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ENVIRONMENTAL EFFECTS MONITORING (EEM) AT PULP AND PAPER MILLS:

SYNTHESIS OF THE 48 CYCLE 2 STUDIES CONDUCTED IN QUEBEC

by

Raymond Chabot, Alan Willsie, Julie Veillette and Pedro Nilo

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Environment Canada
Environmental Protection Branch
105 McGill, 4th floor
Montreal, Quebec
H2Y 2E7
E-mail: esee.qc@ec.gc.ca

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ABSTRACT

The main objective of the national Environmental Effects Monitoring (EEM) Program is to assess the effectiveness of the federal regulations protecting fish and fish habitat and the use of fisheries resources. The assessment is based on studies conducted in the receiving environments of pulp and paper mills, where the magnitude of the effects of mill effluents and their spatial extent are measured.

The EEM program is based on the weight-of-evidence approach wherein several different parameters are reviewed to determine the magnitude of the effects on the environment and, in the end, the adequacy of the regulations. EEM studies generally include a definition of the effluent mixing zone, a survey of fish sentinel species and a benthic communities study in the receiving environment, sublethal toxicity assays on mill effluent and measurements of water and sediments quality in the receiving environment. Monitoring studies can also include analyses of chemical tracers of exposure, analyses of chlorinated dioxin and furan congeners in fish and a sensory study on fish tainting.

In Quebec, 46 studies (including three joint studies) representing 50 pulp and paper mills were completed in April 2000 for Cycle 2 of the EEM; two other studies were finished in 2002. Seven studies dealt with mills that discharge their effluents into marine or estuarine environments; 41 studies concerned mills in the freshwater environment (i.e. lakes and rivers). Overall, the Cycle 2 studies conducted in Quebec pointed to a general improvement in the state of health of aquatic environments receiving pulp and paper mill effluents. Some general conclusions have been drawn and the overall results indicated trends similar to those in the rest of Canada.

Just as it did in Cycle 1, the benthic community survey proved to be a very effective tool for comparing the quality of habitats upstream from pulp and paper mills against those located downstream, in freshwater environments. The vast majority of Cycle 2 benthic surveys in freshwater ecosystems showed that there exist significant differences for at least one endpoint between exposure and reference areas and/or differences in community structure. The results indicated that fish habitat was often degraded in exposure areas relative to reference areas. Certain criteria, however, may have a marked influence on abundance (habitat) or taxon richness (ecozone).

In the majority of cases, the main differences were seen in the greater abundance of invertebrates in exposure areas, something which can be related to effluents, at least in areas closest to outfalls.

When the results were analysed in consideration of estimated natural variability, 40% of studies showed invertebrate density in exposure areas to be higher than the threshold level of twice the mean standard deviation in reference areas. Other parameters (richness, diversity and evenness) varied little from one area to another. In the marine environment, the effluent of three out of five mills appeared to have an inhibitive effect on the benthic fauna near outfalls by reducing community abundance and/or richness and/or biomass. These results were consistent with what was seen at the majority of mills in the marine environment in the rest of the country.

Despite the obviousness of the effects of effluents on benthic fauna, comparison between Cycle 1 and Cycle 2 results showed that the situation has improved greatly with the installation of secondary treatment systems — as the results for freshwater environments will testify most particularly. The number of pulp and paper mills with equivalent benthic abundance in exposure and reference areas as well as the number of mills with higher taxon richness in exposure areas increased in Cycle 2. Almost all the studies comparing results between cycles showed clear signs of improvement, as illustrated by either a reduction in the abundance of taxons that tolerate environmental enrichment, an increase in the proportion of pollution-sensitive invertebrates or a reduction in total benthic abundance to a level approaching that measured in reference areas. It was more difficult to make generalizations about the marine environment, however, due to the small sample size.

With regard to fish, the quality of adult fish surveys improved vastly over the previous cycle due, among other things, to increased fishing effort and to the use of more varied types of fishing gear. . When data is expressed on an endpoint basis, most of the fish populations do not show statistically significant differences between exposure and reference zones. However, at the individual mill level, results show significant statistical differences between exposure and reference areas in the majority of fish populations for at least one endpoint. The general trend pointed to an increased condition factor and relative liver weight and a decreased relative gonad weight in exposure areas. This generally agreed with the Cycle 2 observations from across the country. According to our experts, this response pattern would seem to be indicative of eutrophication of the receiving environment, along with a disruption in endocrine function in fish.

