

Science Sprints

Science Synthesis Strategies at the Science-Policy Interface to Support Regulatory Programs

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1.0 Goals of The Science Sprint Initiative

In our experience, ecological scientists commonly want their knowledge to be used to inform effective policies. One critical science-policy interface is the use of best available science (BAS) to regulate economic actions that potentially damage common pool resources. Regulatory protection has been frequently cited as the necessary foundation for stewardship and restoration (Goetz et al 2004; Greiner 2009)

Undertaking costly restoration actions without a complementary protective strategy is unlikely to achieve the desired outcome of long-term improvements in ecosystem condition (Goetz et al 2004).

Regulators are required to apply the best available scientific evidence using methods defined by state and federal statutes, codes, and rules and informed by case law. The application of scientific evidence within this legalistic context is a unique and interdisciplinary technical discipline.

Each regulatory workgroup uses specific practices to evaluate risk and certainty to constrain and shape actions that might otherwise degrade public trust resources. Laws and regulations shape how best available science can be used for regulatory decisions. For example, the Washington State Hydraulic Code, the Endangered Species Act, and the Washington State Shoreline Management Act may all require agency evaluation of a shoreline development proposal. However, differences among authorities may lead to valuing different ecosystem services and the use of different practices to evaluate evidence, which may trigger different regulatory responses.

However, the underlying body of scientific evidence available to make policy determinations is independent of this legal context. Using scientific methods, practitioners among private, public, local, state, and federal institutions routinely synthesize available scientific evidence, formulate and test novel hypotheses, and publish results. It is this routine synthesis of evidence, as part of the scientific method that is particularly important at the science-policy interface.

However, science synthesis may often fail to support regulatory work. There are multiple factors that work in concert to prevent the synthesis of the best available scientific knowledge from being used in regulatory decision-making.

1. **Limited Synoptic Products** - The science community may not publish its synthesis work and instead is rewarded for observations around targeted research questions. Regulation is necessarily interdisciplinary and synoptic, and scientists may not consider in their work the kinds of comparisons that support clear regulatory determinations, and the weighing of risk or certainty. Thus both the quality, structure, and availability of synoptic assessment may be limiting.
2. **Limited Regulatory Capacity** - Regulators have very limited capacity to locate, review, and synthesize evidence across a wide range of disciplines. As an example, despite the

long period of time over which the Shoreline Management Act has been implemented, some important aspects of that work, such as quantitative accountability for “no net loss” have never been well developed ([Kramer et al 2010](#)).

3. **The Slow Process of Science** - The process of gathering and analyzing quantitative evidence is laborious, and there are disincentives for the rapid exchange of early and inconclusive results. Peer-reviewed publications may lag many years behind initial findings that could still inform the overall weight of evidence or support risk management. Scientists also struggle with limited capacity which can protract investigation.
4. **Weak Storage and Retrieval Systems** - Empirical evidence stored in unpublished formats (e.g. monitoring reports, project reports, or grey literature) are often not located by search engines, or may be routinely lost through agency website updates or the loss of institutional knowledge (e.g. retirement). While conferences and symposia provide opportunities for networking and cross-pollination among scientists, they are currently poor vehicles for the synthesis of citable evidence to support regulation.
5. **Incoherent Needs Assessment** - Regulators distributed among authorities and situations, and operating with limited resources are rarely able to describe a systematic approach to knowledge development. “Science plans” are commonly developed by academic and agency institutions to define voluntary funding, but are isolated from robust regulatory system analysis.

If science funding programs and science practitioners want their knowledge development to provide the maximum benefit to society, then that work must be informed and organized to support the needs of regulatory decisions. And if regulatory decisions are to be based on the best science, that science needs to be organized in a way accessible to regulatory decision-makers.

In 2022 and 2023 an interdisciplinary and cross-silo team, involving regulators, funders, and scientists from state and federal programs used a modest science synthesis award to prototype methods for bridging the gap between science and regulatory decisions. This is a report of our findings and recommendations for developing such a practice that we describe as “science sprints”.

Herein we propose principles, strategies, and an approach for implementing “science sprints” to improve the science-policy interface in support of regulatory decision-making. This approach favors rapid iteration, high transparency, strong organization and archiving of evidence, robust conceptual framing, narrow scopes of inquiry, and separation between the presentation of evidence and the development of regulatory policy.

We propose that this framework could be incorporated into ongoing science funding and programmatic efforts so that ongoing investigations better support public interest decisions and are applicable in a regulatory context. This approach would result in subtle but useful changes to how we conduct conferences, fund science efforts, or define and scope investigations.

We also recognize that these improvements have a cost. Thus our goal has been to identify mechanisms that deliver the most value with the least cost. We presume science practitioners, funders, and regulators are inherently interested in improving the science-policy interface. Our

approaches encourage crowd-sourcing and open knowledge networks to increase efficiencies. Our aim is to leverage and increase value creation using existing activities and organizational structures.

Managing the quality of science synthesis is not a novel challenge. Many public science agencies have strong practices that don't need to be reinvented. We propose augmenting the many excellent qualities of individual workgroups by considering additional shared practices that improve the science-to-regulatory-policy interface, and that we maintain and improve those practices with the direct participation and feedback of regulatory workgroups.

We believe that improving collective effort in science synthesis is likely to have benefits far beyond regulatory policy. Voluntary restoration efforts also benefit from science synthesis. However, regulatory support is the focus of this initiative because regulatory shops have limited capacity to participate in or fund scientific inquiry, and thus regulatory frameworks are often neglected in the existing science-for-planning process. Efficient and precise regulation is our primary protection tool on the road of ecosystem stewardship.

