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An Anguillid lens: how Eels reconnect people and waterways

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The population decline of American Eels (*Anguilla rostrata*) in North America represents multiple crises: ecosystem destruction, industrial impact, forced relocation, cultural disenfranchisement, water degradation, and biodiversity loss. Once a key component of Indigenous societies, trade routes, economies, and ceremonial cycles, today Eels experience migration barriers and habitat degradation stemming from waterway abuse and land use alteration. The development of agricultural and industrial social norms has led to dramatic reductions in Eel populations across North America. Fishery agencies familiar with Eel life cycles often list species as depleted, and disappearance of Eels is well-accepted in all sectors. Related species of Anguillid Eels are in decline globally. Yet, in some areas, American Eels continue to migrate, grow, and even thrive. This article proposes Eel continuity as powerful survivorship in troubled times, a counter-narrative to overwhelming stories of environmental pessimism. Although Eels are often discredited, reviled, and disrespected by Americans and Canadians alike, their contributions to marine and aquatic zones are underestimated and poorly understood. This article employs a reflexive method of dialogue and commentary from two Eel advocates with interdisciplinary training and backgrounds, who envision relational, wisdom-based practices that meaningfully integrate Indigenous, community, academic, and other forms of knowledge about Eels and about water.

KEYWORDS

American Eel, *Anguilla rostrata*, indigenous water governance, migratory fish, decolonizing conservation, citizen science, community science

1 Introduction

Freshwater is the lifeblood of communities. Countless species of fish, plants, and others rely upon the symbiotic relationships that exist in the world's freshwater systems. Freshwater is also historically linked to claims of colonial occupation and control (Willow and Orr, 2019), increasingly associated with extractivist activities. The framework of settler colonialism, as a way of being, exacerbates existing issues of freshwater access for communities who experience environmental injustice. There is acceptance of and indifference to embedded forms of motivated targeting, including racism, dispossession, and the "slow violence" (Nixon, 2013) of impoverishment and systemic barriers of political inequity and policy design. To describe legacy environmental, social, spatial, and interspecies injustice facilitated by settler colonial legalities and related systems, Meissner has used the term "settler colonial contributory injustice" (2021) to indicate structural, profound consequences for the viability of Indigenous lifeways, including relations with water. We suggest that violence against Eels is a form of settler colonial contributory injustice.

Biodiversity and ecosystem resilience across the planet have suffered as a result, with specifically negative effects on freshwater environments (Lapointe et al., 2014). Simultaneously, Indigenous populations around the world continue to assert their responsibilities to water by nurturing, articulating, expressing, and living their legal responsibilities (McMillan, 2012; McGregor, 2014; Giles et al., 2016; Leonard et al., 2023). Recent calls from Indigenous scholars suggest that water governance policy research must adhere to “principles of rematriation, reclamation, and restoration, emphasizing the significance of centering Indigenous leadership, authority, and knowledge in Water research” (Leonard et al., 2023). Rematriation is a long-running movement to restore appropriate Indigenous leadership roles to women for purposes of healing, caretaking, balance, and other goals as determined by Indigenous communities and their specific knowledge systems. In the growing movement for Indigenous environmental justice, Land Back, Water Back, and similar missives, the authors contextualize rematriation pertaining to water as follows:

“Rematriation seeks to restore Indigenous ways of caring for Water and aligning with it as a sacred being, by returning and restoring Indigenous ways of knowing and being in relation to Mother Earth. It also refers to returning decision-making power, knowledge, and responsibility for Water to Indigenous Peoples, recognizing our significant roles in Water governance. This can involve restoring Indigenous Water ceremonies, management practices, recognizing and supporting grandmother Water keepers, and addressing the impacts of colonialism and patriarchy on our access to and relationship to Land and Water” (Leonard et al., 2023, p. 2).

Our article seeks to follow this logic by offering a place-based example of resilience, connectivity, and recovery as seen in the life cycle of Eels. We do this not through simply anthropomorphizing Eels, or assigning human characteristics to their plight, but rather, by demonstrating that human behaviors specifically affect the viability of Eels, and thereby the species, which connects to the health of freshwater systems. *Anguilla rostrata* (American Eels) are migratory fish that take a catadromous journey—one that begins in deep ocean waters, following the current of the Atlantic Gulf stream.

Every spring, millions of tiny Eel larvae begin a journey toward freshwater sites. This journey leads them to streams, creeks, ponds, rivers, lakes, and other freshwater bodies. They metamorphose and grow as they travel and enter estuary and freshwater systems along the Eastern seaboard of North America, enriching the waters where they travel by bringing ocean-derived nutrients and biomass within their bodies. Female Eels journey particularly far, up to hundreds of kilometers from tidal waters up into headwaters, and typically grow larger and live longer than male Eels (Goodwin, 2003). Their faster growth rate and larger size of female Eels may allow them to maximize a wider range of prey species in their habitats (Oliveira and McCleave, 2002). Female eels require good habitats, ample food resources, and often decades to develop, and it is their viability which is most threatened by “anthropogenic pressure” (Drouineau et al., 2018a,b) induced by human societies. Today’s nation-state boundaries including provincial and state configurations of Canada and the U.S. overlap boundaries and jurisdictions across historic

Eel habitat: “it has long been recognized that the St. Lawrence River Eel fisheries were among the most productive in the world and that Eels produced in Ontario waters contributed significantly to these fisheries” (MacGregor, 2009). It is also notable that in the Saint Lawrence and Ottawa River systems, American Eels “among the largest and most fecund of the species, and local populations in the Ottawa River are almost entirely composed of large, female Eels” (Woods et al., 2022).

