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A commentary on the role of hatcheries and stocking programs in salmon conservation and adapting ourselves to less-than-wild futures

Hannah L. Harrison[1] | Valerie Berseth[2]

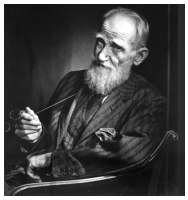
[1]Marine Affairs Program, Dalhousie University, Halifax, Nova Scotia, Canada

[2]Department of Geography and Environmental Studies, Carleton University, Ottawa, Ontario, Canada

Correspondence
Hannah L. Harrison, Life Sciences Centre, Room 809, 1459 Oxford Street, PO Box 15000, Halifax, NS B3H 4R2, Canada.
Email: hannah.harrison@dal.ca

Abstract

Hatcheries and stocking programs serve a variety of objectives, including the conservation of salmon populations. Much attention has been given to the importance of genetic integrity and adaptive capacity of salmon stocks, particularly as they interact with hatchery-origin fish. Literature on hatchery and stocking programs has increasingly focused on genetic indicators of quality and success, with genetically 'wild' salmon valued over hatchery-influenced salmon. However, conservation in the Anthropocene is challenging paradigms of wildness and definitions of conservation success. For salmon populations that exist on the ragged edge of climate change where threats are unlikely to be remediated to the status of ecologies past, definitions of 'wild' and the role of conservation hatcheries and stocking becomes convoluted. If definitions of 'wild' or 'natural' salmon depend on salmon archetypes situated in historic ecologies, then what do salmon futures look like? In that context, we argue to expand from primarily genetic criteria for conservation stocking to additional criteria cognizant of hybrid ecosystems and future human-salmon relationships. We draw on the concept of adaptive epistemologies within the context of conservation-oriented hatchery and stocking programs to critically reflect on knowledge paradigms and values that underlie salmon conservation stocking efforts and the changing ecosystems in which they are situated. We critique 'wild' discourses rooted in western thought and make suggestions toward a reimagining of salmon conservation-via-hatchery in the Anthropocene that allows for expansive human-salmon futures. Critically, we conclude with warnings against using the arguments in this paper as social permission to use hatcheries as a conservation panacea.



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Etymology of Ghot
George Bernard Shaw (1856–1950), polymath, playwright, Nobel prize winner, and the most prolific letter writer in history, was an advocate of English spelling reform. He was reportedly fond of pointing out its absurdities by proving that 'fish' could be spelt 'ghoti'. That is: 'gh' as in 'rough', 'o' as in 'women' and 'ti' as in palatial.
If you'd like to listen to an abridged and annotated version of this article, visit: https://doi.org/10.53962/kk47-wsmx

KEYWORDS
adaptive epistemologies, Anthropocene, conservation, hatcheries, salmon, stocking

1 | INTRODUCTION

In the Anthropocene, questions of how to manage wildlife and its ecosystems are ever-challenging (Cooke et al., 2019; Daniels & Mather, 2017; Steffen et al., 2017). Wildness or naturalness have emerged as benchmarks in some species as a delineation of whether humans may enact conservation and through what means. In both Pacific (*Oncorhynchus* spp.) and Atlantic (*Salmo salar*) salmon, the discussion of wildness and conservation approaches is exemplified within the debate over hatcheries and stocking as conservation tools, particularly in how 'wildness' and 'naturalness' are intertwined with understandings of fitness and values of maintaining biodiversity and adaptive capacity in salmon populations, and whether hatchery and stocking efforts are effective, successful, or 'good' in achieving conservation goals.

In recent decades, divergent perspectives over the use of hatcheries to stem losses or rebuild salmon populations have become contentious and polarized, particularly in contexts where non-hatchery-produced populations still exist. This debate is increasingly driven by a focus on the genetic and, more recently, epigenetic impacts of hatchery-origin salmon on non-hatchery-origin salmon populations. McMillan et al.'s (2023) recent literature review on the impact of hatchery salmonids on wild salmonids found 126 out of their 207 reviewed papers to report on genetic impacts (e.g. diversity), with 106 of those papers (84%) reporting adverse or minimally adverse effects. Within the broader literature, studies have demonstrated that hatchery production can produce heritable maladaptive genes and reduced fitness within just one generation (Araki et al., 2007; Christie et al., 2016; Larsen et al., 2019). These effects can produce deleterious consequences for salmon population dynamics and demographics, including changes in population structure (Eldridge & Naish, 2007), reduced effective population sizes (Christie et al., 2012; Hagen et al., 2021), altered migration and spawn timing (Nelson et al., 2019), early maturation (Larsen et al., 2019), replacement of 'wild' salmon with hatchery-origin fish (Bottom et al., 2021), reduced resistance to infection (Nekouei et al., 2019), reduced evolutionary fitness (Christie et al., 2014), amongst others. As a result, the risks of hatchery production extend to the broader populations of salmonids with whom hatchery fish interbreed, challenging the effectiveness of hatcheries as a conservation tool (Christie et al., 2014; Hilborn, 1992).

