Design Standards for Improving Fish Habitat Management

[1]G. Gillespie, [1, 2]L. Carl, [3]R. Mackereth, [4]L. Greig, D. [5]Ming, [6]M. Boivin, and [7]T. Allison.

[1] Watershed Science Centre, Trent University, Peterborough, ON
[2] Ontario Ministry of Natural Resources, Peterborough, ON
[3] Ontario Ministry of Natural Resources, Thunder Bay, ON
[4] ESSA Technologies Ltd, Richmond Hill, ON
[5] Department of Fisheries and Oceans, Burlington, ON
[6] Department of Fisheries and Oceans, Peterborough, ON
[7] Department of Fisheries and Oceans, Burlington, ON

February 2002

Canadian Manuscript Report of Fisheries and Aquatic Sciences 2592

Fisheries and Oceans

Pêches et Océans

Canada

Canadian Manuscript Report of
Fisheries and Aquatic Sciences

Manuscript reports contain scientific and technical information that contributes to existing knowledge but which deals with national or regional problems. Distribution is restricted to institutions or individuals located in particular regions of Canada. However, no restriction is placed on subject matter, and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Manuscript reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1-900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 901-1425 were issued as Manuscript Reports of the Fisheries Research Board of Canada. Numbers 1426-1550 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Manuscript reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport manuscrit canadien des
sciences halieutiques et aquatiques

Les rapports manuscrits contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui traitent de problèmes nationaux ou régionaux. La distribution en est limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministére des Pêches et des Océans, e'est-à-dire les sciences halieutiques et aquatiques.

Les rapports manuscrits peuvent être cités comme des publications complèrwa. Le titre exact paraît au-dessus du résumés de chaque rapport. Les rapports manuscrits sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*,et ils sont classés dans l'index annuel des publications scientifiques et techniques du Ministére.

Les numéros 1 à 900 de cette série ont été publiés à titre de manuscrits (série biologique) de l'Office de biologie du Canada, et aprés le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés comme manuscrits (série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros 901 à 1425 ont été publiés à titre de rapports manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 sont parus à titre de rapports manuscrits du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 1551.

Les rapports manuscrits sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur don't le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Manuscript Report
of Fisheries and Aquatic Sciences 2592

February 2002

Design Standards for Improving Fish Habitat Management

by

[1]G. Gillespie, [2]L. Carl, [3]R. Mackereth, [4]L. Greig, D. [5]Ming, [6]M. Boivin, and [7]T. Allison.

Addresses: [1] Watershed Science Centre, Trent University, Peterborough, ON
[2] Ontario Ministry of Natural Resources, Peterborough, ON
[3] Ontario Ministry of Natural Resources, Thunder Bay, ON
[4] ESSA Technologies Ltd, Richmond Hill, ON
[5] Department of Fisheries and Oceans, Burlington, ON
[6] Department of Fisheries and Oceans, Peterborough, ON
[7] Department of Fisheries and Oceans, Burlington, ON

Minister of Supply and Services Canada 2001
Cat. No. FS97-4/2592 ISSN 070-6473

Correct citation of this publication:
Authors. date. Title. Can. MS Rpt. Fish. Aquat. Sci. 2592: xx+XXp.

Abstract

The 'Design Standards for Improving Fish Habitat Management Workshop' brought together scientists and managers from a variety of disciplines and agencies to develop scientific design standards for assessing the effectiveness of fish habitat mitigation and compensation measures. The workshop was held at the Leslie M. Frost Natural Resources Centre in Dorset, Ontario, from March 06-08, 2001. The current habitat referral system of Fisheries and Oceans Canada (DFO) was used as the context for decision-making in the workshop exercises. DFO habitat referrals are requests for review of proposed development activities that may harmfully impact fish habitat under Section 35 of the Fisheries Act. The workshop was structured to integrate participants from different disciplines into breakout groups centred on three specific development activities; culverts, stream realignment, and shoreline stabilization. These project activities are frequently submitted to DFO for review and often require mitigation and/or compensation measures to avoid or reduce adverse effects on fish habitat.

A series of keynote presentations introduced concepts on current stream ecosystem research, integrated experimental design, and the use of hypothesis-of-effects (HoE) diagrams in the development of generic study designs. These talks set the stage for group discussion on developing design standards. A HoE model was used as a conceptual framework for the development of cause-effect pathways for key issues, linking activities that change habitat with ecological indicators. Physical, chemical and biological processes and terrestrial and aquatic linkages were incorporated across spatial and temporal scales. Each breakout group fine-tuned the HoE diagrams drafted by the steering committee and produced study designs for their respective development activity. The workshop helped identify knowledge gaps and research needs for improved management of fish habitat in Canada related to the three activities.

This report not only describes the workshop proceedings but also outlines the entire process that was taken to organize the workshop. The framework and process developed for the workshop should provide a useful template for determining how development activities lead to impacts on fish habitat and whether mitigation and compensation actions avoid, reduce or offset harmful impacts. It is hoped that other scientists and managers can adopt the approach used here to develop study designs for additional development activities. Information contained in this report will also help identify issues related to temporal and spatial scale that arise when developing these types of experimental designs.

Résumé

L’atelier sur les normes de conception pour améliorer la gestion de l’habitat du poisson (Design Standards for Improving Fish Habitat Management Workshop) a réuni des scientifiques et des gestionnaires de divers organismes et disciplines pour qu’ils élaborent des normes de conception scientifique pour l’évaluation de l’efficacité des mesures d’atténuation et de compensation de l’habitat du poisson. L’atelier s’est tenu au Centre de ressources Leslie M. Frost de Dorset (Ontario), du 6 au 8 mars 2001. Le système actuel de renvoi des projets de Pêches et Océans Canada (MPO) a été utilisé comme contexte dans les exercices de prise de décisions de l’atelier. Les renvois au MPO de projets concernant l’habitat sont des demandes d’examen des propositions d’aménagement qui pourraient avoir des effets nocifs sur l’habitat du poisson en vertu de l’article 35 de la *Loi sur les pêches*. L’atelier était structuré de façon à intégrer les participants de différentes disciplines dans des sous-groupes se concentrant sur trois activités précises d’aménagement : les ponceaux, l’alignement de cours d’eau et la stabilisation des rives. Ces projets sont souvent soumis à l’examen du MPO et ils nécessitent souvent la prise de mesures d’atténuation et/ou de compensation pour éviter ou réduire les effets négatifs sur l’habitat du poisson.

Dans le cadre d’une série de discours-programmes, on a présenté des notions de la recherche actuelle sur les écosystèmes aquatiques, des concepts expérimentaux intégrés et de l’utilisation de schémas d’hypothèses des effets (HoE) dans l’élaboration de modèles d’études polyvalents. Ces présentations ont donné le ton à la discussion en groupe sur l’élaboration de normes de conception. Un modèle HoE a été utilisé à titre de cadre conceptuel pour la création de voies de cause à effet relativement aux questions clés, reliant les activités qui modifient l’habitat aux indicateurs écologiques. Des processus physiques, chimiques et biologiques ainsi que des liaisons terrestres et aquatiques ont été intégrés dans des échelles spatiales et temporelles. Chaque sous-groupe a peaufiné les schémas HoE esquissés par le comité de direction et a produit des modèles d’études pour son activité d’aménagement respective. L’atelier a permis de cerner les lacunes au niveau des connaissances et les besoins en matière de recherche à combler pour améliorer la gestion de l’habitat du poisson au Canada relativement aux trois activités.

Le présent rapport ne décrit pas seulement les travaux de l’atelier, il explique aussi tout le processus suivi pour organiser l’atelier. Le cadre de travail et le processus mis au point pour l’atelier devraient fournir un modèle utile pour déterminer, d’une part, la façon dont les activités d’aménagement entraînent des répercussions sur l’habitat du poisson et, d’autre part, si les mesures d’atténuation et de compensation permettent d’éviter, de réduire ou de compenser les effets nocifs. Il est à espérer que d’autres scientifiques et gestionnaires adopteront l’approche utilisée ici pour élaborer des modèles d’études pour d’autres activités d’aménagement. Les renseignements contenus dans le présent rapport aideront également à reconnaître les questions reliées aux échelles temporelles et spatiales qui se soulèvent lors de l’élaboration de ces types de concepts expérimentaux.

Acknowledgements

We would like to thank Drs. Tony Underwood, Roger Green and Philippe Archambault for their work on the statistical models and Cheryl Lewis (OMNR) for her support. We thank Dr. David Evans for his work with the HoE protocol. We would particularly like to thank Vic Gilman (DFO) for his commitment, staff and financial support. We would also like to thank Jennifer Aikman, Corissa Carveth (Watershed Science Centre), and Scott Gibson (University of Toronto) who volunteered their time to help at this workshop and recorded all breakout group discussions:

We greatly appreciate the work of the breakout group facilitators:
Dr. Leon Carl, Lorne Greig, and Dr. Robert Mackereth.

The workshop steering committee members spent much time and effort in the development and direction of this workshop and deserve special thanks:
Dr. Leon Carl (co chair), Dr. David Evans, Vic Gillman (co chair), Karen Gray, Lorne Greig, Dr. Mike Jones, Dr. Chris Katopodis, Dr. Robert Mackereth, Debbie Ming, Dr. Ken Minns, Jason Quigley, Dr. Keith Somers, and Mike Stoneman.

These sponsors provided support for the workshop:

- Ontario and Great Lakes Area –Fish Habitat Management Program, DFO
- Aquatic Research and Development Section (OMNR)
- Great Lakes Fishery Commission
- Watershed Science Centre, Trent University

Table of Contents

1 Introduction

There are high levels of uncertainty associated with management decisions concerning development activities that impact fish communities and habitat. Management agencies routinely require a variety of mitigation and/or compensation measures to address impacts on fish habitats from development. These requirements are largely based on the professional judgment of biologists and habitat managers. To date, there has been incomplete scientific evaluation of the effectiveness of these measures. Uncertainty about the effectiveness of these measures leads to the risk that the conservation and protection of fish habitat will not be attained. To minimize this risk creative interaction between scientists and managers is needed to advance environmental and resource management (Underwood 1995) through rigorous tests of the effectiveness of mitigation and compensation measures.

The purpose of this project was to work toward reducing this risk by developing scientific design standards for assessing the effectiveness of mitigation and compensation measures used in development projects affecting fish habitat. This required a lengthy preparatory process undertaken by a steering committee and culminated in a facilitated workshop in March 2001. Using these design standards to test hypotheses would reduce the uncertainty through the creation of rigorous new science. The framework and process developed for the workshop should provide a useful template for determining how development activities lead to impacts on fish habitat and whether mitigation and compensation actions avoid, reduce or offset impacts. The framework and processes should be of particular interest to management agencies concerned with site-specific and cumulative impacts on fish habitat.

The current habitat referral system of Fisheries and Oceans Canada was used as the context for decision-making in the workshop exercises. DFO referrals are requests for review of proposed development activities that may harmfully impact fish habitat under Section 35 of the *Fisheries Act*. These include activities such as dredging, infilling, stream crossings (i.e. culverts, bridges), stream realignment, and shoreline hardening. When a proponent submits a proposal, it is evaluated by a biologist to determine whether mitigation or compensation is required to avoid, reduce, or offset losses or changes in the productive capacity of fish habitat. Currently, there are significant science needs related to mitigation and compensation measures. One of the goals of this workshop was to design generic methodologies to address these science needs.

The workshop was held at the Leslie M. Frost Natural Resources Centre in Dorset, Ontario, from March 06-08, 2001 and focused on developing the design step of an Adaptive Management system (Figure 1; Holling 1978). The purpose of this report is to describe the planning of the workshop, the workshop itself, the designs created there, and the process and framework used to create these designs.

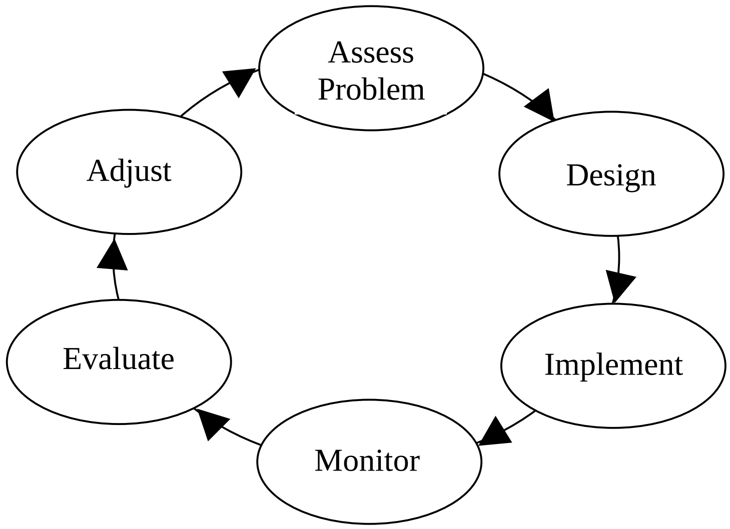


Figure 1: Diagram of an adaptive management system (Holling 1978).

1.1 Workshop Preparation

Successful completion of the Design Standards initiative required a cooperative effort by managers, field biologists and researchers with a clear, shared understanding of the objectives and technical issues critical to sound experimental design. To make effective use of the time committed by participants (Appendix A.1) at the experimental design workshop, careful planning of the workshop process was required. This was accomplished by a multidisciplinary steering committee (Appendix A.2). Members of the steering committee were chosen to provide expertise in management, field biology, experimental design, adaptive management plus workshop design and facilitation. The team provided a diversity of expertise and perspective necessary for the design process. In addition all members of the steering committee were familiar with the DFO habitat referral process.

The work of the steering committee involved:

- clarifying the objectives for the project;
- commissioning a survey (Appendix B) which was conducted before the workshop to obtain information on regional differences in practices currently used in reviewing development activities. The survey was administered to various fish habitat biologists employed by the Fisheries and Oceans Canada and employees of Ontario Conservation Authorities involved in the fish habitat referral process. Thirty-nine surveys were completed by employees from: DFO Maritime, Gulf, Laurentian, Pacific, Central and Arctic Regions, and Conservation Authorities;
- examining the results of the survey to assist in the determination of nationally relevant development activities for use in the workshop break-out sessions and choosing three development activities;
- developing a set of preliminary Hypotheses-of-Effect (HoE; Jones *et al.* 1996) diagrams to illustrate the ecological pathways affected by each of the development activities;

- establishing the workshop agenda (Appendix C) and designing a process for guiding the deliberation of workshop break-out groups; and,
- selecting workshop participants based on their interest, experience and expertise to ensure the attendance of a multidisciplinary and multi-agency mix of people. Members included individuals representing Fisheries and Oceans Canada, provincial government agencies, Conservation Authorities, universities, non-governmental organizations, and consultants.

The work of the steering committee was documented in a project prospectus used to brief workshop participants and for briefing DFO management on progress. The project planning undertaken by the steering committee involved seven intensive (one or two days) planning meetings and several conference calls plus the work of a half time assistant over a ten month period.

It was recognized early on by the steering committee that a flexible scientific study design system was needed to examine science needs related to the effects of development activities and the mitigation and compensation measures associated with these development activities. This system is intended to be applicable to different project types across regions, provinces and states. Using an Adaptive Management approach, participants at the workshop considered what study design approaches are appropriate (*e.g.* Before/After sampling of Control/Impacted sites; BACI) and worked toward developing designs to encompass a wide range of circumstances. In keeping with the Adaptive Management approach, the process used HoE diagrams as a basis for discussion and development of designs.

1.1.1 Use of Hypothesis of Effect Diagrams

Hypothesis of Effects diagrams were developed before hand by the steering committee for each of the selected development activities. The HoE diagrams identified the cause-effect chain linking specific development activities and productive capacity impacts and highlighted uncertainties relating to impacts on fish and fish habitat productivity. Discussion of the HoE diagrams helped to identify measures needed in the design phase to assess cause-effect relationships. A generic HoE evaluation protocol based on nine questions (articulated in sections 1.1 and 1.2 following the thought process of the steering committee) was developed prior to the workshop to guide participants through the design process in breakout sessions focused on particular development case studies. The nine questions or steps were found to be effective because they provided strong spatial and temporal perspectives and a scientifically rigorous context for assessing mitigation and compensation measures.

1.1.2 Nine Steps used for the Hypothesis of Effect Evaluation Protocol

The steering committee developed the following prototype process for designing and implementing adaptive learning in a management context based on the use of assessment and monitoring of the effects of development activities and of associated mitigation and compensation actions in Canadian freshwater fish habitats.

1. Review HoE structure

   a. What is missing and what is miscast?

2. Space
   a. What is the range in size of the river or lake systems impacted?
   b. What is the surficial geology?
   c. What is ecosystem or watershed features-vegetation?

3. Temporal Dynamics:
   a. How do the seasons modify the cause-effect pathways?
   b. How does the perturbation stage of development modify the cause-effect pathways?

4. Understanding the hypothesis:
   a. Are there linkages that we really know well?
   b. Are there linkages that are relatively uncertain?

5. Which of these pathways are important and more tightly linked to fish production (endpoint)?
   a. What level of risk to fish production does each pathway have?

6. Mitigation/compensation (management intervention) overlay on HoE pathways.
   a. How does the intervention modify the cause-effect pathways?

7. What are the Key pathways?

8. What single question are you going to test (e.g. which testable hypothesis from the HoE diagram are you going to test)?

9. Design: (stratification/replication/at site design)
   a. What variables do you measure?
   b. How one measures variables at site?

Once a consensus study design is developed and tested it can be widely implemented (Figure 1). The availability of a general and flexible study design will reduce redundancy and noncommensurability of data collected by different agencies within or across different regions. Effectiveness monitoring can then be applied at many sites with modest levels of effort to produce evidence of efficacy. Broad and standardized coverage will allow questions about different scales and cumulative impacts to be answered with greater statistical power.

1.2 Workshop Structure and Objectives

The workshop was structured to integrate participants from different disciplines into breakout groups centred on three specific development activities; culverts, stream realignment, and shoreline hardening. The steering committee chose stream realignment, shoreline hardening and culverts for the breakout groups because they are common throughout Canada and are frequently submitted to DFO for review.

To set the stage for the breakout sessions, a series of keynote presentations introduced concepts on the following topics:

- current stream ecosystem research;
- integrated experimental design; and,
- hypothesis-of-effects diagrams as a conceptual model to facilitate the development of study designs for testing the effectiveness of mitigation and compensation measures.

The HoE diagram was used in the breakout sessions as a conceptual guide for the development of cause-effect pathways for key issues, linking activities that change habitat with ecological indicators. The workshop review of each of the HoE models highlighted uncertainties relating to impacts on fish and fish habitat productivity (Appendix D, E & F). Discussion of the HoE models also helped to identify measures needed in the design phase to assess cause-effect relationships. The models encouraged groups to focus at appropriate spatial and temporal scales while assessing the research and management needs of fish habitat. Each breakout group was given a list of objectives for each working session, and was asked to fulfill these objectives with their selected development activity in mind.

The HoE models were refined during the workshop by following the pathways for the selected development activities. Focusing on science needs across Canada, each group identified key linkages and worked through the HoE models incorporating physical, chemical and biological processes including terrestrial and aquatic linkages across spatial and temporal scales. This process helped in designing generic methodologies for selected mitigation/compensation measures.

The objectives for the workshop were two fold:

1) To develop a flexible scientific study design with examples for use in assessment and monitoring programs for selected development activities, including the choice of variables, appropriate control treatments, method for choosing sampling sites, etc.

2) To identify significant areas of uncertainty where effort is needed to fill information gaps for the assessment and monitoring of mitigation and compensation projects.

2 Results of Break-out Group Discussions re Specific Design Initiatives

The following sections of this paper describe the breakout sessions and design standards developed for the three activities within the context of the HoE diagram. The diagram was used as a conceptual model for the development of cause-effect pathways for key issues, linking activities that change habitat with ecological indicators. Physical, chemical and biological processes and terrestrial and aquatic linkages were incorporated across spatial and temporal scales. This process helped identify knowledge gaps and research needs for improved management of fish habitat in Canada.

