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SCIENCE ADVICE ON OFFSETTING TECHNIQUES FOR MANAGING THE PRODUCTIVITY OF FRESHWATER FISHERIES

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

Context:

Legislative amendments to the Fisheries Act (2012) will change the way Department assesses and manages impacts on aquatic ecosystems. The amended Act will require the Department to protect the ongoing productivity of commercial, recreational and Aboriginal (CRA) fish populations and species and ecosystems that either contribute to or support these fisheries. To help managers make consistent decisions with respect to protecting ongoing productivity of CRA fisheries, the amendments to the Act also include a new Section 6, which outlines four considerations which the Minister must take into account before authorizing a project that has the potential to cause serious harm. Section 6(c) specifically requires the Minister to ensure that methods to avoid, mitigate or offset serious harm have been considered before issuing a Fisheries Act authorization.

DFO Program Policy Sector has requested scientific guidance towards the implementation of these amendments to the Fisheries Act. Participants reviewed methods that can be used to offset fisheries productivity losses resulting from works, undertaking or activities within aquatic ecosystems, and provided operational guidance to the Fisheries Protection Program.

This Science Advisory Report (SAR) is from the June 4-6, 2013 national peer review on "Science guidance for Fisheries Protection Policy". Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule *as they become available.*

SUMMARY

- This Science Advisory Report (SAR) summarizes a literature review of methods that have been used to increase fisheries productivity and which might be potential methods for offsetting serious harm to fish under the Fisheries Protection Provisions (FPP) of the *Fisheries Act* (2012).
- In general, this review and science advice focus on freshwater fisheries, given this has been the principal focus of the associated management program. Some consideration has also been given to estuarine, coastal and marine environments, however further work is required for these areas.
- The success of offsetting measures, as reviewed, varies widely depending on location, site-specific characteristics, species targeted, and environmental conditions. All methods reviewed have potential benefits and challenges with respect to their implementation.
- No single best approach for offsetting needed to maintain or increase fisheries productivity was apparent from the literature. Although limited, empirical data on the effectiveness of offsets varies widely. Statistical and modelling approaches and successful examples from other jurisdictions suggest that offsets should be larger than the area destroyed to counter-balance this uncertainty, and/or delay in becoming functional habitat.
- Methods that use data specific to the region or fisheries in question are more scientifically defensible.
- To promote the ongoing sustainability of CRA fisheries, offsets should be designed to increase the productivity of the fishery(ies) affected by the serious harm. In specific cases this may be modified by fisheries management objectives or other resource management considerations (e.g. species at risk, aquatic invasive species etc.).
- Monitoring and auditing are essential to determining the success of any offsetting program. Both compliance and effectiveness monitoring should be conducted. Previous science advice on monitoring the effectiveness of habitat compensation projects (DFO 2012) can provide guidance for monitoring of offsetting.
- Due to the inherent variability associated with offsetting, an adaptive management component should be included in offsetting programs.

INTRODUCTION

Recent changes to Canada's *Fisheries Act* (Bills C38 and C45; 2012) will alter the way Fisheries and Oceans Canada (DFO) assesses and manages the impacts of development projects on aquatic ecosystems. The Department will shift to a focus on managing impacts to fish and fish habitat, specifically those that are part of commercial, recreational and Aboriginal fisheries (CRA), to manage their sustainability and ongoing productivity (DFO 2013a). The Department gives top priority for maintaining or improving fisheries productivity through avoiding impacts to fish and fish habitat via project relocation and redesign, and reducing impacts via mitigation measures. It considers that only after reasonable, cost-effective efforts have been exhausted will other options to offset residual impacts be considered.

Offsetting is one of the major concepts that have been explored worldwide in recent years as a means to reduce or compensation for impacts to fish productivity, habitat loss, or other ecosystem functions. While there are multiple definitions to describe the concept, in general:

> *Offsets are used after appropriate steps have been taken to avoid and mitigate impact resulting from project developments, and are intended to fully counteract residual effects (serious harm) on fish and/or fish habitat; thereby maintaining or increasing fisheries productivity.*

The *Policy for the Management of Fish Habitat* (1986) used the term *compensation* to describe the "replacement of natural habitat, increase in the productivity of existing habitat, or maintenance of fish production". Offsetting does not have the same legal definition as compensation but the policy intent is similar in addressing the effects of projects on fish or fish *habitat*.

The amount of offsetting needed to ensure there are no adverse impacts of the project at the scale of fisheries productivity needs to be carefully considered. Uncertainties about the impacts of projects and the effectiveness of offsetting programs should be taken into account in the design of offsetting programs. This will require working within risk-based approaches, which will be the subject of a future CSAS advisory document.

In addition, monitoring should be conducted; both compliance monitoring to ensure that the offsetting interventions were implemented as intended, and effectiveness monitoring to ensure that productivity is indeed maintained or increased. The proposed *Application for Authorization under Paragraph 35(2)(b) of the Fisheries Act Regulations* includes provisions to require appropriate monitoring related to offsetting done under the Fisheries Protection Provisions (FPP). Science advice on monitoring the effectiveness of habitat compensation has been previously provided (DFO 2012). This earlier advice is an appropriate starting point for monitoring of offsetting, although once the details of the offsetting policies and programs are provided, it may be appropriate to review this guidance within that specific policy context of offsetting.

This report summarizes a review of methods that have been used to maintain or potentially increase fisheries productivity, primarily through habitat interventions and thus might be potential methods for offsetting serious harm to fish under the FPP of the *Fisheries Act* (2012). Specifically, habitat restoration, fish habitat creation, stocking, and chemical manipulations (including nutrient additions) were reviewed for their ability to increase fisheries productivity. The review primarily focused on freshwater fisheries and their habitats, although some coastal and marine examples were provided as well.

