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PERSPECTIVE

On the troubling use of plastic ‘habitat’ structures for fish in freshwater ecosystems – or – when restoration is just littering

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Abstract

The creation and deployment of plastic structures made out of pipes and panels in freshwater ecosystems to enhance fish habitat or restore freshwater systems have become popularized in some regions. Here, we outline concerns with these activities, examine the associated evidence base for using plastic materials for restoration, and provide some suggestions for a path forward. The evidence base supporting the use of plastic structures in freshwater systems is limited in terms of ecological benefit and assurances that the use of plastics does not contribute to pollution via plastic degradation or leaching. Rarely was a cradle-to-grave approach (i.e. the full life cycle of restoration as well as the full suite of environmental consequences arising from plastic creation to disposal) considered nor were decommissioning plans required for deployment of plastic habitats. We suggest that there is a need to embrace natural materials when engaging in habitat restoration and provide more opportunities for relevant actors to have a voice regarding the types of materials used. It is clear that restoration of freshwater ecosystems is critically important, but those efforts need to be guided by science and not result in potential long-term harm. We conclude that based on the current evidence base, the use of plastic for habitat enhancement or restoration in freshwater systems is nothing short of littering.

Key words: restoration ecology, fish habitat, attraction–production, recreational fishing, conservation, habitat enhancement

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Introduction

Aquatic ecosystems around the globe have suffered from habitat alteration and loss for decades (Arthington et al. 2016). This is particularly evident in freshwater systems and has contributed to dramatic declines in freshwater biodiversity (Dudgeon et al. 2006; Reid et al. 2019). Indeed, losses have been so extreme that protection and restoration of freshwater systems are included in the so-called ‘emergency recovery plan’ for freshwater biodiversity (Tickner et al. 2020). Habitat alteration and loss come in many forms including the loss of structural habitat features from lotic and lentic systems. For decades, research has focused on how to restore such environments to benefit aquatic biodiversity (e.g. Søndergaard et al. 2007; Wohl et al. 2015). Even created environments such as reservoirs have benefited from such habitat enhancement initiatives (Moore and Thornton 1998; Cooke et al. 2016). Freshwater restoration and habitat enhancement can include many techniques (e.g. biomanipulation, reducing nutrient inputs, riparian/shoreline plantings) although one of the most common methods is the addition of physical habitat structure in the form of woody materials (e.g. logs, root wads, stumps; also sometimes referred to as coarse woody debris).

Structural aspects of freshwater habitat are particularly important for freshwater fishes (Sass et al. 2022) and provide a range of ecological functions (Harmon et al. 1986). Freshwater fishes use these structures for a variety of purposes such as feeding and predator avoidance (Sass et al. 2022). Much of what we know about the value of structural aspects of fish habitat comes from experiments where various structural elements are removed and (or) added (e.g. Bryant 1983; Lehane et al. 2002; Helmus and Sass 2008; Sass et al. 2012; Sass et al. 2019) and it is clear that in most systems the addition of woody structural habitat (particularly where it is absent or minimally present such as in some reservoirs, lakes and rivers) derives some benefit to fish (Sass et al. 2022). However, there are also instances where such structural additions simply serve to attract and aggregate organisms rather than improving fish abundance or condition (Lindberg 1997). Given the current freshwater biodiversity crisis, efforts to restore or enhance freshwater systems may include the addition of structural elements of habitat. Ensuring that such efforts benefit freshwater and in no way harm aquatic life should be paramount to those engaging in such restoration and habitat enhancement efforts (Cooke et al. 2018).

