partnership with landowners that included riparian and wetland buffers of native trees and shrubs (over 37 ha) to reduce the impacts of erosion and improve water quality; retiring floodplains from agriculture (over 5 ha); the re-establishment of wetlands (over 5 ha) to help reduce inputs of sediment and nutrients; and the installations of water and sediment control basins (WASCoBs) to manage rural storm water by reducing erosion and excess sediments and nutrients from entering the Ausable River watershed. SCRCA worked with landowners on habitat stewardship projects aimed at assisting in improving aquatic and riparian habitat within the Sydenham River and its tributary watersheds. Projects have included: planting of riparian buffers (over 70 ha) to control erosion and overland flows; and wetland habitat enhancement and restoration (over 9 ha). Combined, these projects are expected to aid in reducing sediment and nutrients from entering the Sydenham River watershed. The UTRCA has worked directly with landowners to implement soil and water conservation practices to reduce			

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3] [4]
		nutrient and sediment loads to the North and Middle Thames watersheds. Stewardship projects have included the creation of wetlands (0.2 ha) and retirement of highly erodible lands (over 20 ha). The LTVCA has started a project to restore riparian buffers within the Thames River watershed. Multiple restoration initiatives (for example, tree/shrub and prairie riparian buffers, and wetland projects) have been completed. Similar restoration initiatives, such as the construction of riparian prairie buffers, have been accomplished by the LTVCA. GRCA has created or expanded riparian buffers and installed WASoBs to reduce erosion and excess sediments and nutrients from entering the Grand River watershed.			
Tile drainage: Work with landowners to mitigate the effects of tile drainage. **Herd management:** Encourage the active exclusion of animals from the watercourse. **Livestock waste management:** Assist with establishing adequate manure collection and	Stewardship	Work continues with landowners to develop agricultural BMPs, which include Environmental Farm Plans and Nutrient Management Plans, and considerations of tile drainage. Ontario Nature removed drainage tiles from a former agricultural field that were causing erosion, created vernal pools and constructed berms adjacent to the river to slow water flow and reduce the amount of sediment loading into the Sydenham River. This project is part of the Sydenham River Nature Reserve and also included planting the former agricultural field. SCRCA worked with farmers to implement 731 m of livestock exclusion fencing and 1 watercourse crossing, which is expected to help reduce erosion and nutrient loading, and eliminate direct physical harm to RH and KS in the Sydenham River and associated wetlands.	v	Water quality, siltation	**CAs**, **OSCIA**, DFO, OMECP

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3] [4]
storage systems to avoid accidental spills, and winter-spreading of manure. **Farm planning:** Encourage the development and implementation of Environmental Farm Plans and Nutrient Management Plans.		The Species at Risk Farm Incentive Program (SARFIP), through the Ontario Soil and Crop Improvement Association (OSCIA), continues to provide funding to agricultural landowners to support species at risk through stewardship activities and BMPs.			
Sewage treatment: Work with landowners to improve faulty septic systems.	Stewardship	No progress has been made regarding this measure.	v	Water quality	
Soil testing: Encourage soil testing to determine fertilizer application rates.	Stewardship	No progress has been made regarding this measure.	v	Water quality	
Awareness–stewardship actions: Increase public knowledge of stewardship options and financial assistance available to	Awareness	The aforementioned HSP, CNFASAR, and AFSAR programs are key sources of funding that DFO makes available for stewardship projects targeting recovery of species at risk, including the RH and KS. Annually, DFO promotes these funding opportunities to applicable CAs, Indigenous peoples, and other key stakeholders. Through partnerships with watershed-based conservation organizations (for example, CAs), DFO staff have promoted the implementation of BMPs via presentations, project reviews, and site meetings with the agricultural	vii	Water quality, siltation, water quantity	**DFO**, **CAs,** MECP

