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Cumulative effects considerations for integrated planning in DFO

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF BOXES

LIST OF TABLES

ABSTRACT

Integrated planning is a policy driven process to establish ecosystem, cultural, social, and economic objectives in line with a given policy. Integrated plans can provide the overarching framework for multi-jurisdictional engagement, the inclusion of community and stakeholder interests, the setting of ecological objectives informed by multi-sectoral interests, the compilation of information from different knowledge systems, and ecosystem-based and adaptive management. They are a valuable platform for incorporating cumulative effects in decision making because comprehensive assessments of cumulative effects require an understanding of the ecological impacts of human activities to inform the policies and legislation used to manage them. Integrated planning can be used to operationalize an adaptive management approach that includes monitoring the state of fish and fish habitat and compliance with regulatory actions. Synthesis of information about past and current works, undertakings, and activities (and activities not under the jurisdiction of Fisheries and Oceans Canada) within an integrated plan will position the Fish and Fish Habitat Protection Program (FFHPP) to determine the effectiveness of Departmental management and conservation strategies for fish and fish habitat and evaluate program performance. However, FFHPP will also require an integrated planning policy to establish goals for planning and the processes to implement integrated plans through regulatory decision making process regarding project proposals. The context and scope of such a policy will also help frame the science needed to inform the planning process, the monitoring activities, and the regular review of the performance of the framework, and individual integrated plans regionally. We provide and customize examples from integrated planning internationally.

INTRODUCTION

Integrated planning is a policy driven process to establish objectives that may include ecosystem, cultural, social and economic objectives depending on the policy. Integrated planning is generally used in the development of plans and programs to deliver legislative and policy goals and objectives in the management of natural resources including restoration and conservation strategies (Cormier et al., 2017; Lester et al., 2020). Within the context of cumulative effects, integrated planning can also set environmental targets to address those effects. Industry sectors can then use such targets to manage the pressures generated from specific industries (Stephenson et al., 2019). Cumulative effects present a challenge to current regulatory processes, as they frequently occur at different spatial and temporal scales from the original pressures that stem from the kinds of effects that are typically considered in the process. This implies that cumulative effects concerns raised by stakeholders are not necessarily the result of current or even local activities and their pressures. The effects can be the result of past activities and their pressures that occurred in other areas and which may manifest at different landscape scales. Thus, collaboration across jurisdictions, stakeholders and landscapes is key to the success of integrated planning to ensure that human activities and their pressures are managed by best available tools (Newton and Elliott, 2016). Using a combination of evidence-driven, along with qualitative approaches, expert and local knowledge, integrated planning could bring together stakeholders and competent authorities to figure out how to address the cumulative effects identified through monitoring and assessment (Klain et al., 2014; Stelzenmüller et al., 2021; Zaucha and Gee, 2019). Finally, the context of any integrated planning process should be established in policy to scope the development and environmental concerns to be considered before the planning initiative starts (Lawrence, 2011; Sitas et al., 2013; Stelzenmüller et al., 2021), which includes the scientific support needed for regional cumulative effects assessment and parts of the management cycle outlined in Figure 1.

The recent amendments to the *Fisheries Act* (*FA*) states that cumulative effects (CE) of past and current works, undertakings and activities (WUA) shall be considered for all regulatory decisions regarding the Fish and Fish Habitat Protection and Pollution Prevention of the *Act*. This amendment raises the question as to how CE could be considered in such decisions through integrated planning while being scientifically underpinned. The Fish and Fish Habitat Protection Program (FFHPP) requested scientific advice as per the following terms of reference:

Understanding cumulative effects in integrated planning:

1. Outline the state of knowledge on how cumulative effects are currently understood to manifest on the landscape.
2. Identify approaches currently used to understand and adaptively manage cumulative effects on the landscape.

This document was developed closely with another research document focused on the science needed to support cumulative effects considerations in project review determinations. The two CSAS research documents (Cormier et al., 2022; Hodgson et al., 2022) provide the Department with preliminary scientific advice on the consideration of cumulative effects (CE) within FFHPP. Although cumulative effects and cumulative impacts are often synonymous (Box 1), we use the current FFHPP policy statement definition of cumulative harmful impacts from works, undertakings and activities that generate pressures and ultimately cumulate effects as impairment to fish habitats to support fish life processes as well as effects to fish species, life cycles and functions.

INTEGRATED PLANNING AND PROJECT REVIEW

The authors of each team recognize that addressing CE involves multiple levels of management and policy across a broad range of activities (Figure 1). In the preparation of this document, we attempted to generalize our advice by focusing on two levels of CE considerations: (i) the watershed, ecosystem and integrated planning needs (Cormier et al., 2022), and (ii) the site, project, and decision making review needs (Hodgson et al., 2022). These two perspectives are multifaceted and can be lumped in different ways, but they are part of a circular process. The integrated planning scale advises on methods and information required to synthesize FFHPP activities across sectors, jurisdictions and regions to achieve broader environmental and ecosystem goals. The project review scale advises on standardization and interlinking of methods and information required to track CE in project review.

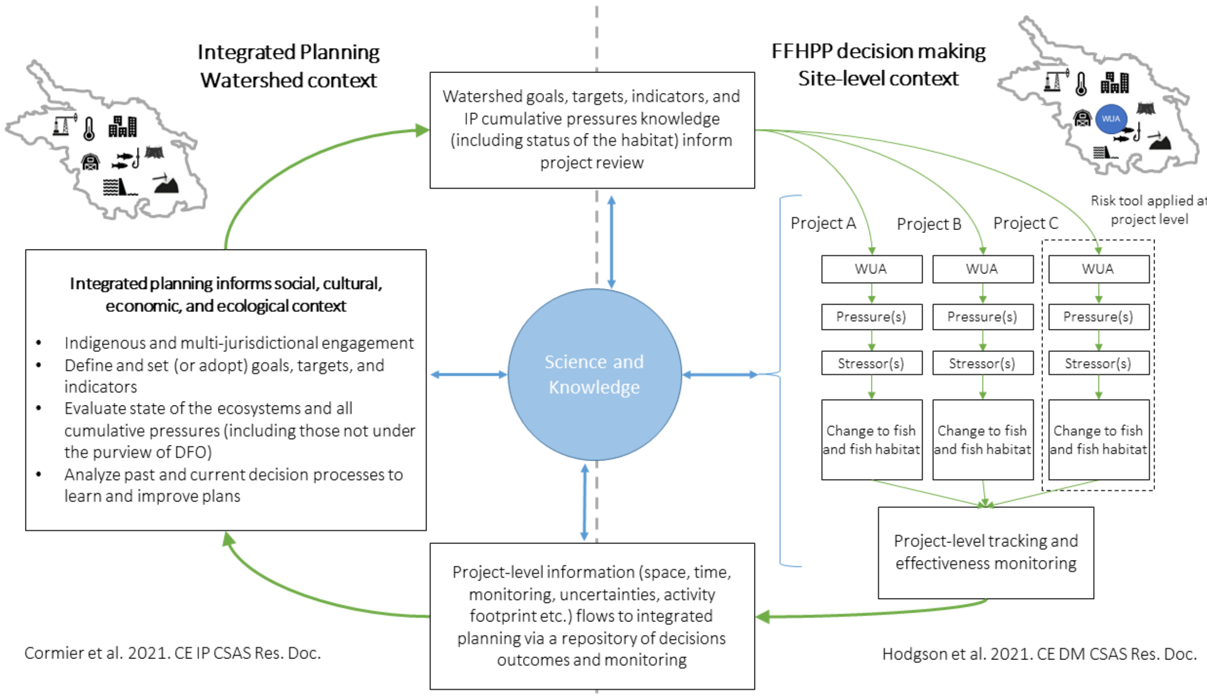

Figure 1. Cyclical flow of information between types of activities in the Fish and Fish Habitat Protection Program (FFHPP) of Fisheries and Oceans Canada with Science support and knowledge transfer is needed within and at each level of information exchange (i.e. human activity decision making and watershed level planning). Projects range from numerous small to large projects within the integrated planning spatial unit.

