# Receiving Environmental Effects Monitoring: Why, What, How and So What?

**By**

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This review provides current information on proven ways and means to do receiving environmental effects monitoring and the value of this type of monitoring. It is based upon knowledge and experience gained during three decades of conventional (non-radiological) receiving environmental effects monitoring (EEM) that Ontario Hydro completed last year to fulfill provincial regulatory conditions of CCW discharge permits for nuclear generating stations. We are continuing on a reduced scale to use EEM test predictions of effects in order to determine the need for remediation or the performance effectiveness of past efforts. The field-testable predictions were generated from conceptual, computer and laboratory-based models. The cost-effectiveness of past EEM depended upon the extent that we applied the best methods to deal with the fundamental stages of: scoping, survey design, analysis, reporting and follow-up.

Scoping was based upon conceptual impact models of cause-effect linkages that were developed during stakeholder workshops. The workshops included internal and external stakeholders. The most recent scoping exercise for the issue of metals emissions from admiralty brass condensers included input from both external scientific peer review and a community advisory group. The scoping exercise should reduce the total set of predictions to a subset that are most likely to happen, most biologically significant and scientifically understood well enough to merit the expense of field testing.

Survey designs attempted to find the best allocation of sample types and sample units in space and time to have a reasonable (80%) chance of detecting the predicted effects. The ideal survey design tested for effects from Before the project to After between reference and impact sites (Before-After/Control-Impact design). In some cases the pre-project Before period was already over, and the survey tested for a spatial gradient of effects with proximity to the facility or for exceedances of published numerical environmental quality standards. The optimal designs were statistical and model-based. The model-based aspect took into account of scientific uncertainty about biological population responses and natural variability. The statistical aspect was to assure that the survey sample size was calculated to detect a reasonable minimum level of effect according to a specific statistical test, chosen before sampling started. The most frequently suitable test was a repeated measures analysis of variance for results from fixed sample locations.

Analysis was for effects at the individual, population and community levels of biological organization. Most field measures were at the individual and population-level. Fish population-level analyses tried to determine if incremental annual population mortality due to the facility in addition to natural mortality was less than a threshold of 20% . This level of incremental annual mortality was known to be within the compensatory capability of most fish populations in the absence of other major stresses.

Our programs used a 10-year study duration composed of 4 preoperational years, 3 commissioning years and 3 operations years. The three-year operational period was found to be insufficient to detect effects on reproduction in fish populations due to the longer maturation time of individuals relative to other biota. The existence of multi-facility sites allow us to extend the study duration at Bruce and Pickering. At Darlington, the effects monitoring program was stopped then started again after a few years at a reduce scale, to allow time for affected individuals of populations to become sexually mature and of a size large large enough to be captured in our standard gear.

Reporting changed from descriptive volumes of ad hoc results to hypothesis-based integrated summaries. The most recent and effective effects report was written in a more visual magazine-style suitable for general understanding by non-specialists. This was done through collaboration of the senior scientist and a science magazine writer. The full data set and technical reports were included in a CD-ROM mounted in the back cover. This report was well-received by all internal and external stakeholders.

Quality assurance and quality control checklists were developed in more recent studies to check the integrity of scoping, design, analysis and reporting. These checks were needed since even the best environmental effects monitoring results are usually indeterminate involving weight-of-evidence and application of judgement. The end results are only as sound as the predictions that were driving them and the methods used to achieve them.

Follow-up management actions in response to the effects monitoring program results were appropriate at all sites to monitor or remediate ongoing impacts. These were mainly aquatic impacts from condenser cooling water systems and terrestrial impacts from massive landscape/shoreline changes during site construction. Remediation has included action at design stage (Darlington condenser cooling water system) or retrofits (Bruce 5-8 intake fish deterrent curtain), habitat rehabilitation, restoration and specialized monitoring . An example of speciallized monitoring was the three decades of intermittent monitoring (1963-82, 1987-90, 1996) of the response of a local smallmouth bass population to the effects of the multi-station Bruce Nuclear site. Even after three decades, using the best available techniques and internationally-recognized fisheries experts, the population response is not well enough understood to reliably predict it's fate.

In future, it is known that regulatory requirements for receiving environment biomonitoring will increase. Also, environmental management systems are including receiving environment measures as indicators of environmental performance. The need for this work continues for us on a reduced sampling basis for special investigations (e.g. Admiralty Brass condenser emissions), environmental assessments or for decision support on site impact and habitat management actions.

