A SCIENCE-BASED FRAMEWORK FOR ASSESSING CHANGES IN PRODUCTIVITY, WITHIN THE CONTEXT OF THE AMENDED *FISHERIES ACT*

Figure 1: Department of Fisheries and Oceans' (DFO) six administrative regions.

Context:

Human activities in or around fish-bearing waters have the potential to affect the capability of those aquatic habitats to support the production of fish for fisheries. Such activities will be managed through the Fisheries Protection Provisions (FPP) of the 2012 amendments to Canada's Fisheries Act. Section 6.1 of the Act sets out the purpose of the Fisheries Protection Provisions, which is to guide decision-making to provide for the sustainability and ongoing productivity of commercial, recreational and Aboriginal fisheries.

Decisions related to sustaining the ongoing productivity of commercial, recreational and Aboriginal (CRA) fisheries should be informed by measures of past, current, and future productivity. Although direct estimates of productivity are unavailable for most fisheries, indirect and surrogate measures of productivity abound. Thus, science-based guidelines for choosing direct or surrogate measures of productivity are important for policy development. Within the context of this Science Advisory Report (SAR), guidelines take the form of criteria to ensure consistency of approach regardless of location or spatial scale. Projects (sometimes called works, undertakings, activities; w/u/a) that affect fish habitat can be assigned into one of three types: 1) projects that reduce habitat quantity; 2) projects that affect habitat quality, and 3) projects with impacts on scales large enough to result in ecosystem transformation (such as a change in fish species composition). The first class reduces productivity primarily by simply having less habitat to support fish, the second primarily through affecting fish vital rates (i.e. fish growth, mortality, etc.), and the third class both of the above. Each of these processes can result in the habitat being able to support fewer fish.

This guidance on measures of productivity builds on existing tools to assess impacts of projects on fish habitat, and in particular makes use of Pathways of Effect (PoE) models. A series of PoE models have been previously developed by Fisheries and Oceans Canada (DFO) for common activities associated with a broad range of in-water and land-based projects. PoE models describe the type of cause-effect *relationships that are known to exist between activities and impacts, and the mechanisms by which anthropogenic stressors ultimately lead to effects in the aquatic environment. Each pathway represents an intervention point to which mitigation measures may be applied to reduce or eliminate a potential effect. When mitigation measures cannot be applied, or cannot fully address the effects of a stressor, any remaining effects are referred to as residual effects.*

Building on the general definition of fisheries productivity, the science advice within this report provides a framework for the assessment of changes in productivity caused by the residual effects of projects, identified primarily on the basis of the PoE. The report identifies indicators and metrics that can be used to directly or indirectly estimate such changes in fisheries productivity.

This Science Advisory Report is from the March 12-14, 2013 National Peer Review on Additional Science Guidance for Fisheries Protection Policy: Science-based Operational tools for Implementation. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- A framework for assessing changes in fisheries productivity resulting from works, undertakings or activities (projects) is described. Generally, this framework involves determination of impact type and scale; existing Pathways of Effects (POEs) are used to determine potential residual effects; appropriate metrics of productivity are chosen to assess these residual effects; and residual effects on productivity are used to inform decision making.
- This framework is to be applied in cases when a technical assessment concludes that the project is likely to result in a permanent alteration to habitat or death of fish.
- Fisheries productivity can be directly quantified using a number of indicators, including yield or catch rates, or measured indirectly by examining components of fisheries productivity or their covariates (i.e. surrogates). Fisheries productivity is determined by the biological productivity of the fish (and fish that support such fisheries) and by fishery dynamics. In this SAR, we focus on assessing the impacts of projects on components of fisheries productivity related to the biology of relevant fish. These components correspond to a species' life cycle and include measures of vital rates (e.g. growth, survival, reproduction, migration).
- Serious harm is characterized primarily by using Pathways of Effects (PoE) models to identify endpoints that cannot be avoided or mitigated (i.e. the residual effects of stressors). PoE endpoints are linked to possible biological outcomes: localized effects on habitat quantity, effects on habitat quality, and ecosystem transformations.
- For projects considered likely to result in ecosystem transformations (often large enough to be measured in hectares), productivity assessments are recommended at the population or ecosystem scale.
- For projects that affect the quantity and/or quality of habitat (or cause the death of fish) in the project vicinity, components of fisheries productivity are analysed using a life cycle approach (reproduction, growth, survival, migration). Qualitative and quantitative metrics for each component of productivity are tabulated.
- Productivity-state response curves describe the relation between the change in habitat conditions (or the death of fish) and its effect(s) on a component of fisheries productivity and provide a direct link between Serious Harm and productivity.