As expected with a diverse, articulate group, approaches to addressing the problems differed. The following breakout subgroup reports reflect this diversity. Readers should be aware that hypothesized outcomes of various habitat alterations on fish habitat have not been verified by a literature search or reference. Comments should therefore not be considered supporting information for environmental assessment. As well, comments on typical or normal DFO practices should be considered only in the context of this report and reflect only the opinions of the representatives present at the workshop.

2.1 Stream Realignment Breakout Group

The group decided that their task would be fulfilled if they focused on examples of specific development activities associated with stream realignments as opposed to considering one overall impact type. This approach allowed the group to consider the details of specific examples. In turn, they were able to think through issues surrounding program design, detecting change in response to the development activities, and evaluating the effectiveness of the required mitigation/compensation. Understanding that the overall objective for the session was to develop a design (or designs) with national relevance, the group identified two examples of development activities that typify projects in different regions across the country. These include:

i) removal of beaver dams from low gradient streams (common in central and eastern portions of the country);
ii) connection to (or reconnection of) parallel side channels in high gradient streams (common in western portions of the country).

The group began their deliberations with the first of these examples, and worked it through in considerable detail. This formed the basis for developing the general approach to design. Near the end of the breakout session, a short time was spent considering a design for the second example. However, it was not discussed in sufficient detail to warrant inclusion here. Keep in mind the “example” of the removal of beaver dams from low gradient streams is intended to serve as a template (approach) for how to develop research designs for other stream realignment development activities.

The first example of a research objective, identified by the group, was the determination of the response of fish production (measuring biomass, growth, or abundance) when a low gradient stream has beaver dams removed and replaced with riffle/pool sequences. This scenario consists of a stream flowing through agricultural land. The stream has several beaver dams built along a 2 km stretch in this area. During the spring runoff, these dams inhibit water flow causing the farm fields to flood. The proponent wishes to dredge out the dams and riverbed to maximize water flow in the spring and accommodate early planting. Some characteristics of the stream include fine grain noncohesive substrate, warm water, 3 m width, continuous flow, 1% gradient, and forested riparian zone downstream. The fish community consists primarily of smallmouth bass and cyprinids.

The suggested mitigation by DFO was to install riffle/pool sequences along this 2 km length of stream. A revised HoE protocol was used to focus the group on the study design. This development activity and mitigation was designed to maximize water conveyance without net loss to fish production. In order to identify relevant uncertainties (*i.e.* science needs) and monitor the effects of activities, it was proposed that a multi-site experimental management study, utilizing adaptive management principles be conducted.

2.1.1 Background of Case Study

Working through the revised HoE model and linkages (Appendix D), the group started with the development activity of removing riparian vegetation along one side of the stream bank during construction. This would result in a reduction of shade and cover over the stream, reduced detritus and terrestrial input, reduced woody debris, and ultimately increased water temperature. To limit agricultural erosion, mitigation would involve re-establishing the vegetative buffer. Substrate characteristics will change by the loss of fines and importing course material (gravel cobbles) for riffles. The removal of the beaver dams would tend to shift aquatic macrophyte community composition from those that prefer a silty substrate to those better suited for riffles and pools. Detritus and other terrestrial inputs are valuable forage for invertebrates and a reduction in this resource would lead to changes in invertebrate community structure. The fish community may change from low water velocity species to those that utilize higher water velocity. Loss of the nursery habitat (loss of aquatic vegetation) in the beaver ponds may negatively affect cyprinids.

Beavers build side channels at the surface of banks when building dams; therefore, a reduction in side channels will occur after the removal of the beaver dams. While these side channels increase shoreline, they are constantly disturbed from beavers dragging trees and branches through them; resulting in low invertebrate production. Reduced side channels will decrease sediment nutrient flux and detritus input. These side channels could be critical as nursery habitat for cyprinids, protected from smallmouth bass.

The group decided there would be relatively little change in the shoreline profile/slope; therefore it was not necessary to follow this HoE pathway. As well, construction was considered a pulse response that can be mitigated and did not require attention. However, channel morphology was thought to be a critical link in the HoE. The stream will be changed from a stepped beaver dam structure to a riffle/pool sequence structure. The amount of storage in the pools will be reduced and there will be more high velocity areas found in the stream, resulting from the placement of the riffles and from the loss of attenuation in the beaver ponds. As well, the increased roughness from the riffles will affect velocity though there will be no change in base flow. Because the conveyance of runoff at the altered site will be increased, there will be a shorter duration of peaked flow, here as well as downstream. The overall stream depth will be less (as the new pool depths will be shallower). During and after construction, it is important to keep soil from the farm fields from entering the stream; otherwise, the soil will fill in pools and cover cobble areas.

The group hypothesized the following short-term effects due to changes in substrate composition:

- initial drop in density of invertebrate community richness then recovery over a year;
- shift in invertebrate species composition due to change in habitat from beaver ponds to riffle/pools – (gradual shift dependent on sediment inputs, frequency, velocity and design);
- increased diversity of fish spawning and nursery habitat.

There will be a decrease in off channel habitats, which will affect fish spawning and nursery habitat. However, water quality will increase with the addition of riffles resulting in increased oxygen, which will increase invertebrate and fish habitat quality.

With the suggested enhancement of new spawning opportunities, the group hypothesized increased recruitment of bass and suckers and reduction in cyprinid habitats. Bass forage on cyprinids; thus a forecast increase in bass production will increase cyprinid mortality. In regards to fish production it was predicted:

- there would be reduced P:B due to a shift in the fish community towards larger individuals;
- there would be an increased variability in fish biomass both over time and spatially;
- there would be increased diversity with a decrease in individual abundance over time; and
- there would be an increase in the spatial range of bass populations.

Monitoring Design for Stream Realignment

The design process followed by and recommended by the group includes seven steps as outlined below. Results of the group discussion regarding each step are also presented.

1. Establish an overriding hypothesis:

   H_o = Stream realignment does not have any harmful effect on fish production (*i.e.* No Net Loss).

2. Establish more detailed and specific predictions within the overriding hypothesis.

   This should be based upon the experience of field biologists and researchers familiar with the type of intervention and a literature review to consolidate the available knowledge of potential effects. The more directed (specific nature of the change) and precise the prediction, the greater the statistical power (*e.g.* a one-tailed versus a two-tailed test).

H_1 = Increased bass population due to increased oxygen and improved habitat.
H_2 = Increase number of fish species but a decrease in abundance of individuals.
H_3 = Increase in abundance of (rheophyllic) fish species which prefer high velocity water.
H_4 = Increase in invertebrate diversity.
H_5 = Increase in habitat diversity.
H_6 = Reduction in P:B.

3. Define criteria for and select a control site or series of control sites:
   - A key component in the design process is the selection and subsequent assessment of a reference reach. This reach should display similar physical properties and characteristics to the subject site or reach (location of development activities). The reference site must be stable and in a healthy state. Assessing and understanding the channel dynamics of this reference reach can serve as the model to develop appropriate design solutions. It is important to find a control system geographically close to the treatment system. Preferred characteristics of the control site (or sites) include:
   - Same drainage area.
   - Similar topography.
   - Similar surficial geology.
   - Same landuse.
   - Proximity.
   - Similar slope and substrate.
   - Similar water chemistry.
   - Stream must be of the same order.
   - Whenever possible choose multiple reference sites in similar streams in the same watershed. In a properly controlled study one needs to know the natural variation (background) in a system that cannot be attributed to the development activities. Inclusion of multiple sites can help to estimate the variability between streams (ideally 3–5 replicate sites within a stream) and increase the statistical power. As the number of reference sites decrease, the requirement for similarity between treatment sites increases. The corollary that as you increase reference sites, the requirement for similarity decreases, is false. Reference (control) sites should always be chosen to be as similar as possible to the treatment site.
   - Beavers are highly dynamic – a single reference site has inherent problems.
   - Best approach is a random sample of reference sites.
   - Location of sampling within reference sites/streams should also be random.

4. Define the experimental treatment (both actions and timing) and the extent of pre/post sampling:
   - In an ideal situation, sampling 3 years prior and 3 years post development activities would be preferred, as this establishes baseline data. Multiple years of post development sampling will help to follow recovery and if necessary, modify the management strategy.

5. Define the temporal details of the sampling protocol:
   - Sample treatment and control sites at the same time of day every time. In order to acquire a good estimate of the mean it was suggested to sample every two weeks during the spring, summer, fall and when possible winter. If you have a priori knowledge of the variables that may change most, you should allocate most of your sampling effort to these. The group recommends some preliminary sampling to assess what the variability of the sampling is and how many replicates are required to account for this variability.

6. Define the spatial details of the sampling protocol:
   - Sampling of sites should be upstream and downstream of development activities in the same stream.

7. Define criteria for selection of variables to measure and specific measurement variables consistent with the criteria.
   - Relevance – a hypothesized change.
   - Sensitivity.
   - Cost of measuring.
   - Ease of measurement.
   - Error associated with measurement.
   - Measure species at family level to speed up the process (higher level of taxa).
   - Stratify by riffle or pool.
   - Allocate more effort to those areas that are more variable (balance design) based upon preliminary sampling.

Given these criteria, the members of the breakout group identified the following variables for measurement in the beaver dam removal example development activities.

1. Physical Measurements
   a. Substrate – grain size samples.
   b. Bed morphology [Digital Elevation Model, (DEM)] - this will include woody debris.
   c. Flow.

2. Biological Measurements
   a. Invertebrates (family level) – *i.e.* could use basket samplers and fill them with substrate (e.g. gravel) and let them colonize, at designated time intervals (*i.e.* annually) remove and count biota.
   b. Fish – use relative index of abundance, catch per unit effort (CPUE), and attempt to reduce fish mortality when sampling.
      fish species, size, age, and abundance (key is consistency between sites).
   a. Vegetation (cover) – sample annually mid-summer.

3. Chemical Measurements
   The group predicted chemical measurements were not likely to be affected by stream realignment; therefore, they are not recommended. However, if chemicals are a concern, a simple analysis of the water such as temperature, total phosphorous (TP), and oxygen (O_2) (P will not be mobilized now that there is an increase in O_2) can be performed.

It is important to note that the above measurements were chosen because they are sensitive to change (Table 2.1).

Table 2.1. Comparison of response variables across several design criteria.

	Criteria			
Response Variable	Relevance	Sensitivity	Ease of Measure	Measurement Error
Substrate Pools	system driver	Yes	Moderate	Moderate
Riffles	system driver	Yes	Moderate	Moderate
Morphology	system driver	Yes	Easy	Low
Flow*	system driver	Yes	Difficult to easy	
Invertebrates	response	Yes	Variable	** Low – uncertainty between sampling methods
Temp. & Oxygen	response	Yes	Easy	High to low
Fish abundance	response	Yes	Easy	Difficult to measure, gross changes in rank order should show up over time.
* Be clear as to why flow is being measured. Distinguish between hydrology (discharge) and hydraulics (velocity). It was suggested that there would be no impact on hydrology. Therefore, you must decide why you need to measure velocity (*i.e.* sediment movement).				
** It will be difficult achieving consistent methods between beaver ponds and riffle/pool areas when measuring invertebrates. A coarse measurement at a higher taxa will suffice, however be up front that you may be ignoring possible important observations at the species level.				

All variables need to be measured and are important in aggregate. In developing designs, cost should also be considered, but the group did not have this information available to them for further discussion.

Due to the time constraint the group was unable to construct a statistical model. However, Roger Green designed a statistical model (Appendix G) for this group and submitted it at a later date.

Final Considerations

The group realized after going through this exercise that a simple act of removing several beaver dams will lead to complex changes in biotic structure. The hypotheses related to these changes were fairly simple however a design to adequately test the hypotheses was complex and would require substantial resources to implement. Both management biologists and researchers realized that careful planning and an adaptive management approach of taking appropriate referrals and assembling them into the initial study design were necessary to reduce costs and insure that a good test of mitigative and/or compensation measures is carried out.

2.2 Shoreline Hardening Breakout Group

The breakout group began by reviewing the suggested HoE model (Appendix E) to identify deficiencies in the linkages and recommend improvements to the HoE. In a riverine context, hardening is used in response to flow conditions whereas in a lake environment it is used in response to wave action. The breakout group chose a large lake with a shoreline impacted by wave action.

Shoreline hardening encompasses a wide range of activities normally carried out along a lake's shoreline for protection against wave action. Examples of these activities include in-filling below the high water mark, shoreline hardening by excavating back onto the property to install an armourstone wall, or large scale in-filling from a marina. Given the focus of a lake environment, variables such as hydraulics, shoreline structure, shoreline profile, water level fluctuation and erosion were added to the HoE model to take into account these development actions. Descriptions for each linkage in the diagram are outlined in Appendix E.

The group first listed different types of hardening (Table 2.2) and then chose three scenarios for discussion. Only two were discussed due to time contraints.

Scenario 1. Shoreline Hardening

The first scenario involved a private landowner with property on a large, high energy lake. The landowner's shoreline is eroding and bank protection is required to avoid further property loss. Shoreline protection is a legal right and therefore frequently requested in areas affected by wave action. These projects make up a large percentage of DFO referrals. They are often approved through the *Fisheries Act* Authorizations or Letters of Advice, and can require mitigation and compensation to avoid a HADD of fish habitat.

Using the HoE model, the group identified variables that would be impacted by a shoreline protection project (1st row of HoE model; Appendix E). Shoreline stabilization would normally involve the placement of rip rap and armourstone in the form of a vertical wall or a sloping revetment. Encroachment/loss of littoral habitat, shoreline profile, shoreline alignment and shoreline roughness were suggested as potential development activities caused by these activities. Pathways of effects were drawn onto the HoE model in order to relate the project impacts to fish production (Appendix E).

Encroachment onto the lakebed and a loss of littoral habitat were categorized as press disturbances resulting from the construction of a sloping revetment or vertical wall. Water-soil linkage would in turn be altered and a loss of wetland vegetation would occur. The group agreed that issues pertaining to encroachment and loss of littoral area would be negligible. Therefore this pathway was not pursued.

Table 2.2: Possible development projects related to shoreline hardening.

Category	Type	Examples
A: On-Shore	Vertical Protection/Wall	Armourstone Gabion baskets Concrete Steel sheet piling Log cribs
	Sloping Protection/Revetment	Cobble berm Rip-rap and armourstone Bio-engineered material
	Artificial Beach	
	Beach Nourishment	
B: Protruding	Groynes	Cobbles Shingle beach
	Breakwater	
	Piers	
C: Off-Shore	Islands and Reefs	Armourstone Rip rap
	Breakwater	

Another potential pathway discussed by the group stemmed from a change to shoreline slope by replacing a natural shoreline with a vertical structure. This would cause a change in hydraulics both in terms of wave action and littoral drift. A sloping revetment rather than a vertical wall may slightly dissipate wave action but may also interfere with coastal currents. A change in hydraulics at or along the shoreline would have an effect on several physical and biological characteristics. Affected physical attributes would include erosion, water quality, substrate characteristics, cover and temperature. This may provoke biological responses in egg incubation/nursery habitat, fish spawning, invertebrates, aquatic macrophytes/periphyton and fish distribution. Changes to recruitment, feeding/growth and fish community would lead to a redistribution of, or a change in fish production.

The group decided shoreline infilling would be minimal and was therefore not considered. As well, loss of riparian vegetation was not thought to be a critical link. Often landowners have previously cleared riparian vegetation for a better view or improved access to the water’s edge. The result being increased risk of shoreline erosion and an eventual need for bank stabilizing structures. A loss of riparian vegetation would therefore be a contributing factor rather than a direct effect of shoreline hardening.

Shoreline stabilization projects may cause a directional change in the alignment (plan view) of the shore. In addition, a change to shoreline roughness, in other words a change in the type of material constituting the shoreline, would occur. The group felt that the effects resulting from a change in shore alignment and shoreline roughness would follow the same pathways as changes to shoreline profile described previously.

It became apparent through discussions that many linkages affiliated with the chosen pathways of importance were relatively uncertain. Linkages between shoreline hardening and effects on biological attributes relating to fish (rows 4, 5 and 6 of HoE model Appendix E) were found to be the least known. Impacts on physical habitat variables seemed to be better understood.

Based on the pathways investigated above, a consensus was reached as to which pathways would need to be considered for further study. Shoreline roughness and shoreline profile as they affect hydraulics and in turn erosion, water quality, substrate characteristics and cover with resulting changes to invertebrates and fish distribution, were deemed the most critical pathways for this scenario (Appendix E). Upper level biological attributes such as recruitment, feeding/growth and fish community were not included in the chosen key pathways because they could not be measured in a simple, adaptable study design.

For the purposes of this exercise, adjustments to slope and material type were considered the most important mitigation options. Increased slope and placement of rock material of appropriate size, diameter and shape would be considered adequate mitigation for a shoreline stabilization project by current DFO practices. Substrate enhancement at the toe of the structure was suggested to be the most applicable compensation technique. An example of compensation would be to install armourstone in the form of fingers protruding from the shoreline with cobbles laid along the base. Such efforts would create sheltered interstitial spaces for invertebrates and small fish and presumably replace fish habitat lost from encroachment and reduced littoral area.

Preliminary questions regarding scientific uncertainty around mitigation and compensation dealt with the need to understand baseline conditions prior to shoreline alteration. Whether or not there is a change in baseline conditions after shoreline stabilization, whether the change is harmful to fish, and whether mitigation has an effect on that change. Questions regarding the temporal and spatial scales of these changes were also introduced. Important variables, as well as spatial and temporal scales to which they should be measured, are shown in Table 2.3.

The study requirements should be kept to a minimum in order to be undertaken by proponents or agencies of varying resources. For example, it would not be reasonable to expect a private landowner to undertake a large scale monitoring program spanning several years as a condition of approval for a shoreline stabilization project. The number of variables to be measured was reduced by focusing on the lower level biological variables such as egg incubation/nursery habitat, fish spawning, invertebrates, aquatic macrophyte/periphyton and fish distribution. The group agreed to focus on measuring fish distribution and invertebrates for this exercise.

Proponents are often required to change their shoreline stabilization project from a vertical wall to a sloped revetment as mitigation for impacts to fish habitat. Scientific study is needed to support such decisions by determining whether a sloping rock revetment has less impact on fish production than a vertical wall. In addition, armourstone fingers at the base of the revetment are sometimes proposed as compensation for the resulting loss of fish habitat by encroachment. Two comparative study designs were proposed to respond to uncertainty regarding the defensibility of these mitigation and compensation techniques.

Table 2.3. Physical and biological variables, as well as spatial and temporal scales to which they should be measured.

Variable	**Temporal Scale**	**Spatial Scale**
Physical		
Encroachment	> press	10 x 50m
Shoreline Roughness	press	10 x 50m
Hydraulics	variable	10 x 50m +/- 10%
Sediment transport	variable	Parked*
Cover	press	1m
Substrate characteristics	press	10 x 50m +/- 200%
Shoreline profile (water depths near shore, bottom)	Variable	10 x 50m +/- 200%
Biological		
Invertebrates	1 year	10 x 50m +/- 200%
Fish distribution	1 year	10 x 50m +/- 200%
* no consensus was reached		

Snap-shot Design

The snap-shot design is a coarse design involving a comparison of two types of sites following full manifestation of the project effects. Uncertainty relating to the lag time of the impact is avoided. The two groups of sites compared would include one group of vertical walls (no mitigation/compensation) and another group of sloping revetments with armourstone fingers (with mitigation/compensation). Groups would be compared only once. Lag time would likely vary with each individual project and would have to be estimated prior to investigation. Sampling would be done at a time of year when fish and/or invertebrate distribution is best represented. Sites would consist of past projects referred to DFO for review and both groups (with mitigation/compensation vs. without mitigation/compensation) would be spatially and ecologically interspersed. In the absence of temporal replicates statistical power could be improved by increasing the sample size. Experimental details for this design are outlined in Appendix G.