The material in the "Categories of Methods" section is presented for what is expected to be the typical scenario where offsetting is being considered: a project has been proposed, a decision has been made that residual impacts on productivity are large enough to require offsetting, and the task is to design an offsetting plan that effectively counteracts residual effects of the project impacts on habitat or death of fish. It is inferred that offsetting of habitat impacts or death of fish would counteract the predicted loss in productivity. Within this SAR, guidance is also provided on 'Habitat Banking' as a possible approach to implement offset measures. Advice within this SAR is based primarily on information and experiences within Canada, however, experiences from other countries are also taken into consideration and briefly summarized.

Overview: Benefits and Challenges of Offsetting Approaches

As with any resource management technique or tool, there will be both challenges for implementation and associated trade-offs, leading to both opportunities and challenges of any offsetting approach.

As per the associated literature review, some potential benefits of implementing an offsetting project are provided below:

- Offsetting techniques can enhance the quality of fish habitat, resulting in increased productivity to area in which the damage or destruction occurs, thereby reducing further risk to fish habitat overall;
- Time lags and uncertainty can be reduced or eliminated by offsetting impacts of a project before the project is constructed;
- Flexibility in the approach can lead to creative initiatives and potentially more successful outcomes than is the case with strict adherence to *like-for-like* replacement;
- Offsetting projects can lead to economic benefits as seen in other countries through the creation of spin-off industries to support offsetting; for example the development of 'banks' and support services (monitoring, insurance, legal, technical support);

In cases where there is an overarching plan or program (i.e. coordinating multiple offsetting projects), additional benefits have been reported, including:

- Alignment of the offsetting programs with regional/local fisheries management, watershed and land-use planning objectives can result in the creation of larger, connected, and more effective restoration or habitat creation projects; and
- Coordination across multiple jurisdictions and environmental regulations.

The literature has also reported some challenges in implementing offsetting programs, including:

- Most offsetting programs do not account for the value of ecosystem services or factors including those that can significantly affect populations such as meta-population dynamics and connectivity, although some do account for the latter;
- There is uncertainty in species or ecosystem responses when replacing one area that will be destroyed or damaged by development by another newly created or enhanced area (the area created or enhanced through offsetting techniques);
- There can be time lags between the damage caused by development and the functioning of the offset area;
- It is often difficult to quantify the amount of offsets needed to ensure that productivity is maintained or increased;
- There can be challenges in selecting a biologically or environmentally suitable location for offsetting, as well as debate regarding the public benefits of offset locations (if the offset is located in a different area from the habitat destroyed there may be public opposition);
- There is often insufficient monitoring to determine whether the offset complied with requirements and whether it functioned as expected;

- Often impacts of development or results of offsetting practices are not adequately documented or quantified;
- Offsets are usually considered for one or a few species without consideration of the ecosystem context of both the impacted area and the offset habitat. For example, a proposed project could destroy rare or unique habitats, including the habitats of species at risk or result in direct mortality of those species.

These challenges can be encountered for any activities seeking to reduce or eliminate the impacts of development on ecosystems (i.e. mitigation). To varying degrees, the challenges can be minimized and sometimes avoided by adding appropriate rules and restrictions to an offsetting policy, supported by compliance and effectiveness monitoring.

Offsetting methods can be categorized into four general classes (and one approach) for offsetting activities, most with multiple subclasses. Selection of one or a combination of classes has to be matched to the specific circumstances of the project for which offsetting is required. The advice in this SAR takes into account several principles derived from legislation and policies relevant to the DFO. These include:

- *Serious harm to fish* is defined in the *Fisheries Act* as death of fish or permanent alteration or destruction of fish habitat. Thus, interventions which directly address the impact of the work, undertaking or activity are preferred, particularly if the serious harm is to fish habitat (rather than death of fish).
- Interventions under the jurisdiction of the Minister of Fisheries and Oceans are preferred, when available, although many offsetting options may fall under joint jurisdiction with other Departments and/or other levels of government.
- Offsetting projects should strive to generate self-sustaining benefits that do not require maintenance or interventions, beyond sustainable harvest management and usual standards of habitat protection.
- The benefits of the offsetting should be designed to benefit the fishery(ies) which incurred the loss of productivity.

Some offsetting activities are not discussed within this document as they are principally governed by other jurisdictions or legislative authorities. Such activities could lead to benefits or negative impacts, and include, for example; reducing point source pollution, genetic manipulation, introduction of new species and prescribing land management practices.

When developing an offsetting plan or project, the use of metrics of productivity may be relevant at several stages (i.e., both pre- and post-project). A review of metrics suitable for fisheries productivity measurements is underway, and will be the basis of future advice to managers in this respect (forthcoming). There also should be sufficient information available on the species/ecosystem that will be affected to appropriately determine the level of impact and what processes may be affected by a proposed development. Previous advice on the use of Pathways of Effects and State Response Curves (DFO 2013b) could be followed to assess this information.

Classes of Methods

In this section four classes of methods for offsetting serious harm to fish are discussed, along with one distinct approach (banking). For each, a standard list of considerations is outlined (description, "best case" outcomes, likelihood of success, etc.). For each class, advice is provided when undertaking and designing a specific offsetting project in that category. Within each category neither factors listed as positively or negatively affecting success nor consequences listed as secondary effects are expected in every offsetting project. When it is advised that a particular thing *can* happen or *has been* reported, it should not be inferred that the described result will *always* happen or has happened in *every* case. However the considerations have been documented often enough for the particular category that they should be included in project planning for that category of offsetting. Ecosystems are complex and an adaptive management approach should be adopted as specific desired outcomes are not guaranteed. In addition, there are a number of considerations that are relevant to all the classes, and need to be taken into account in all cases.

