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How value conflicts infected the science of riparian restoration for endangered salmon habitat in America's Pacific Northwest: Lessons for the application of conservation science to policy

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ABSTRACT

Conservation policy relies on input from science, yet scientists are often frustrated by the 'gap' between their recommendations and policy decisions. In this paper we examine one such 'gap': how a long-standing conflict of values functioned to 'infect' the synthesis and application of riparian science for salmon habitat restoration projects. We do this by analysis of a policy debate over the required minimum width of riparian buffers in voluntary conservation programs on agricultural lands in the Puget Sound region of Washington State. Based on an analysis of expert interviews and document analysis, we first outline the key features of the values debate. We then show the ways values 'infected' the debate over the science of riparian restoration. We identify a set of four 'stumbling blocks' in the science to policy gap that together led to both an intractable debate and an over-simplification of the science: conflation of science and policy, application of science out of context, limited consideration of alternatives, and obscuring debate via technical and bureaucratic language. We conclude with a set of 'waypoints' that can help ecologists, conservation managers and policy makers to better navigate the journey from science to policy.

1. Introduction

In Western Washington State controversy erupted in 2011 over demands by treaty-holding Native American tribes for stricter regulation and enforcement to protect salmon habitat. Passionate debate focused on salmon habitat restoration programs targeting agricultural land. We focus on one especially contentious proposal regarding the appropriate width for restored riparian habitat on agricultural lands: are 10-meter buffers sufficient to provide salmon habitat or should 30-meter buffers be required?

The current controversy sits within a larger, longer debate about what actions and sacrifices should be taken (and by whom?) to protect salmon (Breslow, 2014). Salmon are a cultural keystone species for Native American tribes (Garibaldi and Turner, 2004), regional icon, and important commercial fishing resource. Efforts to address salmon declines extend decades in Washington State, as does opposition to such efforts by the agricultural community. For example, over 20 years ago Eastern-Washington farmers fiercely opposed proposals to remove three dams in an effort to open up salmon habitat. The debate has come to focus on natural science and Western law, in large part due to the efforts of Native American tribes (Breslow, 2014).

In studying this case, we address intended (but also actual empirical) interaction between values, policy, and science. Prescriptive work addresses ways values and science ideally interact in creating environmental policy, via structured processes or participatory dialogues (Gregory and Wellman, 2001; Ryfe, 2005). When applied well, such approaches are effective (e.g. Failing et al., 2012). Yet empirical studies show often such guidance is not heeded. Requirements for 'science-based' decision making can force values to become 'invisible' or 'fugitive;' in these cases decision-making takes the shape of a values debate cloaked in scientific language (Satterfield and Levin, 2007; Turner et al., 2008; Witter and Satterfield, 2014). But do fugitive values also have an impact on production of scientific conclusions—and not just application? When values are excluded from science-policy, do they shift to occupy science?

We explore mechanisms through which determining the 'adequate' width for riparian buffers came to be reified—and how that width was contested. We begin by asking: How did riparian restoration become an intractable problem? And why was a small rule change in buffer-widths important to the tribes and opposed by farmers? We explore these

Abbreviations: CREP, Conservation Reserve Enhancement Program; NOAA, National Oceanic and Atmospheric Administration

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questions by revealing unexpected ways that science and values were used in a riparian-restoration controversy over minimum riparian buffer-widths within the Washington State Conservation Reserve Enhancement Program (CREP). We elaborate value and paradigm differences, elicited via interviews and document analysis, and discuss how riparian science shaped—and was shaped by—policy. In sum, we analyze how, as one informant explained, "riparian buffers" became "fighting words."

1.1. Debates at the intersection of values, science and policy

The need to understand multiple dimensions of value in conservation science and policy has recently received attention both in academic literature on the emerging concept of relational values (Chan et al., 2016; see also Betts et al., 2015) as well as in the science-policy platform IPBES, which emphasizes nature's benefits or value importance to people (Díaz et al., 2015; Pascual et al., 2017). Such efforts acknowledge that 'value' has many meanings, including economic value, ecological value, values as principles, as well as values as lay philosophies of concern (Arias-Arévalo et al., 2018). Similarly, Tadaki et al., 2017 refer to values as magnitude of preference, as contribution to a goal, as an individual priority, and as relations (2017). Together these definitions reflect the fact that there are many value languages, each of which highlights different modes of expression and meaning, and/or accept the incommensurability of some values (Avcı et al., 2010; Martinez-Alier, 2008; Trainor, 2006). Most of these definitions and reviews also reference the value fundamentals first designated by O'Neill, Holland & Light, and summarized as three ways of environmental concern: living well from the world, living well in the world, and living well with the world (2008). In what follows, we reflect this multi-dimensional tradition of value meanings, while also accepting that value discourse is often narrative in form and thus 'thickly' expressed as bundles or layers of politically-valanced principles and beliefs along with valued entities or states (Klain et al., 2014; O'Neill et al., 2008).

We also accept that most science-policy debates are value debates. For example, Jasanoff (2005) has shown the value-basis of the GMO debate in Germany and the US. Satterfield and Levin (2007) show the value-basis for a debate about restoration of a former nuclear-testing site. Oreskes and Conway (2012) has shown how values—and power—shape the debate over climate science. These authors show, in particular, that when discussion of values is precluded or silenced in controversial science-policy debates, those value debates simply shift to occupy science.

Methods exist to address this fact. From local to regional scales deliberative approaches have been developed to guide the integration of science and stakeholder values in contexts of participatory decision making (Gregory et al., 2012), assessment processes (Farrell et al., 2001), public participation and deliberative democracy (Beierle, 2002; Dietz, 2013; Ryfe, 2002), and environmental policy and planning (Bennett et al., 2016; Satterfield et al., 2013).