The results were consistent when analysed by sex or juvenile versus adult fish. However, response type and frequency were varied widely depending on the family of fish being considered. The results indicated that some species were more sensitive to mill effluents than others and this should be taken into account when selecting sentinel species in forthcoming cycles. In the marine environment, shellfish exposed to effluents had heavier tissue weights than those in reference areas, which also suggests the effect of eutrophication of this environment.

It should be pointed out that certain confounding factors may have contributed to the effects observed in fish populations in Cycle 2. The results obtained in exposure areas could have been influenced by, among other things, effluent discharges from other industrial plants or municipalities. A significant source of pollution was reduced considerably in late 1999 with the installation of wastewater treatment plants by several municipalities which were not previously treating their effluent. The Cycle 2 results in the receiving environments of the majority of mills cannot be used to establish whether the effects observed are related solely to mill effluents. Subsequent monitoring cycles will probably make it possible for us to distinguish between the effects attributable to paper mills and those that may be due to other sources.

There were no obvious signs of improvement in the state of health of fish in the Cycle 2 results relative to Cycle 1. Indeed, there appears to be an across-the-board increase in higher endpoint values in exposure areas. This may be attributable to an improvement in fishing methods or possibly to the better survival and return rates of sentinel species in certain mill effluent exposure areas.

Research projects were conducted during Cycle 2 to verify the usefulness of various complementary approaches to EEM or the use of bioindicators. The results of studies of hormonal and enzymatic activity in fish did not agree neither between them nor with the results of monitoring studies of sentinel species. Additional research is needed before such approaches can be integrated into EEM. These tools could be useful for the investigation of the cause of certain effects in fish, for example. The health assessment index did agree somewhat with the monitoring studies, but the biotic integrity index provides information on trends in fish community diversity. The latter requires information that is not available in a sentinel species study. This discrepancy underlines the difficulty of extrapolating the results obtained for one or two species to an entire community.

No chemical tracer studies were required for mill effluents with resin acid concentrations below 50 µg/L in Cycle 2. The chemical tracer results proved conclusive for three out of five mills, confirming the exposure of fish to the effluent. Further to the introduction of secondary treatment systems, the levels of resin acids in effluent and in the receiving environment are much lower at almost all mills, making their detection in fish highly unlikely.

Changes in mill processes and wastewater treatment systems over the years have led to a major reduction in discharges of chlorinated dioxins and furans throughout the pulp and paper sector. A single mill, Smurfit-Stone Container in Portage-du-Fort (PP1102), was required to analyse dioxin and furan levels in fish during Cycle 2, because the concentrations in its effluent exceeded the discharge standards. The levels detected in fish in the exposure area of this mill were the same as in its reference area. Moreover, concentrations were well below Health Canada standards for the consumption of fish.

A single plant, Tembec in Témiscaming (PP1094), was required to carry out a sensory evaluation of fish tissue because of complaints to the regional office of the Ministère de l'Environnement du Québec. The results of this study confirmed fish tainting as a difference was observed in the taste of fish caught in the exposure area versus fish caught in the reference area.

The results of sublethal toxicity tests showed that there was a significant reduction in effluent toxicity between the two cycles. This trend was also observed nationally. The improvement in effluent quality was attributed to the installation of secondary treatment systems. Toxicity levels were higher at Quebec mills equipped only with primary treatment systems in Cycle 2 relative to those with secondary treatment systems.

Regardless, mill effluents still showed sublethal effects most of the time, particularly in certain tests. In Cycle 2, *Ceriodaphnia dubia* was the most sensitive freshwater organism, whereas it was the alga *Champia parvula* in tests done in the marine environment. Assays on *Menidia beryllina* have exhibited no toxicity in the past five series of tests for mills discharging to the marine environment.