General Considerations:

Fisheries management objectives: Section 6 of the *Fisheries Act* requires that the Minister of Fisheries and Oceans takes fisheries management objectives into account in decisions on issuing authorizations. Based on past Science advice on Conservation Objectives, this is best done by taking Fisheries Management Objectives into account at the early stage of setting objectives for the offsetting program. When Objectives for offsetting programs are consistent with the relevant Fisheries Management Objectives, depending on scale, the offsetting objectives can contribute directly to achieving the broader Fisheries Management Objectives.

Time lags: Many offsetting programs will have time lags between manipulation of the habitat or introduction of fish, and population-scale responses occurring in the affected fish populations. However, such time lags can be accounted for in the quantification of the required offset. Monitoring programs and calculation of offsets should also address expected time lags.

Uncertainties: Uncertainties regarding the effectiveness of offsetting plans or techniques will usually be greater than the uncertainties regarding the impact magnitude of any project for which offsetting is needed. These uncertainties have to be taken into account in the design of offsetting programs, using the risk-based approaches for which advice will be provided in future.

Ecosystem characteristics: All offsetting programs should be designed within an ecosystem scale of potential effects. This means the description of context for an offsetting program should:

(a) include the general status and trends of the local environment;
(b) consider other stressors on the system; and
(c) be designed correctly to address the particular circumstances for each project.

Estimates of equivalence: Given the goals of offsetting, estimating the equivalence of the consequences of serious harm and offsetting benefits of the offsetting project or plan requires a "common currency", which has not yet been established. Moreover, the more different the direct effects of the offsetting project are from the direct effects of the project itself, the more complex the "currency exchange" can be. Development of common spatial units, currencies and tools or models for calculation of offsets requires further work as a priority for all the offsetting classes.

Human Access: Almost any project development (and many offsetting plans) will change human access to fish and fish habitats (e.g., a new road providing access to fishing opportunities). In the development of this advice it is unclear if and how the impacts of increased human access on fish and fish habitats should be taken into account in design and monitoring of offsetting programs, nor how this increased access caused by the offsetting project is included in the offsetting plans. This is a pervasive impact, however, that requires further consideration, and should be taken into account in design of offsetting plans and fisheries management objectives. There are advantages and disadvantages to increased human access. Without access, there would be no fishery(ies), however increased fishing pressure can exert considerable impacts on both habitat and fishes.

Monitoring: Both compliance and effectiveness monitoring are considerations in all classes of offsetting projects and other approaches (e.g. habitat banking). .

Limiting factors: In all classes of offsetting techniques, effectiveness can depend at least in part on targeting the interventions on factors and stages that are limiting to productivity of associated fish populations. The more that is known about the potential limiting factors in population dynamics, the better offsetting plans can be designed. Case-specific information may be very beneficial as different areas may have different or multiple limiting factors.

Main Categories and their Key Features:

From the literature reviewed, offsetting methods fall into four major categories. These classes of methods include habitat creation, physical habitat manipulations, stocking (of fish), and chemical alterations. Habitat banking is described as a potential implementation approach for offsetting plans in general. Guidance on these broad categories is provided in the following sections.

ANALYSIS

Habitat Creation

1. General description

Aquatic habitat creation is the creation or expansion of aquatic habitat into a previously dry area or terrestrial area. This offset activity is generally intended to replace productivity that was destroyed or degraded by a project and cannot be restored by manipulation of the original or surrounding aquatic habitat. Habitat creation techniques include creation of artificial or expansion of natural stream channels, lakes, side channel habitats, estuaries, river mouths, and wetlands. Water level fluctuations and hydrologic conditions should be considered when defining ‘terrestrial or dry’.

2. Best case outcome

Habitat creation may result in productivity gains similar to or greater than the affected area. The effectiveness of an offsetting project creating new habitat is influenced by physical and biological factors, and its success could take years or decades to achieve and verify.

3. Likelihood of success

Habitat creation can provide for fish production, but there is less certainty around meeting specific productivity/fisheries management goals. Numerous studies have examined the success of habitat creation projects with gains ranging from negligible to better than the reference habitat (i.e. compared to prior state of affected area or proximal similar habitat to that being created).

4. Factors known to affect success

The success of habitat creation for increasing fisheries productivity is increased when:

- there is an understanding of limiting factors for the CRA fishery;
- for habitats used by adult fish, appropriate measures are put in place to ensure new habitats are not subject to exploitation (i.e. fishing pressure) such that the potential productivity is not realized.
- there is endorsement or acceptance by the public and/or government for the created habitat and potential associated loss of terrestrial habitat;
- appropriate structural design and long-term maintenance plans are developed to ensure the habitat and productivity are sustained;
- consideration is given to land tenure and history of project area; including provision for long-term tracking of objectives of the offset;
- offsetting is *"like for like"* as this simplifies equivalence calculations;
- some level of biological transplanting (vegetation and/or fish) can decrease the time lag to becoming fully functional; and
- the size and type of the habitat created and the assemblage of early fish colonizers contribute to the likelihood of success and uncertainty in meeting fishery objectives.

Habitat creation is less successful when:

- deterioration occurs of the constructed channels, structures, habitat features and substrates;
- surrounding terrestrial vegetation is simple or poorly developed;
- insufficient baseline or reference data are collected to determine if success criteria have been met.

5. Secondary effects

In a positive sense, many habitat creations are not designed for a single species, so in many cases a suite of species can be positively affected by the activity.

Nevertheless, the creation of habitat can result in a number of negative impacts, including:

- a direct, measurable loss of terrestrial ecosystems, which provide benefits for humans and habitat for other flora and fauna;

- creating accessibility to a previously isolated site to complete the habitat creation project may degrade or destroy other aquatic and terrestrial habitat;
- possible unintended side-effects (e.g. fish contamination, unintended increases in productivity of non-target species, potentially to the detriment of the target CRA species);
- increased fishing pressure on targeted species; and
- potentially high monetary costs of undertaking a project.

