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SCIENCE ADVICE ON THE DETERMINATION OF OFFSET REQUIREMENTS FOR THE FISHERIES PROTECTION PROGRAM

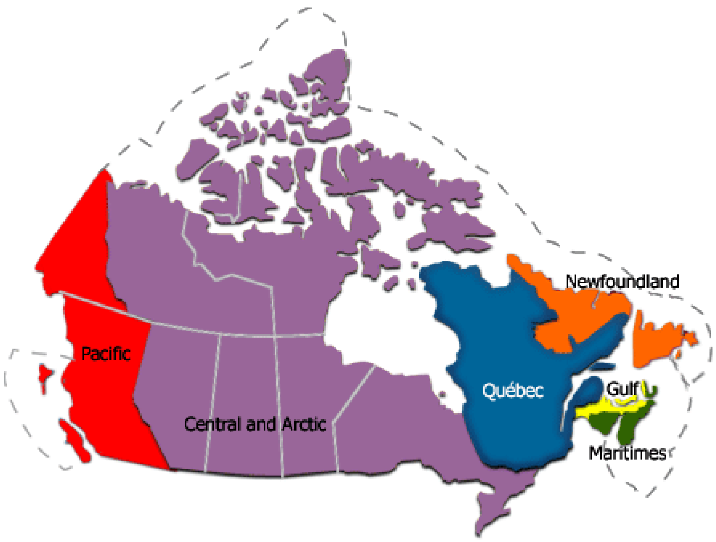

Figure 1: Department of Fisheries and Oceans' (DFO) six administrative regions.

Context:

Amendments to the Fisheries Act (2012) came into force in 2013. These amendments change the way that Fisheries and Oceans Canada (DFO) assesses and manages impacts on aquatic ecosystems. The amended Act focuses on the sustainability and ongoing productivity of commercial, recreational or Aboriginal fisheries.

The DFO Ecosystems and Fisheries Management has requested scientific advice concerning the implementation of the Offsetting Policy and the associated amendments to the Act. The intention is to use this science advice to support the development of additional guidance on determining offsetting requirements that could both aid proponents in the development of their offsetting plans and associated monitoring requirements, and assist DFO staff when assessing proponent submissions.

The current request for advice is to:

- a) *Consolidate and integrate existing scientific advice related to the Fisheries Protection Program (FPP) through the lens of offsetting impacts to fisheries productivity;*
- b) *Provide detailed advice on acceptable methods to calculate offset requirements including key considerations and assumptions on:*
  - i) *The prediction of benefits from proposed offset projects (i.e., identification of baseline for both impact and offset sites, predicted loss at impact site, and predicted gain at offset site).*
  - ii) *The calculation of equivalency between impact and offset when they are unlike (e.g., focus on different types of habitat and fish species). Key aspects would be to advise how to choose an appropriate common currency and how to ensure that offsetting measures balance project impacts.*

This Science Advisory Report is from the National Peer Review meeting of November 25-26, 2014 on the Science Guidance for Fisheries Protection Policy: Advice on Developing and Reviewing Offsetting Requirements. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule](#) as they become available.

SUMMARY

- "Equivalence" in the Science Advisory Report (SAR) is taken as equivalence in fisheries productivity; here counterbalancing any decline in productivity as determined by death of fish or the permanent alteration or destruction of habitat and corresponding inferred loss of productivity caused by the development project with an the increase in productivity due to offsetting measures.
- Establishing "equivalency" through provision of a large amount of lower quality habitat to offset impacts on a lesser amount of better quality habitat is not preferred scientifically. Reasons are given in the SAR.
- When using models with any of the classes of equivalency metrics, a degree of validation of model performance is required. Field validation of model predictions under conditions similar to those where the development project and/or offsetting measures will occur are always preferred.
- Seven classes of equivalency metrics for Steps 1, 2, and 3 were reviewed. These were:
    1) In-kind habitat
    2) Habitat functions and ecosystem services
    3) Habitat suitability indices
    4) Fish biomass or abundance
    5) Fish or ecosystem production
    6) Fishery metrics
    7) Other "value-based" metrics, focused on economic or societal values.
- The seventh class is outside the scope of this advice. The six remaining classes of equivalency metrics vary in a continuum from being very close to the direct first-order impacts of the development project (impacts on habitat features or death of fish) to being actual measurements of fisheries productivity.
- Data availability is an important consideration. All the classes of equivalency metrics perform better with reliable input data of whatever type the metric requires, and longer time series of information on recent conditions.
- A tabulation (Table 3) is presented of the appropriateness of each class of equivalency metrics for the various scales of development project impact and offset type (in-kind or out-of-kind), which should inform case-specific selection of metrics for establishing equivalency.
- This advice focuses on freshwater ecosystems, but there is a need for advice on offsetting that explicitly takes considerations specific to the marine environment into account.

INTRODUCTION

In November 2013, amendments to the Fisheries Protection (FP) Provisions of the *Fisheries Act* came into force. These amendments included Section 6 (s.6), which outlines four factors that the Minister must consider before authorizing a project that has the potential to cause serious harm to fish. Of particular relevance for this Science Advisory Report (SAR), the Minister must consider the measures and standards to avoid, mitigate or offset serious harm to fish that are part of or support a commercial, recreational or Aboriginal fishery. In addition, the proponent must include an offsetting plan as a regulatory requirement when submitting an application for authorization (*Applications for Authorization under Paragraph 35(2)(b) of the Fisheries Act Regulations*). This offsetting plan should include the objective, the measures, and an analysis, using scientifically defensible and clearly described methods, on how the measures will meet the offsetting objective. The offsetting plan must also outline a monitoring plan that assesses the effectiveness of the offset. The *Fisheries Productivity Investment Policy: A Proponent's Guide to Offsetting* (FPIP) or the "Offsetting Policy", was also made public in November 2013. The Offsetting Policy offers flexibility in choosing offset methods provided that increases in fisheries productivity are achieved and that the four key principles outlined in the Offsetting Policy are met.

The second principle in the Offsetting Policy states that "*benefits from offsetting measures must balance project impacts."* This principle is meant to capture the idea of equivalency between impact and offset, in relation to fisheries productivity (see: Terms and Definitions section for further explanation of this relationship). While the Offsetting Policy notes that achieving such equivalency may be easier to demonstrate when offsets are designed to provide similar function to the affected habitat, it does not describe acceptable methods for calculating losses and gains. The policy also indicates that time delays between the impacts and the functioning of the offsetting measures should be avoided but when they are unavoidable, offset measures must make up for fisheries productivity that has been lost because of the delay.

This Advice addresses metrics and methods that can be used to determine the equivalency of project impacts and offsetting gains. These equivalency methods can be employed when a development project has been determined to cause residual serious harm to fish, and hence requires preparation of an offsetting plan that balances the project impacts to support decision-making with regard to an authorization. Equivalency metrics are reviewed and recommendations are provided on their applicability to categories of project impacts and offset.

ANALYSIS

The Offsetting Policy provides a general overview of the components of developing an offset plan and submitting it to Fisheries and Oceans Canada (DFO), and provides some general guidance on each step. Although the guidance in the Offsetting Policy ends with submission of the Offset Plan to DFO, this SAR addresses those steps involved in estimating and evaluating equivalency. In the framework for this SAR, the steps are summarized as:

1) Characterize serious harm
2) Select offset measures
3) Determine amount of offset
4) Conduct the offsetting measures
5) Monitoring and reporting of effectiveness.