## Introduction

This review describes proven ways and means to perform receiving environmental effects monitoring, and the value of doing it. It is based upon knowledge and experience gained during three decades of conventional (non-radiological) receiving environmental effects monitoring (EEM) that Ontario Hydro completed last year to fulfill provincial regulatory conditions of CCW discharge permits for it's nuclear generating stations situated on the Great Lakes. We are continuing on a reduced scale to use EEM test predictions of effects in order to determine the need for follow up remediation and to test the performance effectiveness of past remedial efforts. The field-testable predictions are generated from conceptual, computer and laboratory-based models. The cost-effectiveness of past EEM depended upon the extent that we applied the best methods to deal with the fundamental stages of: scoping, survey design, analysis, reporting and follow-up.

The remainder of the paper will answer for EEM the questions of: what is it? Why do it? How do you do it right? What's next?

- **What is Environmental Effects Monitoring (EEM)?**

Environmental effects monitoring (EEM) is monitoring to detect (and quantify) ***changes*** in the ***bio-physical*** natural environment due to station construction and operations. Our first effects studies in the 1970's measured ***change*** as a <u>trend through time</u> in the mean abundance of a particular aquatic species population (e.g. bass) or a spatial patter in the biological community of populations (e.g. bottom-living invertebrates). The ***bio-physical*** environment was specified by the regulatory permitting basis for our programs. The field survey programs were two-pronged and simultaneous, one to measure physical changes due to cooling water intake and discharge, and the other to measure the biological responses. Our monitoring programs would have been broader in scope if the purpose have been to verify the socio-economic predictions of the submitted environmental proposals for the developments (Ontario Hydro 1975). The projects were EA-exempt since they pre-dated the provincial EA Act of 1976 and were not appropriate to the federal EA process existing at the time. Newer projects such as the Bruce Used Fuel Dry Storage Facility are subject to the federal EA process (Ontario Hydro 1997).

EEM is designed to test for change. The real test is for the ***difference*** between what has happened in the impacted area versus what would be expected in an unimpacted environment. We needed to somehow predict what would have happened without the power plant. This is done by having control or reference sites to provide a measurement of the natural state of the environment without the power plant impact. Trend data without this spatial and temporal control information could not prove or disprove impact. The statistical test is for a change in the size of the difference that exists between impact and reference sites from the baseline period to the impacted condition. In some situations it was not possible to have an actual field reference location or baseline period of sampling. The impact had already started and there was no preoperational baseline data. An example was the 1997 field survey of environmental effects of admiralty brass condenser metals emissions at Pickering (ASI 1998). In those situations the prediction of no impact is based upon a regulatory standard (e.g. water quality objective, sediment quality guideline) or a published threshold for effect from the scientific literature (e.g. tissue contaminant level known to cause reproductive impairment from laboratory studies) or spatial reference sites (ASI 1998).

- **Why Do EEM?**

Environmental effects monitoring (EEM) is becoming more common as either a provincial or federal regulatory requirement with each passing year. Federal and provincial regulatory agencies now require EEM in follow-up to environmental assessments (EAs) and in permits for industrial wastewater direct discharges. It is also required by the federal liquid effluent regulations for metals mining and pulp & paper industrial sectors (Environment Canada 1992). A federal guideline is in preparation on how to do effective follow up monitoring of EAs (Munn and Wheaton 1997). Federal and provincial laws require effects monitoring for new projects or modifications adjacent to a wetland (CCG 1993; MNR 1992). Most recently, both Environment Canada and the Atomic Energy Control Board have publicly stated that an assessment is underway (Environment Canada 1995) for radiological effects on non-human species from nuclear generating stations and the future will involve EEM (Maloney 1996). A bio-physical effects hindsight evaluation for Pickering NGS is currently in preparation for AECB later this year (SENES Consultants Limited 1998).

Another reason for EEM is to provide a factual basis for dealing with regulatory constraints associated with potential impacts. The regulatory agencies can exercise the U.N. Rio Summit "precautionary principle" to require compensation or mitigation in the absence of conclusive evidence on impact (Peterman and M'Gonigle 1992; Keating 1993). Some existing regulatory standards have the potential to be overly restrictive in with respect to protection against impact on biological resources. For example, water quality objectives and sediment quality objectives/guidelines that do not take into account site-specific factors (e.g. pH, hardness, organic content) affecting metal speciation and uptake by organisms have been shown to be overly conservative (Renner 1997; 1998; Lee and Allen 1998; Hall et al 1998).