Yet we remain less clear about how value debates infuse or infect science-policy claims as these debates unfold over time and when serious deliberation of options does not occur. We fail to understand, in other words, when and how value debates become intractable and so often paralyze policy responses. Importantly it is often these very cases of intractable values and paralyzed policies where 'best available science' is sought as a solution, in essence, asking 'more of science than it can deliver' (Gregory et al., 2006, p. 781).

In what follows, we tackle this gap between value position and scientific insight via the example of riparian restoration. Our purpose is to illustrate how 'cleansing' policy debates of value considerations can be the very undoing of the intended policy itself. Specifically, we identify the mechanisms by which the definition of an adequate buffer—using width as the single metric—became reified as government scientists were asked to define and defend riparian-restoration recommendations. Our argument is that however much each position within the debate reflected value-specific and politically strategic ends (i.e., protecting what each group valued as an outcome for riparian zones), the escalating focus on scientific and technical aspects functioned to obscure value positions, ultimately hindering productive or deliberative discussion.

2. Methods

Our site—the Puget Sound—is a region of Washington State, characterized by several watersheds which drain into a common ocean sound. We focus on two groups: (1) the Treaty Rights at Risk movement, a group formed to protect the treaty rights of Native American Tribes and (2) Conservation Districts, government funded but non-regulatory organizations that implement voluntary conservation programs. Access to both interviewees and materials was facilitated by our team's close work with two local organizations: the Snohomish Conservation District and the Puget Sound Partnership. Data collection and analysis were informed by local partners and our previous research with farmers in the area (Chapman et al., 2019).

Twelve expert interviews (Flick, 2018) were conducted with staff members from Conservation Districts (3), state and federal agencies (4), tribal organizations (3), and local/regional government (2). Interviews are referred to in the text as e.g., [Interview01].[1] Interviews focused on: a) opinions about agricultural land management; b) respondent's own environmental values; c) experiences and views of current proposals regarding riparian buffer program rules. Interviews were conducted by the first author in November 2016, lasted between ½ hour and 2 h and took place by phone or at participants' offices or homes.

We reviewed over 50 documents based on our knowledge and interviewee's suggestions. These included: reports, white papers, meeting minutes and agendas, documents shared as part of meetings (technical documents, letters), videos, images, newspaper reports, blog posts, PowerPoint slides, technical guides, summaries of legal proceedings, websites and, in a few cases, commentaries provided by interviewees. We then selected three groups of documents (19 individual documents) for detailed coding and analysis (selection listed in Supplementary Information and referred to as e.g. [Doc 1] below). Document selection comprised covering key decisions in the buffer-width debate, providing descriptive value language, and achieving diverse perspectives.

The first author coded interview transcripts and documents using NVivo qualitative analysis software and analyzed both interview transcripts and documents focusing on themes of values and paradigms (results in Section 3) and the use, synthesis, and application of riparian science (results in Section 4).

In addition to the 19 documents coded and analyzed, we applied a 'forensic' approach to understand how riparian science was translated into policy synthesis. This involved tracing scientific conclusions and figures across scientific papers and government reports on riparian science (cited as references in text).

3. Value conflicts contest the future, not the science

3.1. Treaty rights at risk

Salmon are key resources guaranteed to over 20 Western Washington tribes with whom the US government signed treaties in 1854–55. These treaties granted tribes the right to fish *"at usual and accustomed grounds"* [Doc13]. These resources, including salmon, but also elk and deer, oysters and clams, are essential to many dimensions of tribes' way-of-life. An Upper Skagit Tribal member explains: *"It's not just fishing, it's all of it. It's the hunting, it's the gathering, it's the commercial*

[1] While all interviews informed our analysis, only those sections of the paper that refer explicitly to insights or direct quotes from interviewees are specified. Interviewees are not further specified in order to maintain confidentiality.

side of it; it's the subsistence side of it; it's the religious component of it; it's the traditional side of it. It's like 'who are these people?' Probably a good part of the treaty represents who the Indian people are" [Doc17, #6]. When tribes signed treaties, they assured protection and access to their most important resources. Securing this right in practice took decades of efforts known as the Fish Wars, including "Fish-Ins" where tribal members were often arrested for exercising their treaty-guaranteed rights by fishing at their traditional grounds. The struggle is captured by a quote from Chief Red Cloud: *"They made us many promises, more than I can remember, but they never kept but one; they promised to take our land, and they took it"* [Doc13].

Finally, the 1974 Boldt decision firmly established tribes' right to fish half of the harvestable salmon and established tribes as co-managers of the salmon resource [Doc13]. However, without sufficient salmon to fish, this treaty-guaranteed right was and is essentially meaningless. Therefore in 1980, a further ruling confirmed the responsibility of state and federal agencies to protect salmon, in light of tribal treaty-rights. Regardless, four of eight anadromous salmonid species native to the Puget Sound are threatened under the Endangered Species Act: Chinook (*Oncorhynchus tshawytscha*), Hood Canal summer chum (*Oncorhynchus keta*), steelhead trout (*Oncorhynchus mykiss)* and bull trout (*Salvelinus confluentis*) (Washington State Recreation and Conservation Office, 2017).