Yet, hatcheries continue to be used as conservation tools, particularly in places where salmon runs are in decline. Why does stocking persist despite the controversy? We have heard multiple explanations from our colleagues in the scientific community, ranging from the perception that local communities or managers are ignorant or naive of the negative or fruitless outcomes of stocking for conservation, to the more condemning language of Young's (North Atlantic Salmon Conservation Organisation, 2017) seven H's that point toward misplaced hope, hubris, habits, and other human frailties elicited (or perhaps enacted) by hatcheries in the pursuit of conservation outcomes. While these explanations may be, at least in part, true, observations in our own research suggest that they explain only part of a bigger story that is rooted in concerns for the future and a shifting calculus around the values of 'wild' within those salmon places teetering on the edge of climate-driven change and, potentially, irreversible loss.

In this perspective, we adopt a future-oriented lens to interrogate the role that hatcheries may play in salmon conservation at the advancing edge of climate change impacts. While much of the concern about genetic risks is attributed to large-scale hatchery production contexts, here we are focused specifically on hatcheries that produce salmon (*Oncorhyncus* spp. and *Salmo salar*) for conservation purposes. Our aim here is not to refute science demonstrating negative genetic (and other) impacts of hatchery programs on wild populations (which we generally support), nor to argue that hatcheries are a panacea for biodiversity loss (unequivocally, they are not). However, we question the merits of reductionist positions that overly simplify the multi-faceted and context-dependent issue of what constitutes an 'appropriate' salmon through definitions of 'wild'. We offer two arguments, followed by two warnings. First, the criteria for measuring the success of conservation hatcheries must be expanded beyond genetic reference points (and their relationships to fitness and adaptive capacity) or baselines of 'wild' salmon pasts as salmon social-ecological systems are disrupted by climate change. Second, the present debate is missing a broader engagement with the social and cultural contexts in which conservation hatcheries operate and the challenges communities face in conserving salmon relationships, which they will continue to face in a no-analogue future. We propose that the knowledge infrastructures (Hirsch & Long, 2020) surrounding salmon conservation-oriented hatchery and stocking programs must adapt to remain sustainable, useful, and relevant to the communities (human and non-human) in which they are embedded. Finally, we warn that our arguments should not be misinterpreted as permission to stock but rather are an effort to expand the salmon conservation stocking debate forward into new and more productive arenas.

2 | CAUGHT IN A LOSE-LOSE PARADOX?

Salmon hatcheries come in many shapes and sizes and operate based on any number of stated (and sometimes unstated) objectives, including restoration, mitigation (e.g. hydropower), fisheries enhancement and conservation. These objectives are, by and large, about the production of fish for various users or, occasionally, for the existence

of fish themselves or ecosystem approaches to restoration. We limit our focus to conservation-oriented stocking, which aims to 'restore extinct, endangered, or threatened populations, or to reduce the risk of extinction' (Naish et al., 2007:68). While some may argue that large-scale production hatcheries achieve conservation aims by increasing overall salmon population sizes, we specifically refer to stocking programs which generally operate at smaller scales, rely on local broodstock, explicitly aim to minimize the threats of introduction to non-hatchery populations, and are often (but not always) engaged in local communities of practice. Often, conservation hatcheries are used as a last line of defence against extinction, though the decision to introduce conservation-focused stocking activities varies across contexts.

In that context, the hatchery debate hinges on a central question: are hatcheries effective conservation tools? One's answer to this question can be broadly understood to stem from two endpoints on a spectrum of desired outcomes: (1) whether conservation hatcheries produce a qualitatively 'good' returning adult salmon capable of reproduction and (importantly) human use (which could include existence value) or (2) whether conservation hatcheries produce a genetically 'good' salmon that reflects 'wild' (non-hatchery-origin) historical genetic population and/or sub-population composition, does not detract from the total effective population, is capable of reproduction, and then human-oriented priorities. This latter set of desired outcomes aligns with priorities in evolutionary ecology, population biology, genetics, and ecology literature that prioritize 'wild'-type fish and situates conservation hatcheries in essentially a lose-lose paradox when used to support existing wild (sometimes called 'natural') populations.

The conservation hatchery paradox (Figure 1) can be described as such: On one hand, if conservation hatcheries 'work'—that is, produce meaningful numbers of returning adult spawners—those hatchery-origin fish create a variety of negative effects for existing non-hatchery-origin populations. Broadly, these effects can be created in hatchery-origin fish by both the contained rearing environment and the process by which mating pairs are matched. In other words, the fish they create are not sufficiently wild-type enough to interact in non-hatchery-origin stocks without consequence. As a result, a conservation hatchery and stocking program that successfully creates returning adults to spawn with/amongst wild populations is, ultimately, creating harm (of varying and context-dependent sorts) through the successful production of less-than-wild fish. In the context of climate change, there is particular concern about negative impacts on adaptive capacity.