The five step approach is considered a workable framework, within which packages of offsetting measures can be developed based on sound science. The five steps have appropriate flexibility to take additional relevant factors into account, including fisheries management objectives and other societal objectives, feasibility of offsetting projects, and costs. All those factors are relevant to consider when choosing among alternative offsetting options that are individually scientifically sound. The flexibility in the five-step framework should also be applied in the context that how much is demanded from proponents during the planning of offsetting measures and should take into account some proportionality to the scale of expected impacts of the operational project.

It is further noted that this is a high level framework. The five steps do not explicitly reference all parts of past and present advice on offsetting, although some aspects of past advice are highly relevant to the current SAR, such as that the policy requirement that effects of offsetting have to be self-sustaining. There is no need to include every operational detail explicitly in the overarching framework. However, implementation of the framework requires consulting the more detailed advice and guidance on offsetting and not just the high level framework contained in this advice.

This advice focuses on components of Steps 1 (i.e., predicting impacts), 2 (i.e., predicting benefits), and 3 (i.e., establishing equivalence) in the framework, which together deal with determining the nature and amount of offsetting required. However it is stressed that Steps 4 and 5 are also crucial for offsetting to meet the objectives of the Act and the suite of relevant Fishery Protection (FP) Policies. Step 4 requires that the offsetting measures, once designed, be constructed or otherwise implemented according to their design. Compliance with the design of the offsetting measures, once the offsetting measures are approved, is not addressed in this science advice, but is necessary if the predicted benefits are to have the potential to be realized. Step 5, monitoring, specifically for follow-up evaluation of effectiveness of the offsetting measures, and as necessary adaption of the offsetting measures, is also essential (DFO 2012). There will be uncertainty about the actual outcomes of even well designed and implemented offsetting measures that use familiar methods. Consequently outcomes of offsetting, as well as the offsetting measures themselves, must be documented. If the monitoring finds that the effectiveness of the offset is not adequate (see below) the proponent may be required to do more to improve effectiveness or otherwise achieve equivalence.

Appropriately conducted monitoring provides two classes of benefits, one project-specific and another at the program level. The first is to provide accountability for meeting the requirements of the Act and the FP Policies, that the residual harm of the development project is counterbalanced by offsetting measures. The second acknowledges that data on real-world performance of various offsetting measures under a range of environmental conditions are few and sparse. Building up databases of how offsetting measures actually perform under various conditions will allow progressive improvements in predicting both impacts and benefits, and in the design of future offsetting measures under increasingly diverse circumstances.

Fisheries management and other relevant societal objectives can influence both development of and choices among options for how to conduct several steps in the offsetting framework, and are taken into account in Ministerial decisions on developments projects. For many Canadian watersheds, the absence of comprehensive and integrated strategies or plans, including explicit objectives, provides serious limitations on how effectively the framework can be implemented. All the steps can still be completed in the absence of such Plans and Objectives, but decision making may be more difficult, and the effectiveness of offsetting activities may be less than optimal if watershed or landscape scale factors are not considered.

Where policies do exist and give different “policy value” to different aquatic species, these differences can be accommodated in the computational procedures below. That does not mean to say that the methods and data for calculating differential economic or societal value for different species will necessarily be known or available whenever they are desired. Rather, if such differential economic or societal values can be provided by appropriate policy or management agencies, they can be included in the computational steps to establish equivalence.

It is important to know what factors currently limit productivity of a population, particularly when offsetting measures are intended to provide benefits to a targeted fish species. Otherwise well implemented offsetting projects can fail to produce the expected benefits, because the population productivity continues to be limited by factors not mitigated by the offsetting measures. Even at the community and ecosystem scale, well implemented offsetting projects can fail to provide expected benefits if factors limiting community or ecosystem productivity are not addressed by offsetting measures. According to the language of the Act it is the productivity of Commercial, Recreational or Aboriginal (CRA) fisheries that must be protected. In practice achieving this may require addressing limiting factors of a population, community, or ecosystem, depending on the watershed and the nature of the residual serious harm. These limiting factors are likely to be incompletely known, and sometimes not known at all. For development projects with small to medium sized expected impacts, if limiting factors are unknown like-for-like habitat replacement may have a better chance of achieving equivalency than alternatives that require more complex assumptions about the dynamics of the fish populations or communities expected to be affected. However, the greater the residual serious harm that has to be offset, the greater are likely to be the costs of required offsetting measures and need for post-development adjustments, and the less feasible it becomes to conduct like-for-like offsetting measures. As those costs and likely needs for further adaptation of offsetting measures rise, there is likely to be a corresponding increase in the value of pre-development project identification of limiting factors, and documentation of the status and natural variation of the system that will be affected by the development project, and where the offsetting measures will occur if the locations are different.

Use of Terms for the Science Advisory Report (SAR)

Several terms used in the SAR have both vernacular and technical meanings, with the technical meanings rooted in the Act, the FP Policies, or past science advice. The terms below all have such technical meanings, and every effort will be taken to use them consistently and only in their technical senses, as defined. If they have to be used in another sense in the SAR, the different meaning will be made explicit, and apply only to that use of the term.

Development project: Term used throughout the SAR to refer to the full set of activities intended by the proponent to achieve their development objectives. This advice is written in the context of new projects. However on scientific grounds the metrics and methods can be extended to existing projects that have ongoing operations that require authorization, should policy and management choose to do so.

Impacts: The residual serious harm to fish as determined and quantified for each phase of a proposed development project. These impacts may include determining the extent, duration and magnitude of residual serious harm to fish and fish habitat in terms of the number of fish killed, area of habitat destroyed, area of habitat permanently altered and degree of alteration. The full footprint of a development project is relevant to evaluation of the project's impacts. Guidance on the determination of impacts is contained in DFO 2013, 2014a.

Benefits: The consequences of the offsetting measures on fish or fish habitat are intended[1] to counterbalance residual serious harm of a development project. If an offsetting activity has consequences that have negative impacts on other fish or fish habitats, such consequences are among the relevant factors in determining equivalency.

[1] Note that according to FPP, the *realized* benefits from offsetting must counterbalance the impacts. Because this SAR addresses considerations during planning as well as implementing of offsetting measures, the scope of "benefits" includes the *intent* to counterbalance impacts during planning stages, as well as the realised outcomes of the measures, once implemented.

Equivalency: Equivalency is the state when the benefits from offsetting measures are equal to the impacts of the development project. For cases where habitat is being altered or destroyed equivalency is achieved when $A_p V_p I = A_o V_o R$, where *A* is the area of the development project where residual serious harm occurs, *V* is the value of the fisheries or ecological resources at each site, I is the intensity of impact (i.e., the reduction in services), *R* is the increment of value associated with the offset measure (the increase in services), and the subscripts are for development project (*p*) or offset measures (*o*). This is often expressed as the area of offset needed for equivalency:

$$A_o = A_p V_p I / V_o R$$

Note that these equations do not take explicit account of the time dimension or adjustments for uncertainty. For those reasons or other policy considerations ratios greater than 1:1 (i.e., the predicted benefits>predicted impacts) may be required for offsetting measures to be approved.

Equivalency currency or equivalency metric: The common unit of measure used to compare impacts and benefits.

In-kind and out-of-kind: Used in this SAR to reflect the distinction between offsetting measures that address the same species or habitat as the project impacts (in-kind), and offsetting measures that are designed to increase productivity by means other than replacing lost habitat or habitat function (out-of-kind). (see p.10 of Proponents Guide to Offsetting).

Offsetting measures: Term used throughout the SAR to refer to the full set of activities intended by the proponent to counterbalance the residual serious harm of the development project.