- Density-dependent processes can be incorporated into productivity assessments, but detailed information on the biology of the species and a population model will be required.

INTRODUCTION

During the preparation of this report, the June 2012 amendments to the *Fisheries Act* (FA) were not yet in force. When in force, these amendments will make substantive changes to the way in which Canadian fishes and fish habitat are protected. The newly introduced Fisheries Protection Provisions (FPP) include Section 6.1 (the purpose for decision-making): to provide for the sustainability and ongoing productivity of commercial, recreational, or Aboriginal (CRA) fisheries". These FPP replace the former Fish Habitat Protection Provisions, and the amended Section 35 establishes the prohibition that "no person shall carry on any work, undertaking, or activity that results in serious harm to fish, as defined by the *Fisheries Act*, that are part of a commercial, recreational or Aboriginal fishery, or to fish that support such a fishery". The amended FA defines serious harm to fish as "the death of fish or any permanent alteration to, or destruction of, fish habitat", and gives the Minister of Fisheries and Oceans the authority to authorize a work, undertaking, or activity (w/u/a) that causes serious harm to fish, if this is considered acceptable after taking specified factors into account. Section 6 of the amended *Fisheries Act*, identifies the factors for Ministerial consideration in decision-making:

a) The contribution of the relevant fish to the ongoing productivity of commercial, recreational or Aboriginal fisheries;
b) Fisheries management objectives;
c) Whether there are measures and standards to avoid, mitigate or offset serious harm to fish that are part of a commercial, recreational or Aboriginal fishery, or that support such a fishery; and
d) The public interest.

Taken together, the purpose (Section 6.1), prohibition (Section 35), and factors (Section 6) introduce the need for metrics of productivity and methods to assess how a development project may affect productivity. This SAR was requested in order to build upon the DFO 2013 (CSAS SAR 2012/063) that introduced a conceptual framework (productivity-response curves) for considering impacts on productivity via changes in habitat or fish populations. The productivity-response curves are used with Pathways of Effect models to deduce the likely impacts of projects on components of productivity.

There are two key phases in which technical assessments are required:

1) Serious harm evaluation (determining whether serious harm is likely to occur); and
2) Productivity assessment (estimating impacts to productivity after it has been determined that serious harm to fish is likely to occur).

The advice in this SAR focuses on the second phase but the first phase is briefly described for context. Within the productivity assessment phase, the steps to determine the type and scale of project impacts (localized effects on habitat quantity, effects on habitat quality, and ecosystem transformation) are described. This SAR also includes guidance on appropriate techniques to commence estimation of potential impacts of a project on components of fisheries productivity, specifically on the productivity of fish. In particular it provides guidance on circumstances when it would be appropriate to use one or more of the following approaches:

a) Habitat-based surrogates of productivity;
b) Direct evaluation of the scale and severity of project impacts on vital rates (qualitative, semi-quantitative, or quantitative); and

c) Detailed assessment of the project impacts on fish productivity (e.g., using a fish population model.

Productivity assessments determine, to the extent possible, whether or not the death of fish or alterations of fish habitat are likely to affect life history processes of fish that are part of (or support) CRA fisheries, and if so, the likely direction and magnitude of the changes to the relevant life history processes and inferred effects on fisheries productivity. Science advice in this current document provides a scientific basis for understanding how project impacts typically can affect various biological components of productivity (see DFO, 2013 and Bradford et al., 2013).