Replicated Control-Treatment Design

A two-stage approach was used for the replicated control treatment design. Stage 1 would require a study of past monitoring projects in order to estimate variability among sites over time. By looking at pre-existing data, replication and time duration requirements could be refined according to changes observed. Project databases maintained by DFO and Conservation Authorities could be used. Data for a number of sites, including projects that have been mitigated (sloped revetments) and projects not mitigated (vertical walls), would be analyzed for each year chosen. If there were no noted difference in fish and invertebrate distribution between mitigated and non-mitigated sites, it would not be feasible to continue on to Stage 2 of the experimental design. However, if change was apparent through time, for example higher survivorship at mitigated sites over non-mitigated sites, continuation of the study using newly proposed projects would have merit. This “pre-study” would give some idea of the variability in key variables and whether the design would have suitable power.

Stage 2 would involve a comparison between three sites with mitigation (slope treatment) and three sites with compensation (slope treatment + compensation). The group decided that only invertebrates would be sampled in order to minimize the temporal scale of sampling. Invertebrates live highly stationary lives and therefore, would only require sampling once a year, as opposed to fish, which due to seasonal and daily variation would require sampling many times a year over several years. Spatial concerns would be addressed by carrying out 4 samples within an area twice the size of the project foot print. Experimental details for the Replicated Control-Treatment Design are described in Appendix G.

The final step in creating a practical study design was to determine what sampling gear would be used to collect the data. Invertebrate sampling is more cost effective, less time constrained and would be used as a surrogate for fish. Minnow traps, slurp guns and kick samples are some of the methods suggested for sampling invertebrates.

Scenario 2. Marine and Breakwater

The group followed through the HoE Protocol in the same fashion as the previous scenario, using the improved HoE model. Important pathways were drawn onto the diagram relating the disturbance to fish production (Appendix E*)*. In this case, many aspects of a marina including the construction, maintenance and operation needed to be considered. Impacts from boats, parking lots and docks were integrated into the HoE model.

The group briefly discussed applicable pathways of effects. The construction of a marina would cause encroachment onto the lakebed and a reduction in littoral habitat within the facility footprint. Encroachment/loss of littoral habitat would in turn directly impact biological functions such as egg incubation/nursery habitat and fish spawning. A marina would also cause disturbance to shoreline profile by altering slope. Shoreline roughness would be impacted as bank materials might change during construction or operation of the marina.

Shoreline profile and shoreline roughness would have an effect on both sediment/contaminants and hydraulics, which may in turn cause a change in erosion, water quality, substrate characteristics, cover and temperature. Finally, shore alignment, and hydraulics, may change due to dredging and shoreline alterations as these are commonly a part of marina construction and maintenance. The group felt that all biological variables in the HoE model would be affected as they relate to fish production. The group also agreed that pathways stemming from shore alignment and shoreline roughness (Appendix E) would be the key pathways that should be investigated.

Adjustments to slope and material type, and maintenance of circulation by use of floating docks were thought to be the most important mitigation techniques for the marina scenario. Enhancements of spawning substrate, terracing and reef creation were the compensation measures chosen to counter balance habitat loss from the marina footprint.

A good marina design provides adequate water circulation to preserve coastal processes and avoids the need for maintenance dredging. The group proposed a study design, which would begin by comparing marinas with good circulation to marinas with bad circulation, and in turn comparing them to reference sites without marina development over several years. For example, a range of energy levels could be identified using sites with marinas and sites without marinas. Fish community changes (or changes in another variable) would be assessed to determine whether or not there is a relationship between fish community and changes in energy levels. Data from DFO referrals could be used for this type of study, looking at both pre- and post-development conditions. As knowledge pertaining to the effects of habitat change on specific biological variables increases, so will the tools for studying the success of mitigation and compensation measures. Specifically, if patterns in fish community vs. energy level are observed, a second study design would come into play.

The second study design would consist of a three level BACI (Before/After, Control/Impact) approach comparing marinas without compensation, marinas with compensation, and reference sites before and after marina construction. A comparison of changes in water quality (*e.g.* temperature, turbidity), contaminants (in fish and sediment) or sedimentation/substrate type (deposition rings) could be used. Experimental details for the study designs are shown in Appendix G.

Final Considerations

The process of using HoE model and objectives was carried out successfully by this group. The recommended designs differed substantially and reflected the very different nature of the two examples carried to completion. The group was able to accomplish its assignment because they came to an early agreement on problem definition and examples to work through. Thus experts were able to contribute meaningfully to the discussion at different times. Having the right mix of experts in this group contributed to its success. Our coastal zone engineer explained engineering design while researchers were able to ask specific questions that lead to testable hypotheses. Lastly the experimental design experts translated the hypotheses, variables and other details into a statistical model for testing. All were necessary in this effort. The group also found having a facilitator and a process to work through, with a minimum of normal workday distractions (*e.g.* phone calls) allowed members to concentrate and interact in a creative atmosphere with a successful endpoint.

2.3 Culvert Breakout Group

The objective for this breakout session was to define a series of testable hypotheses related to the impact of culverts on fish habitat and to provide a practical experimental design to test these hypotheses. The culverts breakout group was successful in creating a generic study design that can be utilized to address a broad range of general hypotheses dealing with culvert impacts. However, it became clear that the potential fish habitat impacts of culverts are far from a generic problem. The tremendous variability in the type of effects and the spatial and temporal scales at which these effects may operate means that the application of any general study design requires careful case specific consideration.

2.3.1 Sampling Design for Culverts

The group deviated from the proposed sequential approach for assessing the HoE protocol. The following is a summary of the main points of the groups discussion and evaluation of the proposed HoE (Appendix F).

1. Review of the provided HoE model

The initial review of the proposed HoE model resulted in several suggested changes by members of the group. Changes included:

- Changing sediment contaminants to sediment bedload.
- Linking sediment bedload to channel morphology.
- Addition of a box for groundwater movement to deal with culverts that are placed over upwellings.
- Linking temperature to invertebrates.

It became clear that the linkages in the HoE model represented a very generic evaluation of culvert effects. Given the variability in the potential effects of culverts, depending on culvert type, geographic area and type of aquatic system involved, the group decided that it would not be feasible to produce an all-inclusive generic HoE model. Therefore, although these changes were mentioned, the group decided to concentrate on some key pathways in the HoE model which are of broad ecological and management concern.

2. Level of Risk

Based on the collective experience of the members of the group, two key pathways were identified as the primary risks to fish habitat resulting from culverts:

i) culverts as a barrier to fish passage; and

ii) sediment inputs, both acute and chronic, associated with culverts.

Although other linkages in the HoE were considered important, these two potential effects were considered to be relatively common and of significant potential effect to fish and fish production. Also, mitigation measures are commonly employed to prevent these effects and efficacy of such measures requires validation. The group decided to focus on testing mitigation measures and not address compensation.

3. Linking Pathways

The process of designing research to evaluate the linkages in the HoE model and to test whether mitigation measures are effective was complicated by a lack of agreement within the group on the appropriate scale at which to address the question. The design could focus on fish production (at the top of HoE model) or on the primary linkages within the diagram. The ‘top down’ approach has the advantage of directly addressing fish production, or some surrogate of fish production, which is the stated objective of the *Fisheries Act* and supporting policy. However, such an approach may not discretely test the series of hypotheses linking cause and effect in the HoE and may not directly assess the efficacy of mitigation measures. The ‘bottom up’ approach has the advantage of directly testing primary impacts of culverts and allows a direct test of mitigation practices. The disadvantage is that testing the primary hypotheses does not address the overall cause (culvert) and effect (change in fish production) relationship.

The group debated the relative advantages and disadvantages of the two approaches but was not able to agree which was optimal. The decision is not a scientific one: reasonable hypotheses and study designs could be developed for either. The preferred option is really a management decision based on what information best meets management goals.

4. Hypothesis and Design

On the afternoon of day 2 the group was split into three sub-groups. Sub-groups one and two developed hypotheses associated with each of the two identified risk factors, barriers and sediment respectively, and a third group was tasked with the development of a statistical approach to the design of a generic study to evaluate the hypotheses that were being developed by subgroups 1 and 2.

a) Barriers to fish passage sub-group

In theory, a properly designed and installed culvert will not impede the movement of fish in the system. However, there are a number of factors which, alone or combined, may result in culverts creating a temporary or permanent barrier to fish movement. The group first identified key factors:

- Species in system (due to differences in swimming ability)
- Migration requirements of each species
- Critical habitat requirements of fish
- Perching (*i.e.* downstream erosion that leaves the culvert above stream level)
- Culvert Design: type, depth, slope, length
- Flow velocity and water level
    - High flow (spring or rain events): fish will have problems moving up the system due to swimming limitations
    - Low flow (summer, dry periods): insufficient water level in culvert for fish to swim up- or downstream

The group decided to focus on the final point, flow velocity and water levels, because they felt this factor posed a significant risk to fish populations yet is poorly understood. The following specific questions were posed:

a) With current culvert designs, do naturally occurring increases in water flow (such as spring peak flows) result in velocities in culverts that impede fish passage?
b) Are current mitigation measures effective and adequate in restricting water velocities that may impede fish passage?
c) Are reductions in water depths within culverts during low flow periods impacting fish passage?
d) Are mitigation measures effective at maintaining water depths in culverts which are adequate to allow unimpeded fish passage?

The group discussed several mitigation measures that should be evaluated:

- Culvert design: open, box or pipe culvert?
- Was the culvert embedded (*i.e.* installed below the grade of the stream bed)?
- Was the culvert backfilled?
- Design Capabilities: what level of flow is the culvert designed to accommodate?
- Width: is stream width within the culvert less than or greater than the original bankfull width?

These mitigation measures need to be evaluated after installation of the culvert and also over time to ensure that conditions don't gradually degrade.

The group was able to summarize some of the main risks that culverts pose to fish passage through stream systems and the factors that need to be considered when evaluating fish passage through culverts. The discussions established a context within which specific hypotheses and experimental designs could be developed, however, the group did not have time to develop a specific example.

b) Sediments sub-group

The sediment subgroup identified a general study objective: to evaluate whether culvert installation changes suspended sediment and sediment deposition downstream.

Two specific hypotheses were identified:

Ho_1: Sediment and erosion control measures result in no significant differences in suspended sediment concentrations and sediment deposition rates downstream of culverts as compared to upstream.

Ho_2: There are no significant differences in suspended sediment concentrations and sediment deposition rates downstream of culverts designed for specific flood return frequencies as compared to upstream of the culvert.

Like the barrier sub-group, this group discussed a number of factors that are expected to influence the risk of sediment problems resulting from culvert installation:

- Different stream types.

- Surficial geology.
- Watershed size.
- Culvert types (embedded, what level).
- Design: 20 yr. return, 50 yr. return, 100 yr. return flood events.
- Time since installation.

As with the barrier sub-group, this group was able to identify some of the primary concerns about sediment inputs following culvert installation and the key factors to consider when evaluating impacts to stream habitat. However, the group did not have time to develop specific hypotheses to study the sediment impacts of a certain type of culvert installation.

c) Design sub-group

The group began by identifying three main categories of experimental design that might be used to address the issue of culvert impacts:

1) Reference site approach: one or more impacted sites are sampled along with a number of comparable but unimpacted sites. The level of impact at the perturbed site is determined by comparing site conditions to what is predicted based on model (*e.g.* multiple regression) predictions generated by the control, or reference, observations.
2) Comparison of groups: comparing a group of impacted sites with a group of control sites.
3) Upstream/Downstream comparison: this approach relies on an ‘internal’ control system.

The group decided that, given the type of development activities that culverts may cause, the Upstream/Downstream design, along with a before/after comparison would be the optimal approach. This approach has complex steps, but is highly tractable as long as it is kept simple. A schematic representation of the study design is shown in Figure 2.

The main advantage of this approach is that it can still be utilized without having before data or using a control site. In the absence of before data this design can be utilized to show if the culvert in the stream exhibits differences upstream and downstream of the structure. Theoretically, if a culvert were installed properly, there would be no change in stream characteristics and mitigation measures employed would be acceptable. However, having a before component in the study design is desired as it allows a true assessment of the effects of culvert construction on fish production.

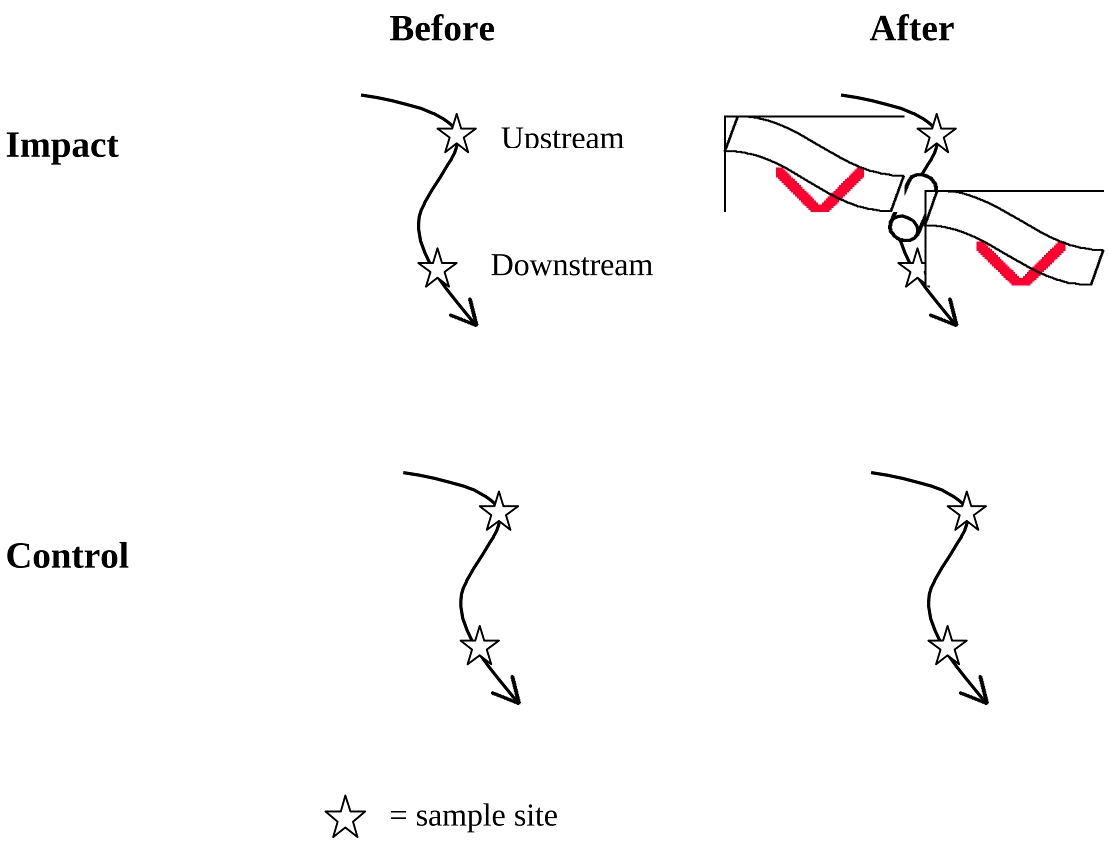


Figure 2: Schematic of a generalized experimental design to evaluate culvert impacts.

Design Preamble

An example of an ANOVA design to analyze results from this experimental design is provided in Appendix G.

The optimal design has Upstream-Downstream "internal" controls, so data are (X upstream – X downstream) or (X upstream/X downstream), depending on the actual variable measured. The latter (ratio) would probably "behave" better if transformed to logarithms. Of course, where data are, for example, number of fish swimming upstream from a given downstream position, data are X upstream (but the upstream – downstream "control" is still there).

There are also controls on nearby tributaries where there is no culvert. This verifies that upstream-downstream changes are not general (regardless of building a culvert) or, if general, not as great as where a culvert is built.

Temporal variance is probably not known for most variables. It would be desirable to estimate variance at some longer (among Periods *e.g.* seasons) and shorter (among Times *e.g.* daily in each Period) scales. The need for this and the relevant time-scales need to be determined by careful consideration of the relevant biology and hypotheses. If it was determined that temporal variance was not a factor, the study design would be simpler and potential problems of non-independent data through time would be avoided.

5. What question are you going to test?

A clear consensus that emerged from the discussions was that 'culverts' represented a highly variable suite of potential impacts to stream systems. Culverts can range in size from small pipes to very large structures and while their potential to result in some types of development activities to aquatic systems may be similar (*e.g.* sediment risk) there are also risks that are unique to certain types of culverts (*e.g.* fish passage may be affected by a small pipe but is not expected to be affected by a large, open-bottomed culvert that spans the bankfull width of the stream). In addition, site-specific variables such as fish community, land-use or stream habitat type may have different levels of influence on the risk to fish productivity posed by different culvert types. Finally, the spatial and temporal impact of various culvert types may be very different. Therefore, in order to develop specific hypotheses to evaluate culvert impacts and the effectiveness of mitigation measures, the definition of culvert also needs to be specific.

Culvert Matrix

To deal with the variability in risk factors associated with culverts, the group discussed the development of a classification system for culverts. By focusing on the specific risks posed by a particular culvert type such classification would serve as a first step in developing hypotheses to test for culvert impacts and mitigation efficacy.

Three different aspects of culverts were proposed for stratification:

- Structure: *e.g.* open bottom, box, pipe, arch, stacked or cylindrical
- Size: flow capacity *e.g.* 10, 25, 50 or 100 year high flows
- Land use effects: *e.g.* forestry, urban, rural

The group proposed that a matrix be created to identify specific problems associated with culverts (Table 2.4). The matrix approach is not likely to work if the matrix becomes too complicated and it was decided to focus on only 3-4 variables considered most likely to influence the fish species in question. Once key variables are identified, more explicit features such as mitigation and compensation can be identified.

Table 2.4. An example of a matrix classifying culverts and identifying specific problems associated with each type.

	Culvert Type	
Land Use Effects	**Pipe (small 10yr flood)**	**Pipe (large 100yr flood)**
Forest	Fish passage Sediments	Not used
Urban	Most habitat loss	Low flow design

The group worked through an example of how the culvert classification could be incorporated into the overall HoE process. Following a series of steps, numbered below, the group selected and discussed a specific example of a culvert impact and the design of a study to test the impact.

1. Start with a generic hypothesis based on a link or series of links in the HoE model:
    - Placement of a culvert in a stream will impede fish passage.

2. The classification matrix can be used to identify culvert installations (*i.e.* type, size, land use) that are predicted to have a high risk of development activities. The general hypothesis can then be focused on a more specific context:
    - Forest management areas, gravel haul roads, small corrugated pipe culverts.

3. Refine the general hypothesis with predictions based on literature results:
    - Brook trout populations work as metapopulations therefore the placement of a culvert into a stream will impede movement-creating isolated populations.
    - Fragmentation will create a difference in brook trout abundance.

4. Study design considerations:

    Using this study design (Figure 2), it is not necessary to include a control site because of the upstream/downstream sampling design. However, there are a number of design constraints which must be considered:

    - Upstream/downstream data are not independent so analyses must be done on differences, or ratios, of upstream and downstream data.
    - There will be spatial and temporal variability in response variables both within and among sites.
    - If ‘before’ is incorporated it complicates the design. Although it is more complicated to use before in the design, it is beneficial because it will explicitly show where impacts will appear. Without this element, it will make results of the study more difficult to justify. In this circumstance, one will have to disclose what they do not know about the system.
    - The design does not allow for considerations to the spatial extent of effects of culverts.

- Cannot test for effects due to increased variance through time, but this can be built in by different structuring of sampling periods.
- Some thought needs to be given to the magnitude of effect that will be considered an impact and which will result in recommended changes to policy.
- The need to revisit sites adds to the complexity of the design. Having a less complicated design is much more desirable as it limits sources of variability.