2.0 Strategies and Principles

Our approach has developed around four underlying arguments:

1. The synthesis of the best available scientific evidence is as critical as new discoveries to the policy and regulatory decision process because the synthesis of BAS is essential for supporting regulatory decision-making and policy development. Decisions are rarely made from a single study but rather from a body of knowledge derived from multiple studies.
2. Science synthesis is a never-ending process, and so each synthesis effort can create more value if it is designed as part of a collective network of efforts supporting the refinement of synthesis over time.
3. Centralized systems that provide synthesis in support of regulatory decision-making are rare and given staffing constraints are unlikely to emerge. Thus, efficient methods will likely depend on self-organization network processes among existing efforts.
4. The interpretation of ecological science through the lens of regulatory practices is a specialized and complex field, and so for this network process to be effective, professional regulators are necessarily involved.

[Ryder et al \(2010\)](#) offer principles to guide the development of BAS, which we adapt and reframe here to highlight the development of BAS for regulatory systems:

1. Have we created a **cooperative process** where an **interdisciplinary team** produces shared knowledge that meets the needs of regulatory staff? (see section 2)
2. Have we carefully framed a **clear policy or management question** relevant to regulatory staff? (see section 3, step 1)
3. Have we defined the properties of the best available science and **what available scientific evidence is best** from the perspective of regulatory programs? (see section 3, step 1)

4. Have we **organized evidence to evaluate clear hypotheses** referencing an applicable and existing regulatory framework? (see section 3, step 1)
5. Have we **communicated in formats useful to our regulatory partners**? (see section 3, steps 1 and 4)
6. Have we **clearly stated assumptions, terms, uncertainties, and associated risks** common in the context of regulated environments and actions? (see section 3, step 3)
7. Have we **recorded decisions about the inclusion or exclusion of evidence** consistent with regulatory principles? (see section 3, step 2)
8. Have the outputs of our efforts **supported future synthesis** as new evidence is developed? (see section 3, step 5)

Careful consideration of certainty and risk over a specific landscape is critical to regulatory practices. Regulation is necessarily place-based, and concepts must be applied to a regulated context. Science synthesis that supports regulation must employ a refined consideration of likelihood over a specific field of activities and phenomena.

Regulatory work is fundamentally a risk management exercise. Different authorities may vary in their allowance for risk, and thereby consider differently the burden of proof. One analysis may be required to demonstrate a high level of certainty that there will be a specific predictable effect, while another analysis may be required to avoid unacceptable risks (a more precautionary approach).

[2.1 Early Two-way Interaction With Regulatory Workgroups](#)

We propose that science synthesis will be more effective for regulation if scientists have early and frequent two-way interactions with regulatory staff. These interactions are not intended to decrease the discipline of the scientific method, but so that scientists can accurately understand the conceptual context of regulatory efforts, and how the organization of scientific evidence makes it more or less useful for regulatory decision-making and informing policy.

Each agency asks specific questions about specific activities in particular environments. Scientists may or may not understand the concerns of regulatory practitioners. The way that evidence is gathered and compared may strongly affect the applicability of that evidence in a regulatory context. Regulators must answer specific questions about how changing the scope, timing, or design of an action will avoid or minimize effects. By developing that understanding, scientists can evaluate phenomena to reduce uncertainty in ways that are applicable to the regulatory context.

The emphasis on two-way interactions is necessary, because scientists may think of regulators as just another object of study, rather than a client shaping the structure of knowledge formation. We propose that value is created when the assumptions and concepts of both scientists and regulators are exposed to the scrutiny of the other. Because regulation is a highly structured and interdisciplinary technical practice, it is unlikely that scientists making a shallow foray into the practice will develop the robust understandings necessary to effectively create value. Scientists can also serve to question assumptions that may be buried under layers of past policy decisions to identify where scientific uncertainty may be embedded in decision-making frameworks (i.e.,

asking how policymakers know what they think they know). We suspect that the dialectic between disciplines is mutually beneficial.

2.2 Narrow, Incremental, Organized and Well-Documented Synthesis

Many local regulatory processes (such as the Growth Management Act or Shoreline Management Act) result in each county or city jurisdiction using limited resources to hire private consultants to complete a very broad science synthesis effort to support regulatory decision-making over a landscape of ecosystems and human activities. Given the extensive and interdisciplinary nature of regulatory practice, it is unlikely that these limited efforts can adequately capture the breadth, nuance, and frequently changing nature of scientific knowledge. These individuals and often uncoordinated efforts may thus lack place-based knowledge, scientific nuance, and in particular less readily available evidence or knowledge (e.g. gray literature, monitoring reports, consultant reports, or traditional ecological knowledge)

To avoid this tragedy¹ the repeated and hurried assembly of BAS by regulatory shops must be complemented by a more robust science synthesis process that bridges the gap between science and regulatory decision-making. Such an interdisciplinary deep dive should explore the most important topics, and that can after completion be easily accessible during more routine synthesis efforts required of local jurisdictions. Deeper investigations can only be supported by incremental and narrow exploration of selected topics by teams of regional experts, and through interaction between policy experts, theoretical science experts, and holders of place-based knowledge. These efforts become accessible if they are organized around regulatory needs and principles, and are well documented, resulting in citable archives that are easy to discover online.