6. Knowledge/Information required to design a program

Prior to designing an offset plan, the following baseline data common among most offsetting projects requires consideration:

- habitat creation projects may require considerably more physical habitat to be created than was affected; thus more detailed planning information may be required than other offsetting projects;
- information obtained from public consultation; and
- species in the affected system, current productivity estimates, biophysical characteristics of impacted area, survey/engineering of area of creation, hydrology, or assumed regional benchmarks.

7. Quantifying equivalence

- The simplest quantification is *like-for-like* (similar habitats) where the creation of a similar type of new fish habitat in the same area is intended to offset the loss of existing fish habitat.
- Ratios or models may be used to take into consideration uncertainty about the benefits (e.g. time-lag, uncertainty in the resulting productivity, trade-offs).
- If the habitat created is within the range of the affected population(s) (e.g. within the same ecosystem), benefits will go to *the* fishery(ies) that is affected by the project.
- More distant habitat creation may increase the production of other fisheries, but not necessarily the one affected by the project. In such instances, public consultation should be considered.

8. Scale considerations

Habitat Creation can be a preferred offsetting option when the activity has a large scale construction phase (e.g. hydro-electric installations) as synergies can be found with respect to equipment use that make habitat creation more economically feasible.

9. Monitoring

For a more complete treatment of post-project monitoring, please refer to the findings on compensation monitoring (DFO 2012) for program-level recommendations. In addition, the following monitoring factors should be addressed:

- there is a short term need to inspect the habitat created or physical works for compliance and structural integrity;
- for certain factors (e.g. extreme events like floods) – more frequent monitoring may be required. Projects may be particularly vulnerable early in the construction/implementation phase;
- pre-monitoring to establish baseline condition (i.e. the pre-impact structure and function of the fish habitat) is essential to determine success;
- sufficient effectiveness monitoring to ensure level of productivity has been met, and
- adaptive management triggers to respond to issues at an early stage.

Physical Habitat Manipulations

1. General description

This category of offset activities includes physical manipulation of existing habitat to improve habitat function and productivity (i.e. enhancement or restoration) and the removal of barriers to restore connectivity or to allow increased access to unused habitats by target species. The techniques used are often those employed for habitat restoration including increasing structure through the placement of coarse material (e.g. reefs, boulders, spawning beds) or woody debris, increased shoreline complexity, river bank stabilization and channel complexing. Improving access to off-channel habitats, and the removal of natural or anthropogenic barriers to migration can also be used to improve productivity. Re-vegetation of riparian areas, and the creation of vegetated areas in lakes, estuaries and coastal areas has been used. Lastly, flow management can be used to improve fisheries production in rivers where flows are regulated. Flow management can improve productivity by changing the availability of preferred hydraulic habitat, or water quality conditions (particularly temperature, vegetation and suspended sediments).

These activities are generally focussed in areas where habitat conditions are considered poor (or degraded) so there is greater scope to achieve larger benefits. The poor habitat considered for enhancement may have a naturally poor productive capacity or have been degraded by human activities.

2. Best case outcome

There is considerable experience with many of these methods in freshwater, providing many lessons that help to increase success from engineering and biological perspectives. In general, physical alterations take effect immediately as new structures and features are colonized immediately. The benefits of plantings or enhancements dependent on a biological succession process may not be fully realized for many years (e.g. 5-50 years). There is also a large body of literature to draw upon for marine restoration and enhancement, however most evidence comes from tropical reef systems, mangroves and estuaries.

3. Likelihood of success

The outcomes of these types of activities are well-documented in the restoration literature, and are highly variable. The success of habitat restoration is increased when:

- the greatest benefits will occur when the activities are planned in a watershed or ecosystem context.
- the stability and effectiveness of constructed works is context dependent. In high energy ecosystems (rivers prone to flooding or exposed coastal zones) deterioration of these works can be expected. For example, watersheds with logging impacts, increased peak flows and sediment loads can move structures or bury them in sediment. Natural changes in channel or shoreline location can render the works ineffective.
- structures to improve access to isolated habitats can be very successful, but periodic maintenance is likely required to maintain function.
- the success of flow manipulations is highly variable, especially when the degree of change is small relative to the natural discharge.

4. Factors known to affect success

Habitat manipulations can improve fisheries production when:

- structures are designed and engineered to withstand likely extreme events, or are designed with the expectation of being affected by high flows, storm events etc.;
- there is sufficient knowledge of habitat features that limit fisheries production, and the manipulations address those limitations;
- there is a plan for monitoring and periodic maintenance to ensure long-term sustainability of the offsetting project;
- restoration efforts ensure all life stage requirements are addressed within the watershed or landscape used by the fish expected to benefit from the restoration;
- appropriately targeted fishery closures are implemented to allow for development of the fish that will contribute to the CRA fishery;
- there is public consultation and coordination between jurisdictions and stakeholders;
- hydrological conditions allow for manipulation of downstream habitat without affecting downstream or proximal habitats; and
- removal of barriers where targeted species can co-habitate with existing species without negative impacts (e.g. aquatic invasive species have been considered).

Physical habitat manipulations can fail to meet expectations when:

- other ecosystem conditions overwhelm the contributions made by the physical habitat manipulation (i.e., background conditions);
- the modifications fail to function as expected;
- the manipulations do not address habitat supply limitations;

- the works only serve to aggregate target species rather than contribute to new production, potentially leading to localized overharvesting and little gain in overall production;
- the stability and effectiveness of constructed works is context dependent. In high energy ecosystems (rivers prone to flooding or exposed coastal zones) deterioration of these works can be expected. For example, watersheds with logging impacts, increased peak flows and sediment loads can move structures or bury them in sediment. Natural changes in channel or shoreline location can render the works ineffective;
- when habitat changes actually favour competitors or predators of the fish that are part of CRA fisheries more than the CRA fish itself, or when removal of barriers allow invasion of a watershed by new competitors or predators.