Fisheries productivity: In the context of the FPP, 'fisheries productivity' is a primary objective of offsetting measures under the Act and the FPIP. There is a large scientific and management literature on "biodiversity offsets" Offsets of "fisheries productivity are considered sufficiently analogous to 'biodiversity offsets' that lessons drawn from that literature will be considered in this report.

Value: In this SAR, unless otherwise qualified, "value" refers to the ecological value of fish or fish habitat to a population, aquatic community or ecosystem. It does not include economic or other societal values unless those adjectives are used. The economic or societal values are legitimate considerations in decision-making about impacts, offsetting and equivalency. They may even be part of fisheries management and other relevant societal objectives that are included in evaluation of offsetting measures. However, such economic and societal values are outside this advice, and need to be developed further and reviewed by appropriate experts.

General Points about Implementing Steps 1-3 of the Framework

There are many computation similarities between Steps 1 and 2, and many of the calculations involved in predicting impacts and predicting benefits may be similar or identical. However there are some important differences between those two steps which should be taken into account.

Step 1, predicting impacts, may have guidance and strive to meet constraints from Federal, Provincial and other legislation and policy, other than solely the provisions of the *Fisheries Act*. These affect Step 1 in the sense that predicted impacts may not comply with legislation and policies, and rather than proceeding with the design of projects to offset the impacts, the design of the development project may need to be adapted until the legal or other policy constraints are met. That is, offsetting may not be an acceptable solution for certain development projects in some locations. Although the same policies and legislation would apply to offsetting options being designed in Step 2, the options are designed to produce benefits rather than impacts. Consequently it is much less likely that legislation or policy would be constraining (although they may provide a partial basis for choosing among options).

Step 1 may also be more deeply grounded in empirical data than Step 2, in that usually more will be known about the initial conditions for predicting project impacts than for offsetting projects because of requirements for baseline data for review. In addition although both Step 1 and Step 2 involve predicting how the aquatic ecosystem will react to anthropogenic alterations, in part because of past work on Pathways of Effects the nature of the changes to the ecosystem resulting from a development project will often be known with less uncertainty than how productive a constructed or modified ecosystem will be. Thus the more that predictions of future fisheries productivity from the offset measures depend on how the ecosystem develops as a result of those measures, the more uncertain the predictions for Step 2 will be compared to the predictions from Step 1.

In addition to uncertainty about the actual responses of the ecosystem to the alterations caused by the development project and the offsetting measures, many impacts from the development project will commence almost immediately, whereas benefits associated with offsetting measures may accrue incrementally over a long time course. That alone will usually make predictions of offsetting benefits in Step 2 more uncertain than predictions of development project impacts in Step 1. This difference in time course of initiation of impacts and benefits creates an incentive for habitat banking (see DFO 2014c) to have a role in offsetting, because uncertainty about benefits from offsetting measures can be reduced substantially.

A third factor contributing to possibly greater uncertainty of predicted benefits is that as the scale of development projects increases, the scrutiny they receive to comply with federal, provincial, territorial statutes often increases as well. This means that scenarios involving a wide range of ecological, social and economic externalities often have to be explored. In practice offsetting measures may not have to consider as large a number of externalities in their planning, but their outcomes are no less vulnerable to them. To the extent that this happens for a development project, it would also make predicted benefits more uncertain than predicted impacts.

The likely greater uncertainties of predictions of benefits (Step 2) than predictions of impacts (Step 1) need to be taken into account in establishing equivalency (Step 3). As the difference in uncertainty between the two predictions increases, the need to be more risk averse in estimating benefits than in estimating impacts increases[2]. "Equivalency" then would not be the ratio of the average predicted benefit over the average predicted impact. Rather, a level of risk aversion appropriate for predicting the impacts would first be determined, taking all relevant legislative operating requirements into account. Then a higher level of risk aversion, informed by the consequences of uncertainties of predicted impacts and predicted benefits, would be determined. Equivalence would then be the ratio of the two predictions, each at its appropriate degree of risk aversion. Since such computations are often complex and case-specific data may be unavailable, standardized multipliers may be used.

"Equivalence" (Step 3) is established in FP Policies and consistent with the Act as equivalence in productivity; here counterbalancing any decline in fisheries productivity as determined by death of fish or the alteration or destruction of habitat and corresponding inferred loss of

[2] In this context, being "risk averse" would mean, in practice, that whatever the likelihood might be of underestimating the residual serious harm of a development project and the possible size of those underestimates, the likelihood of underestimating benefits, and the possible size of the underestimation of benefits from the offsetting measures would have to be lower.

productivity caused by the project with an increase in productivity due to offsetting measures. Changes to fisheries productivity for other reasons, including adjustments in fishing pressure or the construction of fishery infrastructure, are not considered here in the estimation of benefits.

The need for equivalency is the same for proposed development projects in both marine and freshwater systems. However, various classes of equivalency metrics may have different statistical power and feasibility in marine and freshwater systems, and choices of offsetting measures may also be different. As has been the case with most Science advice to FPP to date, this SAR focuses on freshwater ecosystems, but there is a need for advice on offsetting that explicitly takes considerations specific to the marine environment into account.

When predicting impacts and benefits and establishing equivalency, seasonality can be a very important factor. Studies drawn from areas with milder climates may give little or no consideration to overwintering habitats, which can be very important for fisheries productivity in the Canadian context. Further, fish abundance and habitat use can vary with season and environmental conditions; sampling needs to be standardized to the flow regime and ecological phenology of the watershed and tied to relevant life history stages, and not simply tied to a calendar date.

Establishing “equivalency” through provision of a large amount of lower quality habitat to offset impacts on a lesser amount of better quality habitat is not preferred scientifically. Reasons include:

- When environmental conditions are variable, better quality habitats for a species or community remain able to support populations when lower quality habitats may be unable to support the species. As a consequence the offsetting benefits would be lost even if under average or good conditions there could be equivalency.
- Similarly, even if the lower quality habitats remain able to support a remnant population under unfavourable environmental conditions, energetic costs are often higher in lower quality habitat, so net productivity may become negative even if the population can survive.

It is acknowledged that small amounts of very high quality habitat may be more vulnerable to an unfortunately placed or timed catastrophic event than much larger amounts of lower equality habitat. However the increased robustness to environmental variation is considered to outweigh the greater risk to unlikely catastrophes, supporting the preference for offsetting with the highest quality habitat that is feasible and cost effective.

When using models with any of the classes of equivalency metrics, a degree of validation of model performance is required. Field validation of model predictions under conditions similar to those where the development project, and where the offsetting measures will occur is always preferred. However, the costs of such validation can be high, and may be justified only for development projects where large impacts (habitat or ecosystem transformations) are expected. However, a minimum standard for the use of any model in establishing equivalency is that it be peer reviewed by a group of experts with competencies appropriate to the model, and not directly involved with either development of the modelor the specific project to which it will be applied. This peer review does not have to be conducted before every application of a model, but has to have done for a sufficiently comparable system. “Sufficiently comparable” is a scientific judgment that takes into account both the nature of the ecosystem (including the populations of particular interest) and the type of development project and/or offsetting measures under consideration.

For a given development project and associated offsetting measures “equivalency” can be established for many of the classes of equivalency metrics. It can also be established at the scale of a single species, a subset of key species, potentially the full fish community, or even via indirect properties such as habitat or secondary productivity not directly tied to any fish species. It was noted that deciding the biological scale at which to achieve equivalency, and the choice of metrics can affect what constitutes “equivalency” substantially, because of the different scientific demands that have to be addressed during planning. Thus fisheries management and other societal objectives should be considered in making such choices, to increase the likelihood that the choices of scale and metrics meet the objectives of the Offset Plan. However, specific advice on selection of species was not provided at this meeting, beyond confirming that past advice on implementing the FPP has discussed the selection of species and is relevant to establishing equivalency (DFO 2014a, b, d). The provision of clear scientific advice for FPP implementation may be limited unless fisheries management objectives are clear and explicit, and functionally impeded (although not procedurally impeded) in the absence of comprehensive watershed/ecosystem (or larger) management strategies and plans.