A. rostrata have been historically present in North America for millennia and have been a reliable source of medicine with cultural and spiritual significance (Allen, 2008). Eels are an unfailing source of all-season food for Indigenous societies. Often cited are quotations from archival records including the Jesuit relations of the 1600s and 1700s.

“Eel constitutes a manna exceeding all belief. Experience and ingenuity have rendered us so expert in catching them that one or two men will take five or six thousand in a single night; and this fishing lasts for two whole months, in which an ample provision of them is made for the whole year; for the Eels here have excellent qualities for keeping, whether dried by fire or salted, and are much better than any Eels in France (Thwaites, 1896-1901).

The omnipresence of Eels is well noted: Eels were an essential staple for Indigenous communities of the Great Lakes and Saint Lawrence River valley, due to the fish’s sheer abundance, high fat content, multiple methods of being caught, and ease of long-term storage through drying and smoking (Casselmann, 2003). Early colonists learned torch and spear fishing (Recht, 1997) in the eighteenth and early nineteenth century from Haudenosaunee and Algonquian tribes. Eels were a treasured source of nourishment for early settlers in colonial times, for example this story from the Saint Lawrence watershed. In 1655, on the Salmon River, while reviewing possibilities for a French settlement a colonist exclaimed “besides the fish caught there at different seasons, Eels are so abundant in the Summer that a man can harpoon as many as a thousand in one night” (Recht, 1997, p. 444).

Eels in all life stages continue to be extracted and used as a source of profit in multiple fisheries, legal and illegal, in the US and Canada (Walker et al., 2019). Today, there are very few examples of Eel management where Indigenous law, legal traditions, policies, and/or input are at the forefront of working with Eel populations in North America, despite ongoing grassroots movements to address histories of political and social exclusion affecting Indigenous communities (MacGregor et al., 2008; McMillan, 2012; Giles et al., 2016). There is also a marked inability to mobilize Indigenous knowledge in institutions where “Indigenous knowledge is neither generated nor held” (McGregor, 2021) which means that a thoughtful, integrated approach is needed, one that recognizes the weight of colonialism and dispossession both on human communities and on Eels.

The global decline of *Anguilla* species, including American Eels, is a unique and specific indicator of human influence on water quality, ecosystem integrity, and the overall sustainability of biological life. If humans and other species require water as a prerequisite for living conditions, ongoing damage and threats to freshwater systems constitute an intergenerational dystopian

(Whyte, 2017) degradation that affects not only Indigenous peoples, but all of life. The power dynamics of settler colonialism create conditions that render Eels vulnerable to violent and destructive deaths on a large scale through “hidden spaces of violence” (White and Springer, 2018) constituted by land and water altering infrastructures, perceived as defaults of modernity.

These infrastructures (such as hydroelectric facilities and dams, roads, culverts, and agricultural configurations) have often been designed without consent from, and despite the resistance of, Indigenous communities. *Anguillid* Eels represent and facilitate profound connections and relationships throughout water systems. Their migration and the conditions which support their migration must be prioritized as issues of significant concern. Eels rely on good water quality (for biodiverse food sources and a lack of harmful pollutants) and well-connected waters (for access to habitats and to sustain migration routes). As such they are a superb lens to look at one’s own home waters.

If you live within the range of an *Anguillid* Eel, a question to ask yourself is “do I have Eels in my local waterway? And If not... why?” Eels supply a relevant and immediate focus on place and environment. In this article, we share our observations and insights as individuals who work in larger systems to which we belong and where the study of Eels is a personal and vocational priority. We add our specific experiences as concerned and invested professionals who take a place-based interest in Eels along with interest in developing wider narratives about their historic and future significance to freshwater management, relationality, and collective meaning-making. We suggest that *Anguilla rostrata* must be elevated as a focal species in all areas of freshwater management, valued for its inherent ecological roles and status as “ambassador” of watershed health in freshwater systems.

To address the plight of American Eels, which have been extirpated, reduced, threatened, and/or depleted in several areas, we recommend foregrounding Indigenous rights, responsibilities, and histories in planning and policy design. Indigenous communities have a long history with Eels and often hold extensive knowledge about their habitats and life cycle (Allen, 2007; Schweid, 2009; Giles et al., 2016). We suggest a reflection on the past, and action in the present toward developing truthful, place-based narratives to cultivate futures that are dramatically different for Eels and for the wellness of all freshwater species.

1.1 All about Eels

Anguilla rostrata (American Eel) is one of 19 species and subspecies of catadromous migratory fish (Righton et al., 2021) which hatch in the oceans and migrate up coastal rivers and freshwater streams. Eels mature for years or decades in brackish and freshwater habitats before returning to the ocean to spawn once at the end of their life. These 19 species of *Anguillid* Eels are found in many areas of the globe, spawning in the Atlantic, Pacific, and Indian Oceans. In this paper the term “Eel” refers specifically to these migratory species, differentiated from other marine and freshwater fish with “Eel” in their common name. We capitalize the term as a mark of respect.

