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Compliance with Canada's *Fisheries Act*: A Field Audit of Habitat Compensation Projects

JASON T. QUIGLEY*
Oceans, Habitat and Enhancement Branch
Fisheries and Oceans Canada
Suite 200, 401 Burrard Street
Vancouver, BC, Canada, V6C 3S4

DAVID J. HARPER
Habitat Policy and Regulatory Affairs
Fisheries and Oceans Canada
Suite 12E, 200 Kent Street
Ottawa, ON, Canada, K1A 0E6

ABSTRACT / Loss of fish habitat in North America has occurred at an unprecedented rate through the last century. In response, the Canadian Parliament enacted the habitat provisions of the *Fisheries Act*. Under these provisions, a "harmful alteration, disruption, or destruction to fish habitat" (HADD) cannot occur unless authorised by Fisheries and Oceans Canada (DFO), with legally binding compensatory habitat to offset the HADD. The guiding principle to DFO's conservation goal is "no net loss of the productive capacity of fish habitats" (NNL). However, performance in achieving NNL has never been evaluated on a national scale. We investigated 52 habitat compensation projects across Canada to determine compliance with physical, biological, and chemical requirements of Section 35(2) *Fisheries Act* authorisations. Biological requirements had the lowest compliance (58%) and chemical requirements the highest (100%). Compliance with biological requirements differed among habitat categories and was poorest (19% compliance) in riparian habitats. Approximately 86% of authorisations had larger HADD and/or smaller compensation areas than authorised. The largest noncompliance in terms of habitat area occurred in riverine habitat in which HADDs were, on average, 343% larger than initially authorised. In total, 67% of compensation projects resulted in net losses of habitat area, 2% resulted in no net loss, and 31% achieved a net gain in habitat area. Interestingly, probable violations of the *Fisheries Act* were prevalent at half of the projects. Analyses indicated that the frequency of probable *Fisheries Act* violations differed among provinces. Habitat compensation to achieve NNL, as currently implemented in Canada, is at best only slowing the rate of habitat loss. In all likelihood, increasing the amount of authorised compensatory habitat in the absence of institutional changes will not reverse this trend. Improvements in monitoring and enforcement are necessary to move towards achieving Canada's conservation goals.

Loss of fish habitat, a leading factor in the decline of Canada's fisheries resources (Beamish and others 1986; Pearse 1988), has occurred at an unprecedented rate through the last century. For example, in the world's premiere salmon-producing watershed, the Fraser River (Levy 1992), approximately 90% of the fish habitat in the lower watershed has been lost during the 20th century (Levings and Nishimura 1996). Human population growth, and the concomitant increase in landscape development, is likely a key factor in this downward trajectory (Lackey 2001). Indeed, there is a striking negative relationship between wild salmon populations and human population density (Hartman and others 2000).

In response to this habitat loss, the Canadian Parliament enacted the habitat provisions of the *Fisheries Act* in 1976, which effectually made the *Fisheries Act* one of the strongest pieces of environmental legislation in Canada. A "harmful alteration, disruption, or destruction to fish habitat" (HADD) cannot occur unless authorised via Section 35(2) of the *Fisheries Act* by Fisheries and Oceans Canada (DFO) (see Goodchild 2004 for detailed overview). Implementation of Section 35(2) of the *Fisheries Act* is guided by the *Policy for the Management of Fish Habitat* (DFO 1986) (hereafter the Habitat Policy), the cornerstone of DFO's habitat management program, which states that the guiding principle to DFO's conservation goal is "no net loss of the productive capacity of fish habitats" (NNL). If a proposed development project (e.g., mine development, highway construction, etc.) is deemed to result in a HADD after project relocation and redesign have

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*Author to whom correspondence should be addressed; *email:* jason.quigley@ceaa-acee.gc.ca

been considered, DFO will only issue a *Fisheries Act* authorisation if NNL can be achieved through the construction of compensatory habitat to offset the residual impacts from the development project. The amount and type of compensation habitat required is guided by national policy that recommends a minimum compensation ratio of 1:1 and a hierarchy of compensation options, with like-for-like habitat at the site as the most preferred option (DFO 1986, 2002). An authorisation legally binds the proponent to design, develop, monitor, and maintain the compensation habitat.

Systematic, quantitative, and independent evaluations of DFO's performance in achieving NNL through compensation habitat have rarely been undertaken. In fact, since the inception of the Habitat Policy, more than 2500 authorisations have been issued yet only 103 compensation projects have been evaluated to determine their performance in achieving NNL (Harper and Quigley 2005a). In a national study, Drodge and others (1999) documented that DFO's habitat management staff allocate 1.7% of their workload to compliance monitoring. Consequently, the long-term success rates and efficacy of fish habitat compensation projects are not well known (DFO 1997; Lister and Bengeyfield 1998; Lange and others 2001).

The few evaluations of compensation habitat that have occurred have indicated that proponent compliance with the authorisation's requirements has been poor (Harper and Quigley 2005a). Postconstruction monitoring is a legally binding requirement of proponents in virtually all fish habitat compensation projects, yet it is completed less than 43% of the time (Harper and Quigley 2005b). Even when completed, monitoring requirements are generally superficial, resulting in qualitative reports that simply document that compensation was completed (e.g., photographic record) (Goodchild 2004), rather than provide measurable indices of whether the compensation project achieved NNL. Compliance with authorisation requirements cannot be gleaned from monitoring programs in many instances (Harper and Quigley 2005b). Moreover, bias can be introduced into monitoring conducted to evaluate the success of compensation projects because self-assessments are often completed by proponents with an invested interest in the outcome, and in many cases by the same individuals involved in the design. Such a systemic lack of effective monitoring has likely constrained DFO's ability to adaptively manage its habitat management program.

The importance of an ongoing evaluation of DFO's performance in achieving the objectives of the Habitat Policy has been recognised by the Auditor General of Canada (Government of Canada 1997), the Standing Committee on Public Accounts (Government of Canada 1998), and DFO itself (Lange and others 2001). It is critical for regulatory agencies to conduct evaluations of the performance of such core policies in order to build on their successes and learn from past mistakes to be able to improve habitat conservation for the future. In this article, we describe a field audit of fish habitat compensation projects across Canada that was conducted to determine compliance with physical, biological, and chemical requirements of Section 35(2) *Fisheries Act* authorisations. Specifically, our objective was to quantify the achievement of NNL in the field and investigate factors related to noncompliance in order to suggest improvements to habitat conservation practices.