There was insufficient time at the meeting to review adjustments for time lags and time trends in impacts or benefits using discount rates, and use of specific multipliers to adjust for uncertainty in establishing equivalency. However the validity of the past general advice on these topics (DFO 2014c) was confirmed. The use of discounting to help account for differences in time courses of impacts and benefits, and multipliers to help account for uncertainties are both considered scientifically appropriate practices. More research and field validation of model performance are both needed to improve practice in this area. It was noted that investments by project proponents in data collection and model validation can be repaid by only needing to apply lower multipliers for equivalency of offsetting measures if uncertainties about impacts are lower, and to make fewer adjustments over time if the offsetting measures are producing the predicted benefits. Similarly an adaptive approach using monitoring and contingency measures may also reduce the need for multipliers that account for uncertainty.

Several approaches are available to reduce and manage uncertainty in Steps 1 to 3 of the offsetting framework. In general well planned and comprehensive baseline data collected over an appropriate time period can reduce uncertainty in predictions of potential impacts (Step 1) and the benefits offset measures (Step 2). Rigorous analytical and modelling approaches , that include multiple metrics weight-of-evidence approaches, scenario and sensitivity analyses, and field validation of models all can reduce or at least increase reliability of estimates of uncertainty (Step 3). Also, appropriate peer review of predicted impacts, benefits, and evaluations of equivalency increases confidence in the predictions and evaluations, even if the analytical estimates of uncertainty are not reduced. Where particular approaches for addressing uncertainty are especially relevant to application of one of the equivalency metrics, they are discussed further in the corresponding section of this SAR.

General Points about Equivalency Metrics

Seven classes of equivalency metrics for Steps 1, 2, and 3 were reviewed. These were:

1) In-kind habitat;
2) Habitat functions and ecosystem services;
3) Habitat indices;
4) Fish biomass or abundance;
5) Fish or ecosystem production;
6) Fishery metrics;
7) Other “value-based” metrics, focused on economic or societal values.

The seventh class, on economic or societal value metrics was outside the scope of the request for advice, because it would have required additional expertise at the meeting and is not considered further in this SAR.

The six remaining classes of equivalency metrics vary on a continuum from being very close to the direct first-order impacts of the development project (i.e., impacts on habitat features or death of fish) to being actual measurements of fisheries productivity. For a given development project or set of offsetting measures there will be some necessary set of assumptions of population and ecosystem responses to both the development project and offsetting measures and uncertainty associated with all the assumptions. It is important to understand how the treatment of those assumptions and uncertainties varies along the continuum.

Choices of metrics close to the habitat measurement end of the continuum focus on the direct consequences of the development project and offsetting measures on aquatic habitat. The computations implicitly assume that if the habitat characteristics are equivalent the subsequent assumptions about population and ecosystem responses to the habitat alterations are the same in both the numerator (estimated benefits from Step 2) and denominator (estimated impacts from Step 1) of equivalency, and cancel out of any further computations. Thus, the assumptions do not add uncertainty to the equivalency calculation but the uncertainties still exist in the numerator and denominator of the equivalency calculation, even if they are assumed to exactly cancel out. Choice of metrics closer to the fishery productivity end of the continuum require dealing explicitly with many more of the population and ecosystem responses to development projects and offsetting measures. Therefore, metrics on the fishery productivity end of the continuum are usually more complex and demand more data and models. However, the calculations directly address more of the assumptions necessary in establishing equivalence in terms of fisheries productivity, providing greater transparency about what is assumed about the consequences of both the development projects and offsetting measures. When there are important questions or concerns about these assumptions, the more complex computations may be preferred.

As emphasized in past advice on the general productivity response curves in the FPP, nonlinearities are expected to be common in the responses of fish populations and ecosystems to alterations by development projects and offsetting measures (i.e. impacts and benefits; DFO 2013, DFO 2014b). It has also been stressed (DFO 2014a) that many development projects will affect more than one life history stage of species of interest, and many species in a lake or watershed. The general offsetting framework can handle both the potential non-linearities and impacts on multiple life history stages. However these complexities create a strong incentive to use classes of equivalency metrics such as fish abundance or production that incorporate nonlinearities and multiple impacts in population models; these considerations are not addressed in simpler equivalency metrics. If simpler metrics are used then the potential non-linearities and multiple impacts have to be addressed more explicitly.

Within groups of experts, of practitioners and of management authorities participants may hold diverse views on the relative confidence in the feasibility and reliability of metrics that do not directly predict fisheries productivity. This is largely because demands for information on both the ecosystem and fisheries biology increase as one progresses towards the classes of metrics more directly related to fisheries productivity, and can increase even within a class, depending on the choice of species or community metrics). A preference for computationally simpler methods closer to the habitat end of the continuum is reasonable, but scientifically requires the assumption that population or ecosystem responses to a given habitat condition are the same, whether the condition results from a development project or offsetting measures. This assumption is most likely to be met when project impacts are simple to describe and can be offset with in-kind measures, and becomes less tenable for large-scale impacts and out-of-kind offset measures.

With regard to guidance on “best practices” for choices among classes of metrics for estimating equivalence, if there are multiple feasible options, several factors should be considered. Some factors are not addressed by natural science disciplines (the focus of this SAR), including societal preferences, comparative costs of estimation of costs and benefits, etc. and are not discussed here. However there are also some important considerations from the natural science perspective.

- Data availability is an important consideration as all classes of equivalency metrics perform better with reliable input data, and longer time series of information on recent conditions.
- There is a trade-off between typically greater computational simplicity on the “habitat” end of the continuum and more explicit treatment of assumptions at the “productivity” end of the continuum. The trade-off favours habitat-related metrics when “all other things are equal”, but if it is known that different assumptions have to be made to predict impacts and benefits on CRA fisheries productivity (for example the immediate ecological consequences of the kinds of offsetting measures are quite different from the immediate consequences of the development project), then metrics closer to the productivity end of the continuum are needed.
- If there are scientifically based reasons to consider the habitat that is to be affected by development projects or improved by offsetting measures is underused relative to its quality for reasons that have little to do with the project (e.g., the system is overfished), it is recommended to use whatever metric best reflects the true quality of the habitat. If the limiting factor that makes the habitat underutilized is unknown, establishing it before the development project or offsetting measures occur can save substantial time and money in the long run. It can allow more accurate estimation of the true impacts of the development project, and save costly investments in ineffective offsetting measures.
- When collecting baseline data for estimating either impacts or benefits, non-lethal sampling methods are often available for quantifying status of populations. These should be considered in all cases, and may be especially important when key species of concern are rare, protected, or otherwise highly valued by society.
- Experience with use of all these classes of methods is growing, as are data bases relevant to their application. For case-by-case applications the information sources at the time of planning should be consulted, rather than solely relying on precedents that may be out of date or of lower relevance to local conditions.

Equivalency Metrics

Table 1 is a brief overview of the equivalency metrics reviewed in this advice; more detailed descriptions are found in the following sections. Example Applications and Example Metrics are meant to be illustrative of common current practice and should not be interpreted as restrictive (i.e. a particular class of metrics is likely to have more applications than the ones listed in the table, and a given Example Metric might serve the needs of more classes of metrics than the specific one which it illustrates).

Table 1. Listing of equivalency metrics that can be used to determine offset requirements.