Today, the high market value of Eels (Walker et al., 2019) continues to fluctuate and grow based on a global trade market. The poaching and targeting of Eels in North America have made the species vulnerable to a range of already-existing modern pressures, including water pollution, overfishing, habitat loss, and the severing of river systems from dams, culverts, and other water control devices (Dekker, 2009; Jacoby et al., 2015). Several of these drivers are linked to the recent century of accelerated climate change, which has a cascade of effects on Eels. Climate change that affects Eel migration has many driving forces, from oceanic larval and drift patterns to the fragmentation of streams and habitats (Drouineau et al., 2018a,b). In North America it is estimated that the American Eel (*Anguilla rostrata*) declined 72% from 1950 to 2006. A related, sister species, which migrates and spawns to and from the same site is the European Eel (*Anguilla anguilla*), whose populations dropped by over 90% in many European rivers in a similar timeframe (Limburg and Waldman, 2009).

A. rostrata is listed as “threatened” by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2012). The most recent benchmark assessment of the Atlantic States Marine Fisheries Commission concludes that “the stock is depleted, meaning it is at or near historically low levels due to a combination of historical overfishing, habitat loss, food web alterations, predation, turbine mortality, environmental changes, toxins and contaminants, and disease” (Atlantic States Marine Fisheries Commission, 2023). *Anguillid* Eels are a vital part of cultures around the world, both for their nutritional value as well as their spiritual significance (Recht, 1997; Davis et al., 2004; McMillan, 2012; Tsukamoto and Kuroki, 2014; Giles et al., 2016; Noble et al., 2016). In recent decades, Eels are arguably depleted in terms of their perceived value in a social and ecological sense as well, despite the often-clandestine activities of the trade market in coastal zones off Northeastern US and Canada (Walker et al., 2019). In many American rivers, decades of legacy pollutants and declining fish stocks have meant few residents have a deep relationship with the fish in local rivers (Limburg and Waldman, 2009).

This means that populations of people living in Eel habitats today may have very little awareness of an Eel’s role ecologically and historically. Eels are often maligned as slimy, snake-like, and dangerous (Batt, 2009). Despite a long history of sustaining Indigenous societies and newcomers alike, in a contemporary sense Eels have slowly fallen out of culinary flavor at a mainstream level in the US AND Canada (Schweid, 2009). They remain treasured and respected food, medicine, and ceremonial offerings for North American Indigenous peoples including the Mi’kmaq and others (MacGregor et al., 2008; McMillan, 2012; Giles et al., 2016; Noble et al., 2016).

Some Eel researchers argue that a systems approach must be taken and measures to protect Eels require “coordinated international management, acting on each source of anthropogenic pressure” (Drouineau et al., 2018a,b). Others argue that areas where Eels are abundant should be targets of fisheries and commercial activities in order to garner interest and capital association with the species (Kahn, 2019). Management strategies put forth by Indigenous groups (Davis et al., 2004; Giles et al., 2016; Noble et al., 2016) have advocated for localized, place-based approaches that respect and integrate Indigenous

culture, language, ecological knowledge, and perspectives into managing human behavior to support the wellbeing of vulnerable Eel populations.

Bi-national management across jurisdictions and legal systems, e.g., US and Canada, has been identified as a significant challenge (MacGregor et al., 2008; Engler-Palma et al., 2013). On a macro level, *Anguillid* experts have suggested that a comprehensive and interdisciplinary engagement is needed: a combination of natural, cultural, and social sciences facilitate an understanding of the animal's physiology, evolution, and ecology alongside relevant factors like archaeology, tradition, idioms, fishing, economics, and environment, respectively (Tsukamoto and Kuroki, 2014, v).

The range of migratory habitat for *A. rostrata* is astounding; it extends in multiple directions, estimated at a range of "latitudinal ~7000 km, Greenland to northern South America, longitudinal ~5000 km, Rocky Mountains to the mid-North Atlantic Ocean and altitudinal several thousand montane streams to 700m ocean depths" (Cairns et al., 2022).

Eels have multiple interesting physical characteristics which fascinate scientists and capture imaginations. They undergo significant physical transformation several times through their maturation, beginning as small eggs drifting along the Gulf Stream each Spring. They morph through multiple life stages, each with its own nomenclature, from tiny oceanic "leptocephali" to sexually mature "silver eels" (Figure 1). Until the final stage of their lives, Eels live in fresh or brackish water, and when they return to the ocean, generally in Autumn, they enter a fasting state and digest their own stomachs (Jellyman, 2022). The scale of their journey is one aspect of their resilience and persistence. Eels follow celestial cues (Cresci et al., 2019) on their migration as do many migratory fish. They carry keen olfactory senses and an "internal, magnetic compass" (Béguer-Pon et al., 2015) connected to the Earth's meridians as well as cycles of the moon. Nocturnal and dormant during the day, Eels require minimal light pollution and "freely connected" waters to navigate during nighttime hours. Although they can climb waterfalls (Schmidt et al., 2009) they are also attracted to velocity in waters such as those occurring in natural whirlpools.