ASSESSMENT

Evaluation Framework

Phase 1: Serious harm evaluation

A technical assessment of PoE to determine likelihood of serious harm:

In the first phase, the proponent designs the project (using standard guidance from DFO and other best management practices to avoid and mitigate impacts to fish and fish habitat) and self-assesses whether there is likely to be serious harm to fish. This self-assessment consists of estimating *residual impacts* to fish and fish habitat. “Residual impacts” are the ways that the aquatic environment is changed as a result of unavoidable impacts associated with the project, and/or the likelihood that fish are killed directly. The PoE models developed by DFO are the primary means to identify any residual effect(s) of a project, which would lead to reductions in fish productivity and ultimately reduced fisheries productivity. However this SAR does not include guidance on how to determine whether or not Serious Harm has occurred, but does provide guidance on how to proceed if such a determination has been made and concluded that Serious Harm has occurred.

A project-specific assessment of fisheries productivity is not needed at this stage. When the proponent’s evaluation concludes that no residual impacts are anticipated, productivity assessments are not required.

Phase 2: Productivity assessment

A technical assessment following the determination that serious harm is likely to occur:

When self-assessment in Phase I indicates that residual impacts are anticipated, and if it is determined that a project’s unavoidable residual impact(s) causes Serious Harm, then an evaluation of the effect the project on fisheries productivity can assist decision making (i.e., Section 6 of the *Act*). Assessments should use the PoE as the primary means to identify and organize predicted residual effects on fish and fish habitat. In the assessment of a project, PoE are screened for those that are not relevant to the project in question, or for which the effects identified by the endpoints can be avoided or mitigated. For the remaining endpoints (the “residual effects”), the predicted change in biological productivity or a component of productivity is analyzed.

The first step is to determine what type and scale of impacts are likely to result from the project. These technical assessments may require different levels of detail for individual projects, corresponding to their type and scale of impact. The determination is undertaken by linking PoE endpoints to possible biological outcomes, in three possible contexts (DFO, 2013):

a) Effects on habitat quantity;

b) Effects on habitat quality; and

c) Effects likely to cause ecosystem transformation

Projects that alter habitat quality and/or quantity.

For projects that cause a change in *habitat quantity* and/or *habitat quality* in the vicinity of the project, component(s) of biological productivity that are altered by the residual effects should be analyzed. Ongoing fisheries productivity results from fishery dynamics and individual fish completing their life cycle, and having vital rates (reproduction, growth, survival, and migration) that are sufficient to generate a sustainable yield at the population level (Fig. 1). If a project causes an adverse change in any of the components of biological productivity, potential effects on fisheries productivity can be inferred via the pathways in Figure 1.

Major components and subcomponents of productivity from the model of Figure 1 are listed in Table 1, and some of the mechanisms that can cause a reduction in productivity are shown. Table 1 is not comprehensive, but does show the most common ways which biological productivity may be affected.