2.3 Use of Grey Literature, Expert Elicitation, Traditional Ecological Knowledge

For many important topics in ecosystem management, important observations and empirical evidence may be located exclusively in deliverables to state and federal grants, unpublished project and program datasets, and the unpublished field observations of experts. Unless published in peer-reviewed journals, these project outputs may be poorly organized, and useful parameter estimates may be scattered among many hard-to-locate documents. These are examples of scientific evidence that are not readily available to a standard peer-reviewed synthesis effort.

Where a topic is informed by this “gray literature” (e.g., government reports, memos) that has typically received various degrees of peer review, the role of the author team (defined below) must include not only synthesis of findings but consistent evaluation of the nature of the evidence—a synthesis not of all evidence but a synthesis of best evidence, as described by Slavin (1995). In these cases, it is particularly important for the author team to consider if the evidence is representative, if the argumentation is logical given our understanding of the context of observations, if alternative hypotheses were considered, and if conclusions apply to all

¹ A literary definition is intended, where noble characters struggle but inevitably fail because of inherent flaws.

circumstances. By considering a wide range of sources of knowledge, the overall weight of evidence can be considered and areas of uncertainty or variation can be identified.

Prolonged observation and interaction with ecosystems provide valuable insights that are complementary to and not replaced by quantitative analysis. The term Traditional Ecological Knowledge (TEK) describes:

a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment (Dudgeon & Burkes 2003)

This cumulative body of cultural knowledge is often concerned with particular places. While definitions of BAS may discount place-based knowledge as subsidiary to controlled quantitative scientific methods, this does not mean that qualitative knowledge is not extremely useful if not an essential part of the scientific method. Interestingly, Sullivan et al (2006) in defining common areas of weakness in ecological understanding (described in more detail below) describes a science weakened when findings are not grounded in long-term observation of natural history. In this way, long-term qualitative observation may provide critical perspectives to inform quantitative practices. Quantitative methods that fail to consider the natural history of a site or species may make faulty assumptions or fail to control for important factors.

In this initial effort, initial attempts to incorporate tribal perspectives were not successful (specifically attempts to explore beach nourishment effects of shellfish) and other TEK holders were not readily identified. There are many aspects of our methods that may inhibit the incorporation of TEK (e.g., the framing of questions, the speed of the project, the social networks of project managers, etc.). Continued work to equitably, justly, and meaningfully engage traditional knowledge-holders as to if, how, and when TEK can be incorporated into regulatory systems will be valuable to pursue and consistent with emerging policy (CEQ 2022).

2.4 Commitment to Existing Social Networking Strategies

We propose including two-way communications activities before, during, and after a science sprint effort to ensure that synthesis goals are met. Communication events may be organized around science sprint phases as described below, however, the overall purpose of communications is not only to achieve a discrete objective of the science sprint phase, but rather to repeatedly strengthen a community of practice, increase information sharing, and build relationships for future coordination and collaboration.

This inclusion of community development as part of synthesis practices aims to increase the capacity of a social network to develop synthesis.

- Identify one or more regional technical forums and a social-political forum for distributing updates (in our case we used the PSEMP nearshore workgroup and the PSEMP board)

- Collect emails of all contacts made over the course of the sprint, and where possible authors of reports and documents cited in the synthesis, and use these resources to increase the coherence of social networks.
- Throughout the gathering of evidence, identify contacts and communication channels that are not currently included or are under-accessed through existing regional technical forums.
- Provide periodic updates during the sprint (see below) using the tools described above.
- Publish and archive products and sources of evidence on a reliable open knowledge network, such as the [Salish Sea Restoration Wiki](#) (for a full discussion, see section 5.0 below).
- Integrate the solicitation of new evidence and informants into all communications events.

3.0 Proposed Science Sprint Approach

These methods offer a language for making science synthesis efforts more transparent and repeatable. Having a consistent protocol reduces the time and effort necessary to scope, design, and implement a science synthesis effort, which frees more resources to be applied to the work of discovering and analyzing evidence. These protocols do not constrain methods, but, to use an aviation metaphor, serve as a “pre-flight” checklist to maximize value creation.

We anticipate that science synthesis is a common element of a wide range of science efforts. Wherever science synthesis is occurring, there is potential value for supporting the science-regulatory decision-policy interface. These methods aim to capture and realize that potential value, by improving and enhancing a synthesis process.

We assume that project managers and funders will need to discriminate where improvement or enhancement actually creates value. This discrimination process cannot typically be completed in isolation, and ultimately depends on involving Regulatory Advisors in the scoping process (step 1) by asking, “can integrating a more rigorous science synthesis into this science effort result in improving BAS for regulatory programs?” We also recognize that some synthesis efforts are necessarily constrained in their scope, and all such efforts are not suited for increased investment to leverage increased community value.

These proposed methods are presented as a series of steps. Step 1 establishes the bounds of a synthesis project. Steps 2 and 3 describe the knowledge discovery phase of the work, and while presented as a sequence, this portion of an effort is commonly iterative. An initial literature review is used to develop a rough conceptual model, which organizes interviews with informants, reveals more evidence, which refines the model, etcetera. Iteration of evidence analysis, interview, and model refinement continues among the Author Team, Project Coordinator, Science Team, and Informants until sources of evidence are exhausted.

Steps 4, 5, and 6 describe processes by which the Author Team exposes their findings to successively larger audiences beyond their Science Review Team, including their Informants and Regulatory Advisors, as well as Technical Audiences.

