A Framework for the Scientific Assessment of Potential Project Impacts on Birds

Alan Hanson, Ian Goudie, Anthony Lang, Carina Gjerdrum, Richard Cotter, and Garry Donaldson

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This Technical Report has been prepared for information purposes only. It has been written for broad application and does not reflect the specific circumstances which may be encountered for a particular assessment. The information provided is not a substitute for CEAA, SARA, MBCA or any regulations under these acts. In the event of an inconsistency between this Technical Report and the Acts or their regulations, the Acts or regulations prevail. Official information on MBCA, SARA, and CEAA can be found in the legal text of the *Canadian Environmental Assessment Act, Migratory Birds Convention Act, 1994*, and the *Species at Risk Act* available on the Department of Justice Canada website at: http://laws.justice.gc.ca/en/index.html.

SUMMARY

The conservation of migratory birds is the responsibility of the Government of Canada. Environment Canada (EC) is the lead federal department for migratory bird conservation in Canada as mandated by the *Migratory Birds Convention Act, 1994*. As such, EC is recognized as the agency responsible for, and a source of expert information on, migratory birds in environmental assessment (EA). The Canadian Environmental Assessment Act (*CEAA*) is a planning and decision making tool used by the federal government to identify environmental effects and required mitigation and determine if significant environmental effects are likely. An EA determination should be based on technical analyses, stakeholder/public input, and supported by a strong rationale and well documented information. An independent reviewer reading the EA report should be able to come to the same conclusions, based on the information and rationale provided. This Technical Report was designed to help proponents make scientifically based conclusions on potential and realized project impacts on birds, and to evaluate the effectiveness of mitigation strategies in support of the EA decision making process.

Projects and human perturbations may affect migratory birds in a variety of ways from changing abundance, demography and behaviour to habitat loss and alteration. Project scoping can identify issues where data requirements vary considerably. Scientific credibility is based on the collection of baseline information, and the use of valid data collection techniques, statistical analyses, results interpretation, discussion, and presentation. The scientific approach requires application of standard data collection protocols, and syntheses of many aspects of theoretical ecology and statistics that are supported in the scientific literature. Most of all, delivery of science-based information on environmental effects requires a concerted commitment to the principles of ecological risk assessment, environmental effects monitoring and follow-up studies. The scientific information and process used to reach conclusions in EA need to be understandable and publically defensible.

A scientific framework for determining and managing effects of projects on birds was developed (Figure 1). Through a comprehensive review of existing literature and information, and in consultation with EC, persons undertaking EAs should first define study areas, identify existing baseline information and information gaps, and highlight potential effects of proposed project. By determining indicators of predicted effects, cost-effective assessments can be designed that measure the effects directly or indirectly. The next critical step is the development of ecological hypotheses, and a conceptual model that sets the stage for the development of cost-effective sampling design, statistical analyses, testing of hypotheses and interpretation of results. The priority is to avoid, and secondly to mitigate, negative impacts in order to support sustainable development. Because the magnitude of many impacts is unknown at the time of the EA, follow-up monitoring studies are often necessary. Persons undertaking EAs should apply the precautionary principle when data, scientific knowledge or understanding are limited or have high uncertainty. Environmental effects monitoring and follow-up studies provide the information required for adaptive management to further refine mitigation of effects.

In order to predict, study and manage the effects of a project on migratory birds, it is important to implement an ecosystem-based approach that identifies valued ecosystem components and surrogates, including species at risk, indicator, keystone, umbrella, flagship, and economically important species. This approach also considers landscape-level issues, such as the degree of fragmentation and connectivity of habitats expected after construction of proposed projects. While emphasis is habitat-centred, there needs to be a focus on assessing guilds of species (e.g., those sharing the same habitat). Proponents should consider potential effects at the level of species and communities; issues such as increased competition, predation, brood parasitism, and/or shifts that might occur in food availability and habitat need to be examined. An important component of ecosystem integrity is biodiversity. Impacts on biological diversity should be minimized by adopting the guiding principle of no net loss of the ecosystem function supported by species, populations and/or genetic diversity. Findings within a defined study area need to be related to local, regional and national population level trends, and conservation issues.

Environmental effects studies are designed to assess the environment before and after the human perturbation. The optimal study design has one or more control sites separate from the treatment site that is similarly sampled before and after the perturbation. The Before-After-Control-Impact (BACI) study design is commonly used in studies of environmental impact. The ability for proponents to mitigate impacts is commensurate with the quality of the scientific work undertaken to initially measure effects. In some cases these can be inferred from obvious situations (e.g., removal of habitat) or previous experience and studies (e.g., dose-response predictions). EAs oftentimes will require significant pre-development data in order to identify and mitigate impacts. Techniques to address study design, assessment of data types, statistical analyses, power tests and determination of effect size are well developed in the scientific literature and should be used.

This report provides a conceptual framework for scientifically assessing potential impacts on migratory birds and an overview of scientific approaches, impact types, and survey methods.

Belief involves convincing yourself.
Science involves convincing others.

RESUME

La conservation des oiseaux migrateurs relève du gouvernement du Canada. Environnement Canada (EC) est le principal ministère fédéral responsable de la conservation des oiseaux migrateurs au Canada, tel que le prévoit la *Loi de 1994 sur la convention concernant les oiseaux migrateurs*. À ce titre, Environnement Canada est reconnu comme l'organisme responsable du volet sur les oiseaux migrateurs dans le cadre des évaluations environnementales (EE) et comme source d'informations spécialisées à ce sujet. La *Loi canadienne sur l'évaluation environnementale* (LCEE) est un outil de planification et de prise de décision utilisé par le gouvernement fédéral pour déterminer les effets environnementaux et les mesures d'atténuation nécessaires, et pour établir la probabilité que des effets environnementaux importants se produisent. Une détermination de l'évaluation environnementale doit reposer sur des analyses techniques ainsi que sur la participation des parties prenantes et du public, et s'appuyer sur une justification solide et des informations bien étayées. Une tierce personne prenant connaissance du rapport d'évaluation environnementale devrait être en mesure, en se basant sur l'information et la justification fournies, d'en arriver aux mêmes conclusions. Le présent rapport technique a été conçu pour aider les promoteurs à tirer des conclusions scientifiques relativement aux impacts sur les oiseaux de projets éventuels et déjà réalisés, et à évaluer l'efficacité des stratégies d'atténuation à l'appui du processus décisionnel dans le cadre de l'évaluation environnementale.

Les projets et les perturbations anthropiques peuvent nuire aux oiseaux migrateurs de bien des manières, qu'il s'agisse d'en modifier l'abondance, la démographie et le comportement ou qu'il s'agisse de l'altération ou de la perte de leur habitat. Le cadrage d'un projet peut aider à déterminer des questions dont les exigences en matière de données peuvent varier considérablement. La crédibilité scientifique repose sur la collecte d'informations de référence et sur l'utilisation de techniques de collecte de données valides, d'analyses statistiques et d'interprétation, de discussion et de présentation des résultats. L'approche scientifique exige l'application de protocoles de collecte de données standards et la synthèse de nombreux aspects de l'écologie théorique et des statistiques étayés par la littérature scientifique. Par-dessus tout, la diffusion d'informations scientifiques sur les effets environnementaux exige un engagement concerté à l'égard des principes de l'évaluation du risque écologique, du suivi des effets environnementaux et des études complémentaires. L'information et les processus scientifiques utilisés pour en arriver à des conclusions dans le cadre des EE doivent être compréhensibles et publiquement défendables.

Un cadre scientifique pour déterminer et gérer les effets de projets sur les oiseaux a été élaboré (figure 1). Après avoir procédé à un dépouillement exhaustif de la documentation et de l'information disponible, en consultation avec Environnement Canada, les personnes qui entreprennent une EE doivent d'abord définir les zones d'études, déterminer l'information de référence existante ainsi que les lacunes en la matière, et mettre en lumière les effets possibles du projet proposé. En établissant des indicateurs des effets prévus, il est possible de concevoir des évaluations rentables pour mesurer les effets de façon directe ou indirecte. L'étape cruciale subséquente est l'élaboration d'hypothèses écologiques et d'un modèle conceptuel qui réunit les conditions nécessaires à l'élaboration d'un plan d'échantillonnage

rentable, à des analyses statistiques, à la mise à l'essai d'hypothèses et à l'interprétation de résultats. La priorité consiste à éviter, et par la suite à atténuer, les impacts négatifs afin de soutenir un développement durable. Puisque l'amplitude de bien des impacts est inconnue au moment de l'EE, des études de surveillance complémentaires sont souvent nécessaires. Les personnes qui entreprennent une EE doivent appliquer le principe de précaution lorsque les données, les connaissances scientifiques ou la compréhension sont limitées ou présentent une grande incertitude. Les études de suivi des effets environnementaux et les études de suivi complémentaires permettent d'obtenir l'information nécessaire à la gestion adaptative afin de raffiner ultérieurement l'atténuation des effets.

Afin de prédire, d'étudier et de gérer les effets d'un projet sur les oiseaux migrateurs, il est important de mettre en œuvre une approche écosystémique qui identifie les composantes valorisées de l'écosystème et les substituts, incluant les espèces en péril, les espèces indicatrices, les espèces clés, les espèces parapluie, les espèces emblématiques et les espèces ayant une importance économique. Cette approche tient compte également des questions à l'échelle du paysage, telles que le degré de fragmentation et de connectivité des habitats après la construction des projets proposés. Bien que l'accent soit mis principalement sur l'habitat, il faut également porter attention à l'évaluation des guildes d'espèces (celles qui partagent le même habitat, par exemple). Les promoteurs doivent tenir compte des effets au niveau des espèces et des communautés; des problématiques telles que la compétition accrue, la prédation, le parasitisme des nids, ou encore les changements qui peuvent survenir dans la disponibilité de nourriture ou dans l'habitat doivent être examinés. Une importante composante de l'intégrité des écosystèmes est la biodiversité. Les impacts sur cette dernière doivent être minimisés par l'adoption du principe directeur selon lequel il ne doit pas y avoir de perte nette du fonctionnement écosystémique soutenu par les espèces, les populations et la diversité génétique. Les constatations établies dans une zone d'étude définie doivent être liées aux tendances des populations à l'échelle locale, régionale et nationale ainsi qu'aux problématiques de conservation.

Les études sur les effets environnementaux sont conçues pour évaluer l'environnement avant et après la perturbation par les humains. Le plan d'étude optimal comporte un ou plusieurs emplacements témoins distincts de l'emplacement de traitement, qui fait aussi l'objet d'un échantillonnage avant et après la perturbation. Dans les études d'impact environnementales, on utilise couramment un plan de comparaison avant-après avec témoin (BACI, pour Before-After-Control-Impact). La capacité des promoteurs d'atténuer les impacts est proportionnelle à la qualité du travail scientifique entrepris à l'origine pour mesurer ces effets. Dans certains cas, ces effets peuvent être déduits à partir de situations évidentes (suppression d'habitat, par exemple) ou d'expériences et d'études précédentes (prévisions de la dose-effet, par exemple). Dans le cadre des EE, il faudra bien souvent d'importantes données de référence pour déterminer quels sont les impacts et les atténuer. Les techniques servant à la réalisation du plan d'étude, de l'évaluation des types de données, des analyses statistiques, des tests de puissance ainsi qu'à la détermination de la taille de l'effet sont bien élaborées dans la documentation scientifique et on se doit d'y avoir recours.

Ce rapport présente un cadre conceptuel pour l’évaluation scientifique des impacts potentiels sur les oiseaux migrateurs ainsi qu’un aperçu des approches scientifiques, des types d’impacts et des méthodes de relevé.

> La croyance implique de vous convaincre vous-même.
> La science implique de convaincre les autres.

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1. INTRODUCTION

1.1 Purpose of Technical Report

The conservation of migratory birds is the responsibility of the Government of Canada and derives from the ratification in 1916 of an international treaty, the Migratory Birds Convention. Environment Canada (EC) is the lead federal department for migratory bird conservation in Canada as mandated by the *Migratory Birds Convention Act, 1994*. As such, EC is recognized as the agency responsible for, and a source of expert information on, migratory birds in environmental assessment (EA). The Canadian Environmental Assessment Act (*CEAA*) is a planning and decision making tool used by the federal government to identify environmental effects and mitigation, determine if significant environmental effects are likely, and provide information for the decision whether to support the project. An EA decision should be based on technical analyses and stakeholder/public input and supported by a strong rationale and well documented information. An independent reviewer reading the EA report should be able to come to the same conclusions, based on the information and rationale provided. This Technical Report was designed to help proponents make scientifically based conclusions on potential and realized project impacts on birds, and the effectiveness of mitigation strategies in support of the EA decision making process.

While only those species of birds specified in the MBCA are under federal jurisdiction, this Technical Report provides guidance on study design and survey methods that are suitable for gathering information on all bird species. Proponents are reminded that non-MBCA bird species are under provincial or territorial jurisdiction. The protocols suggested in this document are not meant to replace information provided by provincial or territorial authorities. Proponents are urged to contact the relevant provincial or territorial authorities to determine what requirements or expectations they may have with respect to bird monitoring pre- or post-construction.