Methods

All authorisations issued between 1994 and 1997 were collected from five provinces: British Columbia, Manitoba, Ontario, New Brunswick, and Nova Scotia. Geographic stratification into five provinces ensured a mixture of coastal and interior regions of Canada (Figure 1). A subset of the authorisations were then selected randomly from each province. Field audits were completed from May to October of 2000 and 2001; therefore, the projects had a postconstruction age range of 4 to 8 years. Authorisations were partitioned based on the type of fish habitat that had been impacted by the HADD. The habitat categories included riverine (both in-channel and off-channel fluvial habitat), standing water (marine, estuarine, and lacustrine habitat), and riparian. A hierarchy of compensation options, from most to least preferred, that compare the habitat type and ecological unit of compensation habitat relative to the impacted habitat is provided in the Habitat Policy (DFO 1986, 1998). We described compensation projects based on a modified hierarchy of preferences. This included three basic classifications: (1) like for like habitat: create similar habitat at or near the site in the same ecological unit (e.g., replace off-channel habitat with off-channel habitat); (2) like for unlike habitat: create or increase the productivity of unlike habitat in the same ecological unit (e.g., replace in-channel habitat with off-channel habitat); and (3) increasing like habitat productivity: increase the productivity of like habitat at or near the site (e.g., enhance existing in-channel habitat to compensate for in-channel habitat loss). Ecological unit was defined as "populations of organisms considered together with their physical environment and the interacting processes amongst them" (DFO 2002a).

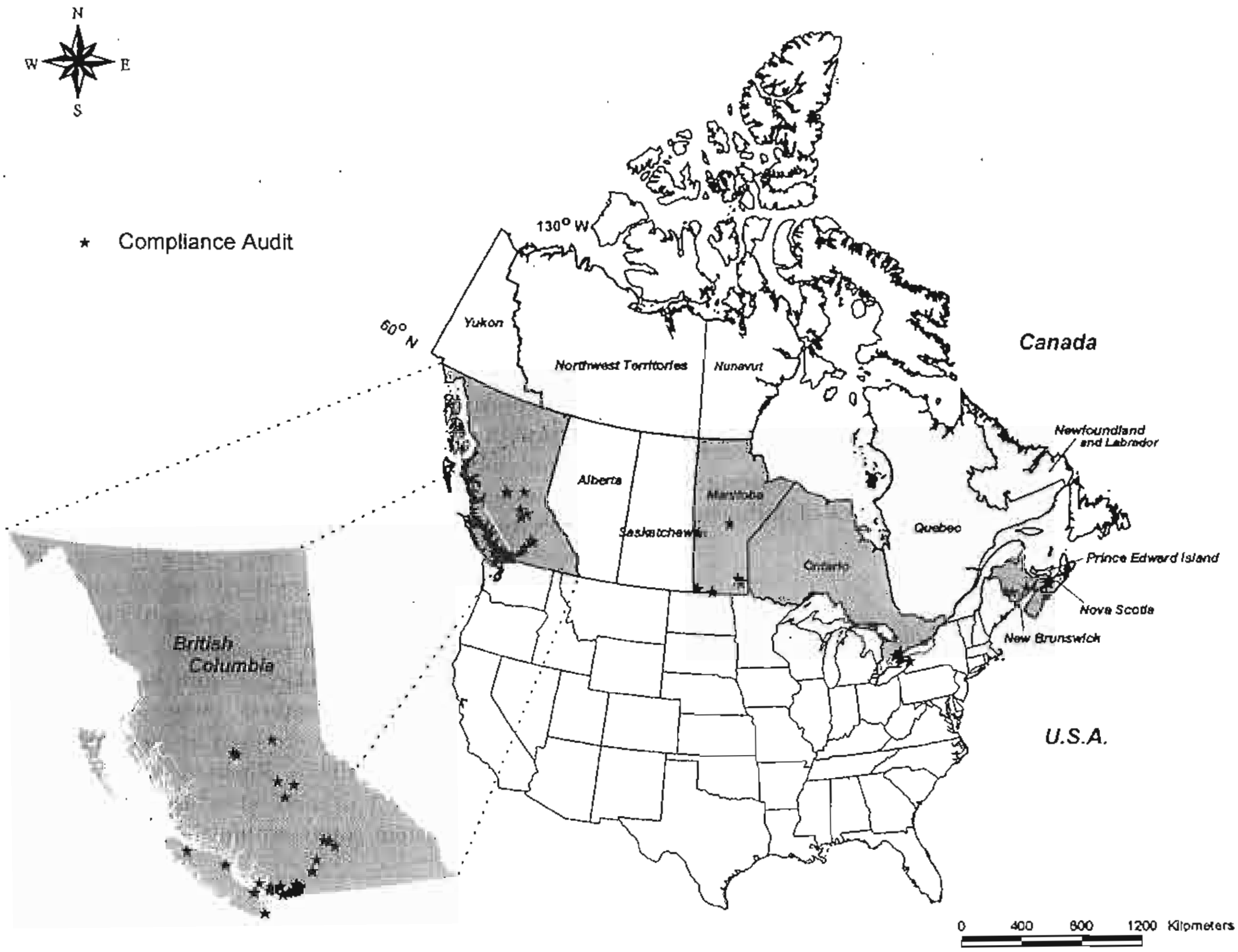

Figure 1. Location of compliance audits across Canada ($n = 52$).

Field Methods

The legally binding requirements in each authorisation were partitioned into the following categories. Compliance with each requirement was audited in the field.

HADD Area Requirements

Requirements in this category included the physical area (square meters) of each component of the authorised HADD (most projects specified HADD areas in multiple habitat categories). Many authorisations specified the HADD area both in writing and in a scale drawing appended for further detail. Scale drawings were digitised using AutoCad 2000i (Autodesk) to compare to written HADD areas. Preliminary review of the files indicated that in many cases, HADD areas described in writing and in scale drawings were inconsistent, thereby providing the proponent with greater latitude in interpreting the habitat area legally allowed to be destroyed. Discrepancies in HADD areas between scale drawings and the authorisation text were recorded as authorisation contradictions. During field audits of projects with authorisation contradictions, a noncompliant score was assigned only if the project's actual HADD area exceeded the larger of these two areas. In some cases, the HADD area was not clearly distinguishable during field audits. In these situations, the proponent was assumed to have been compliant and scored accordingly. A surveyor's chain was used for compliance measurements.

Compensation Area Requirements

The physical area (square meters) of each component of the authorised compensatory habitat was included in this category. The compensation areas were often specified both in writing and in a scale drawing.