About 40 years ago, there was a big push to evaluate various anthropogenic materials for use in artificial reefs in the marine realm. From used tires (Campos and Gamboa 1989) to war ships (Johnston et al. 2003), many different artificial materials and structures were sunk in coastal marine waters in an attempt to enhance or restore marine ecosystems (Bohnsack and Sutherland 1985; Ramm et al. 2021). The nature of the marine environment is such that many of these anthropogenic structures were often quickly colonized and encrusted by sessile organisms. Fish (and other organisms) of various sizes would take up residency and provide opportunities for anglers, divers and spearfishers to connect with wild marine life (e.g. Stolk et al. 2007; Shani et al. 2012). Over the last few decades, there has been vigorous debate about whether these anthropogenic materials were actually enhancing production or were simply serving to redistribute organisms (i.e. the attraction–production controversy; Bohnsack and Sutherland 1985; Grossman et al. 1997; Osenberg et al. 2002; Sass et al. 2022). There was also discourse about the extent to which such efforts could be considered restoration or a form of pollution (MacDonald 1994; Chou 1997; Eggen 1997; Baine 2001). Over time, research revealed that artificial materials such as tires and ships led to the release of a number of contaminants (e.g. Collins et al. 1995; Devault et al. 2017). Although artificial reef development continues to this day, it is being done more cautiously given an expanded evidence base revealing uncertainty about ecological benefits and a growing understanding of the negative environmental consequences of placing structures made of anthropogenic materials in the ocean. In fact, some efforts have been undertaken to remove tire reefs (see Sherman and Spieler 2006). Concurrently, there has been increasing public awareness about the plight of oceans and plastic pollution which is also contributing to more scrutiny about the materials used in artificial reefs. There are some interesting parallel developments in the freshwater realm, which is the focus of our essay.

The concept of freshwater reefs or other artificial habitats is not entirely new with examples extending back to the 1970s using tires (Prince and Maughan 1978). However, it was not embraced to the extent it was in the marine realm. More typically, large wood structures or placement of rocks are commonly used approaches for the restoration or enhancement of lotic and lentic freshwater environments (Thompson et al. 2018; Rytwinski et al. 2019; Sass et al. 2022; Theis et al. 2022). Over the last decade or so, there has been growing popularity in the use of various structures composed largely of plastics

(Sass et al. 2022). For example, polyvinyl chloride (PVC) or acrylonitrile butadiene styrene (ABS) piping or panels (as well as other plastic materials) in a range of sizes and configurations such as crib-like structures or those that mimic a tree (see Fig. 1) are being added to lentic freshwaters. Such projects are usually led by government agencies or local angling clubs, but individual anglers

Fig. 1. Examples of fish habitat structures that have been placed in freshwater systems. Materials used vary from discarded PVC pipe, corrugated sewer pipe, vinyl house siding or blinds, and plastic palettes. Some of the styles are given specific names. For example, A is often referred to as 'porcupine' style, B is more of a 'tree' style, C is a series of upwards pointing 'fingers', while D is referred to as a 'Georgia cube'. E is more like a 'spider' style whereas F (created out of plastic palettes and incorporating some tree material) is more 'tent' style. Photo Credits (all public domain): (a) Georgia Department of Natural Resources; (b) Florida Fish and Wildlife Commission; (c) Illinois Department of Natural Resources; (d) Georgia Department of Natural Resources; (e) City Water Light and Power; (f) Georgia Department of Natural Resources.

or waterfront property owners may also undertake such activities themselves. Many of the projects are 'do-it-yourself' where various plans can be found online (e.g. youtube.com/watch?v=r4J_HDl8oxg; wired2fish.com/fishing-tips/building-fish-habitat-to-enhance-older-lakes/; texasfishingforum.com/forums/ubbthreads.php/topics/10191294/DIY_Fish_habitats/attractors_o) and used to source and then construct plastic habitats. There are also bespoke products available from commercial manufacturers that can be purchased. Deployment typically happens from a large boat or barge with structures weighted down using heavy materials such as concrete blocks. These projects are often conducted with great fanfare including press releases and even politicians on site to celebrate the 'conservation' work. To authors (i.e. several scholars who work and teach in the realm of ecological restoration, freshwater ecology, and freshwater conservation and management), this is greatly troubling in that the addition of plastic structures to freshwater bodies is akin to littering. Ecological restoration remains imperfect (Suding 2011), but we know the value of using natural materials such as wood (i.e. logs, trees), rocks and native vegetation so are perplexed by the emphasis on plastics. Here, we outline a number of issues with these activities and the associated evidence base and then provide some suggestions for a path forward.

The Issues

Confusing habitat enhancement for fishing with restoration

Underpinning many of the issues related to use of plastics in restoration projects is confusion about their intended purpose. Many of the efforts that involve deployment of plastic structures are masqueraded as conservation or restoration projects but in reality are about making anglers happy. If placed in a landscape that is relatively void of structure, fish are attracted and anglers are afforded increased opportunities to easily target fish (Lindberg 1997). The locations of structures (maps and GPS coordinates) are intentionally shared with the angling public so they can be targeted. At best, this is about achieving a fisheries management objective and has little if anything to do with conservation or restoration. Even if these are properly called habitat creation or 'enhancement', they are not being done through an ecological lens (Bradshaw 1996). When organizations including natural resource management agencies and angling groups deploy plastic structures under the auspices of 'conservation or restoration', it serves to confuse the public that these actions are both necessary and in the best interests of the aquatic ecosystem. For the reasons we outline here, we submit that use of plastic in restoration is littering and not at all aligned with contemporary perspectives on restoration or conservation that are rooted in evidence. Moreover, it is widely accepted that form without the function or the function in an artificial configuration does not constitute restoration (NRC 1992; Hobbs and Norton 1996) – and in the case of plastic use as artificial structures – that is certainly the case.

