

05-452



Environment
Canada

Environnement
Canada

Canada



NATIONAL WATER
RESEARCH INSTITUTE
INSTITUT NATIONAL DE
RECHERCHE SUR LES EAUX

TD
226
N87
No.
05-452

Design and Implementation
of a Decision Support System
for Environmental Effects
Monitoring
By:

W. Booty, I. Wong, D. Lam,
O. Resler

NWRI Contribution No: 05-452

Design and Implementation of a Decision Support System for Environmental Effects Monitoring

William G. Booty* , Isaac Wong, David Lam, Oskar Resler

ABSTRACT

The Environmental Effects Monitoring (EEM) Statistical Assessment Tool (SAT) Decision Support System (DSS) has been developed to provide a user-friendly data analysis, display and decision support tool for Canada's federal environmental effects monitoring program for pulp and paper and mining industries. The target users include industries, consultants, Regional EEM Coordinators, National EEM Office and scientists involved in EEM-related research. The tool allows the assessment of the effects of effluent from industrial or other sources on fish and benthic populations. Effect endpoints, which are used as indicators of potentially important effluent effects, are measured at effluent-exposed sites and are compared statistically to measures at reference sites, in order to determine if changes have occurred and the magnitude of changes. The results are used in assessing the adequacy of existing regulations for protecting aquatic environments.

NWRI RESEARCH SUMMARY

Plain language title

Design and Implementation of a Decision Support System for Environmental Effects Monitoring

What is the problem and what do scientists already know about it?

The environmental effects of pollutants on aquatic life needs to be quantitatively measured and the results used to enforce Canadian Pulp and Paper Effluent Regulations (PPER) and Metal Mining Effluent Regulations (MMER). In collaboration with research scientists across Canada, the National Environmental Effects office has developed guidelines and procedures for industry to carry out to monitor the effects of effluents from their operations.

Why did NWRI do this study?

NWRI was asked to provide technical support in the form of a decision support system tool that would allow the National EEM office and industry to perform consistent assessments of the effects of effluents on fish and benthic populations.

What were the results?

The EEM-SAT DSS has been tested by the EEM National office as well as by external users and has proven to substantially improve the ability of the user to generate consistent analyses that are required under the Canadian EEM program for pulp and paper industries. A significant proportion of the time spent on developing the EEM-SAT DSS involved the data entry design and analysis results data management. Efforts were made to ensure that the design would be generic enough to allow the system to work for the other sector data analyses.

How will these results be used?

The results will be used across Canada to assess the adequacy of existing regulations for protecting aquatic environments.

Who were our main partners in the study?

Environment Canada - National Environmental Effects Monitoring Office

Conception et mise en œuvre d'un système d'aide à la décision pour le suivi des effets sur l'environnement

William G. Booty*, Isaac Wong, David Lam et Oskar Resler

RÉSUMÉ

Le Système d'aide à la décision (SAD) de l'Outil d'évaluation statistique (OES) de suivi des effets sur l'environnement (SEE) a été élaboré pour servir d'outil convivial d'analyse de données, d'affichage et d'aide à la décision pour le programme fédéral canadien de suivi des effets sur l'environnement de l'industrie des pâtes et papiers et de l'industrie minière. Parmi les utilisateurs visés figurent les industries, les consultants, les coordonnateurs régionaux de SEE, le Bureau national des études de suivi des effets sur l'environnement et les chercheurs dans des domaines liés au SEE. L'outil permet d'évaluer les effets d'effluents de sources industrielles et autres sur les populations de poissons et d'organismes benthiques. Les paramètres d'effet, qui sont utilisés comme des indicateurs d'effets potentiellement importants des effluents, sont mesurés à des sites exposés à des effluents et statistiquement comparés à des mesures prises à des sites de référence afin de déterminer s'il y a eu des changements et, si oui, l'ampleur de ces derniers. Les résultats sont utilisés pour évaluer l'efficacité des règlements actuels en matière de protection des milieux aquatiques.

Sommaire des recherches de l'INRE

Titre en langage clair

Conception et mise en œuvre d'un système d'aide à la décision pour le suivi des effets sur l'environnement.

Quel est le problème et que savent les chercheurs à ce sujet?

Il faut quantitativement mesurer les effets environnementaux des polluants sur la vie aquatique et utiliser les résultats pour appliquer le *Règlement sur les effluents des fabriques de pâtes et papiers* (REFPP) et le *Règlement sur les effluents des mines de métaux* (REMM). En collaboration avec des chercheurs de tout le Canada, le Bureau national des études de suivi des effets sur l'environnement a élaboré des lignes directrices et des procédures à l'intention de l'industrie afin que celle-ci fasse le suivi des effets des effluents provenant de leurs opérations.

Pourquoi l'INRE a-t-il effectué cette étude?

On a demandé à l'INRE de fournir un appui technique sous la forme d'un système d'aide à la décision qui permettrait au Bureau national des ESEE et à l'industrie d'effectuer des évaluations cohérentes de faire des évaluations cohérentes des effets des effluents sur les populations de poissons et d'organismes benthiques.

Quels sont les résultats?