5. Mitigation and Compensation (management intervention):
   - Although mitigation and compensation specific to the design was not dealt with within the group, it is assumed that it would be part of the design process.

An advantage of using a forest management example is that it allows for the development of using the ‘before’ as part of the study design. This is because culvert locations are stipulated in forest management plans far in advance of the construction stage. In this situation the variables can be measured at upstream and downstream sites selected before construction and the sites after construction.

In the event that a “before” site cannot be utilized due to construction times or other considerations, the upstream downstream design allows for a comparison of sites in the vicinity of the culvert. One would hope in achieving no net loss of habitat (fish production) that there is no difference between the upstream and downstream measurements with presence of a culvert. When before data are not available, results become dependent on spatial differences.

6. Some Final Considerations

The session concluded with a review of some important factors to consider when designing study to assess culvert impacts:

- By creating different classification matrices, the design can be used for a variety of purposes.
- Landuse and culvert size differences can also be addressed in the design by adding terms to the model.
- Although the design is expandable, it is not wise to create an extremely complicated matrix.
- Software is available to analyze this design.
- Two measures of addressing power can be used: a) cost benefit analysis: determine the optimal answer for choice of culvert size and effect to fish production; b) can run models beforehand showing what the expected impact on fish production will be and determine what chance it has of occurring. In having these two structures, they can be set up using ANOVA or General Linear Models creating different classes of tests.
- When assessing fish, one needs to start lower on the HoE model and move upward throughout as effects are determined and understood.
- It is the biologist’s job to see what causes streams to be different. There is a need to stay consistent with the issues and what the desired outcomes are. Biology should dictate the data that are meaningful and should be collected.

- In the absence of an understanding of effect size and required power, 30 is the desired sample size as it results in a balanced model.
- If the choice has to be made to have more streams or more times, for practicality purposes incorporate more streams.
- Anything involving presence/absence uses a frequency analysis. However, it is recommended that this type of analysis be avoided.
- Less complicated to have no ‘before’ treatment. In practice, where impacts are expected that term would disappear. This makes results a little more difficult to justify, at this point one will have to state what they don’t know.

In conclusion, the group encountered two major difficulties when working through the process proposed for the workshop. First, it became clear that culverts are a diverse group of structures and may result in a complex suite of possible development activities to aquatic systems. This complexity is difficult to capture in a single HoE model. The group suggested a classification system in order to be more specific about the type of culvert and the expected impact. Second, the group had difficulty determining if the design should focus on primary impacts (*e.g.* increased sediment following culvert installation) or how the impact ultimately affects fish productivity in the system. Both approaches have advantages and disadvantages, however, the decision about which to focus on is not a biological decision. The information needed to manage fish habitat and develop policies to protect habitat needs to be clearly identified to provide a focus for the design of research efforts. As a final product, the outcome of this discussion produced a design that exhibits a great deal of spatial and temporal flexibility. A key thing to remember is that no matter what study is done; it ultimately will provide help in designing studies in the future.

3 Conclusions - What did we learn?

Land use development without proper mitigation and/or compensation can be a causative factor in aquatic habitat degradation. Unfortunately, there is a great deal of uncertainty regarding the effectiveness of mitigative and/or compensation measures required by DFO and other regulatory agencies. The consequence of uncertainty that leads to ineffective measures is the risk of proponents spending funds with no realized gain or protection, loss of credibility of the regulator and, most importantly, cumulative effects of site level development that lead to extensive and permanent loss of aquatic resources. The Design Standards Workshop was successful in bringing together a diverse group of experts who came up with meaningful designs for testing the efficacy of common mitigation for landuse development. This outcome was a result of the creative interaction between science and management that is necessary for the advancement of environmental and resource management (Underwood 1995). Critical to this successful outcome, was a very strong commitment from DFO and OMNR managers to support this effort with funding and staff participation in the steering committee and the workshop.

Having a broad array of expertise was instrumental in the planning and laying the process out to maximize the contribution of the participants at the workshop. The steering committee invited to the workshop a large number of scientists with strong expertise in experimental design because it was recognized that this critical component is often addressed late in designing projects. Having this wealth of expertise ensured that statistically appropriate models for testing real management science needs were designed. At the same time, field biologists and other experts, such as fluvial geomorphologists, provided invaluable expertise and reality checks which brought the group back from sometimes wide-ranging discussions.

The design process was the result of numerous discussions between practitioners of various disciplines within each breakout group. Three key attributes of the design process are: 1) it is adaptive; 2) it is integrative; and 3) it is iterative. The HoE facilitated design process we used is adaptive, in that it is applicable to a wide range of research studies and allows for new information to be considered as it becomes available from other disciplines. The HoE approach was accepted by participants as a good method for defining complex environmental problems and is recommended for similar problems in the future. The steering committee chose this model because it supports an adaptive experimental assessment and management (AEAM) approach by fostering communication regarding the specific character of hypotheses about important ecological processes. The steering committee strongly believes that AEAM is an excellent method for tackling issues related to landuse development.

Most participants found that the intensive sessions provided an excellent learning environment. Experimental design experts learned about biology and managers came to understand that seemingly simple questions often required careful articulation and complex designs. This realization was an important achievement of the workshop and is an important point of consideration for facilitation of future sessions. As managers and science experts interact, they will improve their ability to communicate the knowledge base and the way resources are managed. Two common issues that came up in the groups were the need to state research and management hypotheses in a simple and rigorous fashion and the need for appropriate controls or reference sites included in a design. There was also much discussion of the importance of scale both in terms of measurement and impact on fish populations. As well, groups routinely discussed the substitution of space for time scales in experimental design due to the necessity of providing answers in a timely fashion. Literature reviews were also widely recommended to consolidate the available information, attain an up-to-date understanding of the state of knowledge and thus ensure that new studies are justified. The value of using models as a conceptual tool and for study design purposes and the need to develop predictive models to forecast an aquatic ecosystem response to disturbances were also stressed.

Scale and Design Considerations

All breakout groups agreed a design should enable detection of changes at various scales (watershed to site). It was apparent from working group discussions however that there is a gap in the scientific research addressing scale issues. Observations regarding the question of spatial scale of analysis emerging from workshop discussion include:

- Consideration of scale is critical at all stages of project design and management.
- Investigations should be designed to address system complexity at decreasing scales; starting small and attempting to extrapolate this information to larger scales has not been effective.
- It is important that multiple sites within a watershed are examined, and sampling occurs at different scales so as not to miss effects occurring at individual scales.
- Research should be initiated at the watershed level to develop an overall picture of how the system functions.

In addition, the workshop discussions highlighted the following general considerations about the design of studies to assess mitigation and/or compensation effectiveness:

- The study design also needs sufficient power to detect differences.
- Using proponents to collect data could reduce the cost to an acceptable level. Methods to ensure measurement consistency by proponents are an important consideration of this approach.
- The sampling design should balance tradeoffs between spatial and temporal coverage to get temporal information about how the system works combined with information about the spatial variability of the resource. Some sites should be sampled intensively every year, and other sites randomly to cover the spatial resources in strata. With this additional information, designs such as those proposed in the workshop can be strengthened with greater specificity and likelihood of success.
- Inter-annual variability of fish communities and physical characteristics should be measured within spatially stratified homogenous units. Transferability of the results across scales should be explicitly considered in this context.

Design Framework

One of the most important objectives of the workshop was to develop a framework for designing experiments to address science needs of aquatic resource management. The framework the steering committee worked through and used in the workshop is considered to have been an excellent choice (Appendix H). This framework was tested and refined during the workshop by following through the process with the selected development activities.

- The process begins with choosing a steering committee with the appropriate disciplines needed to define the management problem as articulated by management representatives on the committee.

- Next the committee constructs a simple HoE to be used as the basis for discussion.

- The committee would then write a brief prospectus outlining the problem and current state of the science to be distributed to managers and participants.

- Participants for breakout sessions are selected to include management biologists (needed for practical experience and buy-in for implementation), research scientists from appropriate disciplines and experts in experimental design.

- The larger group would meet in facilitated breakout sessions over 1 to 2 days and follow the 9 steps articulated in the design protocol to develop a study design. All three of our breakout groups addressed the nine steps in a different order suggesting that order is not critical. What is important is that the issues articulated in the steps are resolved. Often this occurred by parking an issue and moving on. A later return usually helped resolve the issue.

Throughout the process it is important that managers and science workers communicate and agree that the objective of the exercise is to implement a field study based on the breakout groups recommendations. With the Design Standards Workshop the steering committee received strong commitment from DFO managers to implement one of the designs. This was instrumental in motivating the committee and participants and convincing them that the exercise was not trivial.

In terms of the adaptive management cycle which we outlined in the Introduction (Figure 1), the framework we are presenting centres on the 'assess problem' and 'design' stages. Our framework and protocol are good templates for moving through these two steps. The implementation of one or more of the field designs is obviously critical and in terms of resources will require commitment from both managers and researchers to carry through. This step can not be over emphasized and is often not given enough consideration.

Next Steps

This workshop yielded experimental designs for three common development scenarios in Canada. Following the workshop, the steering committee recommended that DFO adopt the culvert design for implementation in the next phase of the overall initiative. Culverts were recommended because there are a large number reviewed each year ensuring a sufficient sample size. In addition, there are many science issues that need to be addressed to fully understand how to best mitigate the adverse effects of culverts on fish and fish habitat. At the present time, the steering committee is discussing strategies for funding the actual field design of the model. In addition, a subset of the steering committee is writing up the results of the workshop for submission to a management journal.

Relevant Literature

Clarke, K. R. and R. H. Green. 1988. Statistical design and analysis for a 'biological effects' study. Mar. Ecol. Prog. Ser. 46: 213-226.

Edwards, D. 1996. Comment: The First Data Analysis Should be Journalistic. Ecol. App. 6(4): 1090-1094

Eberhardt, L. L. 1976. Quantitative ecology and impact assessment. J. Envir. Man. 4: 27-70.

Ellison A.M., 1996 An Introduction to Bayesian Inference for Ecological Research and Environmental Decision-Making. Ecol. App. 6(4):1036-1046

Green, R. H. 1979. Sampling design and statistical methods for environmental biologists. Wiley, New York.

Green, R. H. 1984. Statistical and nonstatistical considerations for environmental monitoring studies. Environ. Monit. Assessm. 4: 293-301.

Green, R. H. 1987. Statistical and mathematical aspects: distinction between natural and induced variation. In "*Methods for Assessing the Effects of Mixtures of Chemicals*", V.B. Vouk, G.C. Butler, D.V. Upton, D.V. Parke, and S.C. Asher, pp. 335-354. John Wiley & Sons, Chichester UK.

Green, R. H. 1989a. Power analysis and practical strategies for environmental monitoring. Environm. Res. 50: 195-205.

Green, R. H. 1989b. Inference from observational data in environmental impact studies: what is valid? what is possible? 47th Session, International Statistical Institute, Paris.

Green, R. H. 1993. Application of repeated measures designs in environmental impact and monitoring studies. Austr. J. Ecol. 18: 81-98.

Green, R. H. 1994. Aspects of power analysis in environmental monitoring. In "*Statistics in Ecology and Environmental Monitoring*", D.J. Fletcher and B.F.J. Manly, pp.173-182. University of Otago Conference Series, University of Otago Press, Dunedin, New Zealand.

Green, R. H., S. M. Singh, and R. C. Bailey. 1985. Bivalve molluscs as response systems for modelling spatial and temporal environmental patterns. Sci. Tot. Envir. 46: 147-169.

Holling, C.S. 1978. *Adaptive environmental assessment and management.* John Wiley, New York, New York, USA.

Imhof, J.G. , J. Fitzgibbon, and W.K. Annable 1996. A hierarchical evaluation system for characterizing watershed ecosystems for fish habitat. Can. J. Fish. Aquat. Sci. 53(suppl. 1): 312-326.

Jones, M.L., R.G. Randall, D. Hayes, W. Dunlop, J. Imhof, G. Lacroix, and N.J.R. Ward. 1996. Assessing the ecological effects of habitat change: moving beyond productive capacity. Can. J. Fish. Aquat. Sci. 53 (Suppl. 1): 446-457.

Ludwig D., 1996. Uncertainty and the Assessment of Extinction Probabilities. Ecol. Appl. 6(4): 1067-1076.

McDonald, L. L., and W. P. Erickson. 1994. Testing for bioequivalence in field studies: Has a disturbed site been adequately reclaimed? Environmental Toxicology and Chemistry 183-197.

Parrish, D.L., M.E. Mather, and R.A. Stein. 1995. Problem-solving Research for Management: A Perspective. Fisheries vol. 20, No. 10: 6-12

Stewart-Oaten, A. 1996. Goals in environmental monitoring. In: Detecting Ecological Impacts: Concepts and Applications in Coastal Habitats, edited by R. J. Schmitt and C. W. Osenberg, p. 17-27. Academic Press, New York.

Suter, G. W. 1996. Abuse of hypothesis testing statistics in ecological risk assessment. Human and Ecological Risk Assessment 2: 331-347.

Underwood, A. J. 1981. Techniques of analysis of variance in experimental marine biology and ecology. Ann. Rev. Oceanogr. Mar. Biol 19: 513-605.

Underwood, A. J. 1991. Beyond BACI: experimental designs for detecting human environmental impacts on temporal variations in natural populations. Austr. J. Mar. Freshw. Res. 42: 569-587.

Underwood, A. J. 1992. Beyond BACI: the detection of environmental impacts on populations in the real, but variable, world. J. Exp. Mar. Biol. Ecol. 161: 145-178.

Underwood, A. J. 1993. The mechanics of spatially replicated sampling programmes to detect environmental impacts in a variable world. Austr. J. Ecol. 18: 99-116.

Underwood, A. J. 1994a. Things environmental scientists (and statisticians) need to know to receive (and give) better statistical advice. In: Statistics in Ecology and Environmental Monitoring. Edited by: D.J. Fetcher & B.F.J. Manly, University of Otago Press, Dunedin (New Zealand). pp. 33-61.

Underwood, A. J. 1994b. On beyond BACI: sampling designs that might reliably detect environmental disturbances. Ecol. Appl. 4: 3-15.

Underwood, A.J. 1995. Ecological research and (and research into) environmental management Ecol. Appl. 5(1): 232-247.

Underwood, A. J. 1997. Experiments in ecology: their logical design and interpretation using analysis of variance. Cambridge University Press, Cambridge, UK.

Ver Hoef, J.M. 1996. Parametric Empirical Bayes Methods for Ecological Applications. Ecol. Appl. 6(4): 1047-1055.

Walters, C. J. and R. H. Green. 1997. Valuation of experimental management options for ecological systems. J. Wildl. Man. 61: 987-1006.

Appendix A.1 - Participants List

Tracy Allison
Workshop Coordinator/Project Assistant
Watershed Science Centre
Trent University, Symons Campus
1600 West Bank Drive
Peterborough ON K9J 7B8
Phone: (705) 755-2276
Fax: (705) 755-2276
Email: tallison@trentu.ca

Jeff J. Andersen
Aquatic Resource Technologist
Central Lake Ontario Conservation Authority
100 Whiting Ave.
Oshawa, ON
Phone: (905) 579-0411
Fax: (905) 579-0994
Email: jandersen@cloca.com

Dr. Philipe Archambault
Environmental Science Division, Regional Oceans and Environment Branch, Fisheries and Oceans Canada, Institut Maurice-Lamontagne
850 route de la Mer, C.P. 1000
Mont-Joli, Quebec G5H 3Z4
Phone: (418) 775-0752
Fax: (418) 775-0718
Email: archambaultp@dfo-mpo.gc.ca

Dr. Robert Bailey
Associate Professor
University of Western Ontario
Zoology Dept.
London ON N6A 5B7
Phone: (519) 661-4022
Fax: (519) 661-2014
Email: drbob@uwo.ca

Derrick Beach
Senior Habitat Protection Engineer
Department of Fisheries and Oceans
304-3027 Harvester Rd., P.O. Box 85120
Burlington ON L7R 4K3
Phone: (905) 639-7432
Fax: (705) 639-3549
Email: beachd@dfo-mpo.gc.ca

Dave Borutski
Provincial Fish Ecology Specialist
Alberta Fisheries & Wildlife Management Division
Main Floor, South Petroleum Plaza, 9915-108 St.
Edmonton AB T5K 2G8
Phone:(780) 427-9973
Fax: (780) 422-9559
Email: dave.borutski@gov.ab.ca

Andy Bramburger
Fish Habitat Monitoring Technician
Department of Fisheries and Oceans
Bayfield Institute, 867 Lakeshore Rd.
P.O. Box 5050
Burlington ON N1A 2X5
Phone: (905) 336-4564
Fax: (905) 336-4819
Email: bramburgera@dfo-mpo.gc.ca

Lori Cook
Planning Ecologist
Toronto and Region Conservation Authority
5 Shoreham Drive
Downsview ON M3N 1S4
Phone: (416) 661-6600 ext. 5350
Fax: (416) 661-6898
Email: lcook@trca.on.ca

Appendix A.1 cont'd. - Participants List

Rick Courtney
Impact Assessment Biologist
Department of Fisheries and Oceans
800 1601 Airport Rd. NE
Calgary AB T2E 6Z8
Phone: (403) 292-5165
Fax: (403) 292-5173
Email: courtneyr@dfo-mpo.gc.ca

Sean Geddes
Aquatic Biologist, Plan Review
Grand River Conservation Authority
400 Clyde Road, P.O. Box 729
Cambridge ON N1R 5W6
Phone: (519) 621-2761 ext.248
Fax: (519) 621-4844
Email: sgeddes@grandriver.ca

Gloria Gillespie
Research Biologist
Watershed Science Centre
Trent University, Symons Campus
1600 West Bank Drive
Peterborough ON K9J 7B8
Phone: (705) 755-2287
Fax: (705) 755-2276
Email: ggillespie@trentu.ca

Dr. Lee Grapentine
Research Scientist
National Water Research Institute,
Environment Canada 867 Lakeshore Road
Burlington ON L7R 4A6
Phone: (905) 336-6479
Fax: (905) 336-4699
Email: lee.grapentine@cciw.ca

Dr. Roger Green
Emertius Professor
University of Western Ontario
Email: rgreen@uwo.ca

David Harper
Habitat Assessment Biologist
Department of Fisheries and Oceans
402-998 Thurlow St.
Vancouver, BC V6E 1W6
Phone: (604) 666-3512
Fax: (604) 666-0417
Email: harperd@dfo-mpo.gc.ca

John Heinonen
Physical Scientist
Department of Fisheries and Oceans
360-555 West Hastings St.
Vancouver, BC V6B 5G3
Phone: (604)666-0126
Fax: (604) 666-0292
Email: heinonenj@dfo-mpo.gc.ca

Appendix A.1 cont'd. Participants List

Jack Imhof
Aquatic Habitat Ecologist
Ontario Ministry of Natural Resources
1 Stone Rd. West
Guelph, ON N1G 4Y2
Phone: (519) 826-4938
Fax: (403) 826-4929
Email: jack.imhof@mnr.gov.on.ca

Dr. Don Jackson
Professor
University of Toronto
25 Harbord St.
Toronto, ON M5S 3G5
Phone: (416) 978-0967
Fax: (416) 978-8532
Email: jackson@zoo.utoronto.ca

Jeff Johansen
A/Chief, Major Projects Review Unit
Department of Fisheries and Oceans
Major Projects Review Unit, 1220A-555
West Hastings Street
Vancouver, BC V6B 5G3
Phone: (604) 666-2057
Fax: (604) 666-7907
Email: johansenj@dfo-mpo.gc.ca

Margaret Keast
Impact Assessment Biologist
Department of Fisheries and Oceans
310-1975 Scarth St.
Regina, SK S4P 2H1
Phone: (306) 780-8729
Fax: (306) 780-8722
Email: keastm@dfo-mpo.gc.ca