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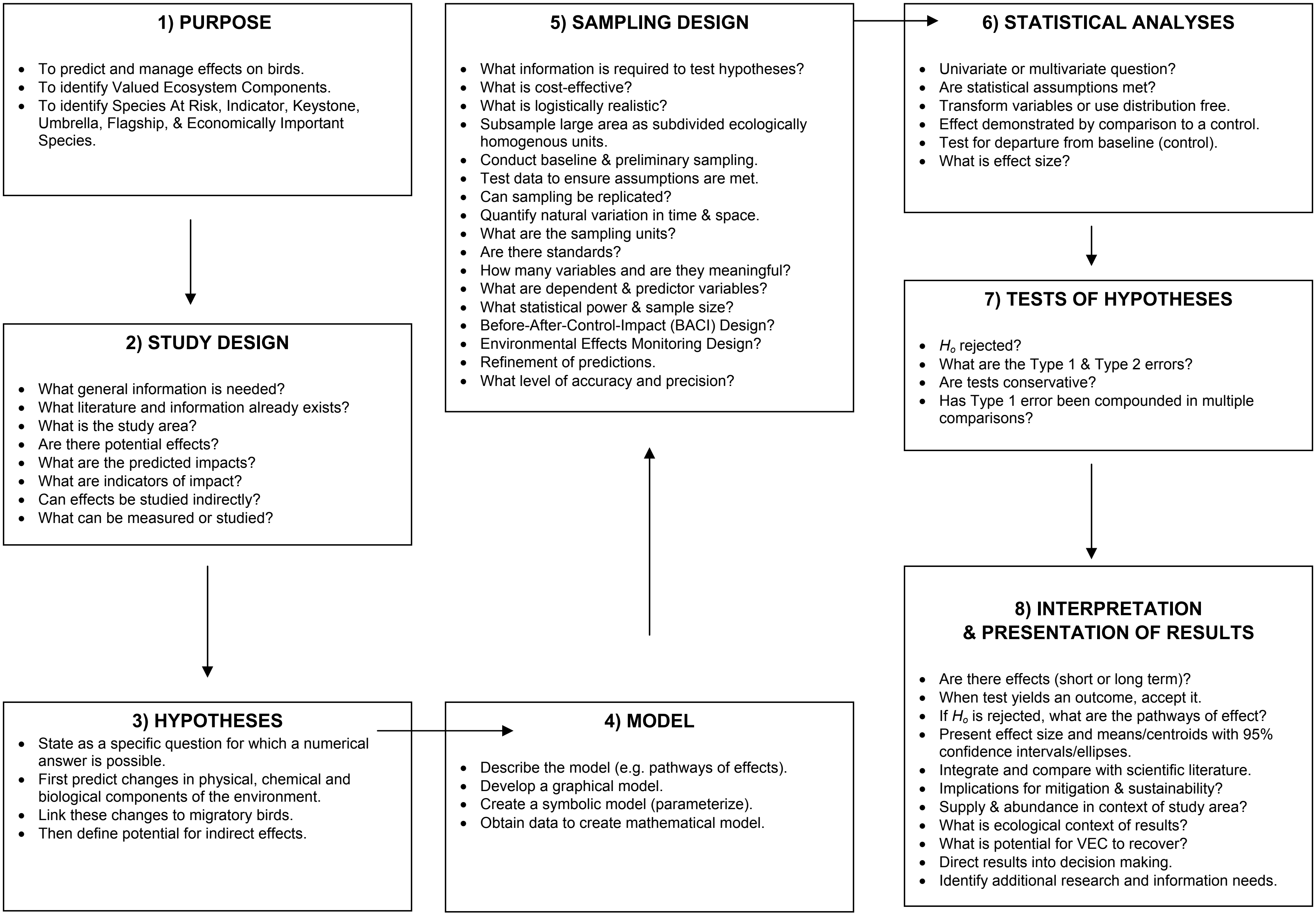


Figure 1- Scientific framework for determining potential effects of projects on migratory birds.

The EA process should be a logical sequence from baseline information and data gathering to impact prediction, hypothesis testing and environmental effects monitoring. The EA process should support scientifically defensible conclusions regarding the potential impacts of a project on migratory birds, and by extension, publically defensible decisions regarding the likelihood of significant adverse environmental effect. A strong scientific basis by which to predict and measure effects on migratory birds is guided by standardized field protocols that can vary by species groups, season, and location. Application of statistical analytical approaches and succinct presentation of findings can provide clear estimates of effects, significant effect size, certainty, and potential measures for mitigation (Figure 1).

> "Knowledge of many facts does not amount to understanding unless one also has a sense of how the facts fit together"
>
> Peter Kosso (2007)

Although the types and amount of data required for an EA can vary among projects, a scientific approach to environment assessment is applicable to all EAs. A scientific approach to EA does not necessarily require more sampling, wider scoping, more variables, or additional costs; it primarily involves using the data collected to provide valid information on the potential impacts of the project and defensible conclusions. It has been asserted that a central question in resource and environmental management is what qualifies as fact (Susskind et al. 2007), and there has been criticism of the EA process in Canada (Nikiforuk 1997, Gibson 2002), yet there has been little focused attention on the scientific fundamentals of EA in recent years (Baker and Rapaport 2005, Noble 2006). It is important that persons undertaking EAs adhere to the scientific fundamentals in making impact predictions and conclusions (e.g. Beanlands and Duinker 1983, Green 1979). EA should be considered in the context of environmental risk assessment and not simply as an administrative impediment to be overcome in order to receive a permit to proceed with a project.

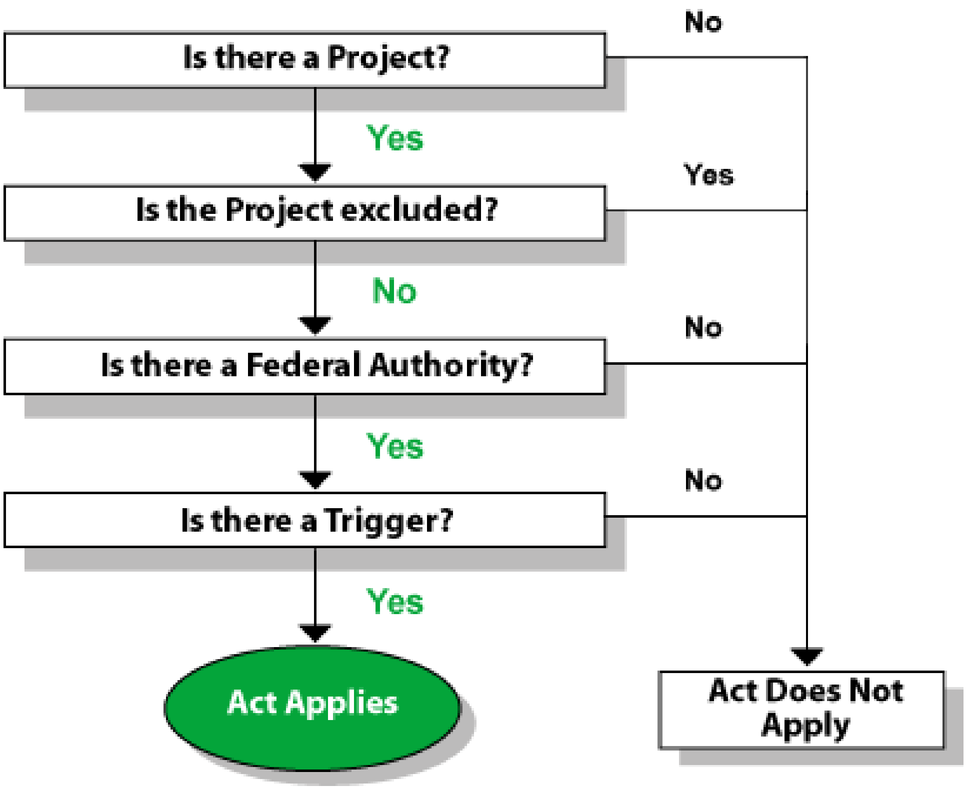
> The Federal Court decision released on March 5, 2008 held that the Report of the Joint Review Panel approving Imperial Oil's Kearl Oil Sands Project did not provide a rationale for its conclusions on greenhouse gas emissions. As a result, the Court remitted the matter back to the same Panel with a direction to provide a rationale for its conclusions.

1.2 The *Canadian Environmental Assessment Act*

The Government of Canada supports its mandate for the conservation and protection of migratory birds under the *Canadian Environmental Assessment Act* (*CEAA*) that is invoked when the project specifically involves federal lands, federal funding and/or whenever a federal authority is asked to provide a license, permit, certificate or other regulatory authorization prescribed in the Law List Regulations (see Figure 2a from CEAA Web Site www.ceaa-acee.gc.ca). Although EC is the judiciary authority on migratory birds in Canada, the vast majority of migratory birds in Canada occur on habitat that is outside of direct federal jurisdiction and/or ownership. Therefore, EC works cooperatively with provincial, territorial and private landowners when assessing potential impacts of development on the environment. EC has previously provided EA guidelines on the important concepts and principles needed to assess potential project impacts on migratory birds (Milko 1998a, 1998b, 1998c).

An EA can be subject to the *CEAA*, provincial EA legislation or legislation that involves multiple jurisdictions. Initially, EC reviews an EA to determine whether further assessment is required in relation to migratory birds, identifies other expertise (i.e., who should be involved), assists in developing the scoping guidelines, and provides direction to proponents. EC reviews the EA reports and supporting analyses to assess conformance to stated guidelines, the accuracy of predicted effects and the effectiveness of proposed mitigation measures. Mitigation and follow-up programs are then implemented as appropriate (Figure 2).

The January 27, 2009 decision of the Joint Review Panel, established by the Federal Minister of the Environment and the Alberta Energy and Utilities Board, was that the application by EnCana for licenses to drill three wells lacked complete and up-to-date pre-disturbance assessments for the proposed drilling sites. Given this shortcoming, the Panel was unable to fully assess the potential environmental impacts of the three proposed wells, as required by Section 3 of the *Energy Resources Conservation Act* and accordingly, the Panel found that it was not in the public interest to approve the three-well application at the time.



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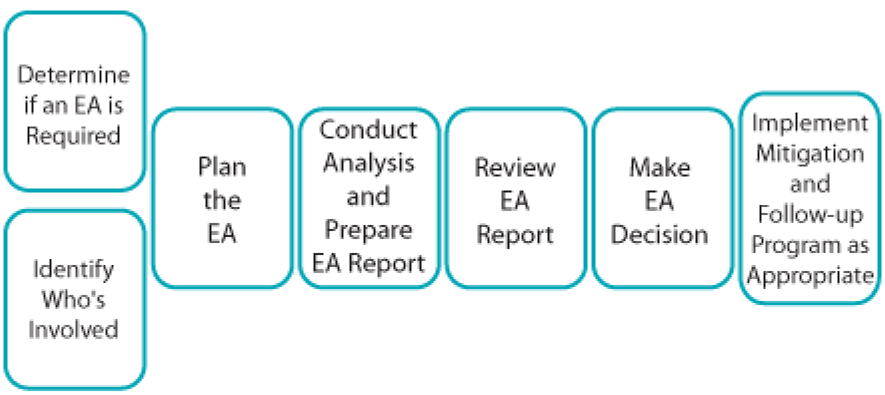

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Figure 2 – Canadian Environmental Assessment Agency schematic diagram of application of the *Canadian Environmental Assessment Act* (A) and flowchart for developing and approving an environmental assessment (B). For a complete description of figure, go to www.ceaa-acee.gc.ca.

1.3 The *Migratory Birds Convention Act, 1994*

Canada and the United States signed the *Migratory Birds Convention* in 1916 in order to save migratory birds from excessive harvest and to ensure their preservation. The Convention provided a coordinated system of protection between the two countries which led to Great Britain, on behalf of Canada, adopting the *Migratory Birds Convention Act* (MBCA) in 1917, and the United States adopting the *Migratory Bird Treaty Act* in 1918. The MBCA was completely updated in 1994 and is now referred to as the *Migratory Birds Convention Act, 1994.* Additional amendments in 2005 included stronger enforcement provisions and a significant increase in penalties. It is the responsibility of the Federal Government of Canada to protect and conserve the roughly 400 species of Migratory Birds regularly occurring in Canada. Canadian Wildlife Service (1991) provides the list of bird species protected under the MBCA, which derives from Article 1 of the Convention. The list includes all seabirds (except cormorants, pelicans), all waterfowl, all shorebirds, and most landbirds (birds with principally terrestrial life cycles). Migratory birds may be seasonal or full time residents, migrants, or stage in a defined ‘study area’.

The purpose of the MBCA is the protection and conservation of migratory birds as individuals and as populations. *The Migratory Birds Regulations* (MBR), in Section 6, prohibit the disturbance, destruction, and taking of a nest or egg of a migratory bird; or the possession of a live migratory bird, or its carcass, skin, nest or egg, except under authority of a permit. It is important to note that under the current MBR, the incidental take of migratory birds caused by development projects or other economic activities is illegal. Section 5.1 of the MBCA also prohibits the deposit of harmful substances to migratory birds in waters or an area frequented by migratory birds or in a place from which the substance may enter such waters. Since 2002, endangered and threatened migratory birds species at risk (species, subspecies, distinct populations) have federal legislative protection under the *Species at Risk Act* (SARA).

As part of its mandate for the conservation of migratory birds, EC may identify information requirements that a proponent must fulfill when seeking approval of a project registered under EA legislation. This Technical Report was developed to provide guidance to proponents, consultants and regulatory agencies in addressing the baseline data and information needs that are a prerequisite to scientifically predicting potential environmental effects of projects on migratory birds.

1.4 Previous Guidance

Milko (1998a, 1998b, 1998c) provided guidance on the assessment of potential impacts on migratory birds, forest habitat of migratory birds and wetlands. These guidance documents were developed to identify the types of information and analyses that EC would expect to be included in an EA that deals with impacts on migratory birds. Kirk (2000) provided information on determining significance of impacts on birds and the development of a decision support system. Persons undertaking EAs should consult the Canadian Environmental Assessment Agency, herafter referred to as CEA Agency, web site for additional information that may be posted in the future (www.ceaa-acee.gc.ca).

Lynch-Stewart (2004) provided information on EA and Wildlife at Risk. Recently, guidance was developed on required information for assessing potential impacts of wind power projects on migratory birds (Environment Canada 2007a, 2007b).

2. Scientific and Ecological Best Practices in Support of EA

2.1. Science in Support of EA

EA offers an opportunity to assess the potential environmental effects of proposed projects on migratory birds so that informed decisions can be made that minimize impacts to birds and their habitats prior to actual project commencement. The types and amount of information that should be included in EA documents, and that are necessary to derive scientifically and publically defensible conclusions, are dependent on the specifics of the project and have a direct relationship with the potential for adverse effects (CEA Agency 2007a,b,c,d). Various quantitative and qualitative methods are used to predict project effects, including mathematical and physical models, laboratory and field experiments and field and case studies (CEA Agency 2007a). Whether a science based conclusion is needed to provide the rationale for a determination will also be dependent on the project. In general, a scientific approach to EA is potentially advantageous to all parties as it should result in decisions based on sound and credible information.

> "The EA report documents the process, methodologies, and decisions undertaken during the EA planning and analysis; and supports the findings and recommendations from the analysis. The EA decision must always consider the conclusions of the significance of the residual adverse environmental effects as outlined in the screening report. The EA report supports the EA decision making by clearly explaining the basis for the significance determination. An independent reviewer reading the EA report should be able to come to the same conclusions based on the information and rationale provided. Any controversy, criticism or challenge of the EA decision will focus on the content of the EA report and the rationales provided."
>
> CEA Agency (2007a)

According to the CEA Agency (2007a) the review of the EA report is to ensure that:
1) effects have been adequately identified and assessed;
2) the EA process is transparent;
3) the report contains accurate and supporting information to withstand third party or public scrutiny;
4) information presented is adequate to support government decision making; and
5) the assessment is legally compliant with the EA legislation of the jurisdictions involved.

The EA decision should be based on technical analysis and stakeholder/public input and supported by strong rationale and well documented information (CEA Agency 2007a). An EA that has scientific credibility reduces the potential for professional and societal criticism of the process and subsequent decisions (e.g. Matthews 1975; Schindler 1976; Rosenberg et al. 1981). If the responsible authority concludes that it is uncertain whether the project is likely to cause significant adverse environmental effects, then the responsible authority shall request that the project be referred to a mediator or review panel (*CEAA* 20.1.c.i).