At times, Eels can mistake the velocity in hydroelectric turbines for natural water flow. This has led to large-scale depletion and millions of dead Eels accumulating in recent years near sites where hydroelectric facilities operate, with turbines that shred their bodies, concrete walls that they smash into, and other barriers which cause Eels physical harm and distress. Turbines alone are known to be one of the most significant threats to Eels, causing the death of millions (Limburg and Waldman, 2009; Schweid, 2009).

The migratory path of *A. rostrata* includes estuaries and ecologically sensitive environments such as salt marshes, mangroves, and freshwater streams. These habitats are particularly relevant to the development of young Eels and are a place where they spend a lot of time in the yellow stage of their lives. Prior to sexual maturity, migrating Eels who head toward the ocean move significant and necessary nutrients and energy from watersheds, estuaries, and salt marshes to ocean waters (Eberhardt, 2019). Eels also have a symbiotic relationship with freshwater mussels, which enables the two species together to contribute

to water quality through greater water filtration with the Eel as host and the mussel as affiliate (Galbraith et al., 2018). The depletion of both mussels and Eels (as well as other freshwater residents, including fish and plants) threatens water quality and viability.

Currently, significant data gaps exist in many aspects of Eel biology (Jacoby et al., 2015; Righton et al., 2021). There is much speculation about migration, which is inherently limited by a dearth of certainty toward deep oceanic knowledge. There is existing data about the physiology of Eels and uncertainty about characteristics throughout each of an Eel's life stages. As they travel from oceanic into freshwater environments, their bodies metamorphose, and their roles in ecosystem and freshwater systems change, as do their dietary and maturation needs. Eel physiology and characteristics are studied to gain understanding of their specific dietary and other needs as each phase develops.

For example, it is notable that in the young and delicate leptocephalus stage, Eels have specific needs in the ocean: "extensive feeding trials in aquaculture laboratories have shown that they will not ingest most things and that a quite specific food source is required for them to grow and reach metamorphosis" (Tsukamoto and Miller, 2021). It is thus important to relay the interconnections between marine system health, the health of freshwater systems, and the ongoing connections that enable or limit the viability of growth. Environmental frameworks and idealisms of "repair" and "restoration" often tout the importance of interconnected ecosystems. It is also important to note that settler colonialism creates systems of exclusion, invisibility, and persistent disparity (Elias and Joshi, 2021).

The Eel lives and demonstrates systemic interconnectedness on a large scale for thousands of miles and as such is an ideal species through which to focus a holistic lens that analyzes social, cultural, and biological vectors of human society proven to directly impact Eel migration. We propose that there is an "inherent" value of Eels closely tied to large-scale ecological integrity. *Anguillid* Eels are panmictic: all adults likely breed together in the Sargasso Sea, and young Eels are likely distributed randomly throughout their possible range, regardless of where their parents matured. Care must be taken that the inherent importance of Eels in their ecology is not devalued or disrespected for short-term and speculative economic gains, a long running practice of colonially induced water control and management. We now turn to the suggestion that Eels offer an entry point to better understanding of freshwater systems for residents who may be disconnected by the "muck of the colonial condition" (Gomez-Barris, 2017, p. 109).

1.2 Ambassadors of freshwater

The dependence of Eels on multiple habitats from ocean to estuary to freshwater stream makes them both vulnerable to change, but also superb "flagship" species (Itakura et al., 2020). Here we consider Eels as "flagship" species because they serve as ambassadors for a host of ecological topics. Many individual Eels spend much of their lives in freshwater, bookended by near-miraculous migrations to the sea. This means that they

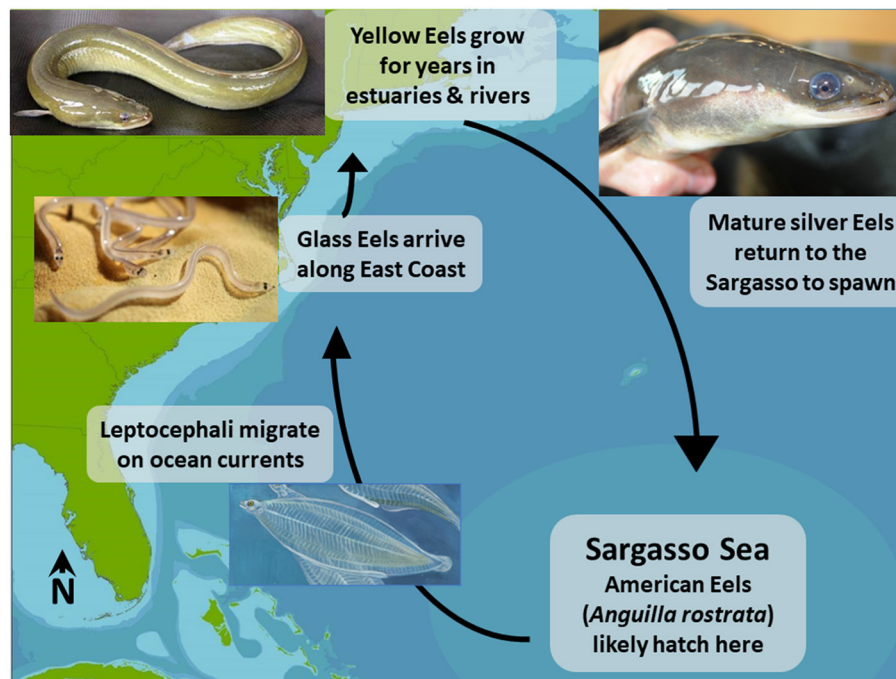


FIGURE 1
The life cycle and generalized migration route of the American Eel (*Anguilla rostrata*) along the East Coast. Courtesy of Christopher Bowser and Ram Papish.

are prime indicators of ecosystem health; preserving all aspects of healthy freshwater is crucial to Eel conservation. Because of their relatively long residence in freshwater, up to decades, they can document exposure to persistent lipophilic pollutants like PCBs within their tissues (Ashley et al., 2003). Eels are a lens and bridge to examine stressors like water pollution and habitat loss.