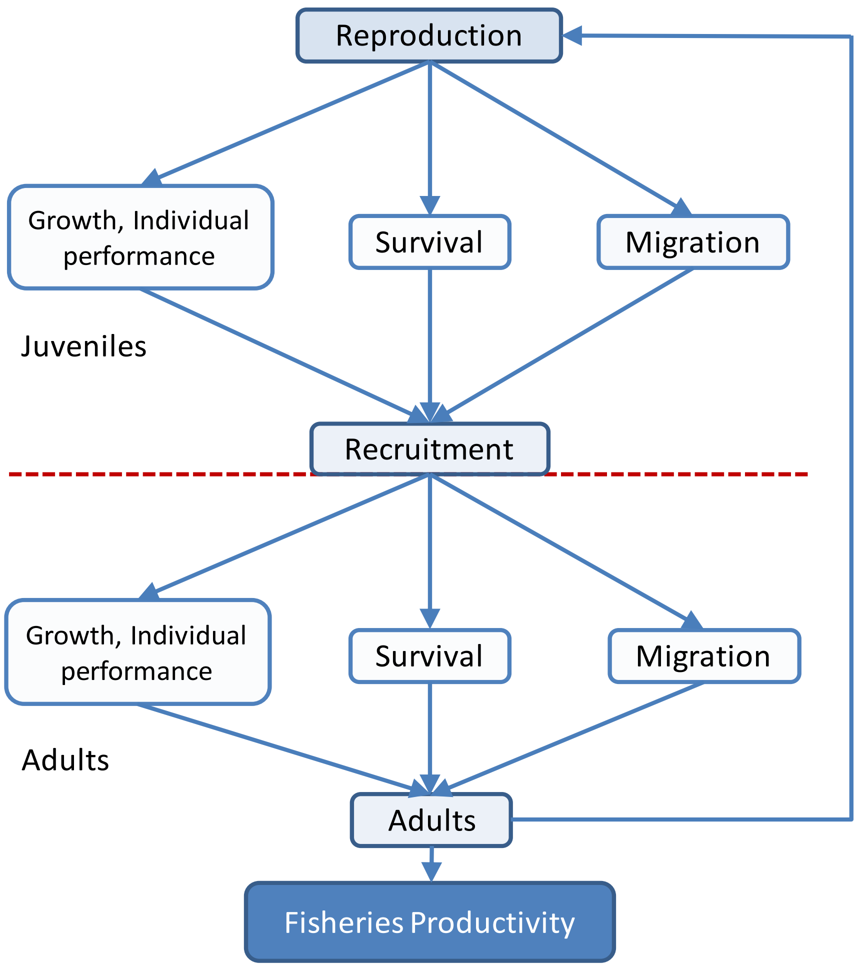

Figure 2. Generic life cycle model for a freshwater or diadromous fish, showing the major components of biological productivity. Individual performance refers to growth, body condition, parasite burdens, stress or other factors that affect individual fitness.

Table 1. Relation between biological components and subcomponents of fisheries productivity and examples of mechanisms that cause changes in productivity.

Component of Productivity	Sub-components	Mechanism
Growth	Insufficient food supply	• Reduction of food quality • Reduction of food quantity • Increase in competition
	Reduction in ecological efficiency	• Reduction in foraging efficiency • Reduction in bioenergetic efficiency
Individual performance	Stress	• Suboptimal environmental conditions
	Disease	• Increase in infection • Increase in disease severity
Survival	Direct mortality	• Killing of fish by project
	Indirect mortality	• Increase in predation • Starvation • Exceedance of environmental tolerances • Habitat supply limitation
Migration	Habitat isolation	• Blocking of passage
	Reduced migration	• Deterioration in migration conditions
Reproduction	Delay or Absence of Adult maturation	• Sub-optimal environmental conditions • Insufficient ability to store energy for maturation or egg production • Absence of environmental triggers for maturation
	Reduced reproductive success	• Reduction in spawning habitat quality • Reduction in spawning habitat quantity • Sub-optimal environmental conditions for reproduction

DFO has reviewed the majority of projects with potential for residual effects, and categorized them by impact type – loss of wetted area; change in sediment concentration; change in structure and cover; change in nutrient concentration; change in food supply; direct mortality; change in temperature; change in noise and vibration; change in electromagnetic field; change in access to habitat; change in dissolved oxygen; and baseflow and hydrodynamics (see Table

1 in Bradford et al., 2013). For each impact type there are one or more applicable PoE models, and there are one or more endpoints associated with each PoE. For each PoE endpoint, mechanisms that define more precisely how residual effects could affect fish or fish habitat are identified along with biological components of productivity that may be involved (see Table 1 in Bradford et al., 2013).

The productivity-state relation links a residual effect identified by the PoE analysis to a component of productivity for a CRA fishery (Fig. 2). Pairs of PoE endpoints and components of productivity form the axes for the appropriate productivity-state relation(s) for the project. Potential indicators for the assessment of changes to productivity are provided in Table 3 in Bradford et al., 2013.