Le SAD de l'OES de SEE a été testé par le Bureau national des ESEE ainsi que par des utilisateurs externes et a montré qu'il améliorerait substantiellement la capacité de son utilisateur à produire les analyses cohérentes exigées par le programme canadien des ESEE pour les fabriques de pâtes et papiers. Une partie importante du temps d'élaboration du SAD de l'OES de SEE a été consacrée à la structure de saisie des données et à la gestion des résultats d'analyse. On s'est efforcé de faire en sorte que la structure soit suffisamment générale pour permettre au système de travailler pour les autres analyses de données de secteur.

Comment ces résultats seront-ils utilisés?

Les résultats seront utilisés dans tout le Canada afin d'évaluer l'utilité des règlements actuels pour protéger les milieux aquatiques.

Quels étaient nos principaux partenaires dans cette étude?

Environnement Canada – Bureau national des études de suivi des effets sur l'environnement

**Design and Implementation of a Decision Support System for
Environmental Effects Monitoring**

William G. Booty*, Isaac Wong, David Lam, Oskar Resler
National Water Research Institute, Environment Canada, 867 Lakeshore Rd.,
Burlington, Ontario, CANADA L7R 4A6

* Corresponding author, Ph: (905) 336-4718, Fax: (905) 336-4400, email: bill.booty@ec.gc.ca

Keywords: Environmental effects monitoring, decision support, statistical analysis

1. Introduction

In Canada, pulp and paper and mining industries are currently required to conduct EEM under the Pulp and Paper Effluent Regulations (PPER) and Metal Mining Effluent Regulations (MMER). Each monitoring cycle of EEM requires submission of data and reports by pulp and paper mills and mines across Canada (Walker et al. 2002). In order to provide consistent data analysis and focus of reporting by the various industry members, a semi-automated analysis tool was required. The EEM Statistical Analysis Tool Decision Support System (EEM SAT DSS) was conceptualized and developed for initial testing as a demonstration project under the Environment Canada Northern Rivers Ecosystem Initiative for pulp and paper mills situated along the Athabasca River in the province of Alberta.

An effect, as defined within the EEM program is a statistically significant difference in fish, fish usability, or benthic invertebrate community endpoints measured between an area exposed to effluent and a reference area or a statistically significant gradient in these endpoints from the exposure to reference area. It should be pointed out that not all effects

identified in the EEM will represent damage to fish, fish habitat, or the usability of the fisheries resources, but the effects can represent differences or gradients that may reflect changes to the ecosystem associated with the effluent. Detailed information on the effects, including the magnitude, geographic extent, and possible cause will also be used in the management of the aquatic resources. The decision support system helps the user to screen data, select the appropriate statistical procedures and to help make decisions about the significance of the overall effects at each site.

This paper is focused on the development issues of the decision support system as well as examples of outputs from the system.

2. System Design

The EEM SAT DSS flow schematic is shown in Figure 1. It has been developed based upon the RAISONTM Decision Support System framework (Booty et al., 2001; Lam et al., 2004), with interfaces constructed using Visual Basic 6.0. The overall design of the system is based upon the EEM procedures developed through the National EEM office of Environment Canada (Environment Canada, 1998).

Figure 1

The EEM database is created by the National EEM office using data supplied by industry for each site. Routines have been created to provide data input validation and to provide feedback to the user when suspect data is entered. Once the data have all been entered, the data analyses are performed.

2.1 Fish Community Analyses

The overall fish analysis pathway is shown in Figure 2. Fish monitoring for the EEM program involves monitoring both sexes of two sentinel species at reference and exposure areas to determine if there are differences in the growth, reproduction, survival or condition of fish populations. Sex differences are common due to differences in overall energetic requirements between male and female fish. Effect endpoints include weight at age, size-at-age, relative gonad size, liver weight, and condition factor for fish and taxon richness, Simpson's diversity and evenness indices, and Bray-Curtis index for benthos.

A summary of the EEM-SAT fish analysis procedures is as follows:

1. Isolate data: Data is selected on the basis of Study ID, species and gender/sex.
2. Log₁₀ transform dependent and independent variables (if necessary): One of the criteria of the ANOVA and ANCOVA procedures is that the data should be normal. This includes body weight, total length, fork length, standard length, age, gonad weight and liver weight.
3. Checking for Outliers: Scatter plots of fresh weight vs. age, gonad weight vs. fresh weight, fresh weight vs. length, liver weight vs. fresh weight (all variables are in logarithmic scale) are presented. When a scatterplot illustrates outliers, the user should be given an opportunity to identify, modify, and/or delete data.

Although there is no formal guidance on screening data on the basis of studentized residuals, a rule of thumb is that when studentized residual exceeds 4, this indicates that the observation may be unusual and the observation should be

removed and the analysis should be re-run. In addition, the user should pay attention to the high "leverage" values. Those observations tend to potentially skew the observed relationship in one direction or another. There is professional judgment used to determine whether the data with high leverage should be excluded. A common approach is that if they grossly skew the expected relationship, then exclusion should be considered.