Dr. Bruce Kilgour
Senior Consultant
Jacques Whitford Environment Ltd.
2781 Lancaster Road, Suite 200
Ottawa, ON K1B 1A7
Phone: (613) 738-0708
Fax: (613) 738-0721
Email: bkilgour@jacqueswhitford.com

Lonnie King
Fish Habitat Biologist
Department of Fisheries and Oceans
867 Lakeshore Road
Burlington, ON L7R 2A6
Phone: (905) 336-4606
Fax: (905) 336-6285
Email: kingls@dfo-mpo.gc. ca

Teresa Labubuda
Coastal/Civil Engineer
Conservation Halton
Phone: (905) 336-1158 ext.234
Fax: (905) 336-7014
Email: admin@hrca.on.ca attn:T.Labuda

Marc Lange
Area Habitat Biologist
Department of Fisheries and Oceans
5204-50th Ave, Suite 101
Yellowknife, NWT X1A 1E2
Phone: (867) 669-4912
Fax: (867) 669-4912
Email: langem@dfo-mpo.gc.ca

Appendix A.1 cont'd. Participants List

Dr. Michel F. Lapointe
Associate Professor
McGill University/Geography
805 Sherbrooke St. W.
Montreal, PQ H3A 2K6
Phone: (514)398-4959
Fax: (514) 398-7437
Email: lapointe@geog.mcgill.ca

Scott MacNeill
Fisheries Biologist
Ganaraska Region Conservation Authority
P.O. Box 328
Port Hope, ON L1A 3W4
Phone: (905) 885-8173
Fax: (905) 885-9824
Email: fisheries@grca.on.ca

Deborah Martin-Downs
Senior Fisheries Biologist
Gartner Lee Limited
140 Renfrew Drive, Suite 102
Markham, ON L3R 6B3
Phone: (905) 477-8400 ext 225
Fax: (905) 477-1456
Email: dmdowns@gartnerlee.com

Shelley Matkowski
Fish Habitat Biologist
Fisheries Branch, Manitoba Conservation
200 Saulteaux Cres.
Winnipeg, MB R3J 3W3
Phone: (204) 945-7789
Fax: (204) 948-2308
Email: smatkowski@gov.mb.ca

Steve McGovern
Leader-Aquatic Ecosystem Team
Ontario Ministry of Natural Resources
Box 3020 Ontario Government Complex,
Hwy. 101 East
South Porcupine, ON PON 1HO
Phone: (705) 235-1211
Fax: (705) 235-1251
Email: steve.mcgovern@mnr.gov.on.ca

Fiona McGuiness
Waterpower Biologist
Ontario Ministry of Natural Resources
300 Water St. PO Box 7000
Peterborough ,ON K9J 8M5
Phone:(705) 755-1522
Fax: (705) 755-1267
Email: fiona.mcguiness@mnr.gov.on.ca

Dr. Robert A. Metcalfe
Science Coordinator-Waterpower Project
Ontario Ministry of Natural Resources
Aquatic Ecosystems and Science Section Applied
Research and Development Branch
300 Water St. P.O. Box 7000
Peterborough, ON K9J 8M5
Phone: (705) 755-1577
Fax: (705) 755-1267
Email: robert.metcalfe@mnr.gov.on.ca

Cindy Mitton-Wilkie
Senior Environmental Planner-Fisheries
Ministry of Transportation
3rd Floor, Building D, 1201 Wilson Ave
Downsview, ON M3M 1C1
Phone: (416) 235-5230
Fax: (905) 235-4940
Email: cynthia.mitton@mto.gov.on.ca

Appendix A.1 cont'd. Participants List

Pierre Nellis
Biologiste
Department of Fisheries and Oceans
850 rte de la Mer, c.p. 1000
Mt-Joli, PQ G5H 3Z4
Phone: (418) 775-3802
Fax: (418) 775-0718
Email: nellisp@dfo-mpo.gc.ca

Jim Niefer
Fish Habitat Technician
Department of Fisheries and Oceans
401 King St. W. P.O. Box 1000
Prescott, ON
Phone: (613) 925-2865 ext. 137
Fax: (613) 925-2245
Email: nieferj@dfo-mpo.gc.ca

Richard Orr
Impact Assessment Biologist
Department of Fisheries and Oceans
310-1975 Scarth St.
Regina, SK S4P 2H1
Fax: (306)780-8722
Email: orrr@dfo-mpo.gc.ca

Ed Paleczny
Aquatc Habitat Biologist
Ontario Ministry of Natural Resources
300 Water St. PO Box 7000
Peterborough, ON K9J 8M5
Phone: (705) 755-1913
Fax: (705) 755-1957
Email: ed.paleczny@mnr.gov.on.ca

John Parish
Fluvial Geomorphologist
PARISH Geomorphic Ltd.
10 Mountainview Road S, Suite 201
Georgetown, ON L7G 4J9
Phone: (905) 877-9531
Fax: (905) 877-4143
Email: jparish@parishgeomorphic.com

Rick Portiss
Co-ordinator of Environmental Projects
Toronto and Region Conservation Authority
5 Shoreham Drive
Downsview, ON M3N 1S4
Phone: (416) 661-6600 ext. 5302
Fax: (416)661-6898
Email: rportiss@trca.on.ca

Dr. Tom Pratt
Community Production Scientist
Fisheries and Oceans, Great Lakes Laboratory for Aquatic Sciences
1 Canal Dr.
Sault Ste Marie, ON P6A 6W4
Phone: (705) 942-2848
Fax: (705) 941-3025
Email: prattt@dfo-mpo.gc.ca

Scott Reid
Fisheries Biologist
Golder Associates Ltd.
2180 Meadowvale Boulevard
Mississauga, ON L5N 5S3
Phone: (905) 567-4444 ext.1353
Fax: (905) 567-6561
Email: sreid@golder.com

Appendix A.1 cont'd. Participants List

Les Stanfield
Senior Research Biologist
Ontario Ministry of Natural Resources
Lake Ontario Fisheries Unit,
RR4 Picton, ON KOK 2TO
Phone: (613) 476-8777
Fax: (613) 476-7131
Email: les.stanfield@mnr.gov.on.ca

Nadine Stiller
Fish Habitat Biologist
Department of Fisheries and Oceans
501 University Cres.
Winnipeg, MB ROG 1NO
Phone: (204) 984-3636
Fax: (204) 984-2404
Email: stillern@dfo-mpo.gc.ca

Jennifer Thomas
Fish Habitat Biologist
Department of Fisheries and Oceans
DFO_FHM P.O. Box 5050, 867 Lakeshore Rd.
Burlington, ON L7R 4A6
Phone: (905) 336-4938
Fax: (905) 336-6285
Email: thomasj@dfo-mpo.gc.ca

Dr. Tony Underwood
Professor
Centre for Research on Ecological Impacts of Coastal Cities
Marine Ecology Laboratoratories A11
University of Sydney, Australia NSW 2006
Phone: 61-2-9351-2590
Fax: 61-2-9351-5617
Email: aju@bio.usyd.edu.au

Donna Wales
Infromation Management Coordinator
Ontario Ministry of Natural Resources
300 Water Street 2nd Floor North Tower
P.O. Box. 7000
Peterbourogh, ON K9J 8M5
Phone: (705) 755-2113
Fax: (705) 755-1640
Email: donna.wales@mnr.gov.on.ca

Neville Ward
Regional Fisheries Biologist
Ontario Ministry of Natural Resources
P.O. Box 5080, 808 Robertson Street
Kenora, ON P9N 3X9
Phone: (807) 468-2706
Fax: (807) 468-2736
Email: neville.ward@mnr.gov.on.ca

Appendix A.2 – Steering Committee.

Dr. Leon Carl – co-chair
Director
Watershed Science Centre
Trent University, Symons Campus
1600 West Bank Dr.
Peterborough, ON K9J 7B8
Phone: (705) 755-2268
Fax: (705) 755-2276
Email: leon.carl@mnr.gov.on.ca

Dr. David Evans
Ontario Ministry of Natural Resources
MNR/Trent University, 1600 West Bank Dr.
P.O. Box 4840
Peterborough, ON K9J 8N8
Phone: (705) 755-2256
Fax: (705) 755-2276
Email: david.evans@mnr.gov.on.ca

Vic Gillman - co-chair
A/Area Director
Department of Fisheries and Oceans-Ontario
Bayfield Institute,
867 Lakeshore Road P.O. Box 5050
Burlington ON 7LR 4A6
Email: gillmanv@dfo-mpo.gc.ca

Karen Gray
A/Program Services Coordinator
Department of Fisheries and Oceans
Fish Habitat Management - Ontario Area,
867 Lakeshore Road.
Burlington ON 7LR 4A6
Phone: (905) 336-6235
Fax: (905) 336-6285
Email: grayk@dfo-mpo.gc.ca

Dr. Mike Jones
Associate Professor
Department of Fisheries and Wildlife
13 Natural Resources Bldg. Michigan State University
East Lansing, MI, 48824-1222
Phone: (517)432-0465
Fax: (517)-432-1699
Email: jonesm30@msu.edu

Dr. Chris Katopodis
Regional Habitat Engineer
Department of Fisheries and Oceans
Freshwater Institute, 501 University Crescent
Winnipeg MB R3T 2N6
Phone: (204) 983-5181
Fax: (204) 984-2402
Email: katopodisc@dfo-mpo.gc.ca

Dr. Robert Mackereth
Research Scientist
Ontario Ministry of Natural Resources
Centre for Northern Forest Ecosystem Research
955 Oliver Rd.
Thunder Bay ON P7B 5E1
Phone: (807) 343-4009
Fax: (807) 343-4001
Email: rob.mackereth@mnr.gov.on.ca

Debbie Ming
Fish Habitat Biologist
Department of Fisheries and Oceans
Fish Habitat Management- Ontario Area
867 Lakeshore Rd.
Burlington ON 7LR 4A6
Phone: (905) 336-4592
Fax: (905) 336-6285
Email: mingd@dfo-mpo.gc.ca

Appendix A.2 cont'd. – Steering Committee.

Dr. Charles K. Minns
Department of Fisheries and Oceans
Bayfield Institute (GLLFAS), CCIW
Burlington ON 7LR 4A6
Phone: (905) 336-4874
Fax: (905) 336-6437
Email: minnsk@dfo-mpo.gc.ca

Dr. Keith Somers
Acting Manager
Dorset Environmental Science Centre
Ontario Ministry of the Environment
1026 Bellwood Acres Road, PO Box 39
Dorset, ON, P0A 1E0
Phone: (705) 766-2408
Fax: (705) 766-2254
Email: keith.somers@ene.gov.on.ca or somers@zoo.utoronto.ca

Jason Quigley
Habitat Assessment Biologist
Department of Fisheries and Oceans
Habitat and Assessment Land Stewardship Unit
360-555 West Hastings St.
Vancouver BC V6B 5G3
Phone: (604) 666-7918
Fax: (604) 666-0417
Email: quigleyj@dfo-mpo.gc.ca

Mike Stoneman
Fish Habitat Biologist
Department of Fisheries and Oceans
800 1601 Airport Rd. NE
Calgary AB, T2E 6Z8
Phone: (403) 292-5171
Fax: (403) 292-5173
Email: stonemanm@dfo-mpo.gc.ca

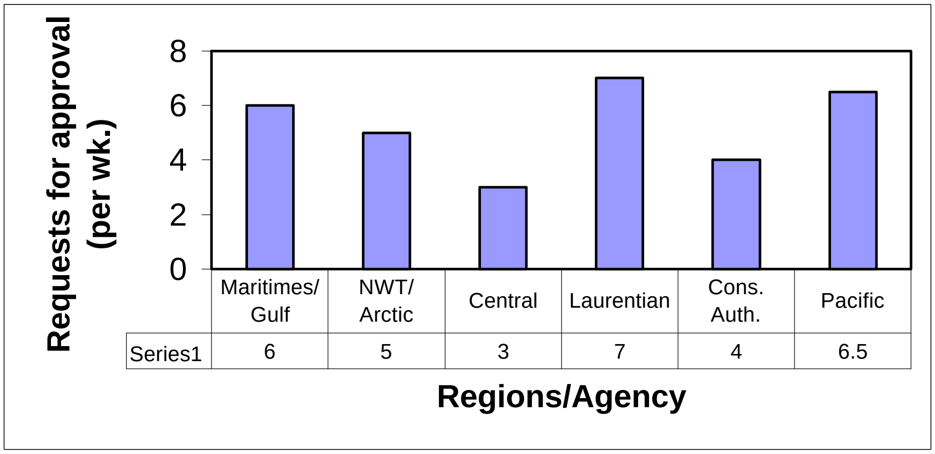
Facilitator

Lorne Greig
Senior Systems Ecologist
ESSA Technologies Ltd.
Suite 301, 1595 16th Avenue
Richmond Hill ON L4B 3N9
Phone: (416) 657-2170
Fax: (416) 657-2172
Email: lgreig@essa.com

Appendix B - Development authorization telephone survey.

1) *How many requests for approval do you typically receive per week? This included both approvals and reviews. Results were supplied within their own agency.*

Results of Question 1



As these results indicate, survey respondents are engaged in assessing several referrals per week. The Laurentian region closely followed by the Pacific region handled the largest number of referrals. The lowest number of approvals handled was in the Central (Ontario) region. However, combining Central Ontario with the Conservation Authorities referrals indicate these regions have a similar number to other areas.

2. What are the three most prevalent development activities that you see in a year that have potential to impact fish habitat in your region?

Response to Question 2

Region/Agency	Top Three Development Activities
Maritimes/ Gulf	1. Linear Development 2. Forestry Practices and Warfing 3. Stream Restoration and Mining.
NWT/Arctic	1. Mining 2. Linear Development 3. Oil and Gas Exploration
Central	1. Linear Development 2. Infilling 3. Dock Construction, Shoreline Stabilization and Stream Realignment.
Laurentian	1. Hydro-electric Development 2. Dredging 3. Warf Repairs
Ontario Conservation Authorities	1. Linear Development 2. Drainage 3. Subdivision Construction
Pacific	1. Linear Development 2. Forest Development Plans

A common prevalent development activity encountered across Canada by DFO and Ontario Conservation Authorities is linear development. This includes actions such as the construction of culverts, roads, and bridges. Other development activities expressed may have a strong connection to regional differences such as pipeline crossing and hydro development.

3. What major fish species are of concern?

This question was originally designed to assess the number of species present in each region that were riverine or lacustrine. After speaking to survey participants, it was much easier to name a few key species that are important when dealing with a referral. Both specific species and families were named.

Maritimes/Gulf: Four specific species were identified and others were grouped into families.

Species named	Families Identified
Speckled Trout	Trout
Atlantic Salmon	Salmonids
Smelt	Shellfish
Herring	Eels
	Lobster

NWT/Arctic:

Species Named	Families Identified
Atlantic Salmon	Salmonids
Brook Trout	
Arctic Char	
Lake Trout	
Whitefish	
Walleye	
Pike	
Grayling	

Central:

Species Named
Brook Trout
Pike
Muskie
Whitefish
Lake Trout
Perch
Baitfish

Laurentian:

Family Named
Salmonids

Pacific:

Species Named	Family Named
Cutthroat Trout	Salmonids
Steelhead	

Ontario Conservation Authorities:

	Species Named		Families Named
Baitfish	Smallmouth Bass	Redside Dace	Salmonids
Muskie	Largemouth Bass		
Brook Trout	Northern Pike		
Walleye	Lake Trout		

Thirteen (39%) identified all species being important under the F*isheries Act*. All of these respondents were from Ontario, 54% were from Ontario DFO, and 46% from Conservation Authorities.

4. *What do you consider while assessing the development and possible need for mitigation and compensation?*
    A. *The magnitude of the development?*
    B. *The type of ecotype or habitat being altered?*
    C. *The presence of Vulnerable, Threatened or Endangered Species (VTE)?*

Several respondents stated that all three criteria were considered when assessing a development project. Some participants were able to rank the criteria as to what they considered the most to the least. Of those that were able to provide a ranking, the results are tabulated below.

Results of Question 4

Region/Agency	Ranking #1	Ranking #2	Ranking #3
Maritimes/Gulf	Ecotype	VTE	Magnitude
NWT/Arctic	Ecotype	VTE	Magnitude
Central	Ecotype	Magnitude	VTE
Laurentian	Magnitude	VTE & Ecotype equal	
Conservation Authorities	Ecotype	Magnitude	VTE
Pacific	Ecotype & VTE	Magnitude	

5. What knowledge base is used to make a decision regarding authorization including selection of mitigation and compensation terms?

Response to Question 5

Maritimes/Gulf	NWT/Arctic
1. Personal Experience 2. Information available and compromise with proponent Magnitude Sensitivity Available Data Arial Impact Biology of species HADD policy Surface Area Water resource inventory Local knowledge	1. Past Experience All information available Habitat modelling DFO protocol HADD policy Consultation with others Consultation with proponent
Central	**Laurentian**
1. Past Experience 2. Existing Data & DFO publications Checklists Negotiations Standard protocols No net loss guidelines Potential Impacts Photos	Guidelines for region Team meetings HADD policy Previous experience

Maps Decision tree	
Pacific	Conservation Authorities
1. All information available Consultation with proponent Decision tree Checklist Past Experience Application of BMP Environmental assessment	1. Past Experience 2. Lists 3. Guidelines and Site Characteristics Magnitude Season Available data Decision tree OMAFRA municipal drains checklist Training DFO thermal determination protocol Stream class protocol MNR NERVIS Historical information

6. *Proponents monitoring, mitigation and compensation terms and actions are verified, audited and enforced by: Whom, how and when?*

Majority of respondents from all regions across Canada and Ontario Conservation Authorities stated that there are virtually no checks on monitoring, mitigation and compensation terms with the exception of large special projects. The only data that many are relying on were letters that proponents were required to submit stating what was done, but rarely were monitoring reports followed up. Investigations take place on a reactionary basis when reported by citizens or other agencies.

Lack of monitoring of proponents actions was largely due to lack of money, staff and time. Several respondents stated that follow up on proponents actions is necessary as habitat compliance is extremely low. A few conservation authorities argued that it needs to be more explicit as to who is responsible to do monitoring as different organizations assume that another is doing the job.

Several respondents stated that a way to solve this is to hire staff that are solely responsible for compliance monitoring or to hire more biologists to ease the load of approvals so those in charge of approving developments can monitor projects from start to finish.

7. *Is there an ongoing monitoring program of evaluating developers actions in your region?*

Response to Question 7

Region	**Yes**	**No**	**Sometimes**	**N.A.**
Maritimes	25%	63%		
NWT/Arctic	33%	66%		
Laurentian		100%		
Central	13%	38%	25%	13%
Conservation Authorities	29%	71%	6%	
Pacific		66%	33%	

For those who answered no, the reasons were based on lack of staff and money.