5. Secondary effects

- Many offsetting projects are designed in consideration of a relatively small number of species, so in some cases other non-target species can be positively affected by the activity. Activities such as riparian planting with native species can result in more general ecosystem benefits including increases in terrestrial species, water quality improvements and shading.
- Potential risks of increasing connectivity or to disturbance of any habitat is that this may increase undesirable species or Aquatic Invasive Species, particularly when barriers to migration are removed.
- Trade-offs may also occur if the habitat work results in a transformation of habitat type. For example, covering a boulder filled stream bed with spawning gravel will likely have negative impacts on small or young fishes, although fish that the habitat was designed for may benefit.
- Intensive habitat manipulations can have negative impacts on non-target species, biodiversity priorities (i.e. competing interests), and have differing stakeholder values (e.g. fisheries with differing habitat needs).

6. Knowledge/Information required to design a program

The background environment (watershed stressors) should be assessed as this will affect the stability and longevity of constructed works. Knowledge of factors limiting target fish populations will permit offset activities to be targeted for maximum effectiveness.

There is considerable available knowledge and information/guidance regarding engineering design for many types of habitat manipulations. Per other methods the following also aid in designing a program:

- public consultation (for acceptance and additional information); and
- assessing current productivity by establishing baseline conditions and using comparative approaches before restoration activities take place.

7. Quantifying equivalence

- For salmonids and some fish communities, extensive knowledge and biostandards are available to calculate productivity or surrogate losses from impacts, and gains from manipulation of physical habitat
- For large ecosystems such as marine or large lake environments it is difficult to quantify productivity impacts and benefits of habitat manipulations. Tools which are useful at the scale of habitat manipulations and population, community, and ecosystem-based methods should be explored.
- Species trade-offs need to be considered as manipulations of existing habitat can increase suitability for non-target species at the expense of target species. The acceptability of these trade-offs can be informed by stakeholders or Fisheries Management Objectives (FMOs).
- Some types of habitat manipulations will not become fully functional for a number of years and offsetting plans may need to account for these delays.

8. Scale considerations

- *Like-for-like* methods are the simplest to assess and prescribe, particularly for small-scale impacts.
- If works are within the range of the population (eg, within the same ecosystem), benefits will go to *the* fishery(ies) that is affected by the project.
- More distant offsets will increase the production of other fisheries, but not necessarily the one affected by the project

9. Monitoring

There are many examples of monitoring habitat manipulations, in the habitat restoration literature. The technical report described in DFO (2012) will provide guidance. Those documents distinguish among compliance, functional, and effectiveness monitoring and specify some monitoring methods for each.

Stocking

1. General description

Stocking is the practice of releasing fish into a natural ecosystem to augment the natural supply of individuals, increase productivity of a wild population, overcome a recruitment limitation, increase fishery yields, or boost declining fish stocks. Most stocking requires ongoing intervention and is therefore generally not self-sustaining. In some cases, stocking is used to create a put-and-take fishery. Stocking may occur through the translocation of wild adults (trap, truck and transfer), stripping eggs from wild adults which are then hatched and released, or releasing individuals that have been reared from domesticated stock. There are variants on these three main approaches to stocking, including the collection of wild larvae to be reared and released, or ‘seeding’ sites with adults, post-larvals or juveniles (e.g. lobster, scallops). Stocking has been used both as ongoing enhancement programs and temporary measures to overcome bottlenecks or limitations.

2. Best case outcome

When stocking or translocation is successful, sustainable populations of fisheries can be established or enhanced through short-term programs (e.g. a single or few release events). When large project impacts transform ecosystems, stocking can be used to ensure the presence of fishes suitable to the new environmental conditions.

3. Likelihood of success

While there are studies that have shown stocking to be beneficial for the abundance of the target population, a recent review of stocking studies showed that most stocking programs had negative ecological or genetic impacts on natural populations of the same species. Some studies did not find any negative impacts, and very few studies reported enhancement of wild stocks. This suggests that the use of stocking to augment or establish self-sustaining populations should be carefully planned to achieve the management objectives. There are examples of successful stocking when the objectives are to sustain a fishery.

4. Factors known to affect success

When the objective is to augment or establish self-sustaining populations, success of stocking is increased when:

- local, wild-origin brood stocks are used;
- supplementation hatcheries, designed to integrate wild and captive-reared individuals, are used;
- proper location and timing windows are identified;
- harvest is delayed until at least two reproductive cycles have been completed;
- reintroductions occur within the species historic range; and
- fish are transferred to a relatively stable environment (e.g. no significant fluctuations in lake levels (e.g. highly variable reservoirs).

When the objective is to augment or establish self-sustaining populations, stocking is less successful when:

- hatchery fish are released into habitats where existing populations are at or near carrying capacity;
- released fish are immediately consumed by predators or removed through fishing; and
- released fish compete with wild stocks for limited resources.

5. Secondary effects

In recent years, stocking in freshwater ecosystems has been shown to have negative impacts, including:

- reduced reproductive fitness of wild populations through breeding and reduced genetic diversity;

- reduced survival of wild fish through competition or increased predation;
- reduced quality of individuals, including smaller size, earlier smolting and lower survival;
- in marine ecosystems, the stocking of individuals has been associated with the introduction and spread of aquatic invasive species; and
- when stocked fish are exploited, harvest levels can be maintained as long as stocking programs are maintained, which can result in increased by-catch of wild population(s).