4. Analyses of Variance (ANOVA) test (Figure 3): Carry out ANOVA to test for differences between areas, and calculate means and standard deviations for each key variable for all areas (reference, near field, exposure and far field). Once the groups are identified to be significantly different, the user needs to determine which pairs differ. This is done using Tukey's HSD Post Hoc test (SYSTAT 11 2005). Assumptions for ANOVA are that the data for reference and exposure populations are normally distributed; the variances are equal between the reference and exposure populations and the error terms are independently distributed.
5. Analyses of Covariance (ANCOVA) and Regression (Figure 4): This is done using the General Linear Model (GLM) (Environment Canada, 2000). In particular, a contrast statement is used to test relationships among reference/far field vs. near field/exposure. The test is composed of two parts. It is carried out first to determine whether the slopes are approximately parallel. If the slopes are parallel, it then requires determining if the elevations of the regressions are significantly different. ANCOVA combines the features of ANOVA and regression, and can be used to compare regressions among treatments (i.e.

reference vs. effect areas). Assumptions of ANCOVA are that the residuals are normally and independently distributed with zero mean and a common variance; the independent variable (covariate) is fixed and measured without error; the relationship has the form specified (linear regression) and the slopes of regression lines among areas are equal.

Figure 2

Figure 3

Figure 4

2.2 Benthic Community Analyses

For the purposes of the EEM program an "effect on the benthic invertebrate community" means a statistical difference between benthic invertebrate community measurements taken in an exposure area and a reference area (e.g., control/impact design) or a statistical difference between measurements taken at sampling areas in the exposure area that indicate gradually decreasing effluent concentrations (e.g., a gradient design). The EEM SAT DSS program only pertains to control/impact analyses at this stage of development. The benthic analysis procedures are represented in Figure 5. Users of the EEM SAT DSS select the mill site and then choose to analyze the descriptive statistics or the effect analyses (ANOVA) for the benthic invertebrate effect endpoint of interest. The effect endpoints for benthic invertebrate analyses are abundance, mean # of taxa, Bray-Curtis index, evenness and Simpson's Diversity Index. These descriptors are largely summary

metrics selected to encompass the range of effects, which may be a result of mine or pulp and paper effluents.

Figure 5

3. EEM SAT Decision Support Applications

3.1 Fish Size-at-Age (Effect Endpoint)

In this example of the decision support process, the rates of growth are described by the relationship of size (as weight or length) to age. Over the entire life span of the fish, this relationship is curvilinear, with the rate of increase declining as fish approach the limit of their life span. Size-at-age may be estimated by calculating the regression relationship between body size (weight or length) and age for each sampling area (reference and exposure). Calculation of mean age is meant as a gross reflection of the age distribution of adult fish collected from each area. Variability in mean age of fish can be estimated using ANOVA as shown in Figure 6. Site difference in length and weight can also be analysed in this fashion. As shown in Figure 6, for Study PP1129, there is a significant difference between the Reference and the Exposed data about the mean of the effect endpoint "Age" using the ANOVA analysis. The mean age of the Reference and the "Exposed" sites are 4.575 and 5.294, respectively. The magnitude difference is 15.7%. The test p-value of the ANOVA test is 0.004 which is less than α , 0.05.

Figure 6

The EEM SAT DSS automatically \log_{10} transforms all ANCOVA based analyses. It also uses weight as the covariate. Body weight is corrected by subtracting the gonad weight and liver weight from the body weight prior to analysis. The EEM SAT DSS follows the two-step (slopes, then intercept) analyses. If slopes are not significantly different at the alpha value specified by the user, then the test for intercepts (least squared means) proceeds automatically. If slopes are significantly different, the software will not test for differences in intercepts. Endpoints analyzed by ANCOVA (size-at-age, relative gonad size, condition, and relative liver size) have only one component in the EEM Statistical Assessment Tool: 1) Effect Analyses. Any descriptive measures associated with the analyses are included in the ANCOVA result table. An example is shown for one of the mill sites in Figure 7. In this example, the effect endpoint "size at age" is examined. Using ANCOVA testing the slope difference between the "Reference" and "Effects" data shows that test p-value is 0.071 and is smaller than the α , (0.05), therefore, there is no significance difference. However, testing difference of the means indicates that the test p is almost zero and is statistically significant against α , 0.05.

Figure 7

3.2 Benthic Endpoints

All benthic endpoints are analyzed by ANOVA and have two components in the EEM Statistical Assessment Tool: 1) Descriptive Statistical Analyses and 2) Effect Analyses. An example of an effects analysis of a site (name deleted for privacy) is shown in Figure 8 for benthic abundance. In this example, the test p-value is 0.562, which is substantially

greater than α (0.05). This indicates that there is no significant difference between the "Reference" and the "Near-Field" sites.

Figure 8

The EEM-SAT DSS file open and save options allow users to generate scenarios for comparison with different level of significance.

4. Conclusions and Recommendations

The EEM-SAT DSS has been tested by the EEM National office as well as by external users and has proven to substantially improve the ability of the user to generate consistent analyses that are required under the Canadian EEM program for pulp and paper industries. A significant proportion of the time spent on developing the EEM-SAT DSS involved the data entry design and data analysis results management. This included the bookkeeping of all stages of data analysis so that the user was able to change any of the analysis options as well as keep track of removed outliers. Efforts were made to ensure that the design would be generic enough to allow the system to work for the other sector data analyses.

