A comparison of the areal extent of fish habitat gains and losses associated with selected compensation projects in Canada

ABSTRACT

We conducted a review of studies that evaluated the effectiveness of fish habitat compensation projects in achieving the conservation goal of no net loss of productive capacity of fish habitat in Canada. Combined, the 103 compensation projects assessed in the 10 studies created and/or restored 493,205 m^2 of fish habitat to offset habitat impacts totalling 1,142,648 m^2. Most of the compensation projects assessed were a result of impacts to estuarine and riverine in-channel habitats. Forestry and urban development activities resulted in the greatest percentage of compensation projects. Overall, 64% of the projects were deemed to have achieved no net loss. Fifty percent of the projects had a compensation ratio (compensation area:impacted area) of less than 1:1. The small number of studies found in the literature suggests that performance evaluations are rarely conducted, limiting our ability to practice adaptive management. We advocate that a national monitoring program be developed through which the achievement of no net loss can be assessed on an ongoing basis.

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Introduction

To counter the negative impacts that development activities were having on fish habitat, the government of Canada amended Canada's Fisheries Act in 1976 to include physical habitat protection provisions that prohibit the harmful alteration, disruption, and destruction (HADD) of fish habitat, unless authorized by the Minister of Fisheries and Oceans Canada (DFO). In 1986, DFO implemented the Policy for the Management of Fish Habitat (the Habitat Policy) to support the physical habitat provisions of the Fisheries Act. The Habitat Policy, the cornerstone of DFO's fish habitat management program, states that DFO's long-term objective is "the achievement of an overall net gain of the productive capacity of fish habitats." This objective is to be achieved by meeting the Habitat Policy's goals: (1) fish habitat conservation, (2) fish habitat restoration, and (3) fish habitat development (DFO 1986).

To achieve the conservation goal, DFO applies the Habitat Policy's guiding principle of no net loss (NNL) when proposed development projects have the potential to result in a HADD and a net loss of the productive capacity of fish habitat. Under this principle, DFO requires the proponent to relocate or redesign the proposed development to avoid the potential HADD or to fully mitigate any impacts the proposed development may have on fish habitat (DFO 1986, 1998). If the HADD cannot be avoided or fully mitigated, DFO will then authorize the HADD under Section 35(2) of the Fisheries Act if it is deemed acceptable. To achieve NNL, DFO will require the proponent, through the legally binding authorization, to compensate for the unavoidable losses of productive capacity of fish habitat that result from the HADD. The proponent typically is required to create or restore habitat to compensate for the losses according to DFO's hierarchy of preferences (DFO 1986, 1998). The hierarchy includes a range of compensation options from the most preferred option of creating or restoring like habitat at or near the development site to the least preferred option of artificial propagation. Furthermore, the proponent typically is required to conduct follow-up monitoring to assess the effectiveness of the compensation measures taken to conserve the productive capacity of fish habitat. Follow-up monitoring is intended to allow both the proponent and DFO to take an adaptive approach to habitat compensation.

Since the implementation of the Habitat Policy in 1986, DFO has authorized more than 2,500 HADDs across Canada, resulting in the implementation of thousands of compensation projects (DFO 2003). While the Habitat Policy "provides objective statements against which the department can measure its performance in fish habitat management" (DFO 1986), few evaluations of the performance of these compensation projects in achieving NNL have been conducted (Cudmore-Vokey et al. 2000). The importance of evaluating whether these compensation projects are achieving NNL has been recognized by the Auditor General of Canada (1997), the Standing Committee on Public Accounts (1998), and DFO itself (Lange et al. 2001). In response, a national evaluation program designed to assess the performance of compensation projects in achieving NNL was initiated in 2000. As part of this program, we compiled and reviewed all of the studies in the peer-reviewed and grey literature that have assessed habitat compensation projects to determine their success in achieving NNL. We provide an indication of the types of projects that have been assessed in Canada, what habitats have been affected, and what habitat management approaches have been used when compensating for HADDs and monitoring the success of the compensation works. We also provide a synopsis of proponent compliance with authorization requirements and the number of habitat compensation projects achieving NNL.

