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A Review of Equivalency in Offsetting Policies

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Foreword

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

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ABSTRACT

Under the *Fisheries Act* (2012), when a project or development activity is determined to cause serious harm to fish, the Minister shall consider whether measures and standards have been applied by a proponent to avoid, mitigate or offset serious harm to fish. Here **offset** refers to measures to counterbalance the impacts of the project and could be in the form of habitat replacement, enhancement or other activities designed to increase fisheries productivity. **Equivalency** refers to the methods used to compute the amount of offsetting required, relative to the magnitude of the impact.

This report provides an overview of methods, approaches and considerations for equivalency calculations that are part of offset programs to maintain habitat or biodiversity. Programs for the US, Europe and other regions are summarized as is the international literature on offset and equivalency methods. Approaches for dealing with uncertainty and time delays in impacts or benefits are reviewed and illustrated with hypothetical examples. This review is intended as background information for the development of offset procedures in support of the fisheries protection provisions of the *Fisheries Act* (2012).

Examen des équivalences dans les politiques de compensation

RÉSUMÉ

En vertu de la *Loi sur les pêches* (2012), lorsqu'il a été établi qu'un projet ou que des activités de développement causeront des dommages sérieux aux poissons, la ministre doit déterminer si le promoteur a mis en application des mesures ou des normes afin d'éviter, d'atténuer ou de compenser les dommages sérieux causés aux poissons. Dans ce contexte, le verbe **compenser** fait référence à des mesures visant à contrebalancer les répercussions du projet et qui pourraient prendre la forme d'un remplacement ou d'une amélioration de l'habitat ou encore de toute autre activité visant à accroître la productivité des pêches. Le terme **équivalence** fait référence aux méthodes utilisées pour déterminer le niveau de compensation requis par rapport à l'ampleur des répercussions.

Le présent rapport donne un aperçu des méthodes, des approches et des points à prendre en compte dans le cadre de la détermination des équivalences qui font partie des programmes de compensation visant à protéger l'habitat ou la biodiversité. Les programmes pour les États-Unis, l'Europe et les autres régions du monde sont résumés, ainsi que les publications à l'échelle internationale traitant des méthodes de compensation et d'équivalence. Les approches relatives à la gestion de l'incertitude et aux délais concernant les répercussions ou les avantages sont examinées et illustrées au moyen d'exemples hypothétiques. Cet examen permettra de recueillir des renseignements généraux en vue de l'élaboration de procédures de compensation à l'appui des dispositions relatives à la protection des pêches de la *Loi sur les pêches* (2012).

INTRODUCTION

Under the *Fisheries Act* (2012), when a project or development activity is determined to cause serious harm to fish, the Minister shall consider whether measures and standards have been applied by a proponent to avoid, mitigate or offset serious harm to fish as part of the Section 6 (s6) considerations. The fundamentals of "avoid, mitigate and offset" build on the concepts of a mitigation hierarchy that is internationally recognized as a best practice in reducing risks to biodiversity (BBOP 2009; Quetier and Lavorel 2011; ICCM 2013). The objective of offsetting in relation to the *Fisheries Act* is to counterbalance unavoidable serious harm to fish resulting from a development proposal with the goal of maintaining or improving the productivity of the affected commercial, recreational or Aboriginal fishery. Since 'ongoing productivity' of fisheries (see DFO 2013a; Randall et al., 2013) is the main goal (s6.1 of the *Fisheries Act*), offset measures may use a 'like for like' approach (i.e., habitat replacement) as was the norm in the past under the 1986 policy (DFO 1986) or may increase fisheries productivity in a given area by other means (e.g., removal of barriers to passage, habitat creation targeting limiting factors, etc.), or use other tools to increase fisheries productivity. Many of the common methods to offset fisheries productivity have been reviewed (Loughlin and Clarke 2014) and advice pertaining to their use provided (DFO 2014b).

Equivalency is the term commonly used in the biodiversity offsetting literature when impacts of a project are compared to the benefits of an offsetting activity. When the offsetting targets something other than a direct replacement of lost habitat, some form of equivalency analysis may be required to allow a comparison of the losses from the impact to the expected gains from the offset, although many equivalency calculations can also help scaling 'like for like' approaches. In this way the concept of equivalency can be seen as an integral part of the mitigation hierarchy as depicted in Figure 1, which has been modified from Quetier and Lavorel (2011). As stated above, in its simplest form an equivalency calculation is a balancing of the losses and gains associated with an impact and the resulting offsetting (Lipton et al., 2008, Vaissiere et al., 2013) but many equivalency calculations also include methods to deal with uncertainty and time lags (see discussion below). Offset policies may require that offsets be larger than the anticipated impacts (requiring the use of multipliers) in order for the offsets to account for uncertainty and time delays (McKenney and Kiesecker 2010; Overton et al. 2013).