Some possible future modifications to the system to improve its efficiency include:

- The choice of the transformation type should be automated based on the outcome of the residual plot

Decision Support System for Environmental Effects Monitoring

- The outlier detection module can be enhanced with a fuzzy rule-based expert system to provide the degree of belief that the points are actual outliers or not
- The current system is desk-top based and since the system is scheduled for ongoing improvements, the deployment of the updates may be slow to reach the hands of the users. It is recommended a web-based approach be considered so that the users can always access the most up-to-date version of the system.

Acknowledgements

The authors wish to thank the National EEM office, Dr. Monique Dube, Dr. Bruce Kilgour, Dr. Rick Lowell, Mr. Philip Fong, and Mr. Alex Storey.

References

Booty, W.G., Lam, D.C.L., Wong, I.W.S., and Siconolfi, P.: 2001, 'Design and implementation of an environmental decision support system', *Environmental Modelling and Software*. **16**, 453-458.

Environment Canada: 2000, 'Data Interpretation Guidance for Environmental Effects Monitoring', National EEM Office, Environment Canada, Ottawa, Ontario.

Environment Canada: 1998, 'Pulp and paper technical guidance document for aquatic environmental effects monitoring'. National EEM Office, Environment Canada, Ottawa, Ontario (EEM/1998).

Lam, D.C.L., Leon, L.F., Hamilton, S., Crookshank, N., Bonin, D. and Swayne, D.A. : 2004, 'Multi-Model Integration in a Decision Support System: A Technical User Interface Approach For Watershed and Lake Management Scenarios', *Environmental Modelling & Software*. **19**, 317-324.

SYSTAT 11 Statistics II: 2005, 'General Linear Models', Richmond, CA, pp. 139-205.

Walker, S.L., Hedley, K, and Porter, E.: 2002, 'Pulp and Paper Environmental Effects Monitoring in Canada: An Overview', *Water Quality Research Journal of Canada*, **37**(1), 7-19.