AutoCad 2000i (Autodesk) was used to digitise scale drawings for comparison to written compensation areas. Preliminary review of the files indicated that compensation areas described in writing and in scale drawings were often not equivalent, thereby providing the proponent with a broader range of habitat area legally required for compensation. Discrepancies in compensation areas between scale drawings and the authorisation text were recorded as authorisation contradictions. During field audits of projects with authorisation contradictions, a noncompliant score was assigned only if the project's actual compensation area was smaller than the lesser of these two areas. A surveyor's chain was used for compliance measurements. Authorisations often specified a compensation ratio of habitat area to be created relative to destroyed. Field measurements allowed comparisons of authorised versus actual compensation ratios.

Construction Specifications

Construction specifications represent requirements in the authorisation that pertained to the construction and development of the HADD or compensatory works. These construction specifications indirectly influenced or mitigated impacts to fish and fish habitat. Requirements categorised as construction specifications included elevations of structures, channel gradients, culvert lengths, culvert widths, culvert characteristics (e.g., open vs. closed bottom), riparian buffer areas, and bank stabilisation specifications (e.g., size and characteristics of rip-rap). A surveyor's level and rod, surveyor's chain, and clinometre (Suunto PM-5) were used in accordance with their manufacturer's instructions for compliance measurements.

Habitat Features

Requirements in this category included specifications for habitat features that functioned to directly benefit fish and fish habitat. Examples of requirements in the habitat features category include in-channel habitat complexing with boulders or large woody debris, spawning gravel addition, pool and riffle creation, weirs, baffles, and fishways. Habitat features also included channel creation such as low flow channels, diversion channels, and off-channels. Presence, absence, and characteristics (number, dimensions) of habitat features were measured according to standard methodologies (Schuett-Hames and others 1994; RIC 1997).

Mitigation

The mitigation category included requirements designed to minimise impacts to fish and fish habitat during the construction period. Mitigation requirements typically included specifications to maintain water quality and prevent introduction of deleterious substances to fish habitat (e.g., water treatment ponds, silt fences, straw bales, rock-lined ditches, etc.). Often, mitigation requirements were not possible to evaluate because we audited projects many years after the construction period. However, in some cases evidence of mitigation existed at the time of the audit (e.g., presence of sediment and erosion control structures).

Biological

Requirements in the authorisations that were biological in nature were included in this category. These requirements included fish utilisation (different age-classes and life history stages), fish biomass and densities, benthic invertebrate re-colonisation, riparian re-vegetation (percent survivorship, stem density, diversity), and fish access. Water velocity was measured with a flow meter (Halltech FP 101, Guelph, Ontario) to evaluate potential for fish passage. Fish sampling was completed by electroshocking (Smith Root 12B) with the two-pass removal method (Seber and LeCren 1967). Surber samplers were used to measure macro-invertebrates (RIC 1997). Riparian vegetation was sampled in either 1 m^2 and 50 m^2 quadrats (Koning 1999) or total stem counts within the entire compensation area.

Chemical

The chemical category included requirements that specified particular water quality parameters such as water temperature, dissolved oxygen, and suspended sediment concentration. A portable digital meter (Hanna HI9143) was used for field measurements of temperature and dissolved oxygen (DO). Water samples (1l) were taken and suspended sediment concentration was determined in the laboratory by filtration.

Compliance Scoring

Authorisation requirements were often composed of many characteristics. Each characteristic of a requirement was evaluated separately in order to determine degrees of compliance. For example, a construction specification requirement for an open bottom culvert with a width of 3 m was evaluated as three requirements (culvert presence/absence, open vs. close bottom, width). If a given requirement was met or exceeded from a habitat conservation perspective (such as if the culvert width was greater than three metres), a score of 1 (compliant) was assigned. A noncompliant finding resulted in a score of zero. If a noncompliant finding rendered subsequent requirements unachievable (such as absence of the abovementioned culvert), these additional requirements (open-bottom, width) were not scored. An authorisation could not be scored noncompliant twice for the same requirement. We did not attempt to determine whether a noncompliant finding was due to failure over time or because the requirement was not completed initially. Either way, if the requirement was not met at the time of the audit, a noncompliance score was assigned. The mechanism of failure did not alter compliance scoring.

Compensation ratios (compensation area:HADD area) were investigated to determine whether some habitat categories were more difficult to compensate than others. The difficulty in compensating within each habitat category was characterised as a percentage failure rate (f) by subtracting from 1.0 the actual compensation ratio observed in the field (a) divided by the required compensation ratio in the authorisation (r) (*sensu* Robb 2002).

$$f = (1.0 - (a \div r)) \times 100$$

The ratio (q) necessary to overcome these failure rates and achieve the required compensation ratios was calculated by dividing the required ratio (r) by the failure rate (f) subtracted from 1.0.

$$q = r \div (1 - f)$$

A separate category, probable violations of the *Fisheries Act*, was used to categorise new, unforeseen HADDs (Section 35(1)), or introductions of deleterious substances to fish-bearing waters (Section 36(3)), that occurred outside the scope of the authorisation. Most findings of noncompliance with the requirements of an authorisation could in essence be considered a violation of the *Fisheries Act*. Therefore, in order to distinguish between noncompliance with a requirement and additional ecological impacts beyond the scope of the authorisation, these noncompliance findings were not included in this separate category. For example, if a given authorisation required 1000 m^2 of off-channel compensation habitat to be created and we measured the compensatory works to be 600 m^2, this would be recorded once as a noncompliant finding. However, if we discovered that construction crews had deposited multiple bags of concrete in the off-channel compensatory habitat, this incident, clearly outside the scope of the requirements in the authorisation, would be recorded as a probable violation.

Data Analyses

Descriptive statistics (mean ± 1 standard error (SE)) were used to summarise and describe the compliance results. Compliance with the HADD area and compensation area requirements was most often either 100% or zero. Therefore, logistic regression analyses were used to assess relations between compliance with the HADD area and compensation area requirements and the following independent variables: compensation project age (years), HADD area (m^2), compensation area (m^2), financial security per square meter of compensation habitat ($/$m^2$), total financial security ($), monitoring reports required (n), authorisation contradictions (n), monitoring compliance (Yes or No), DFO field inspection (Yes or No), development activity (roads/urban/other), habitat category (riverine, standing water, riparian), hierarchy of compensation preferences (1, 2, 3), and geographic region (West = BC; Central = MN, ON; East = NB, NS). We used analysis of covariance (ANCOVA) to determine whether compliance with habitat features, biological requirements, construction specifications, and number of probable violations was associated with the same independent variables (the covariates were the continuous variables and the factors were the class variables) as in the logistic regression analyses. After deleting nonsignificant independent variables, either regression analyses (for continuous variables) or analysis of variance (ANOVA) (for class variables) were used in the final model. Multiple comparisons of class variables were completed using Tukey's HSD test. For all analyses, a Shapiro–Wilk test statistic was used to test for normality, and data were visually inspected for homogeneous variances. Compliance data in the habitat features requirement category were square root transformed to minimise the effects of heterogeneous variances. Outliers (> 3 SD from the mean) were removed from calculation of the means (Sokal and Rohlf 1981). All tests were considered to be significant to a $P \leq 0.05$. Statistical analyses were completed using SAS statistical software, release 8.02 (SAS Institute 2001).