Step 1 - Define Scope and Identify Teams

A sprint effort begins by selecting a narrow area of inquiry, that addresses an important area of uncertainty, that could likely be improved through a more robust synthesis of evidence. Thus, we propose three criteria for project topic selection:

1. there is a body of evidence available for synthesis;
2. that evidence has a bearing on regulatory determinations—a bearing on how we assess the gain or loss of habitat services caused either by development actions or conservation measures; and
3. there is an inconsistent understanding or interpretation of that evidence in the scientific and/or regulatory community.

There are likely areas of regulatory interest and uncertainty but where there is no body of evidence to synthesize. These areas may be important priorities for new research but may not be valuable for synthesis efforts.

Thus, topic selection and scoping require some interaction between regulators and scientists. While the scope of review must be kept narrow to allow for rapid iteration and to maximize investment in the highest value topics, it must be broad enough to encompass the variation of situations that regulators will likely encounter in the field, and thus create policy value.

Example: After soliciting topics from regulatory partners that had a high potential impact and abundant uncertainties, we selected the use of beach nourishment for compensatory mitigation as our initial topic. We were aware of several recent studies exploring the effects of marine shoreline armoring and beach nourishment. We were aware of the extensive use of beach nourishment as a mitigation measure in coastal permitting, and we had indications that there was a range of opinions about the effects of beach nourishment and that recent science had not been uniformly integrated into regulatory policies. We were also aware of diverse practitioners with unpublished gray literature relevant to beach nourishment and that the broader scientist and practitioner communities around the world had also considered this topic.

Clear Roles and Responsibilities

As part of a sprint, we define clear roles so that responsibilities can be easily and transparently delegated, and that important social functions of the synthesis process are not neglected in favor of more technical concerns. A completed science sprint can accurately identify participants based on the role they played in the synthesis process. There may be overlap in roles, and the budget process should aim to fill all roles.

- **Author Team** - We recommend no less than a pair of scientists serve as investigators and writers for a synthesis project, typically representing more than one agency or institution, to increase the independence of the effort from institutional pressures. Pairing leadership increases the retention of knowledge, diversifies network reach and analytical style, and creates internal accountability in the sprint process. The author team may have contractual or in-kind assistance to support their efforts, depending on their capacity. The author team is ideally formed of active scientists with a strong technical

background in aspects of the subject being studied, but they do not serve as weighty informants for the sprint topic.

- **Project Coordinator** - separating a project coordination role from the author team enables the engagement of a different set of perspectives and networks to maximize the social value of the synthesis project. A coordinator should have relationships with regulatory communities affected by the synthesis, and have sufficient technical expertise to augment the critique of products from both a science and policy perspective. The project coordinator monitors the integrity of the science sprint process and compares the effort to science sprint objectives. The decision process governing the effort typically involves consent among the Author Team and Project Coordinator.
- **Science Review Team** - a set of interdisciplinary scientific peer reviewers are selected based on the specific needs of the scope. The review team provides detailed technical reviews of draft projects at key milestones. They may be recognized experts in an important aspect of the subject and may include key informants, but informants should not form a preponderance of the review team. They generate a detailed written critique over the life of the project. They may be compensated to assure focused and substantive review. This differs from the common use of “science advisory groups” which may not reliably provide detailed and critical reviews. The science review team ideally produces a durable body of commentary on the sprint process.
- **Informants** - the synthesis process aims to access a wide range of informants through an iterative interview process. Informants are more numerous than the Science Review Team. The purpose of the sprint is to exhaust available informants so that all applicable evidence is gathered. Informants are used to gather peer-reviewed publications, technical reports, unpublished data, professional opinion, anecdotal evidence, and traditional ecological knowledge. Informants include weighty investigators in the field of study, and in some cases, compensation may be necessary to support their full participation. Informants are cited.
- **Regulatory Advisors** - the project coordinator supports regulatory partners in evaluating the effort to ensure that the sprint is creating value for regulators. Regulatory staff may have limited capacity to engage in science synthesis. The Project Coordinator is responsible for engaging and facilitating the involvement of regulatory advisors based on their limitations and needs. In this way, the project coordinator serves as staff to the regulatory client.
- **Technical Audiences** - technical audiences (including TEK-holders when possible) are cultivated to maximize recruitment of informants and create a feedback loop between the synthesis process, and future development of scientific evidence. Technical audiences are created using existing networks (for example the Puget Sound Ecosystem Monitoring Program). However, the artful use of snowball sampling is likely to reveal additional audiences that are not part of existing networks, and the sprint process can create social value by enhancing networks around the field of study.

EXAMPLE: In the Beach Nourishment effort active scientists from WDFW and NOAA were paired to form the author team (Lambert & Chamberlin), with funding focused on supporting the WDFW staff as the key writer. A senior regional restoration program staff with strong networks,

also at NOAA, provided pro bono labor as Project Coordinator (Cereghino). A science review team was assembled to include physical scientists (Blue Coast Engineering), coastal ecologists (Toft/Dethier), and salmon biologists working on projects using quantification of ecosystem services (Kiffney). Informants were solicited through the networks described above, and through the PSEMP Nearshore Workgroup as a technical audience. A small team of regulatory advisors was solicited from NOAA's Puget Sound area office, WDFW HPA program, and Ecology's Shoreline Management program. A budget was reserved for one key informant, known to have extensive unpublished data or a large number of regional projects. Ultimately the sprint and associated conversations greatly strengthened relationships between NOAA and WDFW staff, however, the relationship with Ecology staff was not adequately cultivated.

Refined Scope

Once a topic is identified and a social network established, the scope of the sprint should be clarified and narrowed to support efficient work and define project roles.