Substituting natural substrates with plastic can disrupt ecosystems

Artificial fish habitat structures composed of PVC or similar plastics provide a semblance of usable habitat space for fish (e.g. Santos et al. 2011a; Sass et al. 2022), but what about the rest of the aquatic food web? Artificial structures mimicking plants may serve as an adequate facsimile of a macrophyte bed for fish, but this omits the important habitat provisions of aquatic plants. Aquatic plants supply energy and oxygen via photosynthesis, which is life-sustaining for all aerobic organisms, especially large sport fish. Rooted plants secure sediments, which increases light penetration and water clarity. Finally, aquatic plants are habitat for a myriad of other aquatic organisms, from bacteria to algae, zooplankton to macroinvertebrates – all of which are food for fish at various stages in their life cycle. Ultimately, using plastic waste to build artificial fish habitat ignores and displaces the components and essential ecosystem processes that remain missing when plastic is chosen over plants, woody materials, or rocks and boulders. For example, several studies have shown that benthic community composition is distinctly different on plastic substrates compared to natural substrates, and that some organisms/taxa are missing from plastic habitat (Kettner et al. 2017; Sanabria-Fernandez et al. 2018; Miao et al. 2019; Wu et al. 2019). Notable shifts in community composition can also alter the essential biogeochemical functions (e.g. decomposition, nutrient cycling) that microbes provide in aquatic ecosystems (Hoellein et al. 2014; Miao et al. 2020; Miao et al. 2021). This may not seem like an obvious problem for the fish (which plastic structures are designed to attract), but the indirect consequences are likely substantial if the aquatic food web cannot be sustained when natural substrates such as plants, logs and rocks remain missing due to habitat alteration (e.g. removal of materials) or in newly created habitats (e.g. reservoirs, artificial ponds).

Invasive species love artificial habitat structures

Artificial habitat structures are usually employed in disturbed ecosystems that need restoration. These same degraded ecosystems are also typically at risk of invasion by non-native species for several reasons, including open niche opportunities (MacDougall and Turkington 2005; Havel et al. 2015). Rather than enhancing habitat quality for native species, artificial habitat structures can favour colonization and establishment of non-native species (García-Gómez et al. 2021). In marine systems, where most research has occurred, sessile organisms such as invasive tunicates and bryozoans have been shown to prefer artificial substrates, including PVC (Geraldi et al. 2014; Pinochet et al. 2020). In an experimental system, invasive freshwater snails consumed more periphyton on simplified artificial substrates than complex substrates (Tramonte et al. 2019). In North America, invasive dreissenid mussels (zebra, *Dreissena polymorpha*, and quagga, *Dreissena bugensis*) can colonize soft sediments and hard substrates, but they tend to prefer hard substrates (Depew et al. 2021). Ackerman et al. (1992) showed strong adhesion of zebra mussels to PVC in substrate adhesion trials, and as such, PVC-based artificial habitat structures would be expected to provide ideal adhesion sites for dreissenid mussels. Overall, unintended consequences of deploying plastic structures in the name of restoration should be considered, particularly if those structures also favour ecologically damaging invasive species.