The EA itself rarely provides absolute certainty about the presence or absence of an effect because the development or perturbation is generally at the proposal stage and the actions and impacts are yet to occur. EA should include post-project monitoring when reasonable uncertainty exists that predicted outcomes will be realized; this also includes the effectiveness of mitigation (CEA Agency 2007b). To truly address potential environmental impacts it is necessary to quantify the natural variation in the ecosystem and contrast this with the variation evident in 'indicators' following the development. Post development monitoring ("follow-up") is required when knowledge is not sufficient to make environmental impact predictions with complete confidence. A scientific framework for data collection and establishment of baseline conditions is essential if conclusions are to be made based on post-project monitoring.

> "It may be difficult to draw conclusions from the follow-up program if there is a poor understanding of the baseline conditions and ecological trends and the environmental effect predictions were vague and qualitative."
>
> CEA Agency (2007a)

Green (1984) stressed that a good *a priori* design of environmental studies is needed, validated by preliminary sampling so that the eventual results are conclusive. Environmental studies should be a logical flow of purpose, question, hypotheses, model, sampling design, statistical analyses, tests of hypotheses, interpretation, and presentation of results (Figure 1). Progress in the practice of EA and our understanding of ecosystem response to perturbations can only be made through comparison of expectations (predictions) with the reality of actual outcomes through measurements and analyses of results. The publication of rigorous results can benefit the scientific community at large and improves predictive certainty for future projects.

> "Solving a problem is nothing more than presenting the problem in such a way that the solution becomes obvious"
>
> - Herbert Simon, MIT, Nobel Prize in Economics 1978

2.2 The Scientific Method

If decisions are said to be based on science, then technically and publically accepted definitions of science (Kuhn 1970), scientific method (Peters 1991), scientific reasoning (Giere 1991) and code of scientific conduct (Committee on Science, Engineering, and Public Policy 2009) must be adhered to. The Webster Dictionary (1975) definition of the **scientific method** is ‘a research method characterized by the definition of a problem, the gathering of data, and the drafting and empirical testing of the hypothesis.’ Equally important in the EA context is the public expectation of what the scientific method entails (e.g., the Wikipedia definition below).

A Public Perception of the Scientific Method (Wikipedia: Accessed April 15, 2009)
The scientific method refers to the body of techniques for investigating phenomena, acquiring new knowledge, or correcting and integrating previous knowledge. It is based on gathering observable, empirical and measurable evidence subject to specific principles of reasoning. A scientific method consists of the collection of data through observation and experimentation, and the formulation and testing of hypotheses. Scientific researchers propose hypotheses as explanations of phenomena, and design experimental studies to test these hypotheses. These steps must be repeatable in order to dependably predict any future results. The process is objective to reduce a biased interpretation of the results. Another basic expectation is to document, archive and share all data and methodology so they are available for careful scrutiny by other scientists, thereby allowing other researchers the opportunity to verify results by attempting to reproduce them. This practice, called *full disclosure*, also allows statistical measures of the reliability of these data to be established.

Science can contribute to EA at an applied level when testable hypotheses are formulated that lead to measurements of environmental variables (Raybould 2006). It is important to note that the scientific method deals not only with hypothesis testing but also with the presentation of data, and associated statistics, and ensuring that there is an objective transparent process. Quantitative predictions lead to a firm foundation in measurement, in contrast to descriptive studies that do not provide conclusions by themselves. Descriptive studies are valuable to the extent that they are used to direct and focus the longer-term experimental studies because they provide a basis for the conceptualization and formulation of workable hypotheses (Beanlands and Duinker 1983). In its simplest form, the null hypothesis is that the human perturbation in question does not have a significant effect on migratory birds.

A publicly defensible EA should be founded in the scientific paradigm that can be stated as:

Null Hypothesis (H_o): The project or perturbation will not have a significant effect on (populations of) migratory birds.

Alternative Hypothesis (H_A): The project or perturbation will have a significant effect on (populations of) migratory birds.

As will be further discussed in Section 3, significance can be measured in statistical, biological, environmental, or societal terms. For statistical hypothesis testing, the null hypothesis states that there will not be a statistically significant impact. From this fundamental paradigm arises a series of predictions as to what negative consequences might emerge. Regulatory agencies direct proponents to undertake studies to address these concerns. A scientific approach to EA is however more than null hypothesis testing as will be discussed in Section 3 (e.g., Germano 1999).

2.3 Ecosystem Approach

Increasingly, EAs for migratory birds are focused on species of concern, biodiversity and ecosystems (see www.ceaa.gc.ca). A major goal is to achieve an ecosystem based approach, which has been described as conservation planning to protect, maintain, and where necessary restore, fully functioning ecosystems at all spatial and temporal scales by designing human activities that fit within the constraints of sustainable development. An EA should be not only scientifically defensible but also conducted within an ecosystem context (Milko 1998a). Ecosystems are dynamic in nature and changes (variation) are normal ecological processes. Nevertheless, projects often cause changes outside the realm of natural variation (*e.g.* magnitude, rate, extent). Inappropriate human use of ecosystems and landscapes can have serious and long-term negative ecological, social, economic, and cultural impacts (Hammond 2002).

In considering effects on migratory birds, an ecosystem based approach requires addressing landscape-level issues such as the degree of fragmentation and connectivity of habitats expected after construction of proposed projects. While emphasis is habitat-centred there also needs to be a focus on assessing guilds of species (e.g., those sharing the same habitat; Kirk 2000). Proponents are encouraged to consider potential effects at the level of species and communities through examination of issues such as potential for changes in competition, predation, brood parasitism, and/or shifts that might occur in food availability and habitat. Findings within a defined study area need to be related to local, regional and national population level trends and conservation issues.

An important component of ecosystem integrity is biodiversity, and persons undertaking EAs should minimize impact on biological diversity by adopting the guiding principle of ‘no net loss’ of ecosystem function, habitat connectivity, species populations or genetic diversity. General considerations of biodiversity in EA include defining the spatial parameters that characterize ecological processes and components in order to provide a regional context for impact analysis of a proposed project (Environment Canada 1996). There needs to be a strong focus on species at risk (Lynch-Stewart 2004).

Mitigation of impacts needs to be similarly developed in the context of ecosystem conservation in order to maintain natural biodiversity. For example, the restoration of ‘natural’ landscape following construction should use plant species native to the area, and precautionary techniques should be applied to reduce the risk of introducing exotic species to plant communities in relatively pristine areas.

2.4 Precautionary Principle and Adaptive Management

An essential component of EA is the prediction of changes from baseline conditions due to human induced perturbations, with verification and quantification of predictions during post development monitoring. A primary role of EA is to identify potential negative impacts requiring mitigation. Ideally, negative effects of human-induced perturbations should be avoided. For an ecosystem-based approach to be effective it must exercise the *Precautionary Principle* as part of its guidance because there is always some level of scientific uncertainty pertaining to ecosystem functioning. Decisions, interpretations, plans and activities should err on the side of protecting the ecosystem (Santillo et al*.* 1998). Adaptive management is exercised within the constraints of the precautionary principle in that actions that do proceed are continuously evaluated and optimized to maintain or restore ecological health and biological diversity (Hammond 2002).

Because proponents want their projects started as soon as possible, it is frequently necessary to commit to further studies after the EA has been completed and approved. Emphasis in EA is on prediction of impacts, and hence there needs to be a committed focus on monitoring of environmental conditions post development when there is limited certainty in predicted outcomes (Duinker 1989). Information from post-development monitoring should be used to increase the certainty of predicted outcomes in the future. The duration of post-project monitoring will be a function of the temporal variability of each response variable in question and the predicted lag time between the project and its impacts on the response variables. Given that post-project monitoring may be required for many years, the selection of key response variables and the development of an appropriate study design are important. Direction for effects monitoring is provided in CEAA as “follow-up programs” (CEA Agency 2007b).

3. STUDY DESIGN CONSIDERATIONS

3.1 Identify General Issues and Questions

EA scoping identifies what information is required, and the study strategy specifies how to acquire it. A problem must be carefully analysed, and a literature/information review should be conducted before studies aimed at solving it commence (Beanlands and Duinker 1983). Study objectives should be evaluated so that efforts can be devoted to studies with a high likelihood of producing useful results. Highly accurate, detailed information is of little value if decisions are made on the basis of other considerations. Decision analysis helps to ensure that the scientific protocol, modeling and data collection remain focused on the objectives.

Study questions should include:

1. What are the ecological goals?
2. What general information is needed?
3. What are specific information needs?
4. Do decisions require accurate and/or precise characterization of a variable?
5. Is it possible to acquire adequate scientific information and test for effects?
6. How will the information be used to satisfy the ecological goals?
7. How will specific information be used in decision-making?

The following general ecological perspectives should be applied to EA (Beanlands and Duinker 1983, Orians et al. 1986):

1. Strive to develop a study design that assumes an opportunity to measure change after project initiation.
2. Strike a compromise between studying the valued ecosystem components (VECs) and the nearest surrogate components for which useful predictions are possible.
3. Take advantage of the information available from natural and man-made occurrences and natural records.
4. Focus numerical data collection around a statistical definition of the natural variation of environmental components in time and space.
5. Refine a concept of environmental effects until it can be stated as a specific question for which a numerical answer is possible.
6. First attempt to predict project-induced changes in physical and chemical components and their impacts on organisms. Then focus attention on indirect effects operating though changes in habitat or food.
7. Consider the long term potential of the ecosystem or component to recover from an expected impact, to predicting the initial outcome of the perturbation.

These considerations should be integrated and expanded using the framework that shows the process from the purpose, into study design, hypotheses, models, sampling design, statistical analyses, hypotheses testing, and interpretation (Figure 1).

3.2 Determine Significance Levels

The concept of 'significance' is extremely important in EA but also one of the most challenging to define. One of the stated purposes of *CEAA* is to ensure that projects do not cause significant adverse environmental effects. This determination is an objective test from a legal standpoint, which means that all decisions about whether or not projects are likely to cause adverse environmental effects must be supported by findings based on the requirements identified in *CEAA* (www.ceaa-acee.gc.ca). The determination of significance is therefore more difficult without the support of a scientific assessment or analysis. The reader is directed to the CEA Agency web site and the reports on 'significance' sponsored in 2000. Kirk (2000) developed a prototype decision support tool to help determine the significance of impacts on birds based on regional and international conservation priorities; Gibson (2001) attempted to link the concepts of significance and sustainability. Significance in an EA context should attempt to link the statistical, ecological and social context of predicted impacts on migratory birds.

The three broad steps to determine significance are:

1. Deciding whether the environmental effects are adverse,
2. Deciding whether the adverse environmental effects are significant, and
3. Deciding whether the significant adverse environmental effects are likely.

Adverse effects are deemed significant based on (i) magnitude, (ii) geographic extent, (iii) ecological context, (iv) environmental standards, and (v) ecological risk analyses. Any or all of these aspects should be quantified where possible and tested for statistical significance. The potential adverse effects are further scrutinized in the context of probability of occurrence and scientific uncertainty. A statistical approach can provide direct quantification of these latter parameters as α and β, respectively, (see Section on statistical power) because $1-\alpha$ is the probability that there is an effect when there is, and β is the probability of accepting that there is no effect when in fact there is.

Determination of significant adverse environmental impacts should include the following considerations [adapted from Beanlands and Duinker (1983)]:

1. <u>Statistical Significance</u>
   The scientific approach attempts to isolate man-made effects from natural variation whereby: (i) measurements are undertaken to test for change, (ii) it involves the detection of a departure from baseline conditions, which implies that baseline conditions must be known, and (iii) its proper interpretation requires the use of acceptable statistical procedures for analyzing observed departures from normal variability.

2. <u>Ecological Significance</u>
   The professional value judgement of whether a predicted impact impinges on the ecosystem either directly or through effects on ecological functioning and biodiversity. Such a judgement recognizes that an effect that is statistically measurable may not be of ecological significance (e.g., certain behavioural effects).

3. <u>Social Significance</u>
   Proposed projects may have considerable implications to social acceptance, and be deemed unacceptable to the local people in many situations for reasons that are more aesthetic and traditional than ecologically-based.

Statistical significance has a very precise definition whereby null hypotheses (no impact) are considered falsified if the probability of the findings is less than some predetermined level (usually $\alpha = 0.05$); that means that there was a 1-in-20 chance of the observed condition happening naturally (e.g. by chance). Hence the scientific method can determine if there is a statistically "significant" environmental effect, and it can provide some measure of effect size. In theory, this can be put into a local and/or regional context depending on the availability of regional ecological information. Whether those scientific conclusions support or question the sustainability of a project, the significance of the adverse environmental impact is a value judgment resting in the public interest and their elected officials. Therefore EA is a process that melds statistical science and social science into a final document supporting sustainable development.

In addition to discussions of significance it is important to remember that provisions under the MBCA make it illegal to kill, harm, or harass a migratory bird or to disturb, destroy or take its nest or eggs.

3.3 Define the Study Area

The geographic boundaries of the potential environmental effects of the proposed project must be identified. These boundaries should encompass migratory birds and their habitats that would be affected by the project as part of the ecological processes and ecosystem components of a larger study area. For migratory birds this can be challenging because of the mobile nature of birds, their varied habitat requirements and the seasonal use of habitats. Nevertheless, it is critical that a potential impact area be clearly defined by the proponent in agreement with EC early in the planning stages. Using an ecosystem approach, functionally defined study areas might, for example, encompass watersheds, and can be applied at the level of ecodistrict, and be important for biodiversity and ecosystem connectivity (Hammond 2002).

3.4 Obtain Baseline Information

Impact is often calculated as the difference between the state of the system of interest before and after perturbation. In general, an EA needs to define baseline information and must address basic requirements in determining potential for effects:

1. What species or species groups are potentially involved?
2. What are the numbers and temporal and spatial variation present?
3. What time of the year are they present?
4. What habitats are used, and by which species?
5. What is the general ecology of the valued ecosystem components?
6. What are the key indicator species?
7. Do species at risk and species of conservation concern occur in the study area?
8. Is there critical habitat in the study area?
9. What variable(s) may best track changes due to predicted effects?
10. Can effective samples of data be achieved?

The baseline data need to be collected in a scientific manner in order for them to be compared to post-project conditions. The baseline must consist of statistically adequate descriptions of the variability (e.g., seasonal, annual, spatial) inherent in specific ecosystem components (Beanlands and Duinker 1983). There may be existing information on migratory birds for the study area, which may be of great value especially if it is long term and covers a large spatial area (Table 1). Sometimes it is necessary to hypothesize (predict) the nature of the variability in order to design a meaningful monitoring program for such a baseline (Duinker 1989).

Lemieux et al. (1997) provided good examples of how carefully collected baseline data gathered as number of breeding pairs of migratory birds could be used to generate densities of birds (e.g., pairs per ha) by habitat type (Table 2). Habitats predicted to be affected by the project can be interpreted as the equivalent loss of pairs of migratory birds using ecological land classifications (Table 3). Such baseline information is extremely valuable in assessing the relative local impact on an array of migratory bird species. A high level of rigor and detail are required for species at risk (Environment Canada 2004, Table 4).