In Figure 1, the grey dashed line in the center of the diagram conceptually separates the cumulative effects (CE) considerations between the landscape or watershed-level context of integrated planning and the site-level context of project review. Integrated planning should happen at a watershed scale to encompass any hydrological connectivity that can, depending on the types and magnitudes of the pressures, allow CE to spread to other ecosystems and persist for many kilometers downstream. Watersheds are also good boundaries because they include terrestrial activities (e.g., forestry or land cover change) that can affect the state of fishes and their habitat. Site-level information can include the characteristics of the habitat and fish habitat at the WUA site or zone of influence (Hodgson et al., 2019). Ecosystem and watershed information required for CE considerations in project review can be generated from integrated planning, while information at the site level is generated from project review. Site-level information from multiple projects can be compiled to inform watershed considerations in integrated planning. The Science sector can advise and iteratively support evidence-based approaches for integrated planning, project review activities, and information flows. At the project scale, the green arrows represent the currently-considered linear pathways from WUAs to pressures to stressors to effects. The red arrows indicate potential linkages between project pressures and stressors, along with the accompanying, potentially additive changes to fish and fish habitat. The current CSAS process speaks to the scientific and management challenges imposed by these currently unconsidered and unmanaged additional pathways, as well as their subsequent impacts on information flow, planning and decision-making. Thus, Cormier et al. (this res doc) initially advises on CE considerations for integrated planning, and Hodgson et al. (2022) on CE considerations for project review, with some necessary overlap. It is expected that the processes and science at both scales will be iteratively improved through adaptive management and adhere to precautionary principles as uncertainties are addressed.

In this research document, we provide an overview of integrated planning approaches used in freshwater and marine environments. We then examine how CE considerations would be needed for an integrated planning approach in key aspects of FFHPP policy. We highlight the science inputs that would be needed to inform such a process. We also introduce the scientific challenges of conducting cumulative effects assessments due to the uncertainties in linking stressors and their effects to specific activities and their pressures, which are not only influenced by the pressures of human activities, but by natural variability and external factors such as climate change. We highlight how this challenge is compounded by the need to identify the regulatory and non-regulatory tools suitable to prevent or mitigate pressures from these activities. Finally, we discuss the important role of integrated planning to implement adaptive management strategies.

INTEGRATED PLANNING AND CUMULATIVE EFFECTS

Generally, the context and scope of aquatic and marine planning initiatives is set in policy, usually as a requirement of legislation (Neuendorf et al., 2018; Zaucha and Gee, 2019) and science can help identify the risks to those policies (Lausch, 2019). Integrated planning is mostly concerned with the protection and conservation of ecosystems or with addressing environmental issues such as cumulative effects. Depending on the legislation, however, integrated planning can also be undertaken to simply organize development activities and reduce conflicts between users of a given space. For example, planning under the European Maritime Spatial Planning Directive (MSPD) (European Union, 2013) has more to do with spatial allocation of maritime activities to reduce health, safety, and conflicting uses for economic development, while the European Marine Strategy Framework Directives (MSFD) (European Union, 2017a, 2008) has to do with the implementation of an entire suite of measures to achieve and maintain good environmental status. These two directives introduce the need for extensive coordination and collaboration between the competent authorities' mandates with planning to address their respective development and environmental objectives. Concomitantly, there is also growing global consensus that integrated watershed planning in the freshwater realm is needed to manage natural resource uses and to conserve ecosystems (Daniel et al., 2019). A freshwater example is the Canada-US Great Lakes Water Quality Agreement (Canada and United States, 2013). As with the marine examples, this agreement also includes ecological objectives considered within the context of cross-sector pressures and beneficial use impairment targets in Areas of Concern and lake-wide management planning (Creed et al., 2016; Friedman et al., 2015).

Such land-based planning requires extensive coordination and collaboration to bring together the different natural resource interests and the many specialists and jurisdictions to develop and implement a plan (Heathcote, 2009). Land-based, watershed, and urban planning are well-established processes used to organize human activities in relation to land-use, natural resources and conservation (Maring and Blauw, 2018; Sinclair et al., 2018; Sitas et al., 2013). However, the successful implementation of a plan depends on the ability and capacity of authorities and their stakeholders to integrate the plans' objectives within their industry sector plans (Chaffin et al., 2014; Cormier et al., 2019; Cumming et al., 2020; Stelzenmüller et al., 2021; Stephenson et al., 2019). Such integration continues to be a significant challenge in any implementation because of the work involved in adapting regulatory and non-regulatory frameworks that are well entrenched in sector management practices (Cormier et al., 2017; Elliott et al., 2020a; Stephenson et al., 2019).

Cumulative effects are the result of alterations to ecosystem structures and functions that occur, in some cases, over a long period or over large interconnected areas. From an ecosystem-based management consideration, human activities intentionally or inadvertently cause temporary or permanent changes to habitats and the biota. These changes and their effects on individual organisms may interact to drive ecosystem conditions beyond the normal range of variability into a degraded state (Jones, 2016). Recognizing that environmental impact assessments cannot adequately consider cumulative effects beyond a specific project (Cooper and Sheate, 2002; Foley et al., 2017; Noble et al., 2017), a key role of integrated planning is to establish the state of the cumulative effects through science-based CE assessments (CEA) at a broader landscape scale. Such CEAs should inform environmental impact assessments as to the potential contribution of a project proposal to the current level of those effects (Dubé et al., 2013; Noble et al., 2017). Given the scientific uncertainties in linking effects (to pressures and their activities as well as the management and operational uncertainties in the effectiveness of any mitigation, offsetting and restoration strategies (DFO, 2014), a strategy of integrated planning and environmental assessment processes can only be expected to address cumulative effects and realize results in the long-term and not in the immediate or medium term (Duinker et al., 2013). This implies that long-term monitoring programs are needed using indicators that can detect or predict anthropogenic changes within the background natural variability (e.g. signal-to-noise ratio) (Appendix I) (Elliott and Quintino, 2018). This is an important aspect considering the need to manage the right pressure-activity combinations to address those effects and the significant cost trade-offs that are most often involved in avoidance, mitigation, offsetting, or restoration decisions (Cormier et al., 2019). Depending in the status of the watershed or landscape (i.e. level of degradation or vulnerability), the emphasis on those different management actions would differ (e.g. more on avoidance/protection and restoration versus mitigation and offsetting). In data poor situations, more qualitative approaches could be used (Tallman et al., 2012), and in all situations historical knowledge of the landscape and relationships between biota and their surroundings should inform all integrated planning (IP) steps (Williams et al., 1997).