Eels are especially powerful as a ambassador for stream connectivity and dam removal. On the East Coast of North America, many diadromous fish (species that migrate between salt and freshwater) benefit from the removal of dams relatively close to the coast and head of tide. Because they frequent all nodes and corners of freshwater systems, Eels benefit from all dam removals, including small and out of date mill dams, even on headwater streams out of range of other diadromous species (Machut et al., 2007). This makes restoring connectivity in streams and watersheds a cause for celebration, not just for the Eels but for the improved water quality and flow that benefits thousands of species. Improved connectivity can create better recreational opportunities and fewer infrastructure risk costs for human societies.

Eels have multiple roles in the trophic levels and food chains of freshwater ecosystems. Juvenile “glass Eels” arrive as important food sources for many animals as they energize from winter to spring. Contrast this with more mature yellow Eels, which are often an apex predator in freshwater habitats and can make up a significant biomass of resident fish (Casselman, 2003).

The ambassadorship of Eels is also expressed as a gateway for non-scientists and non-fisher people to learn from local waterways and complex ecologies.

One way this can be done is through “community science,” also called “citizen science.” These endeavors can mean different things for different purposes, from smartphone-based observation apps to guided, in-the-field monitoring, all offered under an umbrella of increased public participation in organized science by non-experts (Bonney et al., 2016). Sponsored community science has a long history in North America, starting with the Christmas Bird Count a century ago, and now flourishing with examinations of insects, plant buds, weather, and urban heat islands (Dickinson and Bonney, 2012).

Participatory research via community science in fisheries has grown as well in recent years (Oremland et al., 2022). This parallels a rising recognition of the public’s role in reconnecting rivers that have been dissected and deflected by dams and other structures (Brink et al., 2018). Global outreach events like the World Fish Migration Day galvanize public support for migratory fishes and dam removal through in-person events and social media (Brink et al., 2018), which in turn may inspire participants to join community science efforts and advocacy organizations.

By naming Eels “ambassadors of freshwater” we recognize that Eels have an ancient tenure in North American waters and have historically dominated major arterial waterways including

the Saint Lawrence, Ottawa, and Hudson rivers (Recht, 1997; Casselman, 2003; Schmidt et al., 2009; Engler-Palma et al., 2013; Noble et al., 2016; Walker et al., 2019) along with countless others along the eastern seaboard. Studying their lives, and their untimely deaths induced by dams, habitat alteration, and other infrastructural barriers, we posit Eels as the center of future water management. Few species can bring together all of these threads: biological restoration, reconnected waters, public participation, and the hope of ecological and historical healing from trauma, including unrecognized historical trauma on waters (McGregor, 2014) with the relevance and immediacy that Anguillid Eels can.

1.3 Positionality: how and why we connect with Eels

We offer these contextual framings about ourselves and our investments in Eels to demonstrate that we each work in and with conflicting and overlapping systems: educational systems, nonprofit systems, land-based learning, Indigenous knowledge systems, intergenerational accountability, and others. It is important to note that our pleas for improved relations with Eels come from a deep subjectivity: “the knowledge we produce is always linked to the people we are, but also the places we know, live in and love” (McElhinny, 2021).

From Leora Gansworth

As Anishinabe-kwe I know my inherent connection with water and my responsibilities to water in a basic sense. I continue to grow my life and practices from that relationship. I have always known that my father’s side of the family comes from *Ongwehonwe*¹ Eel clan people. My paternal grandmother was a matriarch of the Onondaga Eel clan. My *Ongwehonwe* ancestors have a long history in the lands now called New York State and beyond.

Clans (we say *doodem* in *Anishinabemowin*) have specific meanings to different tribes and Nations. My mother’s side comes from *Omamiwininiwug*² (along the Ottawa river) and other ancestry. We carry these multiple histories and bloodlines and so many of them have intimate histories with waters that are historical sites of dense, consistent, generational Eel populations that meant so much to my ancestors.

In our way of thinking and being, as *Anishinabeg*, we understand that animals give their lives and their medicines to support and sustain us. Animals have stood up for *Anishinabeg*, the people, offering to love and provide for us unconditionally and in all ways. They benefit us spiritually, emotionally, mentally, physically. Animals love us and they continue to teach us how to live. Animals are part of each of our Creation

Stories (Day et al., 2014). So they walk with us and provide guidance throughout our life. I have learned much about life by studying the different animals that my families are related to. I continue my journeys to learn my peoples’ oral and spiritual histories and laws along with cultural and ecological values.