8. How is your monitoring data being used?

Response to Question 8

Maritimes	**NWT/Arctic**	**Laurentian**
Not Used: 50% Is Used: 50% -assessment of poor decisions -overview of project -compliance monitoring -determine if methods are adequate.	Not Used: 33% Is Used: 66% -GIS applications -Compliance monitoring -Impact assessment -follow up actions that need to be taken.	Is Used: 100% -To verify project as being constructed as planned -Assess impact prediction -Effectiveness of compensation -In the future: use to analyze competency of our own monitoring.
Central	**Pacific**	**Conservation Authorities**
Not Used:43% Is Used: 57% -Determine if requirements for authorization are met.	Not Used: 33% Is Used: 66% -Used by BI 2 to assess whether or not letter of credit can be released. -Determination of whether or not habitat mitigation and compensation were successful.	Not Used: 18% Is Used: 35% N.A: 47% -support of subwatershed plans -future project development -determine negative effects -reporting to DFO, OMNR and general information for the public -Development of S.E. Ontario Municipal Drains project -Future: adaptive management -Used when requested

9. Is your monitoring data adequate for the purposes intended?

Response to Question 9

Region/Agency	Yes	No	Somewhat	N.A.
Maritimes	25%	25%	38%	13%
NWT/Arctic	33%	33%	33%	
Laurentian			100%	
Central	43%	14%		43%
Conservation Authorities	35%		6%	59%
Pacific	33%	67%		

10. Is the Impacted site compared with nearby unaffected sites?

Response to Question 10

Region/Agency	Yes	No	Sometimes	N.A.
Maritimes/Gulf	50%	50%		
NWT/Arctic	100%			
Laurentian	100%			
Central		27%	71%	
Conservation Authorities	31%	38%	13%	19%
Pacific	33%	66%		

11. Do you pool your monitoring data across a larger area for analysis purposes?

Response to Question 11

Region/Agency	Yes	No	Sometimes	N.A.
Maritimes/Gulf	13%	75%	13%	
NWT/Arctic		100%		
Laurentian			100%	
Central	14%	86%		
Conservation Authorities	33%	47%		13%
Pacific		100%		

12. Do you pool your data with neighbouring agencies for analysis purposes?

Response to Question 12

Region/Agency	Yes	No	Sometimes	N.A.
Maritimes/Gulf	25%	50%	25%	
NWT/Arctic	33%	66%		
Laurentian		100%		
Central	29%	71%		
Conservation Authorities	23%	41%	6%	29%
Pacific		100%		

13. Do you interact with other agencies for the purposes of large-scale management? This could be for review and approval or watershed management etc.

Response to Question 13

Region/Agency	Yes	No	N.A.
Maritimes/Gulf	87%	13%	
NWT/Arctic	100%		
Laurentian	100%		
Central	86%	14%	
Conservation Authorities	50%	40%	13%
Pacific	66%	33%	

14. What size of management unit do you use for fish habitat management decisions in your region?

Response to Question 14

Maritimes/Gulf	**NWT/Arctic**	**Laurentian**
1. Watershed 2. Dependent on project 3. Region -fish/unit area -zone of impact -100m2	1. Dependent on project	1. Often do not use a management unit. Have sometimes used m2
Central	**Pacific**	**Conservation Authorities**
1. Watershed 2. Site -reach -lake -m2 -watercourse	- Site - Size of development	1. Watershed 2. Site 3. Subwatershed - local scale - watercourse - m2

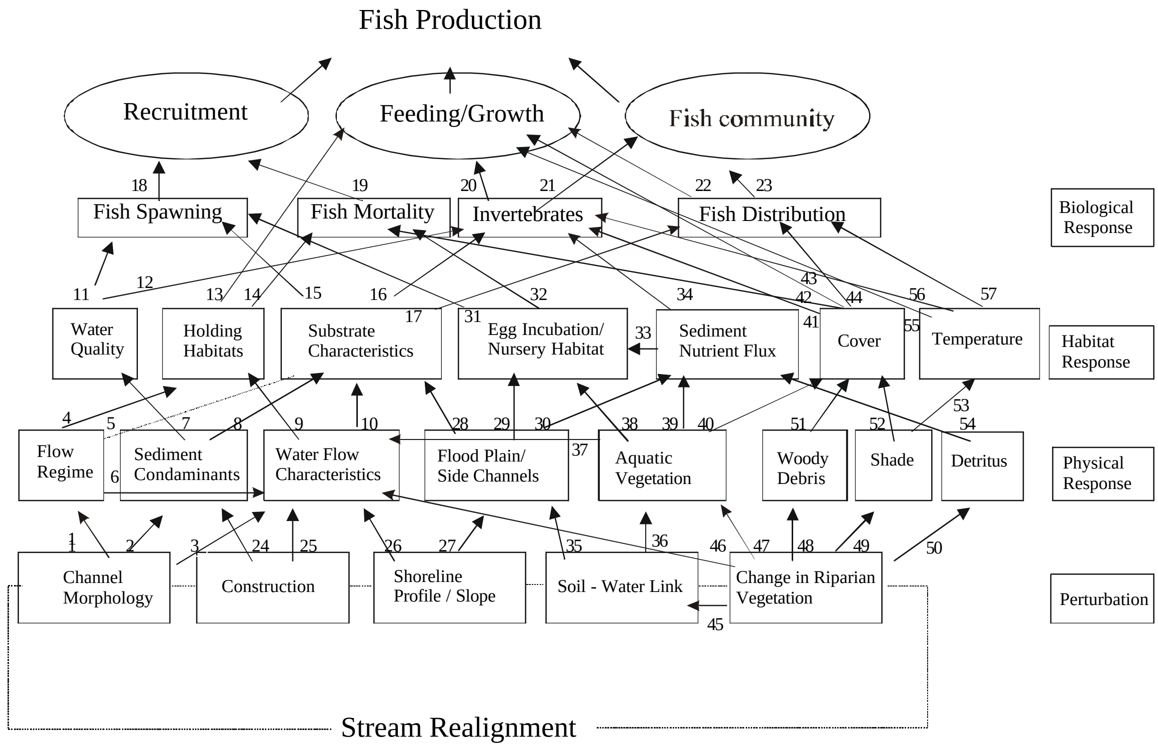
Discussion

The survey results suggest there is a substantial amount of referral activity throughout Canada. The type of development varies from region to region, however linear development is important in most regions. It is a concern that only one region has guidelines and many biologists rely on experience in determining mitigation and compensation. There was little monitoring of activities or use of data that were collected. There was good interaction among agencies and management was often at the watershed scale. These results tend to confirm the steering committees assessment that there is a lack of good science on mitigation and compensation and that the workshop was timely in addressing science needs.

Appendix C - Workshop Agenda.

Date	Time	Description
Monday March 5/01	4:00 Onwards	Arrival of Most Participants Check in Dorm 70 First Floor
Tuesday March 6/01	7:30-8:00	Breakfast
	8:00-8:30	Check in Main Building Foyer
	8:30-8:45	Introduction/Frost Centre – Dr. Leon Carl
	8:45-9:00	Address by Karen Gray
	9:00-9:30	Lorne Greig-Approach to Workshop
	9:30-10:00	Jason Quigley-DFO, Outline of the 3 selected development activities
	10:00-10:30	Coffee Break
	10:30-11:00	Dr. Dave Evans - Mitigation and Compensation-ho it fits into HoE models
	11:00-12:00	Dr. Tony Underwood- Experimental Design
	12:00-1:30	Lunch
	1:30-2:00	Approach/Objectives of Subgroup Discussion
	2:10-3:00	Subgroup Discussions
	3:00-3:30	Coffee Break
	3:30-5:00	Subgroup Discussions
	5:00-7:30	Dinner
	7:30	Social
Wednesday	7:30	Breakfast
March 7/01	8:30-9:00	Reality of Stream Ecology-John Parish
	9:00-10:00	Subgroup Discussions
	10:00-10:30	Coffee Break
	10:30-12:00	Subgroup Discussions
	12:00-1:30	Lunch
	1:30-3:00	Subgroup Discussions
	3:00-3:30	Coffee Break
	3:30-5:00	Subgroup Discussions
	6:00-7:30	Banquet Dinner
	7:30	Social
Thursday	7:30	Breakfast
March 8/01	8:30-10:00	Complete subgroup discussions
	10:00-10:30	Coffee Break
	10:30-12:00	Defining Report
	12:00-1:00	Lunch
	1:00-3:00	Wrap-up Discussions – Dr. Keith Somers

Appendix D - Hypotheses of Effects Model for Stream Realignment



Appendix D cont'd - HoE – Stream Realignment Linkage Statements

Link 1. A change in channel morphology will lead to changes in the downstream flow regime.

If the channel is straightened or hardened, this will increase the downstream flow resulting in scouring of the riverbed and flushing any contaminants within.

- Measure velocity and hydraulic head

Link 2. A change in channel morphology will lead to changes in sediment/contaminants.

A reduction of the quantity of sedimentation may affect the production of benthos and a subsequent decrease in forage habitat for benthos feeders. If however, the flow velocity is reduced the deposition of sediments could accumulate in habitats where the normal substrate is composed of rocks and gravel. An increase in sediment deposition could result in an increase in contaminant load, thus altering the quality of the food web.

Link 3. A change in channel morphology will lead to changes in water flow characteristics.

Link 4. A change in flow regime will lead to a change in holding habitats.

- difficult for fish to find backwater
- difficulty swimming
- eliminate midchannel habitat

Link 5. A change in flow regime will lead to a change in substrate characteristics.

Changes in water velocity associated with different flows will change the spatial distribution of sedimentation within the river, leading to a change in substrate composition at specific locations downstream of the realignment. Changes in the quality or quantity of fish habitat arise from changes in such habitats as temperature, water velocity, and turbidity.

Link 6. A change in flow regime will lead to changes in water flow characteristics.

Link 7. A change in sediment/contaminants will lead to a change in water quality.

Decreases in water quality (↓ Oxygen concentration, Δ water temperature, Δ turbidity).

Link 8. A change in sediment/contaminants will lead to a change in substrate characteristics.

Link 9. A change in water flow characteristics will lead to a change in holding habitats.

Link 10. A change in water flow characteristics will lead to a change in substrate characteristics.

Link 11. A change in water quality will lead to a change in fish spawning.

Link 12. A change in water quality will lead to a change in the invertebrate community.

Link 13. A change in holding habitats will lead to a change in the feeding and growth of fish.
Link 14. A change in holding habitats will lead to a change in fish mortality.

Dewatering of spawning habitat during egg incubation, stranding of eggs or decreases in water quality can affect egg survival.

Link 15. A change in substrate characteristics could lead to a change in fish spawning.

An increase in sediment deposition in gravel areas may reduce the suitability of these areas as spawning habitat.

Link 16. A change in substrate characteristics will lead to a change in invertebrates.

Link 17. A change in substrate characteristics will lead to a change in fish distribution.

Link 18. A reduction in fish spawning will reduce fish recruitment and ultimately fish production.

Link 19. An increase in fish mortality will reduce fish recruitment and ultimately fish production.

Link 20. A change in the invertebrate community could change the feeding and growth of fish.

Link 21. A change in invertebrates could lead to a change in fish community.

Link 22. A difference in fish distribution will affect feeding and growth potentials of fish.

Changes in fish distribution alter feeding regimes, and may increase competition within and between species for prey items.

Link 23. Changes in fish distribution of several species will overall affect the fish community.

Changes in fish distribution will cause competition between species changing the relative abundance of species in the community.

Link 24. Construction could disrupt sediments and possibly lead to soil contamination.

Link 25. Construction could change water flow characteristics.

Link 26. A change in shoreline profile could alter water flow characteristics.

If the slope of the bank is too steep, there will be an increase in the velocity of the water runoff. At the commencement of construction the vegetation along the bank will be reduced contributing to an increase sediment load. However, this situation should only be temporary until the vegetation is regrown. The deleterious effects of a change in channel morphology can be reduced if the “soft engineering” design is followed as stated in Newbury and Gaboury (1993).

Link 27. A change in bank profile could alter the adjacent flood plain and/or side channels.

Link 28. A change in flood plain/side channels could change the substrate characteristics.

No new sediment is deposited once the floodplain is out of reach of floodwaters. Vegetative organisms modify the rates of water movement by slowing runoff and increasing the storage capacity of soils. Changes to floodplain regions may result in a decreased ability to lower downstream peak flows and channel erosion. Activities such as straightening the stream channel could increase slope, decrease roughness and consequently increase flow velocity altering size and structure of floodplains and side channels. Reduced flooding into floodplain areas reduces spawning opportunities for species that utilize these habitats. Changes in floodplain areas also disrupt nutrient changes, which facilitate plankton production in floodplain habitats. Thus, the food chain on which fish larvae depend will be modified or even eliminated, resulting in reduced recruitment. As nursery areas, floodplain pools produce fish biomass, which can return to the stream in periods of stream-pool connection. These pools may also act as fish havens if catastrophic stream mortality occurs.

Link 29. A change in flood plain/side channels could reduce nursery habitat.

Link 30. A change in flood plain/side channels could change sediment/nutrient flux.

Link 31. A reduction in egg incubation/nursery habitat could result in reduced fish spawning.

Link 32. A reduction in egg incubation/nursery habitat could result in an increase in fish mortality.

Link 33. A change in sediment/nutrient flux will lead to a change in egg incubation/nursery habitat.

Link 34. A change in sediment/nutrient flux will lead to a change in invertebrates.

Link 35. Changes in soil-water interaction will result in changes to floodplain and side channels.

If through stream realignment the stream looses meandering and/or the banks are hardened, the water velocity will increase. This could be deleterious to species that require access to floodplains and side channels for an integral part of their lifecycle. For instance, during high flow events these areas are available to fish at spawning habitats. However, they require a 2 – 3 week period to allow for movement, reproduction and incubation before the water levels drop. It is possible that with stream realignment, the high flow event could be reduced to ≤1 week, leaving the fish and spawn isolated and ultimately dead.

Link 36. Changes in soil-water interactions will lead to changes in aquatic vegetation.

The dominant hydrological function of wetlands is the transport of water and sediment. Changes in the soil-water interactions lead to the loss of vegetation through the reduction of habitat heterogeneity and changes to drainage patterns.

Link 37. Changes in aquatic vegetation could change water flow characteristics.

Link 38. Loss of aquatic vegetation will cause changes in egg incubation and nursery habitat.

Many fish move into shallow waters to spawn. Often they return to areas where they were hatched. Vegetation provides shelter while spawning and serves to hide eggs and provide shelter for young fish from predation.

Link 39. Loss of aquatic vegetation will lead to changes sediment/nutrient flux.

Link 40. Loss of aquatic vegetation will lead to changes in cover.

Aquatic macrophytes are important for providing shelter and spawning sites for fish and invertebrates and emergence routes for insects.

Link 41. Changes in cover can lead to changes in invertebrates.

Link 42. Changes in cover can lead to changes in fish mortality.

Link 43. Changes in cover influence feeding patterns and growth in fish.

Diet reflects preference and what food is available in the environment. Particulate matter accumulated by woody debris and vegetation is an important food source for stream dwelling invertebrates. Vegetative characteristics also provide habitat areas for many species of prey items. Changes in this cover will result in displacement or loss of prey items requiring a change in feeding areas and energetic costs to the fish. Studies have shown that when cover is provided for fish the pattern of socially dominant fish denying subordinate fish access to food was eliminated.

Link 44. Availability of cover affects distribution of fish species.

Both indirect and direct evidence shows that the species in an assemblage of fishes partition the resources available to them. Structural complexity offers more opportunities for resource partitioning through increased cover and changing flow characteristics. Loss of cover results in a more homogenous habitat, which will displace some species of fish.

Link 45. A change in riparian vegetation could lead to a change in the soil-water link.

Link 46. A change in riparian vegetation could lead to a change in water flow characteristics.

Link 47. A change in riparian vegetation could lead to a change in aquatic vegetation.

Link 48. A change in of riparian vegetation could cause changes in recruitment of woody debris into the stream system.

Woody debris in stream enhances fish habitat. Woody debris aids in pool formation, provides structural escape cover, and is an important roughness element that create habitat heterogeneity and stability. Woody debris can form dams that act to modify sediment discharge.

Link 49. Loss of riparian vegetation will result in less shading properties over the stream.

Link 50. Loss of riparian vegetation will result in reduced detritus entering the stream.

Link 51. Changes in woody debris influence cover that fish have available.

Debris such as downed trees, snags and logs play a critical role in healthy streams by affecting channel width and depth and providing pools for fish to rest and feed. Pools slow a streams flow and keep gravel, which is necessary for spawning beds, from being washed away.

Link 52. Changes in shade provided by riparian vegetation will change the amount of cover available to the fish.

Link 53. Changes in shade provided by riparian vegetation will influence water temperature in the stream.

Shading by riparian vegetation reduces temperature fluctuation by insulating the stream environment. Removal of riparian vegetation will increase water temperature. Temperature fluctuations will be greater in shallow streams.

Link 54. Changes in the amount of detritus could change the sediment nutrient flux.

Link 55. Temperature fluctuations impact metabolic processes in fish influencing growth and prey availability.

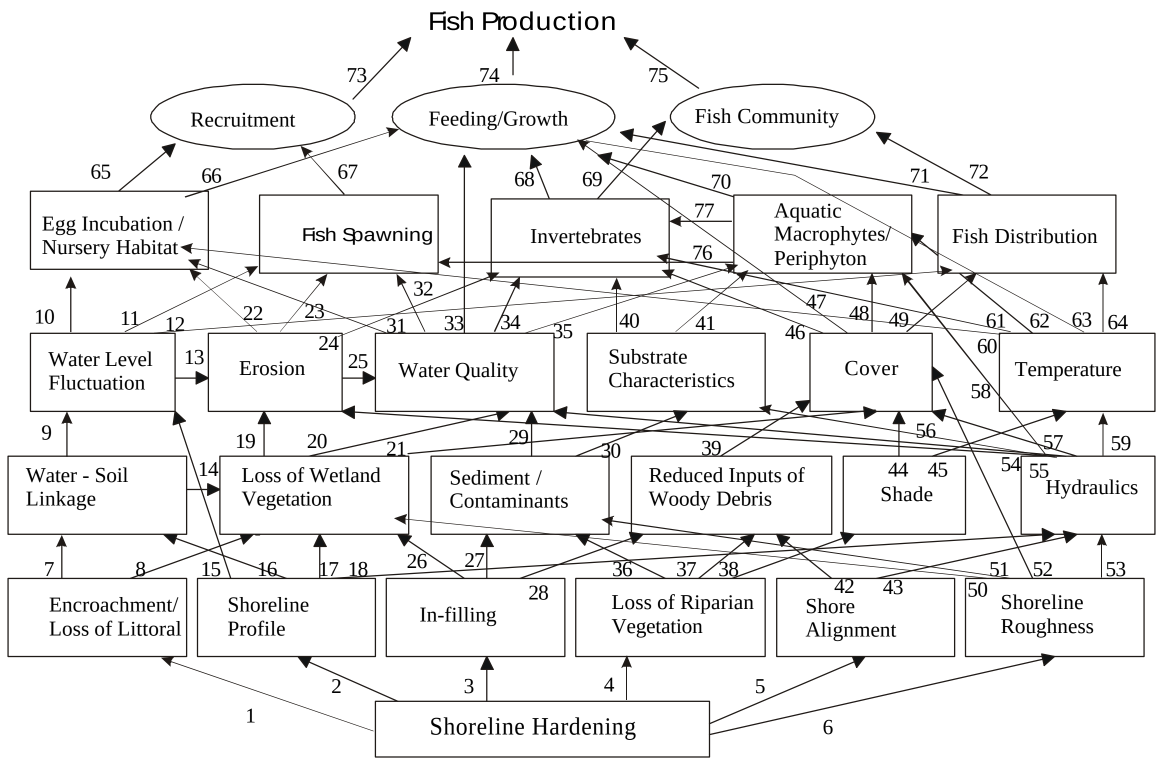
Temperature has a controlling effect on the rates of both food consumption and metabolism, and so affects growth.

Link 56. Changes in temperature could change invertebrate community.

Link 57. Changes in temperature will effect the distribution of fish species.

Patterns in spatial distribution have been linked to environmental factors, especially depth and temperature, with temperature being the overriding factor controlling both movement and habitat use. Fish select temperature regimes in which they maximize their lifetime production.

Appendix E - Hypotheses of Effects Model for Shoreline Hardening



Appendix E cont'd - HoE - Shoreline Hardening Linkage Statements

Link 1. Shoreline Hardening will cause encroachment onto the lakebed and a loss of littoral area.

Link 2. Shoreline profile will be altered by changes in slope as a result of shoreline hardening.

Link 3. In-filling will occur if shoreline hardening involves an expansion of the current shoreline into the lake (*i.e.* wet area becomes dry).

Link 4. Shoreline hardening projects may involve the removal or loss of riparian vegetation.

Link 5. Shore alignment, or the contour of the lake bank, will be altered as a result of shoreline hardening.

Link 6. Bank material, or shoreline roughness, will change due to shoreline hardening.