6. Knowledge/Information required to design a program

Stocking programs should consider:

- the National Code on Introductions and Transfers of Aquatic Organisms (2003) (e.g. translocations);
- availability or surplus of wild spawning adults to obtain broodstock or knowledge of the genetic origin of other broodstock material;
- possible fitness and genetic impacts on wild fish;
- how stocking density varies with other density-dependent factors (e.g. impacts on juveniles, food availability, etc.);
- disproportionate predation of stocked individuals (e.g., juveniles);
- predator population dynamics and activity periods;
- timing of release;
- stocking fed versus unfed fish;
- methods and locations of release of stocked fish;
- quantities of released fish;
- impacts on other species (in one study, stocked fish resulted in lower mercury levels of a sport fish in reservoirs);
- current fishing pressure;
- availability of suitable habitats; and
- possibility of attracting fishing effort and predators to an area; possibility of increasing by-catch and predation on non-target species.

7. Quantifying equivalence

The simplest quantification is *like-for-like* (fish-for-fish) where stocking is used to offset the killing of fish (mortality). Quantifying the equivalence of stocking needs to consider the relative survival of stocked individuals and their expected fecundity to project the benefits of the stocked fish to fisheries productivity.

8. Scale considerations

Stocking is most likely to have population-level effects and may affect non-target species. In inter-connected systems, stocking may impact species and fisheries in non-target ecosystems. In large ecosystems, stocking needs to be conducted at an appropriate scale to be successful.

9. Monitoring

When stocking, additional monitoring effort may include:

- estimation of abundance and biomass of both wild and stocked individuals to establish the success of stocking activities;
- continued monitoring until the 2^{nd} generation if the intent is to establish a self-sustaining population due to the poor performance of stocked individuals and their progeny that has been documented in many cases;
- genetic monitoring to detect negative secondary effects on wild populations; and
- monitoring of fish community or assemblages that may be negatively affected by interactions with stocked fish.

Chemical alterations:

1. General description

Various types of chemical manipulations have been used as potential offset methods, including nutrient additions, nutrient removals, pH modification, and remediation of contaminants.

Nutrient additions: Nutrient additions to aquatic habitat (e.g. fertilizers, carcasses, etc.) can be used as a method to boost primary productivity and may ultimately, boost fish productivity. Adding nutrients may be a viable method of improving productivity, particularly in oligotrophic lakes and rivers or in regulated rivers where man-made structures block nutrients from flowing downstream or hydraulic alterations affect nutrient flow.

Nutrient management: Management of excessive nutrient inputs into waterbodies, or removal from water (e.g. through vegetation sequestration).

Chemical manipulation: Some waterbodies in Canada have been modified by past anthropogenic stressors (e.g. acid rain, pollutants) such that the chemical characteristics of the fish habitat has significantly impaired their ability to produce fish tissue that can be safely fished and ingested. In these cases restoring the natural chemical composition of the habitat through the additions or removals of chemicals could markedly improve fish production and fish health.

Under the Policy for the Management of Fish Habitat (1986), chemical manipulation was not a preferred option to address impacts of projects. Under the FPP, a policy decision and regulatory guidance has not yet been provided with regard to chemical manipulations and is still required. Nevertheless, it is recognized here that chemical manipulation can be a means to increase fisheries productivity, taking into account the considerations reviewed below.

2. Best case outcome

There is empirical evidence that the fertilization of waterbodies can lead to increased fish production without destabilizing trophic levels (e.g., sockeye salmon nursery lakes).

There is empirical evidence that point source control of nutrients can reduce hyper-eutrophication and lead to increases in productivity of target fisheries species (e.g., Lake Erie, point source phosphorus controls).

There is experimental and field evidence that liming of acidified waterbodies can lead to restabilization of trophic levels (e.g., liming of streams in Nova Scotia, mitigation of low pH in streams and its effects on salmonids).

Decreased contaminants and sediments in water and decreased the body burden in fishes.

3. Likelihood of success

The likelihood of short term success increases when there are fewer links between the species directly affected by the chemical manipulation and the CRA fishery, and the trophic pathways are simpler. However few chemical/nutrient manipulations are likely self-sustaining and so their success generally erodes over time if the source of problem is not directly addressed.

However, ecosystem regime shifts may be a special case in which the ecological equilibrium of the fish habitat has been shifted by chemical manipulation towards an alternative state (e.g., increased fertilization may increase benthic fish species whose presence stirs up nutrients/sediments thus maintains nutrient rich conditions).

4. Factors known to affect success

Offsetting with respect to **nutrient alteration** is likely to be more successful when:

- trophic levels of the target species in the food web are known
- watershed-level drivers of nutrients are known (e.g., point/non-point sources; soil phosphorus concentrations,, etc.)
- physical/chemical characteristics of system related to nutrient cycling are known (including turnover, stratification patterns, flushing rates, trophic status of water body)
  - **specifically for nutrient additions:**
    - nutrients are limiting (i.e. oligotrophic systems) and the limiting nutrients are known (e.g., nitrogen, phosphorus)
    - timing of nutrient addition is appropriate
  - **specifically for nutrient management:**
    - nutrients are in excess (i.e., eutrophic to hyper-eutrophic systems)

Nutrient alteration is less successful when:

- target trophic state of waterbody is dissimilar to background state

- **specifically for nutrient additions:**
    - only a small proportion of fertilizer added makes its way to the target fish.

Treatments to reduce **acidification** are more successful when:

- forage fish base has not been extirpated by current pH

Treatments to reduce **acidification** are less successful when:

- water bodies are large and have complex morphology
- background water chemistry suggests naturally acidic conditions

Contaminant control is most successful when:

- contaminant pathways and concentrations in food webs are known
- a relationship between contaminants and fish vital rates is known

Contaminant control is less successful when:

- the source of contamination is not addressed or when it is not the limiting factor to productivity.

5. Secondary effects

The benefits and costs to non-target species (including benthos, plankton) may result in undesirable consequences to target fisheries. This reflects both the higher physiological sensitivity of different trophic levels to chemical alterations as well as the potential destabilization in food web dynamics.