On the other hand, if conservation hatcheries do not 'work'—that is, no meaningful production of returning adult spawners—they are perceived as a waste of money and effort, possibly to the detriment of other salmon conservation activities such as habitat improvement (Jaeger & Scheuerell, 2023). Further, any fish that do return may have deleterious effects on existing non-hatchery-origin stocks anyway.

This summary of the paradox facing conservation hatcheries is meant to be illustrative as it lacks the nuance and detail of many of the biophysical processes mentioned. It is further compounded by the challenges of effectively monitoring stocking efficacy (e.g. expense and managerial capacity). Similarly, we acknowledge some work refutes or gives exceptions to this cycle (e.g. Heard, 2012), and we strongly emphasize that hatcheries and stocking programs are deeply contextual, making it difficult to generalize perfectly across

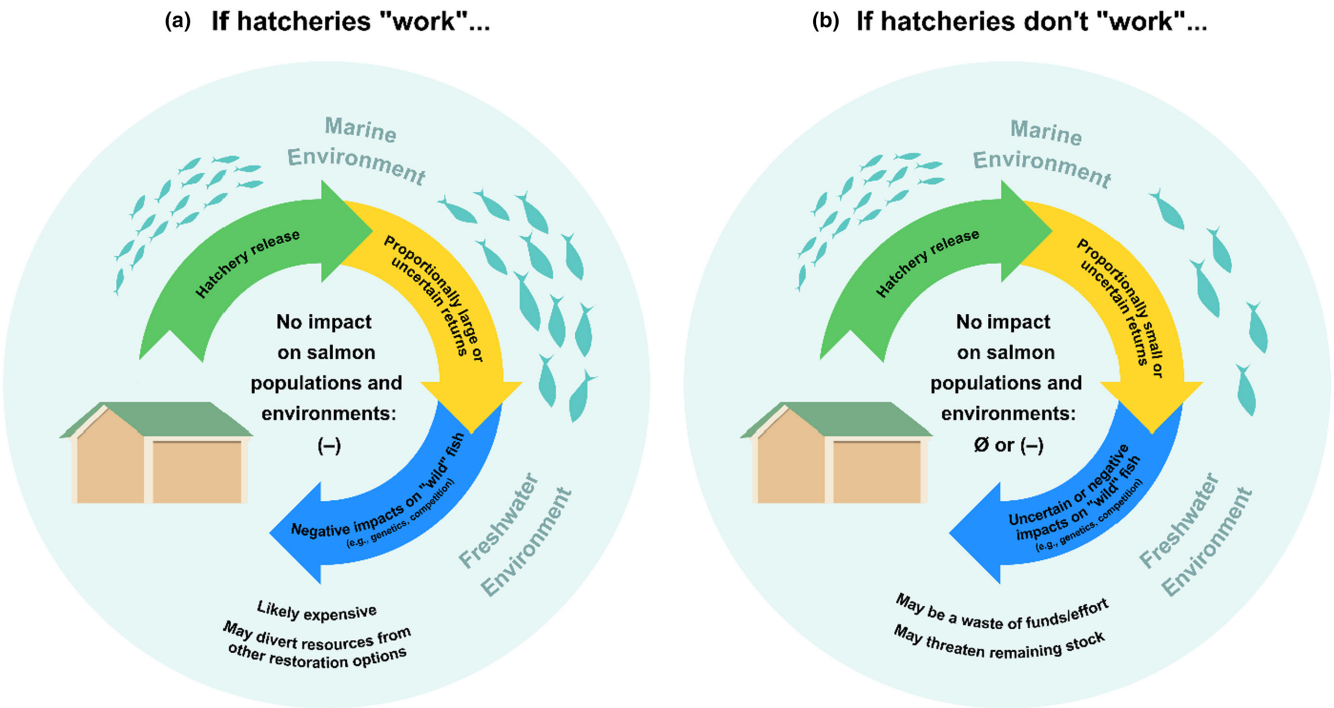

FIGURE 1 Simplified 'Lose-Lose' Conservation Hatchery Paradox.

these programs. However, we illustrate this paradox to demonstrate that the issue of 'wildness' within hatcheries, particularly in defining their effectiveness or appropriateness for conservation, is at the core of the hatchery debate.

This discussion has found a crucible in the genetics literature, specifically in how it delineates and defines wildness via genetic and epigenetic impacts wrought by the captive-rearing process on hatchery-reared fish and later by those fish on non-hatchery-reared conspecifics. As our understanding of genetics has improved, definitions of what distinguishes 'wild' and hatchery salmon have shifted from qualitative indicators (i.e. behaviour and appearance) to technically-driven definitions (i.e. fish multiple generations removed from hatchery-origin relatives) (Berseth & Matthews, 2021; Harrison et al., 2019). In response, jurisdictions across the salmon stocking world are responding by (broadly):

1. Reforming hatchery and genetic management plans to minimize the genetic risks by prioritizing and monitoring genetic diversity within stocked systems, though budgetary constraints remain a challenge (Mobrand et al., 2004; see example: Oregon Department of Fish and Wildlife, 2017, p. 10 Indicator 14(f)).
2. Pursuing the production of more 'wild-type' salmon through approaches such as captive habitat enrichment and hatchery reform.
3. Curtailing or eliminating conservation stocking programs all together.