Metric class	Example application	Example metric
Habitat	In-kind habitat replacement	Area and habitat type
Habitat or ecosystem function	Replacement of lost function potentially using unlike offset measures	Habitat function metrics (e.g., cover, substrate) Secondary production
Habitat suitability or capacity for select species	Reductions in habitat quality or quantity offset by (unlike) improvements to habitat quality	Weighted useable area, Habitat Suitability Indices
Fish abundance	Creation of new habitats with similar expected fish communities. Created habitat may be unlike affected ones	Biomass, density, smolt production observed (baseline) or predicted (offset). Regional fish density reference data may be used
Fish production	Habitat loss or ecosystem transformation requiring unlike offsets. Can be used when new fish community is unlike affected one	Fish production lost/gained; direct measurements or regional standards, P/B predictors
Yield/fishery benefits	Predicted benefits to fishery (catch, angler satisfaction, participation) of the offset relative to losses to the fishery	Observed fishery statistics or predictions based on fishery models

In-Kind Habitat Replacement (Area/Type)

In-kind habitat replacement, or like-for-like habitat offsets, balance losses by benefitting the specific fish populations in the geographic areas that will be affected by the proposed development. By keeping losses and gains comparable in habitat type and area, it is assumed that the productivity and biodiversity of the ecosystem is most likely to be maintained.

Application

Replacing in-kind habitat is the simplest offset method to employ since establishing equivalency is relatively straightforward. Replacing in-kind habitat is best suited for habitat losses that affect the quantity of habitat (e.g., category 1 in DFO 2014b) without resulting in habitat conversion (e.g., river to reservoir). The biggest advantage of in-kind habitat currency is the computational ease of establishing equivalency and for implementing offset ratios as it is a simple summation of equivalent units. This simplicity allows for a streamlined assessment approach and repeatability of application. The biggest drawback of this currency is that one assumes that fisheries productivity will be equivalent once the new habitat develops to full functionality and simply replacing habitat thus meets the intent of the *Fisheries Act*, which may not always be the result. Habitat replacement can become complex if multiple habitat types are affected by the project, which increases in likelihood as the scale of development projects increases and greater impacts are expected. Successful in-kind habitat replacement may be less likely when impacts are large; equivalency may have to be documented in terms of productivity, not just habitat area.

Metrics, Data and Methods

The metric for in-kind habitat replacement is m^2 of habitat and since the units are the same for 'in-kind' offsets, establishing equivalency by assessing productivity is not necessary. Calculation of habitat lost/gained is by the relatively straightforward method of measuring area lost/gained by habitat type. Establishing equivalency is simply a matter of measuring the area of the created habitat as required by the terms of the authorization. The data required are:

1) The project area (in m^2) baseline of existing habitat that will be lost, by habitat type if more than one is being destroyed; and,

2) The predicted area and type of the created habitat.

Some consideration (usually a multiplier) to account for uncertainty and time lags may be included in the determination of offset size. Typically since this type of offset is employed for smaller impact projects and the replacement habitat is often created from dry land or very low value habitats, the baseline (pre-development) of the offset area is not considered in the calculation. In addition, typically the fishery value of the offset habitat is not modelled, although the effectiveness of the created habitat may need to be assessed as part of a monitoring plan, and would be required if this is an authorized offsetting plan (DFO 2012).

Key uncertainties

Replacing in-kind habitat requires measurement of habitat features (area-based measurement), but has little uncertainty in the measurement of baseline habitat to be lost, or in the prediction of habitat to be created, assuming that the replacement habitat can be successfully constructed. The validity of this assumption is more certain for habitat types which have often been created and which have been the subject of much research. Uncertainty increases for habitat types less well studied or in cases where the long-term structural integrity of the habitat is highly uncertain. Long-term efficacy of in-kind created habitat should be part of the monitoring program.

Habitat Characteristics and Function

This class of equivalency metrics is used when the offset is designed to replace a lost habitat characteristic that is directly linked to one or more ecosystem functions and is often referred to as a service-to-service equivalency. Ideally, these functions would be directly or indirectly related to CRA fisheries production, and could include habitat features such as structure, cover, substrate type, physical processes, or be integrated by measures such as secondary production. Habitat function offsets may or may not be applied using the same habitat type as that lost, which could fall under the category of lost habitat quantity or quality (categories 1 and 2 in DFO 2014b).

DFO's Pathway of Effects diagram endpoints list habitat characteristics or functions that are subject to negative residual effects from typical projects (e.g., change in structure and cover, sediment concentrations, nutrient concentrations; see DFO 2014a). These diagrams provide a useful guide for identifying ecological functions likely to be negatively affected by the activity. An overview of how these ecosystem functions (i.e., Pathways of Effects (PoE) endpoints) respond to typical human perturbations and the anticipated shape of generic productivity-state response curves is available (DFO 2014a). Offsetting these lost functions could include replacement of the same habitat features that were destroyed, or replacement by different features that provide an equivalent or different ecosystem function.

Application

Service-to-service equivalency calculations assume that providing an equivalent quality and quantity of habitat service will translate into equivalent fish productivity. When the same service is provided by the offset then it is assumed that the support function provided by the ecosystem service will not alter the fish community dynamics, although it may be influenced by the ecosystem context of the offset.

A habitat function currency is best suited for projects affecting habitat quantity or quality where the offset is designed to balance the lost habitat characteristic or function, or to provide an alternate function that may be deemed preferable in light of predominant habitat availability (or limitation). When the offset replaces the same function (e.g., the same services of the same type and quality), quantifying equivalency will be straightforward using a metric that describes the dominant function of the habitat. The habitat function currency also has the advantage of providing some flexibility in terms of the choice of offset. If non-critical or non-limiting services are lost offsetting could be designed to provide an alternate service that is scarce or limiting.

Metrics, Data and Methods

Examples of common indicators associated with habitat function include measures of substrate type and characteristics, densities of riparian or aquatic macrophytes or large woody debris, or density and biomass of secondary producers (entire community) at some level of taxonomic separation. A number of models exist that could convert density and biomass of secondary producers to production (which may be then linked to fisheries productivity by using Production:Biomass ratios (commonly called P:B ratios in the technical literature) and basic environmental measures (e.g. water temperature, habitat type).

The primary data needs are:

1) The characterization of the impact site, expressed in terms of the equivalency metric being used to calculate the offset requirements, by direct sampling or regional benchmarks; and,
2) Predictions of the equivalency metric at the offset site, based on baseline data (such as natural sites near the project), regional benchmarks, or models.

The function or service for which equivalency is calculated will typically be inferred from data on measurable characteristics of the state of the habitat, population, or community, as function or service are often difficult to measure directly.

Key uncertainties

The magnitude of uncertainty depends on the metric chosen. In the case of a service-to-service offset where m^2 of habitat of similar function is the metric, measurement uncertainty will be minimal. In this case, the greatest uncertainty will come from the effectiveness of the proposed offset, which depends on the type of habitat service provided. In addition, while equivalency may be technically met on an aerial basis, the linkage of the habitat function to fisheries productivity may be system-specific so context needs to be considered. For out-of-kind offsets uncertainty increases commensurate with the complexity of the metric selected, diminishing quantity and quality of empirical regional data, difficulty in collecting site-specific field data, and the degree of validation of models available for predicting future value of the offset habitat. While specific relationships between selected metrics and aspects of CRA fisheries species may not be available, the scientific literature, expert knowledge, productivity-state curves, and pathways of effects models can all be used to infer linkages. The uncertainty associated with these inferences will increase as less data-rich species have to be used, or data have to be taken from increasingly different watersheds.