Link 7. A reduction in littoral zone along the shoreline will alter the linkage between water and soil.

Link 8. A reduced littoral zone along the shoreline will result in a loss of wetland vegetation.

Link 9. Changes to water-soil linkage as a result of shoreline hardening and in turn loss of littoral area/vegetation will increase water level fluctuations.

Link 10. Increased fluctuation of water levels will create unstable conditions for fish in terms of egg incubation and nursery habitat.

Link 11. Increased fluctuation of water levels will create unstable spawning conditions for fish.

Link 12. Fish distribution will change due to increased fluctuation in water levels.

Link 13. Increased water level fluctuations will cause an increase in erosion along the shoreline.

Link 14. A reduction in the water-soil linkage will result in a loss of wetland vegetation.

Link 15. A decrease in shoreline profile (slope) will result in an increase in water level fluctuations.

Link 16. A decrease in shoreline profile will alter the water-soil linkage.

Link 17. Wetland vegetation will be lost as a result of decreased shoreline profile/slope.

Link 18. Changes to shoreline profile will alter hydraulic processes.

Link 19. A loss of wetland vegetation will cause increased shoreline erosion.

Link 20. Water quality will be reduced as a result of lost wetland vegetation.

Link 21. Cover will be reduced from a loss in wetland vegetation.

Link 22. Increased erosion will cause a reduction in egg incubation/nursery habitat.

Link 23. Increased erosion will cause a decrease in spawning habitat and fish spawning.

Link 24. Invertebrate abundance and diversity will be reduced as a result of increased erosion along the shoreline.

Link 25. Water quality will be negatively impacted by increased erosion.

Link 26. Lake in-filling could cause a loss of wetland vegetation (*e.g.* filling in a wetland).

Link 27. In-filling of the lake can result in the introduction of sediment/contaminants.

Link 28. In-filling from shoreline hardening can result in reduced input of woody debris to the lake.

Link 29. The introduction of sediment/contaminants to the lake will result in decreased water quality.

Link 30. Sediment/contaminant input to the lake will result in a change to substrate characteristics (*e.g.* increased sedimentation).

Link 31. Reduced water quality will have a negative impact on egg incubation/ nursery habitat.

Link 32. Fish spawning will be reduced through decreased water quality.

Link 33. A reduction in water quality will cause a reduction in fish feeding and growth.

Link 34. Invertebrate populations and/or communities will be altered as a result of decreased water quality.

Link 35. Reduced water quality will cause a decrease in aquatic macrophytes/periphyton.

Link 36. A loss in riparian vegetation will result in increased input of sediment/contaminants.

Link 37. Reduced input of woody debris will result from a loss of riparian vegetation.

Link 38. A loss of riparian vegetation will result in a shade reduction along the shoreline.

Link 39. Reduced input of woody debris will cause a reduction in in-water cover.

Link 40. A change in substrate characteristics will result in a change to invertebrate communities.

Link 41. A change in substrate characteristics will cause a change in aquatic macrophyte/ periphyton composition.

Link 42. Alteration of shore alignment may result in reduced inputs of woody debris to the lake.

Link 43. An alteration to shore alignment will result in hydraulic changes along the shoreline.

Link 44. A reduction in shade will result in reduced cover for fish.

Link 45. Water temperature will increase as a result of reduced shade over the water.

Link 46. A reduction in cover will cause a reduction in invertebrates.

Link 47. Feeding and growth by fish will be negatively impacted by a decrease in cover.

Link 48. A reduction in cover will cause an increase in aquatic macrophytes/periphyton.

Link 49. Reduced cover will result in a decrease in fish distribution.

Link 50. A change to shoreline roughness will cause a loss of wetland vegetation.

Link 51. Reduced shoreline roughness will increase sediment input/contaminants.

Link 52. Reduced shoreline roughness will result in a decrease in cover.

Link 53. Hydraulic processes along the shoreline will be altered as a result of changes to shoreline roughness.

Link 54. Changes to hydraulics will cause increased erosion in the lake.

Link 55. Water quality will be reduced as a result of hydraulic change.

Link 56. A change to shoreline hydraulics will result in altered substrate characteristics.

Link 57. A change in hydraulics will cause a reduction in cover.

Link 58. Aquatic macrophytes/periphyton abundance will change as a result of altered hydraulics.

Link 59. Changes to hydraulic processes will result in changes to water temperatures.

Link 60. Changes in water temperatures will have a negative impact on egg incubation/nursery habitat.

Link 61. Invertebrate composition will change due to changes in water temperature.

Link 62. Aquatic macrophytes/periphyton will increase with an increase in water temperature.

Link 63. Changes in temperature will impact fish feeding/growth.

Link 64. Fish distribution will be altered as a result of changes to water temperature.

Link 65. A decrease in egg incubation/nursery habitat will cause reduced recruitment in fish.

Link 66. A decrease in egg incubation/nursery habitat will result in reduced feeding/growth by fish.

Link 67. A reduction in fish spawning will cause a reduction in recruitment.

Link 68. A reduction in invertebrates will result in decreased feeding opportunities and growth of fish.

Link 69. Fish community will be reduced as a result of lower invertebrate numbers.

Link 70. Feeding opportunities and growth by fish will be reduced as a result of a decrease in aquatic macrophytes/periphyton.

Link 71. Feeding/growth will decrease as a result of lower fish distributions.

Link 72. A reduction in fish distribution will cause a decrease in fish community.

Link 73. Negative impacts of recruitment will result in decreased fish production.

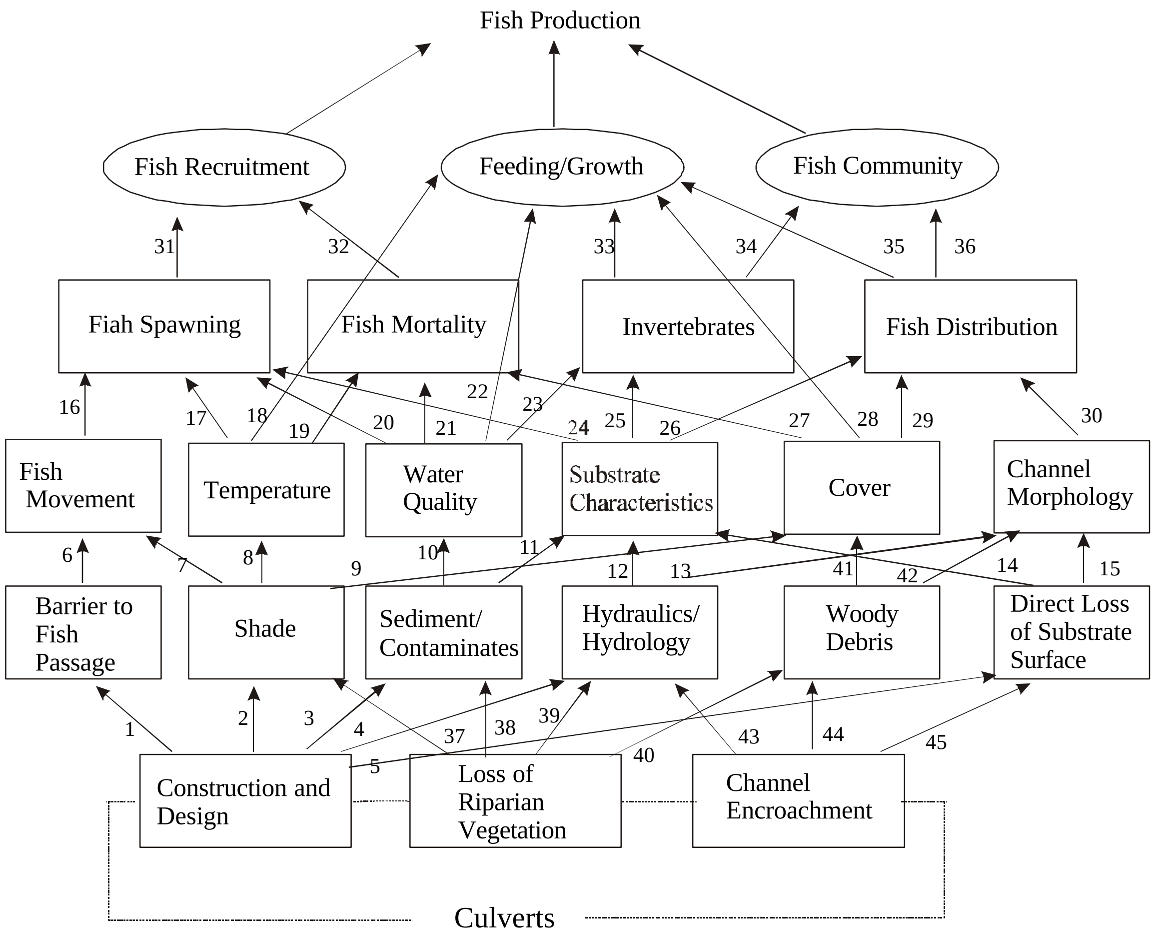
Link 74. A reduction in feeding/growth potential will cause a decrease in fish production.

Link 75. A decrease in fish community will result in reduced fish production.

Link 76. A change in aquatic macrophytes/periphyton density would cause a change in fish spawning.

Link 77. A reduction in aquatic macrophytes/periphyton will cause a reduction in invertebrate numbers.

Appendix F - Hypotheses of Effects Model for Culverts



Appendix F cont'd - HoE - Culvert Linkage Statements

Link 1. When constructed poorly, culverts can be a barrier to fish passage.

Culverts can be insurmountable barriers to migrating fish when constructed improperly. Non-embedded and undersized culverts are more likely to become impassable because of increased water velocities, lack of water depth and resting pools, and outfalls created by scouring and heaving.

Link 2. Construction of culverts and loss of riparian vegetation will result in less shading properties over the stream.

Link 3. Construction of culverts will increase the risk of contamination being added to the soil.

Construction equipment may add machinery oil and fluids to the riverbed contaminating the benthos habitat.

Link 4. Construction of culverts can change the hydraulics/hydrology of a stream.

Link 5. Construction of culverts can cause a direct loss of substrate surface.

Link 6. Barriers caused by improperly installed culverts limit fish movement within the stream.

Link 7. Changes in shading properties can influence fish movement.

Link 8. Changes in shading properties will influence water temperature in the stream.

Shading by riparian vegetation reduces temperature fluctuation by insulating the stream environment. Removal of riparian vegetation will increase water temperature. Fish select temperature regimes in which they maximize their lifetime production. Fish are expected to inhabit areas based on temperature preferences and optimal energetic requirements. Changes in temperature will effect distribution of prey, and possibly change diel movements.

Link 9. Changes in shading properties can affect stream cover.

Link 10. A change in sediment/contaminants will lead to a change in water quality.

Decreases in water quality can lead to changes in foraging ability and subsequent fish mortality.

Link 11. A change in sediment/contaminants can change substrate characteristics.

Link 12. Changes in hydraulics/hydrology will influence substrate characteristics.

A change in hydraulics/hydrology will affect water storage and release capabilities of the soil, as well as substrate stability.

Link 13. A change in hydraulics/hydrology will change channel morphology.

Link 14. Direct loss of substrate surface will cause changes in substrate characteristics.

Link 15. Direct loss of substrate surface will cause changes in channel morphology.

Loss of substrate surface will make banks more susceptible to erosion. Sediments carried into the stream will be deposited, changing the overall channel morphology.

Link 16. Limitations to fish movement within a stream will limit access to spawning areas.

Link 17. Changes in temperature will impact fish spawning.

Water temperatures are one of the main environmental cues that serve to initiate gonadal maturation and spawning. Changes in expected yearly temperatures may shift spawning times, durations, and lessen ovarian maturation.

Link 18. Temperature fluctuations impact metabolic processes in fish influencing growth and prey availability.

Temperature has a controlling effect on the rates of both food consumption and metabolism, and so affects growth.

Link 19. Changes in temperature could have an effect on fish mortality.

Younger fish are the most sensitive to thermal stresses, and temperature tolerance is acquired gradually. Fish in intensive temperature extremes-succumb to viral, bacterial, and other infectious disease, leading to high rates of mortality.

Link 20. Loss of water quality will affect fish spawning.

Link 21. A negative change in water quality will affect fish mortality.

Changes in water quality such as lower oxygen concentrations change in water temperature and change in turbidity, can lead to changes in foraging ability and fish mortality.

Link 22. Changes in water quality can influence prey availability and growth in fish.

Link 23. Changes in water quality will affect invertebrates present.

Negative changes in water quality such as those noted for Link 17, often lead to the increased growth of algae, which attracts invertebrates such as chironomids, which specialize in feeding on this plant. Other species of invertebrates once present in the system will be displaced

Link 24. Changes in substrate characteristics can affect fish spawning.

Link 25. Changes in substrate characteristics will influence the diversity and abundance of invertebrates.

In general, diversity and abundance increase with substrate stability and the presence of organic matter. Other factors that appear to play a role include the mean particle size of mineral substrates, the variety of sizes, and surface texture.

Link 26. A change in substrate characteristics will influence fish distribution.

Fish often occupy niches of certain habitat characteristics, changes in this niche will affect what fish are found in the area.

Link 27. Changes in cover can lead to fish mortality.

Eggs and yolk-sac larvae have little or no capacity to evade predators in the absence of parental care. Success of young is dependent on the availability of suitable prey and the ability to avoid predators through refuge.

Link 28. Changes in cover influence feeding patterns and growth in fish.

Diet reflects what food is available in the environment. Particulate matter accumulated by woody debris and vegetation is an important food source for stream dwelling invertebrates. Vegetative characteristics also provide habitat areas for many species of prey items requiring a change in feeding areas and energetic costs to the fish. Studies have shown that when cover is provided for fish the pattern of socially dominant fish denying subordinate fish access to food was eliminated.

Link 29. Availability of cover affects distribution of fish species.

Both indirect and direct evidence shows that the species in an assemblage of fishes partition the resources available to them. Structural complexity offers more opportunities for resource partitioning through increased cover and changing flow characteristics. Loss of cover results in a more homogenous habitat, which will displace some species of fish.

Link 30. Changes in channel morphology will affect fish distribution.

Channel morphology affects fish distribution in relation to habitat characteristics.

Link 31. A reduction in spawning area access will reduce fish recruitment and lower fish production.

Link 32. Increased fish mortality will lead to a decrease in fish recruitment.

Link 33. A change in invertebrate composition and population will effect feeding and growth of fish.

Link 34. A change in the invertebrate community will lead to changes in the fish community.

Changes in the invertebrate community will cause competition between species leading to changes in the fish community composition.

Link 35. A change in fish distribution will affect feeding and growth potentials of fish.

Changes in fish distribution alter feeding regimes, and may increase competition within and between species for prey items.

Link 36. Changes in fish distribution of several species will overall affect the fish community.

Changes in fish distribution will cause competition between species changing the relative abundance's of species in the community.

Link 37: Loss of riparian vegetation will reduce the shade over streams.

Link 38: Loss of riparian vegetation will influence amount of contaminants in the soil.

Several species of plants have the ability to uptake various metals into their vascular systems removing contaminants from the environment. Loss of vegetation would lead to contamination in the soil and increased amounts of surface runoff entering the stream.

Link 39. Loss of riparian vegetation will lead to changes in hydraulics/hydrology of the stream.

Removing riparian vegetation will cause the surrounding riverbed to become saturated in periods of high precipitation changing overflow characteristics of the stream. In periods of drought riparian vegetation serves to maintain soil moisture and intactness preventing erosion.

Link 40. Loss of riparian vegetation will cause changes in recruitment of woody debris into the stream system.

Woody debris in a stream enhances fish habitat. Woody debris aid in pool formation, provides structural escape cover, and is important as roughness elements that create habitat heterogeneity and stability. Woody debris can form dams that act to modify sediment discharge.

Link 41. Changes in woody debris can influence cover that fish have available.

Debris such as downed trees, snags and logs play a critical role in healthy streams by affecting channel width and depth and providing pools for fish to rest and feed.

Link 42. Changes in the amount of woody debris can produce changes in channel morphology.

Woody debris aids in the formation of pools and provides increased complexity to channel form by trapping sediments, altering flows and modifying sediment discharge.

Link 43. Channel encroachment could affect stream hydraulics/hydrology.

Link 44. Channel encroachment will lead to loss of woody debris recruitment into the stream.

Link 45. Channel encroachment will lead to a direct loss of substrate surface.

Pools slow a streams flow and keep gravel, which is necessary for spawning beds from being washed away.

Appendix G - Design Models

Stream Realignment Design

Below is a summary of a MINITAB simulation using an ANOVA model for stream realignment. The temporal aspect of the design is based on a Before-Impact period of 3 years (in this example) and an After-Impact period of 3 years, with seasonal sampling within each year (4 times a year; *i.e.*, every 3 months). Spatially, there is one Impacted (realigned) stream and 3 Control streams. Each stream is characterized by 3 Control sites (above the Impact) and one Impacted site (below). Both Pools and Riffles have been sampled within each site (*i.e.*, stratification by major habitat type) providing 3 Pool-Riffle pairs. In addition, 2 random replicate samples were taken within each Pool and Riffle. With everything considered, we end up with 2 * 3 * 4 * (1+3) * (1+3) * 2 * 2 * 3 = 4608 total observations at all places and times. The y variable is simulated as random normally distributed numbers with a mean of 20 and standard deviation of 4. Thus the data are actually null-hypothesis data (see below for details).

```
note  the following MINITAB code creates the design variables and
simulates the data

MTB > set c1
DATA> (1 2) 2304
DATA> end
MTB > code (1) "B" (2) "a" C1 C1
MTB > set c2
DATA> 2(1:3) 768
DATA> end
MTB > set c3
DATA> 6(1:4) 192
DATA> end
MTB > set c4
DATA> 24(1 1 1 2) 48
DATA> end
MTB > code (1) "C" (2) "I" c4 c4
MTB > set c5
DATA> 24(1 2 3 1) 48
DATA> end
MTB > set c6
DATA> 96(1 1 1 2) 12
DATA> end
MTB > code (1) "C" (2) "I" c6 c6
MTB > set c7
DATA> 96(1 2 3 1) 12
DATA> end
MTB > set c8
DATA> 384(1 2) 6
DATA> end
MTB > code (1) "P" (2) "R" c8 c8
MTB > set c9
DATA> 768(1:3) 2
DATA> end
MTB > random 4608 c10;
SUBC> normal 20 4.
```

note the following MINITAB code confirms that our simulation results are consistent with our intentions

```
MTB > desc c10
```

Variable	N	Mean	Median	TrMean	StDev	SE Mean
Y	4608	19.933	19.919	19.936	3.955	0.058

Variable	Minimum	Maximum	Q1	Q3
Y	6.814	33.518	17.281	22.550

MTB > Histogram 'y'.

Histogram of “Y” with N = 4608 showing the distribution of simulated values
Each * represents 20 observation(s)

```
Midpoint        Count
       6            1  *
       8           11  *
      10           48  ***
      12          134  *******
      14          263  **************
      16          599  ******************************
      18          832  ******************************************
      20          921  ***********************************************
      22          786  ****************************************
      24          537  ***************************
      26          317  ****************
      28          111  ******
      30           30  **
      32           16  *
      34            2  *
```

```
MTB > info
```

	Column	Count	Name	
T	C1	4608	BA	Before-impact years vs After-impact years
	C2	4608	yr	Among years within B and within A
	C3	4608	sn	Seasons within years
T	C4	4608	CIstms	Control streams vs Impacted streams
	C5	4608	stms	Among streams within C (only one in I)
T	C6	4608	CIsites	Control vs Impacted sites within streams
	C7	4608	sites	Among sites within C (only one in I)
T	C8	4608	strata	Pool vs Riffle within sites
	C9	4608	repstra	Among reps of Pool-Riffle within sites
	C10	4608	y	The y (response) variable

Note: This model results in the following:

```
MTB > GLM 'y' = c1 c2(c1) c3(c2) c4 c4*c1 c4*c2 c4*c3 c5(c4) c6(c5) c7(c6) &
CONT>      c8(c7) c9(c8);
SUBC>   Random c5 c7 c9;
SUBC>   Brief 1 ;
SUBC>   EMS.
```

General Linear Model Design Matrix: y versus BA, CIstms, etc., ...