Environmental assessment is often spatial in context because of locations of individuals and species, habitat areas of potential occurrence and/or loss, seasonal variations, and physical location of projects. Geographic Information Systems (GIS) are especially valuable in conveying spatial (e.g., critical habitat) and temporal data, and integrating project design with ecological data. For example, it can be valuable to discuss noise disturbance effects on birds in the context of buffer zones of certain radii from source because noise effects have been demonstrated to be a nonlinear function of distance (e.g., Reijnen and Foppen 1994; Reijnen et al. 1995).

Table 1. Examples of sources of existing information on migratory birds.

Source	Web Site
Species at Risk Registry	www.sararegistry.gc.ca
Committee on the Status of Endangered Wildlife in Canada	www.cosewic.gc.ca
NatureServe Canada's Conservation Data Centres (CDC)	www.natureserve-canada.ca/en/cdcs.htm
Maritimes Breeding Bird Atlas	www.mba-aom.ca
Les Oiseaux du Québec	www.oiseauxqc.org
Québec Breeding Bird Atlas	http://www.atlas-oiseaux.qc.ca/index_en.jsp
Atlas of the Breeding Birds of Ontario	www.birdsontario.org/atlas
Saskatchewan Bird Atlas	http://gisweb1.serm.gov.sk.ca/imf/imf.jsp?site=birds
The Federation of Alberta Naturalists	www.fanweb.ca
British Columbia Breeding Bird Atlas	www.birdatlas.bc.ca
Breeding Bird Survey data	www.pwrc.usgs.gov/bbs
Northwest Territories/Nunavut Bird Checklist Survey	www.mb.ec.gc.ca/nature/migratorybirds/nwtbcs
Christmas Bird Count	www.audubon.org/Bird/cbc
Canadian Migration Monitoring Network	www.bsc-eoc.org/volunteer/cmmn
Avian Knowledge Network	www.avianknowledge.net
eBird Canada	www.ebird.org/canada
Canadian Biodiversity Information Facility	www.cbif.gc.ca

Table 2. Estimating hypothetical effect size by integrating ecological land classification with estimated breeding bird densities from Lemieux et al. (1997).

Habitat – Sphagnum and Balsam Fir (wetland edge)			
Species	No. of Indicated Pairs (5 ha sampled)	Density (pairs/ha)	Estimated Total No. Affected (100 ha)
Fox Sparrow	10	2	200
Northern Waterthrush	15	3	300
Yellow-rumped Warbler	14	2.8	280
Rusty Blackbird	4	0.8	80

Table 3. Summarizing hypothetical effect size by habitat types from Lemieux et al. (1997).

Total Numbers of Breeding Pairs Affected per Habitat Type					
Species	Spagnum-Balsam Fir (100 ha)	Osmunda-Black Spruce (35 ha)	Aspen/Birch-Balsam Fir (500 ha)	Herb Rich Balsam Fir (150 ha)	Total No. Pairs Impacted (785 ha)
Fox Sparrow	200	100	0	50	350
Northern Waterthrush	300	100	0	0	400
Yellow-rumped Warbler	280	100	100	75	555
Rusty Blackbird	80	35	0	0	115
Philadelphia vireo	0	0	5	1	6
Ovenbird	0	0	150	25	175

Table 4. Considerations for assessing environmental effects on wildlife at risk. Adapted from Lynch-Stewart (2004).

Characterization of Wildlife at Risk and their Vulnerabilities	Possible Environment-Species Interactions
Status/rank: global, national, provincial/territorial	
Population size and extent of occurrence ▪ Size of area used ▪ Percentage of range in Canada/province	What is the proportion of the population that uses the project area?
Trend in population	How can the project influence these trends? What is the quantitative or qualitative assessment of population viability? How might the project affect this viability model?
Geographic distribution	What is the proportion of the extent of occurrence or area of occupancy represented by the study area.
Natural or anthropogenic threats affecting population viability	How can the project contribute to/affect these threats?
Potentially limiting attributes making it susceptible or limiting recovery potential	How can the project affect these attributes?
Activities likely to affect individuals or populations	How many individuals or what proportion of the population might be affected? To what degree? Will other projects or activities intensify these effects?
Seasonality and adaptability to climate extremes	Which project activities could interfere with seasonal activity? How? Which project activities and design features could contribute to increased stresses on species if climate extremes are considered?
Species interrelationships ▪ Significance of ecological/ecosystem role ▪ Other species that share the same threats	How might the project affect predator/prey and other species relationships?
Habitats and residences ▪ Occupied and other habitats that potentially may be utilized ▪ Critical, survival or recovery habitat ▪ Key habitat attributes ▪ Trends in habitat	What types of habitats occur in the project study area? What proportion of the total survival or recovery habitats occur in the study area? How might the project directly or indirectly influence these habitats/key habitat attributes? What effect might this have on individuals or populations.
Ecological processes and functions critical to the maintenance of habitats	How might the project influence these processes and functions?
Relevant policies or legal requirements	What are the requirements for species protection?
Goals, objectives, approaches for recovery	How can the project influence recovery of the species?
Ongoing recovery activities	How can the project influence ongoing recovery activities?

3.5 Conduct Preliminary Field Inventory

EA needs to determine the effects of the project on the environment with associated impacts on species in a biological community. To effectively do this, a sampling program must be designed to obtain data for analysis by some statistical method, to test whether there is evidence of an effect on the biota, and to quantitatively describe any effect (Green 1979). This usually requires preliminary field investigations and sampling. Descriptive inventories are not, in themselves, support for EA predictions, and persons undertaking EAs are advised to use inventories of natural resources (based on surveys, existing knowledge, and anecdotal information) to improve scientific predictions. In many cases follow-up studies are necessary to test predictions refined from preliminary field studies and EA preparations.

3.6 Identify Potential Impacts

Impacts of projects on migratory birds should be evaluated and interpreted at multiple scales because negative effects may apply to:

1. Individuals
2. Populations
3. Species
4. Species groups
5. Short term or long term time scales
6. Habitat quantity
7. Habitat quality
8. Demographics (e.g., survival and/or recruitment)
9. Behaviour (e.g., avoidance, feeding, breeding success, etc.)

An ecosystem-based approach is best accomplished through the consideration of multiple species and/or species groups that integrates considerations of habitat at an ecodistrict level (Hammond 2002).

A basic understanding of potential effects of projects on migratory birds are known (Appendix 1, 2), and their quantification requires appropriate survey techniques (Appendix 3, 4). Environmental effects should be defined for each project phase. The effects on migratory birds should be differentiated into impacts on individuals/populations and impacts on habitats. Although the distinction is intuitively clear, there can be considerable variability in the relative quality of the assessed information. For example, the inundation of a forested river valley should lead to a relatively accurate quantified loss of riparian habitats whereas the knowledge of densities and populations of birds is less precise. In some cases, the quantity of habitat lost may be determined whereas the actual bird species composition and abundance is poorly understood but may be inferred from published studies.

3.7 Assess Impacts on Habitat

During project scoping the types of habitat changes should be conceptualized and, based on this, certain effects should be anticipated. The prediction of these potential effects provides for the identification of indicator variables that can then be measured and monitored for estimating environmental effects (see Figure 1). Habitat change can be categorized into four categories:

1) Habitat Quantity
Loss of habitat is usually caused by the clearing of vegetation (e.g., forests) or the destruction of substrate (e.g., beaches, dunes and wetlands). Such loss may or may not be followed by habitat replacement. If not, then it is referred to as a net habitat loss. Net losses have an overall impact on bird fauna. It is not correct to assume that the birds will go elsewhere because such effects reduce the carrying capacity of the landscape to support migratory birds, and some species are considered limited by available habitat (Lemieux et al. 1997). The significance of the impact can be evaluated in terms of individuals lost if there is concern for population trends or status. This is frequently the case for species at risk. Often there is insufficient information to fully understand the implications of habitat loss; for example, is the habitat underutilized for other reasons, such as when a population is far below carrying capacity of the habitat? Loss of habitat is a formative negative impact because populations themselves have the capacity to recover in numbers whereas habitat loss is often irreversible (see Appendix 1).

2) Habitat Quality
Habitat can be physically altered by the introduction of pollutants, change in age structure of vegetation, vegetation species composition, etc., which indirectly can affect vital demographic rates, such as survival of birds or the foods on which they depend. Some examples include oil spills, changes in salinity, and increased sedimentation.

3) Habitat Disturbance
Quality of the habitat can also be affected by other factors such as presence of structures (e.g., turbines especially in open habitats such as grasslands), movement (e.g., turbine blades), noise levels, human presence, introduced species, increased abundance of predators, increased edge, etc. These changes can (i) affect the degree to which birds continue to use the habitat, or (ii) negatively affect vital demographic rates (e.g., survival and productivity).

4) Habitat Replacement
The original habitat may be removed and replaced by another type of habitat. A classic example of an immediate effect might be the inundation of a river valley creating a man-made lake for a hydroelectric reservoir. More often habitat replacement occurs after project implementation, such as the progressive successions of the wetlands of the Peace-Athabasca Rivers into shrub and forest following the damming of the Peace River (Gill and Cooke 1974).

3.8 Assess Impacts on Individuals and/or Populations

Project related activities may affect the abundance of birds and could be observed as reduced densities or even subsequent absence from the affected area. Effects may be subtle and evidenced as a progressive decline over time following project initiation, or be dramatic and rapid due to habitat creation or destruction (e.g., ice-free open water, landfills, etc.). The ecological setting for effects is important and impacts could affect the distribution of species if their occurrence is localized within the impacted zone.

Evaluating impacts on animal populations is inherently more complex than evaluating habitat impacts because individuals are mobile and affected by demographics related to survival, mortality, recruitment, immigration and emigration. Many of these vital rates could potentially be affected by a project. For example, opening an uncovered landfill near a coastal area could radically affect immigration into local gull colonies. Impacts at different life-stages must be considered, such as on breeding adults or on nests (eggs and nestlings), as well as the different periods of the year (summer, migration, winter). The species present in the study area may also show seasonal variation. Short- and long-term effects must also be examined. Some perturbations might affect reproductive rates showing no demonstrable effect on adults but having significant observed impacts years later when recruits are expected. Thus, well established scientific definitions and predictions of project effects are of vital importance to the effectiveness and accuracy of an EA (see Figure 1).

3.9 Assess Impacts on Behaviour

Birds are relatively visible wildlife and lend themselves well to observational study. Bird behaviour is an extensive science and much has been published on the effects of human activities on behaviour. Project activities and other perturbations have the potential to cause behaviour alteration such as avoidance, nest abandonment or collision with structures. Effects on behaviour may also be manifested as indirect effects through such factors as increased predation (e.g., edge effects) and/or species introductions.

Because bird behaviours are usually observable they can be measured, and thus there is potential to monitor behaviour as a surrogate for other levels of impact that may be more difficult to measure. For example, reduced time spent feeding due to disturbance may be ultimately a surrogate to predicting a reduction in body condition that can affect survival and reproduction (Reed et al. 2004, Krapu and Reinecke 1992). Alert and vigilance behaviours can be indicators of stress in individual birds that increase in a dose-response manner (Goudie and Jones 2004). Nevertheless, there are potential problems with *a priori* selection of behavioural variables to predict an effect. There is a diversity of behaviours in birds and detection of effects may best be addressed by a multivariate approach; in some cases, disturbance may result in inactivity that would be undetected in a study limited to overt responses (Goudie 2006), or the wrong single response variable may have been selected for study.

Demonstrated effects on behaviours should be considered surrogate to other potentially more deleterious implications on demographic parameters. Ideally, studies need to substantiate the effectiveness of (behavioural) surrogates in assessing meaningful effects on individuals and populations (i.e., demographic impacts).

3.10 Assess Mitigation Efficiency

Mitigation means the elimination, reduction or control of the adverse environmental effects of a project, and includes restitution for any damage to the environment caused by such effects through replacement, restoration, compensation or any other means (CEA Agency 2007a). Ideally, it is desirable to mitigate all potentially negative impacts. The ability for proponents to mitigate impacts is dependent on the work undertaken to measure effects in the first place. In some cases these can be inferred from obvious situations (e.g., removal of habitat) or previous experience and studies (e.g., dose-response predictions). Nevertheless, many EAs would benefit from collection of *de novo* information in order to identify and mitigate impacts. The collection of this information will be influenced by spatial and temporal variability.

Findings of follow-up studies need to flow from structured Before-After-Control-Impact (BACI) or similar study designs (see Section 3.11, Appendix 5), and integrated into project design and operation through adaptive management that is applied within the context of a precautionary principle (Hammond 2002).

3.11 Incorporate Environmental Effects Study Design

In EA, proponents should describe the relative abundance and use of migratory bird habitats in the impact area and compare these to similar habitats in the regional landscape that will not be affected by the proposed project. This is important for identifying good representative control or reference areas for monitoring environmental effects (Milko 1998a). The use of controls in both space and time is the foundation of the Before-After-Control-Impact (BACI) design. This experimental design has controls in both space and time, and the General Linear Model for BACI is a two-way ANOVA with an area by time 2 X 2 factorial design whereby the evidence for impact effects is a significant interaction term (Green 1979) (Figure 3). Goudie and Lang (2008) and Underwood (1992, 1994a) provided detailed information on BACI study design.