Plastic is pollution

Plastic pollution is a global environmental problem (Moore 2008; Welden 2020; Li et al. 2021). As countries around the world work to reduce plastic waste in the environment (Jia et al. 2019; Horejs 2020), it is contradictory to promote plastic structures as habitat restoration. Furthermore, plastics in the environment (including in aquatic systems) can break up into smaller plastic particles called microplastics and nanoplastics (Andrady and Zhu 2021; Sipe et al. 2022), leach plasticizers (e.g. di-(2-ethyl hexyl) phthalate) into the environment (Gunaalan et al. 2020) and release dissolved organic carbon that can be consumed by bacteria (Romera-Castillo et al. 2018; Sheridan et al. 2022). Ironically, a recent meta-analysis in freshwater systems suggests that microplastics are detrimental to fish (Hossain and Olden 2022) which alone should be sufficient evidence to abandon this practice. All of this suggests that although it may be possible to remove these plastic structures from freshwater systems, but physical and chemical traces of these structures could remain for decades. Further, PVC and ABS appear to be the more commonly used plastics in fish habitat structures; however, not all PVC and ABS are created the same way. Depending on the use and requirements, different materials can be added during production (Babinsky 2006; Hermabessiere et al. 2017). For example, plasticizers can be used to increase flexibility, and UV stabilizers and absorbers (of various sorts) can be added to improve longevity, but these additives can be harmful to biota (Teuten et al. 2009; Liu et al. 2020). We acknowledge that UVB rays are absorbed by water – usually by ~ 1 m — and attenuation would be even greater for turbid waters such that the use of UV stabilizers may not be needed. Nonetheless, it is unclear how these plastics will perform in underwater environments. Most testing has been in terrestrial environments (usually in buildings or underground as sewer pipes; Makris et al. 2020, 2021) with very little testing in water or for extended periods. In fact, the evidence base is greatest for underground applications (where there is no light and limited biological activity given that pipes are often laid in crushed aggregates) or for short term (usually <2 years) exposure to sun (see Folkman 2014; Makris et al. 2020, 2021). It is difficult to extrapolate these circumstances to aquatic environments. Relatedly, much of the work done on plastics assumes that the materials are new. Many of the restoration projects involving plastics are re-using materials that have been harvested from waste streams. Although it is laudable to re-use materials, it is unclear the extent to which that prior use may accelerate degradation or introduce other contaminants. Beyond the placement of these structures, many of them (especially the DIY ones) are assembled on shorelines or at boat ramps using drills and saws. These construction activities can also lead to the creation of microplastics that can easily get washed into surface waters. Such activities should not take place near surface waters given such a direct path of introduction. In short, the idea of adding plastic to natural waters is particularly puzzling given the major attention that has been given to plastics in the environment over the last decade or so and the mounting evidence base of the manifold negative environmental consequences that arise from such plastic pollution in aquatic systems.

Cradle-to-grave consequences associated with use of plastics

In addition to issues stemming from the presence of plastics in aquatic environments, there are many other cascading consequences associated with production. For example, the production of plastics contributes substantially to greenhouse gas emissions and global climate change (Nkwachukwu et al. 2013). Emissions are generated throughout the entire production process of plastic: extraction of raw materials, production and manufacturing, 'end of life' waste management and transportation of materials. Indeed, almost all types of plastic are derived from fossil fuels, and extraction of these raw materials produces greenhouse gases via direct emissions (i.e. methane leakage), fuel combustion and energy consumption (i.e. drilling) (Hamilton et al. 2019). The next step in the production process after extraction is refinement and manufacturing, which also includes energy intensive activities: the production of olefins (raw monomers), the polymerization of olefins into plastic resins and other chemical refining processes (Hamilton et al. 2019). After plastic has been used, waste management typically occurs across three pathways, landfill disposal, recycling plants or incineration, which are all associated with greenhouse gas emissions (Shen et al. 2020). Taken together, all steps of plastic production require infrastructure such as pipelines, transportation (e.g. access roads) or associated facilities, and this infrastructure results in intensive land clearing, use and alteration (Hamilton et al. 2019). The production of plastics can also result in negative consequences on freshwaters. For example, water injection during the fracking of fossil fuels can result in the addition of adverse chemicals (e.g. volatile organic compounds) to waterbodies and groundwater can also be infiltrated from plastic pollution (Nkwachukwu et al. 2013). This is all to say that use of plastics as artificial structures has broader consequences that alter climate (Hamilton et al. 2019), pollute the atmosphere and influence aquatic life. Sometimes materials that are used for construction of artificial structures are sourced from waste streams as opposed to being purchased as 'new'. Although this reduces material going into traditional waste management streams, it puts that waste into our aquatic systems. Reduce, reuse, recycle is certainly important, but dumping plastic waste into freshwater ecosystems is entirely inconsistent with the spirit of waste management or responsible freshwater stewardship (Sass et al. 2022). In some cases, the use of plastics is resorted to because of a lack of local wood to be used as more natural materials. However, when considering the cradle to grave (life cycle) of plastics (see Vahidi et al. 2016) and the fact that they (and the materials needed to produce them) were also transported, perhaps from the other side of the world, having to source wood (from sustainable harvesting operations) is simply the responsible thing to do. Sometimes easy and cheap comes at a cost and when it comes to our freshwater ecosystems, alternative natural approaches should be taken.