The goal of this paper is to review offset policies and equivalency methods from jurisdictions outside of Canada, as well as information from the international scientific literature. This review is intended to inform the development of the policies and procedures for offsets in the fisheries protection provisions (FPP) of the *Fisheries Act.* Specific advice on equivalency calculations for the implementation of FPP will be the subject of a Science advisory process scheduled for 2014.

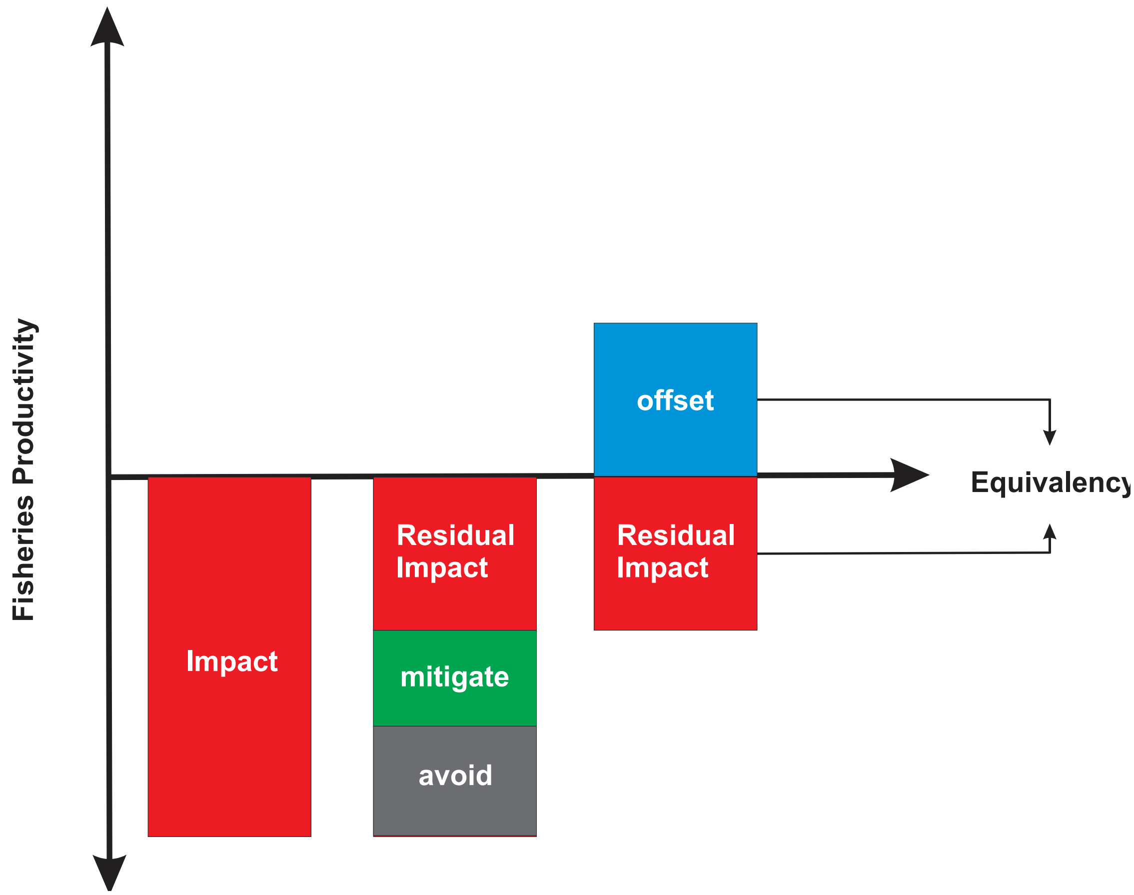

Figure 1: Conceptual diagram for how equivalency fits into the mitigation hierarchy (adapted from Quetier and Lavorel 2011 and DFO 2013b)

EXISTING TYPES OF EQUIVALENCY ANALYSES

Allen et al., (2005) and Chapman and Lejeune (2007) review the major types of equivalency analyses that have been developed, mainly in the United States of America (USA). These are briefly described below.

SERVICE-TO-SERVICE EQUIVALENCY

Service refers to ecosystem services that natural resources provide to humans. In the case of FPP this mainly refers to the functions that habitat plays in fisheries productivity. Service-to-service equivalency is developed on the basis of replacing damaged ecosystem or habitat function with an amount of new or altered habitat that can deliver the lost services. This is most commonly achieved with Habitat Equivalency Analysis (HEA).