Related to environmental governance trends toward ecological risk aversion (i.e. precautionary approach) and improved knowledge of the effects of the hatchery environment on salmon, some authors describe hatchery-based stocking programs as an exercise in hubris (North Atlantic Salmon Conservation Organisation, 2017, p. 20), or demonstrations of 'techno-arrogance' and 'half-way technologies' (Brown et al., 2013; Meffe, 1992). Others have prescribed conservation stocking programs as appropriate only in scenarios, 'where and when there are no wild salmon, or where and when the integrity of wild salmon is not a management priority' (North Atlantic Salmon Conservation Organisation, 2017, p. 24), where populations are exigent or in a state of being critically endangered where threats cannot be removed; in such cases, live gene banks (Lennox et al., 2021) or the 'capture, transport, and stocking of wild fry' (North Atlantic Salmon Conservation Organisation, 2017, p. 25) are suggested as best case approaches that prioritize minimizing the genetic (etc.) challenges of typical hatchery-driven programs.

To be clear, we share in the concern and critique of many hatchery and stocking programs from ecological, biological, and genetic points of view, including in the context of conservation-focused stocking. We also maintain that the social benefits of stocking do not alleviate the ecological problems, nor are they an excuse to stock irresponsibly (consider Grant et al., 2017; Lorenzen et al., 2010). However, we argue that these concerns are one part of a larger picture, wherein salmon-dependent communities are facing the potential of a future without salmon, and that additional factors relevant to assessing the efficacy of hatchery programs are missed by the aforementioned prescriptions.

3 | CONSERVATION FOR WHO, WHEN AND WHY?

Conservation-oriented hatcheries and stocking programs (and desires for them) often sit at the intersection of complex social-ecological systems. In some places, these systems have become the ragged edge of no-analogue climate futures and accompanying societal shifts. Hatchery programs conserve more than fish—they also support the continuation of human–salmon relationships. Where conservation work is undertaken by communities, hatcheries facilitate social and psychological benefits to those participating in stocking (i.e. habitat improvement work from hatchery volunteers) (Harrison, Kochalski, et al., 2018), act as locations where scientific and local knowledge may be used and hybridized together for conservation purposes (Harrison, Rybraten, & Aas, 2018), and can provide local employment opportunities (Amberson et al., 2016; Harrison & Gould, 2022).

The social outcomes of conservation hatchery and stocking programs are frequently left out of discussions of their value and assessment or are sidelined as less relevant to decision-making than the more easily measured economic, ecological or genetic outcomes. This helps explain why the hatchery debate persists, and new conservation stocking programs continue to take flight despite a sometimes-touted 'consensus' in the literature advising otherwise. While Young (North Atlantic Salmon Conservation Organisation, 2017) explains this as a series of errors in human attitudes, incentives, and understanding of risk and proclaims stocking to be stuck 'in a conceptual and operational rut (pg. 28)', we suggest instead that conservation approaches designed solely to adhere to biological or ecological outcomes are missing the inherently *human* endeavour that is conservation. In other words, conservation stocking for iconic salmon species often includes inexplicit social objectives that these programs may be successfully meeting, thus changing the calculus for local conservationists as to how they view stocking efficacy, measure success and evaluate risk. In other words, the hatchery conservation paradox is only true if social outcomes and objectives are not accounted for. To that end, genetics-driven evaluation of hatchery 'success' is poorly suited to account for or measure these social outcomes or to capture the evolving (re)conceptualizations of human-salmon relationships in a changing climate that cannot be measured solely by assemblages of DNA.

Moreover, the environment in which this calculus plays out is also changing. Record-breaking heatwaves, droughts, and extreme weather events have had devastating effects on salmon populations, and unprecedented disaster mitigation efforts are being pursued to mitigate mass mortality events (e.g. Kwan, 2023). With these competing ontologies of salmon conservation in mind, we see local-level practitioners and managers becoming trapped in a decision-making

vice in places where conservation hatcheries sit in rapidly shifting environmental and social contexts.

On one side of the vice, genetics-driven science and policy support the removal and/or reduction of conservation stocking, often with the potential for social conflict where social objectives and outcomes of stocking are threatened. On the other side, rapid environmental (and accompanying social) change that situate practitioners and managers in impending no-analogue climate futures where the only acceptable approaches to stocking-based salmon conservation are highly technical, often expensive and require significant technical expertise (i.e. live gene banks), or require existing fish stocks and intact yet underutilized ecosystem capacity (i.e. wild smolt redistribution), and the historical knowledge and technical ability to establish how genetically 'wild' salmon can be known in that system. In our experiences working with local salmon stocking communities and fisheries managers working with limited data and resources, this vice is squeezing out those in most need of a robust toolbelt of conservation options as they cope with the novel ecosystems of the Anthropocene (Hobbs et al., 2009).