Further, species trade-offs are likely between ranges of physiological sensitivities or ecological specializations (e.g., lake trout (nutrient poor) vs. walleye (nutrient rich); acid tolerant vs. acid sensitive species; bioaccumulation of contaminants within benthic vs. pelagic foragers).

The control of sources and inputs of nutrients and contaminants has significant social planning considerations and associated co-benefits, including economic and human health issues (e.g. wastewater management, drinking water quality, etc.). As with many offsetting methods, this is usually expensive but may provide long term benefits.

6. Knowledge/Information required to design a program

The following information would be required to design an adequate offsetting program (above and beyond typical survey requirements):

- information about lower trophic levels (including benthos and plankton), bottom-up processes and ecosystem dynamics (re: all types of chemicals);
- limiting resources (re: nutrients);
- water chemistry analysis (re: contaminants);
- baseline biological contaminant loads in fish tissue (re: contaminants);

- knowledge of source, sinks and retention rates (re: all types of chemicals);
- watershed-level data (re: all types of chemical manipulations; e.g. buffering capacity, nutrients, point/non-point, natural levels of phosphorus); and
- sensitivity of fish species to change(s).

7. Quantifying equivalence

To quantify equivalence for offsets of chemical alteration, consideration should be given to the vulnerability of each life history stage(s) affected by the chemical(s) under consideration. It is possible that total phosphorus (linked to fish biomass) may be an appropriate metric in some cases. Linkages to effects on vital rates are important.

8. Scale considerations

Controlling the source of harmful chemicals has been shown to be effective on large and small scales (e.g. inland versus the Great Lakes) and is thus likely scale invariant. Phosphorus, nitrogen and micronutrient (e.g. iron) manipulations are usually large-scale undertakings.

9. Monitoring

Generally, monitoring programs that are biologically-based require the same characteristics as other offsetting options with the additional need to consider:

- contaminant loads in fish tissue (re: contaminants); and
- condition and abundance of lower trophic levels (re: all types of chemical manipulations).

Habitat Banking

In the literature, the terms *habitat banking* and *offsetting* are often used interchangeably. In this SAR, we differentiate the terms, and when we intend to refer to habitat banking, this will be done explicitly. Habitat banking is an approach for using offsetting methods, like those outlined above, in achieving offsetting. Habitat banking schemes or frameworks vary widely in their implementation and levels of planning but all have some common properties; most notably the creation of an initial deposit in a *bank* of restored, or created, and sometimes preserved, habitat that can be used to offset future losses. Banks can be created to offset impacts of multiple projects. Many of the principles outlined in the most ecologically grounded banking frameworks can be used in implementing any offsetting plan.

1. General description

Habitat banking is a formalized approach for creating offsets up-front through a trading/transaction system. It has been called by various names depending on the goal of the bank (e.g. conservation or biodiversity banking where protection of species at risk or biodiversity are concerned). It can be an approach for considering all offset measures within a defined area, and requires by default a common ecological currency. The role of economic valuation in these trade-offs is still under development. This ecological currency can be translated into monetary values where a third party is the banker. Here we concentrate on the ecological aspects of habitat banking.

2. Best case outcome

Banking by definition minimizes the time lags between loss and offsetting by accruing gains in functional or productive habitat first before losses are incurred. Thus the best ecological outcome would be no even temporary loss of productivity of CRA fisheries because of immediate offsetting of residual impacts of a project. The standardized approach and accounting framework needed for banking (including a metric or suite of metrics to be used as a currency for trading offsets and losses) would be an additional outcome with benefits in other types of applications as well.

3. Likelihood of success

If it is a well-regulated, well-monitored bank the likelihood of success may be greater than traditional offsetting situations because the uncertainty in achieving offset goals after a loss or harm is reduced. The benefits expected from the offset have been demonstrated before the impact occurs (e.g. showing that the habitat is used for successful spawning and rearing). However, a fully functional offset (*deposit)* may take years to establish.

4. Factors known to affect success

Factors that increase the ecological success of a habitat bank are:

- properly defining ecologically meaningful spatial boundaries for the bank;
- having a pre-established accounting framework and ecological currency used for trading;
- having explicit management objectives for the service area of the bank and its intended ecological outcome(s) (e.g. conservation, fisheries productivity);
- using inclusive governance processes including consultation to establish bank objectives;
- having a third party banker may be beneficial; and
- monitoring and using an adaptive management approach to offsetting techniques and their implementation improves efficiency.

Factors that decrease the ecological success of a habitat bank are:

- scale of bank is inappropriate for usage requirements;
- adaptive approach and monitoring not taken (an iterative approach revisited on a regular basis is recommended);
- trading and currency rules are not established up-front; and
- impairment occurs too soon before offset habitat becomes fully functional.

5. Secondary effects

A landscape-scale and planning based approach to banking allows the combination of small-scale improvements to offset multiple losses to be combined into larger higher impact gains as a banking reserve for future losses. In a multiple stakeholder or a third party situation, experts may determine the most appropriate offset given knowledge of the area, ecological objectives and applicable policies and regulations.

Governance mechanisms for banking are different and possibly more complex than traditional offsetting approaches. There may also be de-coupling of the bank from local site productivity or departmental management priority areas or objectives if the scale and trading system is not properly defined or regulatory mechanisms for bank set-up are not in place. ‘Hoarding’ of ecological credits may occur in some governance frameworks.

6. Knowledge/Information required to design a program

Steps involved in an ecological approach to banking include:

- baseline information and inventory of aquatic habitats within that landscape;
- selection of ecological currency or metrics to be used for trading;
- set-up of an accounting framework;
- setting of objectives for the bank (locally and nationally);
- design of a monitoring and adaptive management program to ensure that;
- deposits (offsets) are functioning as intended and established before impacts or losses are incurred; and
- policy and advice to inform governance and monetary transactions.