Habitat Equivalency Analysis

Possibly the most discussed equivalency method in the literature is the Habitat Equivalency Analysis (HEA) which was first developed by the National Oceanic and Atmospheric Administration (NOAA) of the USA (NOAA 2006). HEA was first introduced to help scale compensatory requirements for natural resource damage assessments in marine and coastal areas related to oil spills, hazardous substance releases and physical habitat damage (Allen et al., 2005; NOAA 2006). HEA is considered a generic method and thus can be adapted to a variety of situations (Ray 2008). The method has been used in a variety of aquatic habitats (e.g., Chapman et al., 1998; Milton and Dodge 2001; Fonseca et al., 2004), in *ex ante* assessments (Roach and Wade 2006; Lipton et al. 2008) and has been proposed to be the basis for equivalency assessments for several European environmental laws (Lipton et al., 2008).

HEA is a service-to-service approach for calculating equivalency which mainly uses habitat area. Habitat losses are based on the area affected, and the concept of "service loss" which is a scalar that pro-rates the damages. Service losses are generic values (usually as a percentage of the undamaged habitat) that attempt to integrate the overall loss of service, avoiding the need for detailed ecosystem studies. When similar types of habitat are available for offsetting the equivalency calculations are straightforward, and are largely based on habitat area affected, prorated by the service loss, and the area of the offset habitat. If the offset habitat is significantly different in nature conversion factors can be used to rate the potential rate of service provision so that amount of offsetting required is appropriately scaled to the damages.

RESOURCE-TO-RESOURCE EQUIVALENCY

Resource Equivalent Analysis (REA) uses units of a resource (such as a fisheries species) to define equivalency rather than the ecosystem services provided by habitats. Losses can be calculated using methods to predict changes in population abundance or productivity (Bradford et al., 2014; de Kerckhove 2014.) as a result of project impacts. Offsets attempt to replace the loss in abundance or productivity, and can use a suite of techniques that could focus on habitats or life stages other than the ones involved in the damage or loss assessment. Methods of calculation are similar to those of HEA.

VALUE-TO-VALUE EQUIVALENCY

Value Equivalency Analysis (VEA) scales damages and offsets using an economic analysis of their value. This method is not commonly used because of the complexities of valuing ecosystem services, but may be necessary when the offsets involve other species or ecosystems to the those being damaged, or if the offsets are non-ecological form, such as economic, educational or social instruments. Lazo et al., (2005) provides an example of this approach.

REPLACEMENT COST APPROACHES

As an alternative to a full economic value or utility of ecosystem damages, the simpler replacement cost approach has been developed. The assumption of this method is the cost of creating or replacing lost habitat (or resources) is a minimum estimate of the value of the resources lost, and can be used as a guide to scaling offsetting activities (Strange et al., 2004).

COMPONENTS OF AN EQUIVALENCY ASSESSMENT

Not all offset policies require an equivalency calculation (see reviews in McKenney and Kiesecker 2010; Quetier and Lavorel 2011). Policies that require offsets to be "in-kind" or like-for-like such as the wetland mitigation techniques in the USA or Habitat Hectares in Australia use the product of a pre-set score or ratio and the area of habitat impacted to compute the amount of similar habitat that is required to be replaced to achieve the offset. Policies that allow for "out of kind" offsets require an equivalency analysis as the impacts and offsets are of a different form than a like-for-like comparison. One aspect that is common to all equivalency analyses is the requirement that a common metric (or indicator) be used to calculate the gains and losses. For example, for a project that is predicted to kill adult fish an appropriate offset might be the creation of spawning habitat if that has been deemed a limiting factor for the species of concern. In this case the concepts of adult equivalency or reproductive potential (i.e., eggs per recruit) (see Boreman 1997) might provide a useful metric. A review of metrics suitable for fisheries productivity measurements has been conducted which should guide mangers in this respect (de Kerckhove 2014*)*.

While the various equivalency assessments can differ slightly in their requirements there are three core steps that must be completed (Quetier and Lavorel 2011; Vaissiere et al., 2013).

1. First the losses must be quantified. This should be conducted with respect to the baseline condition or reference state and also include any primary restoration that can be completed at site to improve conditions (see Figure 2, upper panel).
2. Next the anticipated gains from the offsets should be quantified (represented by the shaded area in Figure 2 (lower panel).
3. The final step in the equivalency analysis is to scale the offset activity such that the total increase in services from the offset equal the services lost from the impact (i.e., the shaded areas in Figure 2 are equal). Here the policy goal is the achievement of no net loss of productivity. No consideration is made for uncertainty in this example.

Some equivalency assessments also include an initial step to scope the potential for offsetting (Lipton et al., 2008) and/or assesses if offsetting should even be attempted as some ecosystem aspects cannot be offset (BBOP 2012). In a proposed equivalency analysis for the European Union, Lipton et al., (2008) suggest inclusion of a final step related to monitoring and reporting and NOAA (2006) states that either a calculation of costs (if the proponent is not conducting the offset) or performance standards be established to allow auditing. While monitoring and cost are not strictly required to calculate ecological equivalence they are necessary items of any offsetting policy and will be required when an offsetting plan is submitted to DFO (see Application for Authorization under Paragraph 35(2)(b) of the *Fisheries Act* regulations). As part of an overall policy, monitoring results can be used to both audit the offsetting project/program and reduce uncertainty in future projects when conducted in an adaptive framework. A similar conclusion was arrived at by DFO Science during a previous advisory meeting related to habitat compensation (DFO 2012) and work is ongoing to develop a monitoring framework that could be used when offsetting of serious harm is required.