Rather than further tightening this vice through polarizing debates over hatchery technologies, we ask: is it possible to approach these complex problems in a way that better allows local-level practitioners to work with the environments they have (rather than those of the past) while still giving attention to best available science and conservation practices?

Acknowledgement of the Anthropocene requires rethinking definitions of desirable ecological conditions, particularly in whether those definitions are achievable or, at the local level, practical (Daniels & Mather, 2017). For instance, Alexandra (2022) questions previous approaches to maintaining or restoring historic assemblages of organisms or habitats, arguing that 'linear projections or static views of "nature", "natural" systems or "natural" regimes for fire, water or biodiversity have limited utility (pg. 5)'. Similarly Hobbs et al. (2009) explain that many restoration projects are driven by a commitment to historical ecologies (and the 'good' qualities we often assign them) and attempts to reestablish 'past relationships between people and ecosystems.'

But, if those past relationships (and we are referring here to the recent past, wherein human-ecosystem relationships practised by Indigenous Peoples for thousands of years have been fundamentally disrupted and altered through colonization, industrialization, and urbanization (Atlas et al., 2021; Dick et al., 2022)) between people and ecosystems have led to our current state of biodiversity loss, cascading natural disasters and such environmental crises, should we be striving to recreate or preserve them? Do they serve the social-ecological future toward which we are moving? If our previous nature-endorsing approaches have continually separated humans from nature and wildness, how do these views stand up to the inherently nature-sceptical reality we now occupy, where the delineation between human and nature has become nearly impossible to identify (see Soper, 1998 and other work)? As the Anthropocene situates system-wide threats as likely to only be mitigated and never removed, these arguments require that conservationists rethink their adherence to past ecological baselines and the relationships with nature based upon them.

It is with these questions in mind that we offer a multi-faceted critique of the current genetics-driven approach to defining wildness in salmon conservation and, consequently, what technologies may be permitted for (particularly local) conservation work.

4 | RETHINKING 'WILD' IN THE ANTHROPOCENE

The literature debating concepts of wildness are multi-disciplinary and wide-ranging, spanning fields of restoration ecology to philosophy. In the hatcheries literature, wildness is complicated by the mixing of hatchery and non-hatchery-origin fish genetics, and their offspring—new assemblages of 'wild' and 'non-wild' genetics—are less 'wild' and, by extension, less fit. Though from the riverbank or end of a reel they may seem qualitatively and behaviourally 'wild', they fall neatly into neither category. The offspring of these half-wild/half-not-wild fish are even more complex as more permutations of wild and non-wild interactions occur, particularly if they are part of salmon populations that have been introgressed by hatchery-origin fish for many years. Where does one (can one?) draw the line between 'wild' and what is somehow less-than-wild? And on balance, how much does wildness matter in how we construct the future and reckon with the past (Collard et al., 2015)?

In practice, some policies draw this line according to lineage, where wildness is a function of generational distance from hatchery origin (Berseth & Matthews, 2021; Irvine, 2009) with the goal of maintaining of effective population size. In the United States, for example, offspring of hatchery-born parents can be considered natural origin fish as long as they were born from parents that spawned 'in the wild' (National Marine Fisheries Service, 2018). Meanwhile, in Canada, salmon must be at least two generations removed from hatchery origin before they may be considered 'wild', irrespective of the origins of fish prior to those two generations (Fisheries and Oceans Canada, 2005, 2022). These definitions of wildness for an anadromous, border-crossing fish and the consequences such definitions bring to deciding appropriate and acceptable conservation technologies can seem, in some contexts, poorly aligned with the realities of conservation work. Crucially, this metaphorical teasing of alleles misses critical aspects of what makes salmon the important fish that they are, and how human-fish relationships play out.

First, definitions of wildness-by-genetics centre western science to the exclusion of other ways of knowing and relating to salmon, and doubles back to ideas of Edenic nature and 'places untrammeled by man' (Kareiva, Marvier, and Lalasz 2012, and in line with Cronen, Collard et al., 2015). This colonial mindset in a sense re-tools Meffe's (1992) original argument of techno-arrogance (1992), a potential exercise of colonial arrogance (or violence?) through western technologies and interventions. Indigenous communities around North America (and elsewhere) have stewarded relationships with fish since time immemorial (Dick et al., 2022; Thornton et al., 2015).

Delineating wild fish only by genetic measures devalues these long-standing relationships and worldviews that hold fish and human in relation to one another, critiques that have been offered by Indigenous voices and scholars (Fletcher et al., 2021; Silver et al., 2022), yet are largely ignored in the conservation stocking debate. In this sense, the 'shackles of wilderness' (Fletcher et al., 2021) are inappropriate and dehumanizing constructs that can further alienate Indigenous (and, arguably, non-Indigenous) societies from salmon relationships that may carry them into an uncertain future.