Results

A total of 52 authorisations and associated habitat compensation projects were audited across Canada in British Columbia ($n = 36$), Manitoba ($n = 5$), Ontario ($n = 4$), New Brunswick ($n = 3$), and Nova Scotia ($n = 4$) (Figure 1). This sample represents approximately 42% of the total number of authorisations ($N = 124$) issued in these provinces during 1994 to

Table 1. Mean number of requirements and the mean compliance in each requirement category per authorisation (n = 52)[a]

Requirement category	Mean number of requirements (n ± 1 SE)	Mean compliance (% ± 1 SE)
HADD area	1.9 ± 0.2	72 ± 13
Compensation area	2.1 ± 0.2	62 ± 13
Construction specifications	14.2 ± 3.3	74 ± 7.5
Habitat features	19.7 ± 4.4	71 ± 7.9
Mitigation	2.0 ± 0.5	77 ± 22
Biological	12.6 ± 2.9	58 ± 9.4
Chemical	0.2 ± 0.1	100 ± 0
Total	52.8 ± 7.5	n/a

[a]HADD, harmful alteration, disruption, or destruction to fish habitat.

Table 2. Mean HADD area and mean net balance (compensation area minus HADD area) per authorisation in each habitat category[a]

Habitat category	Mean HADD (m^2)	SE (m^2)	Max (m^2)	Min (m^2)	Mean net balance (m^2)	SE (m^2)	n
Riverine	3315.1	1119.5	31,300.0	10	−839.3	755.3	34 (32)
Standing water	5534.0	2400.0	24,500.0	490	4148.1	3499.7	10
Riparian	6632.2	1722.9	60,930.9	10	−3154.2	954.3	43
Total	8626.9	2090.3	92,230.9	40	−2103.1	1237.3	52 (50)

[a]HADD, harmful alteration, disruption, or destruction to fish habitat.
Note that two authorisations in the riverine category were removed as outliers in calculation of the mean net gain (sample size for net balance calculations indicated in parentheses).

1997 inclusive (excluding Ontario). The mean age of compensation projects was 4.4 years (SE = 0.3). Authorisations were a result of the following development activities: urban development (n = 19), roads and highways (n = 18), forestry (n = 6), industrial (n = 2), agriculture (n = 2), private land (n = 2), mining (n = 2), and oil and gas (n = 1). Many authorisations included HADDs in multiple habitat categories. The frequency of HADDs in each habitat category included: riverine (n = 37), standing water (n = 10), and riparian (n = 43). The mean number of requirements per authorisation was 52.8 (Table 1).

HADD Area Requirements

Mean compliance per authorisation with the HADD area requirements was 72% (Table 1). The total and mean HADD areas were 439,971 m^2 and 8626.9 m^2, respectively. The largest mean HADD area occurred in the riparian habitat category and the smallest occurred in the riverine habitat category (Table 2). Approximately 37% (19) of authorisations had larger HADD areas than authorised, and only 7.8% of authorisations had smaller HADD areas. The mean size of the larger HADD areas was not minor. On average, larger HADD areas were 234% greater than the authorised value. This difference was particularly noticeable for larger HADD areas that occurred in the riverine habitat category which, on average, were 343% larger than authorised (Table 3). In contrast, the mean difference for authorisations with smaller HADD areas was not nearly as great as projects with larger HADD areas. The mean size of the smaller HADD areas was 35% less than the authorised HADD areas (Table 3).

Compensation Area Requirements

Mean compliance per authorisation with the compensation area requirements was 62% (Table 1). The total and mean compensation areas were 1,037,086 m^2 and 8741.7 m^2, respectively; however, one authorisation had an exceptionally large compensation area that accounted for 600,000 m^2. Approximately 21% of authorisations had larger compensatory areas than authorised. In contrast, 71% of authorisations had compensation areas that were smaller than authorised. Larger and smaller compensatory works were 46% and 48% different, respectively, from authorised values (Table 3).

Net Balance

In total, 86% of the 52 authorisations had either larger HADD areas and/or smaller compensatory areas than authorised. Only 24% had smaller HADD areas and/or larger compensation than authorised. Authorisations that affected riparian habitat had the greatest noncompliance in terms of area. Approximately 91% (39) of authorisations in the riparian habitat category had larger HADD areas and/or smaller compensation than authorised.

Table 3. Mean size (m^2) of larger and smaller HADD and compensation areas[a]

Habitat category	Mean size (m^2)	Mean difference in area relative to authorisation (%)	N
Riverine	—	—	37
Larger HADD	34,586.8	343	8
Smaller HADD	670.9	33	2
Larger Compensation	350.8	101	9
Smaller Compensation	1818.7	50	15
Standing water			10
Larger HADD	3080.8	2934	1
Smaller HADD	904	16	1
Larger compensation	972.7	63	5
Smaller compensation	5634.2	22	5
Riparian	—	—	43
Larger HADD	1865.4	198	10
Smaller HADD	7730.2	47	3
Larger compensation	159.3	9.4	4
Smaller compensation	1718.6	49	25
Total	—	—	52
Larger HADD	3813.6	234	19
Smaller HADD	5420.2	35	4
Larger compensation	957.1	46	10
Smaller compensation	2727.8	48	34

[a]HADD, harmful alteration, disruption, or destruction to fish habitat.
The mean difference is expressed as a percentage relative to the authorised area. The total represents all 52 authorisations audited with HADD and compensatory areas combined regardless of habitat category.

Overall, the mean net balance of habitat area (compensatory habitat area minus HADD area) per authorisation was −2103.1 m^2. Two authorisations in the riverine category, with net gains of 599,500 m^2 and 118,700 m^2, were removed as outliers from calculation of this mean. Because the mean net balance of habitat area was a much smaller number than expected, we explored the potential outcome if DFO had not been involved. If DFO had not required any habitat compensation in the authorisations we audited, the mean net balance per authorisation would have conservatively been −8627 m^2, not including the subtraction of habitat gains from relocation, redesign, and mitigation resulting from the authorisation process. The largest mean net balance occurred in the standing water habitat category (4148.1 m^2). As a consequence of the considerable noncompliance in both HADD and compensation areas in the riparian category, the mean net balance was smaller (−3154.2 m^2) in this category than in authorisations that occurred in the riverine habitat category (−839.3 m^2) (Table 2).