When it occurred to me to start studying Eels, and when I learned about different aspects of my relationship with Eels, it was through land-based activity, being on the waters, and through ceremonial participation and protocols. It became clear to me that my connection to Eels was tied to these other aspects of who I am, who my ancestors are, and how they were sustained by Eels in such rich numbers. Eel skin, oil, and meat were default materials for seasonal economies and the substance of trade foods, traveling medicines, the decoration of sacred articles and clothing, tools, and other technologies such as canoes.

There are ancient and specific fishing protocols in different tribes for when to sustainably harvest Eels, protocols for giving reverence to them, and intimate watershed knowledge on where to find them. These days, that connection has been greatly altered and I have heard many painful stories of disconnection, fragmented memory, the degradation of homelands, and other forms of loss.

There is archaeological evidence demonstrating fishing sites that contain extensive faunal remains of Eels along with ceremonial artifacts in Algonquin territory (Allen, 2007). Sacred sites are of particular interest to me, sites which were designated by my ancestors as holding power, having specific powers to teach, offer reverence, and respect the laws and Beings of nature. Many of these places and relationships hold memories and physical evidence of Eels, and they have been disrupted and, in some cases, destroyed by colonial practices which were initiated during times when occupying governments wrote legislation about our people as inhuman and incapable of making decisions about environments that were our homes for generations. Eel adornments are also found in grave sites which have been disturbed, looted, and vandalized. Through these revelations I learn about ancient practices of mourning, taking good care, being a good relative, and the power of our Traditional Knowledge and legal systems.

I navigate processes and elements of ecological grief and sorrow affiliated with witnessing the large-scale destruction that leaves Eels the target of settler loathing, violence, and indifference leading to the demise of their populations in many areas throughout territories of both sides of my family.

At the same time, I have learned by working with scientists and others that Eels persist and continue to live despite such disrespect. Much of the knowledge about Eels and many of the

1 A self-referential term used by people also known as the Haudenosaunee (“they are building a long house”).

2 A self-referential term used by people also known as Algonquin-Anishinabeg.

fishing practices which were initiated by my ancestors continue to be used in state and provincial Eel management today. Ancient weirs and other fishing sites are increasingly revealed as people study and inhabit the land, the rivers, the waters that so many Indigenous peoples were forcibly removed from.

I see the re-creation of a world where Eels can freely carry out their magnificent migrations as both an ancestral and personal cycle of reciprocity. Personally the value is beyond physical nutrition: I haven't and wouldn't eat the flesh of an Eel, but they have given me so much nourishment in other ways: from Eels I have been gifted insight, hope, inspiration, humility, love, purpose, and support by listening to, observing, and relating with them. I also know that many of the induced ailments we deal with today: diabetes, arthritis, and other physical conditions are linked to our diets and reduced access to nutritious food including the loss of nutrients that are offered in foods and medicines made from Eels.

This work, to me, is one element in a lifetime of learning, and it is an honor to learn from and be with Eels whenever possible. They are sensitive, strong, beautiful, and special relatives who connect people and waters across time, space, and dimensions. Like Eels, people of my generation may have inherited an external set of circumstances which are not of our design, but my overall goal is to support better aquatic conditions, to change the way I relate to water, and to Eels. It is my desire to contribute to the healing of the planet's waters at large and Eels have shown me pathways toward doing so.

From Chris Bowser

Every ecology textbook emphasizes the interconnectivity of local, regional, and global systems. Eels help us learn that interconnectivity is not just a theory, it's a reality. Eels are accessible mysteries. People frequently live near them, but often they may not know it. If people start to interact with and see Eels, whether through recreational fishing or work on restoration projects, the Eels become a gateway to learning about history, indigenous relationships to these animals, and pathways to restoration and whole-watershed health.

I initially came to work with Eels from the perspective of an environmental educator. Early in my career, I was explaining to a group of students the various sessile creatures that had colonized a discarded plastic toy truck that we just had trawled up from the bottom of New York Harbor. I realized the students were ignoring me but awestruck by a foot-long Eel slowly uncurling from the toy truck's cab! That began a deep dive into learning everything I could about Eels, their incredible biology, and their significance to people around the world.

As I advanced into teaching, I used any opportunity possible to connect with Eel experts around the region and the world. I joined researchers in South Africa's Ngeni River to survey adult Eels, looked for glass Eels near the castle of an Irish pirate queen, and visited an aquaculture facility in northern Morocco. There are people everywhere who are inspired by Eels. They don't just manage or study these fish; there's a fascination and respect at the core. This goes for veteran scientists and curious students. People can be a part of restoration for the Eels and their waters, and also a part of inspiration and renewal in a challenging and often traumatic world. I'm grateful to learn from so many people, from formal scientists and informal nature stewards to new students who discover novel aspects of waters and Eels every day.

I currently work coordinating environmental education programs on Mohicannituck, the "waters that are never still" of the Stockbridge-Munsee Mohicans (a river also known as the Hudson River Estuary). Fish have opened up avenues of place-based education and community engagement, including with Indigenous groups. For example, mutual interest in sturgeon has led to collaboration with the Stockbridge-Munsee Band of Mohicans, for whom sturgeon are vitally present in both the Hudson region as well as their Wisconsin communities. Recently we were honored to seine-net and canoe the shallow waters of Mohicannituck with the [Lenni Lenapekweyok \(2023\)](#), a matriarchs-led group from the five federally recognized Lenape and Munsee-Mohican communities that organizes visits to their homelands focused "on land and water stewardship, culture, language, stories, healing, education, building relationships, and ceremony". These are ongoing steps in reconnecting people, water, and fishes. This can also include Eels, which present unique opportunities all their own.