Habitat Suitability/Capacity for Selected Species

This category includes habitat-based models that make inferences about the biological use of physical habitat features to make quantitative assessments of habitat suitability for select species. It was a frequently used approach under the No-net Loss Habitat Policy. Fish are known to prefer specific habitat features characterised by factors such as depth, velocity, substrate type and vegetation cover, Known associations of species and life-stage with habitat features can be modelled to provide a quantitative value of the habitat lost due to residual effects, and to model the habitat expected to be gained from the proposed offset. For example, stream-based habitat models integrate a hydraulic model with a biological model (habitat suitability criteria, HSC), to calculate weighted usable area (WUA) as a function of discharge and river morphology (e.g., PHABSIM, River2D, MesoHABSIM). In Canada this modeling approach was extended to lacustrine habitat with the Defensible Methods approach, taking into account that the greater utilization of habitat types by different species and life stages are important for sustaining lacustrine fish community productivity. Tools like the Habitat Alteration Assessment Tool, (HAAT) compute weighted useable areas for all fish species that may be present in the lacustrine area being assessed.

Application

Quantitative habitat models can be used for projects affecting both habitat quantity (e.g., infilling a lake shoreline), or habitat quality (e.g., where instream flows are being changed due to a hydropower development, diversion, or water withdrawal). In most cases the offset method used will be to improve habitat elsewhere or to provide unlike, out-of-kind habitat improvement since, for example, a reduction instream flow volume altering the WUA fundamentally cannot be offset by in-kind measures.

Quantitative models provide a defensible basis for determining offset requirements, and can provide an objective basis for negotiations between the proponent and regulators. However, all metrics assume a biological response in proportion to changes in the metric; an assumption that may not always be realized. For example, reducing velocity (via water extraction) in a high gradient, high velocity system often results in greater modelled habitat suitability for life stages or species which prefer low velocity habitats, but the modelled suitabilities may not translate into a corresponding change in fish abundance.

Metrics, Data and Methods

The metric is a habitat suitability index which when multiplied by area generates WUA by species and life stage. Habitat patches have characteristics of depth range, substrate type, cover type and other features depending whether they are lacustrine or riverine. Appropriate models generate suitability values according to species requirements grouped by life stage, trophic level, thermal preference or other relevant factors. Scenarios are produced for pre- and post-development conditions at a proposed site that provide an assessment of the gain or loss of suitable habitat. With the specific tool of HAAT a module is available to add in the post-development conditions with compensation included. More dynamic or variable habitats can require extensive field data collection program. Habitat suitability criteria (HSC) can be site-specific, using locally collected data, or can be determined by an expert process, or using indices from other sufficiently comparable locations (where “sufficiently comparable” is interpreted as described above for peer review of models).

Once the model is developed it is possible to assess the change in WUA caused by the project, and determine the offset needs based on that change. When the models used focus on one or a few key species or communities; the choice of species may be based on local priorities, data availability or representativeness across the whole fish community.

Key uncertainties

Uncertainty in fish habitat suitability modelling arises from sampling and measurement error, the accuracy and precision of locally developed models, and the appropriateness of data, models or relations imported from other sites or the literature. With appropriate attention to study design and analysis uncertainty in the selected suitability index can often be managed to reasonable levels. A critical assumption of this class of metric is there will be a positive relation between fish abundance or productivity and the index being used. This assumption may not hold if the index does not capture the key limiting factors for the population, or if natural variability overwhelms habitat factors. Testing this assumption requires considerable effort, although in some cases the necessary field validation of some habitat suitability index (HIS) models has been conducted.

Fish Abundance Metrics

This currency uses direct measures of the abundance of the species/community that will be affected to determine offset requirements. The use of abundance metrics is an example of resource-to-resource equivalency analysis (REA). The REA approach can be used when impacts are on habitat quality and/or quantity and are also well suited when the impacts to the fishery are the result of lethal or sub-lethal impacts. Abundance metrics, especially biomass, generally are highly correlated to production and can be used as a proxy for fisheries productivity.

Application

Fish abundance metrics are best suited for cases where the offsets are designed to increase the abundance or productivity of the same or similar species as those affected. This can include offset measures for projects that cause an increase in mortality, rather than habitat impacts.

The primary advantage of using a direct measure of the fishery resource is that it can provide additional options when designing offsets. Since the offset is not simply trying to replace the function of the habitat that was impacted, but replace the fisheries productivity or death of fish, it is possible to use offsets that manipulate habitat quality or take other measures to produce the required abundance of fish (although the selection of “other measures” has to take account of the provisions of the FPIP). The use of direct measures of abundance is also often easier for stakeholders to understand.

Metrics, Data and Methods

Density: Density is an absolute measure of abundance for the area under consideration. The area can be a habitat unit or some other area that can be sampled with a reasonable effort. Density is reported as number of individuals per unit area (e.g. # m^{-2}, # ha^{-1}).

Biomass: Biomass, also an absolute measure, is most often calculated by multiplying the density of the individuals by their average weight and is reported in mass per unit of area (e.g. g m^{-2}, kg ha^{-1}).

Catch per unit Effort (CPUE) or Biomass per Unit Effort (BPUE): These are relative measures of abundance; CPUE only deals with numbers while BPUE incorporates the mass of the individuals captured. These measures rely on the sampling effort being standardized to allow comparisons. Since these are relative measures of abundance some caution should be exercised when using these metrics in equivalency analyses, especially if they are to be used in an offset habitat that is not the same as the affected site. If catchability is in any way different in the offsetting habitats relative to the impact area comparisons may be biased.

It is important to view abundance estimates in the context of seasonal and interannual variation, and life history stages, as these metrics can change significantly during life history transitions. Past advice (DFO 2014c) that equivalency should be established for adult equivalency units should be taken into account if the metrics are for other life history stages.

Equivalency analysis based on abundance metrics will require empirical or predicted measures for the affected area and the area proposed for offsetting, and a prediction of abundance metrics after the project and offsetting are completed. Those predictions can be derived from regional benchmarks of abundance, or a validated fish habitat model.

For projects that cause mortality or decrease one or more vital rates (see DFO 2014b), the equivalent adult method can be used; this method converts impacts into the foregone production of adult fish which becomes the unit for equivalency calculations (DFO 2014c).

Fish-based equivalency methods require more information than purely habitat-based methods. Information for the affected site can be collected during pre-project sampling but the estimates for the offset area will have to be predicted. These predictions can be informed through a variety of methods that include past experience, peer reviewed expert opinion, regional benchmarks and/or field validated models.

While there can be technical challenges with collecting biological abundance data, this is a mature field with a number of good reference documents that outline both sampling and statistical methods. Well calculated abundance metrics are generally statistically robust and it is relatively easy to interpret qualitative and quantitative changes in value. Further, many regional benchmarks exist in public and private databases for most North American freshwater fish species. Habitat restoration/creation has a fairly extensive history in North America and this experience should make it possible to characterize benefits in terms of fish abundance with reasonable certainty for ‘common’ habitat manipulations. In situations where experience is lacking, predictions can be informed by expert panels and/or regional benchmarks. These data sources are not mutually exclusive and a project that uses more than one should reduce the overall uncertainty with respect to the predictions.

Predictions of abundance are intended to be used for water bodies with similar biological and physical features to those of the predictive dataset. In situations where the offset consists of the creation or significant modification of habitat, there will often be time lags between the creation of the habitat and its ultimate stable state. In situations where fish community changes are expected more complicated models than simple fish abundance metrics may be required (see below).