In response, tribes published a white paper in 2011, "Treaty Rights at Risk: Ongoing Habitat Loss, the Decline of the Salmon Resource, and Recommendations for Change" [Doc12]. The white paper and associated campaign laid out a suite of policy recommendations and called on US federal agencies such as the National Oceanic and Atmospheric Administration (NOAA) and the US Environmental Protection Agency to take leadership to protect endangered salmon. The white paper and associated campaign criticize federal agencies for tightly restricting tribal fishing while much less regulatory pressure is placed on habitat concerns. These demands can be best understood in a broad historical context of exclusion. For example, overlapping the debate about the width of riparian buffers, was a lengthy legal battle over the many culverts under state-managed highways that blocked fish passage and access to upstream habitat. After a series of court battles and appeals beginning in 2001 and leading all the way to the US Supreme Court, in 2018 the Court confirmed the tribes' right to protect fish habitat (e.g., by demanding that state agencies remove habitat-blocking culverts) (Du Bey et al., 2019). As such, tribes efforts for access to and protection of their treaty guaranteed rights have involved a long "uphill battle" (Du Bey et al., 2019, p. 56).

In this case, the treaty rights at risk white paper was taken seriously. Will Stelle, the West Coast Regional Administrator for NOAA, speaking at a salmon-recovery conference in May 2013, substantiated his agency's commitment to addressing the demands:

> "This missive is not just an idle passing observation. It is the expression of a long-term strategic perspective of the tribal leadership in an intergenerational way… advising all of us that what they see is no good and they will not and cannot accept it. . . So, we in the executive branch take these treaty-rights observations and recommendations deeply seriously. We take them at face value and we believe them to be credible. We are working very hard with the limited tools we have to turn the knobs on the machines that we run in order to change some of that trajectory. [Doc17]

One of the 'knobs' that NOAA turned involved a set of specific policy proposals from the *Treaty Rights at Risk* white paper, asking the federal government to "align funding programs" and condition federal grants to "achieve consistency" with water quality and salmon habitat regulations and plans. In practice this involved requiring federally-funded riparian restoration projects to meet new minimum-width standards, described in a table of stream-types and associated minimum riparian-buffer-widths. This table became known as the "NOAA Riparian Buffer Matrix" [Interview05].

As no legislation requires establishment of riparian buffers in Washington, the new standards applied only to federally-funded incentive programs. Various programs exist in Puget Sound to support and incentivize voluntary riparian-buffer creation on private agricultural land. One, the federally funded Conservation Reserve Enhancement Program (CREP), covers both costs of establishing a buffer and offers landowners annual financial incentives based on width and length of restored land. Most other programs only fund the cost of buffer installation and maintenance.

Prior to the *Treaty Rights at Risk* paper, CREP required minimum buffers of 35-feet (10 m) on each side of salmon-bearing streams. Implementing the NOAA Riparian Buffer Matrix would increase this minimum from 35 to 100-feet (10–30 m). While other federal agencies adopted the NOAA Riparian Buffer Matrix, the agency responsible for CREP delayed doing so until 2015, when it 'reviewed the science' and chose to increase the minimum width to 50 ft., not 100.

The increase in minimum buffer-widths was opposed by local conservation districts, the agencies responsible for implementing CREP as well as a suite of other voluntary conservation programs on private land.

3.2. Using riparian science: The contested value-meanings of a 35-foot riparian buffer

Throughout the debate, groups on both sides referred to the need to base decisions on 'science,' while accusing the other of political motivations. For example, a conservation district letter frames buffer-width policy as political and then argues that instead they should be based on science*: "We encourage that political agendas at least be grounded with some science"* [Doc06]. In parallel, the Northwest Indian Fisheries Commission, which was created following the 1974 Boldt Decision to support the Treaty Tribes, frames the conservation districts' position as 'ideological' and appeals to science (here via 'federal fish agency expertise'): *"It has been repeatedly noted that a few select conservation districts are ideologically opposed to working with federal fish agency expertise, and are unwilling to implement their recommendations!"* [Doc08].

How is it that both 35 and 100-foot buffers can be simultaneously based on science and politically motivated? In the following, we show that depending on what is counted as 'politics' and what as 'science' both assertions can be considered 'true' in some sense. We examined how these groups differently defined the problem at hand, the scope of the system and the definition of both science and success (see Table 1).

We begin by discussing how each group understands the benefits and purpose of a 35-ft buffer. Conservation district respondents often saw diminishing returns from wider buffers. Relatively narrow riparian buffers can function to filter excess nutrients (e.g., nitrogen or phosphorous) and pesticides from agricultural runoff, and shade streams to reduce water temperature (Correll, 2005; Poole and Berman, 2001; Shaw, 2018). Most critically, the option to put in a narrow buffer allows conservation districts to get their 'foot in the door.' Conservation district staff's success depends on building relationships with land-owners. Their arguments about riparian-science use focused on ground-level consequences of stricter requirements within a voluntary program: *"There's obviously an ecological benefit to having bigger buffers. But that's not what we're talking about right now. We're not talking about bigger buffers versus smaller buffers. We're talking about a buffer versus no buffer"* [Interview03].

The Treaty Rights at Risk movement argues that narrow buffers, while benefiting water quality, fail to provide functional salmon-habitat. Few scientific studies have directly examined the salmon-habitat impacts of riparian restoration on agricultural land. However, most salmon biologists believe wider buffers are needed, particularly to provision large woody debris, likely maximized at around 100-feet (30 m) (or about the height of the tallest trees which might fall into the stream). While different tribes and individuals vary substantially in their views, for some tribal members, 35-foot buffers construction is a

Table 1
Points of divergence (values, paradigms, and perspectives) between Conservation Districts and the Treaty Rights at Risk movement regarding riparian science and restoration. Synthesized from analysis of interviews and documents, this table characterizes the dominant views of each of these groups. However, there is substantial variation across conservation districts and tribes as well as among the individuals that constitute each.