CUMULATIVE HARMFUL IMPACTS TO FISH AND FISH HABITAT

The FFHPP policy statement (DFO, 2019) also provides a comprehensive framework of objectives, pressures, and expected outcomes associated with effective management measures. It outlines how regulatory and non-regulatory tools can be applied to avoid harmful impacts to fish and fish habitat to maintain the long-term sustainability of fisheries resources and biodiversity. It also outlines how this can be achieved through standards and codes of practice that avoid, mitigate, and offset harmful impacts to fish and fish habitat. Historically, integrated planning for fish habitat management did have a planning function to integrate industry sector objectives with fisheries management objectives and avoid cumulative losses of habitats that support fisheries resources (DFO, 1986).

Based on the amended *Fisheries Act*, the Fish and Fish Habitat Protection Policy Statement (FFHPP policy statement) defines CE as cumulative harmful impacts on fish and fish habitat that are likely to result from a work, undertaking or activity (WUA) in combination other WUA's that have been or are being carried out (Box 1) (DFO, 2019).

Box 1. Section 8.6 of the Fish and Fish Habitat Protection Policy Statement, August 2019 (DFO, 2019).

FFHPP policy statement Section 8.6: Factors to be considered (subsection 34.1(1)) (d) the cumulative effects of the carrying on of the work, undertaking or activity in combination with other works, undertakings or activities that have been or are being carried on, on fish and fish habitat

The Department defines cumulative effects as any cumulative harmful impacts on fish and fish habitat that are likely to result from the work, undertaking or activity in combination with other works, undertakings, or activities that have been or are being carried out.

The consideration of cumulative effects provides a better understanding of the challenges to the aquatic ecosystem outside of the context of the reviews of specific works, undertakings, or activities. The Department is responsible for collecting the information needed to consider the cumulative effects of a proposed work, undertaking or activity.

Combining the cumulative harmful impacts interpretation (Box 1) with the interpretation of harmful impacts to fish and fish and habitat (Box 2 and Box 3), cumulative effects must be considered as resulting from past or current temporary or permanent WUAs. In the context of fish species this can be interpreted as, 1) increased mortality, or 2) impact on life stages and effects on life-cycle functions. In the context of fish habitat, cumulative effects could be interpreted as impairment to fish life processes resulting from WUAs causing temporary or permanent changes to habitat. Given that effects to fish are more challenging to assess scientifically and directly influence given the species population and ecosystem scales involved, effects to fish habitat tend to be more feasible to address with avoidance, mitigation, offsetting and restoration management strategies of FFHPP. Although the needs and priorities for any cumulative effects assessment fall within the roles and responsibility of the Program and their policies, the combined interpretations above sheds light on the scientific data and tools that would be needed to conduct an assessment for both fish ad fish habitat, and helps to define the scope of field monitoring requirements needed to support such assessment.

Box 2. Section 8.2 of the FFHPP policy statement.

FFHPP policy statement Section 8.2: Death of fish (section 34.4)

The prohibition in subsection 34.4(1) states that: 34.4 (1) No person shall carry on any work, undertaking or activity, other than fishing, that results in the death of fish.

Under subsection 34.4(2) a person may carry on such works, undertakings or activities without contravening this prohibition, provided that they are carried on under the authority of one of the exceptions listed in subsection 34.4(2), and in accordance with the requirements of the applicable exception. In most cases, this exception would be Ministerial authorizations granted to proponents in accordance with the Authorizations Concerning Fish and Fish Habitat Protection Regulations. This exception is provided for under paragraph 34.4(2)(b), which is described further in Section 8.4 below. The Fisheries Act includes a number of other exceptions, some of which have not yet been brought into force, which are described in Section 9 below.

The Department will apply a risk-based approach when evaluating the impacts of works, undertakings or activities on fish. Where death of fish is likely as a result of a work, undertaking or activity, the **Department shall consider the relative contribution of the potentially affected fish and their habitat to the productivity of the relevant fisheries before considering issuing a s.34.4(2)(b) Authorization. In doing so the Department may consider issues such as which species are likely to be affected, at what stage of their life the impacts may occur, and which life-cycle functions may be affected.**

Box 3. Section 8.3 of the policy statement.

> **FFHPP policy statement Section 8.3**: Harmful alteration, disruption or destruction of fish habitat (section 35):
>
> The prohibition in subsection 35(1) states that: 35. (1) No person shall carry on any work, undertaking or activity that results in harmful alteration, disruption or destruction of fish habitat.
>
> Under subsection 35(1) a person may carry on such works, undertakings or activities without contravening this prohibition, provided that they are carried on under the authority of one of the exceptions listed in subsection 35(2), and in accordance with the requirements of the appropriate exception. In most cases, this exception would be Ministerial authorizations granted to proponents in accordance with the Authorizations Concerning Fish and Fish Habitat Protection Regulations. This exception is provided for under paragraph 35(2)(b), which is described further in Section 8.4 below. The Fisheries Act includes a number of other exceptions, some of which have not yet been brought into force, which are described in Section 9, below.
>
> The Department will apply a risk-based approach when evaluating the impacts of works, undertakings or activities on fish habitat. Following from the definition of fish habitat noted above, **the Department interprets “harmful alteration, disruption or destruction” as any temporary or permanent change to fish habitat that directly or indirectly impairs the habitat’s capacity to support one or more life processes of fish**.

The intent of a planning process is to engage partners and stakeholders to support decisions regarding project investments and economic development early on to be better prepared and to advise on mitigation and conservation measures as well as habitat restoration and offsetting strategies (DFO, 2021). In addition, a planning process also needs to identify areas that are sensitive to threats at a landscape scale to provide such advice. Science is also needed to provide information on the state of fish and fish habitat in order to inform the planning process. This requires structured and integrated monitoring programs, and assessment support of varying types. As illustrated in Figure 2, monitoring within the WUA footprint would to allow assessment of the effectiveness of management measures implemented for that WUA. However, additional monitoring of fish habitat would also be needed to assess the pressure footprint from the residual impairment resulting from other WUAs within the same landscape. These data, combined with other scientific knowledge and reference data regarding natural variability, climate changes, would then be used to identify the stressors generated from the pressures that combine in multiple ways (e.g. synergistic, antagonistic Murray et al., 2020) and ultimately assess cumulative effects at a broader ecosystem, effects-footprint level. From this cycle of assessment, the predominant pressures that are threatening fish and fish habitat could then be considered in the planning process to determine the most effective way to reduce and remediate the pressures and ultimately their effects through coordination with other partners or improvements to the regulatory and non-regulatory tools of the Program (e.g. Prime et al., 2013).