7. Quantifying equivalence

A bank needs a standardized ‘ecological’ currency for trading purposes. Productivity equivalents for habitat units using variables that are appropriate for that region and landscape (and depending on the expected impact) can be used in calculations for accounting purposes. Using quantity and quality criteria to evaluate different life stage, species, and fisheries needs can inform decisions based on management objectives of the area.

Calculating equivalence is often complex, and includes challenges related to:

(i) establishing ‘value’ of existing banks relative to ecosystem productivity (i.e., baseline)

(ii) the use of monetary instruments within the banking system has resultant economic analysis complexities.

Often models, based on empirical evidence, are used to calculate trade equivalencies. Mapping, modeling and monitoring can be used to ensure the offset is a gain and is functioning as intended.

8. Scale considerations

A habitat bank requires defining a *service area*. The landscape scale at which a typical fishery or stock is found is an appropriate example of an ecologically meaningful *service area*. Within that landscape, transactions (e.g. deposits / withdrawals) can occur at any scale but a minimum should be defined for consideration. Cumulative impacts and other stressors within that system need to be considered. In some cases, the physical size of offsets may need to be larger than their equivalent natural area(s) because restored or created sites may have lower productivity even when fully functional.

9. Monitoring

The duration of the monitoring should be matched to the objectives of the banks.

Various types of monitoring need to occur in a landscape unit defined by a bank:

- baseline and control monitoring: an inventory and baseline of habitats or variables needed for creating a starting balance sheet for accounting purposes; The baseline monitoring should be long enough to capture natural variability and the impact of other stressors on the system to understand system dynamics;
- longer term monitoring of predefined metrics, including compliance, functional and effectiveness monitoring (DFO 2012);
- impacts Monitoring: Habitat and productivity losses resultant from development impacts should be monitored and gauged using similar metrics and measures as baseline and offset monitoring; and
- there needs to be an audit process and monitoring that occurs to ensure the accounts are accurate and adequate.

Sources of Uncertainty

All offset techniques, whether they include restoration, habitat creation, banking, stocking, or others have potential benefits and challenges. Major sources of uncertainty for each category of offsetting are already summarized in the respective Factors Known to Affect Success section for each class. Key points include:

- Habitat restoration projects can improve fish productivity but may experience structural or ecological failure due to changing environmental conditions.
- Habitat creation may improve fish productivity but there can be long time-lags before created habitat functions as effectively as natural habitats.
- Habitat banking using restoration/creation techniques can have many advantages for developers and sellers but again, relies of the effectiveness of restoration/creation techniques. Fish stocking may increase productivity but can result in negative impacts to the reproductive success or fitness of natural populations.
- Chemical alteration can improve the productivity of a system but often requires continued maintenance.

In addition to the variability associated with the offsetting methods themselves there is also natural variability of fish populations, a changing climate and invasive species to consider.

Therefore when undertaking any management action unexpected and undesired consequences are a possibility. This underlies the need for robust monitoring programs that have the ability to allow adaptation of the offsetting program if warranted.

CONCLUSION

Offsetting programs should have clear goals or targets for their activities. Scientific evidence suggests that a species-only or single-process approach to restoration has a higher likelihood of failure, irrespective of the method used. Instead, a watershed/ecosystem approach focused on restoring natural processes in a dynamic ecosystem is more likely to be successful for local fisheries. Although it is often impossible to know all the factors affecting a watershed prior to undertaking offsetting activities, strong efforts should be made to determine as much about the watershed as possible to better predict potential outcomes of any restoration activities.

OTHER CONSIDERATIONS

In general, the review and this subsequent advice focused on freshwater fisheries. This was choice related to the request for advice but a similar process should be conducted for the marine environment, and properties unique to the Arctic environment. Advice provided regarding large lakes may be applicable to coastal and nearshore oceanic environments.

This review and advice focused primarily on physical and chemical processes that have been used to increase fisheries productivity and thus could potentially be used as offsetting techniques. There may also be biological interventions (e.g. aquatic invasive species control) that might be considered in an offsetting scenario. These would be case specific and would most likely experience similar or greater ecological uncertainties as highlighted in this advice. All of these would have a policy aspect to their adoption which would have to be addressed, and are thus outside of the scope of this exercise.

While no single approach to calculating the amount of offsets needed to increase or maintain productivity was apparent from the literature, this remains a high priority need for the FPP. There are many existing and developing methods to quantify potential impacts of offsetting and these should be reviewed and tested to inform a nationally consistent approach(es) to calculating offset equivalence.

Previous science advice on monitoring for habitat compensation (DFO 2012) should be reviewed and adapted to provide a standard monitoring methodology for offsetting programs.

Finally, there is a need to periodically re-visit the conclusions and advice in this report. The inclusion of a standard monitoring protocol should provide an excellent opportunity for the FPP to evaluate new offsetting projects and techniques. These evaluations should provide the program an opportunity to learn and improve offsetting projects after enough examples have been conducted and examined.

SOURCES OF INFORMATION

This Science Advisory Report (SAR) is from the June 4-6, 2013 national peer review on "Science guidance for Fisheries Protection Policy". Additional publications from this meeting will be posted on the *Fisheries and Oceans Canada (DFO) Science Advisory Schedule* as they become available.

Loughlin, K. L. and Clarke, K. D. A Review of Methods Used to Offset Residual Impacts of Development Projects on Increase Fisheries Productivity. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/097.

DFO. 2012. Assessing the Effectiveness of Fish Habitat Compensation Activities in Canada: Monitoring Design and Metrics. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/060.

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

DFO. 2013b. 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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Canadian Science Advisory Secretariat (CSAS)
Fisheries and Oceans Canada
200 Kent Street Ottawa, ON K1A 0E6

Telephone: 613-990-0293
E-Mail: csas-sccs@dfo-mpo.gc.ca
Internet address: www.dfo-mpo.gc.ca/csas-sccs/

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