Points of divergence	Conservation districts' views and values	Treaty rights at risk movement views and values
Use of riparian science	Consider riparian science in the context of what will work in practice; draw from social science as well as natural science	Demand 'science-based' decisions; use riparian science to argue for greater recognition of treaty guaranteed rights
Purpose of riparian restoration	Incremental restoration and harm reduction; water quality and riparian habitat	Transformative restoration; provision of fully functional salmon habitat
Goal for salmon conservation	Avoid extinction; regulatory compliance with the Endangered Species Act	Avoid 'museum fish' and assure use of salmon for economic and cultural purposes
Spatial scale	Think primarily at the farm scale	Concerned with landscape scale
Temporal scale	Generations	Centuries
Metric of success	Projects, miles, acres, trees	Salmon returns, treaty rights
Policy paradigm	Resource management, i.e., what is the best way to manage the resource? (accepting current political system)	Co-management/treaty rights, i.e., policy or power-oriented ideas about rights to determine natural resource management (challenging current political system)
Value of Salmon	Ecological value as part of healthy ecosystems; Existence value as expressed by the Endangered Species Act; value for the region as icon, for commercial and recreational fishing.	Salmon fishing central for tribal identity, livelihoods, culture, religion, and traditions (e.g., gifting). Fulfilling these values require a certain abundance of salmon.
	Intrinsic ('living with') and instrumental ('living from') values are prominent; intrinsic value maintained by preventing extinction; instrumental potentially substitutable.	Mostly relational ('living in') value; relationships themselves matter, no substitution possible.
What values are at stake in the riparian buffer debate for each?	Relationships and ability to collaborate with private landowners; agency over own work and mission. *For farmers:* vibrant agricultural communities that require a certain abundance of farmland and farmers.	Riparian restoration as expression of tribal sovereignty and identity; long-term intergenerational justice; maintenance of culture and relationships with land, landscape, and animals within a settler-dominated landscape.

waste of limited restoration money, which could be spent creating fully functional habitat. Some conservation district staff see 100-foot buffers as a waste of this same limited restoration money; wider buffers means less length of stream.

The *Treaty Rights at Risk* white paper and tribal interviewees pointed out that most efforts in the Puget Sound have addressed water quality but not salmon habitat, the latter of which requires wider buffers. Constructing 35-foot buffers gives the impression (to farmers, to the public) that salmon habitat is being addressed, when only water quality is improved. In particular, as one tribal interviewee explained, wider buffers are needed to assure that salmon runs are sufficiently abundant to support tribal fishing and the tribes' cultural, traditional, and economic uses of salmon:

> If we continue to stay at the 50-foot buffer, then what we're basically saying is that we're just going to have museum fish. We're going to just be able to go out and look at them but we're not going to be able to catch. [Interview11]

The two groups diverge in the level of salmon recovery sought, but also in their thinking about how to achieve that recovery. For the Treaty Rights at Risk movement, frustration at seeing salmon runs stagnate or dwindle despite marginal improvements in many areas, has led many to conclude that recovery will require broad change on many fronts, not just accepting what seems feasible. Thus, the argument for larger buffers comes not from science showing that restored riparian buffers on agricultural land are the limiting factor for salmon, nor science showing compellingly that anything less than a 100-foot buffer is inadequate, but rather from a mindset-shift findimg some support in science. There is no clear-cut case that salmon recovery requires 100-foot buffers (instead of 35- or 50-foot buffers) or even that those would suffice.

Increasing minimum buffer-widths seems likely to result in less, not more, riparian restoration in the near term. But it may be a crucial long-term step towards establishing tribal treaty-rights as determinants of federal and state environmental regulations. This points to a fundamental divergence of policy paradigms; conservation districts see a resource management issue; the Treaty Rights at Risk movement, rights and responsibilities. Federal courts established that salmon recovery is required by tribal treaties. Yet corresponding laws and regulations are lacking. The Endangered Species Act serves only to prevent extinction—resulting in 'museum fish.' State and federal regulations to increase riparian habitat are limited; and where laws would protect water quality and existing habitat, enforcement is lacking. Low enforcement of existing laws frustrates conservation districts, which sometimes feel they are expected to compensate for poor enforcement via voluntary programs. Agricultural interests are a powerful lobby in the state legislature, which controls funding for state environmental agencies tasked with enforcement. Pushing for 'higher standards' in a voluntary program is the easiest 'knob to turn.'

4. Stumbling blocks on the journey from science to policy

In Section 3 we showed how debate around buffer-widths represented larger issues; concerns about how to secure tribal treaty-rights, including the requisite protections of salmon and concerns about sustaining agricultural communities, lands and culture. Yet the history, context and values behind these concerns became obscured as debate turned to science—specifically natural science—to answer a contested, complex political question. In the current section, we identify four separate missteps that together produced a problematic science-policy gap. Along the way, we explain the approach that came to dominate debate (the 'riparian buffer matrix'), how this came about, and the consequences of this choice.

4.1. Policy and science are conflated: Agency needs frame the scientific debate

While riparian restoration guidelines could potentially incorporate numerous dimensions (e.g., composition of plants, topography, adjacent land use, solar radiation, up and downstream context), debate in Puget Sound focused on just one: buffer-width. There are many different kinds of riparian buffers and approaches to riparian restoration. For example, the 2008 *Conservation Buffers: Design Guidelines for Buffers, Corridors and Greenways* produced by the US Department of Agriculture recommends a planning process to address the many objectives and functions of buffers: water quality, biodiversity, productive soils, economic opportunities, protection and safety, aesthetic and visual quality, and outdoor recreation (Bentrup, 2008, p. 6). In the 136-page guidelines document, planners are guided through processes to consider the various functions associated with each objective, as well as location, structure of the buffer, and the system in which it will operate.