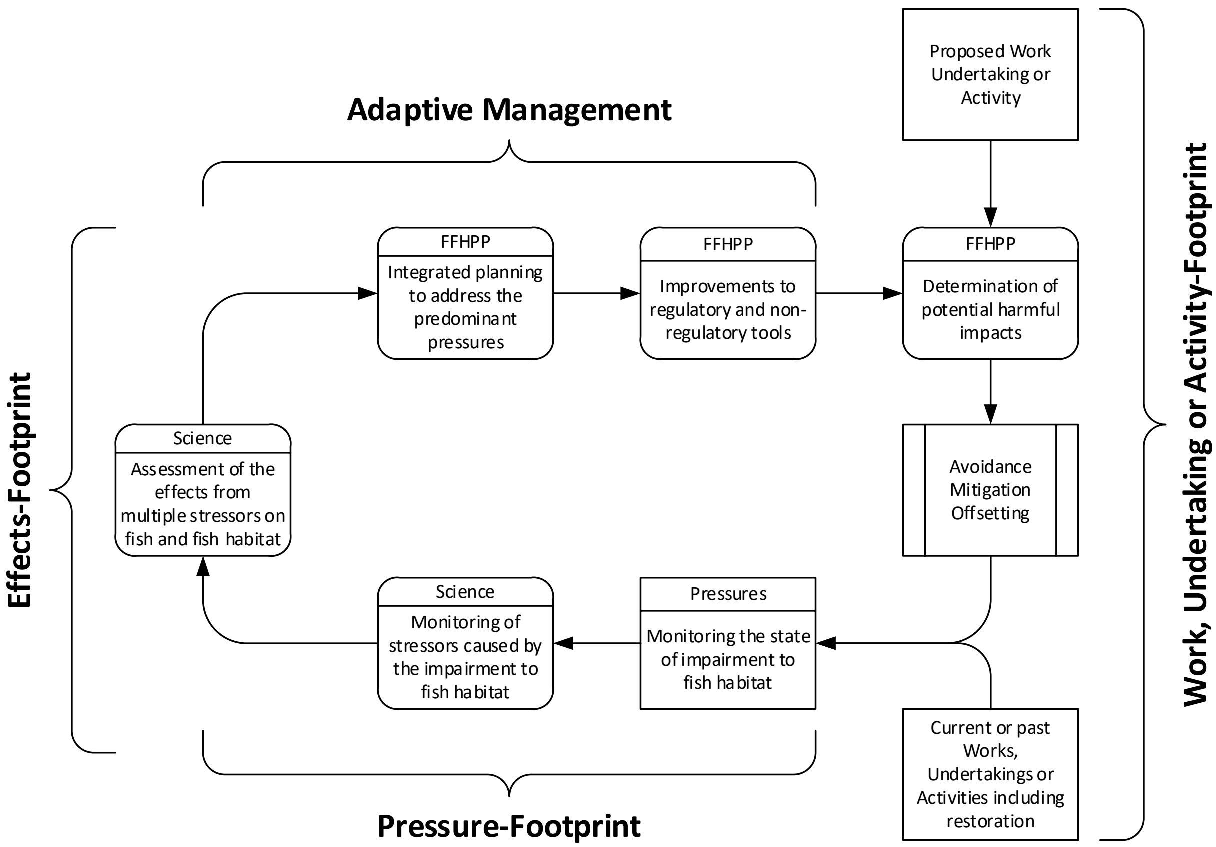

Figure 2. Integrated planning and cumulative effects assessment cycle delineating where WUA, pressure and effects footprints might be considered and by which sector. Stressors, the proximal variables that produce biotic effects are assessed by Science in connecting impairments back to pressures and activities that the Program can manage.

MANAGING THE PRESSURES TO REDUCE THE EFFECTS

Cumulative effects assessments are seldom used in real-world management processes because of the complexities of tracking multiple effects on different ecosystem components and linking these effects to the activities to be managed (ICES, 2019; Stelzenmüller et al., 2018). The context and scope of these assessments varies across management sectors and ecosystems, depending on the spatial and temporal scales involved. This complexity and variability means that each assessment may assume different cause-effect relationships, requiring different data and methods for assessment as well as different indicators and the endpoints (Hodgson and Halpern, 2019; Murray et al., 2020).

Given that planning should ultimately guide management strategies to address cumulative effects, the causes of the effects identified by such assessments ultimately need to be linked to the disturbances from the activities to be managed. Without this link, it is not possible to justify changes to management practices in a regulatory context, and forces the focus onto one of restoration and remediation only. The causal pathways of effects in terms of ecosystem or biotic responses are inherently difficult to link to the root-causes because of the variability in anthropogenic and natural gradients in the pathways of influence, the multiple scale-dependent mechanisms, the nonlinear responses, and the roles of current and historical influences (Allan, 2014), not to mention anticipated. From freshwater to marine ecosystems, there are thousands of cause and effects pathways across watershed (including lakes and rivers), coastal, and marine scales (Borgwardt et al., 2019). There is a need for scientific research to delineate the pressures from the stressors of effects to enable the development of management tools that are most effective at managing activities and their pressures (residual impacts) as shown in Figure 2. We don't necessarily need full understanding however to identify the main management levers to make improvements.

Management measures developed and implemented for causes that are loosely linked to effects can prove to be ineffective (Stelzenmüller et al., 2020). To improve effectiveness, the spatial scale of management and the relevant cumulative effects should be considered. These include an assessment of the area where the human activities occur (activity-footprint), the area covered by the pressures of these activities as the mechanism and intensity of change on the prevailing habitats and species (pressure-footprint), and the area of the adverse effects as a result of the stresses generated by the pressures (effects-footprint) (Figure 2) (Elliott et al., 2020b). Environmental regulatory and non-regulatory frameworks used to manage sector activities regulate the impacts and disturbances within the footprint of the individual activities through conditions of authorizations, licenses, and permits. In contrast, integrated planning identifies the pressures from multiple activities within the footprint of the pressures at a broader landscape scale to establish management strategies to eliminate or reduce the pressures and ultimately the cumulative effects within the ecological footprint of these effects (Elliott et al., 2017; Stelzenmüller et al., 2018).

Using the European MSFD as a guide (Appendix I), Table 1 outlines the type of indicators that would be considered for each of the threats listed in the FFHPP policy statement. As a template, this framework could be further developed to identify the effects at a landscape scale linked to the predominant pressures and impacts, and the human activities that generate them. As mentioned above, the framework adapted to a freshwater context could provide insight as to the different types of indicators that would be needed for monitoring the effectiveness of the management measures in the WUA footprint, the state of impairment in the pressure footprint and the stressors within the effects footprint in relation to specific ecosystem objectives. Table 1 is a preliminary analysis of potential indicators that would have to be developed further in collaboration with FFHPP. More comprehensive lists of pressures and effects are available in the Pathways of Effects CSAS research document (Brownscombe et al 2021). Next steps, perhaps for a DFO cumulative effects working group, would be to specify the indicators to be measured and methods. Table 1 should be compared against other North American (NA) and international efforts in freshwater systems and mapped out against the pathways of effects to connect activity to pressure to stressor and ultimately effect pathways at regional scales. Regional CEAS are most relevant to the integrated planning process.

Table 1. Examples of activities, pressures, and their effects footprints (Figure 2) for freshwater ecosystems using the format of the EU Marine Strategy Framework Directive (Appendix I) as a template.