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3] [4]
participate in activities.		community, drainage engineers, and the Ontario Drainage Superintendents Association. With the aid of HSP and CNFASAR, ABCA has increased public knowledge of stewardship options and financial assistance available to participate in stewardship activities. For example, the ABCA distributed stewardship postcards as a way of engaging landowners, and to inform them of CNFASAR opportunities. Similarly, the LTVCA and SCRCA have provided landowners with information on funding programs that focus on stewardship projects designed to benefit species at risk. With the aid of HSP and SARSP-funded education and outreach programs, the SCRCA has noted an increase in the number of word-of-mouth inquiries from landowners interested in implementing stewardship projects on their property. SCRCA staff attended OSCIA meetings and other related community and agricultural events to raise awareness about stewardship funding available for BMPs.			
Invasive species: Increase public awareness of the potential impacts of transporting/ releasing invasive species.	Awareness	DFO continues to disseminate educational materials (public postings and direct engagement) focused on aquatic invasive species. Additionally, the Government of Ontario has developed invasive species action plans, including a boater's action plan designed to help stop the spread of invasive species in Ontario, and best management practices for watercraft users. Through HSP-funded projects, CAs continue to focus outreach activities on public education and awareness of aquatic invasive species. Briefly, examples include: • through their Great Lakes Program, the Toronto Zoo developed and delivered invasive species outreach presentations at the request of teachers, and opened an exhibit at the Toronto Zoo on Asian Carp	vii	Invasive species	**DFO**, **CAs**, **OMNR**, Toronto Zoo

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3] [4]
		• LTVCA has used social media posts to increase public awareness of aquatic invasive species			
Outreach: Encourage public support and participation by developing awareness materials and programs.	Awareness	Ongoing DFO outreach to Indigenous communities, key stakeholders, and the Canadian public includes information on aquatic species at risk (including RH and KS), helping raise awareness of their status and need for conservation. DFO has delivered presentations that highlight locations of critical habitat and ways to reduce threats to aquatic species at risk. Presentations have been given to environmental students at Fleming College; the Ontario Aboriginal Lands Association (OALA) and the Ontario First Nations Economic Development Association (OFNEDA); the Latornell Conservation Symposium; partner agencies; and members of the Ontario Land Trust Alliance. Additionally, awareness of species at risk has been communicated to the general public and school children by DFO staff at the Canada Centre for Inland Waters open house events in 2018 and 2019 and Take Our Kids to Work Day in 2019. DFO, in conjunction with CAs, have contacted representatives from municipalities, consultants, and contractors to present information related to aquatic species at risk listing changes, funding opportunities, and highlighted CA stewardship projects. Furthermore, with the aid of HSP and SARSP funding, CAs continue their own outreach activities (for example, the ABCA conducts community information sessions and student programs to educate and increase the profile of species at risk in the Ausable River watershed). The SCRCA has continued its education and outreach efforts aimed at assisting with the recovery of a broad range of aquatic species at risk in the Sydenham River through school programs, landowner contact, and direct promotion. The SCRCA continues to produce and	vii	All threats	**DFO**, **CAs**, OMECP, Toronto Zoo

Activity	Broad strategy and approach	Descriptions and results	Recovery objectives	Threats or concerns addressed	Participants [3] [4]
		distribute an annual species at risk newsletter, use social media, and organize workshops and outreach events, all to generate awareness regarding species at risk in the Sydenham River. Additionally, the SCRCA created the Sydenham River watershed website, which was updated in 2021 with species-specific pages for all the species at risk in the Sydenham River watershed, including RH and KS. The LTVCA continues to increase public awareness of species at risk, including RH and KS. They have accomplished this through public meetings and presentations, social media engagement, and the distribution of flyers. Additionally, the LTVCA produced an Aquatic Species at Risk Threat Assessment report that summarizes environmental conditions and threats at the sub-watershed level. LTVCA staff participated in consultation meetings to assist the Chippewas of the Thames First Nation in developing an agricultural management plan. With the aid of HSP funding, the Toronto Zoo's Great Lakes Program continues to offer a curriculum-based education program emphasizing aquatic species at risk and invasive species. Additionally, outreach programs are contributing to stewardship projects, including shoreline clean-ups and tree plantings. Communications and outreach programs continue to be offered through the SARFIP, which helps raise the profile of species at risk on, and near, agricultural lands, and to educate farmers about stewardship activities designed to enhance biodiversity.			