In contrast to this nuanced approach, debate in the Puget Sound focused on developing strict minimum buffer-widths, based on a simple stream classification. One paper in particular, written by agency personnel, explicitly describes the logic for this choice. This paper, Castelle et al., 1994, recommends fixed-width buffers of 50 to 100-feet rather than site-specific variable-width buffers. The authors explain the benefits of fixed-width buffers as follows: "more easily enforced, do not require regulatory personnel with specialized knowledge of ecological principles, allow for greater regulatory predictability, and require smaller expenditures of both time and money to administer" (Castelle et al., 1994, p. 881). In short, fixed-width buffers are easier and cheaper. Even though the recommendation for fixed-width buffers was based on agency needs and not science, this agency-thinking dominated in how the issue was framed. Variable width buffers involve placing value on 'personnel with specialized knowledge' able to develop customized solutions for each project that balance values and trade-offs on a project by project basis. Fixed width buffers instead represent instrumental values of expediency that are often characteristic of centralized management.

4.2. Science from one context adopted in another, without adaptation: Forestry shapes riparian buffers in agricultural contexts

The approach to riparian buffers in agriculture was shaped by experience and science from the forestry sector—for two main reasons. First was the availability of science and scientific synthesis from the forestry context. For example, agricultural riparian-recommendations often referenced the Bureau of Land Management's (1993) 'Forest Ecosystem Management Assessment Team' (FEMAT) report, which was written to address controversy around old-growth forest protection and forestry in the Pacific Northwest and Northern California. This report's analysis and approach were important references for synthesis applied to agriculture in the Puget Sound.

In contrast to forestry, much less is known about riparian restoration on agricultural landscapes, especially considering key salmon habitat impacts such as cooling and large woody debris (Stoffyn-Egli and Duinker, 2013). Most agriculture-focused research on buffers has addressed their use to filter nutrients, pesticides and sediment. As one riparian scientist explains: *"At present most research on riparian buffer zones has been carried out on sites where restoration was not needed. Thus, we know much more about the general water quality functions of riparian buffers than we know about how to restore buffers or how quickly and effectively they regain their functions"* (Correll, 2005, p. 437).

The second reason was a local success story from forestry. The 1987 Timber, Fish, and Wildlife Agreement specified a process to manage forests in Washington State for timber production and wildlife protection, including agreements about riparian buffers. Expert respondents in our study from different groups as well as a variety of policy documents cited this agreement as an exemplary process for agriculture (such as Britney, 2014). A similar forum was indeed convened for agriculture from 1999 to 2003 *"including participation from state and federal agencies, tribal governments and diverse agricultural interests"* [Doc10]. This forum—Agriculture, Fish and Water—sought to address water quality, irrigation and salmon habitat (Spellecacy, 2009). One goal was riparian-buffer guidelines for agriculture that "provide adequate salmon habitat and are implementable" [Doc10]. To be implementable would require the guidelines to have some level of acceptance from the involved parties.

Wide, fixed-width buffers were successful in forestry; in agriculture, the same approach stalled in controversy. In forestry, we ask: as trees are cut closer to a stream, when does functioning of the riparian ecosystem being to decline? In agricultural, where the baseline is often zero trees along the stream, we instead ask: how much will be gained by each foot of vegetation planted?

Within the Agriculture, Fish and Water forum, NOAA developed recommendations later-to-be-known as the 'NOAA Riparian Buffer Matrix.' The NOAA team that developed this matrix, then called 'Federal Option 3,' felt they had determined the narrowest buffers they could justify as scientists, in order to accommodate agriculture. In the words of one interviewee, they "squeezed the rock as hard as possible" to come up with something that would "pass the red face test" for embarrassment. Nonetheless, the Agriculture, Fish and Water forum ended without agreement and Federal Option 3 was shelved.

The Agriculture, Fish and Water forum had sought to apply the science and processes successful in forestry, to agricultural without accounting for the unique ecology, economics, politics, and values of each sector. Ecologically, forestry involves *protecting existing riparian buffers*, likely already used by salmon and where trees may be over 100-years old. Contrast this with *restoring new riparian buffers* in agriculture; trees and shrubs must be planted, maintained, protected from wildlife (e.g., deer), and fenced from livestock. Economically, forestry centers on a few large landowners or tenure-holders whereas many farms in the Puget Sound are small. For small farms, removing 100-feet of streamside property from production could make the farm economically unviable. In Eastern Washington, where farmers often hold large parcels, wide CREP buffers are common (Smith, 2013). But in Puget Sound, small parcels predominate, and wide buffers can remove too high a proportion of a farm's land. This means that individual farmers might feel that such buffers are unfeasible, but also that in some cases whole communities see wide buffers as a threat to agriculture in the region. Conservation can feel like one more burden on an agricultural land base and community that already feel squeezed from many directions (e.g., development pressure, low prices for crops). As agricultural land is lost, so too is the infrastructure (e.g., machine repair, farm suppliers) and community needed to support farming. Politically, forestry could be regulated, but there has been little political will to require farmers to install riparian buffers—and strong resistance from some agriculturalists. By applying the science and guidelines from forestry without considering what those guidelines would mean for agriculture, this became another stumbling block. The values of agriculturalists involved in and potentially threatened by strict rules for riparian restoration were ignored: a desire for or commitment to viable family farms and agriculture communities.

4.3. Inertia of one approach limits development of alternatives: The life and times of the 'Riparian Buffer Matrix'

The approach to riparian *restoration* for agricultural lands in Puget Sound took the form of fixed-width riparian forest buffers, in line with the recommendations by Castelle et al. (1994) and the guidelines developed for riparian *protection* in the forestry context (see examples of different types of guidelines in Fig. 1 as well as in supplementary information table S2). Specifically, the approach taken was to define minimum widths for restored riparian buffers based on a classification of four or five different stream types. Numerous such tables (locally referred to as 'buffer matrices') were proposed and debated over almost 30 years (see supplementary information).