Second, wildness-via-genetics also presents a paradox of simultaneously techno-defined and human-absent wildness (i.e. Edenic nature), which makes wildness practically inaccessible to the category of local salmon conservationists and practitioners with whom we often work. If live gene banking programs are the only acceptable conservation stocking solution, and only when populations are so critically endangered or exigent that any human–salmon relationship with them has already been restricted or prohibited (i.e. angling, food or ceremonial harvest), this suggests that wildness in the Anthropocene is (again) an exercise in the extraction of a valuable resource that can only be measured by the right technologies and becomes the property of those institutions who define and control the assemblage of genetic material deemed necessary to achieve robust effective populations size (see Collard et al., 2015). In essence, the argument that conservation hatcheries should be removed on the basis of genetic risks is effectively drawing lines around how fish 'should' be: a set of values to uphold and maintain through current epistemologies and western-derived visions of nature which require increasing technology and scientific policing to define and create. In our experiences, such criteria and values are ineffectual at accounting for the social benefits (Harrison, Kochalski, et al., 2018) to communities (particularly in rural areas) in which hatcheries are embedded. As a result, they cannot accurately account for the public support that hatcheries receive (Berseth, 2022) nor the interest in new hatchery programs, particularly as seen in some Indigenous communities (Braun, 2022; Herz, 2023; kʷikʷəƛəm Kwikwetlem First Nation, 2022).

Similarly, while we may attempt to define wildness through genetics, this does not translate across multi-national policy regimes where definitions of wildness are shaped by interactions between scientific, social and cultural processes. As a result, wildness varies across borders and over time where a 'wild' salmon on one side of a border loses that status the moment it crosses an invisible, political boundary (Berseth & Matthews, 2021). While salmon are able to traverse the cultural and social relations between nations and states, it would seem our definitions of their appropriateness struggle to do the same.

With these critiques in mind, we argue that decisions about the role of conservation hatchery and stocking programs in the social-ecological systems of the future cannot be based solely on genetics or biological criteria. We instead ask: how can we achieve good, socially robust and adaptive systems around hatcheries and stocking programs for salmon (and human–salmon relationship) conservation, and the conservation of salmon futures?

5 | ADAPTING OURSELVES TO SALMON FUTURES

The impending spectre of climate change-driven loss paired with narrow definitions of appropriate salmon are squeezing practitioners, communities and managers interested in salmon conservation into immobility (Figure 2). Rather than arguing that hatcheries (or other conservation approaches) only belong where the worst has occurred (extirpated or near extirpated populations; to add an 8th H, a 'hail-mary' scenario (Minke-Martin, 2022)) or where 'wildness doesn't matter', perhaps these flawed conservation technologies can be reimagined as facilitators of epistemologies that can rekindle human–nature–salmon relationships and adapt together for the novel ecosystems of the future, and those that are already here. In other words, conservation hatcheries, when operated using best practices, in appropriate places and times, and with appropriate monitoring and evaluation, can be facilitators of stewardship that

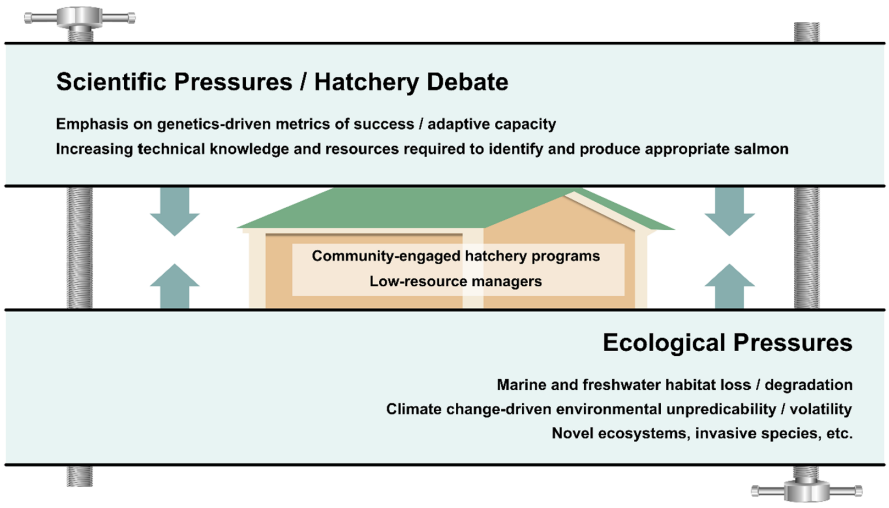

FIGURE 2 Conservation hatcheries and stocking programs caught in the decision-making vice.

(re)forge biotic and abiotic nature-sceptical stewardship for these 'ragged edges' of the salmon world.

Heller et al. (2023) argue that conservation is undergoing a paradigm shift towards 'stewardship-conservation', whereby top-down, command-and-control approaches to managing the environment are giving way to an embrace of ethical and reciprocal relationships between humans and ecosystems. We optimistically agree and suggest that acknowledging how humans and nature are inextricably intertwined and co-dependent could adapt dominant epistemological paradigms toward embracing that humans have long depended on salmon, and that in the Anthropocene, some salmon populations (and certainly human–salmon relationships) may now depend upon human intervention to persist. To do so, it is not enough to only make changes to conservation practices; adapting ourselves requires a deeper transformation in the epistemic culture that constitutes human-salmon relationships and our scientific definitions of how those relationships may take place. Supporting this paradigm shift in the context of salmon conservation hatcheries will require flexible approaches (e.g., adaptive co-management) as well as adaptive epistemologies in the scientific community that re-evaluate what is 'good' against what is practical, liveable and responsive to the future.