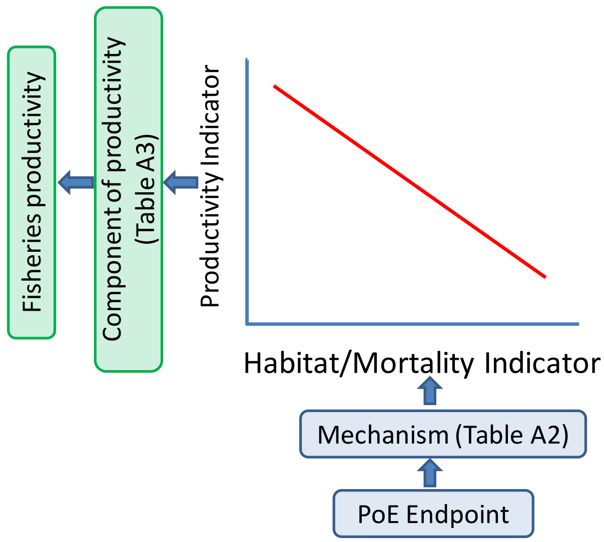

Figure 3. Hypothetical productivity-state curve showing the relation between PoE endpoints, indicators and productivity illustrating how the productivity-state relations fit into the framework of using PoEs and components of productivity. Axes labels refer to Appendix tables in Bradford et al. (2013). The shape and slope of the line is illustrative only.

For some projects there may be more than one residual effect, or species-specific effects that will need to be combined in an overall assessment of the impact of the project on fisheries productivity. Guidance on combining multiple effects on one or more species in an assessment is beyond the scope of this report.

Projects which cause ecosystem transformations

For those projects anticipated to lead to *ecosystem transformations,* changes to fisheries productivity (in terms of fish abundance, species composition, potential changes to fishery catch rates, yield, or catch composition) will need to be assessed. This assessment is conducted at the population or ecosystem level. In some cases it may be possible to use the components of productivity approach and evaluate the implications of a change in vital rates at the population level. In other cases, ecosystem-level analysis is required to predict the changes in fisheries productivity resulting from the project. Some examples are provided in the next section.

Biodiversity (change in species composition) is sensitive to habitat change. Changes in biodiversity will also need to be considered with ecosystem change as there is potential for impacts on fisheries productivity that are not easily captured in typical fish production assessment and modeling. This is especially important when changes to habitat features can be expected to reduce the quality of the habitat for one set of species but improve it for another set (e.g. reservoir creation). Biodiversity trade-offs in this context are usually considered with respect to the fisheries management objectives of the area where the project is occurring. There are numerous indicators of biodiversity, and specific ones have not yet been evaluated for use in particular applications of this framework

In summary, the evaluation framework describes the steps needed to infer or predict changes in biological components of fisheries productivity from the evaluation of project effects on fish and/or fish habitat. In the Conclusions and Advice section, guidance is provided on how to implement the framework for different project types.

Sources of Uncertainty

There will be uncertainty about the possible impacts of any project on productivity of CRA fisheries. This framework is designed in part to provide a systematic way to consider major sources of uncertainty in individual applications.

CONCLUSIONS AND ADVICE

Implementing the Framework (directive to practice)

1) Projects that reduce habitat quantity

Any project that results in a reduction of habitat area supporting a CRA fishery is deemed to cause “destruction” per the definition of Serious Harm. In terms of spatial scale of habitat lost, this can range from a localized infill (e.g., a few m^2) of wetted area to large scale ecosystem loss (e.g., ha). Destruction of habitat can affect fisheries productivity when a loss of habitat area causes a reduction in carrying capacity, resulting in a reduction of fish production and possibly fisheries productivity. Effective loss of habitat quantity can also occur if habitat becomes isolated or inaccessible by blockages or passage issues.

Metrics and analysis:

For localized projects involving infill or habitat loss, this framework recognizes three levels of analysis, each requiring different metrics. This choice depends on the nature of the project, management decision criteria, and fisheries resources at risk. Projects of potentially greater or more complex impacts require metrics which supply more information about the dynamics of the affected fish populations.

Area based metrics. The primary habitat metric is square metres or hectares of lost habitat.

1. Habitat type or quality metrics. Using the area affected, the biological function of the habitat (e.g., spawning, nursery, rearing, migration corridor and food supply) and habitat quality (if available). The relative value of the lost habitat could be calculated by measures such as Habitat Suitability Indices. This habitat-based analysis provides a surrogate assessment of productivity. Such analyses could support assessments of the loss of carrying capacity (as a surrogate for productivity), if the indices are expressed in terms of abundance per unit area.
2. Metrics for fisheries productivity. Estimates or measures of fish production, abundance or yield on an areal basis (per m^2, or ha), along with the area affected are needed to directly estimate the potential change(s) in fisheries productivity. Two approaches may be used: a) scaling up from localized units of habitat, and b) scaling down from ecosystem level models or analyses (see Box 1).