A weak evidence base to support use of plastics yet entrenchment of ideas

There are many DIY guides on how to build such structures. However, there are also several companies that manufacture and market such structures, often with unsubstantiated claims supported by nothing but photographs of fish hanging out around the structures (let alone scientific studies). There are several peer-reviewed studies that have now been conducted. Unfortunately, most of these studies suffer from weak experimental design (e.g. compare different types of plastic structures, but do not use non-enhanced or natural control groups; e.g. Driscoll et al. 2020; but see Baumann et al. 2016 for a good design) and fail to embrace the gold standard 'BACI' design (Before-After-Control-Impact; see Conquest 2000). Studies tend to be of short duration (often one season) making it difficult to determine if there is any long-term benefit (or negative impact). Moreover, most of the endpoints studied socio-economically important species (i.e. gamefish) and failed to consider the food web consequences (Sass et al. 2022). Interestingly, one of the few studies that compared enhancement using natural materials (sunken juniper trees) and plastic reported that fish abundance was nearly 10× higher on the sites enhanced with wood (Magnelia et al. 2008). Similar findings were reported by Rold et al. (1996) where cedar structures attracted more fish than polypropylene structures. Additionally, a recent thesis by Gates (2020) revealed that habitat amount or the presence of alternative physical habitats was more important to fishes and aquatic invertebrates than habitat material type or spatial arrangement suggesting no benefit of plastic structures relative to natural ones. In one of the few studies outside of North America, Santos et al. (2011b) deployed structures in an impoundment on the Parana River in Brazil. They reported that PVC structures were poorly colonized by neotropical fishes compared to ceramic and concrete structures. With few proper ecosystem level assessments, anecdotes beget action and ideas become entrenched even if interventions may not work. Essentially, groups do it as a result of dysfunctional information feedback as is common with fish stocking (Arlinghaus et al. 2022). Essentially, it is about trying to keep up with the 'Jones'.

Sending the wrong message to youth and the public

When it comes to the current popularization of dumping plastic habitat structures into lakes and reservoirs in the name of ecosystem restoration, one cannot ignore the similarities to Dr. Seuss' The Lorax. In that tale, the solution to tree over-harvesting was to replace them with synthetic trees. The moral of the story was that real trees have value not just for the animals in the forest but for the ecosystem services they provide people. Parallels can be drawn between the plastic trees of The Lorax (*sensu* Dr. Seuss) and the plastic habitat structures marketed to improve recreational fisheries. Pitching artificial habitat structures as an environmentally friendly restoration approach that diverts waste plastics away from landfills for a second life in the name of conservation and restoration is disingenuous. It may come across as an innovative form of 'upcycling', but in reality, it is a form of 'green-washing'. Promoting plastic waste as fish habitat not only minimizes the scope of restoration effort required, but it does not shift the ecosystem in a trajectory of natural succession. Marketing of plastic habitat structures also sends the wrong message to the public because it normalizes plastic consumption and associates waste as being environmentally friendly. Have some broken furniture you don't want? Help the fish by throwing it in the lake! Have an old car ready for the scrapyard? Save the fish by dumping it in the lake instead! Even more concerning is that youth (e.g. through outdoor clubs and schools) are often recruited to participate in the building and deployment of such structures, reinforcing the wrong message about ecological restoration and freshwater stewardship. We located a number of media articles that lauded the efforts of an individual youth or youth group in building and deploying plastic structures to emphasize our point.

Lost opportunity to focus on the 'real' restoration of freshwater ecosystems

Relative to other ecosystems, freshwater biodiversity is experiencing significantly more loss at an alarming rate (WWF 2020) and one of the main causes is habitat degradation, destruction or alteration (Dudgeon et al. 2006). As the goal of ecological restoration is to accelerate the recovery of a degraded biological community (Jordan et al. 1988), it is both counterproductive and even ironic to add (more) damaging plastic to struggling ecosystems. Further, restoration ecology is a solution-oriented discipline, whereby ecosystems are returned to a historical or pristine state (i.e. without plastic). Indeed, financial resources devoted to restoration are limited and should be used wisely, with the goal of yielding benefits for aquatic ecosystems (Cooke et al. 2018). The current crisis experienced by freshwater biodiversity requires dedicated time and resources that should be focused on effective techniques and actions that will truly contribute positively to ecological restoration (Lapointe et al. 2014). Due to the time-sensitive nature of the threats facing freshwater ecosystems, we encourage the use of actions based on the best available evidence, which involve the evaluation of intervention efforts in a rigorous, transparent and repeatable manner (Cooke et al. 2018). Broadly, the haphazard application of restoration techniques such as plastic 'habitat' structures represents not only a lost opportunity but could add 'fuel to the fire'.