> "If you are not told anything about the sampling methods,
> you should retain a healthy degree of skepticism about the results"
>
> Ronald Giere 1999

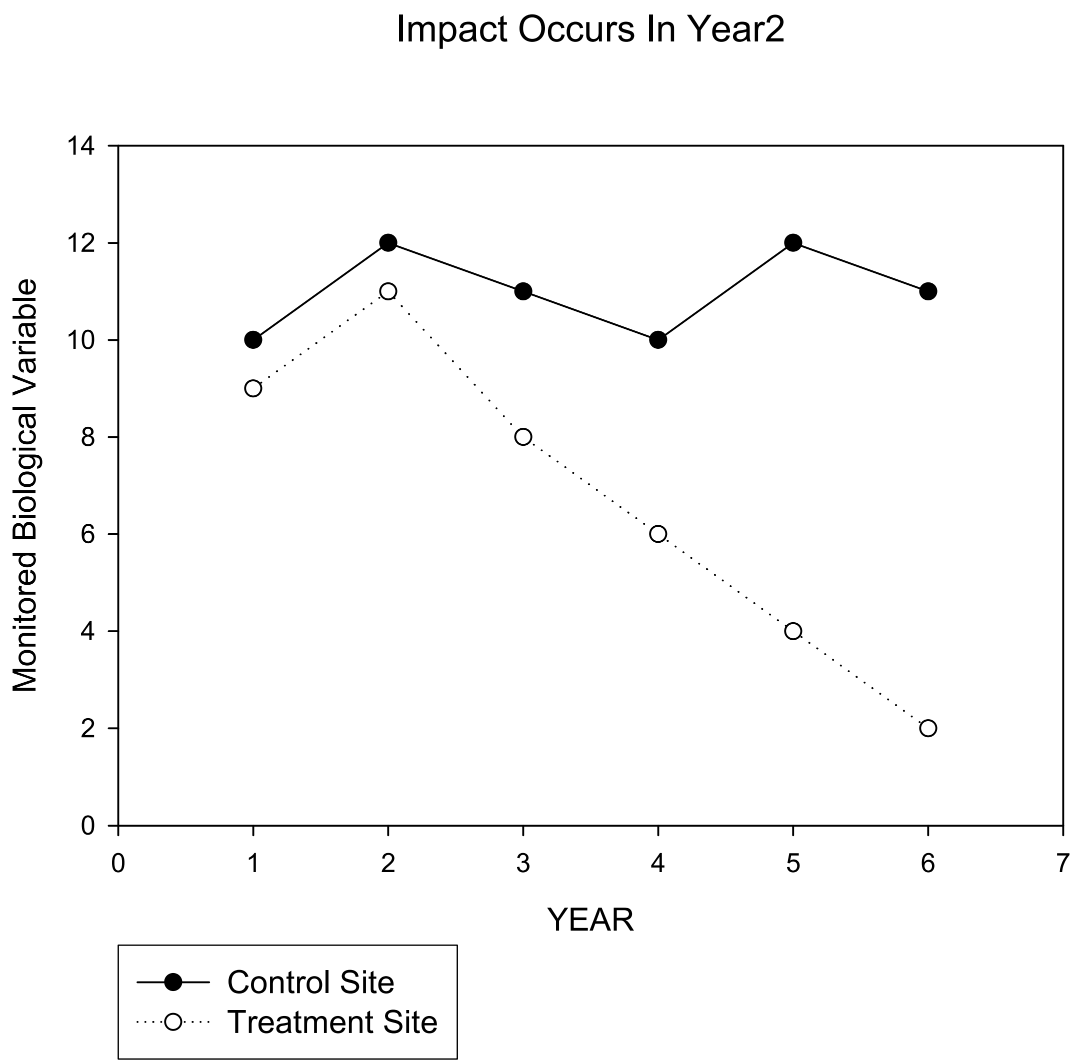

Figure 3 - The theoretical model of a Before-After-Control-Impact (BACI) study design with a significant effect following perturbation.

4. Statistical Considerations of Sampling Design

4.1 Variable Selection

Development of an EA that is scientifically defensible requires concise consideration of what to monitor. This can be viewed as a step-down procedure where it must first be determined what habitats are under consideration, and then what are the associated bird species (Verner 1985). Some species will be identified as sentinel species, umbrella species or keystone species, all of which can help focus on appropriate sampling units (see Figure 1). Indicators may carry much of the information about the structure of a community in space and time. When a large number of variables are measured, there is often high redundancy in the information obtained (MacDonald and Green 1983). To facilitate developing a study design and variable selection, Green's (1979) list of principles of scientific approach to EA should be considered (Table 5).

Table 5. Green's (1979) ten principles of sampling design and statistical methods for environmental biologists.

Step	Principle
1	Be able to state concisely what question you are asking.
2	Take replicate samples within each combination of time, location, and any other controlled variable.
3	Take equal number of randomly allocated replicate samples for comparisons.
4	An effect can best be demonstrated by comparison to a control.
5	Undertake preliminary sampling in order to evaluate nature of potential data.
6	Ensure that the sampling method is representative of variation over range of conditions to be encountered.
7	Subdivide large study areas into ecological homogeneous units and then subsample.
8	Verify sample unit is appropriate to the target species, and estimate required sample size to obtain desired precision.
9	Test data to ensure it meets statistical assumptions, and/or transform as appropriate or use distribution-free (nonparametric) or simulated procedures.
10	When an appropriate *a priori* scientific study yields an outcome, stick with the result.

No matter what species or aspects of their biology are initially chosen to be studied, the ability to determine statistical significance is influenced by what is actually present in the study area. This ultimately dictates the species/parameters selected for study. A statistical design and preliminary field sampling are strongly recommended for determining what can be feasibly measured in the field (Green 1979, 1984; Clarke and Green 1988). Criterion variables should represent a direct, robust linkage to the question and hypotheses, and this is the level at which the hard decisions are actually made. If the EA practitioner cannot establish any linkage between public concern and the criterion variables used in the study, then no one else will either (Green 1984).

Preliminary sampling exposes the limitations of obtaining data for the variables in question. Some variables can be cost-effectively sampled, others can not. The attributes of the data themselves can now be assessed for meeting statistical assumptions (Figure 1), which many ecological data fail to meet (Green 1979). For example, spatial distribution of detected birds could yield distributions (Appendix 6) that are:

- uniform hence the variance is less than the mean (common with territorial songbirds);
- clustered whereby the variance is greater than the mean (e.g., birds occurring in social units); or
- random whereby the variance is equal to the mean (e.g., the case for most rare species).

In other cases, nonlinear models may be more appropriate than linear models (Glass 1967). Understanding the underlying spatial distribution of the data should guide the appropriate approach to statistical analyses of data; for example, rare species should be assessed using an underlying frequency distribution of Poisson or negative binomial (see Section 4.4.). Proponents are cautioned that using statistical tests that assume data have a normal distribution may waste time and resources when later the data are determined to be non-parametric (Green 1979, 1984; Clarke and Green 1988).

It is important to define what constitutes a sample site, and within this, how to collect data that truly represent the intended target population. The narrower the target population is defined, the more extraneous variance can be controlled. Because treatment (and control) areas often present a range of site conditions, it is important that sampling is representative of this variation (Green 1969). Development of a visual model is important at this stage (Figure 1). When there is range in spatial attributes across the study area(s), some form of stratified sampling is required (Schneider 1994). For example, plot counts of songbirds in a treatment and control areas should be stratified for comparisons by habitat types (e.g., softwood forest, hardwood forest, grass land, wetland).

When data on large numbers of biotic variables are collected (e.g., songbird habitat at points along transects), it is advisable to reduce the number of variables to 15 or less by generating a correlation matrix and dropping one variable from pairs of variables that are highly correlated. Retain variables that are as uncorrelated, hence independent, as possible (Green 1979, 1984) in order to better judge significance of individual predictor variables. Once variables have been edited for redundancy, it is best to reduce the dimensionality through principal component analyses (PCA), whereby variables (15 or less) are reduced into a few principal components that are unrelated (orthogonal) to each other, and explain most of the variance (information) in the data cluster. When using this approach, a careful interpretation and explanation of the important principle components is needed.

Interpretation of findings is improved by repeating biological and chemical measures on the same individuals, that is, repeated measures, because it controls for within subject variance and allows more power in statistical testing. The right amount and kind of replication is important, and it is preferable to aim for a balanced design with equal number of replicate animals analysed at each site. Replicate readings can also be taken across different hierarchical levels (Green 1979, 1993) and account for temporal data distribution considerations (Appendix 7).

4.2 Sample Size Requirements

It is often desirable to estimate the statistical power of environmental monitoring studies (e.g., Lougheed et al. 1999). The rejection of the null hypothesis when it is in fact true is called a Type I error (false positive), and this occurs at least 5% of the time when it is established *a priori* that $\alpha = 0.05$. A Type II error is the error of failing to reject a null hypothesis when it is in fact not true (false negative). An efficient statistical analysis method will be as conservative (low Type I error), powerful (low Type II error) and robust as possible (error levels not seriously affected by the type of data collected). The probability of Type I error can be lowered by reducing alpha, for example $\alpha = 0.01$ (1-in-100 chance). In doing so however there is an increase in the Type II error or β which is concluding that H_o is true when in fact it is not. A complication is that β is generally not specified or known. The trade-off is best reconciled through improving study design, especially by increasing the number of samples. Thus for a given α, larger samples will result in statistical testing with greater power $(1 - \beta)$ (Zar 1999). On the other hand, if H_o is in fact false, a statistical test will sometimes not detect this fact, and we make a false conclusion by not rejecting H_o.

In applying the precautionary principle, the power of statistical testing can be decided *a priori*. For example, it may be decided that there is a 0% $(1 - \beta)$ probability that a decline that occurred as a result of the treatment is detected. This can be undertaken if there is basic preliminary statistical knowledge of the sample population, particularly an estimate of variation (variance or standard deviation). The power of detecting a change or difference or correlation can be determined using appropriate formulae (Zar 1999). It is generally not helpful to determine *post hoc* that the findings are very low in statistical power (i.e., retrospective power analysis). Statistical hypotheses and power should be declared before examining the data.

In general statistical power can be increased by:

1. Increasing sample size (*n)*,
2. Increasing difference among population means,
3. Reducing the number of groups for comparisons,
4. Decreasing variability (S^2) within populations, and
5. Increasing the *a priori* level of α (e.g., 0.05 to 0.10).

Goudie and Lang (2008) provide a detailed discussion of sample size and statistical power analysis. It is important to err on the side of caution and always take more samples than estimated to be required. The 'power' of a statistical test is the efficiency of the statistical test, and can relate to the magnitude of any effect (e.g. decrease). Where the error variance S^2 appears in the formulae, any function relating the variance to the mean can replace it, and Taylor's Power Law ($S^2 = a\mu^b$) is used especially when dealing with animal abundances which become the effect expressed as a fraction of the mean (e.g., pollution causing a 33% decrease in abundance, etc.). Hence the total number of animals in *n* samples, *n*μ, is inversely proportional to the square of the effect magnitude, meaning that the criterion of adequate sample size can be based on sampling until some total number of organisms is collected. Power analyses can also be extended to multivariate responses (Green 1989). The number of replicate samples that should be randomly allocated per areas-by-times combination in a Before-After-Control-Impact design where *a priori* it is decided what level of change (e.g., decrease of 50%) can be detected (Green 1979) if there is some preliminary sampling.

4.3 Determining Effect Size

It is important to know effect size because when sample size is not adequate it is possible to statistically conclude that there is not an impact even though the impacts are large and biologically important. Conversely, the opposite holds true, with large enough sample size it is possible to have statistically significant differences that are biologically meaningless, and not indicative of significant adverse environmental effects. Effect size is a numerical way of expressing the strength of the difference between a treatment and a control. Effect size can be measured as the standardized difference between two means (known as Cohen's *d*); or the effect size correlation, which is the correlation between the independent variable values and the corresponding values on the dependent variable. The basic formula to calculate the effect size is to subtract the mean of the control group from that of the experimental group and then to divide the numerator by the standard deviation of the control group.

Effect size calculation varies depending on whether plans are to use ANOVA, t-test, regression or correlation. Effect size is expressed as a decimal and values greater than 1.00 are possible although rare. When the effect size approaches 0.00, it implies that experimental and control groups performed the same. Generally speaking effect size is considered small when $d \leq 0.2$, medium when $d = 0.5$, and large when $d \geq 0.8$. The effect size may be positive or negative implying that the experimental is greater than the control or the experimental is less than the control, respectively. This approach formalizes a measure of effect size. In other circumstances it is more intuitively meaningful to talk about effect size as a proportional change, for example in abundance, in treatment sites versus control. The biological significance of effect size will be determined by ecological context, such as population abundance, distribution, intrinsic growth rate, etc.

Presenting data as means (centroids) plus 95% confidence intervals (ellipses) provide visually intuitive ways to assess mean values and magnitudes of responses in relation to control(s).

4.4 Special Case of Rare Species

EAs involving rare species listed under the federal and provincial species at risk legislations (www.ceaa-acee.gc.ca) require special sampling regimes if field based information is required. Species listed as threatened and/or endangered are protected by regulations and associated significant penalties. By definition, many listed species are uncommon and therefore are a challenge to proponents who wish to demonstrate that appropriate observational sampling techniques have been applied. Surveys for these species are often times developed for a single species and EAs should demonstrate that survey efforts for species at risk were sufficient (Thompson 2004).

Green and Young (1993) reported on the importance of the Poisson and negative binomial distributions for detecting rare species when, *a priori*, it is expected that field data will generate a disproportionate number of zeroes or low numbers of individuals. The Poisson distribution is important in describing random occurrences, when the probability of an occurrence is small. Thus, the Poisson distribution has importance in describing binomially distributed events (they happen or they don't) having a low probability. If the species exhibits a clustered/aggregated distribution then it is more appropriate to apply the negative binomial distribution (Zar 1999) because the Poisson distribution assumes that each sample unit has an equal probability of occurrence of the rare species (see Goudie and Lang 2008).

5. SURVEY METHODS

5.1 Qualifications of Team

Most environmental assessments conducted by proponents are completed by consultants who offer these services to corporations, government agencies, nongovernmental groups and the general public. The qualifications and experience of individuals conducting the work is critical to successful application of the scientific framework. Within the field of EA, there is increasing emphasis on the production of scientifically defensible results. The work completed in the conduct of an EA is designed and developed by individual biologists and scientists. Clearly for migratory birds it is expected that field staff know how to identify birds and appropriate times and places to locate species of interest. It is therefore important that the names of the individuals conducting surveys be provided in addition to information on the timing and intensity of sampling.

The thesis work of postgraduate students in the environmental and biological sciences requires them to generate research hypotheses, design studies to test these hypotheses, collect and analyse data, report results and discuss findings in the context of the published scientific information. Similarly, this is what is expected in a science-based EA.

5.2 Selection of Survey Protocol

A thorough review of local and regional scientific literature, published reports, and data (e.g., Breeding Bird Atlas, Breeding Bird Survey) should be conducted prior to undertaking field investigations (see Section 4.2 in Environment Canada 2007a). This review will assist in determining what new data are required and what survey protocols should be used. It is recommended that standardized published survey protocols be used whenever possible.

As mentioned previously, the survey protocol must be appropriate for the **species** (e.g., American Robin vs. American Bittern), **habitat** (e.g., forest vs. wetland), **geography** (e.g., Labrador vs. southern Ontario), **impact** (e.g., loss of habitat vs. noise disturbance), **response variable** (e.g., presence vs. reduced reproductive success), and **time of year** (e.g., breeding season vs. winter). Appendix 3 provides a synopsis of many survey techniques for migratory birds in various habitats throughout North America. Environment Canada (2007b) has previously described recommended protocols for monitoring impacts of wind turbines on birds. The validity of conclusions on potential impacts on migratory birds is determined in part by the selection of appropriate survey protocols.