Methods

Literature Collection

We searched for studies conducted between 1986 and 2002 that evaluated the effectiveness of habitat compensation projects in achieving NNL using the Aquatic Sciences and Fisheries Abstracts (ASFA) database and the WAVES database. WAVES contains bibliographic information on peer-reviewed and grey literature relating to fisheries and aquatic sciences in DFO libraries. Government reports were also collected from regional DFO offices across Canada.

Data Extraction

For each of the compensation projects assessed by the studies, we recorded the project's location, the development activity (e.g., mining, forestry) and construction work(s) (e.g., culvert installation) that resulted in the HADD, the HADD areas, the compensation areas, the compensation option used, and the duration of the post-construction monitoring program. The time that had elapsed between the implementation of the compensation projects and their evaluation by the studies was also recorded.

The fish habitats affected by the HADD and the compensation were grouped into six habitat categories: riverine in-channel, riverine off-channel, lacustrine, estuarine, marine, and riparian. For each project, we recorded both the total HADD and compensation areas and the HADD area and compensation area within each habitat category. The compensation ratio, the total compensation area relative to the total HADD area, was also calculated.

From each study, we recorded whether the proponent was compliant with the compensation requirements stipulated within an authorization (e.g., did the proponent construct the compensatory habitat?) and whether the compensation project achieved NNL. These determinations were made by the authors of the studies. Many of the NNL determinations were based solely on a comparison of the area of the habitat impacted as a result of the HADD and the area of the habitat gained through compensation. For these projects, the productive capacity of the impacted habitat was assumed to be zero, and the habitat created or restored as compensation was assumed to be fully functional.

The type of assessment each compensation project received in order to make a determination on whether it achieved NNL was categorized as either a file assessment, a compliance assessment, an effectiveness assessment, or a research assessment.

A file assessment consisted of an office review of the compensation project files, including pre-impact assessments, Fisheries Act section 35(2) authorization, and post-construction monitoring reports. A field evaluation of the compensation project was not undertaken in a file assessment. Compensation compliance and effectiveness were typically determined based on a review of the post-construction monitoring reports.

A compliance assessment consisted of a field assessment of the compensation project that included measurements of the HADD and/or compensation areas and verification of the proponent's compliance with the compensation measures within the Fisheries Act section 35(2) authorization.

An effectiveness assessment consisted of a field assessment that included areal measurements of the HADD and compensatory habitats and estimates of their productivity per unit area, usually determined by sampling a suite of ecological indicators such as invertebrate densities, fish biomass and densities, and riparian and aquatic vegetation growth rates. Pre- and post-construction comparisons of the physical areas and habitat productivities of the impacted habitats (or reference habitats representing the HADD habitats) and the compensatory habitats typically were conducted.

A research assessment consisted of a field assessment of the compensation project that utilized an experimental design. Ecological indicators of habitat productivity within the HADD habitats (or reference habitats representing the HADD habitats) and the compensatory habitats were sampled for several years before and after the construction of the compensation project.

Data Summaries

Data extracted from each study were pooled and descriptive statistics, including mean ± 1SE, median, maximum, and minimum, were generated to summarize and describe the HADD areas, compensation areas, monitoring durations, and the time that had elapsed between the implementation of the compensation projects and their evaluation by the studies. We used a linear regression to examine the relationship between HADD areas and compensation areas. Raw data were log(x+1) transformed to meet assumptions of parametric tests. We used an analysis of covariance (ANCOVA) to determine if the regression line was significantly different from the line representing compensation area=HADD area. All tests were considered significant at $P \leq 0.05$. All statistical analyses were performed using SAS (SAS Institute 2001).

Results

Survey of Studies

We found 10 studies containing 109 NNL assessments of 103 compensation projects (Table 1). The projects comprise 4.0% of those authorized during the study period (DFO 2003). One study was national in scope. The other 9 were distributed among three provinces: British Columbia (7), Ontario (1), and Newfoundland (1). Eight of the studies were published as government reports and 2 were published as journal articles. Of the 109 assessments conducted by the 10 studies, 96 were a combination of file reviews and compliance assessments, 12 were effectiveness assessments, and 1 was research. The average amount of time that had elapsed between the construction of the compensation projects and their evaluation by the studies was 4.2 years (max: 12; min: 1; n = 99; could not be determined for 4 projects). Several studies assessed compensation projects that were specific to certain development activities, habitat categories, or compensation techniques.