3.2 Activities supporting the identification of critical habitat

Table 2 provides information on the implementation of the studies outlined in the schedule of studies to identify critical habitat found in the recovery strategy. Each study has been assigned 1 of 4 statuses:

1) completed: the study has been carried out and is concluded
2) in progress: the planned study is underway and has not concluded
3) not started: the study has been planned but has yet to start
4) cancelled: the planned study will not be started or completed

Table 2. Status and details of the implementation of the schedule of studies outlined in the recovery strategy for the Round Hickorynut and Kidneyshell.

Study	Timeline	Status	Descriptions and results	Participants [12]
Assess timeframes (sperm and ova production/release, timing of fertilization, timing and duration of gravid periods, timing and duration of glochidial release, attachment and transformation) and habitat required for spawning.	Ongoing	In progress	Research has been conducted that has improved understanding of the timing of glochidia release in the Sydenham River; and how the timing may relate to host fish activity, which suggests host partitioning (Smodis 2022).	**AI**, DFO
Conduct mussel population surveys.	Ongoing	In progress	Monitoring surveys have been conducted within occupied/recently occupied locations including the Thames (Kidneyshell), Sydenham (both species), and Ausable rivers (Kidneyshell). Quantitative survey methods were employed at these locations that allow for inferences of species abundance, which in turn inform population trajectory estimates.	**DFO**, **CAs**, OMNR
Assess and map habitat conditions in occupied areas (for example, flow, substrate, water clarity and quality).	Ongoing	In progress	Habitat within the distribution of the Round Hickorynut and Kidneyshell has yet to be mapped. Nonetheless, important habitat characteristics continue to be catalogued for future mapping exercises.	**DFO**, CAs

[12] Lead participant(s) is/are listed on top and in bold; other participants are listed alphabetically. Not all activities have specific participants identified.

Study	Timeline	Status	Descriptions and results	Participants [12]
Determine any life-stage differences in habitat use.	Ongoing	In progress	Lum (2020) found juvenile unionids less widely dispersed in the Sydenham River compared to adults. Juveniles appeared to be more influenced by shear stress, suggesting this stage may be particularly sensitive to alterations that impact hydraulic forces.	**DFO**, **AI**, CAs, OMNR
Determine/ confirm host fish species (laboratory and functional) and their distributions and home ranges.	Ongoing	In progress	Although a reasonable understanding of host fish associations with Round Hickorynut and Kidneyshell has been gained, investigations continue to refine and improve knowledge in this area (Shepard et al. 2021). The distribution and home range of the host fishes of Round Hickorynut and Kidneyshell have not been fully characterized or determined.	**DFO**, **AI**
Assess habitat use by host species.	Ongoing	In progress	Fish community assessments continue to be conducted at mussel monitoring stations to assess the presence and habitat use of host species. In addition, sampling for fish species, including habitat data, has been undertaken by DFO, OMNR, and CAs in a number of projects unrelated to mussel research, within sites that are relevant to Round Hickorynut and Kidneyshell (that is, Thames River).	**DFO**, CAs, OMNR,
Determine areas of overlap between mussel and host habitat.	Ongoing	In progress	Although surveys have not been carried out that directly target Round Hickorynut and Kidneyshell host fish habitat, fish surveys conducted at mussel monitoring stations and those unrelated to mussel research continue to shed light on the range of their host fishes.	**DFO**, **OMNR**
Based on collected information, review population and distribution goals. Determine amount and configuration of critical habitat required to achieve goal if adequate information exists.	Ongoing	Not started	As the known range of both species is unchanged, no critical habitat reassessment has occurred. Additionally, no new information has been acquired that would require changing current population and distribution objectives.	**DFO**