Threats to fish and fish habitat as defined in *Fish and fish habitat protection policy statement, August 2019*	**Indicators of WUA-footprints**	**Indicators of the pressure-footprint**	**Indicators for the effects-footprint**	**Good environmental status objectives**
Definitions	Activities are the human actions that can alter ecosystems and can result from human need for food, shelter, transportation, health, and clean water.	Pressures are events or agents (biological, chemical or physical) exerted by one or more human activities to elicit an effect (that may lead to harm or cause adverse impacts). (Murray et al., 2020)	Effects are changes to the environment or to health, social or economic conditions and the positive and negative consequences of these changes. (DFO, 2019)	Objectives are statements that define healthy ecosystem status and are informed by understanding of pristine or near pristine conditions for fish and fish habitat
Habitat degradation, which may occur as a result of the removal or change of important habitat components, blocking fish passage, infilling of lakes, streams or wetlands to create dry land, or other activities in freshwater or marine environments that impair their ecological functions	**Infilling** e.g., for urban development **Draining of wetlands** e.g., for agricultural or development purposes **Dewatering of lakes and or rivers** e.g., for mineral extraction	Permanent physical loss of fish habitat Alteration of water budgets Loss of vegetative nursery habitats	Fish mortality Fish biodiversity loss Declines in fish productivity or changes in community structure	Permanent alteration has minimal impact on lake-wide or watershed-level metacommunity dynamics. Offsetting actions maintain biological diversity and sensitive wetlands are protected. Offsetting actions maintain biodiversity at watershed scale.
Habitat modification, which may alter habitat characteristics (such as flow), negatively affect spawning or rearing, or cause the death of fish, and which may be caused by dams or other impoundments, water diversion, stream crossings or water extraction for municipal, industrial or other uses	**River regulation** e.g., for hydropower generation **Shoreline armouring** e.g., for urban development **Water diversion** e.g., for agricultural irrigation **Dredging of rivers or lakes** e.g., for recreational or commercial navigation	Alteration of flow regimes Fragmentation of habitat Disruption of natural shoreline processes e.g., wave action or sedimentation regimes Alteration of water budgets and groundwater or hydrological regimes Alteration of substrates and bottom sediments	Alteration in the movement and migration of species Loss of nearshore habitats important for different life stages and species Alteration of nutrient dynamics Alteration of habitat use or loss of functional habitats	Level of fragmentation does not disrupt biodiversity, habitat use, and population or community dynamics. Nearshore spawning and nursery habitats are not permanently impacting by armouring activities. Human-induced eutrophication associated with agricultural water withdrawals and fertilizer application is minimized to reduce the potential of harmful algal blooms and oxygen deficiency in bottom waters. Dredging does not result in permanent habitat loss or disrupt the migration and movement of fishes.

Threats to fish and fish habitat as defined in *Fish and fish habitat protection policy statement, August 2019*	**Indicators of WUA-footprints**	**Indicators of the pressure-footprint**	**Indicators for the effects-footprint**	**Good environmental status objectives**
Aquatic invasive species, which may threaten fish through competition, predation or habitat impacts	**Aquaculture of non-native species** e.g., for food **Recreational fishing** e.g., introduction and stocking of non-native species for sport fisheries	Input of genetically modified species and translocation of native species Input or spread of non-indigenous species	Alteration of species composition Declines in less competitive native species Alteration of habitat quality e.g., introduction of Dreissenid mussels	Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems. Non-native species stocking does not disrupt the community dynamics of receiving waters.
Overexploitation of fish, which may lead to depleted or unsustainable populations	**Commercial and recreational fisheries** for food, recreation and or sport	Extraction of, or mortality/injury to, wild species	Loss of fish abundance/biomass Alteration of population and community dynamics	Populations of all commercially and recreationally exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock.
Pollution of many kinds, which may adversely affect water quality and fish health	**Industrial and urban development** e.g., chemical or thermal effluents from industrial activities	Diffuse and point source releases of deleterious substances	Reduction in habitat quality Fish mortality Proliferation of pollution tolerant species and loss of sensitive species	Concentrations of contaminants are at levels that do not give rise to pollution / toxic effects.
Climate change, which is causing water temperatures to increase and is bringing changes to the geographical distribution of some species, rainfall patterns, water levels, flows, water chemistry, and temperature, that are important to support the characteristics and proper ecological function of fish habitat	**Transportation and industrial GHG emissions**	Alteration of thermal and hydrological regimes	Shifts in thermal habitat and dissolved oxygen dynamics Redistribution of spatial range of species	Adaptation actions minimize the effects of climate change on fish and fish habitat resulting in maintenance of biodiversity, species distributions, and community dynamics.

INTEGRATED PLANNING AND ADAPTIVE MANAGEMENT

Adaptive management is the iterative process of learning the effectiveness of management actions through monitoring and evaluation of those actions, which then provides the basis for continuous improvement of management strategies over time (Figure 3) (Faber et al., 2007; Holling, 1978; Walters, 1986). An integrated planning cycle involves planning, plan implementation, and monitoring, with the necessary iterations to operationalize an adaptive management approach (Stelzenmüller et al., 2021). This implies that the measures identified in the plan are monitored and evaluated in terms of the expected outcomes of the measures and the objectives being sought. This also implies the need to monitor conformity and compliance to provide insight into the measures' effectiveness and the performance of the plan in achieving its objectives. Monitoring programs must be fit for the purpose of the plans' intents in order to avoid monitoring for the sake of monitoring (Noble and Birk, 2011).