In total, 67% (35) of authorisations resulted in net losses of habitat area. Approximately 2% (1) resulted in no net loss and 31% (16) achieved a net gain in habitat area. In terms of habitat category, 72% of authorisations with HADDs in riparian habitat, 30% in standing water, and 49% in riverine habitat resulted in net losses of habitat area (Figure 2).

Construction Specifications

Mean compliance per authorisation in the construction specifications category was 74% (Table 1). The most common findings of noncompliance were related to culvert characteristics (dimensions, gradient, embedment) ($n = 21$), channel characteristics (gradient, stability, elevation) ($n = 17$), rip-rap characteristics (dimensions, encroachment, diameter) ($n = 16$), riparian buffer zone attributes (width, exclusion fencing) ($n = 9$), and removal of old road fill ($n = 4$).

Habitat Features

The mean compliance per authorisation in the habitat features category was 71% (Table 1). Common findings of noncompliance were with respect to rock weirs (absence, height, notched) ($n = 65$), organic weirs/digger logs (absence, dimensions, spacing) ($n = 35$), large woody debris (absence, dimensions) ($n = 25$), boulders (absence, diameter) ($n = 25$), and pools/riffles (absence, dimensions) ($n = 23$). Compliance with the habitat features requirement category was negatively associated with the amount of financial security retained weighted by compensation area (Table 4).

Mitigation

Mean compliance with mitigation requirements was 77% (Table 1). The absence of sediment and erosion

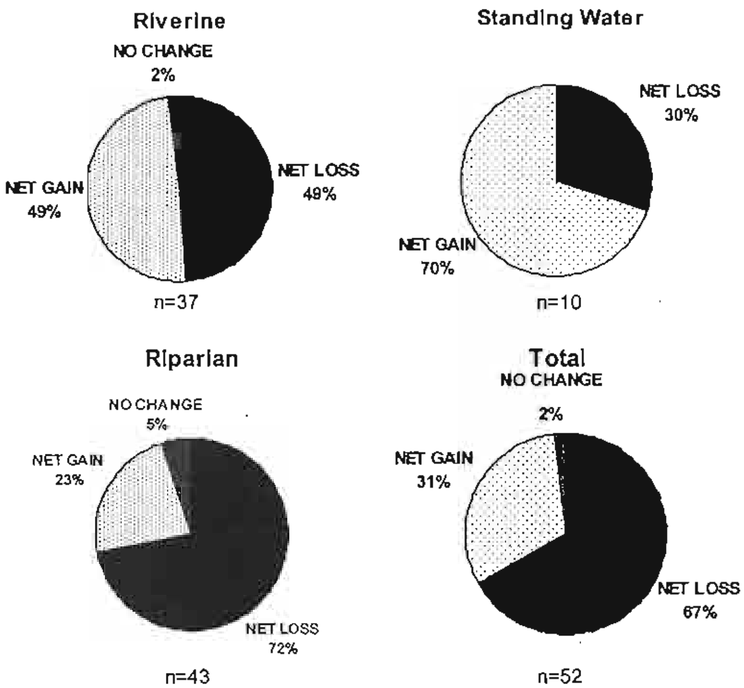

Figure 2. Percentage of harmful alterations, disruptions, or destructions to fish habitat (HADDs) in each habitat category that resulted in net gains, net losses, and no change in habitat quantity. Note that many projects contained HADDs in multiple habitat categories. The total represents the summation of gains and losses of habitat on a project basis, which in many cases included multiple habitat categories.

Table 4. Regression model statistics relating compliance with independent variables describing compensation projects[a]

Compliance category	Regression equation	P value	R^2	n
Compliance with HADD area	n/a	0.0291	1.000	25
Compliance with compensation area	n/a	0.1203	0.646	27
Compliance with construction specifications	n/a	0.9696	0.359	27
Compliance with square root of habitat features*	= 8.415 − 0.066 × (financial security/m² of compensation habitat)	<0.0001	0.331	45

[a]HADD, harmful alteration, disruption, or destruction to fish habitat.
P value, R^2, and n represent the overall regression alpha levels, coefficients of determination, and sample sizes respectively. Only those variables that were significant at the $P < 0.05$ level were retained in the models. The units are as follows: Compliance with Habitat Features (%); financial security/m² of compensation habitat ($/m²). Asterisk indicates significance ($P < 0.05$).

control measures was the most common form of noncompliance ($n = 3$).

Biological

The mean compliance per authorisation with biological requirements was 58% (Table 1). Common findings of noncompliance were riparian revegetation (absence, area, survivorship, species, height) ($n = 151$), fish passage ($n = 9$), and fish utilisation ($n = 7$). Only 19% of authorisations were compliant with riparian vegetation requirements. Authorisations deemed to be noncompliant with the requirement for fish utilisation were often due to inhospitable water quality (low DO) or an absence of the habitat itself that would allow fish utilisation. We found that compliance with biological requirements differed statistically among habitat categories (Table 5). Compliance with biological requirements in the riparian habitat category was less than in standing water (Figure 3).

Chemical. Mean compliance per authorisation with chemical requirements was 100% (Table 1); however, only 10% (5) of authorisations had chemical requirements.

Compensation Ratios

In almost all cases, actual compensation ratios were smaller than required compensation ratios (Table 6). Compensation ratios, weighted by area, ranged from 0.1:1 to 20.4:1. The DFO requested ratios of 1.6:1 and 0.7:1 for replacement of riverine and riparian habitat

Table 5. ANOVA model statistics, their degrees of freedom, and probability levels of significance for compliance with biological requirements and frequency of probable *Fisheries Act* violations

Variable	*df*	*F* statistic	*P* value
Compliance with biological requirements*	2,45	4.155	0.0221
Frequency of probable *Fisheries Act* violations*	2,48	6.241	0.0039

Asterisk indicate variables that differed ($P < 0.05$).