3.3 Summary of progress towards recovery

3.3.1 Status of recovery objectives

Table 3 provides a summary of the progress made towards meeting the recovery objectives outlined in section 2.3. Each indicator has been assigned 1 of 4 statuses:

1) not met: the recovery objective has not been met, and little to no progress has been made
2) partially met, underway: moderate to significant progress has been made towards meeting 1 or more elements of the recovery objective, and further work is ongoing or planned
3) met: the recovery objective has been met and no further action is required
4) met, ongoing: the recovery objective has been met, but efforts will continue as needed to achieve the objectives outlined in the species' recovery strategy

Table 3. Summary of progress made toward meeting the recovery objectives outlined in section 3 of the recovery strategy for the Round Hickorynut and Kidneyshell.

Performance indicator	Status	Details
Determine extent, abundance, and population demographics of existing populations.	Partially met, underway	Surveys, conducted over the past 5 years, have continued to provide valuable information concerning the abundance and range of the Round Hickorynut and Kidneyshell. Kidneyshell were predominantly detected in the Sydenham River and, to a lesser extent, the Ausable River. Round Hickorynut detections continue to be rare, as only 1 live specimen was found in the Sydenham River. Strengthening understanding of the status of Round Hickorynut and Kidneyshell populations is an ongoing process.
Determine host fishes and their distributions and abundances.	Partially met, underway	Potential host fish combinations for both Round Hickorynut and Kidneyshell continue to be explored, as does the strength of the association (Shepard et al. 2021). Fish community assessments continue to be undertaken at unionid index stations by DFO, and conservation authorities. Information collected from these surveys is important in determining if host fish availability is limiting Round Hickorynut and Kidneyshell recovery; however, the distribution and abundance of host fishes has not been fully characterized or determined.
Define key habitat requirements to identify critical habitat.	Partially met, underway	Research conducted in the Sydenham River (and with unionids collected from this system) has aided in furthering the understanding of unionid habitat requirements. For example, Tran and Ackerman (2019) found evidence of resource partitioning in 3 coexisting unionids (including Kidneyshell), while (Lum 2020) helped to define important habitat characteristics for juvenile unionids in the Sydenham River. Eveleens (2021) found positive and negative associations between Kidneyshell and certain benthic macroinvertebrates in the Sydenham River.
Establish a long-term monitoring program for	Met, ongoing	Unionid index monitoring stations have been established throughout the range of the Round Hickorynut and Kidneyshell, and continue to be expanded to include additional locations. Refinement of surveying