- Define the **geographic extent** of the topic being considered.
- Define the **geomorphic context** being considered (for example using process domain concepts such as [Montgomery \(1999\)](#) or process-based landform classifications such as [Shipman \(2008\)](#)). Ecological phenomena often have important contextual linkages to physiographic settings.
- Describe the **regulated activities** being considered as potentially causing effects, as well as the activities that will not be considered.
- Evaluate the **variation in context or activity** that is implied in the synthesis by considering geography, setting, and activities, and if any additional boundaries will be placed on the scope of analysis.
- Describe the **questions and anticipated presumptions of regulatory decision-making** around the topic. It is important for the author team and their informants to understand ecological questions through a regulatory lens. The natural questions that emerge through regulatory processes help clarify the kinds of evidence that may inform those concerns. Regulators are often concerned with the spatial extent, duration, and intensity of effects on specific ecological functions that they regulate. It may also be important and valuable for scientists to document where system complexity may undermine regulatory intentions, by considering important physical or ecological dynamics that indirectly affect regulated resources. The scope should be adjusted to capture a domain that supports regulatory decisions.
- Describe **known areas of uncertainty** that are of interest to regulatory processes.

We expect that throughout a scoping process, that the author team may make many decisions to refine the scope of analysis. By having a clear initial purpose for the work, defined by the needs of regulatory clients, these incremental decisions will be stronger or can be made in consultation with efficient regulatory partners that are already aware of the effort.

EXAMPLE:

For the beach nourishment sprint, we limited our inquiry to focus on the intentional placement of sediment on sand and gravel beaches within the Salish Sea ecological region. We focused on beaches shaped by the force of waves mobilizing and organizing sediments. To understand the dynamics of artificial placement in the context of our understanding of natural input and transport of sediments. Because of the co-occurrence of log placement and sediment placement, and the effects of the wave energy environment on sediment transport, we included consideration of beach logs, breakwaters, and groins in our consideration of sediment dynamics. A list of regulatory questions about beach nourishment was generated by advisors working with quantification of beach nourishment under the Endangered Species Act.

For non-natal nearshore salmon rearing, we limited analysis to observations of fish use in the nearshore habitats after departing natal estuaries, while including re-entry into non-natal systems. The focus was on the relative use of landscape, independent of human activity. Of particular focus was the use of habitats commonly described as “pocket estuaries”. Some effort was spent differentiating among different types of shoreline habitats, compared to the available evidence.

Science Review Team and Informants

The primary purpose of the science review team is to provide a detailed review of written materials produced by the author team. The composition of the science review team should consider:

- The interdisciplinary aspects of the topic,
- The range of stakeholder groups that may have different perspectives, concerns, or analytical approaches to the same topic.
- The ability of review team members to provide substantive review of detailed documents of the project life.

For some topics, a few individuals may have a large proportion of experience with a topic. In identifying science review team members and early informants we favor staff with extensive field science experience. We engage the most experienced on-the-ground practitioners as early informants to take advantage of existing pools of knowledge and experience, reducing the effort necessary to assemble current best-available evidence. This may require the provision of compensation to maximize the ability of experts in the field to participate in the sprint process. We may also include science sprints as part of an award to science teams that complete substantive work aligned with regulatory needs.

EXAMPLE: By limiting the science review team to three groups, we allowed for some redundancy to ensure that adequate labor would be available. Part of team recruitment involved evaluating whether compensation was necessary and at what level. We had hoped to add a tribal shellfish biologist to the team, but were unable to recruit an individual. We identified a biological scientist at UW with extensive local experience monitoring biological functions and services of beaches (J. Toft), a physical scientist and consultant with experience in beach nourishment project management (J. Cote, K. Ketteridge), and two NOAA fisheries scientists with interest in quantification of ecosystem services (P. Kiffney/B. Sanderson). In several cases,

we allowed for more than one person to fulfill a science review role to facilitate fulfillment of duties. We identified a substantive body of unpublished observations and data held by Jim Johannessen, who has extensive experience designing and monitoring beach nourishment projects in Puget Sound.

Step 2 - Gather Evidence and Informants

The author team typically evaluates a topic using a literature search and review to support the development of a working conceptual model. Regional technical networks and the literature review are used to identify initial informants. Initial interviews with key informants identify more published evidence, as well as important dynamics or uncertainties that are not well represented in the published literature. Interviews lead to evidence, and evidence leads to new interviews. The process of gathering and sorting evidence continues throughout the sprint process, with the goal of exhausting available evidence.

Because of this, a system for classifying and tracking evidence is critical for representing this assessment of evidence. At the end of the sprint, archiving evidence is an important step for reaching our aims, and so the premeditated organization of literature supports all aspects of the work. The organization of evidence considers how the evidence informs the conceptual model.

The following concepts help frame the nature of a piece of evidence and allow for systematic evaluation of a source of evidence and documentation of all sources of evidence used in a study. The following elements may be included in a tabular analysis of evidence.

- **Citation** - an appropriate bibliographic reference for the evidence.
- **Extent** - the spatial or temporal extent of information collection upon which the evidence is based.
- **Timing** - the historical context in which evidence was gathered.
- **Proximity** - the degree to which the extent of the evidence overlaps or relates to the scope of the study.
- **Conceptual Proximity** - the degree to which the evidence matches the subject of study. For example, if the topic of study includes chinook salmon, is the evidence about chinook salmon, or an observation of pink salmon in a similar life stage?
- **Conceptual Model Intersection** - this may involve the development of a set of keywords for conceptual model components that are linked by the evidence.
- **Meaning** - finally, a point of evidence results in a narrative interpretation the degree to which the evidence creates certainty or uncertainty.