When the *Treaty Rights at Risk* white paper was published in 2011, one of the demands upon federal agencies was to condition funding of riparian restoration grants upon a particular 'buffer matrix' that was originally derived from the Washington Department of Fish and Wildlife Riparian Guidelines from 1997. This report's 181 pages contain general guidelines intended to support a variety of planning, management, and restoration activities; the riparian widths recommended were not designed for or based on the creation of restored riparian buffers within agricultural lands, where trees must be planted, not only protected. For fish-bearing streams, the recommended width is 150 to 200 ft (46–61 m) (Knutson and Naef, 1997).

NOAA's response to *Treaty Rights at Risk* was to ask federal agencies to condition restoration funding upon compliance with a riparian buffer matrix. Instead of the Washington Department of Fish and Wildlife matrix suggested by the *Treaty Rights at Risk* white paper, NOAA

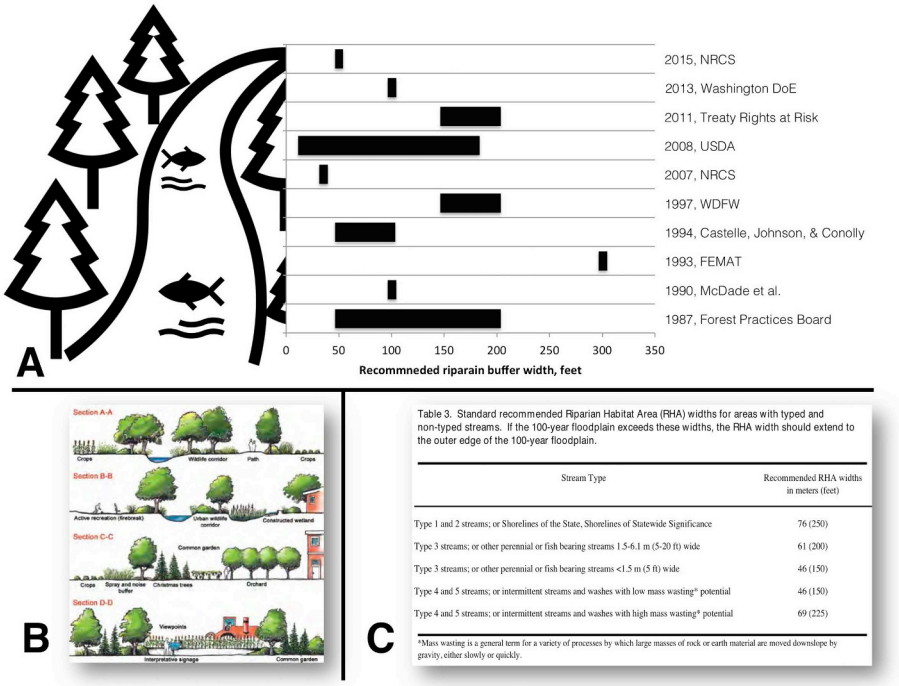

Fig. 1. Different Approaches to Riparian Buffer Guidelines. In panel A, different riparian buffer-width recommendations for salmon bearing streams are illustrated. NRCS = Natural Resources Conservation Service; DoE = Department of Ecology; USDA = United States Department of Agriculture; WDFW = Washington [State] Department of Fish and Wildlife; FEMAT = Forest Ecosystem Management Assessment Team. Panel B shows a figure from the US Department of Agriculture *Conservation Buffers: Design Guidelines for Buffers, Corridors and Greenways,* which illustrates several different types of buffers designed for different purposes. Panel C shows an example of a riparian buffer matrix, in this case from the 1997 Washington Department of Fish and Wildlife Riparian Guidelines. See Supplementary Information for details about these riparian recommendations as well as other riparian standards.

returned to the matrix they had created for the Agriculture, Fish and Water Process in 2002 ('Federal Option 3,' discussed in Section 4.2) [Doc10]. The document became rebranded, officially as the "Interim Riparian Buffer Recommendation" but more informally referred to as the "NOAA Riparian Buffer Matrix". After a "review of the current scientific information" [Doc10], NOAA decided to attach a 10-year old table produced for but never agreed upon within a multi-stakeholder process (Agriculture, Fish and Water). According to Will Stelle, the agency's "view of the buffer table is unchanged. We supported its use in 2002, and we still support its use in 2012" [Doc10]. According to a contact at NOAA, the tribes identified the 2002 buffer-matrix as "good enough for them," despite the fact that the buffer-widths therein were significantly narrower than those called for in the *Treaty Rights at Risk* white paper: approximately 100-feet versus 150–200 ft (46–61 m).

However, the NOAA Riparian Buffer Matrix required significant expertise to implement because widths were based on the tallest mature trees that could potentially grow at the buffer site [Interview05]. Later that year (Oct 28, 2013), the Department of Ecology, produced a set of width measurements that was easier to implement. By using straightforward widths (as opposed to site potential tree heights or buffer-width calculators based on site characteristics) as requirements for riparian buffers, agencies could easily determine if they had met the criteria.

By this point, numerous state and federal government agencies had been involved. Yet a buffer matrix that was "implementable" remained elusive. Then, the Washington Department of Fish and Wildlife "stepped forward" to "take on this buffer issue" [Interview05]. Their most significant decision was to avoid putting forth yet another buffer-matrix, or any "numeric description" of "what constitutes an 'adequate' riparian width" [Doc18]. In a presentation, the agency explained that their guidelines *"do not represent a policy decision about how much is enough, reasonable, or practicable."* [Doc18]. Washington Department of Fish and Wildlife had decided that drawing a line in the sand (or the field or pasture) was more than science could deliver; a scientific report could not answer a policy question. That question required a policy choice, informed—but not determined—by science. A choice *determined by* science would consider the question a technical one. In contrast, a choice *informed by* science would also consider the values of those impacted.