Project Details

The 103 compensation projects assessed by the studies resulted from 9 types of development activities and 23 types of construction works. The development activities that were associated with the greatest percentage of compensation projects assessed by the studies included urban development (23%), forestry (20%), private land development (20%), and roads and highways (16%). Of the 23 construction works identified, bank stabilization (17%), log handling facilities (13%), dock installations (7%), and channel relocations (7%) were associated with the greatest percentage of compensation projects.

Together, the compensation projects created and/or restored 493,205 m^2 (N = 96) of fish habitat to offset HADDs totalling 1,142,648 m^2 (N = 95). For 8 compensation projects, HADD areas were not quantified. Compensatory habitat areas were not quantified for 7 compensation projects. The mean HADD and compensation area per project was 12,025.2 m^2 (SE = 5,627.6) and 5,137.6 m^2 (SE = 1776.4), respectively. For one compensation project the HADD did not occur (even though the compensatory habitat was constructed). For seven compensation projects the compensatory habitat no longer existed or had not been constructed (although the HADD had occurred). Eighty-six percent of the HADD and compensation areas were less than 1 ha. The mean HADD and compensation areas less than 1 ha were 1,684.1 m^2 (SE = 250.4; n = 82) and 1,310.8 m^2 (SE = 198.2; n = 83), respectively.

Table 1. Survey of studies conducted in Canada. The total number of assessments conducted within the 10 studies was 109; however, 6 compensation projects were assessed twice by different studies. Therefore, the total number of compensation projects assessed was 103.

Reference	Location of study	Publication type	Assessment type	Projects assessed
Azimuth Environmental Consulting Inc. (2002)	Ontario	Government report	File review & compliance	14
D. Tripp Biological Consultants Ltd. (2003)	British Columbia	Government report	File review & compliance	3
DFO (1997)	British Columbia	Government report	File review	2
G3 Consulting Ltd. (2000)	British Columbia	Government report	File review & compliance	14
Kistritz (1996)	British Columbia	Government report	File review & compliance	31
Lange et al. (2001)	Canada	Government report	File review	32
Lister (1992)	British Columbia	Journal article	Effectiveness	2
Lister and Bengeyfield (1998)	British Columbia	Government report	Effectiveness	2
Precision Identification Ltd. (2002)	British Columbia	Government report	Effectiveness	8
Scruton (1996)	Newfoundland	Journal article	Research	1

Table 2. The frequency and total area of HADDs and compensation within each habitat as a result of the 103 compensation projects.