6. STATISTICAL ANALYSIS

> "To minimize scientific uncertainty in EA, apply statistical methods to the determination of significance and likelihood of occurrence wherever possible"
>
> CEA Agency 2007a

6.1 Univariate Statistical Procedures

Ecological problems typically lend themselves to univariate and/or multivariate statistical approaches (Fletcher and Manly 1994). Many data require pre-processing because commonly used ANOVA techniques require basic assumptions of normality and equality of variance. Any statistical analysis assumes certain attributes of the data. It is important to recognize that statistical tests are not important when the effect(s) is entirely obvious, e.g., loss of nesting pairs due to complete loss of habitat. Standard assumptions of many parametric statistical tests are random sampling, independent and normal error distributions, homogeneity of error variation among groups and additive effects. Underwood (1994b) provided an example of a common sampling error where field biologists obtained values for cover of plant Species A and Species B from the same quadrats, and then proceeded to analyse them as independent data when clearly the cover of one species in a quadrat is correlated to the cover of the other species. Univariate methods (more uncertain for multivariate), such as t-test and ANOVA, are fairly robust to violations of normality. While this may be the case for tests concerning the difference in means, those concerning variances and covariances are not robust (Green 1979; Clarke and Green 1988). Only proper sampling can ensure independent errors. Logarithmic transformations are widely used because all variables are put onto a common scale of variation regardless of the original units of measurement. Although there are nonparametric (or distribution-free) methods, a trade-off occurs in that methods with fewer assumptions perform less powerful tests of hypotheses (Glass et al. 1972), and experienced scientists consider that parametric statistics are inherently more powerful (Green 1979, 1984).

Biologically defined objectives should determine the statistics rather than the reverse. Statistical tests require biological hypotheses that are formulated in terms of models (see Figure 1) because statistical tests view reality only in terms of tests of hypotheses. Understanding what constitutes change of a kind and of a magnitude to cause significant concern is the fundamental question of good environmental assessment, and is more than just a question of statistical significance. Once hypotheses are clear, the type of appropriate statistical test is generally clear (Appendix 8).

Where possible, avoid correlational analyses in establishing environmental effects. Findings can be more relevant by assessing a dose-response relationship (e.g., Goudie and Jones 2004). In order to relate effects more closely to the perturbation in question, it is often desirable to remove the effects of physical or biological ‘extraneous’ variables not controlled in the study design. A good example of this is the need to control for body weight in relation to contaminant assays, and this is best achieved through an Analysis of Covariance (ANCOVA). Avoid diversity indices for summarizing multivariable biological processes because they are not robust empirical indicators of important environmental health correlates of biological systems (Green 1984).

6.2 Multivariate Statistical Procedures

Univariate methods are extremely powerful in situations where the response of a single variable is of sole interest (e.g., demonstration of dose-response) and other factors can be controlled. In ecology, it is often the case that hypotheses can be best answered by considering a number of variables interacting simultaneously. Hence the emphasis is on sets of inter-correlated variables rather than individual variables (McGarigal et al. 2000). Considering the issue of covariance, the single best description of the response is best achieved through multivariate statistical analyses (e.g., Goudie 2006). Principal Component Analysis (PCA) is suitable to environmental assessment of multiple variables because the procedure reduces dimensionality by creating components that are linear combinations of the original variables, each being orthogonal (perpendicular) to the previous axis, and describing progressively less information in the data set (Appendix 8).

Multivariate Analysis of Variance (MANOVA) maximizes the ratio of among-group to within group variance in canonical scores, and subsequent to a statistically significant MANOVA, a Discriminant Analysis (DA) can be applied. It is logical to consider DA as an extension of MANOVA because overall the interest is in testing the null hypothesis that the groups do not differ, whereas in DA the interest is in describing the linear combinations of dependent variables that maximally discriminate among groups. MANOVA and DA correspond to the inferential and descriptive aspects of analyses much the same way as the univariate ANOVA and subsequent multiple range tests because in the multiple range tests we seek to describe where the differences among groups lie (McGarigal et al. 2000). The multivariate extension of the ANCOVA is the MANCOVA (Appendix 8).

Distribution of samples in multivariate space is derived by scoring the raw data using the principal component or canonical variable (vector), and the resulting ‘scores’ represent the new multivariate data because they are derived from a linear combination of the original variables. The plot of data in two and three-dimensional space provides an intuitive visual interpretation of findings (see Williams (1994) for example of beetle abundance before and after prescribed burnings). By averaging the scores within a particular group we derive the centroid for each group that represents the composite mean of a number of initial variables. Distribution of centroids in multivariate space can be assessed using 95% confidence ellipses or multi-way 95% confidence intervals.

6.3 Demographic Monitoring and Modeling

Assessment of demographic rates in birds can be a powerful approach to measuring impact, especially residual impacts that can extend well beyond the event or implementation of a perturbation (e.g., Esler et al. 2000). Skalski et al. (2005) provide a detailed overview of the analysis of sex, age, and count data in wildlife populations. There are now many techniques that permit assessment of vital rates in animals. One of the most common is radio-telemetry that allows ascertaining mortality in a known-fate context. Recently, there has been an expansion of mark-recapture/resighting analysis techniques that can provide for a much longer period of monitoring, permitting precise estimation of survival rates and other parameters such as immigration/emigration using the software program MARK. Because of their high visibility, these applications hold great promise for monitoring impacts on vital rates of birds, and the software integrates an interactive approach for determining the best fit of environmental covariates that may be affecting survival.

Modeling is a means of integrating considerable information in order to assess for possible implications of perturbations. It can provide a very valuable tool in the EA process and provide the mechanism for developing scientific predictions that can be experimentally tested. Functional models allow for the assessment of effects of altering specific parameters while holding others constant, and can help assess the synergistic or cumulative effects of a range of perturbations (Wiese and Robertson 2004). Demographic models provide a basis for assessing the relative effect (sensitivity) of survival rates of various life stages on population growth rate (McDonald and Caswell 1993, Caswell 2001).

7. PRESENTATION OF INFORMATION AND DATA

7.1 Presentation of Information

Effective presentation of data is very important, and the two most important numerical descriptive measures are measures of central tendency and measures of variability (Ott 1984). As a general practice it is best to report the mean (μ), standard deviation (σ) or standard error ($\sigma / \sqrt{n}$) and sample size (n). Presenting the group means (centroids) with (usually) 95% confidence intervals is valuable practice. It provides for direct visual interpretation of whether there are significant differences when shown in context with other treatment and control groups. If the 95% confidence interval or ellipse overlaps the mean or centroid of another group, they are probably not significantly different. When data have been log-transformed for analyses, a back-transformation (exponent) is required, and an asymmetric interval results.

Reporting of scientific findings and interpretations need to be supported by *bona fide* scientific references. Whether referring to a statistical approach, or information on a species' status, all information is rooted in scientific sources, or in some cases a qualified personal communication. References should report the original source of information and not repeat a statement by an author who was referring to the original source. Unpublished sources of information (including unpublished consultant reports or government technical reports) should be carefully referenced so that others could obtain this same information if required. If possible, peer reviewed publications should be cited instead of unpublished reports.

7.2 Data Storage and Access

Existing data is extremely important and can provide a useful tool on which to base proposed studies. Long-term data exist for programs such as the Christmas Bird Counts (Dunn and Sauer 1997), Breeding Bird Surveys (Bradstreet and Dunn 1997), and Breeding Bird Atlases (e.g., Cadman et al. 2007). These programs are based on a large number of observers and the data are easily accessed.

Environmental data are often limited, and this is especially evident as consultants and agencies attempt to assess status of migratory bird species, populations and habitats. Some of the most extensive studies of environmental effects relate to work conducted under the auspices of EA and environmental effects monitoring. Most of these data serve the purpose of achieving project approval but further commitments should be made for these data to achieve a scientific standard format for archiving and access. A digital copy of survey data should be included with the EA submission. This copy of the data will ensure that data summaries and interpretations presented are correct, and that information on migratory birds collected during an EA is available to regulatory agencies for future reference. The Canadian Wind Energy Association (CanWEA) and the CWS have collaborated to develop a database for the collection of bird-related data from Canadian wind energy projects (Environment Canada 2007b).

Quality control for data can be assured through conscientious oversight and by instituting standard protocols for data collection, presentation and archiving. Species at Risk data is now routinely archived at Conservation Data Centres. In these cases, proponents release specific locations of any species at risk to the management agencies for archiving. This approach could be extended to all migratory bird data. Proprietary agreements and relationships may be entered and committed between responsible regulatory agencies and proponents as necessary, but the long-term benefit would be to increase the availability of data to all and to improve environmental impact assessment.

Proponents are also encouraged to publish study findings in peer-reviewed scientific journals. Relatively few environmental effects studies are published, which ultimately leads to the loss of this information from the greater community (scientists, regulatory agencies, the public, proponents). This would benefit the scientific community and sustainable development in general as well as improve the quality of EAs.

8. SCIENTIFICALLY DEFENSIBLE CONCLUSIONS

EA is a means to ensure that environmental resources (wildlife, clean water, clean air) are sustainably managed. Many aspects of the EA process and final recommendations and approvals are matters of public record. It is therefore important that conclusions in EA reports are reached through a scientific process. This requires a demonstrated adherence to the principles outlined in Figure 1 and full disclosure of information on study design, sampling protocol, existing data, survey results, statistical analysis, with proper referencing as required. Any conclusions related to the significance of potential impacts of the project on migratory birds must be supported by information contained within the EA report.

> "After completing the analysis of effects, it is important to report the outcomes in a manner that is easily understood and well rationalized. Environmental effects should be described in nature, quantity, time and space so that a third party can read the report, understand the predicted effects and arrive at the same logical conclusion based on the information presented."
>
> CEA Agency 2007a

9. CHECKLIST OF THE KEY ELEMENTS OF AN EA

A summary of the key elements of scientifically based EA to assess potential impacts on birds are summarized in Table 6.

10. CONCLUDING REMARKS

Canadians have embraced the concept of sustainable development, and it is incumbent upon government and proponents to provide the tools and information to make sustainable development a reality.

It is hoped that this document will help proponents to cost-effectively obtain the information required for decision-making, and thus increase the scientific validity of decisions reached through the EA process. This process will be iterative whereby government agencies and proponents work cooperatively to make the requirements more clear and cost effective. A true understanding of the costs and benefits of any project can only be assessed with a thorough quantitative assessment of environmental impacts in relation to socio-economic benefits. This is the basis for effective decision-making. A schematic approach for the development of EA for migratory birds that is scientifically defensible is presented as a flowchart in Figure 1. The checklist in Table 6 should be used as a guide in the planning, implementation and reporting of scientific studies of the potential effects of a project on migratory birds.

Table 6. Check list of essential elements in a scientifically-based assessment of potential impacts of a project on migratory birds in an Environmental Assessment.

Step	Element and Description
1	Description of potential impacts of proposed project on migratory birds (scoping), based on the literature, existing data, preliminary field sampling, and nature of proposed project.
2	Statement of testable Ecological and Statistical hypotheses.
3	Description of which established survey methods/protocols were used and why.
4	Description of how sampling program and survey protocol supported the testing of ecological and statistical hypotheses (e.g., provide information on baseline conditions, predicted effects, and verification of predictions).
5	Description of how sampling program and survey protocol provided information on the numbers and density of different bird species.
6	Description of how sampling program and survey protocol provided information on other types of impacts (*e.g.,* habitat loss, reduced reproductive success / survival through disturbance).
7	Description of how temporal and spatial sampling intensity supports statistically/scientifically valid conclusions (e.g., Power Analysis, Ecological Risk Assessment and Environmental Effects Monitoring Literature).
8	Description of how sampling program provided information on how impacts on individuals affects local and regional populations.
9	Identification of persons who conducted work, their qualifications and their contribution.
10	Description of current habitat conditions, proposed future habitat conditions (including disturbance) and how that will affect migratory birds.
11	Conclusions on probable effects of the project on birds in the study area.
12	Conclusions on probable significant effects of the project on birds in the study area.
13	Description of on-going monitoring activities, mitigation, and response plans.

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Appendices

Appendix 1 - Possible impacts on bird habitats and indicators of effect.

Environmental Effect Type	Description of Effect	Indicators of Effect(s)
Habitat loss	Habitat is destroyed and potentially replaced by a different habitat.	- Reduced species diversity and carrying capacity - Bird use of study area before and after - Measures of growth and survival of young - Population displacement and indirect impacts on other sites - Species composition changes
Habitat Modification (Direct)	Habitat remains but is modified (e.g., understory thinning, change in species composition or age structure).	- Reduced species diversity - Increased nest parasitism - Reduced breeding success - Increased predation rate
Introduction of Physical Obstacles	Physical obstructions are put in place (e.g., power lines, roads).	- Mortalities along right-of-way detected by appropriately timed surveys - Use of installations by birds - Barrier effects, change in habitat use
Habitat Disturbance	Includes noise, human activity, and researcher impacts.	- Habitat use before and after - Reduced species diversity - Reduced breeding success
Contamination and Pollution	Deliberate versus accidental; specific substances; specific environmental pathways; bioaccumulation through food chain	- Routes of exposure of toxins; can measure in potential food items - Investigate indicator species (e.g., lichens) - Risk assessment for accidental events
Habitat Modification (Indirect)	Habitat may be impacted by hydrology, change in competitors or predators.	- Shifts in climatic indicators (e.g., degree days) - Water turbidity - Available open water - Bird use of study area before and after
Changes in Food Availability	Habitat may no longer be suitable for preferred food species (e.g. introduction of exotic species); less food can lead to increased competition.	- Measures of food availability - Bird use of study area before and after - Measures of growth and survival of young - Population displacement and indirect impacts on other sites (e.g., crops, development complexes, parking lots, etc.)

Appendix 2 – Examples of project types and potential pathways of effects.