Evidence is discarded when it is deemed not useful because it is geographically or conceptually not close enough while also not contributing a new perspective to the subject.

Differentiate Kinds of Evidence

While gathering evidence, we prepare to describe the weight of evidence using consistent language and rubrics. Most ecological evidence involves extrapolation of observations of past events in particular places to predict the outcome of a new event in a new place. Ecological

assertions used in regulation necessarily involve the evaluation of a weight of evidence to evaluate the certainty of a prediction. In a regulatory context, prediction need not be perfect, in that the likely outcome of an action always occurs in each instance. Instead, the outcome is likely to occur with enough frequency to cross some threshold of effect. This consideration of likelihood, thresholds, and of outcomes is the domain of the regulator. However, the science synthesis process, knowing the importance of this kind of analysis, can array the evidence in such a way that it supports these determinations.

The sources of evidence may be important. [RCW 34.05.271](#) requires WDFW to categorize sources of information used to inform technical documents that directly support the implementation of a state rule or statute. We recommend classifying evidence into the following categories:

1. **Independent peer review:** Review is overseen by an independent third party;
2. **Internal peer review:** Review by staff internal to the Department of Fish and Wildlife;
3. **External peer review:** Review by persons that are external to and selected by the Department of Fish and Wildlife;
4. **Open review:** Documented open public review process that is not limited to invited organizations or individuals;
5. **Legal and policy document:** Documents related to the legal framework for the significant agency action including but not limited to: (A) Federal and state statutes; (B) Court and hearings board decisions; (C) Federal and state administrative rules and regulations; and D) Policy and regulatory documents adopted by local governments;
6. **Data from primary research, monitoring activities, or other sources**, but that has not been incorporated as part of documents reviewed under the processes described in (i), (ii), (iii), and (iv) of this subsection;
7. **Records of the best professional judgment** of Department of Fish and Wildlife employees or other individuals; or
8. **Other:** Sources of information that do not fit into categories i - vii.

In these ways, we organize evidence with an understanding of how various legal authorities may need to evaluate the burden of proof. The language used to describe certainty or risk should be described, discussed, and used consistently. In this way, the interpretation of evidence can be more consistent. In addition, evidence of various kinds can be included, including where the source of evidence applies indirectly (for example, a behavior observed in another species of salmonid that may also occur in a target species) or where it occurs outside of a peer-reviewed journal article (such as unpublished primary data).

Assess the Scale of Effect

Many regulatory systems must make judgments about the scale of an impact so that the relative outcomes of alternative feasible actions can be weighed. Regulators may need to value ecosystem functions through quantitative systems of impact avoidance, minimization, or mitigation. A precise understanding of scale is not possible. However, understanding the range of possible scales of effect can provide enormously valuable information for regulatory decision-making and policy development.

To support quantification and alternative action assessment, specifically review evidence related to the area of effect, the intensity of effect (change in the relative value of services provided by an area), and the duration of effect (including onset and persistence of impacts). These parameters support the quantification of ecosystem benefit and impact assessments.

Inclusive Technical Informants

Gathering evidence is not limited to interaction with a science review team. To maximize the quality of information we propose the use of an interview process to identify peer-reviewed publications, technical reports, unpublished data, professional opinion, anecdotal evidence, and traditional ecological knowledge. Informants and evidence are located through an interactive process. Each informant contact is used to identify new informants. Communications with technical audiences are used to solicit new informants. The following strategies should be considered:

- All communications by the author team or the project coordinator also aim to solicit new evidence or informants.
- Track claims and sources of evidence based on best professional judgment back to specific informants, and confirm claims with informants so they can be attributed.
- Preferentially use one-on-one interview processes to press for precision and clarity of claims.
- Consider the use of structured expert elicitation techniques that evaluate the expert understanding of known information while exploring judgments concerning novel circumstances. (e.g. [Hemming et al 2017](#))
- Use conceptual models to map evidence and elicit feedback from informants (see below).

EXAMPLE: The beach nourishment sprint announced the project through the PSEMP Nearshore Workgroup and the Salmonid Workgroup. In addition, a set of known regional scientists and field experts were contacted directly. An initial literature review identified a body of evidence. The interests of the regulatory advisors were captured during this initial scoping. Several sources of evidence were identified in unpublished data sets, including the existing permit database which described the proximity and extent of the on-the-ground actions common in the regulatory process. The resources were mobilized to bring that evidence into the analysis. A body of evidence was brought into the analysis that was geographically removed (outer coast sediment transports) but was contextualized using a variety of sources of evidence with greater proximity to the scope of the study. A single source of evidence (a contractor responsible for a large number of important projects) was identified as holding key evidence, and a sub-contract was executed to enable his contribution of field data to the effort. All sources of evidence were categorized using the WDFW protocols described above.

Step 3 - Refine Conceptual Models and Develop Narrative

Conceptual models provide both a basis for conversation with informants and a way of organizing the evidence they produce. A conceptual model typically identifies ecosystem structures, processes, and functions within a particular domain. Structures and processes are

usually described in boxes, while arrows show relationships among those structures and processes. Conceptual models may also necessarily layer on critical biological information, such as the behaviors or condition of organisms, to adequately clarify ecological relationships.