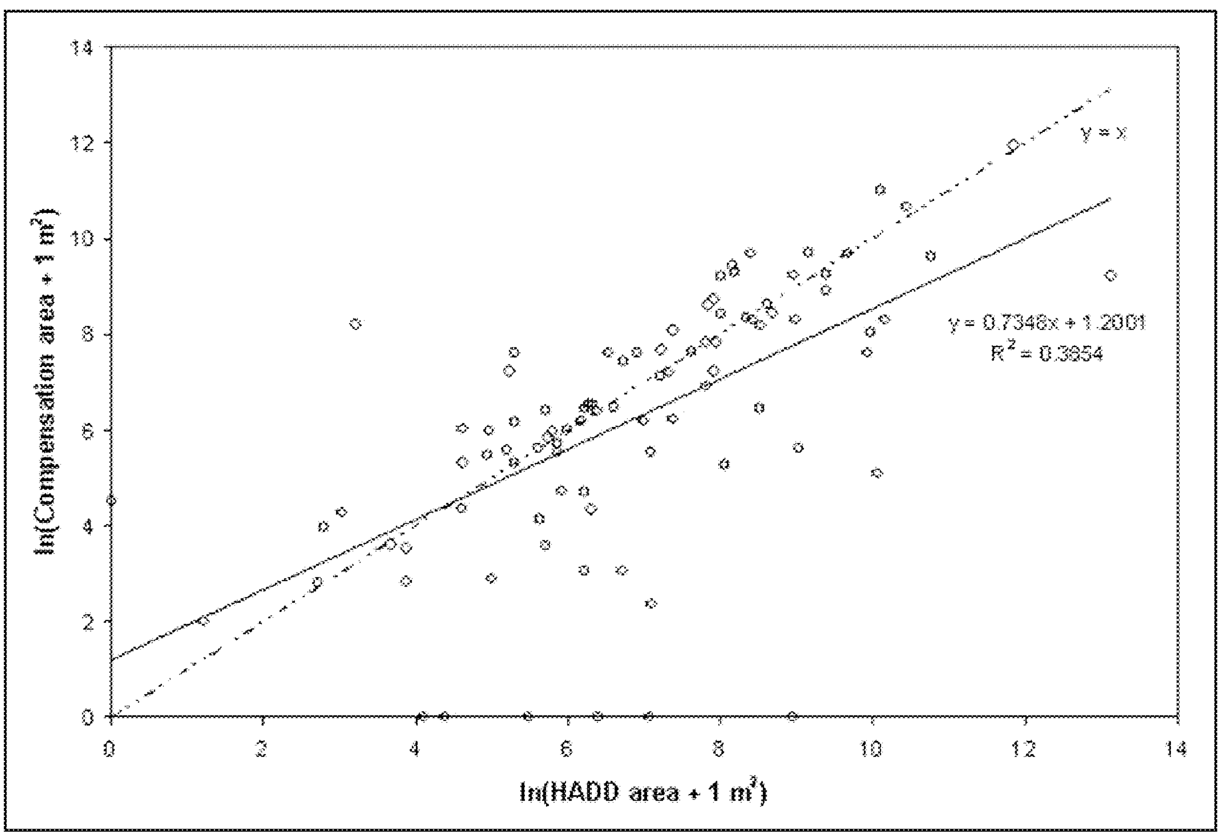
	Frequency		Area (m^2)		
Habitat categories	**HADD**	**Compensation**	**HADD**	**Compensation**	**Balance (m^2)**
Riparian	14	9	9,709	11,077	1,368
Riverine in-channel	24	25	182,699	44,225	-138,474
Riverine off-channel	1	4	1,283	17,389	16,106
Lacustrine	13	11	31,903	60,463	28,560
Estuarine	57	49	271,340	348,892	9,552
Marine	19	11	577,464	11,916	-565,548
Total	**95**	**96**	**1,142,398**	**493,205**	**-649,193**

The majority of the compensation projects assessed by the studies were the result of HADDs in estuarine and riverine in-channel habitats (Table 2). The riverine in-channel and marine habitat categories sustained negative habitat balances as a result of the 103 projects. The largest habitat impact from a single project occurred in the marine habitat category. This project's HADD negatively impacted 505,000 m^2 of marine habitat, and accounted for 44% of the total HADD area for the 103 projects. The riparian, riverine off-channel, lacustrine, and estuarine habitat categories sustained net gains in habitat area as a result of the 103 projects. The largest gain in area (154,300 m^2) from a single project occurred in the estuarine habitat category, representing 31% of the total habitat gained through compensation.

Compensation ratios could be deduced for 92 of 103 compensation projects (Figure 1). Of these, 46 had HADD areas that were greater than the compensation areas (i.e., a compensation ratio of less than 1:1), 37 had compensation areas that were greater than the HADD areas, and 9 had compensation and HADD areas that were equal. There was a direct and significant relationship between HADD areas and compensation areas (R^2 = 0.38; $F_{1,90}$ = 56.45, P < 0.0001), and the slope of that relationship was significantly different from 1 (ANCOVA; $F_{1,181}$ = 7.43; P = 0.0007). Figure 1 indicates that projects with HADD areas greater than 95 m^2 were generally being compensated for at a rate of less than 1:1. Projects with HADD areas less than 95 m^2 were generally being compensated for at a higher rate than 1:1.