Figures

Figure 1 EEM- SAT schematic diagram

Figure 2 Fish Analysis Schematic

Figure 3 Fish ANCOVA Analysis schematic

Figure 4 Fish ANOVA Analysis Schematic

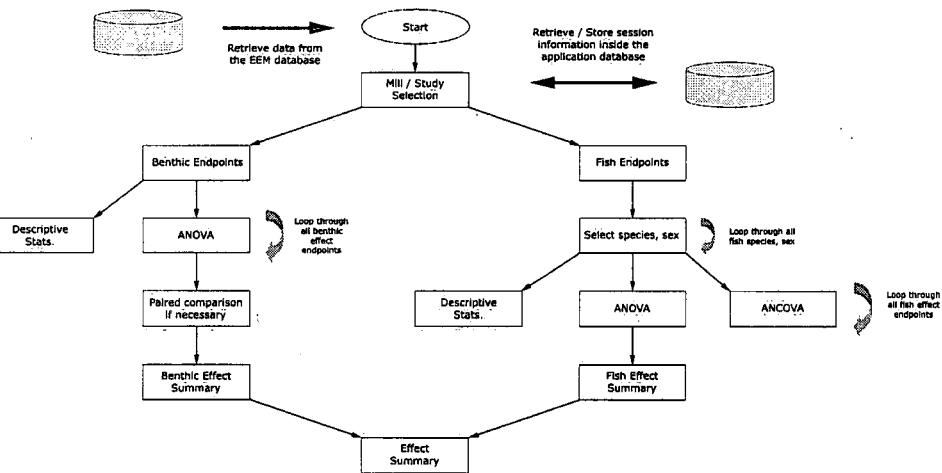
Figure 5 Benthic Analysis Schematic

Figure 6 Fish ANOVA size at age analysis example

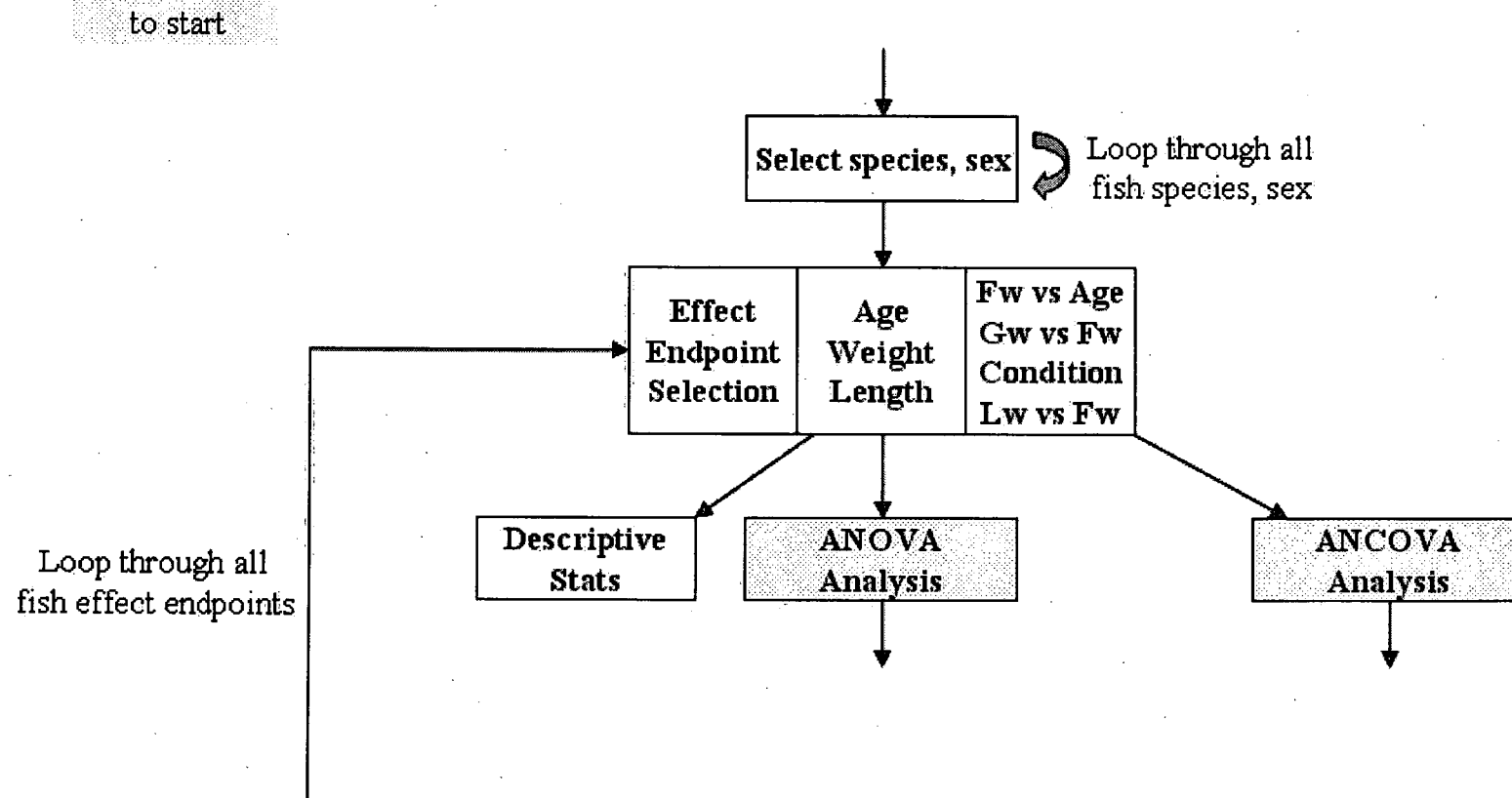
Figure 7 ANCOVA fish size at age analysis example