Each spring along the East Coast, millions of juvenile "glass Eels" arrive in coastal rivers on their journey from the sea to shore ([Sullivan et al., 2006](#)). A colleague suggested that previous professional research on glass Eel abundance ([Schmidt et al., 2006](#)) might be adaptable to students and other community members, and this began the Hudson River Eel Project, a community science effort of the New York State Department of Environmental Conservation that has been running since 2008 ([NYSDEC, 2023](#)).

The project has two goals. The first goal is to take a census of glass Eel migration at about a dozen sites. Each spring about a thousand trained volunteers check ten-foot nets each day for glass Eels. The two-inch translucent fish are counted and released above the nearest barrier to migration, a small act of restoration as that barrier is often a man-made culvert or dam. The nets are checked each day (except in unsafe weather) and follows the protocols of the Atlantic States Marine Fisheries Commission

(Atlantic States Marine Fisheries Commission, 2023). At the end of the season, volunteers gather in local “Eelebrations” to celebrate their season of shared stewardship with stories, reflections, and a look at the year’s data.

The more straightforward conservation questions involve what and where and when, such as population studies or migration patterns. But it is also important to step back and look at the more elusive or difficult questions like “why are Eel numbers at historically low levels around the globe”? Or “who are the communities that suffer the most loss from the decline of fish as nutritional and ecological keystones”? Or “how can conservation of Eels accomplish ecological goals while also keeping respect for multiple communities and cultures as equally important goals”?

Our second goal is to connect people with their shared environment, and to engage people in a suite of science skills and knowledge systems. Participants include a range of ages and backgrounds, from high school students to retirees, and from college interns to organized watershed groups. Motivations for participation are broad, and project surveys have found that internal/personal motivations like being outside and just having fun are as or more prevalent than external motivations like school credit or even conservation. Studies of the Eel Project and other community/citizen science efforts have shown that multiple dimensions of engagement, including cognitive, social, and behavioral dimensions can enhance community science (Phillips et al., 2019). This parallels the Eels ecological multi-dimensionality, reliant on multiple habitats, and connecting to society in relevant economic, ecological, and cultural ways.

I hope that the Eel Project and other community science programs are ways for people, especially young people, to find and nurture their own ecological curiosity (Figure 2). For some careers in conservation, there is still a lingering bias toward white, college-educated males (this author for example). I think that this is changing. Although the pace of that change is variable across fields and organizations, there is a rising tide of diverse leaders and programs that strengthens all corners of conservation. I hope that community science can be one piece of that higher tide.

1.4 Learning to center and support eel migration

Supporting less destruction and violence for Eels (and for many aquatic residents) is a matter of respecting, honoring, and understanding water and its importance to all life. Water is alive, water has agency (McGregor, 2014; Leonard et al., 2023) and for Anishinabeg and other Indigenous peoples, the current “dystopia” (Whyte, 2017) of environmental degradation represents decades

of injustice to water, to Indigenous Nations, relatives, and places. This is not necessary and can change. We suggest the following efforts as foundations toward improved relations with water and with Eels. These can have immense impact when attention is given specifically to the presence, or absence, of Eels in areas where they have historic habitat. We suggest both a re-tracing and a “rematriation” (Leonard et al., 2023) of Eel habitats that begins with concrete actions involving multiple institutions, actors, and opportunities, in recognition of the diverse positionalities one may hold in relation to water and watersheds.

1.4.1 Nourishing systemic and paradigmatic change

Developing a sense of continuity with tradition and remaining adaptive in changed circumstances is, for Indigenous peoples, a way to “reclaim and re-story Indigenous Water Knowledges” (Leonard et al., 2023) for the benefit of all people. Our approach here is to suggest that there is a great deal of potential to rethink “progress” as viewed through an Indigenous lens and with “ethics of responsibility” (McGregor, 2014) at the core of all planning. This means “seeing animals as agents and allowing animal communities to flourish” (Deckha, 2020) which can be facilitated by sharing interdisciplinary knowledge and information about the relationships between waters, Eels, and places where they travel.

It also means restoring decision making power to Indigenous Peoples including the input of women who may have historically been excluded from processes related to fisheries and other policymaking levers (Leonard et al., 2023). Women as Indigenous knowledge carriers may carry specific and nuanced knowledge of local ecologies that impact Eels through Traditional Knowledge or other forms of Indigenous epistemology (McGregor, 2014; Giles et al., 2016). The impact of uplifting and implementing this knowledge has potential benefits which have yet to be realized in any “decolonial moment” that has yet to occur on a widespread scale.

Similarly, resilient systems that draw on Western science must contain “holistic and interconnected building bricks” (Lapointe et al., 2014) that identify and ameliorate multiple threats to freshwater systems and create opportunities for resiliency. To understand water and the conditions that create degraded water, policy must follow natural laws such as the laws of physics and chemistry (Lapointe et al., 2014). Many of the current configurations for agriculture, industry, transportation, power generation, and other factors did not and do not respect these laws, and were instead part of ongoing schemes (Scott, 1998) to generate capital, control, and profit at the expense of water which is made to work (Willow and Orr, 2019) for human benefit.