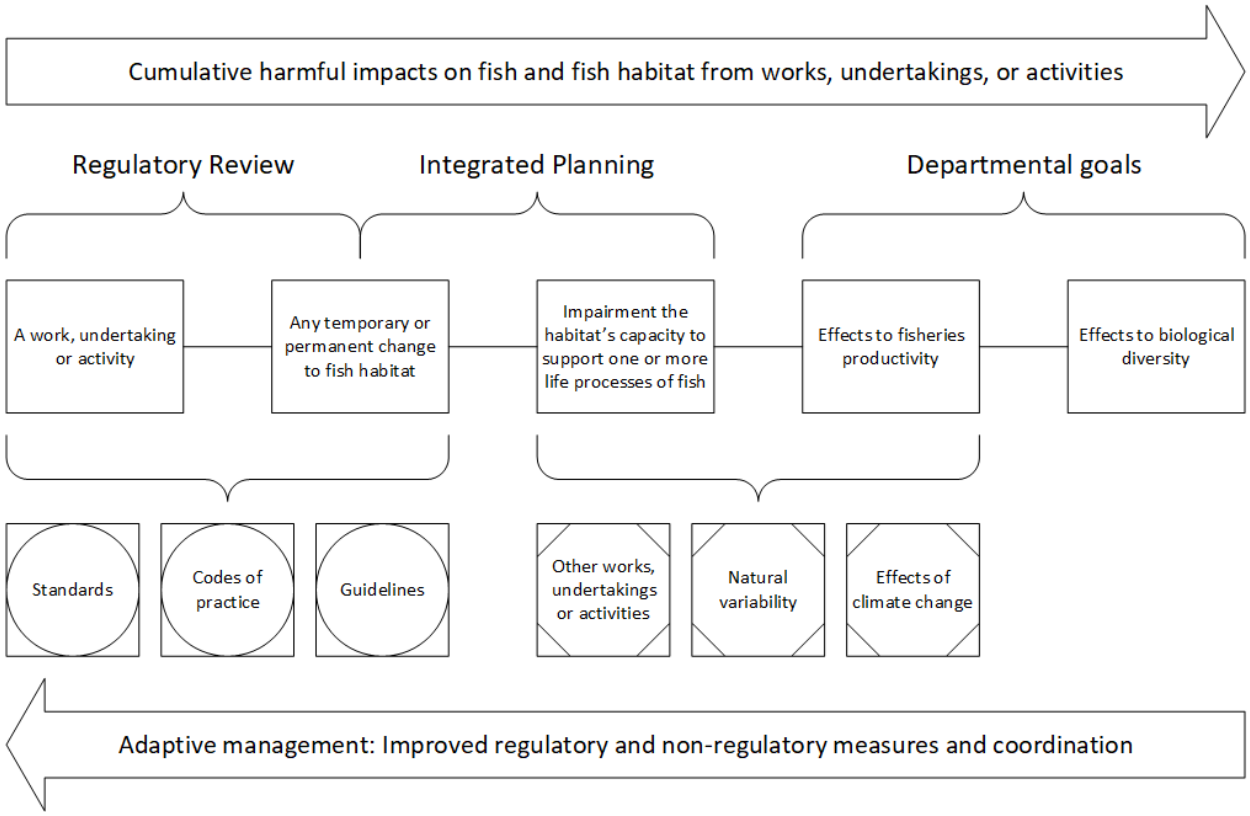

Figure 3. Schematic diagram linking regulatory review or decision making processes in the broader integrated planning framework and beyond. Information flows both ways, as the arrows indicate.

An integrated plan within FFHPP would need to establish what is to be assessed (after engagement with communities, other management jurisdictions, and sectors) to ensure that monitoring programs will deliver the appropriate data to conduct such assessments. Monitoring and tracking project impacts to fish and fish habitat, including compliance, will be needed to provide an understanding of the temporary and permanent changes occurring within the footprint of the projects (including direct and indirect impairments). However, monitoring of the pressures at a broader watershed scale would also be needed to understand the level of impairment to the capacity of fish habitat to support life processes of fish or the level of fish mortality (Box 2 and Box 3). Science would need to develop criteria for impairment in terms of fish habitat capacity to support life processes of fish, and where achievable, the level of fish mortality incurred, but in many regions this involves potentially a huge number of species (Katsanevakis et al., 2020). Nonetheless tools exist that can help standardize equivalencies used for pre and post project evaluations that help gauge the potential impacts even when field data is lacking and where large fish communities are represented by guild and life stage responses in habitat supply (e.g. HEAT, DFO 2019). Analysis of project pre- and post-WUA data, and targeted regulatory monitoring of different types of WUAs, combined with scientific monitoring of reference area with good experimental design, requires coordinated effort that can be facilitated through IP.

Although the science involved in monitoring CE is robust (Dubé, 2003; Dubé et al., 2013), it may not be relevant to the questions needing answers for habitat managers and stakeholders as well as regulators (Duinker and Greig, 2006; Foley et al., 2017). Integrated planning also plays a key role in identifying the questions for science advice, such as further examinations of monitoring and assessment results, regarding new emerging activities and their pressures, as well as improvements to management strategies and their measures (Box 4).

Box 4. Factors that may influence future iterations of a plan during a review.

- new scientific knowledge regarding habitats, species, populations (including thresholds);
- emerging trends in ecosystems processes and components at various scales;
- new types of activities that are not addressed through current measures to address their impacts;
- changes in legislation, policies and programs (as they affect the evaluation endpoints);
- new or more effective technologies to avoid and mitigate harm to fish and fish habitat; and
- new or more effective offsetting and restoration methods or direction.

Integrated planning informs how such information is merged within the context and scope of the policy, for the initial planning and subsequent review phases, and in consultation with partners and stakeholders (Stelzenmüller et al., 2020, 2018). In risk management (ISO, 2018), a residual effect is the deviation from the desired policy objectives that are expected outcomes of management decisions and strategies. Therefore, a cumulative effects assessment tied to a planning policy could evaluate the temporary and permanent changes to fish habitat, the impairment of the habitat's capacity to support life processes of fish, the changes to fish habitat and/or the productivity of the relevant fisheries. It is up to the program and its policies to establish the context and scope of such assessments (Stelzenmüller et al., 2020, 2018). Examples of planning processes are available across a wide range of environmental management strategies (Ehler and Douvere, 2009; Stelzenmüller et al., 2020, 2018). Informed policy ultimately determines the frequency of conducting a review after plan implementation. These periodic evaluations typically vary from 5-year reviews for smaller planning initiatives to decadal timeframes for large scale planning initiatives (Coordinated Science and Monitoring Initiative under Science Annex of GLWQA, 2013; USFWS 2015) (Canada, 2007; Canada and United States, 2013; European Union, 2017b).

There are many types of assessment and reporting tools used to inform policies and management decisions. Each is developed for very specific scales and ecosystem concerns, to address different policy contexts and objectives. They may include, for example:

- the state-of-the-habitat reports and report cards (Anderson et al., 1999; Andersson and Bodin, 2009; Astudillo-García et al., 2019; Logan et al., 2020; Paquette et al., 2020);
- ecosystem overviews (DFO, 2005; Lee, 2006);

- integrated ecosystem assessments (Bain et al., 2008; Foley et al., 2013);
- ecosystem vulnerability assessments (Aps et al., 2018; Pavlickova and Vyskupova, 2015);
- human activity assessments (Halpern et al., 2015, 2009); and
- pressure assessments (Canter et al., 2014).

There are also many cumulative effects assessment frameworks and approaches (Clarke Murray et al., 2015; Duinker et al., 2013; Katsanevakis et al., 2011; Korpinen and Andersen, 2016; Logan et al., 2020). This diversity of approaches highlights the spatial and temporal differences between activities, pressures and effects and the challenges such differences introduce for adaptive management approaches to human activities. Each of these approaches have different relevance to the fish and fish habitat policy objectives from a regulatory review and integrated planning perspective and, more so, for the type of science needed to support it (Bogardi et al., 2020; Borja et al., 2020, 2016). The challenge is to produce cumulative effects assessments that are usable in regulatory and planning processes, implying a tight alignment between the selection of indicators for monitoring and the science needed to do the assessment with an integrated planning policy and process that is designed to use the results of such assessments in the improvement of their management measures and strategies in regulatory processes (ICES, 2019)

Examples of fish and fish habitat cumulative assessments (Pickard and Porter, 2017), or multiple stressor evaluations, in freshwater that would be pertinent to integrated planning as case studies, include (but are not limited to):