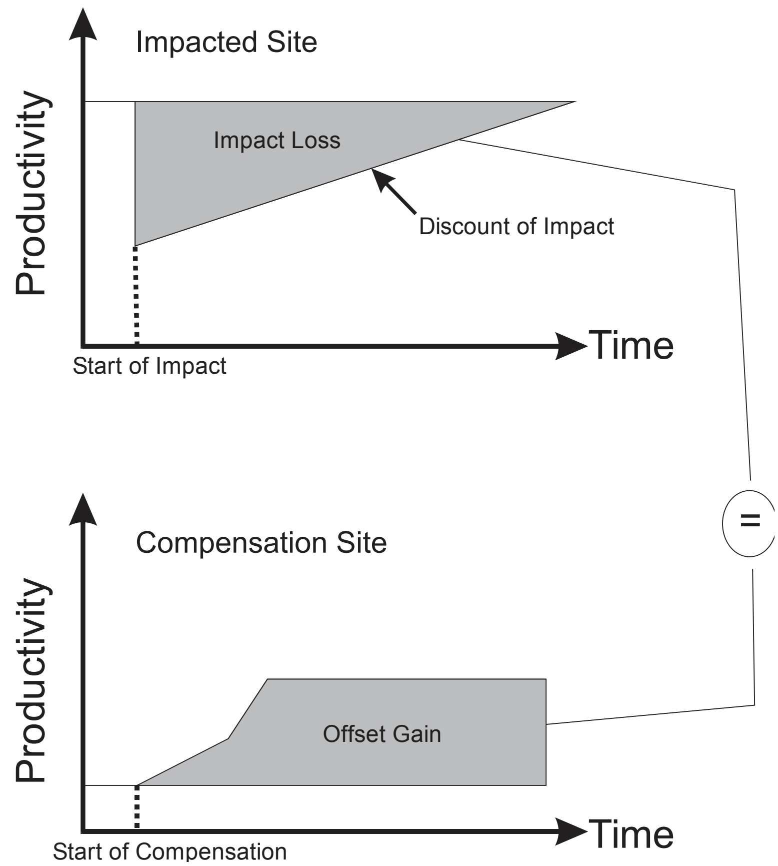

Figure 2: Conceptual depiction of productivity losses at the impact site and gains at the offsetting site. Equivalence is achieved when the shaded areas are equal (adapted from Dunford et al., 2004 and Vaissiere et al., 2013).

CURRENT USE OF EQUIVALENCE IN OFFSETTING POLICIES

Quetier and Lavorel (2011) recently reviewed equivalency methods in biodiversity offsetting policies from around the world. They suggest a hierarchal approach to determining equivalence may be required in offset policies. This stems from the fact that not all offset plans will be the same, some will be reoccurring or conducted on species or in habitats that are relatively well known. In these situations it might be possible to develop 'standardized scoring methods'.

The wetland mitigation scoring systems used in the USA are examples of a standardized scoring method. There are a number of these systems in use (see reviews in Bartoldus 1999; Fennessy et al., 2004) as they are generally developed either for specific geographical area (i.e. US states) or specific wetland types. The main focus of these scoring systems is to evaluate the physical, chemical and biological structure of the wetland to assess its capacity to provide ecological functions resulting from interactions of its component parts (Wainger et al., 2001). For example the Wetland Rapid Assessment Procedure (WRAP) was created for use in freshwater, non-tidal wetlands located in South Florida (Miller and Gunsalus 1999, Chinners Reist et al., 2007). This particular method has six scoring categories:

1. Wildlife Utilization
2. Overstory/Shrub Canopy
3. Vegetative Ground Cover
4. Adjacent Upland Support/Buffer

5. Field Indicators of Wetland Hydrology and
6. Water Quality Input and Treatment.

Scores can range from 0.0-3.0, in 0.5 increments. A score of 3.0 indicates an “intact” wetland, whereas a score of 0.0 indicates a wetland with a reduced functional capacity. Guidance is provided for scoring categories of 0.0, 1.0, 2.0, and 3.0. The final WRAP score is calculated by summing the scores for the scoring categories and dividing by the number of scoring categories used.