Key assumptions and uncertainties

The key assumptions made when using abundance metrics are that there is an inferred link between abundance and productivity, and that abundance can be predicted given the offsetting measures under consideration. It is therefore important to have knowledge of the key production mechanisms (i.e., growth, recruitment, and survival) of the habitat when using abundance as the metric to evaluate habitat-based offsets. When these mechanisms are not as well known it would be beneficial to include additional metrics in the monitoring program to improve knowledge for the future.

Uncertainty associated with estimating abundance can be managed with an appropriate sampling program, although this can be a significant undertaking for water bodies that are large or difficult to access. There are many models that predict abundance, and these can be used to estimate project impacts and offset benefits. Predictions from generalized models are more uncertain than models that are based on site-specific information. How uncertainty varies with the standard of model validation are the same for metrics of fish abundance as for other classes of metrics using models.

Fish Production

This metric class uses either direct measures or modelled population production rates of the species expected to be affected, to determine offset requirements. The use of production metrics as a currency is another example of a Resource Equivalency Analysis (REA) Population production is the main determinate of sustainable yield and thus is well aligned to the sustainability and productivity of fisheries..

Application

Fish production is particularly appropriate in cases where the impacts and offsets are large, and the offsets are likely to produce a different suite of species than those affected by the project. Production can be used in simpler cases, but less demanding metrics may suffice, especially considering the data requirements and associated uncertainties in production estimates.

The use of production metrics is data intensive and can be complicated. Information for the affected site can be collected during pre-project sampling but the data requirements are high. Information for the offset habitats will have to be predicted via modelling or use of reference data. The models require detailed information on either population level and/or stage/habitat specific vital rates (i.e., reproduction, growth, survival). These predictions can be informed through a variety of methods that include past experience, peer reviewed expert opinion, regional benchmarks and/or field validated models, however detailed productivity assessments for many species are still relatively rare in the scientific literature.

The primary advantage of using a production assessment of the resource is that it can provide additional options when designing offsets. Many of the modelling options can test scenarios which can then inform offsets. Because the offset measures are not simply trying to replace the function of the habitat that was affected, it is possible to use offsets that manipulate habitat quality and/or target habitats that are deemed lacking or often limiting in the area of the species/community the offset is being designed to benefit. This approach can also inform managers in situations where the ecosystem is expected to be transformed and species assemblages are expected to change.

Metrics, Data and Methods

Production: Fish production rate is the total elaboration of new body tissue in a population in a unit of time, irrespective of whether or not it survives to the end of that time. The unit of time for measurement of production is often one year, and the units of production are total numbers of fish or kilograms (produced) for a specific species and area ($number \cdot yr^{-1}$ or $kg \cdot yr^{-1}$), or as relative units of kilograms (or number) per hectare per year ($kg \cdot ha^{-1} \cdot yr^{-1}$).

Population structure metrics (e.g., body size, P:B ratios; habitat productivity indices (HPI)): size structure information, especially maximum length, has been correlated with production. The production to biomass ratio (P:B) is an index of the turnover rate of the population. Habitat Productivity Index (HPI) is used as relative measure of a habitat’s productive capacity. HPI is the product of the P:B ratio (often estimated using allometric relations with life history traits) with seasonal biomass of a population. A community index of HPI can be computed by summing indices of all the co-habiting species.

Individual metrics (e.g., growth, survival, reproduction): Individual metrics, also referred to as vital rates, are usually the building blocks of production estimates. They can be expressed per unit of time (e.g., mass gained per season or year).

There are a number of modelling approaches that can be used to investigate the mechanistic relationships between habitat-related impact, or changes to vital rates and production. Stock-recruitment models, Leslie Matrix models, and stage structured habitat supply models are examples of the types of analytical methods that can be used.

The actual calculation of production rate is data intensive and historically it has not been extensively used in habitat-related assessments. Thus, the calculation of production may be reserved for use in larger projects where either entire parts of the ecosystem are going to be negatively affected or the ecosystem is going to be transformed. When an empirical estimate of fish production is required, there are a number of methods that can be found in the literature.

Productivity assessments may combine individual metrics and/or population structure with abundance metrics. In general, a suite of metrics will be more robust than any one single metric when assessing fish productivity. Individual metrics can also give insights into mechanistic links between habitat and production. This can provide a potential early indicator with respect to the success of the offset as well as providing options for adaptive management if the offset is seen not to be working as predicted.

The P:B ratio is an excellent indicator of productivity but the empirical calculation of P:B has the same data intensive requirements as that of production rate. It can, however, be derived from allometry, although with greater uncertainty than if measured directly. In these situations it can be an operational shortcut method to calculating population production. With an estimate of P:B and seasonal biomass the HPI can be calculated. The HPI was originally derived as an index of a habitat's productive capacity for the existing community, however it can also be calculated on a population basis. The HPI may be particularly useful in situations where species assemblages are expected to change due to project impacts.

Key assumptions and uncertainties

Similar to abundance metrics the main assumptions with respect to production are that the impacts of the development project on productivity can be measured or estimated, and that there is a direct link either between production rates per se or the individual vital rates and the offsetting measures. In many cases it is assumed that reproduction and/or recruitment of juveniles is a limiting factor in population production. This is why many offsetting programs focus on spawning habitats instead of taking a more holistic approach to habitat supply. These assumptions are rarely tested and will require a careful consideration of the population biology of the population or species expected to be affected.

Since production metrics are often built on abundance metrics they will have many of the same uncertainties and assumptions (see above). The prediction of fish production metrics resulting from the implementation of offsetting measures will rely on modelling approaches in most situations. Modelling will add uncertainty to the equivalency analysis. Predictions of production metrics in offset habitats will be more robust when the input data (i.e. vital rates) are from water bodies with similar biological and physical features to those of the predictive dataset.

Fishery-Based Metrics

This currency uses the potential yield of fish to fisheries or other fishery-based metrics to determine offset requirements. The use of fishery benefits aligns with the intent of the FPP to provide for the sustainability and ongoing productivity of CRA fisheries.

Application

Fishery-based metrics are most likely to be restricted to large-scale projects that result in ecosystem loss or conversion, potentially affecting existing fisheries and resulting in significant out-of-kind offset requirements. Situations where fishery yield may be preferred over purely biological metrics include those where:

- The target species for offsets are sufficiently different (either in species composition, size, age or other attributes) from those affected that a direct comparison of biological traits is less meaningful;
- Preference for certain fisheries could guide offsetting measures and be quantified in terms of fishery statistics. For example, offsetting measures to enhance Aboriginal use may be best quantified in terms of yield or participation;
- Hatcheries or other means of artificial propagation are being used to increase fishing opportunities;
- There are meaningful differences in the regional fishery management objectives for the affected species relative to those targeted for the offsetting; and,
- Regional benchmarks for fisheries measures (e.g., effort or catch/effort targets, or other measures of fishing quality) exist and can be used to support offset goals.

The primary advantages of the use of a fisheries metric is that it is the currency closest to the intent of FPP with respect to maintaining the productivity of CRA fisheries and will be of direct relevance to fisheries management agencies and stakeholders. Also habitat-specific yield data, particularly long-term, may be readily and sometimes the only data available. It is also a currency of considerable flexibility as it can accommodate extremely disparate impact and offset types.

Metrics, Data and Methods

The metrics for this class of equivalency analysis are:

Yield: The simplest and most commonly used metric for fisheries yield is the number of fish or mass caught annually, usually scaled by unit area (e.g., $kg \cdot ha^{-1} \cdot yr^{-1}$).

Quality: For many fisheries a variety of metrics are used to describe fishing quality. This includes the catch rate (e.g., $fish \cdot angler^{-1} \cdot day^{-1}$). Fish size is also an important contributor to angler satisfaction. Finally, species composition can affect angling quality and participation.