Sound environmental management also requires EEM to understand the ecological effects of our activities. A complete environmental management system needs to take into account the ecological effects on the receiving environment of the facility. This is the ultimate performance effectiveness test of environmental protection systems (Wismer and Kissel 1997).

Effects monitoring is needed to test for the success or failure of ecosystem rehabilitation projects. Since 1995, Ontario Hydro has been involved in ecological rehabilitation projects consistent with the requirements of our Biodiversity Policy (Ontario Hydro 1998). We are striving to maintain and, where possible, improve the integrity of the ecosystems in which we operate. Our scientific emphasis is shifting from investigative work of ecological impact assessments to predicting and testing the performance of conservation actions on lands and waters we own. The science of ecological restoration is new and tells us that many of these actions are experimental and need to be tested for success or failure (Minns et al 1996).

A final reason for EEM is that the environmental impact management decision-making process is occurring more and more at the local level. Municipal governments, local media, interest groups and the general public are becoming more involved in EA and re-licensing hearings. Our neighbours want to see information on observed and detected impacts on our shared biological environment in addition to the customary numbers associated with performance on emissions, effluents and waste. Fact-based information on impacts is necessary to deal effectively with the commonly held perceptions, attitudes, beliefs and myths, and speculation. Stakeholder advisory groups for environmental management are also becoming more common place in our environmental management systems.

- **How Do You Do It Right?**

Experience has shown that EEM can be expensive and unless it is well designed, it typically delivers inconclusive findings on impact. Inconclusive findings themselves can be costly. What does environmental effects monitoring cost? Our Great Lakes environmental effects monitoring, across a range of bio-physical parameters, have typically cost us 0.5M$/y per generating station per year for 10 years of field sampling, followed by about 0.3M$/y for 3 years of reporting. This was expensive compliance, especially when the studies could not provide conclusive evidence on the magnitude of localised station impacts (Ontario Hydro 1992a, 1992b). More focused effects monitoring on a single biological indicator, bottom-living aquatic invertebrates (Sheehan 1995) cost 50k$/y for four years at Lambton TGS on the St. Clair River. A single season for sampling four metals across 12 parameters (water quality, sediment quality, biota tissues) for 21 sample locations, including reporting, cost 100k$ at Pickering NGS.

**Predictions and VEC's**

The key aspect for a cost-effective design is to have a prediction of impact that is field-testable with a statistical-based survey. Predictions are necessary as the basis for design. Sample size calculations depend on magnitude of predicted effect as much as they depend upon the variability of the population parameter. It is now a general expectation that there should be site-specific hypotheses and underlying conceptual cause-effect models for any ecological effects assessment (Waters and Erman 1990; Environment Canada 1990).

For our 5 nuclear stations only the newer "B" stations and Darlington benefited from scientific hypotheses to drive the programs, and only Darlington had that right from the start in 1984. Most of the issues were about fishes, thermal and physical habitat effects as well as intake fish loss. Radionuclides were included but it was solely human pathway based upon the existing compliance monitoring.

An hypothesis of effect is an explicit statement of a set of cause-effect relationships whereby one or more project action is hypothesized to change the status of a valued ecosystem component or VEC (Environment Canada 1990). The choice of biological impact indicators is recognised by both regulators and academics as crucial to the success of effects monitoring (Environment Canada 1992; Cairns and McCormick 1992). Some biological indicators are typically more variable than others and therefore less sensitive for impact detection. For example, the coefficients of variation of fish in our studies were larger (98-174%) than values reported elsewhere for alternative indicators such as shellfish (30-50%) and bottom living insects (20-78%)(Eberhardt 1978). The wrong choices can make the monitoring program inconclusive, expensive, and even ecologically damaging. Choices include what type of organism (microbe, plankton, algae, aquatic plant, invertebrate, bird, fish, amphibian) and life stage as well as what level of biological organisation (tissue, organ, individual, species population, community, ecosystem) (Kelly and Harwell 1988; Environment Canada 1992). The choice of biological response indicator should be the result of scoring based upon published optimisation criteria (Environment Canada 1992; Cairns and McCormick 1992).