Riparian science could explain the ecological benefits of different buffer-widths, but not how to make the trade-off between those benefits and the costs in money and farmland. Neither could riparian science alone determine the consequence of a particular policy. By focusing on buffer width, the debate became a zero-sum trade-off between farmland and fish habitat: each one treasured by its own constituency. This problematic inertia in the prescriptive power of a particular piece of policy guidance represents the third stumbling block in science-policy process.

4.4. Technical language obscures real trade-offs: Specific vegetative prescriptions and alignment with salmon recovery objectives

Throughout official letters and meeting minutes regarding controversy over riparian buffer-widths, obtuse technical language obscured actual issues. For example, the technical language 'to hold Biology Tech Note 14' can be 'translated' as 'to delay implementation of the proposed increase in minimum buffer-widths (from 35 to 100-feet) for participation in CREP.' The State Technical Advisory Committee advising on the buffer-width issue received letters from Conservation Districts across the state opposing the increased widths, which one conservation district framed as "specific vegetative prescriptions" rather than guidelines for riparian buffer projects [Doc01], framing the issue as overly prescriptive. In the *Treaty Rights at Risk* white paper, the words "buffer-widths" are never mentioned; instead, the document refers to "alignment with salmon recovery objectives" and other obtuse language, such as demanding that grants condition funding upon "buffers comparable to those that NMFS [National Marine Fisheries Service] has called for in its RPA [reasonable and prudent alternative] for FEMA's [Federal Emergency Management Agency] National Flood Insurance Program" [Doc12]. That in turn refers to the Washington Department of Fish and Wildlife Riparian Guidelines from 1997 (Knutson and Naef, 1997). The abundance of acronyms (NMFS, RPA, FEMA, etc.), which are not always defined, further obscures the information to those not fluent in their meanings.

Key questions remain unanswered: who is responsible for setting buffers—NOAA, CREP, Washington Department of Fish and Wildlife, Treaty Tribes, the conservation districts? Should riparian buffers serve only to protect water quality or also to provide salmon habitat? In some

cases, are smaller buffers better than nothing? And who has the power to assure their values are prioritized in the debate? Yet these questions are obscured via vague technical or other oblique 'report-referencing' language that evades a straightforward discussion of the issues and the values at stake. While these questions about riparian buffers are certainly relevant for many different people and groups in the Puget Sound, the use of technical language serves as a barrier to participation in and discussion of values and represents a final stumbling block.

5. Discussion

Why is there a gap between science and policy? In our case study on riparian restoration, we have shown how the 'gap,' rather than a static feature to be 'closed,' might be more usefully understood as requiring a journey. Along that journey, we identified four stumbling blocks that limited uptake of science into policy. The first is conflation of science and policy. Simple rules, such as requiring fixed-width buffers, are easier and cheaper to administer. The use of fixed-width buffers applied using a simple matrix, parallels current approaches to stream restoration by private consultants—broadly applicable, simplified methods that are easy to codify and justify (Lave et al., 2010). While most academic scientists of stream restoration oppose such simple approaches, arguing that they obscure the complexity of natural systems, government agencies in the US have embraced them, in part because they allow agencies to justify their decisions by appealing to a seeming standard, e.g., decisions about which stream restoration consultants are hired by US government agencies and what methods are followed (Lave et al., 2010). Policymakers may choose simple guidelines fit for other contexts even over complex guidelines fit-for-purpose. This process highlights why complexity-concepts have seen little uptake in environmental management (Forsyth, 2003), despite 20-plus years of development in the field of ecology; complexity is difficult to administer.

The second stumbling block in our case was applying scientific findings outside of the context in which they were developed. Many of the challenges faced in developing buffer-width standards for agriculture stem from an attempt to apply the research, reports, and processes from riparian buffer *protection in forestry* to riparian buffer *restoration in agriculture*. Applying recommendations out of context fails to account for the ways those recommendations were tailored to fit the original context (Forsyth, 2003). Here we have shown an example where recommendations based on protection were applied to a restoration context, but the problem applies equally to management practices and concepts that are applied unreflexively outside of the context in which they were developed. For example, the Universal Soil Loss Equation was developed in the US Great Planes; efforts to apply the tool out of context, such as in sub-tropical regions, led to an over-emphasis on soil erosion as the primary cause of soil fertility loss (Forsyth, 2003).

In the third stumbling block, inertia of one approach (the riparian buffer matrix), served to limit discussion and development of alternative approaches to the problem. The buffer-width debate focused on specific rules for voluntary programs impacting a tiny area of potential salmon habitat. Rather than a broad search for policies that might meet a variety of needs, the matrix locked attention into its rows and columns. Alternative approaches include working buffers that could increase habitat while providing some income to farmers or enforcement of existing regulations intended to protect riparian forests in agricultural and urban areas (currently such regulations are rarely enforced). Another alternative is to focus on a smaller 'stream reach' scale, where specific local compromises may be easier to achieve than regional scale rules would allow. But once different groups zeroed in on the buffer matrix, a discussion of the real trade-offs involved in salmon conservation and farmland preservation was missed. This stumbling block parallels one of the 'pitfalls of an overemphasis on science': inadequate consideration of alternatives (Gregory et al., 2006).