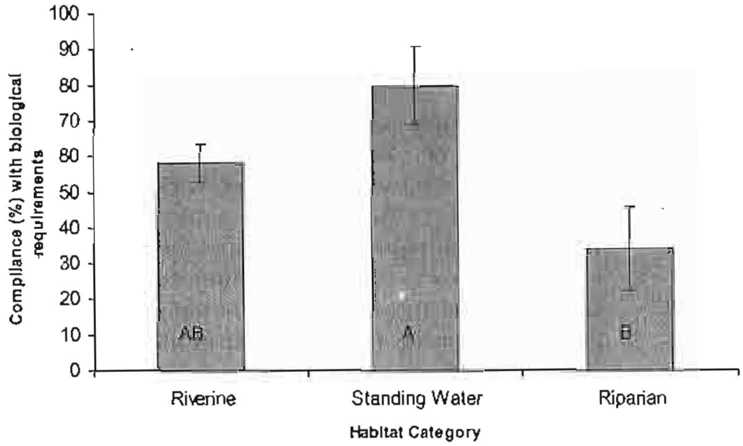

Figure 3. Mean compliance with biological requirements in three habitat categories. Means not connected by the same letter are significantly different ($P < 0.05$). (Riverine: $n = 33$; Standing Water: $n = 7$; Riparian: $n = 8$). Note that four authorisations did not contain biological requirements. Error bars represent 1 SE.

categories (like for like) and achieved ratios of 1:1 and 0.5:1, respectively. In terms of total hectares, authorisations in the riverine habitat category (like for unlike) had the largest gain (71.53 ha), whereas those in the riparian habitat category (like for like) had the largest loss (−11.86 ha). Compensation ratios of less than 1:1 were documented in the following habitat categories: riverine (like for like and increase like productivity), riparian (like for like and like for unlike), and standing water (like for like). Five of eight habitat category and compensation option combinations resulted in negative net balances of habitat area (Table 6).

The DFO would have needed to require a compensation ratio of 2.5:1 in order to overcome the 37% failure rate documented for riverine (like for like) compensation projects (Table 7). The compensation ratio data were not partitioned into those projects that failed temporally versus those that were never implemented; however, the majority of authorisations (90%) implemented some degree of compensation, yet failed over time. Compensatory works were not implemented for less than 10% of the authorisations.

Probable *Fisheries Act* Violations

Of the 52 authorisations audited, the total number of probable *Fisheries Act* violations was 26, exclusive from findings of noncompliance with the requirements of the authorisations. Sixteen authorisations (31%) had one or more probable violations. The mean number of probable *Fisheries Act* violations per authorisation was 0.51 (SE = 0.1). The frequency of probable *Fisheries Act* violations differed statistically among provinces (Table 5). Probable *Fisheries Act* violations were more frequent in central Canada than western Canada (Figure 4). Examples of probable violations include permanent riparian habitat loss and isolation of seasonal off-channel habitat due to channel hardening ($n = 5$), deposit of deleterious substances (e.g., concrete, sediment, etc.) ($n = 3$), smothering of compensatory lacustrine spawning habitat with filter fabric and construction materials ($n = 1$), obstructions to fish passage such as instream silt fences perpendicular to flow, illegal dam construction, impassable culverts (perched, impassable baffles), and impassable compensatory riffle and weir construction ($n = 6$), loss of riparian vegetation to acquire large organic debris for compensatory habitat features ($n = 2$), creation of compensatory habitats with anoxic water quality due to fecal coliform contamination or stagnated ponds ($n = 3$), de-watering of compensatory habitat for dust control during road construction (204,000 l/day) ($n = 1$), stranding of fish and sedimentation of compensatory habitat due to dam removal ($n = 1$), blocked access to side-channel habitat in attempts to enhance performance of in-channel habitat features ($n = 3$),

Table 6. Required and actual compensation (COMP) ratios weighted by area (ha) in each habitat category and compensation option[a]

	n	Required HADD area (ha)	Required COMP area (ha)	Required COMP ratio	Actual HADD area (ha)	Actual COMP area (ha)	Actual COMP ratio	Difference between required and actual HADD (ha)	Difference between required and actual COMP (ha)	Difference between actual HADD and actual COMP (ha)
Riverine: like for like	25	4.49	6.98	1.55:1	4.79	4.67	0.97:1	0.30	−2.31	−0.12
Riverine: like for unlike	4	0.78	15.47	19.78:1	3.69	75.22	20.37:1	2.91	59.75	71.53
Riverine: increase like productivity	5	2.36	0.40	0.17:1	2.79	0.27	0.10:1	0.44	−0.12	−2.52
Standing water like for like	6	3.10	4.22	1.36:1	3.41	3.40	1.00:1	0.31	−0.82	−0.01
Standing water like for unlike	1	0.30	1.00	3.33:1	0.30	0.70	2.34:1	0.00	−0.30	0.40
Standing water increase like productivity	3	1.91	5.54	2.90:1	2.60	9.64	3.71:1	0.69	4.10	7.04
Riparian: like for like	38	26.78	19.20	0.72:1	25.64	13.78	0.54:1	−1.14	−5.42	−11.86
Riparian: like for unlike	3	1.53	0.03	0.18:1	1.55	0.03	0.16:1	0.02	0.00	−1.53

[a]HADD, harmful alteration, disruption, or destruction to fish habitat.
The difference in area between required and actual HADD areas, required and actual compensation areas, and actual HADD and actual compensation areas is calculated.

and exposure of heavy metals during compensatory channel excavation resulting in a bacterial bloom that smothered the substrate and reduced water quality (DO) ($n = 1$).

Authorisation Contradictions

There were 16 authorisations (31%) that contained authorisation contradictions with respect to the HADD area. The mean area of this discrepancy between the authorisation text and scale drawings was 745.3 m^2 (SE = 176.6), a mean difference of 165%. Eighteen authorisations (35%) contained authorisation contradictions with respect to the compensation area. The mean area of this discrepancy was 717.7 m^2 (SE = 246.6), a mean difference of 116%. In total, 19 authorisations (37%) contained authorisation contradictions with respect to the area of the HADD and/or compensatory works. Nine authorisations (17%) contained specific prescription contradictions. These included requiring a total number of plants to be re-vegetated over a particular area at a prescribed density that would be impossible to achieve with the required total number of plants, prescribing the installation of in-stream woody debris to scour pools in a bedrock channel, and requiring 4000 m^2 of re-vegetation in an area that measured only 2500 m^2.

Discussion

The Habitat Policy, and in particular using compensatory habitats to offset habitat losses, is an excellent conservation strategy, potentially serving as a model for other jurisdictions (Goodchild 2004). However, the success of compensation habitat in achieving NNL could be improved through adjustments to how the Habitat Policy is implemented.