Once you have made those choices based on the earlier criteria then you need to decide what to test for and measure. Radionuclide indicators would most likely be at sub-organism level of biomarkers for any VEC. As you move up the levels of biological organization you trade off increased biological relevance and decreased extrapolating error against a weaker linkage of cause -effect to a specific toxic agent (radionuclides, organics etc) and decreased detectability due to more natural variability. For example, a sub-organism level radionuclide effect DNA biomarker would be easier to detect and assign to a specific cause but less ecologically relevant than a population-level indicator. Conversely a fish population-level indicator is quite relevant but difficult to detect (takes decades) and combines responses to stresses.

New federal guidelines require that predictions of effects on a VEC should actually be field-testable hypotheses including: type and magnitude; spatial and temporal extent (including multiple stations combined effects)(Environment Canada 1992; 1997). Other key aspects to ensure a useful and cost-effective monitoring program based upon Environment Canada (1990) and supported by our direct experience are: probability of occurrence; potential ecological and social value; level of (scientific) uncertainty; cost-effectiveness "reasonableness" of sampling; final end-use of data collected.

The key survey design questions were judgmental and inappropriate for decision-making solely by our own scientists. For example, who decides what VEC's? Who decides what size and type of change is acceptable? The answers to these questions are critical in determining the number of samples and programs costs. We started to use stakeholder workshops in 1984 to define the effects hypotheses and cause-effect linkages to scope out the studies.

The key impact issues were summarised at workshops held for each generating station in a series of hypotheses of effects specific to each site. These included bio-physical effects on aquatic, terrestrial and atmospheric components of the local ecosystem in a regional context. . Cost-effectiveness was improved by dropping the programs that had little chance of yielding useful impact results (algae, larval fish and plankton tows) or were not of interest to stakeholders (bottom-dwelling organisms) and focusing on magnitudes of known or most probable effects (intake fish entrainment and thermal discharge effects on spawning and fishing mortality). We are still using stakeholder workshops, but the difference is in the participants. A 1997 scoping exercise for the issue of metals emissions from admiralty brass condensers included input from both external scientific peer review and a community advisory group. The shift in participation is toward the affected public instead of exclusively with government agencies. Just this year, we are using a local citizen stakeholder advisory group and workshop to re-define key bio-physical effects for Pickering as part of an AECB environmental review project (SENES Consultants Limited 1998). This comes 13 years after the original regulatory stakeholder workshop. The scoping exercise should reduce the total set of predictions to a subset that are most likely to happen, most biologically significant and scientifically understood well enough to merit the expense of field testing.

The main outcome of the stakeholder workshops is a report detailing the VEC's and impact cause-effect linkages with a conclusion on detectability and recommendations for follow-up monitoring. By vetting our science through a public advisory process we were able to increase the level of trust, defensibility and credibility. This information is then fit for the intended use in decision-making by management.

**Statistical Design**

At the outset of our programs in the 1970s, the objective of field sampling was to simply "characterise the environment" with the implicit assumption that any detected trend for change would be an effect and any important change would be detectable. Statistical analyses were applied as the final task rather than at the beginning for experimental design. These non-statistical designs could not supply confident conclusions on impact, no matter how sophisticated the final statistical analysis (Ontario Hydro 1992a, 1992b). Without statistical confirmatory tests, we did not know if we could trust the apparent trend or result, since there were no huge impact-caused changes relative to the background variability.

Regulatory agencies are now suggesting statistical calculations of sensitivity be done for final effects reports that purportedly show no effect and to prove there was a reasonable chance (eg.80%) of detecting an important size of impact (Environment Canada 1992). The regulatory standard for acceptable risk of missing an important impact will likely be 20% or less (CEARC 1992). In our Pickering and Bruce studies, the risk was higher, about 40%, of missing a real difference. We discovered that "no effect" monitoring results were misleading if sampling was too infrequent or at the wrong time relative to the natural population cycles of abundance.

What we can do to avoid these errors is to calculate the sample size needed to guarantee a reasonable, or 80% chance of detecting an important size of impact (20% Type 2 error) at low risk to the utility (5% Type 1 error) by way of PC-based software (Goldstein 1989) or tables in statistical texts (Zar 1984). The required inputs to these programs are: the minimum size of impact that is desired to be detected, the acceptable statistical probability of error, the natural background variability in the VEC. The field survey program needs to be designed around a specific statistical model (e.g. analysis of variance, t-test, linear regression) to prove out the impact prediction. Detectability statistical tests should be done both before and after sampling to cost-optimise the survey design. The most frequently suitable test for our surveys was a repeated measures analysis of variance for results from fixed sample locations.