Adaptive epistemologies build on studies of knowledge and justified belief by challenging how scientists deal with environmental change or socio-technical transitions, such as those presented by conservation hatcheries and stocking in the context of climate change and complex human–salmon relationships. Hirsch and Long's (2020) study of adaptive epistemologies in the Columbia River Basin provides a compelling basis for envisioning an alternate future for conservation hatcheries. They document several adaptation strategies that are enabling a shift towards more flexible and stable knowledge infrastructures: (1) modelling future ecosystem states to design restoration programs; (2) designing physical and social infrastructures for longer time horizons; and (3) embracing interdisciplinarity and diverse knowledge systems. While hatcheries and their associated stocking programs, particularly when operated carelessly or in ignorance of best practices, can most certainly be harmful to salmon conservation goals, the cultivation of salmon can have value to the human ecologies that surround human-salmon relationships and environments. In our eyes, conserving those relationships, even if occasionally through flawed technologies, is critical to the conservation of salmon themselves. Genomics and other modes of natural science are, without question, critical to creating adaptive conservation plans (and populations) for salmon futures; however, they must be considered as a tool in a broad social-ecological suite of management approaches and not the penultimate definition of what salmon is good, appropriate or valuable. Indeed, as we write this, the global ocean surface temperature is breaking historical temperature records (Source: Climate Reanalyzer, University of Maine, 11 September 2023), and it could be that in the future, any salmon, regardless of origin or 'wildness', is one worth keeping.

These epistemological shifts must be accompanied by transformations in the broader colonial structures, objectives, and mindsets that structure fisheries science and management (including state-run hatchery systems) (Silver et al., 2022). It is more urgent than ever to re-examine the reliance on western scientific criteria for evaluating success and reimagine alternative futures, 'making room' for other ways of knowing and relating to salmon (Latulippe & Klenk, 2020).

The concerns of salmon conservation stocking are not alleviated by social considerations, but rather give theoretically expanded room to evaluate hatchery and stocking efforts. We frequently hear calls from fisheries managers for stronger tools to incorporate and balance the social and ecological considerations of the systems they manage. To that end, we are working to develop a framework that will allow for the incorporation of socio-cultural considerations into the difficult decision of when, how, and where (not) to stock for salmon conservation. We reiterate that it is essential for hatchery programs to establish clear social objectives and corresponding evaluation criteria for a wide range of areas, including clearly stated socio-ecological objectives, robust community engagement, equitable benefit sharing and the facilitation of cultural practices tied to human–salmon relationships. This also includes the need for exit strategies or off-ramps should objectives not be met, as well as careful attention to the process of decision-making throughout (Figure 3).

6 | CONCLUSION: FINAL THOUGHTS AND WARNINGS

In this perspective, we explore the salmon conservation hatchery and stocking debate through the lens of change—both in the environment and in ourselves. We argue that the means of measuring the success of salmon conservation hatchery and stocking programs should include, and go beyond, genetic reference points, which may mean rethinking our scientific relationships with baselines to 'wild' salmon ecologies of the past as we hurtle forward into the Anthropocene. We suggest that the present hatchery debate is missing a broader engagement with the social and cultural contexts in which conservation hatcheries operate and the vice-like challenges salmon communities face in conserving salmon relationships. We argue for the value of adapting not only our conservation technologies but also our own epistemological assumptions and positions and suggest ways forward for reimagining hatcheries as conservators of human-salmon relationships.

That said, we conclude this article with acknowledgement that our arguments here may be perceived in two ways: (1) as ignorant and promoting of shifting ecological baselines (Pauly, 1995) and (2) tacit permission for the proliferation of salmon stocking programs in the name of conservation. We warn against both of these potential conclusions.

First, shifting ecological baselines is contingent on human forgetting; that is, new generations of managers forgetting or never seeing the ecological quality or abundance that forms a true baseline against which to assess management efforts broadly. Our argument is not to forget or ignore but rather to look forward to futures that await us with clear eyes and reasonably question whether