Compliance with Section 35(2) *Fisheries Act* authorisations across Canada was clearly poor. Interestingly, requirements that had the least influence on fish and fish habitat (construction specifications) had one of the highest compliance rates, whereas compliance with biological requirements, which have direct benefits to fish and fish habitat, was the lowest. Across Canada, we consistently found that riparian habitat compensation was not sufficient to offset habitat losses. In fact, virtually all of the projects audited had either a larger HADD and/or smaller compensation in the riparian habitat category. Riparian habitat is the most frequently affected habitat category by HADDs in Canada (Harper and Quigley 2005b); yet it appears to be the most difficult to compensate for based upon the prevalence of remedial measures requested for riparian compensation (Harper and Quigley 2005b) and the

Table 7. Comparing the actual compensation ratios to the required ratios generates failure rates for each habitat category

	Failure rate (%)	Ratio to overcome failure rate
Riverine: like for like	37	2.48
Riverine: like for un-like	N/A	N/A
Riverine: increase like productivity	41	0.29
Standing water: like for like	26	1.85
Standing water: like for un-like	30	4.74
Standing water: increase like productivity	N/A	N/A
Riparian: like for like	25	0.96
Riparian: like for un-like	11	0.20

The compensation ratio necessary to achieve the required ratios and overcome the failure rates is calculated.

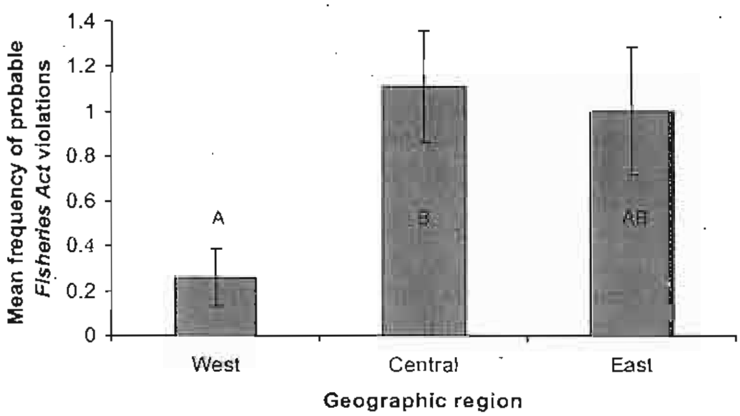

Figure 4. Mean frequency of probable *Fisheries Act* violations in each geographic region. Means not connected by the same letter are significantly different ($P < 0.05$). (West = British Columbia, $n = 36$); (Central = Manitoba and Ontario, $n = 9$); (East = New Brunswick and Nova Scotia, $n = 7$). Error bars represent 1 SE.

poor compliance we observed. Disproportionate loss of riparian habitats relative to other habitat types has been problematic in the United States as well, according to reviews of compensatory mitigation through Section 404 of the *Clean Water Act* (Kunz and others 1988; Sifneos and others 1992a; Cole and Shafer 2002).

Noncompliance with HADD and compensation areas contributed to substantial losses of habitat. The prevalence and magnitude of larger HADD areas and smaller compensatory works far exceeded the gains in fish habitat due to authorisations with smaller HADD areas or larger compensation. Habitat loss as a result of improperly installed or designed compensatory structures (e.g., perched culverts, impassable weirs, dry channels) was also considerable. In many cases, these habitat losses exceeded the original HADD that necessitated the compensation habitat. Poorly designed compensatory works also caused habitat fragmentation by obstructing or impeding juvenile migration, resulting in isolation of individuals from the rest of the population. Clearly, the limited amount and qualitative nature of monitoring (Harper and Quigley 2005a, 2005b) and enforcement (Drodge and others 1999) have constrained the achievement of NNL.

In general, there appears to be a dearth of expertise in compensatory science in Canada, likely due to the lack of monitoring (Drodge and others 1999; Harper and Quigley 2005a, 2005b) and subsequent adaptive management. In some instances, poorly designed compensatory works resulted in negative impacts to fish habitat. These additional HADDs were due to a lack of expertise on behalf of proponents, consultants, or community groups (community groups receiving cash to implement compensatory projects). Many cases could likely have been prevented with a hydrological and engineering review of compensation proposals by DFO.

Ambiguous requirements and authorisation contradictions also contributed to large losses of habitat at compensation sites. Many authorisations contained open-ended requirements such as "the proponent shall monitor water temperature and measure vegetative cover," rather than provide measurable thresholds based on parametric and dimensioned units in reference sites. Poorly defined requirements gave rise to situations where proponents were entirely compliant (e.g., the channel was physically stable) yet functional success of the compensation habitat was doubtful (e.g., the channel was dry and disconnected from the watershed).

Some compensation projects were exceptionally successful in achieving large net gains in habitat area. These projects were characterised by compensation ratios that exceeded 5:1. Compensation ratios are intended to offset the inherent risk of project failure, the value of the impacted habitat, and the temporal loss until compensatory habitat is fully functioning. Although compensation ratios are intended to increase proceeding through the hierarchy of preferences (like for like, like for unlike, increase like productivity) (Minns 1995; DFO 1998, 2002a; Lange and others 2001), this trend was not present in the projects audited.

The failure rates we calculated were a snapshot in time, 4 to 8 years postconstruction. Because habitats are rarely static, it is likely that over time the compensatory works and failure rates will continue to change. Additionally, the failure rates we calculated for each habitat category were both a function of noncompliance and failure (biological and physical) over time. It was not possible to discern the true cause of project failures due to the post-hoc design employed in this study. Ultimately, this distinction does not affect the determination of performance in achieving NNL, but the mechanism of failure does provide insight into recommendations for improvement. Compensation projects that were not completed and/or noncompliant suggest that lack of monitoring and enforcement were more the cause rather than deficiencies in current compensatory science (e.g., regarding appropriate ratios). However, 90% of the projects made attempts to compensate for habitat losses, suggesting that failure over time was likely the primary factor in many cases. Enhanced monitoring and enforcement and improvements in compensatory science are both necessary to address project failure and poor compliance. These institutional failures and lack of scientific understanding have also been suggested as causes to account for the failure of wetland mitigation banking in the United States (Shabman and others 1996; Brown and Lant 1999).