Moving forward

Do no harm

A mantra of any restoration activity should be 'do no harm' (Cooke et al. 2018) – yet by using plastic materials, that basic principle is not met. From the purposeful construction of ABS, PVC and other plastics (and their associated environmental consequences from use of petrochemicals) to the eventual breakdown of these structures, use of plastic for 'restoration' is misguided if not irresponsible. There is a need for full life-cycle analyses of the use of plastics for so-called 'conservation' purposes. We also acknowledge that the use of artificial (non-natural) materials for restoration is not ubiquitous. For example, such methods are not allowed in Wisconsin, USA. Although there are some efforts to evaluate the effects of plastic structures, the endpoints are almost always focused on the presence/absence of fish or angler catch rates relative to areas without such structures. This fails to consider the broader ecological system (e.g. food web), nor does it consider the potential environmental consequences arising from breakdown of plastics over time or leaching. It is remarkable that natural resource management agencies responsible for enforcing regulations related to environmental pollution and littering are themselves encouraging or even deploying plastic structures. When it comes to restoration or environmental interventions, 'do no harm' should be an assumed goal (Cooke et al. 2018).

Develop a decommissioning plan

The concept of decommissioning plans arose in the context of large industrial, military or resource extraction installations. For example, it is a standard protocol today to have such plans developed prior to the approval of new mines (McHaina 2001) and nuclear power plants (Fellingham 2012). It is well known that restoration or habitat enhancement activities benefit from ongoing monitoring – both in terms of effectiveness (Roni et al. 2005) and to ensure some level of longevity of the restoration activities (e.g. that they do not immediately degrade; Sass et al. 2022). A core argument made for the use of plastics is its permanence – the idea that it will be here forever. Although it is true that plastics take exceptionally long times to break down, there are many reasons why a decommissioning plan should be developed (and funded) prior to deploying plastic-based structures. For example, the social license to use plastic in such efforts (if it has ever existed) could change over time requiring removal. Similarly, our understanding of the degradation of these materials in freshwater ecosystems may evolve such that it is determined by regulatory bodies that these materials should not be used. Although PVC pipe itself may last for some time, the adhesives that connect fittings or the cable ties used to hold pieces together will undoubtedly fail more quickly especially in systems with extremes in temperature, wave/current action or storm events. At some point, the structures will fail leaving a literal pile of trash on the bottom or shunted away by currents or storm events. We submit that any restoration or habitat enhancement project involving use of plastic materials (as described here) should have mandated monitoring for integrity of the materials and a funded decommissioning plan if and when the structure fails or if other circumstances require removal. There are lessons to be learned from decommissioning plans developed for artificial reefs in marine systems (Na et al. 2016).

Research is needed on plastic substrate breakdown and leaching

Research on the use of plastic materials for freshwater restoration has focused almost solely on biological endpoints related to the presence/absence of fish (abundance, biomass) with some assessments for structural longevity of the plastic, albeit over short time frames. Because plastic structures are being touted for their longevity, it is important to determine the extent to which these structures persist, with a focus on the breakdown and weathering of the materials (including the fittings/connectors that secure pieces). The literature is lacking in empirical studies that involve deployment of plastics in freshwater systems. The fact that PVC pipes are used for transport of potable water is often used as justification that the material is safe. Yet, such pipes tend to be buried or hidden between walls such that they are not exposed to light or other environmental elements. There are also many different forms of materials with different plasticizers and other additives (e.g. UV stabilizers) that could alter performance. In the presence of wave action, dynamic thermal conditions, biological activity and so on, it is unclear how these materials will perform and the extent to which they will shed microplastics or how polymers will weather or fragment. There are also unknowns related to short- and long-term leaching of materials which will again vary by material and the context in which it was deployed. Although a number of the commercial manufacturers of habitat structures use PVC pipe (and justify it based on longevity and apparent lack of degradation or leaching), there are also many DIY sites that advocate using a variety of new or discarded materials including various other PVC products (such as vinyl siding and vinyl blinds) and other plastic-based pipes. It is impossible to know all of the materials and their composition. Vinyl siding and blinds degrade in the presence of light over a period of time (facilitated because they are thin) and become brittle (embrittlement) leading to fracturing. If materials are 're-used' that have reached the end of their usable life on land, placing them in water would seem like a risky endeavour. This is not the spirit of 're-use' envisioned by those in waste management whereby material is diverted from landfills or recycling facilities to be placed in the bottom of lakes.