Figure 8 Benthic Abundance Analysis Output example

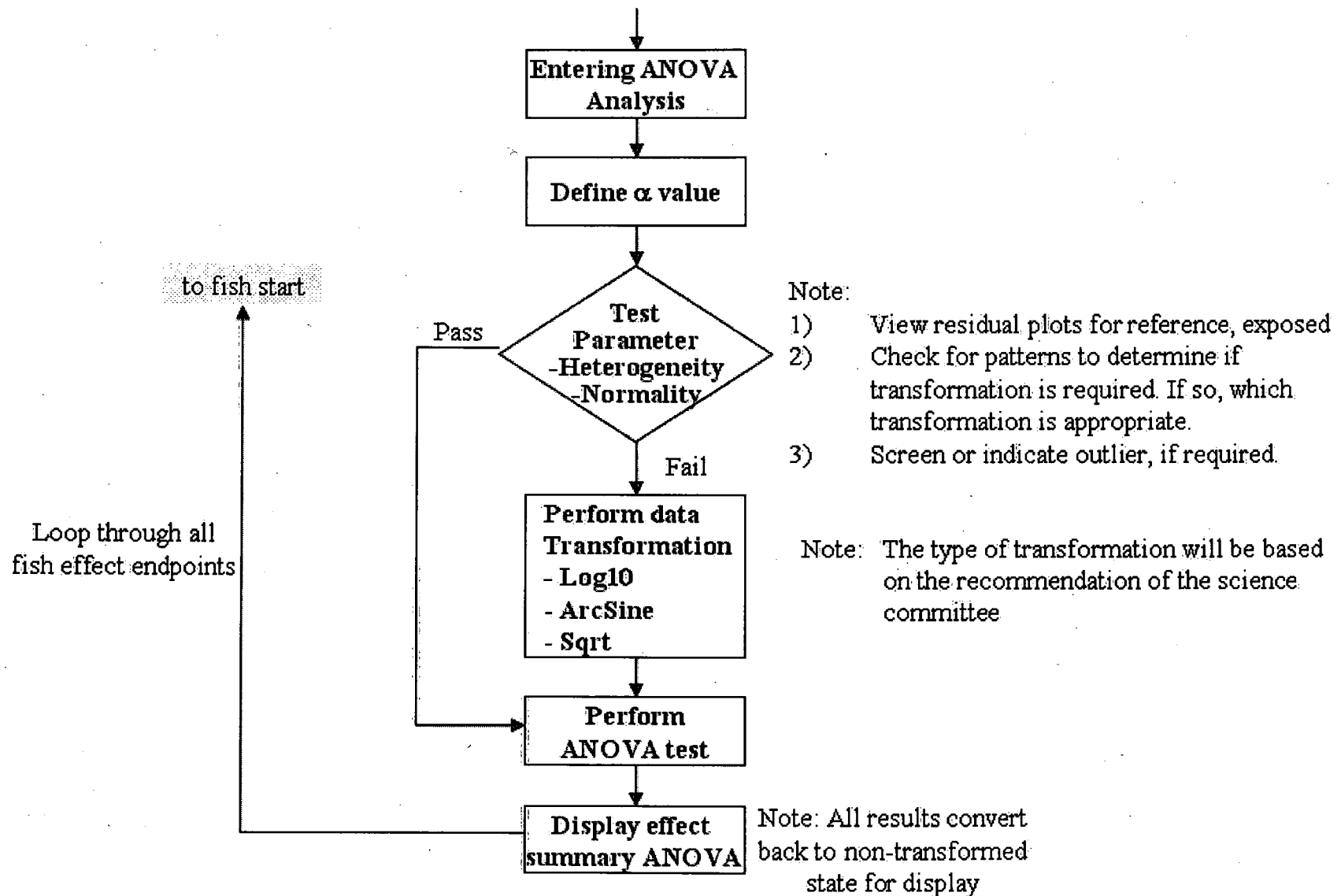
EEM Program flow



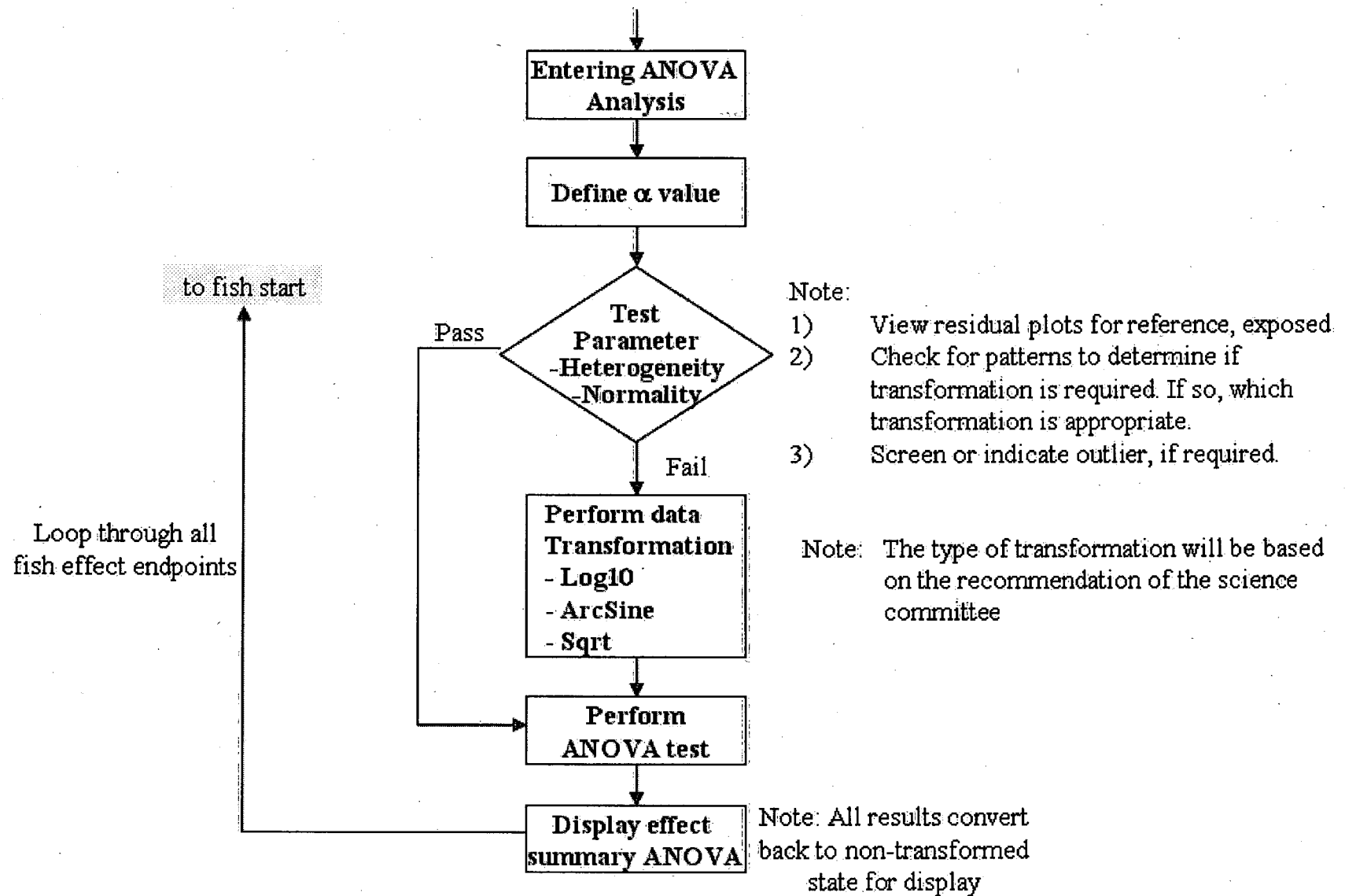
Fish Details Program Flow



Fish ANOVA Analysis



Fish ANOVA Analysis



Benthic Analysis

Select Endpoint

of taxa, Abundance, Bray-Curtis
Simpson's Diversity, Simpson Evenness

Descriptive
Statistics

ANOVA
Analysis

Define α value

Pass

Test
Parameter
- Heterogeneity
- Normality

Fail

Perform data
Transformation
- Log10
- ArcSine
- Square root

Perform standard
ANOVA test

No

Inspect
ANOVA result
for effect
significant

Yes

Define α value

Perform:
1) Paired comparison test
- Ref vs NF
- Ref vs FF
2) Tukey-Kramer test

Display results:
1) paired comparison
2) Tukey-Kramer

Display effect
Summary ANOVA

to start

Loop through all
benthic effect endpoints

Note:

- 1) This test uses 3 residual plots (reference, NF & FF)
- 2) Check plot pattern to determine if transformation is required. If so (i.e., test fails), which transformation is appropriate.
- 3) Screen or flag outliers, if required.

Note: The type of transformation will be based on the recommendation of the science committee

File View Help

Site Selection

Mill: PP1129

Study: PP1129

Fish Species

Species: Cottus Ricei

Sex: ☐ Female ☒ Male

Fish Endpoints

Select Area

- | Effect | Desc | Effect |
|-----------------------|----------------------------------|---------------------|
| <input type="radio"/> | <input type="radio"/> | Age |
| <input type="radio"/> | <input checked="" type="radio"/> | Size-at-age |
| <input type="radio"/> | <input type="radio"/> | Relative Gonad Size |
| <input type="radio"/> | <input type="radio"/> | Condition |
| <input type="radio"/> | <input type="radio"/> | Relative Liver Size |
| <input type="radio"/> | <input type="radio"/> | Weight |
| <input type="radio"/> | <input type="radio"/> | Length |

Benthic Endpoints

Select Area