Standardized scoring systems have the advantage of predefined indicators, making it easier for both the proponent and regulator during assessment. They also provide a level of comparability between projects. Standardized systems generally can deal with ‘like for like’ or ‘like for similar’ offsets. These standardized methods, however, require a significant initial investment to develop and validate the indicators and scoring system. This usually will require the involvement and agreement of stakeholders, scientific experts and regulators. Standardized systems may need to be modulated by local context such as the state of the fishery in question or concurring stressors. Other examples of this approach include the habitat-hectares approach of Australia and the *Biotopwertverfahren* of Germany (Quetier and Lavorel 2011). In Canada with its diverse fishery resources a single standardized scoring system may be impractical but reoccurring impact types with known effects, possibly in restricted geographical areas, might be amenable to such an approach.

In complex or high risk situations Quetier and Lavorel (2011) suggest using a method they term ‘circumstantial reasoning’ which basically equates to indicators and equivalency being determined on a project-specific basis. This approach allows regulators, experts and proponents to explore novel solutions to complex problems and is inherently tied to the local context. The lack of standardization however means comparability between projects may be lost. Conducting equivalence in this way can also be seen to be less transparent and thus harder to communicate to other stakeholders. Examples of this approach include the *Ausgleich* from Germany and the Natura 2000 procedures used in Europe (Quetier and Lavorel 2011). This is also how many large projects subject to environmental review have been handled in Canada in the past (Minns et al. 2011). The creation of protocols or best practises for conducting site-specific analyses would enhance the consistency and quality of these analyses.

RISK AND UNCERTAINTY IN EQUIVALENCE CALCULATIONS

The calculating of equivalence within an offsetting program will have a number of uncertainties that should be acknowledged, assessed and where possible managed to improve outcomes (Moilanen et al., 2009; Maron et al., 2012). Uncertainty can be introduced into the equivalence analysis by uncertainty inherent in impact predictions, time delays associated with the offset method employed, measurement uncertainty related to the metric chosen, uncertainty related to the efficacy of the offset method, as well as natural environmental variability (Lipton et al., 2008; Maron et al., 2012; Overton et al., 2013).

Moilanen et al. (2009) conducted an analysis where many of these uncertainties were incorporated into an equivalency calculation and found that offset ratios would have to be very high (>100 to 1) to guarantee a ‘robustly fair’ exchange in many instances. This type of ‘robust’ equivalency calculation that mathematically includes uncertainty might be preferred in certain situations where outcomes of both the impact and the offset are highly uncertain. The resulting offset ratio, however, may make practical implementation of the offset difficult and Overton et al. (2013) recently recommended that the risk associated with the success of the offset might be better dealt with via other management options (see below).

The risk of offset failure accounts for a great deal of the uncertainty in equivalency calculations (Moilanen et al., 2009; BBOP 2012; Maron et al., 2012; Overton et al., 2013). Overton et al. (2013) estimated this risk to be 10-20% from empirical evidence including examples from Canada (e.g. Harper and Quigley 2005) and Minns (2006) estimated uncertainty due to failure would require a replacement ratio of 4:1 to achieve 'no net loss' of productive capacity. There are two components of this risk: (1), first there is the risk that the offset will never be completed or not fully completed as designed (e.g. Harper and Quigley 2005). Overton et al. (2013) recommend that this portion of the risk is best dealt with via management options that move the risk to the organizations completing the offsets. These could include monetary penalties such as bonds or fines and/or other sanctions such as stop work orders and authorization revoking. The implementation of such measures would require a compliance monitoring and auditing program. Secondly (2) there is the risk even when offsets are completed as designed of partial failure due to uncertainty in the efficacy of the offset, measurement error, and environmental variability. The most commonly used method of incorporating this risk into the equivalency calculation is through the use of multipliers or offset ratios as noted previously (BBOP 2012, Maron et al., 2012, Vassiere et al., 2013, Overton et al., 2013). Common methods used to increase fish production have been previously reviewed (Loughlin and Clarke 2014) and advice on the factors related to their success (DFO 2014b) should be reviewed to help inform these ratios if used. Multipliers are easy to understand, implement and audit but they are often difficult to calculate and agree upon (BBOP 2012). Ideally a set of offset ratios for common offset projects could be developed and published from existing literature. An example of such an approach is given below from Florida for near-shore marine impacts (Table 1 from Vassiere et al., 2013).

Table 1: Compensatory ratios for coastal marine impacts in Florida (source Vassiere et al., 2013).