- Canadian Aquatic Biomonitoring Network (CABiN)
- Wild Salmon Policy – Habitat Indicators (Stalberg et al., 2009)
- Joe Cumulative Effects Impact Model (MacPherson et al., 2019)
- Salmon Watersheds Program
- Skeena Environmental Sustainability Initiative (Pickard and Porter, 2017)
- Watershed Status Evaluation Protocol (Pickard et al., 2020, Porter et al., 2020)
- Moose River Basin CEA (Greig et al., 1998)
- South Saskatchewan River Watershed (Ball et al., 2013)
- Watershed Planning in Ontario (2018)
- Hydro-Quebec CEAs (Berube, 2007)
- Gulf Region watershed restoration (DFO, 2006)
- US Healthy Watersheds Program and US Fish Habitat Partnership

Domestic and International examples from other biota, such as Natura 2000 in Europe (Harker et al., 2021) and the North American Bird Conservation Initiative (nabci.net) might also provide insight into landscape planning that could be modified for aquatic purposes, and also synergies that might exist with existing initiatives that are also using geospatial planning. Several initiatives under the Great Lakes Water Quality Agreement and International Joint Commission have relevance as fish and habitat are often an impairment being assessed or an important indicator in evaluations (Canada, United States, 2013). A comprehensive review of CEAs (especially regional ones) and watershed or large lake planning initiatives related to fish and fish habitat indicators should be undertaken to inform Canadian integrated planning moving forward.

Comparing and contrasting the approaches would provide not only a horizon scan of already available information to FFHPP but also identify gaps that need filling for standardizing a unified approach federally.

DISCUSSION

Challenges for Integrated Planning and Recommendations for Next Steps

Consideration of cumulative effects in an integrated planning setting involves many moving parts that cannot be generalized in one document to cover all scenarios. The definition of CE (Box 1); "*any cumulative harmful impacts on fish and fish habitat that are likely to result from the work, undertaking or activity in combination with other works, undertakings, or activities that have been or are being carried out,"* carries a number of implications in both ecological and legal terms. These implications give rise to a set of challenges that integrated planning will need to address within a framework to integrate each of the following.

Spatial considerations:

Considering WUA's that occur in combination with other works implies spatial overlap, and this overlap will make it difficult to isolate the potentially harmful impacts of one over another. It also leaves open the question of how far-reaching the consideration of impacts and responsibilities should extend. How different pressures should be considered in relation to one another varies considerably depending on a variety of factors such as the ecology of the system, hydrology, and the spatial scale and magnitude at which pressures are exerted. Furthermore, large-scale projects that require impact assessments may need to be considered in a different way than numerous point-source impacts and yet need to be integrated into area-based assessments that inform indicators to be used at the project level and to inform watershed level decisions (e.g. ESAs, restoration and offsetting options). The available knowledge and ability to acquire knowledge about the state of habitats will vary with spatial scale and location, and so too will the uncertainty about the potential pressures and effects. This uncertainty will need to be addressed iteratively through proper management cycles and effective partnerships to update measures. We recommend as a starting point using a tertiary watershed resolution (Chu et al., 2015; DFO, 2019; Paquette et al., 2020) to consolidate information, while a larger, but relatively consistent, spatial area (e.g. secondary watershed or ecoregion) may be more practical for shared visioning, planning, and integration (de Kerckhove et al., 2017).

There are different spatial scales of consideration: mapping, evaluation and assessment. Base information on past or proposed WUAs and the current CE conditions can be mapped at local and sub-watershed scales, the evaluation of activity footprints or stress maps might be at the tertiary watershed sale, however effects footprints may be larger ecoregional units. In Canada, there are roughly 1000 tertiary watersheds and large lake basins (e.g., Lake Winnipeg, Lake Superior) that have already been used for evaluation (Water Survey of Canada. 1977). The US Fish Habitat Partnership uses a HUC 12 watershed system with approximately 90,000 spatial units to map status but a larger ecoregional approach to report on effects and targets. Several ecoregional approaches in Canada exist but their methods should be compared and synthesized to develop a consistent national approach, but one that is customizable to local needs, and does not duplicate effort in well-developed watershed plans that can met the needs of FFHPP. European and US approaches should also be compared and contrasted in a scientific evaluation based on spatial data availability and also evaluated for whether regulatory and policy needs are met.

Temporal considerations:

"…works, undertakings, or activities that have been or are being carried out…" implies an undefined temporal window of overlap between different pressures and their effects. This calls into question the window of responsibility that proponents have, which will likely vary depending both on the pressures and the systems being impacted. Pressures may also have different effects depending on the time of year, the duration of exposure, and the time it takes for a habitat or species to experience deleterious effects. These factors mean that cumulative effects will manifest differently in different systems so that that resilience, phenology, and regenerative capabilities of systems will need to be considered relative to the duration of impacts and their timing. There are also temporal considerations involved in different aspects of integrated planning: like baselines (i.e. what reference point in history, or in novel systems, to start footprint accounting and comparison), the natural temporal variation of systems, and anticipated conditions (future planned projects, climate projections).

Goals and Targets:

The phrase "…harmful impacts on fish and fish habitat that are likely to result from the work, undertaking or activity…" identifies the need for a definition of impacts, and the fish and fish habitats to be considered (Hodgson et al., in review). These impacts will need translation at a species and habitat level to evaluate against measurable targets, such as "0% reduction in habitat available for spawning by Atlantic Salmon", but also what that means for other fish and fisheries in the area. These goals may be drawn from existing resources such as local fisheries and habitat management targets where they exist, or they may need development in watersheds without plans or where there may be balance needed between diametrically opposed management goals. However, the context of cumulative effects requires a broader watershed or ecosystem view. This larger view will likely need interpretation depending on various contexts (e.g., natural capacity or resilience – Leung and Richardson 2016, 2018, degraded conditions – IJC 2020, Cooke et al., 2020) but will ultimately need refinement and compression into decision guidance or actions at the watershed level. Decisions and actions are supported by repeatable goals and targets that integrate across system complexity as simplistically as possible, and which are synergistic with each other, with at least regional standards, goals and targets, but there should be some room for customization if there are unique landscape or ecosystem conditions to consider. Science can help with evaluation of possible or probable options, such as threshold setting that both informs precautionary approaches in pristine areas and restoration practices in degraded areas.

Indicators and Scenario Planning:

To support goals and targets, indicators will be needed that are flexible enough to accommodate a variety of ecological and pressure scenarios. Because of the spatial and temporal components identified above, planning will require both retrospective and forward thinking, as well as data and Indigenous knowledge to support analyses and forecasting. Planning will therefore need to invest in independent baseline and collaborative monitoring that is not driven, but perhaps contributed to, by proponents' data. This monitoring will allow for a broader understanding of the current and achievable state of fish and fish habitats. Tools such as eDNA, community-based monitoring, or remote sensing, and monitoring programs executed by other jurisdictions can be implemented and identified as part of integrated planning (Lester et al., 2020a, 2020b). Investment in modelling approaches that facilitate scenario planning based on standard output indicators are also useful tools (Carlson et al., 2014). These are especially useful where monitoring may not be conducted for long enough periods to observe a response, but when mechanistic connections are understood and can be modelled, or when selection between different actions or management measures needs to be tested and facilitated in decision support systems (these may be spatial planning tools given enough baseline information).