- | Effect | Desc | Effect |
|-----------------------|-----------------------|---------------------|
| <input type="radio"/> | <input type="radio"/> | Abundance |
| <input type="radio"/> | <input type="radio"/> | Mean # of Taxa |
| <input type="radio"/> | <input type="radio"/> | Bray-Curtis Index |
| <input type="radio"/> | <input type="radio"/> | Evenness |
| <input type="radio"/> | <input type="radio"/> | Simpson's Diversity |

Action

Analyse

Submit

Effect Results: Fish

Species: Cottus Ricei - male

MILL: PP1129:

Study: PP1129

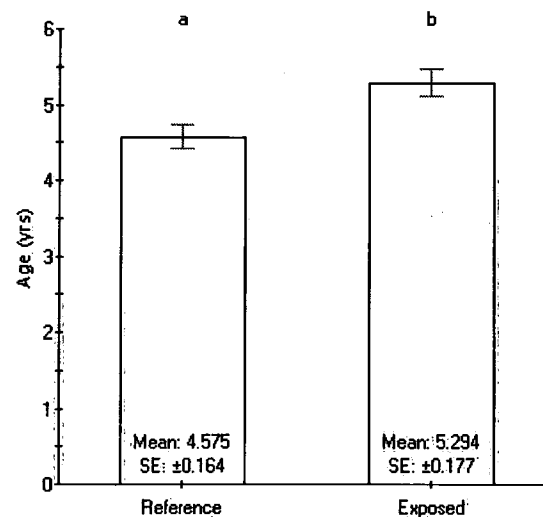
Data: Cycle 2

Transform: None

ANOVA: Age

Source of Variation	SS	df	MS	F	p value	sig p<α	α	Ref	Exp	Direction	Magnitude
								Mean	4.575	5.294	
								SD	1.035	1.031	
								n	40	34	
Model	9.504	1	9.504	8.906	0.004	Yes	0.05			Ref < Exp	+ 15.7%
Error	76.834	72	1.067								
Total	86.338	73									

PP1129: Age: Cottus Ricei - Male



File View Help

Site Selection

 Mill: PP1129
 Study: PP1129

Fish Species

 Species: Cottus Ricei
 Sex: ☐ Female ☒ Male

Fish Endpoints

Effect	Desc.	Effect
<input type="radio"/>	<input type="radio"/>	Age
<input type="radio"/>	<input checked="" type="radio"/>	Size-at-age
<input type="radio"/>	<input type="radio"/>	Relative Gonad Size
<input type="radio"/>	<input type="radio"/>	Condition
<input type="radio"/>	<input type="radio"/>	Relative Liver Size
<input type="radio"/>	<input type="radio"/>	Weight
<input type="radio"/>	<input type="radio"/>	Length

Benthic Endpoints

Effect	Desc.	Effect
<input type="radio"/>	<input type="radio"/>	Abundance
<input type="radio"/>	<input type="radio"/>	Mean # of Taxa
<input type="radio"/>	<input type="radio"/>	Bray-Curtis Index
<input type="radio"/>	<input type="radio"/>	Evenness
<input type="radio"/>	<input type="radio"/>	Simpson's Diversity

Action

 Analyse

Effect Results: Fish

Species: Cottus Ricei - male

MILL: PP1129:

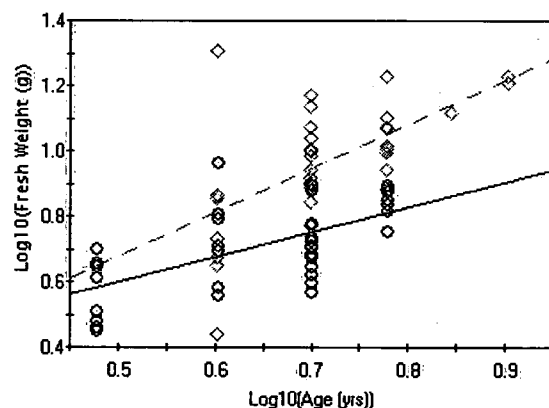
Study: PP1129

Data: Cycle 2

Transform: Unknown

ANCOVA: Size-at-age

		Log Transformed		Slopes Different?				Log Transformed		Means Different?				
Area	n	Slope	SD	R ²	(p value)	sig @ p<α	Magnitude	LS Means	SD	(p value)	sig @ p<α	AntiLog LSM	Magnitude	α
R	40	0.755	0.099	0.394	-	-	-	0.741	0.129	-	-	5.512	-	0.05
E	34	1.353	0.147	0.364	0.071	No	-	0.934	0.130	3.675E-8	Yes	8.585	+ 55.8%	0.05

 Size at age: Cottus Ricei - Male
 PP1129:


○ Reference
 ◇ Exposed
 — Reference $\text{Log}_{10}(\text{Fresh Weight (g)}) = 0.755\text{Log}_{10}(\text{Age (yrs)}) + 0.222$
 - - - Exposed $\text{Log}_{10}(\text{Fresh Weight (g)}) = 1.353\text{Log}_{10}(\text{Age (yrs)}) - 0.001$

File View Help

Site Selection

Mill: PP1091

Study: PP1091

Fish Species

Species: Catostomus catostomus

Sex: ☒ Female ☐ Male

Fish Endpoints

Effect Desc. Effect

Effect ☐ Age

☐ Size-at-age

☐ Relative Gonad Size

☐ Condition

☐ Relative Liver Size

Supporting: ☐ Weight

☐ Length

Benthic Endpoints

Effect Desc. Effect

Effect ☐ Abundance

☐ Mean # of Taxa

☐ Bray-Curtis Index

☐ Evenness

☐ Simpson's Diversity

Action

Analyse

Effect Results: Benthic Invertebrate

Mill: PP1091

Study: PP1091

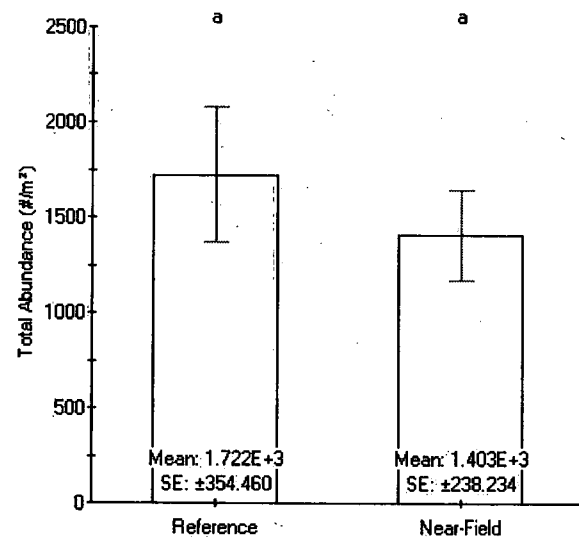
Data: Cycle 2

Transform: None

ANOVA: Abundance

Source of Variation	SS	df	MS	F	p value	sig @ p < α	α		Ref	NF
								Mean	1.722E+3	1.403E+
								SD	1.121E+3	532.707
								n	10	5
Model	3.393E+5	1	3.393E+5	0.354	0.562	No	0.05			
Error	1.244E+7	13	9.571E+5							
Total	1.278E+7	14								

Total Abundance (#/m²) - Benthic Invertebrates
PP1091



Environment Canada Library, Burlington



3 9055 1017 5765 5

PRINTED IN CANADA
IMPRIMERIE AU CANADA



ON RECYCLED PAPER
SUR DU PAPIER RECYCLÉ

National Water Research Institute
Environment Canada
Canada Centre for Inland Waters
P.O. Box 5050
867 Lakeshore Road
Burlington, Ontario
L7R 4A6 Canada

National Hydrology Research Centre
11 Innovation Boulevard
Saskatoon, Saskatchewan
S7N 3H5 Canada



**NATIONAL WATER
RESEARCH INSTITUTE**
**INSTITUT NATIONAL DE
RECHERCHE SUR LES EAUX**

Institut national de recherche sur les eaux
Environnement Canada
Centre canadien des eaux intérieures
Case postale 5050
867, chemin Lakeshore
Burlington, Ontario
L7R 4A6 Canada

Centre national de recherche en hydrologie
11, boul. Innovation
Saskatoon, Saskatchewan
S7N 3H5 Canada



Environment
Canada

Environnement
Canada

Canada