The distribution of compensation options closely followed DFO's hierarchy of preferences with most projects involving the creation of like-for-like habitat as compensation (Table 3). The second and third compensation options in the hierarchy, increasing like-for-like habitat productivity and creating unlike habitat, were each used in 29 projects. The least preferred hierarchy option artificial propagation was used as a compensation option for only one project. One of the projects used a compensation option that was outside of the Habitat Policy's hierarchy of preferences. In this instance, guidelines were to be developed as compensation for a HADD resulting

Figure 1. Compensation areas as a function of HADD areas for 92 compensation projects. Eleven compensation projects were not included because HADD and/or compensation areas could not be quantified from the studies. The hatched line on the figure represents compensation area = HADD area (i.e., a compensation ratio of 1:1). The slopes of the lines were significantly different from each other (ANCOVA; $F_{1,181}$ = 7.43; P = 0.0007).



from road construction. Seventeen of the 103 projects used 2 compensation options when compensating for HADDs.

Of the 103 projects assessed, post-construction monitoring of the compensatory habitat was required for 52 of the projects. Another 29 projects did not require monitoring. For 22 of the projects, it could not be determined whether monitoring was required. Of the 52 projects that required monitoring, the mean duration of the monitoring period was 3.6 years (SE = 0.4). The maximum monitoring period was 15 years and the shortest monitoring period was 1 year.

Of the 103 projects assessed, 86 were found to be compliant with their authorizations, and 66 were determined to have achieved NNL. Of those that were deemed to have achieved NNL, 39 had compensation ratios of 1:1 or greater, 20 had compensation ratios of less than 1:1, and for 7 projects, the compensation ratios could not be quantified.

Discussion

One of the principle findings of our work is that half of the compensation projects assessed had compensation areas that were smaller than the HADD areas, leaving an estimated 65 hectares of impacted fish habitat uncompensated. More than a third of the compensation projects assessed by the 10 studies were determined not to have achieved NNL. It is clearly difficult to achieve NNL when replacing only a fraction of the habitat lost on a project-by-project basis. This should be cause for concern as these results stem from only 4% of the total number of projects that have been authorized under the Fisheries Act (DFO 2003).

While over half of the compensation projects were deemed to have achieved NNL, the reported percentage should be interpreted cautiously since most of the NNL determinations made by the studies were based on the results of qualitative file reviews and compliance assessments. Few of the NNL determinations were based on the quantification of the net change in productive capacity as a result of the compensation project, and in many instances, the productive capacity of the impacted habitat was assumed to be zero, and the habitat created or restored as compensation was assumed to be fully functional. It should also be noted that even if proponents are fully compliant with the compensation requirements of an authorization, this does not guarantee that the compensatory habitat will achieve an equivalent or greater productive capacity than what was lost as a result of the HADD. Studies in the United States examining the effectiveness of wetland compensation projects in achieving NNL under Section 404 of the Clean Water Act have documented that compliance with wetland compensation requirements rarely results in ecological functionality or viability of the compensation (Ambrose 2000; NRC 2001).

Our results demonstrate that a compensation ratio of 1:1 was not achieved for half of the projects assessed. The required compensation ratio for most of these projects likely was 1:1 or greater, but due to proponent non-compliance with the requirements of the authorization or failure of the compensation over time (e.g., in-filling of a channel), the actual compensation ratio when assessed was less than 1:1. The Practitioners Guide to Habitat Compensation for DFO Habitat Management Staff (DFO 2002) suggests that practitioners should aim for greater than a 1:1 compensation ratio due to the uncertainty of success of habitat compensation, the variability in the quality of the fish habitat being replaced, and recognition of the lag time required for the compensatory habitat to become functional. This is sound conservation policy, but Minns and Moore (2003) go further and argue that a minimum compensation ratio of 2:1 should be required when replacing like habitat until the uncertainties associated with measuring the productive capacity of existing and created habitats can be greatly reduced from current levels. Given our findings and the uncertainties associated with measuring productive capacity, resource managers should consider adopting a precautionary approach and increasing minimum required ratios to 2:1 to increase the likelihood that NNL of productive capacity will be achieved.

Creation of like-for-like habitat was the compensation option most frequently selected. This

Table 3. The number of projects employing a given compensation option from DFO's hierarchy of preferences. Options are in order of decreasing preference.