Box 1. Scaling up and scaling down: case studies.

Scaling up from regional standards: Infilling of habitats is assessed (both pre- and post- project) by calculating habitat suitability and then quantifying weighted suitable area (WSA) as the product of suitability and area for each habitat type. Impacts to productivity could then be determined by converting WSA to biomass units (possibly using a regional benchmark approach). WSA and predicted biomass are the metrics resulting from the analysis.

Scaling down from ecosystem-level predictions: For a project involving infill of a shoreline area of a lake, for example, unit area of fish biomass can be determined using an empirical model for lake-wide abundance based on characteristics of the lake and its productivity, scaled down to determine the value (biomass) of the infill area. Adjustments for the value of different habitat types (e.g. nearshore relative to offshore habitat) can be estimated from literature and regional expertise.

2) Projects that affect habitat quality

Some projects alter the characteristics of the habitat, or aspects of the populations in proximity to the project, such that one or more of the components of biological productivity are adversely affected. Permanent alteration of habitat can include changing one type of habitat to another, if the first type is more appropriate or essential for one or more life processes. A change in fisheries productivity occurs if the project will affect one or more vital rates (e.g., growth, survival, migration, reproduction) of fish populations in the project area.

Metrics and Analysis:

Qualitative directional analysis. For smaller projects a PoE and an analysis of effects is used to identify directional changes in one or more components of productivity. Productivity-state response curves are used to infer the shape of the relation between each effect and corresponding component of productivity. For example, a long-term sediment release might be expected to cause a reduction in the component of productivity "*growth*". In this example, there are a number of mechanisms that can lead to a reduction in growth (food production, foraging efficiency, sub-lethal stress). In such cases it may be very difficult to combine or integrate multiple mechanisms to generate a quantitative prediction of change in a component of productivity, for instance in the mass for an individual species and life stage. In the absence of empirical data to relate effect to changes in a component of productivity, a directional analysis using qualitative or descriptive indicators is a suitable alternative.

Semi-quantitative analysis. For projects where the residual impact can be quantified (e.g., a predicted change in temperature), a semi-quantitative prediction of the change in productivity can be used to inform decision-making. A categorization of the change to productivity using an ordinal scale (e.g., "low/medium/ high" or "no effect/effect") based on the impact to habitat (or direct effects on fish) and the shape of the applicable productivity-state response curve is used (refer to Bradford et al., 2013). Where thresholds exist for the selected habitat indicator(s), these can be used to differentiate properly functioning habitat conditions from those that are sub-optimal. Common examples include guidelines for suspended sediment, oxygen, or flow. It is important to note that thresholds have not been developed for all metrics of fisheries productivity.

Quantitative analysis. A quantitative estimate of the effect of a project on an aspect of productivity requires a quantitative productivity-state relation, accurate predictions of the change imposed by the project and baseline state of the habitat and the affected fish. For example, if a project causes a change in baseflow in a stream, there are a variety of models that can be used to evaluate the impacts on carrying capacity and fisheries productivity. Quantitative indicators for productivity are used in these cases, as long as an adequately validated model is available, and uncertainty is reflected appropriately in the model output.

3) Projects that result in ecosystem transformation

Projects that result in an ecosystem transformation (e.g., large-scale effects that result in changes in species composition) are usually the subject of case-specific studies that are part of an Environmental Impact Assessment (EIA). These projects may eliminate habitat altogether, or change habitat quantity and quality in such a way that ecosystem structure and function are altered, thereby altering productivity and local biodiversity. Examples include the conversion of rivers to reservoirs, infilling of lakes, or large-scale projects in coastal ecosystems (e.g., development of new ports).

In such cases, the POE framework can still inform a *Fisheries Act* assessment but these more complex projects can have multiple impact types. For example, a hydroelectric dam may affect the environment through five impact types (see Table 1 in Bradford et al., 2013) and thus have many POE that can potentially affect many species. Such complex interactions are beyond the scope of this SAR.