Risk Categorization & Management Actions:

Ultimately, CE is the recognition of existing risk accrual that requires effective tools for management and planning. The desired management response needs to exist in policy that arises from a set of existing rules. However, our understanding of the existing risk landscape and how that landscape should intersect with rules is still in its infancy. Thus, at least for the near-term, management actions and process will need to be flexible to accommodate this uncertainty, and proponents will need to be guided through this uncertainty that may require offset ratios (DFO, 2016), for example, until uncertainties are reduced by appropriate study. Science can provide support on quantifying and reducing uncertainty, but will require access to existing (e.g., FFHPP's PATH system) and new (e.g., baseline monitoring) data to improve decisions iteratively as uncertainty is reduced. Finally, the lack of a 'one-size-fits-all' approach highlights the fact that it may be impossible to draw direct causal linkages between disparate individual pressures. This knowledge gap means that the resulting unaccounted-for effects must either be dealt with through adaptation of activities or as a shared responsibility of the tolerable risks to fish and fish habitat.

CONCLUSION

Integrated plans can provide the overarching framework for multi-jurisdictional engagement, the inclusion of community and stakeholder interests, the setting of ecological objectives informed by multi-sectoral interests, and ecosystem-based and adaptive management. They are the ideal platform for incorporating CE because comprehensive assessments of CE often require understanding of not only ecological impacts, but the human activities, policies, and legislative infrastructure that lead to CE affecting the condition of natural resources. This requires an open and critical review of management measures in the context of an adaptive management approach that includes monitoring of the state of fish and fish habitat, compliance with regulatory actions, and continual evaluation of whether objectives have been met. This will be the key to determining the effectiveness of integrated plans.

Integrated planning at FFHPP will require policies that support the establishment and implementation of integrated plans, and broad guidance on the goals of the policy e.g., long-term sustainability of fish and fish habitat. For FFHPP to integrate "integrated planning" into their policy/processes they need to consider these elements of an Integrated Plan, some of which are not science-based but are all linked (Zaucha and Gee, 2019):

- clear linkages between the plan and policy to allow for evaluation of the policy's effectiveness given specific targets;
- understanding of the legislative and policy landscape to identify and engage with Indigenous communities, stakeholders, and other governing bodies whose mandates include aquatic ecosystems or fish and fish habitat;
- clear ecological and conservation objectives informed by stakeholder input and broad engagement and consultation with the groups above;
- measurable management and monitoring metrics informed by ecosystem-based science and Indigenous knowledge for cumulative effects assessment and an understanding of how community and stakeholder interests are in turn affected;
- implementing a cyclical process that evaluates watershed metrics (e.g. cumulative activity footprints) against similarly scaled objectives (e.g. population status, habitat quality and quantity in good standing), and the overall plan's performance in terms of the policy objectives (e.g. targets for the areas); and,

- targeted science to understand the cumulative effects in freshwaters at appropriate scales (e.g. watersheds) to determine activity, pressure, and effects footprints of works, undertakings, and activities, and to establish targets for management and monitoring metrics.
- integrated planning monitoring strategies based on assessment of indicator responsiveness and data availability, establishing strong links between planning objectives, indicators, and fit-for-purpose data collection.

Each of these steps will require that systematic processes (e.g., a series of hierarchical rules and needs), are defined and synthesized into an integrated planning template that can be applied in a consistent fashion to different works, undertakings, and activities scenarios, including restoration in different ecological regions of Canada.

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APPENDIX I

Criteria and definitions for activities, pressures and effects based on the EU Marine Strategy Framework Directive (European Union, 2017, 2008).

Indicators of activity-footprints	Indicators of the pressure-footprint	Indicators for the effects-footprint	Good environmental status objectives
Physical restructuring of rivers, coastline or seabed (water management) • Land claim Canalisation and other watercourse modifications • Coastal defence and flood protection • Offshore structures (other than for oil/gas/renewables) • Restructuring of seabed morphology, including dredging and depositing of materials **Extraction of non-living resources** • Extraction of minerals (rock, metal ores, gravel, sand, shell) • Extraction of oil and gas, including infrastructure • Extraction of salt • Extraction of water **Production of energy** • Renewable energy generation (wind, wave and tidal power), including infrastructure • Non-renewable energy generation • Transmission of electricity and communications (cables) **Extraction of living resources** • Fish and shellfish harvesting (professional, recreational) • Fish and shellfish processing • Marine plant harvesting • Hunting and collecting for other purposes	**Biological** • Input or spread of non-indigenous species Input of microbial pathogens • Input of genetically modified species and translocation of native species • Loss of, or change to, natural biological communities due to cultivation of animal or plant species • Disturbance of species (e.g. where they breed, rest and feed) due to human presence • Extraction of, or mortality/injury to, wild species (by commercial and recreational fishing and other activities) **Physical** • Physical disturbance to seabed (temporary or reversible) • Physical loss (due to permanent change of seabed substrate or morphology and to extraction of seabed substrate) • Changes to hydrological conditions **Substances, litter and energy** • Input of nutrients — diffuse sources, point sources, atmospheric deposition • Input of organic matter — diffuse sources and point sources • Input of other substances (e.g. synthetic sub? stances, non-synthetic substances, radionuclides) - diffuse sources, point sources, atmospheric deposition, acute events • Input of litter (solid waste matter, including micro-sized litter)	**Spatial and temporal variation per species or population:** • distribution, abundance and/or biomass • size, age and sex structure • fecundity, survival and mortality/injury rates • behaviour including movement and migration • habitat for the species (extent, suitability) • Species composition of the group **Per habitat type:** • habitat distribution and extent (and volume, if appropriate) • species composition, abundance and/ or biomass (spatial and temporal variation) • size and age structure of species (if appropriate) • physical, hydrological and chemical characteristics *Additionally for pelagic habitats:* • chlorophyll a concentration • plankton bloom frequencies and spatial extent **Ecosystems and foodweb spatial and temporal variation in:** • temperature and ice • hydrology (wave and current regimes; upwelling, mixing, residence time, freshwater input; sea level) • bathymetry • turbidity (silt/sediment loads), transparency, sound	1) Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions. 2) Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems. 3) Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock. 4) All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity. 5) Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters. 6) Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.

Indicators of activity-footprints	Indicators of the pressure-footprint	Indicators for the effects-footprint	Good environmental status objectives
Cultivation of living resources • Aquaculture — marine, including infrastructure • Aquaculture — freshwater • Agriculture • Forestry **Transport** • Transport infrastructure Transport — shipping • Transport — air • Transport — land **Urban and industrial uses** • Urban uses • Industrial uses • Waste treatment and disposal **Tourism and leisure** • Tourism and leisure infrastructure • Tourism and leisure activities **Security/defence** • Military operations **Education** • Research, survey and educational activities	• Input of anthropogenic sound (impulsive, continuous) • Input of other forms of energy (including electromagnetic fields, light and heat) • Input of water — point sources (e.g. brine)	• seabed substrate and morphology • salinity, nutrients (N, P), organic carbon, dissolved gases (pCO2, O2) and pH • links between habitats and species of marine birds, mammals, reptiles, fish and cephalopods • pelagic-benthic community structure • productivity	7) Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems. 8) Concentrations of contaminants are at levels not giving rise to pollution effects. 9) Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards. 10) Properties and quantities of marine litter do not cause harm to the coastal and marine environment. 11) Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.