**Controls**

A variety of investigative methods are available to do EEM. Our most commonly used method was field surveys of resident biota, comparing impacted and reference sites. Some surveys had a temporal comparison between pre-impact and impact periods. These are called Before-After-Control-Impact surveys. In any impact assessment situation, we are trying to decide whether measured differences between control and impact sites have changed from the Before period (preop) to the After period (operational) (Stewart-Oaten et al 1992; Environment Canada 1992).

In the temporal dimension, sampling many times before and after impact accounts for random differences between the sites, and also tests for a sustained pattern of difference baseline to impact. In the spatial dimension, sampling at least two reference sites, accounts for the usual naturally occurring spatial differences in ambient conditions (patchiness). This is the "controls" design factor in time (before and after) and space (control versus impact). We developed this type of design for our effects monitoring of the impact of Lambton TGS FGD effluents on bottom-dwelling organisms in the St. Clair River (Sheehan 1995) and for testing the impact of thermal effluent from the Darlington NGS on spawning round whitefish (Darlington 1997).

Our programs used a 10-year study duration composed of 4 preoperational years, 3 commissioning years and 3 operations years. The three-year operational period was found to be insufficient to detect effects on reproduction in fish populations due to the longer maturation time of individuals relative to other biota. At Darlington, the effects monitoring program was stopped in 1995 to be started again in 1999 at a reduced scale, to allow time for affected individuals of the round whitefish population to become sexually mature and of a size large enough to be captured in our standard gear (Darlington 1997).

Other methods are available when field-based controls in space and time are not a practical option. This was the case when there was no baseline (pre-impact) information or if it was not possible to establish unaffected reference sites. It is not uncommon to combine laboratory, field surveys and computer modeling to deal with the problems of experimental design in the natural environment. We used a bio-physical model developed from 15 years of baseline field surveys and companion laboratory studies to predict cumulative impacts of thermal effluent from two adjacent nuclear generating stations on a local spawning smallmouth bass population (Wismer et al 1997). The laboratory studies were used to define critical temperature-dependent processes of growth, survival and reproduction that were built into the model. The model was then used as a tool to test for change in the impact period, a quasi-control in the absence of a real one. It was not possible to have a true experimental control - the same site without the power plants. The model predictions with and without impact gave support to the notion that much (66%) of the observed local biological response in the late- 1980s was due to uncommonly warm natural background lake temperatures - the three warmest years in the past century - only 33% of the effect was due to the thermal effluent (Wismer 1996).

Field experimental studies have also been used to establish a control population. We have used caged mussels transplanted to the impact site from a remote, unaffected area to test for change (ASI 1998). This takes into account adaptation or acclimation by the resident organisms remaining in the impacted are exposed to the stressor. Fish egg incubation chambers were used in another study to do a direct test on egg survival controlling for combined effects of temperature and siltation (Darlington 1997). In that case, the natural effects of siltation were the major cause of mortality, not power plant thermal effluents.

Other options are available that trade off increased experimental control against realism. Laboratory bioassays of field samples of contaminated media (air, sediment, soil, water, biological tissue) are common (ASI 1998). The difficulty is the unknown extrapolation error from a controlled laboratory situation to the actual field environment (Hall et al 1998). Field experimental enclosures or mesocosms use fabric corrals installed in the natural environment to create both treatment (impact) and control experimental units (Environment Canada 1997). The full range of media (sediments, plants, plankton, invertebrates, fish) are included to simulate the natural environment. The difficulty with these techniques is again the experimental error involved in extrapolating results from an artificial system to the natural environment.

- **What's Next?**

The science of environmental effects monitoring has undergone a major evolution over the past decade. The use of VEC's and predictions of impact cause-effect linkages as the basis for design introduced some necessary discipline into our scoping process in the 1980's (ESSA 1986). This was an inductive process where knowledge and experience were used to develop a conceptual model of impact, some or all of which was later tested with monitoring studies. More recently, a deductive process of ecological risk assessment has been developed in the U.S. (Suter 1993) and adapted to Canada (Environment Canada 1997). This process uses data on exposure (environmental monitoring) and ecological effects concentration thresholds (laboratory toxicity studies) to estimate the risk or probability of adverse effects on biological populations (Hall et al 1998). The quality and applicability of the ecological risk assessment can only be judged by the degree to which its predictions match observed impacts through EEM (Hall et al 1998; Osenberg and Schmitt 1996). There are now good tools in the form of guidebooks available on ecological risk assessment (Suter 1993; Environment Canada 1997; Kolluru et al 1996) and ecological impact assessment methods (Schmitt and Osenberg 1996).