Natural materials such as logs and rocks should always be favoured over artificial materials

The notion that natural materials should be favoured in restoration and habitat enhancement efforts is well embraced by the restoration community and documented in the literature. There will always be exceptions (usually related to natural hazard mitigation; see Rey et al. 2019), but using natural materials and processes has many benefits (Bradshaw 1997; Jones 2013). In an ideal world, within several years of a restoration or habitat enhancement activity, there should be no evidence that it was done by humans. Materials should be selected and placed in ways that emulate nature and become part of the ecosystem (Sass 2009; Theis et al. 2022). In some cases, that means the longevity of habitat structures may be shorter than desired (e.g. as tree materials break down; Nagayama and Nakamura 2010); however, there is much room for testing different wood materials to inform material selection. Engagement with landscape architects (Davis 2000) and ecological engineers (Mitsch and Jørgensen 2003) could help to inform the development of structures that use natural materials, have reasonable longevity and create the level of complexity being touted by those creating structures out of plastic. There is no doubt that structural complexity is ecologically beneficial in aquatic systems (Newbrey et al. 2005; Sass et al. 2012) but that does not mean that it should be constructed of plastic.

Do not masquerade the creation of fishing opportunities as restoration or conservation

If plastic structures are used, it must be clear that it is for creating the structural elements of habitat that are missing (usually in a created reservoir) with the intention of aggregating fish that can subsequently be targeted by anglers. Plastic structures should not be part of the mainstream restoration toolbox. What is particularly disconcerting is that many organizations claim such work to be about 'conservation' (e.g. majorleaguefishing.com/archives/2005-04-29-fantastic-plastic/; thefishingwire.com/union-volunteers-build-85-fish-habitats/), when in reality there is no evidence of broader benefit to ecological structure or function (i.e. it does nothing but concentrate fish in areas where they can be targeted by anglers). In this way, these plastic structures may serve as ecological traps and more research is required to assess the population level consequences of these structures on freshwater fishes (Hale and Swearer 2016). Imagine if the MANY fishing organizations that currently focus their efforts on addition of plastic habitat structures engaged in meaningful ecological restoration that addressed key water quality issues or other constraints on fish populations (e.g. source water protection, riparian planting or even the addition of natural structures in systems where habitat structure is limiting)?

Consult other waterbody users, rights holders and stakeholders about use of plastic structures

We question the extent to which other users of freshwater systems have been consulted about the use of plastic structures in the contexts described here. Freshwater systems are typically multi-purpose and attract bird watchers, divers, kayakers, water skiers and so on. It is well known that outdoor enthusiasts have diverse perspectives and values related to nature and resultant engagement in pro-environmental behaviours (Berns and Simpson 2009; Derek et al. 2019; van Riper et al. 2020). We presume that individuals with perspectives that align more closely with nature and ecocentric views would likely be opposed to plastic structure initiatives. Of course, research on the social aspects of this topic is needed. What is clear is that anglers and fisheries managers alone should not be making these decisions without broader community engagement. Otherwise, there is strong potential for later conflicts which are common in multi-user freshwater systems (Gramann and Burdge 1981). Moreover, Indigenous rights holders should also be consulted given that they are the ultimate stewards of lands and waters and have legal and moral rights according to the UN Declaration for the Rights of Indigenous Peoples (Giunta 2019). Deployment of plastic structures would potentially conflict with Indigenous values and knowledges. There is also need for broader consultation with various environmental regulatory agencies. Even though use of plastic structures has been championed by some natural resource management agencies, those same jurisdictions also have agencies responsible for environmental pollution and protection. Those agencies should also be involved in considering whether plastic structures are appropriate.