Compensation measures	Definition	Impacted habitat	Ratio of unit of compensation to unit of damage
Creation	A new habitat is created near the site impacted	Seagrass and coral reefs	2:1 to 4:1
		Mangrove, marshes	2.1 to 5.1
		Halophyte or estuarine vegetation	1.5:1 to 4:1
Restoration (on the impacted site)	A damaged habitat is restored near the impacted site	Seagrass and coral reefs	2:1 to 4:1
		Mangrove, marshes	2.1 to 5.1
		Halophyte or estuarine vegetation	1.5:1 to 4:1
Ecosystem enhancement	Enhancement of ecological functioning through improvement of environmental conditions	Seagrass and coral reefs	4:1 to 20:1
		Enhancement of wetlands	4:1 to 20:1
Preservation	Habitat protection near the impacted site	Seagrass and coral reefs Mangrove, marshes Halophyte or estuarine vegetation	~ 60:1

Measurement uncertainty can be a problem if inappropriate metrics are selected to represent fisheries productivity. A review of metrics and subsequent advice for their selection is being developed (de Kerckhove 2014) and thus will not be discussed in detail. From an equivalency perspective the farther removed a metric is from the overall objective (i.e., fisheries productivity) the more uncertainty it will introduce into the process. Measurement uncertainty can also be reduced by selecting more than one metric of productivity during effectiveness monitoring (Maron et al., 2012). There will always be a need to develop better metrics but in general if they are selected with existing advice (Randall et al., 2013; Bradford et al., 2014; DFO 2014a; de Kerckhove 2014) measurement uncertainty should be less of a concern for productivity offsets for fish and fish habitat than that expressed for many other biodiversity offsets found in the literature.

Another consideration when calculating equivalency is the time lag often required for the offset to be fully functional. In general it is not considered appropriate to compensate an immediate loss by hypothetical equivalent gains that will only be realized in the future (Norton 2009, Moilanen et al., 2009, Quetier and Lavorel 2011, Maron et al., 2012). Overton et al (2013) estimated that this form of risk ranged from 2 to 4% per year and NOAA (2006) and Julius (1999) state that the economic literature supports a 3% discount rate. Many of the equivalency methods that are based on the HEA family of equations build the 3% discount rate directly into the calculation of losses and gains (NOAA 2006, Lipton et al., 2008). Discounting devalues events (such as habitat loss or gain) that occur in the future relative to those that occur in the present, and the discount rate is the annual rate of loss of value. Minns (2006) evaluated the effect of time lags on achieving no net loss of productive capacity under the 1986 policy (DFO 1986) and found that the longer the impact and habitat compensation was separated in time the more pronounced the time lag effect would be. He suggested a compensation ratio of 2:1 would be required to fully account for the effect of time lags. The effects of time lags can be lowered by having the offsets functioning before the impact either onsite or through a banking mechanism.

The uncertainties and risks discussed above are generally related to the gains side of the equivalency calculation but since the losses in most fishery protection assessments will rely on impact predictions these will also have uncertainty. This will obviously become more important in larger or more complex projects such as those deemed ecosystem transformations in previous advice (DFO 2013a, 2014a). This is an area which requires directed research, however, in the interim well-designed monitoring programs that can objectively assess impact predictions will help define the level of uncertainty that can be expected with prediction of impacts from proposed projects.

In addition to the risks and uncertainty discussed above a changing climate and invasive species can lead to unexpected offsetting outcomes. Therefore when undertaking any management action unexpected and undesired consequences are a possibility which no equivalency calculation would be able to take into account. This underlies the need for robust monitoring programs that have the ability to allow adaptation of the offsetting program if warranted.

EXAMPLE CALCULATION

There are several resources detailing how to conduct HEA. NOAA (2006) is the primary guide but Allen et al. (2005) and Lipton et al. (2008) provide additional examples. Kohler and Dodge (2006) also developed a visual version that has been published as freeware. These resources were used to complete the following hypothetical example.

HYPOTHETICAL EXAMPLE

Highway construction in Newfoundland is going to infill a lake that is used by both Atlantic salmon and Brook trout. The lake has a surface area of 100 ha and will be cut in half by a silt screen over a two year period during construction. It is assumed that due to heavy silt loads and actual infilling no fish will survive the construction phase, after construction the shoreline will be lined with washed substrate leaving a total infill footprint of 30 ha. The proponent would like to conduct an equivalency analysis as recreating lake habitat is not a viable option. Salmonid biomass is selected as the metric as there is reasonable data for both lake and stream habitats that can be used as regional benchmarks.

The first step in the equivalency analysis is to quantify the loss. Cote et al. (2011) notes that a 100 ha lake in Newfoundland is predicted to have an average salmonid biomass of 2.7 kg ha^{-1}, corresponding to a total 'standing stock' of 270 kg for the lake. The service loss will be 50% of the lake in the construction years with a two year "settling" period where service lost was estimated at 40% and then the permanent loss will be 30% of the lake. Calculations were continued until the biomass from the lake had little current 'value' after discounting, at 100 years, although offset ratios vary little after the first 50 years. Calculations are presented in Table (2) with the total service loss for this scenario being 2793 kg.

Table 2: Calculation of service loss resulting from a hypothetical infilling of a lake. Discount rate is calculated as $1/(1+r)^t$ where r is the discount rate and t is the time interval.