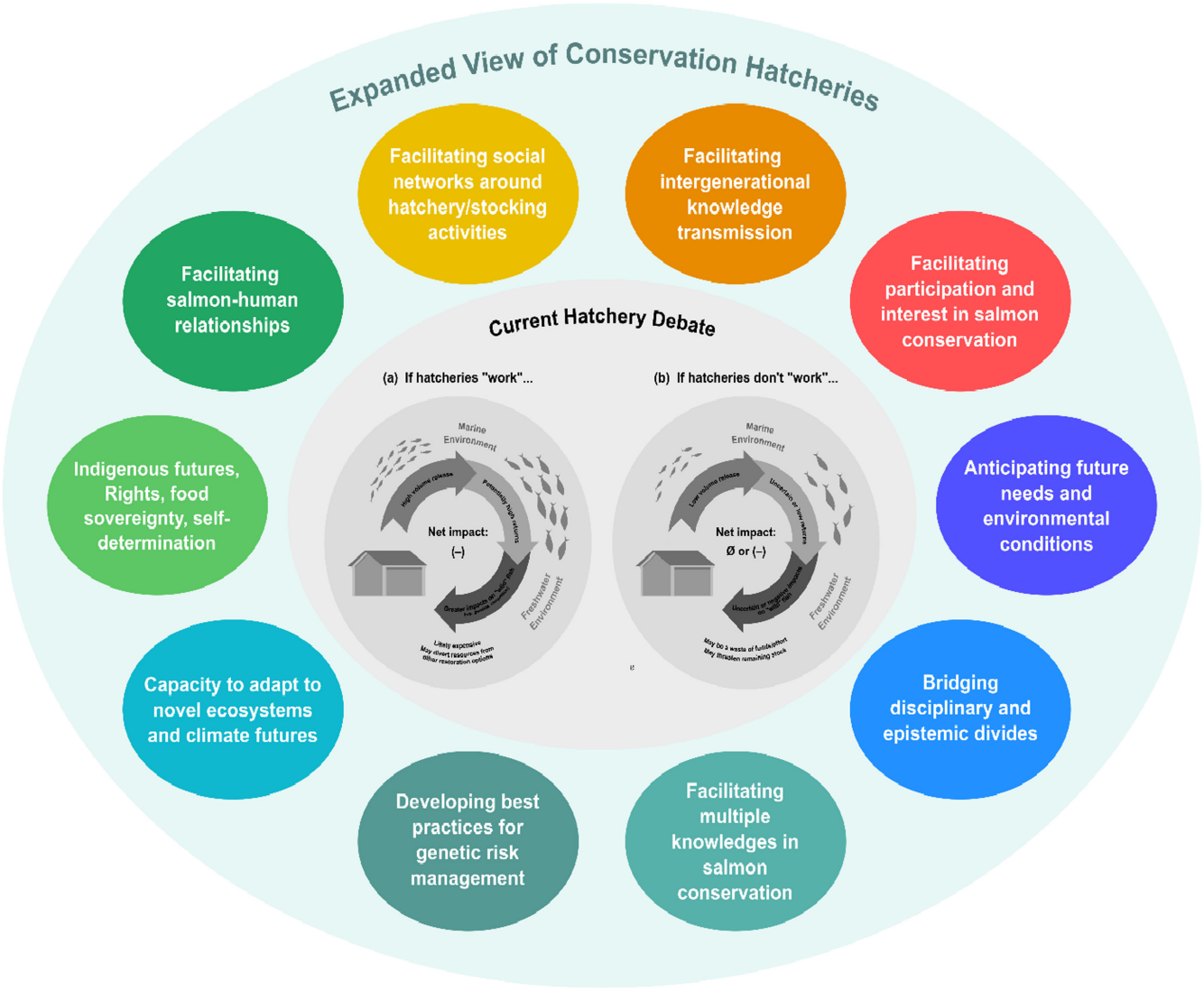

FIGURE 3 Expanding the conservation hatchery debate through adaptive epistemological lenses and knowledge infrastructures.

our standards, methods, and ways of thinking are appropriate for salmon, and ourselves, in places that meet the contexts laid out in this paper.

Second, we reiterate that we share high-level agreement with the many-faceted critiques levelled against salmon stocking programs; hatcheries produce risks for non-hatchery-origin fish and their ecosystems, and these risks are significant in conservation-focused stocking programs. Our arguments in this paper should not be construed as reasons to excuse or ignore those risks. Whenever possible, risks of all varieties should be minimized, objectives of hatcheries and stocking programs should be clearly stated, time-bound and monitored, and best cultivation practices should be followed. Ultimately, conservation hatcheries are inherently a bandage over deeper problems, and any hatchery or stocking program should come, at minimum, in tandem with efforts to improve upon those root problems. As stated before, sometimes the best solution will be to close a hatchery program or avoid establishing one altogether.

However, we also see a broader, more complex picture of the social–ecological environment in which conservation hatcheries and stocking programs are embedded. We encourage all participants in the conservation hatchery and stocking debate to think critically about how, as Thorstad et al. aptly describe, 'policies and decisions that disconnect people from wild salmon, or cause them to feel alienated from conservation efforts, can be counter-productive to long-term conservation goals' (Thorstad et al., 2021). We agree strongly with their call for 'innovative solutions' that maintain human connections to salmon (if perhaps not in the mode of connection-making) and suggest that a new-to-this-debate paradigm—one that is grounded in those relationships—is needed to advance debates about wildness and the role of conservation hatcheries in human–salmon futures.

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CONFLICT OF INTEREST STATEMENT

The authors state no conflict of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

ORCID

Hannah L. Harrison https://orcid.org/0000-0002-1411-4039

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