Finally, in the fourth stumbling block, focus on the scientific basis of buffer-widths via highly technical language, served to inhibit a discussion of underlying value and political issues. Rather than discuss rights and responsibilities at the heart of the conflict, attention focused on effectiveness curves and stream classifications. When environmental conflict is forced into science-focused discussions, values become 'fugitive,' still dominating the discussion, but coded in technical terms that limit participation and discussion of the key points of contention (Satterfield and Levin, 2007).

Yet as our case shows, even for regional environmental management and planning, focus is often on "science-based decision making," especially in the US, which (in theory) largely eschews discussion of values in favor of science-based decision making (Jasanoff, 2005). This is so much so that one state legislature considered banning resource management agencies from using social science or considering the values of people impacted by their decisions (Manfredo et al., 2019). The Endangered Species Act, one of the strictest pieces of environmental legislation in the US, specifically calls for the use of 'best available science' in policy decisions. But in highly politically charged situations, this demand typically functions to politicize science (Pielke, 2006). When scientific findings contradict the interests of powerful actors, these actors then seek to influence the production or interpretation of that science (Oreskes and Conway, 2012). In essence, when science-based decision making is the focus of politically charged debates, the always-extant value debates simply shift to occupy the science. The emergence of certain 'truths' can be a product of their alignment with the positions of powerful actors (Tomlinson, 2011). In these cases, scientific knowledge can be considered as co-produced by both science and politics (Forsyth, 2003).

Differences in ideas about place, aesthetics, nature and science across farmers and farm advocates, Treaty Tribes and advocates of restoration help explain differences in expectations regarding farmland preservation versus salmon restoration (Breslow, 2014). In this paper we have formed two broad categories of "Conservation Districts" to represent agricultural concerns and "Treaty Tribes" to represent salmon conservation concerns. This binary served to simplify, for analysis and communication, what in reality is a complex, and multi-faceted debate. There are 12 conservation districts in Puget Sound and over 20 Treaty Tribes, as well as numerous government, civil society and industry groups. Levels of trust and communication between local tribes and conservation districts vary by watershed and particular individuals in each context and constellation have served to shape the tone of dialog—by fostering collaboration or by sharpening debate. The particular appeals—of Treaty Tribes to Western science and law and agricultural interests to tradition and heritage—can also be seen as politically motivated strategic choices on behalf of each group (Breslow, 2014). But behind these strategic appeals are deeply held values. For treaty-holding tribes salmon are fundamental to their identity. For farmers, control over how they manage their land and what constitutes a good farm is fundamental to their identity (Chapman et al., 2019). But for both values and politics, science cannot be the arbitrator of these differences. Riparian science is needed to inform the debate. But as we have shown in this case study, looking to scientific synthesis for policy answers, without accounting for the politics and values of the different actors involved, only led to more and not less controversy.

6. Conclusion

This case study of riparian buffers for salmon revealed how an output of 'science' (the riparian buffer matrix) can make values fugitive, obscuring conflicts about the scale of the problem, exacerbated by a preference for simple policy solutions cloaked in technical language. The demands placed on the riparian buffer matrix—to answer a policy question using natural scientific synthesis—were far too great and led to a conflation of science and values. This matrix was created to determine appropriate thresholds for specific policy applications—questions that require far more judgments beyond science. We have shown

how an effort to close the science-policy gap functioned to politicize science and fueled controversy. A more fruitful approach would delve into the 'gap' and acknowledge the political, economic, historical and values questions that are part of many conservation issues.

Based on this case study, we suggest a number of waypoints for a smoother journey along the road from science to policy. Each might help to remove a stumbling block to the implementation of 'best available science.' These remedies include:

1) Expand the fields of science included to incorporate social as well as natural sciences, including qualitative social science (Charnley et al., 2017). This would have allowed policy makers to consider the social and political context in which natural science is used and adapt recommendations on that basis.
2) Adapt and if needed re-think scientific recommendations taken from one context before application in new social, political, legal, or ecological contexts. By considering explicitly the ways that agriculture differs from forestry, and restoration differs from protection, agencies might develop feasible recommendations. Consideration of context should also include the historical origins of different groups' positions and of ecological changes across the landscape. The frustration of the Treaty Rights at Risk movement is based on a history of failed promises and unfair treatment. These concerns might have been more effectively addressed via changes in decision-making process than in buffer-widths.
3) Address limitations imposed by existing legislation, power structures and agency jurisdiction (Chapman et al., 2017). A fundamental challenge involved who had jurisdiction to regulate habitat creation (i.e., what agency should regulate habitat and under what law?).
4) Elicit a wide variety of alternative approaches from diverse sources to move beyond institutional inertia. The focus on defining a buffer matrix served to limit explorations of alternative pathways that might have been more fruitful, such as the stream-reach-scale approach described above.

In Puget Sound, government agencies, NGOs, Treaty Tribes and agricultural interests are forming groups and processes to discuss these trade-offs. Multi-stakeholder policy-planning processes such as Snohomish County's Sustainable Lands Strategy and Agricultural Resilience plan bring together representatives from agriculture with those from environmental, government, and tribal groups to converse about the region's future, given predicted increases in population, sea level, and land prices. Recognizing their inter-related futures, these groups seek integrated land use and policy plans to address agricultural resilience, floodplain management, salmon protection and land use. By focusing on an integrated approach that address the fundamental issues, these groups are beginning to find a more fruitful path forward.

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CRediT authorship contribution statement

Mollie Chapman:Conceptualization, Writing - review & editing, Methodology, Investigation, Formal analysis, Data curation, Writing - original draft, Visualization, Funding acquisition.**Terre Satterfield**:Conceptualization, Writing - review & editing, Methodology, Funding acquisition, Supervision.**Kai M.A. Chan**:Conceptualization, Writing - review & editing, Funding acquisition, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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