Metrics and analysis:

Projects that lead to an ecosystem transformation are best evaluated by directly assessing changes in fisheries productivity at the population or ecosystem scale. Both habitat quantity and quality will change and the quantitative approaches outlined in the previous sections can be employed. However, it is important to match the scales of estimates of impacts on components of fisheries productivity to the scales of the impacts on habitat relative to the full area contributing to that productivity. In some cases whole ecosystems will be lost or transformed and the impact on fisheries productivity can be expressed in terms of fish production or fishery-based statistics such as yield or use. Further Science guidance is needed for ecosystem-level analysis of productivity.

Next Steps

The scope of this advice has primarily focused on the freshwater environment; given this has been the historical focus of much of the Department's management of fish habitat. Future consideration of estuarine, coastal and marine environments is required.

Science guidance is required on how to combine the assessments of multiple effects on productivity from one or more projects into an overall assessment which can be used to inform decision-making. Additional Science guidance is also needed on how to apply the assessment framework to multi-species fisheries, fisheries in marine environments, and to fishes with atypical life histories.

Summary

The steps outlined in this framework are summarized in Box 2 below.

Box 2: A summary of the proposed framework for the assessment of project-related effects on fisheries productivity

A. Determine impact type (quantity/quality/transformation) and scale of impact.

B. For transformations an ecosystem-level analysis of productivity may be appropriate (then skip to F)

C. Use PoEs as a starting point to determine residual effects (unmitigated effects on fish or habitat), and identify indicators for endpoints

D. Identify potential metrics of productivity (qualitative, semi-quantitative, quantitative) based on the appropriate components/ecosystem in question and the residual effects

E. Assess impacts to components of productivity using approaches based on project type

F. Combine assessment of effects on productivity for an overall assessment to be used in the decision framework (additional guidance is needed on this step).

OTHER CONSIDERATIONS

Incorporating density-dependent processes into the assessment

Population processes are categorized as those that are density-independent (where vital rates change in ways that are unrelated to population density), and those that are density-dependent (where changes in vital rates co-vary with density). When vital rates (e.g., growth or survival) are negatively correlated with density, the dynamics are considered *compensatory* in nature because they will tend to stabilize population abundances. When populations are reduced in numbers due to an agent of mortality (e.g., fishing), other vital rates often increase and this will tend to compensate for the increase in mortality. Thus compensatory processes may mitigate some types of environmental impacts, but the extent depends on the temporal sequence of events in the life cycle, the strength of the compensatory response, and the scale and persistence of project impacts on habitat or fish populations. For some species, *depensatory* density dependent processes can lead to further reductions in vital rates and population abundance, particularly when breeding populations are fragmented or small.

The linkages between particular types of habitat alterations and compensatory and depensatory life history processes are poorly quantified for most fish populations and habitat types. Consequently, for most projects, it should be assumed that impacts to components of productivity have a direct, proportional impact on fisheries productivity. To incorporate either compensatory or depensatory density-dependent processes in productivity assessments, evidence of such processes is needed and a population model will be required to evaluate the interaction of the project-related impacts and the compensatory or depensatory processes on fisheries productivity. Case-specific evidence for compensatory or depensatory processes will rarely be available, unless the specific area affected by the project has been studied thoroughly in the past. Hence evidence for the presence of either type of process will often have to be inferred from knowledge acquired from past occurrences of similar activities in similar habitats, supporting generally similar fish populations.

An assessment incorporating density-dependent processes will also require information on the status of the affected species, and other pressures on the population. This information is necessary because the mitigative effects of compensation are limited when populations are being kept well below their carrying capacity by some factors unrelated to the project whose impacts are being assessed. For cases involving populations that are heavily fished, or are impacted by natural processes that reduce productivity (e.g., unfavourable ocean conditions for salmon) it should be assumed that all population processes are density independent, so population impacts are proportional to the scale of the project relative to the productive habitat for the population. Those species where there is a high likelihood of depensation at small population sizes will require site-specific analysis.