Step up and step in: all hands on deck to restore freshwater ecosystems

We posit that stakeholders involved with plastic habitat structures have good intentions. We would like to use this opportunity to emphasize that their help is desperately needed to reach the goal of ecological restoration, particularly in freshwater systems (Cooke et al. 2022). The United Nations designated 2021–2030 as the 'Decade for Ecosystem Restoration' (Aronson et al. 2020) and the frontline of this movement will include diverse stakeholders including anglers, local communities, landowners, practitioners, Indigenous peoples, and scientists. To capitalize on the Decade, it will be imperative to work together and roll up our sleeves to implement restoration actions and techniques that are guided by evidence. Freshwater biodiversity is imperiled and we certainly need all the help we can get, but we also need those efforts to be effective and not cause additional environmental problems. The fact that so many individuals and organizations want to engage in freshwater stewardship is very promising, but if that effort is mis-directed towards efforts that are harmful, those efforts are counterproductive. It is time to ensure that freshwater stewardship groups are provided with an evidence-based restoration and habitat enhancement toolbox that includes strategies that truly benefit freshwater ecosystems (including fish). We appreciate that assembling plastic structures can be fun and may even be a form of creative expression, but that does not mean it is good for freshwater ecosystems.

Conclusions

Here, we report on a troubling trend of plastic materials being used for the restoration or enhancement of freshwater ecosystems. Indeed, the use of plastics in freshwater systems is being celebrated by outdoor media, angling groups and even natural resource management agencies (ms-sportsman.com/columns/plastic-in-lakes-not-bad/). A press release from the Kansas Department of Natural Resources in 2015 indicated that their goal as an agency was to produce and deploy between 150 and 300 PVC Georgia cubes per year for use in lakes (ksoutdoors.com/KDWP-Info/News/News-Archive/2015-Weekly-News/1-29-15/NEW-FISH-ATTRACTORS-FOR-KANSAS-LAKES). In one news story, it is reported that a single artificial habitat complex created out of plastics weighed over 7,000 pounds and covered 8,500 square feet (news-leader.com/story/news/local/ozarks/2019/01/16/artificial-homes-fish-reclaimed-vinyl-construction-material/2580347002/). We found a single example where an extension or outreach document explicitly dissuaded use of plastic structures and instead encouraged use of natural materials (extension.tennessee.edu/publications/Documents/W921.pdf), suggesting that others are beginning to take note of this issue. Moreover, some jurisdictions simply focus on providing guidance for using natural materials without explicit mention of plastics (e.g. Wisconsin DNR Fish Sticks Guidance Document on improving lake habitat with woody structure; p.widencdn.net/jcv7ac/Outreach_FishSticksBestPractices). It is difficult to estimate the scope and scale of such deployments, but they appear to be particularly popular in the United States, as well as other regions such as in impoundments in Brazil (Santos et al. 2011b) and Australia (Norris et al. 2021). Our literature searches were restricted to English, but we failed to find examples of plastic use for this purpose in other countries. Nonetheless, as the United States is often viewed as a leader in aquatic research and management, it is probable that these approaches will be embraced elsewhere.

We do not have all the answers. Is there a single smoking gun paper that we can point to that demonstrates definitively that use of artificial plastic habitats in freshwater ecosystems is harmful to aquatic life? No. However, there are a litany of reasons described above, from climate change to aquatic pollution (in various forms including microplastics and leachate), that support a rationale for reducing our use of such adverse materials. The intentional addition of plastics to imperilled freshwater ecosystems therefore seems nonsensical and short-sighted. The evidence base is sufficiently small that it is unclear whether these devices derive benefits beyond potentially aggregating fish for capture. However, what is even more concerning is our lack of understanding regarding the long-term deployment of plastic structures in freshwater ecosystems. Plastic pollution is a ‘hot topic’ these days and there is public and regulatory concern about how to address this issue. It is our perspective that dumping plastic materials into waterbodies under the auspices of aquatic restoration or fisheries enhancement is misguided. We contend that use of plastics in freshwater ecosystems for restoration or fisheries enhancement is simply littering. We predict that it is only a matter of time before the tide will change, and we will be investing funds to remove these structures from freshwater systems, not unlike what we have done with tire reefs in marine systems over the last few decades.

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Author contributions

SJC conceived and designed the study. SJC, MLP, JCV, and AEK drafted or revised the manuscript.

Conflict of interest statement

Cooke is a subject editor for FACETS but was not involved in handling this manuscript.

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