Despite the progress in EEM noted in the preceding paragraph, the techniques still more often than not, deliver uncertain results. An example was the long-term pulsed monitoring (1963-82, 1987-90, 1996) of the response of a locally spawning smallmouth bass population to the effects of the multi-station Bruce Nuclear site. Even after three decades, using the best available techniques (field, laboratory, computer models) and internationally-recognized fisheries experts, the population response is not well enough understood to definitively predict its fate (Wismer et al 1997). This was due to the inherent variability in the fish population reproductive processes (Griffiths et al 1998). However, enough was understood that a precautionary approach to managing potentially adverse effects indicated a need for remedial action (Wismer 1996).

The trend for improvement in coping with this inherent uncertainty is toward more explicit treatment of uncertainty in the design and analysis. The science does not deal in absolutes but in probabilities of effects. These numerical probabilities are now being included in the statistical design and conclusions on effects. Environmental decision-makers need an appreciation of the limits of the scientific approach and level of uncertainty associated with any assessment of ecological risk before they can responsibly use the results. The use of numbers, computer models and statistical-based surveys does not guarantee conclusive results or avoid the need for scientists to make judgements. Although the scientific goal is almost always confirmatory statistical analysis and factual objective understanding, lack of attention to the EEM design factors or simply uncontrollable natural factors often make the result fall short of the ideal and they become a matter of profession opinion or informed data-based judgement. The less fact-based a scientific inference is the more likely it is influenced by the personal values of the scientist or the environmental stakeholder that is purporting it.

Quality assurance and quality control checklists were developed in more recent studies to check the integrity of scoping, design, analysis and reporting. These checks were needed since even the best environmental effects monitoring results are usually indeterminate involving weight-of-evidence and application of judgement. The end results are only as sound as the predictions that were driving them and the methods used to achieve them.

The inherent uncertainty of the science and the results of EEM have led to more attention to effective communication. In the past, critics have wondered if EEM and ecological risk assessment is just a tool used by a scientific and technical elite to impose their values and priorities on the public under the guise of scientific objectivity (Lackey 1994). In the present, we have recognized this issue by involving community and environmental stakeholders in study scoping (SENES Consultants Limited 1998). Trust and credibility has been enhanced by using independent 3rd party review of terms of reference, design, methods, results and final reports. Our effects reporting has changed from descriptive volumes of ad hoc results to hypothesis-based integrated summaries (Wismer 1996). The most recent and effective effects report was written in a more visual magazine-style suitable for general understanding by non-specialists. This was done through collaboration of the senior scientist and a science magazine writer. The full data set and technical reports were included in a CD-ROM mounted in the back cover. This report was well received by all internal and external stakeholders (Darlington 1997). This report created a new level of understanding both among staff and the local public of the scientific approach and the environmental effects.

Another example of reporting improvements is the use of both a "hot-line" for questions and a computer internet web page to increase the level of communication and understanding during the present environmental review at Pickering. It is in our best interest to make the effort to communicate our study results in a form that is understandable to our neighbours. Information in a form understandable to the general public is increasingly needed in support of re-licensing and environmental assessments. Scientific peer-reviewed and published results are necessary to keep our tools sharp, but communication in accessible forms is vital to providing end-results that are fit for our intended use.

The so-called "burden of proof " of verifying the null hypothesis of no impact is shifting from government to industry. It is becoming incumbent on industry to provide statistical proof that EEM designs have a reasonable (or 80%) chance of detecting impact if there was no impact detected. The public desire for proof was evident in the example of the present assessment of radiological impacts on non-human biota under the *Canadian Environmental Protection Act* and its Priority Substances List 2, and the AECB declaration of the intent to include non-human species radiological monitoring in the future (Tamm 1997; Maloney 1997). Although, there is no technical reason to doubt that environmental protection of non-humans is achieved with the present focus solely on human health (UNSCEAR 1996), the public has demanded scientific proof in hearings (Maloney 1997).

As industry moves more towards voluntary standards for environmental performance such as ISO 14001 and the CEA Environmental Commitment and Responsibility Program (CEA 1998), credible and tangible measures of environmental impact performance of impact on receiving environment flora and fauna will be in demand (Betts 1998; Wismer and Kissel 1997).

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