SOURCES OF INFORMATION

This Science Advisory Report is from the March 12-14, 2013 National Peer Review on Additional Science Guidance for Fisheries Protection Policy: Science-based Operational tools for Implementation. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

Bradford, M.J., R.G. Randall, K.S. Smokorowski, B.E. Keatley and K.D. Clarke. 2014. A framework for assessing fisheries productivity for the Fisheries Protection Program. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/067.

DFO. 2013. Science Advice to Support Development of a Fisheries Protection Policy for Canada. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/063.

APPENDIX 1. TERMS AND CONCEPTS

Carrying Capacity is the maximum density of fish a unit of habitat can support. The amount of habitat and its carrying capacity usually determine the maximum size of a population.

A ***component of productivity*** is an aspect of fish population productivity (e.g., growth, survival, migration, reproduction, called "**vital rates**") that may be altered by a change in conditions caused by a proposed project. Components of productivity may be broken out into sub-components that can be analyzed if sufficiently detailed information is available.

Fish is defined under the *Fisheries Act* includes (a) parts of fish, (b) shellfish, crustaceans, marine animals and any parts of shellfish, crustaceans or marine animals, and (c) the eggs, sperm, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals.

Fish habitat means "spawning grounds and any other areas, including nursery, rearing, food supply and migration areas, on which fish depend directly or indirectly in order to carry out their life processes" (*Fisheries Act* 2012).

Fitness describes the ability to both survive and reproduce, as reflected in the average contribution to the gene pool of the next generation.

Indicators are used to measure project-related change and can include one or more metrics, as well as qualitative, descriptors of change (e.g., "decrease in growth").

Measurements are made in the field to evaluate habitat conditions or the status or characteristics of fish populations or fisheries.

Metrics are used to evaluate a change in fish or fish habitat caused by project activities. Metrics may be used when making predictions monitoring changes in conditions or making predictions about future conditions. Metrics use two or more measurements or predictions to assess change.

Ongoing Fisheries productivity is "yield of all component populations and species and their habitat which support and contribute to a fishery" (DFO, 2013).

Pathways of Effects (PoE) are conceptual diagrams that show how an activity in or near fish habitat can adversely affect habitat and fishes. Within the PoE framework, ***endpoints*** of concern to fish link changes to fish habitat caused by the project to fishes (and by inference, to fisheries productivity).

Project is synonymous with a 'work, undertaking, or activity" as used in the Fisheries Act.

***Productivity Assessment* -** If it is determined that a project's unavoidable residual impacts causes Serious Harm, then an evaluation of the effect the project on fisheries productivity can assist decision making (i.e., Section 6 of the *Act*). Three categories of projects were identified in DFO (2013); those that result in a reduction in local habitat *quantity*, those that decrease habitat *quality*, and those that cause an *ecosystem transformation*.

Regional benchmarks of productivity – indicators of carrying capacity for a particular region, using metrics (e.g., fish biomass or density) which are based on empirical data from reference sites within the region. In this context, a region is a geographic area with similar drivers of productivity and aquatic ecosystem communities (e.g., watersheds or a group of adjacent watersheds, salmon fishing areas, or coastal management areas).

Residual effects are impacts to fish habitat or fish identified in PoE analysis and which cannot be avoided or mitigated.

Serious harm to fish is "the death of fish or any permanent alteration to, or destruction of, fish habitat" (*Fisheries Act* 2012). Pathways of effects are used to identify the residual effects of a project on fish and fish habitat once efforts have been made to avoid or mitigate impacts. Serious harm occurs when a residual effect results in the permanent alteration or destruction of fish habitat or the death of fish. An assessment of fisheries productivity is not needed at this stage, but may be needed at a later stage as part of an offsetting plan.

THIS REPORT IS AVAILABLE FROM THE:

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ISSN 1919-5087

Correct Citation for this Publication:

DFO. 2014. A science-based framework for assessing changes in productivity, within the context of the amended *Fisheries Act.* DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/071.

Aussi disponible en français :

MPO. 2014. Cadre scientifique pour l'analyse des variations de la productivité dans le contexte des modifications apportées à la Loi sur les pêches DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/071.