Performance indicator	Status	Details
Round Hickorynut and Kidneyshell populations, their hosts and the habitat of both.		programs is an ongoing process as new technologies (for example, eDNA), and current sampling regimes continue to be developed and appraised (for example, Reid et al. 2018).
Identify threats, evaluate their relative importance, and implement remedial actions to minimize their impacts.	Partially met, underway	Threat identification and understanding is a continual process important to the recovery of the Round Hickorynut and Kidneyshell. As well as improving the understanding of the impact of generalized land-use patterns (landscape scale), particularly in relation to agricultural activity (Hornbach et al. 2019, 2021) on unionids, a focus on individual contaminants continues. For example, an improved understanding of the implications of the application of road salt (in the Thames River system) and their alternatives to unionids has been gained (Gillis et al. 2021a, 2021b). These investigations continue to contribute in ways that enhance recovery actions, particularly in relation to stewardship projects in the road dense and agriculturally dominant surroundings of the Round Hickorynut and Kidneyshell. For example, many stewardship projects have focused on improving or creating riparian habitat in the vicinity of unionid habitat, projects that collectively are expected to improve water quality (for example, reduction in contaminants) and habitat (for example, through a reduction in sediment loading) for many aquatic species at risk.
Examine the feasibility of relocations, reintroductions, and the establishment of managed refuge sites.	Partially met, underway	Continued development of unionid rearing techniques and their genetic implications will improve the odds of successful relocation/reintroduction programs, should they be deemed necessary in the future. DFO has developed a decision support framework for the conservation translocation of SARA-listed freshwater fishes and mussels for the purpose of identifying and evaluating the potential benefits and risks of translocations, and identifying science-based considerations that should be used to evaluate if, and to what degree, translocations may improve the survival, recovery and management of a given species (Lamothe et al. 2023). DFO has been holding 2 common mussel species, Eastern Elliptio (*Elliptio complanata*) and Eastern Lampmussel (*Lampsilis radiata*), in a lab since 2022 at the Maurice Lamontagne Institute with the aim to develop a protocol for holding freshwater mussels in captivity, which would provide valuable information relevant to future translocations and reintroductions for species at risk (Savard et al. 2023). Donaldson et al. (2019) produced a systematic map protocol and Rytwinski et al. (2021) produced a systematic map to identify, collate, and describe the evidence that exists on the efficacy of captive breeding programs for imperilled freshwater fishes and mussels; specifically, examining their achievement of conservation of recovery objectives in the wild. The purpose of these studies was to inform conservation managers and policy makers of the existing information and to highlight key information gaps for captive breeding programs. No further understanding of the potential for managed refuge sites has been gained in the last 5 years.
Increase awareness about the distribution,	Met, ongoing	Outreach by DFO and conservation authorities has continued and is vital in increasing the public's understanding of unionids, and threats to their persistence. Increased public participation in recovery of

Performance indicator	Status	Details
threats and recovery of these species.		species at risk has resulted in important stewardship projects in the river basins surrounding Round Hickorynut and Kidneyshell habitat.

3.3.2 Completion of action plan

The "Action Plan for the Ausable River in Canada: An Ecosystem Approach" was published in 2018 (DFO 2018a), as was the "Action Plan for the Sydenham River in Canada: An Ecosystem Approach" (DFO 2018b). The Ausable River action plan includes recovery activities for Kidneyshell, while the Sydenham River action plan includes recovery activities for both species.

3.3.3 Critical habitat identification and protection

The critical habitat for these 2 species was identified in the updated recovery strategy (DFO 2013). Using the best available information, critical habitat was identified for Round Hickorynut in the East Sydenham River, and for Kidneyshell in the Ausable River, East Sydenham River, lower Thames River, and Medway Creek (a tributary of the Thames River). Critical habitat orders for both species came into effect in 2019.

3.3.4 Recovery feasibility

The best currently available information indicates that the Round Hickorynut may be functionally extirpated[13]. Recovery of the species is still deemed possible; however, achieving the population and distribution objectives will require a high level of effort and relocations and/or reintroductions will be necessary. Despite this, recovery is still deemed feasible but may need to be reassessed if population augmentation is deemed impractical. Although recovery of Kidneyshell is still deemed feasible, progress to date confirms that a high level of effort is needed to maintain the Medway Creek and St. Clair delta populations.

4 Concluding statement

Over the last 5 years, through the implementation of the activities identified in the recovery strategy for the Kidneyshell in Canada, moderate progress has been made in recovering this species. Although there has been progress made towards the recovery measures for Round Hickorynut, recovery of the species requires a high level of effort and will likely require captive breeding and/or relocations from U.S. populations. Additional recovery measures related to the feasibility of reintroductions may be needed to achieve the population and distribution objectives.

Surveys continue to be conducted in Round Hickorynut and Kidneyshell habitat, with the majority of detections occurring in the Sydenham River. The lone Round Hickorynut detection was from the Sydenham River, while close to 400 Kidneyshell were uncovered over the course of the 5-year time span. Sampling exercises were carried out to fulfill a diverse range of goals, from population surveys to research aimed at improving understanding of the life history of the species. Close to 300 Kidneyshell were detected in the Ausable River, with the majority being uncovered by the Ausable Bayfield Conservation Authority in the course of their routine monitoring. No detections of Kidneyshell occurred in the Thames River, which included sampling in the Medway Creek; however, sampling was upstream of the previous detections of Kidneyshell. Additionally, no sampling of Round Hickorynut and Kidneyshell habitat occurred in the St. Clair River delta during the 2018 to 2023 time period. Historical locations were sampled during this time period (for example, Detroit and Grand rivers) but no live specimens were uncovered.