Year	Standing Stock (kg) A	Service loss B	Discount (3% yr^{-1}) C	Discounted Resource loss (A*B*C)
1	270	0.5	1.00	135
2	270	0.5	0.97	131
3	270	0.4	0.94	102
4	270	0.4	0.92	98
5	270	0.3	0.89	71
6	270	0.3	0.86	69
7	270	0.3	0.84	66
8	270	0.3	0.81	64
9	270	0.3	0.79	62
10	270	0.3	0.77	59
100	270	0.3	0.05	4
Total				2793

The second step in the equivalency analysis is to calculate potential gains. In this hypothetical example we explore two options being proposed by the proponent's consultant. The first option is to restore stream channel habitats that were cut off from the existing streambeds due to log driving activities in the area during the 1950s. The areas are currently dry so they have no fishery value; there is no responsible party for the damage. The proponent plans to restore the areas using natural channel design criteria specifically for salmonids and will include the creation of undercut banks, as habitat for larger salmonids. Additionally the plan would draw water from an upstream pond and have a hydrological control structure at the upstream end to protect the restored habitat from flood events but allow natural flushing flows.

This type of habitat restoration and creation in Newfoundland can be expected to have a salmonid biomass in the range of 30 kg ha^{-2} to 50 kg ha^{-2} (Scruton et al., 1998; Clarke and Scruton 2002; Scruton et al., 2005). The midpoint of this range, 40 kg ha^{-2} was selected for the equivalency calculation. The gain calculation was conducted for the same time period as the losses but the first year will see no service gain as it is a construction year. From previous experience it is expected that salmonids will rapidly colonize the new habitat but it will take some time for it to produce the older individuals. So service gains were estimated at 10% per year for three years (years 2-4) which then increased to 20% per year until the habitat would be expected to be at full productivity by year 8 (Table 3).

The third step in the equivalency analysis is to scale the offset. This is conducted by dividing the anticipated losses by the potential gains (i.e., 2793 / 1140 = 2.45). We used a time horizon of 100 years for this calculation. The non-discounted ratio assuming fully functional restoration is about 2. Since our gain calculation was based on 1 hectare of stream habitat this means to fully offset the loss the proponent would be required to restore 2.5 hectares of stream habitat. The HEA methodology also requires a cost estimate. Using information in a report by Kilgour & Associates and AECOM (2011), the average cost for the construction of an enhanced channel is $1200 per lineal meter. Assuming an average wetted width of 15 m, 1933 meters of stream habitat would be required. This equates to an estimate of 3.48 million dollars for the restoration work. This estimate does not include any cost for monitoring or maintenance that might be required.

Table 3: Calculation of service gains using a stream restoration as the offset (based on 1 hectare of stream habitat).

Year	Biomass (kg) A	Service Gain B	Discount (3% yr^{-1}) C	Discounted Resource gain (A*B*C)
1	40	0	1.00	0.0
2	40	0.1	0.97	3.9
3	40	0.2	0.94	7.5
4	40	0.3	0.92	11.0
5	40	0.5	0.89	17.8
6	40	0.7	0.86	24.2
7	40	0.9	0.84	30.1
8	40	1	0.81	32.5
9	40	1	0.79	31.6
10	40	1	0.77	30.7
100	40	1	0.05	2.1
Total (100 yrs)				1140

The second offset option being proposed is to fix culverts on a number of resource roads in the area to promote connectivity for Atlantic salmon. The main habitat gain would be access to lake habitats in the 20-40 hectare range that are above these collapsed culverts. Consulting Cote et al. (2011) the expected biomass for lakes of this size would be approximately 4.5 kg ha^{-1} but in this case the gain would be incremental as these lakes are not fishless (i.e. they have brook trout). The maximum incremental gain possible was estimated at just less than 50% of the total expected lake biomass at 2.0 kg ha^{-1}. A lake in the middle of the size range i.e. 30 ha was used for the gain calculation (Table 4). The proponent does not want to conduct any ‘seeding’ of these habitats (i.e., fry or adult transfers) and will rely on straying to achieve any gains. While many habitats have been enhanced for Atlantic salmon production in Newfoundland (Mullins et al. 2003) straying has been observed to be a very slow process (Clarke et al., 2001, Clarke and Scruton 2002). Therefore the service gain from this offset was estimated to be 2% per year for 50 years (Table 4).

The potential gains from one 30 ha lake over the same time period is presented in Table 4. To balance the equivalency equation the expected discounted losses calculated in step one are divided by the expected discounted gains. Thus in this case 2793/953 which equals a ratio of 2.9. This means that the proponent would need to improve access to 3 lakes in the 20-40 ha range. If we assume that each lake would require a culvert to be restored we can calculate a construction cost. Consulting Kilgour & Associates and AECOM (2011) the cost for a bottomless culvert which can span a stream up to 6 m wide is \$3000 m^{-2}. Thus if each stream crossing is 50 m^{-2} construction costs will be 0.45 million, again this does not include any costs for monitoring or maintenance.