Effort: In recreational and Aboriginal fisheries participation rates or effort may be used to evaluate offsets. In commercial fisheries logbook information should be available and is appropriate to use. Effort is usually estimated as participants-time per spatial unit (e.g., angler-days$\cdot ha^{-1}$) during creel census programs.

Equivalency analysis based on fisheries metrics will require empirical or predicted measures for the affected area and the area proposed for offsetting (if appropriate, the baseline), and a prediction of fisheries metrics after the project and offsetting are completed.

Empirical estimates of fisheries metrics can be gathered from standard creel or catch sampling programs that estimate effort, catch, and catch composition.

A variety of methods and models are available to estimate fishery metrics for the predictive component of equivalency calculations. Many empirical models that predict yield using ecosystem attributes (lake size, depth, water chemistry, etc.) have been developed and these provide first-order estimates using relatively easy to obtain covariates. In the absence of predictive models a regional analysis of fishery statistics may be adequate to predict the change in fishery effort or quality resulting from the offsetting. For example, average effort data for local lakes may be sufficient to estimate the potential increase in fishing activity associated with stocking a barren lake.

Unfortunately predictive models for yields in rivers are restricted to a few species, which limit the application of this currency in lotic habitats unless case-specific tools are developed.

Key assumptions and uncertainties

Fisheries metrics are the result of interactions between habitat, aquatic species and human behavior. All of these interactions contribute to variation in responses of the fisheries metrics and therefore explicitly to the uncertainty in estimates of those metrics. In the previous classes of metrics different subsets of the interactions were assumed to be the same in the numerator and denominator of the equivalency ratio, and were this not included in the computations of the metrics Thus, fishery metrics must deal analytically with all these sources of uncertainty and thus may appear quantitatively to be the most uncertain of the equivalency currencies.

Using site-specific fishery statistics to estimate baseline conditions is based on the assumption that the existing fisheries resources are well utilized and the resulting statistics provide a reasonable measure of the “service” that is provided by that resource. Fish populations may be underutilized for a variety of reasons, including access, aesthetic values, and the availability of more appealing alternatives. These types of externalities need to be taken into account when empirically-derived fisheries metrics are used to establish the baseline condition, particularly for cases where human use is minimal or restricted. In those cases it may be more appropriate for the purposes of offset calculations to estimate potential yield using a biologically-based predictive model.

All of the empirical predictive relations between lake attributes and fish yield have considerable uncertainty associated with the predictions despite high R^2 values for many of the published log-log regressions, errors of ± 50-100% are observed.

Sources of Uncertainty

Uncertainty in achieving the FPP offsetting goal of balancing losses and gains through equivalency calculations occurs because of sampling or prediction errors associated with the estimation of impacts, and similar errors for the estimation of benefits. These sources of uncertainty were discussed in the preceding sections of the advice on classes of metrics. Further uncertainty is generated during the implementation of the offset resulting from compliance issues, or shortcomings of the offset measures. Such uncertainty is often dealt with through the use of multipliers or ratios to increase the offset requirements. Monitoring and adjustment of management in response to the feedback from monitoring can contribute to managing the consequences of uncertainties at the planning and implementation stages. No additional analysis or recommendations resulted from the meeting with respect to appropriate adjustments for uncertainty, beyond the advice in DFO 2014c. A qualitative summary of the uncertainty associated with the equivalency metrics is provided in Table 2.

Table 2. Qualitative summary of the uncertainty associated with inputs to the equivalency calculations, and uncertainty surrounding prediction of whether fisheries productivity will be counterbalanced by offset measures for each of the equivalency metrics listed in Table 1. Low uncertainty (expressed as the interquartile range as a percentage of the median) ±10%; moderate ± 10-50%; high >± 50%.

Metric class	Uncertainty in equivalence calculation	Uncertainty in fisheries productivity loss and gain
Habitat (like for like)	Low, based on measurements of area during project design	Inferred, assumed low as losses and gains are similar based on like-for like offset
Habitat or ecosystem function	Moderate. Physical measurements of habitat, and secondary production or other indicator	Inferred. Uncertainty could be moderate or high if unlike habitat alterations are used
Habitat suitability or capacity for select species	Moderate, dependent on quality of field program and specificity of species-habitat relations	Relation between habitat index and fisheries productivity assumed or known. Uncertainty could be high. Uncertainty high for non-target species
Fish abundance	Moderate, if based on intensive site-specific field programs Predictive models have moderate to high uncertainty	Direct prediction of biomass or density losses and gains. Uncertainty dependent on methods and models, moderate to high
Fish production	High. Production estimates likely based on inferred P:B ratios or correlates of PModerate if P estimated directly	Direct estimation and prediction of fisheries productivity. Uncertainty high for predictive models (e.g. P/B), moderate for direct estimates
Yield/fishery benefits	Moderate if based on direct sampling of active fisheries; high if based on generic fishery models, or fishery affected by many externalities	High, requires estimates or inference about biological and human response to offsets

CONCLUSIONS AND ADVICE

Six classes of equivalency metrics were reviewed: each differs in its information needs, uncertainty and assumptions. The appropriateness of application of each class to different types of projects and offset measures is summarized in Table 3. Further work is needed to formally incorporate the various sources of uncertainty as well as time lags into the determination of offset requirements.

Table 3. Recommended application of the equivalency metrics based on the impact of the development project and the type of offset proposed.

	Project impact (scale of loss) and offset type (in-kind or out-of-kind)						
	Small[1] habitat losses		**Changes in quality or larger losses**		**Ecosystem loss or transformation**		**Mortality**
Equivalency metric class	In-kind	Out-of-kind	In-kind	Out-of-kind	In-kind	Out-of-kind	Out-of-kind
Habitat area/type	✓✓	✗	✓	✗	✓	✗	✗
Habitat function metric	✓	✓✓	✓✓	✓✓	✗	✗	✗
Habitat suitability index	✓	✓✓	✓✓	✓✓	✗*	✗*	✗
Fish abundance	✗	✗	✓	✓✓	✓✓	✓	✓✓
Fish production	✗	✗	✓	✓✓	✓	✓✓	✓✓
Fisheries metrics	✗	✗	✗	✗	✓	✓✓	✓

Key: ✗ - unlikely to be suitable, ✓ - could be suitable, ✓✓- most appropriate

[1] The term "small" is primarily intended to refer to the spatial scale of the development project or offset. However, when an impacted habitat is rare, a spatially "small" development project may be considered under one of the "larger" impact columns.

* May be appropriate if necessary resources are applied to baseline data collection to develop local HSI models, impact and offset models are verified, and response variable is based on fish abundance or biomass.

OTHER CONSIDERATIONS

This advice is focused on determining the amount of offsetting needed to counterbalance impacts from development projects, and does not consider the details of the design and implementation of the offset measures.

It was recognized that the spatial configuration of development projects and offsetting measures can affect both the predicted impacts and benefits. The same project or offsetting measures may have different ecological consequences depending on how they are placed in the watershed or landscape, because both physical and biological processes can be affected by the larger context in which they occur. The effect of offset measures on fisheries productivity may also depend on whether the offsets address factors that may be limiting populations. Offset design can also affect the persistence and efficacy of offset measures and should be an important consideration in the offset plan.

SOURCES OF INFORMATION

This Science Advisory Report is from the National Peer Review meeting of November 25-26, 2014 on the Science Guidance for Fisheries Protection Policy: Advice on Developing and Reviewing Offsetting Requirements. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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DFO. 2014a. A Science-Based Framework for Assessing the Response of Fisheries Productivity to State of Species or Habitats. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/067.

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