Factor	Type	Levels	Values
BA	fixed	2	A B
yr(BA)	fixed	6	1 2 3 1 2 3
sn(BA yr)	fixed	24	1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4
CIstms	fixed	2	C I
stms(CIstms)	random	4	1 2 3 1
CIsites(CIstms stms)	random	8	C I C I C I C I
sites(CIstms stms CIsites)	random	16	1 2 3 1 1 2 3 1 1 2 3 1 1 2 3 1
strata(CIstms stms CIsites sites)	random	32	P R P R P R P R P R P R P R P R P R P R P R P R P R P R P R P R
repstra(CIstms stms CIsites sites strata)	random	96	1 2 3 1 2 3

Analysis of Variance Table for y, using Adjusted MS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Ho: "Before-impact times don't differ from After-impact times"						
BA	1	47.83	33.48	33.48	2.13	0.144
Ho: "Before-impact years do not differ and After-Impact years do not differ" (separate tests could be done for Before-impact years and for After-impact years, each with 2df)						
yr(BA)	4	38.42	11.79	2.95	0.19	0.945
Ho: "Seasons do not differ within years" (here 4 seasons per year but there could be any number >1"						
sn(BA yr)	18	335.85	344.28	19.13	1.22	0.235
Ho: "Control streams do not differ from the impacted stream" (here it's 3 and 1 respectively)						
CIstms	1	0.47	5.53	5.53	1.07	0.410
Ho: "Any B vs A difference is independent of whether it is C or I streams being considered" (rejection of this BACI-like Ho indicates an impact effect)						
BA*Cistms	1	0.17	0.17	0.17	0.01	0.918
Ho: "Any C streams vs I streams difference is independent of which year is considered"						
CIstms*yr(BA)	4	63.65	63.65	15.91	1.01	0.398
Ho: "Any C streams vs I streams difference is independent of which season is considered"						
CIstms*sn(BA yr)	18	221.44	221.44	12.30	0.78	0.721
Ho: "Control streams do not differ from each other" (there is only one Impacted stream here)						
stms(CIstms)	2	17.13	10.35	5.17	0.81	0.505
Ho: "Control sites do not differ from the Impacted site within streams" (this Ho implies an interaction - nesting is a kind of interaction - between C vs I sites within a stream and C vs I streams, so rejection of this Ho may indicate impact *i.e.* that C sites differ from the I site within streams only within I streams)						
CIsites(CIstms stms)	4	25.45	25.45	6.36	0.30	0.871
Ho: "Control sites do not differ from each other within streams" (there is only one Impacted site here)						

sites(CIstms stms CIsites)						
	8	170.29	170.29	21.29	1.27	0.326
Ho: "Pools do not differ from Riffles within sites"						
strata(CIstms stms CIsites sites)						
	16	268.80	268.80	16.80	1.29	0.230
Ho: "Replicates of Pool-Riffle strata do not differ from each other"						
repstra(CIstms stms CIsites sites strata)						
	64	832.48	832.48	13.01	0.83	0.832
Error	4466	70051.76	70051.76	15.69		
Total	4607	72073.74				

Note: Significant tests are not expected here – since the y values are random normally distributed values
Note: Interactions are tested first, highest level interactions first of all (a nesting is a kind of interaction)
Note: Interactions will indicate impact effects, *e.g.* BA*CIstms is like a BACI design test of interaction
Note: These particular numbers of years within BA, seasons within years, streams within CI, sites within streams, strata within sites, replicates of strata, and samples within strata replicates, are arbitrary (though reasonable I hope). The basic principle of the design and the statistical analysis of data collected using the design would not be affected by different numbers (so long as numbers that are >1 remain numbers >1).
Note: It is uncertain whether effect (2), years within BA, should be a fixed or a random effect. I have left it as a fixed effect (the default) on the grounds that the 6 years are not going to be a representative sample of all possible years in which the study could have been done, so the results pertain to those years. However some people would declare it a random effect on the grounds that the study could have been done in any 6 years so there's nothing special about those years. However in this analysis nothing is seriously changed by effect (2) being random vs it being fixed.
Note: This table of Expected Mean Squares (EMS) is probably of technical interest, and only to a statistician. It shows how the Mean Squares in the ANOVA table above are calculated in this rather complex design.

Expected Mean Squares, using Adjusted SS

```
Source                         Expected Mean Square for Each Term
 1 BA                          (13) + Q[1, 2, 3, 5, 6, 7]
 2 yr(BA)                      (13) + Q[2, 3, 6, 7]
 3 sn(BA yr)                   (13) + Q[3, 7]
 4 CIstms                      (13) + 48.0000(12) + 1.4E+02(11) +
                                 2.9E+02(10) + 4.3E+02(9) + 8.6E+02(8) +
                                  Q[4, 5, 6, 7]
 5 BA*CIstms                   (13) + Q[5, 6, 7]
 6 CIstms*yr(BA)               (13) + Q[6, 7]
 7 CIstms*sn(BA yr)            (13) + Q[7]
 8 stms(CIstms)                (13) + 48.0000(12) + 1.4E+02(11) +
                                 2.9E+02(10) + 4.3E+02(9) + 8.6E+02(8)
 9 CIsites(CIstms stms)        (13) + 48.0000(12) + 1.4E+02(11) +
                                 2.9E+02(10) + 4.3E+02(9)
10 sites(CIstms stms CIsites) (13) + 48.0000(12) + 1.4E+02(11) +
                                 2.9E+02(10)
11 strata(CIstms stms CIsites sites)
                               (13) + 48.0000(12) + 1.4E+02(11)
12 repstra(CIstms stms CIsites sites strata)
                               (13) + 48.0000(12)
13 Error                       (13)

Error Terms for Tests, using Adjusted SS
```

Source	Error DF	Error MS	Synthesis of EMS
1 BA	4466.00	15.69	(13)
2 yr(BA)	4466.00	15.69	(13)
3 sn(BA yr)	4466.00	15.69	(13)
4 CIstms	2.00	5.17	(8)
5 BA*CIstms	4466.00	15.69	(13)
6 CIstms*yr(BA)	4466.00	15.69	(13)
7 CIstms*sn(BA yr)	4466.00	15.69	(13)
8 stms(CIstms)	4.00	6.36	(9)
9 CIsites(CIstms stms)	8.00	21.29	(10)
10 sites(CIstms stms CIsites)	16.00	16.80	(11)
11 strata(CIstms stms CIsites sites)	64.00	13.01	(12)
12 repstra(CIstms stms CIsites sites strata)	4466.00	15.69	(13)

Note: The number in the third column *e.g.* (13) refers to the row in the ANOVA table

Note: The residual error (13) is the error term for the key BACI-type test (of BA*CIstms). This error is the variation among random replicate samples within each replicate Pool and Riffle at each time. There are only two such samples at each place and time but the design's "multiplier effect" (all the places and times) gives us 4466 df for this error term.

Note: The test of 'CIsites(CIstms stms)' which may also indicate impact (see comment above) uses (10) as the error term, which is 'sites (CIstms stms CIsites)' , in other words variation among Control sites within streams. There are only 16 df for this error term, which is enough for robustness (>10), but for greater power in this test one could have 4 instead of 3 Control sites per stream.

Note: This table of estimated variance components (a Model II ANOVA sort of thing **-** see Sokal & Rohlf's "Biometry") is also probably of technical interest, and only to a statistician. N.B.: Variance components in a nested model II ANOVA design can be negative (see Cochran's "Sampling Techniques"), even though the concept of a negative variance tends to bother people. Here with "Ho data" the variance components should average zero with some slightly below and some slightly above zero.

Variance Components, using Adjusted SS

Source	Estimated Value
stms(CIstms)	-0.0014
CIsites(CIstms stms)	-0.0345
sites(CIstms stms CIsites)	0.0156
strata(CIstms stms CIsites sites)	0.0263
repstra(CIstms stms CIsites sites strata)	-0.0558
Error	15.6856

Appendix G cont'd - Snap-shot Design-Shoreline Stabilization

Design 1

Experimental Details
Number of factors: 2
Factor 1 is Treatment has 2 levels is orthogonal and is fixed
Factor 2 is Location has 3 levels is nested in 1 and is random
Number of replicates: 6

The model for this analysis is:
X = MEAN + Tr + Lo(Tr) + RES

Source	DF	MS	F versus
Tr	1	$s_e^2 + ns_{TrLo}^2 + bns_{tr}^2$	Lo(Tr)
Lo(Tr)	4	$s_e^2 + ns_{TrLo}^2$	RES
RES	30		
TOT	**35**	s_e^2	

Design 2
This design has the same effort of sampling as design 1 but is more powerful. This increases the number of locations and decreases the number of units of sampling.

Experimental Details
Number of factors: 2
Factor 1 is Treatment has 2 levels is orthogonal and is fixed
Factor 2 is Location has 6 levels is nested in 1 and is random
Number of replicates: 3

The model for this analysis is :
X = MEAN + Tr + Lo(Tr) + RES

Source	DF	MS	P	F versus
Tr	1	σ	Lo(Tr)	
Lo(Tr)	10		RES	
RES	24			
TOT	**35**			

Appendix G cont'd - Replicated Control-Treatment Design – Shoreline Stabilization

Design 1

This design is relevant when you have one or no "Before" data, and there is no need for different temporal scales. The **Bold** line below is the interaction that you want to look at. This is the same design as the general ANOVA model for culvert impacts "number 2"**.**

Experimental Details
Number of factors: 3
Factor 1 is treatment has 2 levels is orthogonal and is fixed
Factor 2 is location has 3 levels is nested in 1 and is random
Factor 3 is Time has 3 levels is orthogonal and is fixed
Number of replicates: 5

The model for this analysis is:
X = MEAN + tr + lo(tr) + Ti + trXTi + TiXlo(tr) + RES

Source	**DF**	**MS**	**F value denominator term**
tr	1	tr	lo(tr)
lo(tr)	4	lo(tr)	RES
Ti	2	Ti	Ti*lo(tr)
Tr*Ti	**2**	**Tr*Ti**	**Ti*lo(tr)**
Ti*lo(tr)	8	Ti*lo(tr)	RES
RES	72		
TOT	89		

Design 2

Experimental Details
Number of factors: 3
Factor 1 is treatment has 2 levels is orthogonal and is fixed
Factor 2 is location has 5 levels is nested in 1 and is random
Factor 3 is Time has 3 levels is orthogonal and is fixed, you can also increase the number of time
Number of replicates: 3

The model for this analysis is :
X = MEAN + tr + lo(tr) + Ti + trXTi + TiXlo(tr) + RES

Source	DF	MS	F versus
tr	1	lo(tr)	
lo(tr)	8	RES	
Ti	2	TiXlo(tr)	
trXTi	2	TiXlo(tr)	
TiXlo(tr)	16	RES	
RES	60		
TOT	89		

Appendix G cont'd - Replicated Control-Treatment Design – Shoreline Stabilization

Design 3

Experimental Details
Number of factors: 3
Factor 1 is treatment has 2 levels is orthogonal and is fixed
Factor 2 is location has 3 levels is nested in 1 and is random
Factor 3 is Time has 5 levels is orthogonal and is fixed
Number of replicates: 5

The model for this analysis is :
X = MEAN + tr + lo(tr) + Ti + trXTi + TiXlo(tr) + RES

Source	SS	DF	MS	F	P	F versus
tr	1593.4881	1	1593.4881	2.74	0.1733	lo(tr)
lo(tr)	2327.9983	4	581.9996	0.65	0.6257	RES
Ti	913.3222	4	228.3306	0.47	0.7552	TiXlo(tr)
trXTi	1944.3464	4	486.0866	1.01	0.4332	TiXlo(tr)
TiXlo(tr)	7728.9881	16	483.0618	0.54	0.9192	RES
RES	106918.2234	120	890.9852			
TOT	121426.3665	149				

Appendix G cont'd - General ANOVA model design to test culvert impacts.

In what follows, *E* is an experimental treatment (e.g. +Culvert versus - Culvert). Where there is more than one factor (e.g. Large vs. Small Culverts; 10% buried vs. 20% buried), *E* would be an orthogonal and interactive structure (*S* + *B* + *S* x *B*; for Size, Burial, Interaction).

Model

$$X_{ijklmr} = m + E_i + S(E)_{j(i)} + B_k + P(B)_{l(k)} + T(P(B))_{m(l(k))} + EB_{ik} + EP(B)_{il(k)} + ET(P(B))_{im(l(k))} + BS(E)_{kj(i)} + S(E)P(B)_{j(i)l(k)} + S(E)T(P(B))_{j(i)m(l(k))} + e_{r(j(i)l(m(k)))}$$

where:

E_i is Experimental Treatment (*i* = 1 …. *a*), usually fixed;

$S(E)_{j(i)}$ is replicated Stream in each treatment (*j* = 1….*b*); Random and nested;

B_k is Before versus After (*k* = 1….*c*, *c* = 2); Fixed

$P(B)_{l(k)}$ is Period within Before or After (*l* = 1….*d*); Random and nested;

$T(P(B))_{m(l(k))}$ is Time of sampling in each Period (*m* = 1….*e*); Random and nested;

$e_{r(j(i)l(m(k)))}$ is replicated sample unit (*r* = 1….*n*); random and nested;

Nesting is, conventionally, indicated by brackets.

Analysis

The analysis is all about measuring interactions – different responses from Before to After in the different experimental treatments (or streams in the treatments).

Source of Variation	Df	Mean Square estimates	Test versus
E_i	$(a-1)$		Not relevant
$S(E)_{j(i)}$	$a(b-1)$		Not relevant
B_k	$(c-1)$		Not relevant
$P(B)_{l(k)}$	$c(d-1)$		Not relevant
$T(P(B))_{m(l(k))}$	$cd(e-1)$		Not relevant
EB_{ik}	$(a-1)(c-1)$	$s_e^2 + ns_{SETPB}^2 + ens_{SEPB}^2 + bns_{ETPB}^2 + bens_{EPB}^2 + dens_{BSE}^2 + bdenk_{EB}^2$	
$EP(B)_{il(k)}$	$(a-1)c(d-1)$	$s_e^2 + ns_{SETPB}^2 + ens_{SEPB}^2 + bns_{ETPB}^2 + bens_{EPB}^2$	(POOL)*
$ET(P(B))_{im(l(k))}$	$(a-1)cd(e-1)$	$s_e^2 + ns_{SETPB}^2 + bns_{ETPB}^2$	SETPB
$BS(E)_{kj(i)}$	$a(b-1)(c-1)$	$s_e^2 + ns_{SETPB}^2 + ens_{SEPB}^2 + dens_{BSE}^2$	SEPB
$S(E)P(B)_{j(i)l(k)}$	$a(b-1)c(d-1)$	$s_e^2 + ns_{SETPB}^2 + ens_{SEPB}^2$	SETPB
$S(E)T(P(B))_{j(i)m(l(k))}$	$a(b-1)cd(e-1)$	$s_e^2 + ns_{SETPB}^2 + ens_{SEPB}^2$	*e*
$e_{r(j(i)m(l(k)))}$	$abcde(n-1)$	s_e^2	

* These components need Pooling of terms in the model to enable tests.

Modifications

1. You don't need to sample at different temporal scales. So, have some times of sampling Before and again After, randomly chosen and not stratified into Periods and Times as above.

$$X_{ijkmr} = m + E_i + S(E)_{j(i)} + B_k + T(B)_{m(k)} + EB_{ik} + ET(B)_{im(k)} + BS(E)_{kj(i)} + S(E)T(B)_{j(i)m(k)} + e_{r(j(i)m(k))}$$

Source of Variation	Df	Mean Square estimates	Test versus
E_i	$(a-1)$		Not relevant
$S(E)_{j(i)}$	$a(b-1)$		Not relevant
B_k	$(c-1)$		Not relevant
$T(B)_{m(k)}$	$c(e-1)$		Not relevant
EB_{ik}	$(a-1)\ (c-1)$	$s_e^2 + ns_{SETB}^2 + ens_{BSE}^2 + bns_{ETB}^2 + bens_{EB}^2$	(POOL)
$ET(B)_{im(k)}$	$(a-1)\ c(e-1)$	$s_e^2 + ns_{SETB}^2 + bns_{ETB}^2$	SETB
$BS(E)_{kj(i)}$	$a(b-1)\ (c-1)$	$s_e^2 + ns_{SETB}^2 + ens_{BSE}^2$	SETB
$S(E)T(B)_{j(i)m(k)}$	$a(b-1)\ c(e-1)$	$s_e^2 + ns_{SETB}^2$	e
$e_{r(j(i)m(k))}$	$abce(n-1)$	s_e^2	

2. You cannot get Before data and there is no need for different temporal scales. *T* represents random times of sampling after the experimental treatments are applied.

$$X_{ijmr} = m + E_i + S(E)_{j(i)} + T_m + ET_{im} + TS(E)_{mj(i)} + e_{r(mj(i))}$$

Source of Variation	Df	Mean Square estimates	Test versus
E_i	$(a-1)$		Not relevant
$S(E)_{j(i)}$	$a(b-1)$		Not relevant
T_m	$(e-1)$		Not relevant
ET_{im}	$(a-1)$ (e– 1)	$s_e^2 + ns_{TSE}^2 + bns_{ET}^2$	TSE
$TS(E)_{mj(i)}$	$a(b-1)\ (e-1)$	$s^2 + \ s_{TSE}^2$	e
$e_{r(mj(i))}$	$abe(n-1)$	s_e^2	

Comment on sizes of experiments
In the absence of specified magnitudes of differences (Effect Sizes), power is not calculable. Trying to achieve 30 df in divisions means, for full model:
$a = 2$ experimental treatments; $e = 2$ for Before/After
for *SETPB* df = $a(b-1)\ ed\ (e-1) = 4d\ (b-1)(e-1)$
if $e = 3$ Times in each of $d = 3$ Periods

df = $24(b - 1)$

$\therefore$ you need 2 replicate Streams in each Treatment

if $e = 2$ Times in each of $d = 2$ Periods

df = $8(b - 1)$

$\therefore$ you need 5 replicate Streams in each Treatment

for *SEPB* df = $a(b - 1)(c - 1)$

$a = 2$, $c = 2$

$\therefore$ df = $2(b - 1)$

you would need 16 replicate Streams.

Appendix G cont'd – Marina Design

You can increase the number of locations to increase the level of power to find a difference between treatment and energy.

Experimental Details
Number of factors: 3
Factor 1 is treatment has 3 levels is orthogonal and is fixed
Factor 2 is energy has 2 levels is orthogonal and is fixed
Factor 3 is location has 3 levels is nested in 12 and is random
Number of replicates: 5

The model for this analysis is:
X = MEAN + tr + en + lo(trXen) + trXen + RES

Source	SS	DF	MS	F	P	F versus
tr	1025.7314	2	512.8657	0.71	0.5111	lo(trXen)
en	219.8672	1	219.8672	0.30	0.5912	lo(trXen)
lo(trXen)	8665.7766	12	722.1481	0.81	0.6440	RES
trXen	1343.6419	2	671.8210	0.93	0.4211	lo(trXen)
RES	64573.9621	72	896.8606			
TOT	75828.9792	89				

Appendix H Study Design Framework

1). Science need identified by management or science worker(s).

2). Form multidisciplinary steering committee to elucidate problem.

3). Steering Committee drafts HoE model.

4). Confirm Management commitment to implement field study based on resulting design.

5). Identify and confirm breakout group that includes skilled facilitator and experts in study design, science disciplines and management.

6). Hold 1 -2 day facilitated breakout session at facility without work distractions following 9 steps in Appendix D.

7). Managers and researchers commit resources to operational field design of model.

8). Implement and continue in AEAM cycle.