Ambiguous and unclear conceptual models can obfuscate understanding, while clear conceptual models can be used to test expert opinion and represent the weight of evidence. Consequently, conceptual models may be refined over time to represent project learning, and ultimately conceptual models structure the narrative findings of a science sprint effort.

To support the organization of evidence we encourage author teams to identify and stabilize terminology and develop a box-and-arrow conceptual model to represent important relationships. The initial conceptual model should be carefully developed in parallel with the initial literature review. The following suggested conceptual modeling strategies may add value:

- **Where Useful Make Model Elements Specific** - Too much generalization can make the meaning of a model ambiguous to a reader. Consider including specific attributes of ecosystems (for example “offshore winnowing of fine sediments” rather than “sediment transport”) and clarify the strength, certainty, and effects of relationships.
- **Review Old Models** - Evaluate previously developed conceptual models for inspiration, and to ensure that potential influences are not being missed. Ultimately sources of evidence rather than old models should justify model linkages.
- **Build from an Open Structure** - Do not pre-structure the model in a way that confines or drives analysis. For example, PSNERP management measure models forced analysis into columns, presuming the flow of influence from action to process to structure to function limiting representation of feedback loops or how processes directly affect functions ([Clancy et al. 2009](#)).
- **Consider Sub-models or Model Territories** - Consider the identification of “sub-models” or delineation of territories within a conceptual model that describes major components of our understanding of phenomena.
- **Consider Context Models** - You might include a “context model” as a submodel describing how variation in the context of an action or phenomenon affects ecosystem dynamics.

Develop a narrative

Once a large body of evidence has been assembled and described conceptually, the author team constructs a narrative that presents the conceptual models and justifies claims by citing the evidence. The narrative generally follows the structures and dynamics introduced in the conceptual model and systematically summarizes evidence that supports the claims within the model.

Not all elements of the conceptual model may be well described by evidence, and this acknowledgment of observed dynamics, hypothesized or likely alternatives for causation, and the absence of direct evidence is an important part of the synthesis process. In this way, a well-constructed model can encourage a complete synthesis within the domain, and highlights

and does not neglect areas of uncertainty. If the narrative only presents the evidence, then the synthesis process may ignore uncertainty in favor of highlighting areas of knowledge.

The narrative may, in addition, present concepts that exceed the organization of the conceptual model, and introduce and test hypotheses that are important to regulatory decision-making. In this way the evidence can be interpreted in two reinforcing ways: 1) how the system is believed to function conceptually, and 2) how reliably this believed system understanding can be used to predict individual or cumulative effects from a series of specific actions, as required in a regulatory decision.

EXAMPLE: The beach nourishment project deprioritized conceptual models, as a large number of system dynamics were not well described by evidence, and basic presumptions about beach nourishment could be presented using simple model diagrams. Two territories were identified that structured the narrative: what we know about the movement of sediment (quite a bit), and what we know about how a change in beach structure affects services for biota (very little). Ultimately the context of beach placement became an important sub-model, whereby the structure of the beach had a strong effect on the duration of sediment placement. Our understanding of biotic effects was reinforced by varied and contradictory effects. However, the frequent and consistent observation of the rapid transport of sediment out of the placement area reinforced that any claim of a reliably beneficial biotic effect was poorly supported by the strong evidence of physical dynamics.

Step 4 - Share Claims

At some moment internal research and writing shifts to the broader external review of written documents. This sharing of claims begins with the science advisory team, progresses to regulatory advisors, and then ultimately to informants and a technical audience.

The science team is instrumental in developing an early and thorough critique, beginning with initial drafts of the early annotated bibliography and conceptual model. A sequence of science team reviews typically occurs at scoping, with an initial annotated bibliography and its associated conceptual model, and with a draft report narrative.

The coordination with regulatory advisors in this step is critical and should be early. The author team may be disappointed that regulators identify significant factors important in the practical application of knowledge that has been neglected. The author team may be unfamiliar with the character of human development activities or important legal thresholds or controversies. Such concepts may have been identified in step 1. It is not until step 4, however, that the author team learns if the narrative they have constructed matches the needs of regulatory decision-making.

While informants are under no obligation to respond to review, they have an intrinsic interest in how their findings are integrated and may provide important insights into the veracity of the author team's findings.

Acknowledging uncertainty is critical for describing the state of knowledge. [Sullivan et al \(2006\)](#) identify four sources of uncertainty common in environmental sciences, providing a minimum framework for organizing this important part of the science synthesis.

1. lack of basic natural history or demographic knowledge,
2. lack of information about the relationship between environmental parameters and populations,
3. influence of unpredictable events, and
4. high variability in parameter estimates.

The most robust and efficient way to support contestation over claims is through a crowd-sourced online counter-claim process, where reviewers can offer a logical counter-argument or present new evidence. This potential is considered again in Section 5.

Step 5 - Open Publication

Following a systematic review, the author team completes a revision of the draft and submits that work for publication. A draft final publication of results creates a concise product that reflects the findings of the sprint. These initial findings may lead to external peer-reviewed publication or agency publication, and likely include:

1. A final citation list of all evidence
2. A final conceptual model
3. A narrative presenting evidence in the context of the conceptual model
4. Acknowledgement of counterclaims and uncertainties

These products are shared with all participants and interested parties identified throughout the sprint and are circulated among technical audiences. Although publication in a peer-reviewed scientific journal is not essential, doing so strengthens the scientific integrity of the synthesis' conclusions.