[13] A few individuals may still be present in the wild but no reproduction is occurring.

Understanding of Round Hickorynut and Kidneyshell life history continues to be enhanced. For example, further evidence suggests subtle differences in host use between Round Hickorynut populations (Shepard et al. 2021), which has conservation implications. A fuller understanding of life-history traits of Round Hickorynut and Kidneyshell is expected to allow for a clearer understanding of the relative magnitude of threats facing unionids (Mitchell et al. 2018), and hence, aid in focusing recovery activities. Research projects centered in the Sydenham River have improved understanding of the environmental requirements of Kidneyshell, and other at risk unionids. For example, a better understanding of life history subtleties that differentiate adult and juvenile unionid environmental requirements, and the scale of resource partitioning between species has been gained (Tran and Ackerman 2019; Lum 2020). On a landscape scale, correlations between the health of unionid populations and surrounding land use patterns (Daniel et al. 2018) are helping to clarify threats and focus stewardship in areas of greatest need.

The identification of stressors affecting Round Hickorynut and Kidneyshell is an ongoing process and often relies on extrapolation from research on other unionid species or community level responses. For example, a fuller understanding of impacts that surrounding agricultural activity has on unionid communities has been gained (Hornbach et al. 2019; Hornbach et al. 2021). The impacts of contaminants on unionid communities continues to be uncovered, particularly with respect to road salts (for example, Burton et al. 2023), and municipal wastewater effluents (for example, Millar et al. 2022).

Through collaboration with conservation authorities, important stewardship projects continue to be completed with the cooperation of landowners and volunteers. For example, efforts to improve and create riparian habitat throughout the Ausable, Sydenham, and Thames River watersheds have continued. It is anticipated that the combined impact of the myriad of stewardship projects that are ongoing and have been completed will result in improved habitat conditions for the Round Hickorynut and Kidneyshell, along with other species at risk residing within these systems. Continued monitoring is necessary to gauge whether the combined impact of these activities is sufficient to aid in the Round Hickorynut and Kidneyshell, and to determine if overall conditions have improved. Additionally, outreach activities continue to educate and engage the public and stakeholders whose actions may influence the future well-being of the species.

Over the last 5 years, only a single Round Hickorynut was discovered in the Sydenham River. The St. Clair River delta populations may be in decline and the feasibility of establishing managed refuge sites is in doubt. There have been no signs of recruitment in the past 10 years and little evidence prior to that time. Additionally, Kidneyshell in Medway Creek was not detected during the latest survey (Goguen et al. 2023); hence, the status of this population is in doubt. Outside of Kidneyshell populations in portions of the Ausable and Sydenham rivers, little evidence of natural reproduction exists. Recent recovery efforts for Round Hickorynut and Kidneyshell in the St. Clair delta and Medway Creek, indicate that, short of reintroductions, current recovery efforts may be inadequate.

Suggested next steps in the recovery of the Round Hickorynut and Kidneyshell include heavy emphasis on the examination of the feasibility of reintroductions and the continuation of surveys, particularly in the St. Clair River Delta, to determine if Round Hickorynut and Kidneyshell are still present. Further steps could include research that enables refinement of threat categorization, stewardship activities, and further outreach that is both targeted (for example, agricultural

landowners) and that reaches the wider public. DFO remains committed to recovering the Round Hickorynut and Kidneyshell. Progress made to date has built a strong foundation for continued research and management of these species over the next reporting period, and would not have been achieved without the contribution from DFO's partners. DFO is looking forward to continuing this successful collaboration and welcomes the participation of additional partners.

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