1.4.2 Pursuing legal innovation

A growing sense of “climate anxiety” (Blattner, 2021) is affiliated with human and interspecies migration and general environmental destabilization, which leaves a complex role for law and legal framing. Simultaneously, articulating, sustaining, and reclaiming relationships with Eels is necessarily a matter of law and legal intervention (Engler-Palma et al., 2013; Giles et al.,



FIGURE 2
A community scientist holds an American Eel before releasing it back to stream. Photo by Chris Bowser.

2016). There are numerous legal challenges associated with Eel management and even more with freshwater systems (Lapointe et al., 2014; Cairns et al., 2022) We do not fully address these factors in this article; rather, we point to ways that we can support our own roles in the legal, educational, and land-based ecosystems we participate in knowing that the interconnections and needs for collaboration are wide ranging and an ongoing matter of urgency (Engler-Palma et al., 2013; Busch and Braun, 2014; Giles et al., 2016).

These efforts can take many directions. Part of returning Eels to a thriving state is tied to classic efforts of reducing point source water pollution, holding water management systems accountable, establishing protected habitats, and addressing waterways full of plastics and other solid waste, all of which are affected by regional and other laws. In addition, Eel survival depends on river connectivity. The relentless dissection of streams from anachronistic mill ponds to giant hydroelectric dams in the last 200 years is a dramatic expression of extractivism and colonialism, focusing on the technological harvesting of water at the expense of entire cultures and ecosystems and laws which facilitate those practices must be evaluated for current-day applicability and viability.

Honoring and reconnecting broken rivers is an anti-colonial action and “life-affirming practice” (Borrows, 2017) that can unfurl in collaboration with multiple vested interest groups. This is also an opportunity to support Indigenous-led governance and priorities, including Indigenous legal orders and traditions, specifically in relation to water and water residents (MacGregor et al., 2008; McMillan, 2012; Engler-Palma et al., 2013; Giles et al., 2016; Deckha, 2020; MacGregor, 2021; Leonard et al., 2023).

1.4.3 Removing barriers and supporting migration

Eels and other species flourish in the free flow of restored rivers. A full spectrum of strategies is required, including

limited use of specialized fish ladders that help some Eels above dams and other man-made barriers that cannot be removed otherwise (Schmidt et al., 2009). There is also participation in full barrier removal and movement-building to free enslaved rivers. These are actions of anti-degradation, reciprocity, and acknowledgment that existing practices of harnessing, manipulating, and controlling water for the benefit of few is an unsustainable and inequitable practice that can and must change, we must learn to “see as the fish sees” (Gomez-Barris, 2017).

In addition to siting the physical process of barrier removal, educators and individuals can also co-build a respect and wonder for Eels through increased access to rivers for community members. This involves direct education, environmental celebrations, shared stories of fish and families, and community science. Tribal Nations in the United States have taken significant leadership roles in the removal of destructive and outdated dams (Fox et al., 2022) which has improved environmental, social, and economic outcomes for multiple parties including and beyond Tribal Nations.

Participating in similar efforts is feasible, possible, and growable in local settings such as community science, partnerships, and other innovations. Such efforts support water quality improvement, infrastructure safety and climate change mitigation. Dam removal and culvert right-sizing can benefit a host of migratory fish species, with Eels first and foremost. Eels respond to dam removal quickly and measurably, which can strengthen additional efforts to reconnect rivers (Sun et al., 2020).

1.4.4 Honoring the inherent value of Eels

Eels have historically composed sizable percentages of biomass in rivers along the eastern waters of North America. For example, along the Eastern coast of the US, “historically Eels comprised as much as 25% of the fish biomass in coastal streams... but now comprises <1% ...of pre-1980 levels” (Busch and Braun,

2014). They have been unrecognized and overlooked champions of ecology and human life for centuries.

Every spring, they reliably enter freshwater and estuary streams along the Eastern seaboard of North America, bringing with them the mysteries of the sea and the determination to live out a transformative life in freshwater systems. They carry nutrients with them, they give their skin, oil, and flesh to become food for humans and other predators, and they clean the carrion, insects like mosquitoes, and other debris in waterways. Eels have fascinating and charismatic interactions with people and places, and they peacefully rest during the day while reflecting and moving with the lighted map of stars at night.

If Eel populations have been made vulnerable by “settler colonial contributory injustice” (Meissner, 2020) then the questions which follow pertain to “interspecies justice” (McGregor, 2014; White and Springer, 2018; Deckha, 2020) and “reconciliation with the Earth” (Borrows, 2017). A sense of reverence is due, reverence to processes that sustain human life in such intricate and underappreciated ways. At the end of their lives, Eels return their bodies to the water, distributing nutrients to estuaries and beginning another cycle of regeneration when they disappear into the ocean to spawn. Eels provide many gifts to the planet that hosts them. Human societies can and should recognize these gifts and do everything possible to return sustainable living conditions to Eels who may pass through and enhance freshwater during the tenure of their relatively short but immensely meaningful lives. This in turn benefits the freshwater that is so vital to all forms of life: water, the source of human and interspecies nourishment connection and continuity.

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