4.0 The Salish Sea Restoration Platform

Knowledge loss is common in agency science. Public websites are periodically purged and redecorated, documents may be buried in contracting databases, and reports and data may live only on a hard drive, soon forgotten after retirement. While some agencies have robust searchable archives, many do not. Agencies typically only archive their own products.

Substantive ongoing discussion of evidence is rare. Author teams control their pen, and agency publication is a one-way distribution system. Meanwhile, academic and institutional authors define the best available science as interdisciplinary, collaborative, inclusive, and evolving as described by Sullivan et al. (2006) and Ryder et al. (2010).

The Salish Sea Restoration Platform (<https://salishsearestoration.org>) was initially developed by staff at NOAA and WDFW to support the ESRP Learning Program and is being redeveloped under the stewardship of the Society for Ecological Restoration. It is built from the low-cost and

open-source software used to develop Wikipedia. It aims to minimize institutional knowledge loss and support knowledge exchange among practitioners.

It provides an open and searchable portal for storing public domain documents and organizing evidence and links around open-ended topics and categories. It depends on small voluntary contributions associated with individual projects and is managed under a durable operating agreement. It is specific to the Salish Sea Bioregion and captures a broad constellation of social-ecological system knowledge with the aim of supporting long-term stewardship. To our knowledge, it is the only platform that allows the archiving of evidence across agencies and then supports community-based collaboration on organizing that evidence. It is cost-effective and efficient.

Our two science sprints use this platform to archive [the Science Sprint effort](#), its reports as well and key pieces of evidence used in their development, resulting in a new Topic Page for [Beach Nourishment](#) and for [Non-natal Nearshore Rearing of Salmon](#). Those products can be reviewed and commented upon by an open user network.

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Appendix A - Potential Science Sprint Topics

The following topics were identified through conversations with regulators and in interdisciplinary workshops. They are provided in a general order of greater to lesser interest however the ordering is not precise and the analysis is cursory. Suggestions for selection and scoping are offered in Section 3, Step 1, and recommend early strong engagement with regulatory decision makers as a critical step.

Shellfish Aquaculture	What are the effects of industrial shellfish aquaculture techniques on fish and nearshore habitat. Analysis: aquaculture is common and subject to regulatory determinations. There is a body of evidence that has not been strongly synthesized.
Nearshore Habitat Suitability for Salmon	What evidence describes how shorelines with shallow, protected, fine-textured, and vegetated areas with and without freshwater inputs (embayment shoreforms) provide higher habitat functions for juvenile salmon? Analysis: Elements of this topic were considered in the non-natal rearing sprint. It is unclear if there is a body of evidence that can inform the relative value of other habitat attributes.
Armor, Sediment and Beaches	What is the value of sediment input from coastal bluffs for ecosystem services in different settings? How are the benefits of armor removal affected by context? Analysis: Shoreline armoring is commonly regulated and the site specific or cumulative impacts are difficult to quantify. There is a body of evidence.
Benthic Macroalgae Vulnerability	How does shoreline development affect benthic Macroalgae. How do kelp and other seaweeds provide ecosystem services compared to eelgrass? Analysis: While eelgrass are relatively well researched the effects of shoreline development on algae and the relative ecological functions of macroalgae are less well defined (with Mumford 2007 developed without regulatory advice.)
Sea Level Rise	How does sea level rise affect the duration or severity of development effects Analysis: sea level rise may be an important component of effects analysis. This is a broad topic, with many areas for potential synthesis.
Marine Riparian Vegetation	How does the structure composition and width of shoreline vegetation affect shoreline ecological functions? Analysis: While shoreline vegetation is commonly regulated there may be limited body of evidence to synthesize in the marine setting.
Softshore Armoring	How does "softshore armoring" result in gains and losses of ecosystem services? Analysis: While a wide range of variable treatments are regulated, the

	question is ambiguous, and may lack a body of evidence.
Docks	How do we minimize and avoid impacts from docks, and what kinds of mitigation are effective. Analysis: Some recent synthesis work on small docks has been completed by Lambert et al. 2021, and additional evidence may be lacking.
Intertidal Culvert Fish Passage	How do we evaluate impacts of coastal stream mouths affected by transportation infrastructure. Is this about estuary environments? Small streams draining directly into Puget Sound are not likely salmon bearing. Analysis: these features are common, and maintenance is regulated. This may relate to tribal treaty rights. The body of evidence has increased with work by Small and Smith (WDFW).
Micro-Restoration	What are the effects of eco-engineering and small restored shorelines under sea level rise? At what scale is restoration effective? Analysis: small on-site mitigation using habitat features is not uncommon. There may be a body of evidence, largely from City of Seattle projects.
Woody Wrack	What are the measurable benefits of restoring logs on a beach, and how do they interact with sediment? Analysis: Presence of absence of wood is not strongly regulated, and overlaps with softshore armoring, and beach nourishment topics, and may lack a body of evidence.
Tire Reefs	What are the effects of tire reefs, including leaching of toxins? Analysis: regulation of tire reefs is uncommon. There may not be a sufficient body of evidence.
Forage Fish Suitability	How do beach conditions benefit spawning success for forage fish? How do different actions affect these services? Analysis: forage fish functions are a factor in determining the impacts of development on beaches, there is a body of evidence that hasn't been recently synthesized.
Creosote Removal	How do we quantify the effects of removing creosote from the nearshore and intertidal? Analysis: Creosote removal is a common small mitigation action associated with development projects.
Hard Armoring Necessity	How do we evaluate when hard armoring is actually necessary under the law? Analysis: shoreline armoring is frequently analyzed for regulation.