Project Types	Pathways of Effects (common impacts)
Oil/Gas Seismic Exploration – Onshore Military Exercises/Testing – Onshore	Disturbance (e.g., noise, human presence) Habitat alteration (terrestrial and wetland) Edge effects Habitat fragmentation Loss of interior habitat Mortality due to ordinance Mortality – destruction/abandonment of active nests Contamination/mortality via effluent, emissions
Oil/Gas Seismic/ Exploration – Offshore Military Exercises/Testing – Offshore	Disturbance Potential for hearing damage in diving birds Mortality of seabirds due to artificial light attraction
Oil/Gas Drilling/Production – Offshore	Habitat loss Mortality – produced water Mortality – well blowout (accidental) Mortality of seabirds due to artificial light attraction
Manufacturing/Refining/Processing Facility/Mill; Electrical Generating Station Oil/gas Production – Onshore; Shaft Mining Waste Management Facility; Incinerator Bioremediation Facility Commercial/Residential/Cottage Subdivision Military Base	Habitat loss Edge effects Habitat fragmentation Habitat transformation (including invasives) Mortality, habitat loss – fire/explosion (accidental) Mortality, habitat loss, contamination - spill (accidental) Mortality – destruction of active nests Loss of interior habitat Contamination/mortality via effluent, emissions, waste, heap leaching Habitat degradation – emissions Disturbance (e.g., noise, human presence) Elevated predation by waste-feeding species due to increased survival and reproduction Mortality due to wildlife control program Mortality due to collisions or increased levels of hunting
Linear Developments Tunnel Road/Highway Railway Subway Canal Pipeline Electrical Transmission Line	Habitat loss Edge effects Habitat fragmentation Habitat transformation (including invasives) Mortality, habitat loss – fire/explosion (accidental) Mortality, habitat loss, contamination - spill (accidental) Mortality – destruction of active nests Loss of interior habitat Contamination/mortality via effluent, emissions, waste, Habitat degradation – emissions Disturbance (e.g., noise, human presence) Mortality due to wildlife control program Mortality due to collisions or increased levels of hunting

Appendix 2 – (cont'd)

Project Types	Pathways of Effects (common impacts)
Wind Turbine Tall Structures Communication Towers Tall Buildings	Disturbance Avoidance Loss of interior habitat Edge effects Habitat fragmentation Habitat transformation (including invasives) Mortality, habitat loss – fire/explosion (accidental) Mortality, habitat loss, contamination - spill (accidental) Mortality – collisions with structure Mortality – destruction of active nests Disturbance (e.g. noise, human presence) Contamination/mortality via effluent, emissions, waste,
Logging; Silviculture Peat Extraction Agriculture Golf Course Strip/Open pit Mining/Quarrying Landfill	Habitat degradation Habitat Loss Emissions Disturbance (e.g., noise, human presence) Elevated predation by waste-feeding species due to increased survival and reproduction Mortality due to wildlife control program Mortality due to collisions or increased levels of hunting Mortality – destruction of active nests
Reservoir and Water Control Structure	Habitat loss Habitat transformation (including invasives) Edge effects Disturbance (e.g., noise, visual) Mortality – destruction of active nests
Marine Terminal/Base Bridge Underwater Tunnel	Habitat loss Habitat fragmentation Habitat transformation (including invasives) Edge effects Disturbance (e.g., noise, visual) Mortality – destruction of active nests
Dredging/Filling for Navigation	Habitat transformation Disturbance (e.g., noise, human presence)
Aquaculture	Habitat loss and/or transformation in footprint Transformation of adjacent habitat via effluent Disturbance (e.g., noise, human presence) Attraction of birds to facilities
Nuisance Wildlife Control Program	Mortality
Facility to Extract Groundwater	Habitat loss and/or transformation in footprint Transformation of adjacent habitat via effluent

Appendix 3 – Project types and techniques for assessing impacts on migratory birds.

Project Type	Bird Groups	Common Impacts	Variables	Assessment Techniques[1]
Oil/gas seismic exploration and production, onshore	Passerines Waterbirds Raptors	Habitat alteration (terrestrial and wetlands)	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Disturbance (e.g., noise, human presence)	Numbers of individuals, breeding success	Point counts, density x habitat = loss, nest searches, brood counts
	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Point counts, density x habitat = loss, nest searches
Oil/gas seismic exploration, offshore	Seabirds	Disturbance (e.g., noise, human presence)	Numbers of individuals per unit area	Shipboard trip transect survey
	Seabirds	Mortality, potential for hearing damage in diving birds	Corpses per unit area, per unit time	Shipboard trip transect survey
Oil/gas exploration/ production drilling, offshore	Seabirds	Mortality - well blowout (accidental)	Corpses per unit area, per unit time	Instantaneous scan survey
	Seabirds	Mortality of seabirds due to artificial light attraction	Corpses per unit area, per unit time	Area searches, extrapolation to total mortality, Shipboard strip transect survey
Manufacturing/ refining/ processing facility/mill	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat fragmentation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Raptors	Habitat transformation (including invasives)	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Mortality, habitat loss - fire/explosion (accidental)	Numbers of individuals	Site searches & extrapolation to total mortality
	Passerines Waterbirds Raptors	Mortality, habitat loss, contamination via spill (accidental)	Numbers of individuals	Site searches & extrapolation to total mortality
	Passerines Waterbirds Raptors	Contamination via effluent, emissions, waste, heap leaching	Animal health, breeding success	Tissue sampling and toxicological testing; nest searches
Electrical generating station (thermal, hydroelectric, nuclear fission)	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat fragmentation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat transformation (including invasives)	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Disturbance (e.g., noise, human presence)	Numbers of individuals, breeding success	Nest searches, brood counts
	Passerines Raptors	Habitat degradation - emissions	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Contamination via effluent, wastes, emissions	Animal health, breeding success	Tissue sampling and toxicological testing; nest searches

Appendix 3 – (cont'd)

Project Type	Bird Groups	Common Impacts	Variables	Assessment Techniques[1]
Electrical generating wind turbine(s)	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Raptors	Habitat degradation – emissions	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Disturbance (e.g., noise, human presence)	Numbers of individuals, breeding success	Point counts, transects nest searches, brood counts
	Passerines Waterbirds Raptors	Habitat fragmentation	numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Mortality – collisions	Corpses per unit area, per unit time, birds/turbine/year or birds/MW/year or birds/rotor swept area/year.	Site searches
High Structures	Passerines Waterbirds Raptors	Mortality – collisions	Corpses per unit area, per unit time	Site searches
Logging - clearcut	Passerines Waterbirds Raptors	Habitat transformation (including invasives)	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat fragmentation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
Logging - selective	Passerines Waterbirds Raptors	Habitat alteration	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat fragmentation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
Silviculture	Passerines	Reduced biodiversity	Numbers of individuals per unit area	Habitat classification, point counts, density x habitat = loss
	Passerines	Edge effects	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
Sawmill	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat fragmentation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Mortality, habitat - explosion and fire (accidental)	Numbers of individuals	Site searches & extrapolation to total mortality
Peat Extraction	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches

Appendix 3 – (cont'd)

Project Type	Bird Groups	Common Impacts	Variables	Assessment Techniques[1]
Strip mining	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat fragmentation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Raptors	Habitat transformation (including invasives)	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Contamination via effluent, emissions, waste, heap leach pads	Animal health, breeding success	Tissue sampling and testing; nest searches
Open pit mining, quarry, sand/gravel pit Habitat may be made attractive to ground nesters or bank swallows may choose to nest in piles of overburden	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat fragmentation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Raptors	Habitat transformation (including invasives)	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Belted Kingfisher, swallows, Rock Wren	Nesting habitat creation	Number of nests per unit area, breeding success	Nest searches
	Passerines Waterbirds Raptors	Contamination via effluent, emissions, waste, heap leach pads	Animal health, breeding success	Tissue sampling and testing; nest searches
Shaft mining	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat fragmentation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines & raptors	Habitat transformation (including invasives)	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Contamination via effluent, emissions, waste, heap leach pads	Animal health, breeding success	Tissue sampling and testing; nest searches
Uranium waste management	Passerines Waterbirds Raptors	Contamination via effluent, emissions, waste, heap leach pads	Animal health, breeding success	Tissue sampling and testing; nest searches

Appendix 3 – (cont'd)

Project Type	Bird Groups	Common Impacts	Variables	Assessment Techniques[1]
Deuterium production facility; irradiated nuclear fuel processing facility	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat fragmentation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Raptors	Habitat transformation (including invasives)	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Contamination via effluent, emissions, waste	Animal health, breeding success	Tissue sampling and testing; nest searches
Hazardous waste treatment/ incineration/ disposal/recycling facility	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat fragmentation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Raptors	Habitat transformation (including invasives)	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Contamination via effluent, emissions, waste	Animal health, breeding success	Tissue sampling and testing; nest searches
Incinerator: domestic waste, microbial or biological agents	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat fragmentation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Raptors	Habitat transformation (including invasives)	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Contamination via effluent, emissions, waste	Animal health, breeding success	Tissue sampling and testing; nest searches
	Passerines Waterbirds Raptors	Biohazard via effluent, emissions, waste	Animal health, breeding success	Tissue sampling and testing; nest searches
Sanitary landfill, bioremediation facility	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat fragmentation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Raptors	Habitat transformation (including invasives)	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Contamination via effluent, emissions, waste	Animal health, breeding success	Tissue sampling and toxicological testing; nest searches
	Passerines Waterbirds Raptors	Elevated predation by waste-feeding species due to increased survival and reproduction	Numbers of nest per unit area, breeding success	Nest searches, brood counts

Appendix 3 – (cont'd)

Project Type	Bird Groups	Common Impacts	Variables	Assessment Techniques[1]
Commercial, light industrial, residential (incl. airport, aerodrome, runway, military base, transformer station)	Passerines Waterbirds Raptors	Disturbance (e.g., noise, visual)	Numbers of individuals per unit area, breeding success	Point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat fragmentation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Raptors	Habitat transformation (including invasives)	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Disturbance (e.g., noise, visual)	Numbers of individuals, breeding success	Nest searches, brood counts
	Passerines Waterbirds Raptors	Mortality - wildlife control program	Numbers of individuals	Maintenance of wildlife control log/records
Naval exercises	Seabirds	Disturbance (e.g., noise, visual)	Numbers of individuals per unit area	Shipboard trip transect survey
	Seabirds	Mortality - ordinance	Numbers of corpses per unit area	Shipboard trip transect survey
	Passerines Waterbirds Raptors	Disturbance (e.g., noise, visual)	Numbers of individuals per unit area	Shipboard trip transect survey
Infantry/ armoured vehicle/ artillery exercises	Passerines Waterbirds Raptors	Habitat alteration	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Disturbance (e.g., noise, visual)	numbers of individuals, & density	Point counts, density x habitat = loss, nest searches
Low-level flying (military exercises)	Passerines Waterbirds Raptors	Disturbance (e.g., noise, visual)	numbers of individuals, & density	Point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Mortality - ordinance	Numbers of individuals	Site searches & extrapolation to total mortality
Weapons testing	Passerines Waterbirds Raptors	Disturbance (e.g., noise, visual)	Numbers of individuals, & density	Point counts, density x habitat = loss, nest searches
	Seabirds	Mortality - ordinance	Numbers of corpses per	Strip transect survey
	Passerines Waterbirds Raptors	Habitat alteration	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches

Appendix 3 – (cont'd)

Project Type	Bird Groups	Common Impacts	Variables	Assessment Techniques[1]
Armed forces base, land	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat fragmentation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Raptors	Habitat transformation (including vegetation changes due to groundwater alteration, invasives)	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Disturbance (e.g., noise, visual)	numbers of individuals, & density	Point counts, density x habitat = loss, nest searches
Shoreline alteration, naval base, marine terminal	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat fragmentation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Raptors	Habitat transformation (including vegetation changes due to groundwater alteration, invasives)	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Disturbance (e.g., noise, visual)	numbers of individuals, & density	Point counts, density x habitat = loss, nest searches
Shipwreck removal/ destruction	Passerines Raptors	Habitat transformation (including vegetation changes due to groundwater alteration, invasives)	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Disturbance (e.g., noise, visual)	numbers of individuals, & density	Point counts, density x habitat = loss, nest searches
Dam / water control structure & reservoir	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
Bridge, underwater tunnel	Passerines Waterbirds Raptors	Disturbance (e.g., noise, visual)	numbers of individuals, & density	Point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat fragmentation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Raptors	Habitat transformation (including invasives)	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Waterbirds Swallows	Nesting habitat creation (operations), nesting habitat loss (bridge cleaning or decommissioning)	Number of nests per unit area, breeding success	Nest searches
	Passerines Waterbirds Raptors	Disturbance (e.g., noise, visual)	numbers of individuals, breeding success	Nest searches, brood counts

Appendix 3 – (cont'd)

Project Type	Bird Groups	Common Impacts	Variables	Assessment Techniques[1]
Tunnel	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Disturbance (e.g., noise, visual)	numbers of individuals, & density	Point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat fragmentation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
Linear Development (oil/gas pipeline, electrical transmission line, road/highway, railway, canal)	Passerines Raptors	Habitat transformation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat loss, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Habitat fragmentation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Mortality, habitat - explosion and fire (accidental)	numbers of individuals	Site searches & extrapolation to total mortality
	Passerines Waterbirds Raptors	Habitat transformation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
	Passerines Waterbirds Raptors	Mortality (collisions, hunting)	Numbers of individuals	Site searches & extrapolation to total mortality
	Passerines	Alien invasives	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
Dredging/filling for navigation	Waterbirds	Habitat transformation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
Aquaculture development (finfish)	Waterbirds	Habitat loss and/or transformation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
Aquaculture development (molluscs)	Waterbirds	Habitat loss and/or transformation (creation of feeding habitat)	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
Agricultural development	Passerines Waterbirds Raptors	Habitat loss and/or transformation, disturbance, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
Golf Courses	Passerines Waterbirds Raptors	Habitat loss and/or transformation, disturbance, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
Cottage Developments	Passerines Waterbirds Raptors	Habitat loss and/or transformation, disturbance, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches

Appendix 3 – (cont'd)

Project Type	Bird Groups	Common Impacts	Variables	Assessment Techniques[1]
Waste Management Facilities	Passerines Waterbirds Raptors	Habitat loss and/or transformation, disturbance, including edge effects and loss of interior habitat	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches
Taking/destroying wildlife as part of a wildlife management program	Passerines Waterbirds Raptors	Mortality	Numbers of individuals per unit area, breeding success	Point counts, density x habitat = loss, aerial plots, nest searches, brood counts, site searches & extrapolation to total mortality
Facility to extract groundwater	Passerines Raptors	Habitat transformation	Numbers of individuals per unit area, breeding success	Habitat classification, point counts, density x habitat = loss, nest searches

[1]Some species may be too sensitive for application of certain methodologies

Appendix 4 - Survey techniques for quantifying numbers and/or densities of migratory birds in various habitats.