Hierarchy option	Number of projects
Creation of like-for-like habitat in the same ecological unit to benefit affected populations	49
Increase like-for-like productivity in the same ecological unit to benefit affected populations	29
Create unlike habitat in the same ecological unit to benefit affected populations	29
Increase unlike habitat productivity in the same ecological unit to benefit affected populations	2
Create or increase habitat in a different ecological unit to increase the productivity of a different population of the same species	8
Create or increase habitat in a different ecological unit to increase the productivity of different species	1
Utilize artificial production techniques in rare circumstances to maintain a stock of fish	1
Other	1

result was expected as creation of like-for-like habitat is the first option in DFO's hierarchy of preferences. Negative habitat balances still occurred in two of the six habitat categories possibly due to the selection of compensation options such as the creation or restoration of unlike habitat which may have resulted in a gain in one habitat category at the expense of another. Indeed, habitats perceived by natural resource managers to have lower value (e.g., subtidal habitat) have been demonstrated to incur larger relative losses than others (e.g., inter-tidal marsh habitat) (Kistritz 1996). Potentially subjective habitat value determinations made by resource managers when selecting a compensation option such as the creation of unlike habitat could result in unforeseen cumulative effects and difficulties in maintaining biodiversity, although consideration of unlike habitat compensation has been lauded in cases where limiting factors have been addressed (NRC 2001). Systematically tracking gains and losses within each habitat category, both regionally and nationally, would allow resource managers to manage habitat more proactively and ensure that positive habitat balances and biodiversity are maintained.

We found that post-construction monitoring was not required for over a quarter of the projects, and when monitoring was required, it was typically short in duration. Post-construction monitoring of compensation projects represents one of the only opportunities for resource managers to gauge the effectiveness of their habitat management actions and the effectiveness of habitat compensation in achieving NNL. Quantitative pre- and post-construction monitoring should be a requirement of every compensation project to ensure adaptive management occurs. Moreover, consideration should be given to increasing the duration of post-construction monitoring periods beyond the mean of 3.6 years found in this study. The temporal scale of an ecosystem response to a habitat alteration is typically greater than the scales of human interventions and assessment (Minns et al. 1996). When deciding on the duration of post-construction monitoring, resource managers should consider the time required to detect a response from a given habitat alteration, the longevity of a given restoration or creation technique, and the probability and variability of its success (Roni et al. 2002). Most compensatory habitats will require 5 to 20 years of monitoring before their long-term functionality and sustainability can be ascertained (Kondolf and Micheii 1995; NRC 2001; Roni et al. 2002).

Finally, in reviewing the literature, it is apparent that few studies evaluating the performance of habitat compensation in achieving the Habitat Policy's conservation goal of NNL have been conducted in Canada. While the implementation of the Habitat Policy in 1986 did lead to an increase in scientific research relating to fish habitat and fish ecology (Minns 2001), there has not been a corresponding increase in scientific studies examining the effectiveness of habitat compensation measures and habitat management decisions taken to conserve fish habitat. Instead, research relating to the Habitat Policy and habitat compensation has been focused primarily on developing scientific frameworks to determine how a given habitat manipulation will affect the productive capacity of fish habitats (Jones et al. 1996) or how to assess the net change in the productive capacity of fish habitats affected by development activities and associated compensation projects (Minns et al. 1995; Minns 1997, 2001; Minns and Moore 2003).

Of the studies that have been conducted, many employed qualitative methodologies (e.g., file reviews and compliance assessments) rather than quantitative methodologies (e.g., effectiveness assessments) when evaluating the compensation projects. That is, they based their conclusions on the effectiveness of the compensation projects on best professional judgement or indirect data sources rather than collecting and statistically interpreting numeric data (Mason 2002). While the degree of rigor and the methods employed in each study were likely commensurate with available resources, the qualitative information provided by these studies limits the extent of inferences that can be drawn from them. The lack of quantitative studies evaluating the performance of habitat compensation projects in achieving NNL is cause for concern as it unquestionably constrains DFO's ability to adaptively manage its habitat management program. Management actions, including fish habitat compensation projects, should be treated as experiments such that a heuristic approach to habitat management can be adopted (Minns et al. 1996). This will enable DFO to adjust its management approaches and tools based on knowledge gained through these experiments so that future management actions can better conserve fish habitat and ensure the protection of our fish species. Resource managers and scientists clearly need to start working together to develop a scientifically-based national monitoring program through which the effectiveness of management actions taken to protect and conserve fish habitat, including fish habitat compensation measures, can be ascertained on a continual basis.

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