It is important to note that both the required ratios and the ratios we calculated to overcome the failure rates were based strictly on habitat quantity and assumes that the habitats are equivalent in terms of productivity. Accordingly, the ratios calculated to overcome the measured failure rates were contingent upon the assumption that the required ratios were appropriate in the first place from an ecosystem functionality perspective. However, Minns and Moore (2003) argued that fish-habitat linkages have a high degree of uncertainty, providing the impetus to adopt a precautionary approach and implement larger compensation ratios. For many authorisations, habitat losses in some habitat categories (e.g., riparian) did not require compensation, resulting in required ratios that were much less than 1:1. Clearly it would be difficult to achieve NNL of habitat productivity if a given project is only compensating for a fraction of the habitat lost on an areal basis. The smaller that fraction becomes, the greater the productivity of the compensatory habitat needs to be for NNL of habitat productivity to be met. We echo Race and Fonseca's (1996) comment that "concerns about function are eclipsed by concerns about generating habitat in the first place." Based on the magnitude of noncompliance and the failure rates documented in this article, it is clear that both compliance and compensation ratios need to increase if Canada's policy of NNL of habitat productivity is to be achieved.

The lifespan of compensatory works should be commensurate to the longevity of the HADD. The impacts to the landscape from development (e.g., highways, urban development) generally last into perpetuity. However, whether compensation efforts persist over the long term (>50 years) remains uncertain. The long-term prognosis for freshwater compensatory habitats can be tenuous, considering the dynamic nature of watersheds. We observed many compensation projects positioned in landscape locations that will not ensure sustainability (i.e., prone to isolation or destruction during channel-forming flood events).

Financial security is retained by DFO to repair failed compensation habitat as a contingency for complex or risky compensation projects. In theory, riskier compensation techniques should retain greater financial security. In practice, we found compliance with the habitat features requirements was negatively associated with the amount of financial security per square metre of compensation habitat. It is unlikely that this is a causal relationship. Rather, projects that had larger financial security were likely riskier and therefore more prone to failure (i.e., low compliance). Although using financial security as a contingency factor could be an excellent mechanism to work towards conserving fish habitat over the long term, it is rarely implemented. In fact, less than one third of projects in Canada retained financial security and none exercised this option to repair failed compensatory works during the 1994 to 1997 time frame (Harper and Quigley 2005b).

The prevalence of probable *Fisheries Act* violations at compensation projects was surprisingly high, and even more alarming is that this was exclusive of findings of noncompliance with the HADD and compensation area requirements. In many cases, these probable violations compromised compensation efforts and likely reduced their efficacy. In the last 5 years, more than 2529 authorisations have been issued across Canada (DFO 2002b), yet DFO has only ever charged a proponent for noncompliance with the requirements of an authorisation on three occasions (*Regina vs. Wright, Regina vs. GBA Logging Ltd., Regina vs. BHP Diamonds Inc.*). Based on the findings of this study, in the last 5 years there may be more than 1300 authorisations that are in potential contravention of the *Fisheries Act*. This estimate is based upon the frequency of probable violations, which did not include occurrences of larger HADD or smaller compensation areas, and is therefore likely conservative because nearly all of the authorisations audited had either larger HADD and/or smaller compensation areas than authorised. The rarity of DFO field inspections and monitoring (Harper and Quigley 2005b) are likely contributing factors to the prevalence of probable violations.

The geographic disparity in probable violations is interesting and may be an artifact of institutional differences. The DFO's habitat management program in British Columbia has long been considerably resourced, enabling a balanced habitat program including education and stewardship initiatives, guideline development, and multi-stakeholder participatory planning initiatives that contribute to successes in conservation of fish habitat. Habitat management has only recently become resourced comparatively in other parts of Canada (e.g., Manitoba, Ontario) (Goodchild 2004), which may partly explain this finding.

The prevalence of authorisation contradictions was an unexpected finding. These authorisation contradictions generally arose due to a lack of confirmation, on behalf of DFO, that areas contained in the scale drawings provided by the developer conformed to the negotiated areas documented in the authorisation text. The outcome was that these authorisations provided two different areas that were legally permitted to be impacted and conversely compensated. This provided the developer with a much broader range of habitat area legally allowed to be impacted and compensated. These discrepancies were considerable, because the HADD areas on scale drawings were, on average, nearly double the value negotiated in the body of the authorisation.

Noncompliance with habitat conservation requirements is not unique to Canada. In a comprehensive examination including nine studies of permitted compensatory mitigation requirements pursuant to Section 404 of the *Clean Water Act* in the United States, actual compensation ratios were never met (Zedler and others 2001). The average compliance rate with required ratios was 69% in these studies (Zedler and others 2001), which is similar to compliance rates we documented in Canada. Several recommendations have arisen in the United States to address the low compliance rates with Section 404 permits and compensatory wetlands. These include retention of financial security, legally binding monitoring requirements, and legally binding performance measures (Zedler and others 2001). Interestingly, all of these measures have been in place in Canada, yet poor compliance is still pervasive. These measures may also not be adequate to achieve compliance in the United States if additional strategies are not employed.

Rarity of monitoring and enforcement activities has been cited frequently as the primary contributing factors to poor compliance in both Canada (Millar and others 1997; Drodge and others 1999) and the United States (Kusler and Kentula 1990; Sifneos and others 1992a, 1992b; Holland and Kentula 1992; Race and Fonseca 1996; Zedler and others 2001). For instance, Millar and others' (1997) study of nonlegally binding letters of advice from regulatory agencies in British Columbia, Canada found extremely poor compliance (range 15–40%) with requirements to protect fish and fish habitat, and they recommended increased monitoring and enforcement as a solution. Findings of noncompliance in Canada are not surprising considering that in a national study, Drodge and others (1999) documented that DFO habitat management staff allocated only 1.7% and 1.3% of their workload on compliance monitoring and enforcement, respectively. Although recommendations to improve monitoring and enforcement have occurred during major federal funding initiatives in Canada to address these shortfalls (e.g., Green Plan (Environment Canada 1992); Blueprint (Drodge and others 1999)), the deficiency persists. For effective monitoring and enforcement to become reality, a substantial change in the nature and structure of regulatory involvement in compensation habitat, supported by simultaneous changes in human and financial resources, should be considered to address these recommendations.

Since the inception of Canada's Habitat Policy (DFO 1986), there has been a proliferation of authorisations issued, and a strong and growing reliance upon this process as a mechanism to conserve fish habitat in Canada. In the late 1980s, the annual number of authorisations issued numbered in the dozens, whereas in 2002, 426 were issued nationally (DFO 2002b). Habitat compensation, as currently implemented in Canada, is slowing but not stopping the rate of habitat loss (DFO 1997; Metikosh 1997). Increasing the amount of authorised compensatory habitat in the absence of institutional changes in implementation will not reverse this trend. Improvements in monitoring, enforcement, and compensation ratios are necessary for the authorisation process to move towards achieving Canada's conservation goal of NNL. Increasing our experience and understanding of habitat compensation will hopefully provide an important means to reversing current trends in fish habitat loss.

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