Bird Group /Time	Type	Units	Technique	No. of Surveys	Specifics	Application
Passerines/ Breeding Dunn et al. 1997 Dunn et al. 2006 Ralph and Scott 1981	Total count	No. of individuals	Census of singing males & all active birds	At least 2 surveys about 2 to 3 weeks apart	Conducted early in morning during breeding	Anticipated area of affected habitats is relatively small
Bibby et al. 1992 Dieni and Jones 2002 Dunn et al. 2006	Total count on sample plots	No. of individuals per unit area (density)	Census of singing males & all active birds	At least 2 surveys per plot	Plots are stratified to be representative of habitat types; conducted early in morning during breeding	Results are extrapolated to the habitat types in entire study area
Dobkin and Rich 1998 Dunn et al. 2006	Territory mapping	Singing males and/or interspecific interactions (adjusted to indicated pairs or density)	Territory or Spot Mapping on 10 ha quadrats	Normally 7 to 10 visits are necessary	Applied during breeding; conducted early in morning during breeding; plots are stratified to be representative of habitat types	Anticipated area of affected habitats is relatively large but also relatively homogenous
Mooney 2002 Wilson et al. 2000 Zimmerling & Ankney 2000; Siegel et al. 2001 Thompson et al. 2002 Dunn et al. 2006 EC 2007b	Point counts	Singing males and all birds seen (adjusted to indicated pairs or density)	Counting singing males for 10 min from a fixed point with assumed radial coverage out to a specified distance	At least 2 surveys about 2 to 3 weeks apart per station	Conducted early in morning during breeding; data collected in concentric bands: 0-50m, 50-75m, 75-100m, 100+m	Especially suitable to heavily forested, rough terrain, and large areas; provides a good index of relative species abundance
De Lucas et al. 2007 Pagen et al. 2002 Dunn et al. 2006 EC 2007b	Total Count	Migrating birds	Mist netting Linear Survey			
Passerines EC 2007c	Total count, point counts, spot counts	No. of individuals	Census of singing males & all active birds, call backs, indicated pairs (Linear Survey)	At least 2 surveys about 2 to 3 weeks apart	Conducted early in morning during breeding	Linear developments

Appendix 4 – (cont'd)

Bird Group /Time	Type	Units	Technique	No. of Surveys	Specifics	Application
Shorebirds breeding Bart and Earnst 2002 Bart and Earnst 2005 CWS 2007	Rapid counts	No. of paired individuals	Ground count	Rapid counts on sample plots, and intensive counts on subsample of plots	Single observer walks a 10-15 ha plot, surveying 10 ha/h	Tundra and taiga wetlands
Raptors and woodpeckers	Representative count	No. of individuals	Playback of calls of target species (woodpeckers often respond to raptor calls)	At least 2 to 3 surveys within the breeding season	Generally conducted in early morning and/or late evening	Targets species that are difficult to detect; can be used to augment spot mapping
Owls Takats et al. 2001	Representative count	No. of individuals	Playback of calls of screech-owl species (S. Canada) or Boreal and Barred Owl (boreal and mixed wood regions)	At least 2 to 3 surveys within the breeding season separated by a minimum of 7 days	Between one half hour after sunset to one half hour before sunrise	Targets species that are difficult to detect; can be used to augment spot mapping
Secretive marsh species (bitterns, rails, moorhen, coot, solitary-nesting grebes) Conway and Timmermans 2005; Bazin and Baldwin 2007	Representative count	No. of individuals	Playback of calls of target species	At least 2 to 3 surveys within the breeding season	Generally conducted in early morning and/or late evening	Targets species that are difficult to detect; can be used to augment spot mapping

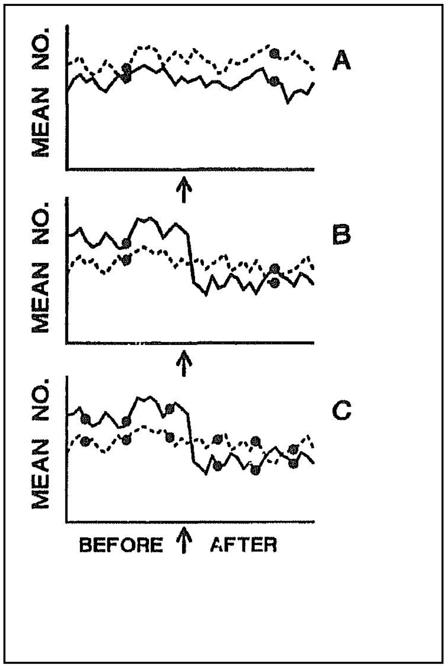
Appendix 4 – (cont'd)

Bird Group /Time	Type	Units	Technique	No. of Surveys	Specifics	Application
Waterfowl Lemieux et al. 1997	Total count	No. of individuals	Indicated Breeding Pair during first 5h of daylight	At least 1 survey for each of early nesting and late-nesting species	Sample plots of 1 km^2 of wetlands are fully inventoried by foot or canoe within the early breeding season up to egg laying or beginning of incubation	Useful for relatively small wetland study areas when a complete census is feasible
Ross 1985; Pollock & Kendall 1987; Caswell & Dickson 1997;	Total count on sample plots or transects	No. of observed individuals	Indicated Breeding Pair during first 5h of daylight	At least 1 survey for each of early nesting and late-nesting species	Sample plots of 25 to 100 km^2 are fully inventoried usually by helicopter within the early breeding season up to egg laying or beginning of incubation	Anticipated area of affected wetlands is relatively large and waterfowl densities are low (e.g., north boreal)
Gabor et al. 1995	Total count on sample plots	No. of observed individuals	Brood count during first 5h of daylight	At least 1 survey for each of early nesting and late-nesting species	Sample plots of 25 to 100 km^2 are fully inventoried usually by helicopter within the mid-brooding season	Anticipated area of affected wetlands is relatively large and waterfowl densities are low (e.g., north boreal)
Bond et al. 1992 Hanson et al. 2008	Evaluation Functional Assessment	Wetlands				
Seabirds (at sea) Tasker et al. 1984 Camphuysen & Garthe 2004; Moulton & Mactavish 2005; EC 2009	Total count in sample transect	No. of individuals	Strip transect from moving platform	100 km of transect during each of winter, spring migration, nesting season, post-breeding dispersal, and autumn migration	Transect 300 m wide from vessel moving at 4-19 kts (10 kts ideal); 10 minute counts; with protocol to avoid bias in numbers of birds in flight;	Used to estimate density in the pelagic zone

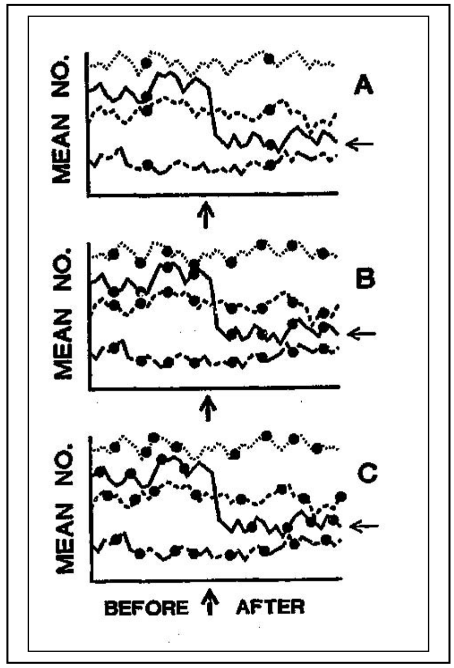
Appendix 4 – (cont'd)

Bird Group /Time	Type	Units	Technique	No. of Surveys	Specifics	Application
Seabirds Walsh et al. 1995 ; Montevecchi et al. 1999)	Total count in sample plot	No. of individuals	Instantaneous survey of plot		Rapid visual sweep and count of semi-circle 300 m diameter at 2 h intervals	Used to estimate density in the pelagic zone from stationary platform, e.g., oil/gas drilling/production platform
Seabirds / breeding Nettleship 1997	Total count (small nesting colonies) or in sample plot (large colonies)	No. of breeding pairs	Aerial photo and/or ground count	At least 1 survey for each of early nesting and late-nesting species	Flat top colony: aerial photo & ground count; cliff: photo count (large colony) or direct (small colony); burrows: quadrats/transects; boulder/cave: count no. pairs displaying on the sea	Nesting colonies

Appendix 5 - Models of Before-After-Control-Impact (BACI) study designs.
Solid lines represent putative impact location, dashed lines are the control locations, circles represent times of sampling, and arrows indicate the beginning of the impact



(Scenario1)



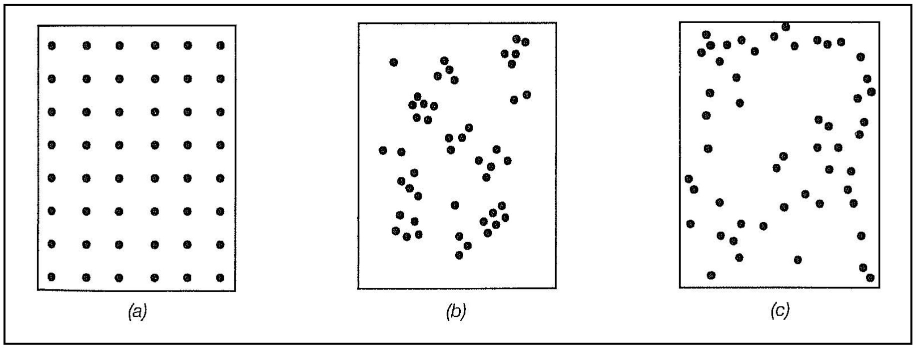
(Scenario 2)

In Scenario 1 when variability in abundance is small (A), a difference between the control and impacted location would be detected even though no impact occurred. In (B) real impact would not be detected because of chance variations, and in (C) a real impact is not detected.

In Scenario 2 chance variation can mask a real effect (A), and is corrected by replicated sampling before and after perturbation.

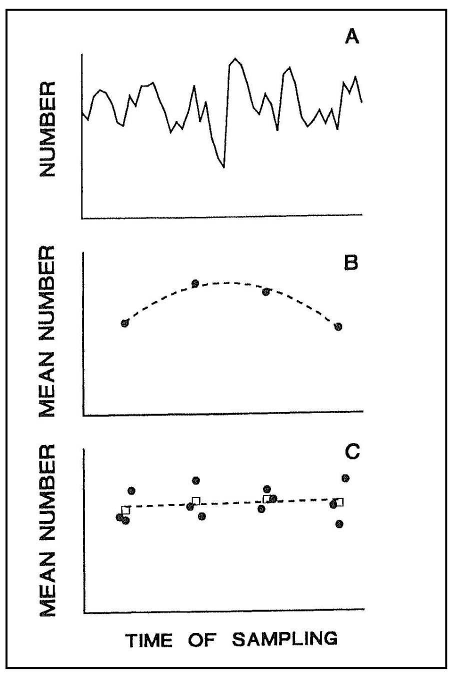
Appendix 6 - Spatial data distribution considerations.

Theoretical population distributions where (a) the variance (σ^2) is less than the mean (μ) (normal), (b) $\sigma^2 > \mu$ (negative binomial), and (c) $\sigma^2 = \mu$ and is random (Poisson). A sampling regime that is inadequate will fail to reveal the underlying nature of the data.



Appendix 7 – Temporal data distribution considerations.

A parameter exhibiting natural variation (A) can be erroneously concluded to exhibit a seasonal effect (B) that is corrected by appropriate temporal sampling replication (C). A sampling regime that is inadequate will fail to reveal the underlying nature of the data.



Appendix 8 - Appropriate statistical considerations and applications.

Consideration	**Important Information**	**Application**
Data Type	Ratio, interval, ordinal (rank), nominal (categorical)	Parametric statistics apply mostly to ratio and nominal data.
Coding	Some coding doesn't change inherent property of variables, others do; sometimes it is necessary to create dummy variables.	Coding can be used to standardize data or may be important to incorporate (dummy) categories into regression.
Accuracy	Indicated as the degree of error associated with a parameter	Report associated variance of measurements
Precision	Defines how consistent a measurement or value is.	Report the level to which a variable is measured
Frequency Distribution	To assess data for distribution type	Often applied as a histogram; parametric statistics assume a normal distribution.
Normal Distribution	Half of values are above the mean and half of the values are below the mean	Can be assessed for symmetry and kurtosis
Outliers	Need to be assessed and removed	Can result from measurement errors, etc.
Data Transformation	Can be necessary in order to convert data to meet assumptions	Many biological data are log-normal but also special cases such as arcsin√ for proportions
Cumulative Frequency Distribution		Useful in determining medians, percentiles and other quantiles
Random Sampling	Each unit has an equal probability of being sampled.	Samples can be assigned using a random number table.
Measures of Central Tendency	Provides information on the average measure	Mean (arithmetic & geometric), Median, Mode
Measures of Dispersion and Variability	Indication of how much the value changes in relation to the mean value	Range, Variance, Standard Deviation, Standard Error
Relating the Variation to Mean	Provides a standardized index of how variable the data are	Coefficient of Variation
Probabilities	Outcomes have discrete possibilities	For determining probability of an outcome
Normal Deviate	Used to normalize or standardize to mean 0 and variance of 1	Termed a Z score and can be applied to estimate probability of occurring
One-tailed or two-tailed	One-tailed tests are more powerful	Defined when direction of anticipated change is only one way or two
Repeated Measures	Repeated measures yield greater statistical power	Measures are repeated on the same individuals
Robust	Validity is not seriously affected by moderate deviations from assumptions	Deviations are more common than not
T-test	Parametric test, assumes normality but is robust	Test for difference between population means

Appendix 8 – (cont'd)

Consideration	Important Information	Application
Confidence Limits	Provides the statistical range within which the mean occurs	Valuable visual presentation of data.
X^2 (Chi-square)	Test of variance from an expected value	Widely used to test a value against an expected value
X^2 (Chi-square) Contingency Tables	Comparisons of traits across groups	Test of Independence of frequencies of occurrences
G-Test	Comparisons of traits across groups with small sample size (< 6 units)	Test of Independence of frequencies of occurrences
Variance Ratio Test	Variances need to be equal in parametric tests	Test for equality of variances
Mann-Whitney Test	Nonparametric when normality cannot be assumed	Tests between population means
Analysis of Variance (ANOVA)	Dependent variable is categorical	Testing across multiple populations
Kruskal-Wallis Test	Nonparametric when normality cannot be assumed	Testing across multiple populations
Multivariate Analysis Of Variance (MANOVA)	Multinormality is assumes	When there is multiple groups and response variables
Discriminant Analysis (DA)	Highlights the differences between groups	The multivariate equivalent of the multiple range test
Multiple Range Test	Required because of increased risk of Type 1 errors	Identifying where significant differences lie among means in ANOVA
Two-Way ANOVA	Dependent variable is categorical. Interaction effects are of interest in BACI	Tests between population means for more than one factor
Analysis of Covariance (ANCOVA)	Dependent variable is ratio and independent variables are ratio and categorical	Tests for significance of group differences.
Multivariate Analysis of Covariance (MANCOVA)	Multiple dependent variables are ratio and independent variables is ratio and categorical	The multivariate equivalent of the ANCOVA
Regression	Dependent Variable is ratio and predictor variables are ratio. It is possible to use dummy variables but not categories	Assessing the effects of indicator variables on the dependent variable when response is assumed to be linear
Canonical Correlation Analysis (CCA)	Multiple dependent Variables are ratio, and predictor variables are ratio. It is possible to use dummy variables but not categories	The multivariate equivalent of the linear regression
Comparing Regression Lines		Test for equality of slopes
Multiple Regression	A dependent variable and more than one predictor variables	Coefficients cannot be interpreted directly due to lack of independence of variables
Correlation Coefficient	No functional dependency between variables is assumed	Values range from –1 to +1 for negative and positive correlations
Generalized Linear Model	A unified approach integrating methodologies into one format rather than individual statistical tests.	Integrates data through examining normal, binomial, and Poisson error terms. Provides for a more conceptualized study design.