These two examples were completed without using any additional offset ratios except the time discounting that was part of the REA equation. This is because there was enough data on habitat quality to create reasonable estimates of the selected metric. In absence of this data an expert panel approach is often used to generate ratios (see: "Portland Harbor Natural Resource Trustee Council "Expert Panel" Discussion of Habitat Restoration for Chinook Salmon" for an example for Chinook salmon in the Willamette River, Oregon). One additional benefit of equivalency analysis such as in our examples is they can help inform monitoring objectives. In the stream restoration example compliance monitoring related to habitat stability would most likely be required and could be conducted in years 2, 7 and every 10 years after. The effectiveness monitoring would most likely consist of quantitative electrofishing in a subset of the restored habitat to monitor biomass again this could be conducted in years 2, 4 and 8 with an option for year 10 if biomass has not attained a minimum of 40 kg ha by year 8. In the culvert replacement scenario effectiveness monitoring ideally would conduct salmonid biomass estimates in a selected number of the upstream lakes. This could be conducted every 5 years given the slow rate of expansion expected. The compliance monitoring in this case would be relatively simple and consist of visual inspection of the new culverts to ensure they are not failing or are blocked by debris.

Table 4: Calculation of service gains using culvert restoration to gain lake habitat as the offset (based on one lake with a surface area of 30 ha).

Year	Biomass (kg) A	Service Gain B	Discount (3% yr^{-1}) C	Discounted Resource gain (A*B*C)
1	60	0	1.00	0.0
2	60	0.02	0.97	1.2
3	60	0.04	0.94	2.3
4	60	0.06	0.92	3.3
5	60	0.08	0.89	4.3
6	60	0.1	0.86	5.2
7	60	0.12	0.84	6.0
8	60	0.14	0.81	6.8
9	60	0.16	0.79	7.6
10	60	0.18	0.77	8.3
100	60	1.0	0.05	3
Total				953

DISCUSSION

The concept of equivalence can be seen as in integral part of the mitigation hierarchy if ‘no net loss’ of the service being managed is a policy goal (Quetier and Lavorel 2011). This is the case for most offsetting policies currently in use worldwide. There are several methods to analyze equivalence described in the literature but most utilize a service-to-service or resource-to-resource approach which aims to maintain ecological integrity thus allowing the service or resource to persist through time. There are also economic methods to analyse equivalence that have not been extensively covered in this review. These economic methods can either use a value-to-value or a value-to-cost approach (see Lipton et al., 2008 for descriptions) but are generally only used to analyse equivalence if an ecological approach is deemed inappropriate (e.g., the impact cannot be offset for technical reasons). Economic approaches to equivalence are also currently considered to be cost-prohibitive as there is a limited database of values that can be used in a benefits transfer which means that original economic research is required to calculate these values on a case by case basis (Roach and Wade 2006).

In its simplest form the calculation of equivalence can be viewed as balancing a mathematic equation with impact losses on the one side and potential offset gains on the other (Allen et al., 2005; NOAA 2006). This has actually been used to advantage in the court system of the USA when calculations derived by the HEA methodology were disputed (Allen et al., 2005). While the actual calculation does not incorporate uncertainty it must be recognized that many of the inputs on both sides do. If these uncertainties and risks are multiplicative then the offset ratios required to achieve equivalence quickly become large (Minns 2006, Moilanen et al., 2009) and they would be impractical to implement (Overton et al., 2013). Current best practices suggest dealing with these uncertainties and risks individually with a wide variety of management options (Overton et al., 2013). For example time lags could be included directly in the equivalence calculation as in our hypothetical example or a standard offset ratio such as 2:1 could be applied as suggested by Minns (2006).

The calculation of equivalence within an offsetting policy can have many benefits. As can be seen from the hypothetical example it allows for differing offsetting options to be explored utilizing a resource based metric. This provides the proponent with greater flexibility with respect to offsetting. When conducted as in our example, they also provide costing and inform monitoring requirements. One of the main criticisms of these calculations however is that they require detailed knowledge and data of the resource being managed (Dunford et al., 2004). In our example there was enough published information to develop regional benchmarks but this may not always be the case. When inputs cannot be derived from the literature, expert panels can be used or local data may be required to be collected.

Finally the science of equivalence is still relatively young. Although HEA was introduced in 1990 many of the primary publications discussing its use appear after the mid 2000’s. With the current move towards biodiversity offset programs throughout the world (e.g., BBOP 2012, ICMM 2013), equivalence analyses are bound to be a topic of study and refinement. Coupled with this empirical examples where equivalence was calculated and monitoring was conducted will be published and help refine our knowledge on the uncertainties associated with offsetting and equivalence. Therefore any equivalence methodology used for fisheries protection in Canada should be subject to periodic review and refinement.

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