Using an index of integration, it was possible to classify mills according to level of sublethal toxicity and the effects of effluents on the receiving environment. Although 9 studies found that mill effluents had strong or very strong effects on benthos or fish, a trend in the majority of plants qualified toxicity and the effects on benthic communities as moderate. These results confirmed the conclusions of the national Cycle 2 assessment, at least where fish habitat is concerned, which found that the general effect for all mills in Canada was moderate eutrophication of the receiving environment. With regard to fish studies, the results were much more variable and the benefits associated with an improvement in effluent quality will probably be more obvious when the Cycle 3 results are in.

RÉSUMÉ

Le programme national d'études de suivi des effets sur l'environnement (ESEE) a pour objectif principal d'évaluer l'efficacité de la réglementation fédérale pour assurer la protection du poisson et de son habitat et pour préserver l'utilisation des ressources halieutiques. Cette efficacité est évaluée à partir d'études réalisées dans le milieu récepteur de chaque usine, où la magnitude et l'étendue spatiale des effets de l'effluent, le cas échéant, sont mesurées.

Le programme ESEE est basé sur l'approche du poids de la preuve où plusieurs paramètres sont considérés pour déterminer l'ampleur des effets sur l'environnement et en bout de ligne, l'adéquacité de la réglementation. Une ESEE comprend généralement la délimitation de la zone de mélange de l'effluent, une étude sur les poissons et une étude des communautés benthiques dans le milieu récepteur, la mesure de la qualité de l'eau et des sédiments du milieu récepteur et des essais de toxicité sous-létale sur les effluents. Les études de suivi peuvent également inclure l'analyse de traceurs chimiques d'exposition, l'analyse des congénères de dioxines et de furannes chlorés dans les poissons et une étude organoleptique sur l'altération du poisson.

Au Québec, 46 études représentant 50 fabriques (trois études conjointes) ont été complétées en avril 2000 pour le cycle 2 des ESEE, tandis que deux autres études se sont terminées en 2002. Sept études portent sur des fabriques qui déversent leurs effluents dans le milieu marin/estuarien et 41 études concernent des fabriques dans le milieu dulcicole (lacs et rivières).

Globalement, les études réalisées dans la région du Québec au cycle 2 ont permis de constater une amélioration générale de l'état de santé du milieu récepteur soumis aux effluents des papetières. Les études réalisées au Québec ont permis de dégager certaines conclusions générales et les résultats globaux obtenus montrent des tendances semblables à celles observées pour les fabriques du reste du Canada.

Tout comme lors du cycle 1, l'étude des communautés benthiques s'est encore une fois avérée un outil très efficace pour comparer la qualité des habitats en amont et en aval des fabriques de pâtes et papiers en eau douce. Dans ce type d'écosystème, la très grande majorité des études de benthos effectuées au cycle 2 a montré qu'il existe des différences significatives pour au moins une variable indicatrice et/ou des différences de structure de communautés benthiques entre les zones exposées et de référence. Les résultats indiquent que l'habitat du poisson de la zone exposée est plus souvent dégradé que celui de la zone de référence. Toutefois, certains critères peuvent avoir une influence notable sur l'abondance (habitat) ou sur la richesse taxonomique (écorégion). Dans la majorité des cas, les différences sont principalement observées au niveau de l'abondance plus importante des invertébrés en zone exposée qui pourrait être reliée à l'effluent à tout le moins en zone rapprochée.

Lorsqu'on analyse les résultats en considérant une estimation de la variabilité naturelle, 40 % des études présentent une densité d'invertébrés en zone exposée supérieure au seuil de deux fois l'écart-type à la moyenne de la zone de référence. Les autres paramètres (richesse, diversité ou régularité) varient peu d'une zone à l'autre. En milieu marin, l'effluent de 3 fabriques sur 5 semble avoir un effet inhibiteur sur la faune benthique située à proximité des émissaires en réduisant l'abondance et/ou la richesse et/ou la biomasse de ces communautés. Ces résultats sont cohérents avec ce qui a été observé pour la majorité des fabriques en milieu marin dans le reste du pays.

Malgré l'évidence d'effets des effluents sur la faune benthique, nous constatons que suite à l'implantation des systèmes de traitement secondaire, la situation s'est grandement améliorée comme en font foi les résultats du cycle 2, notamment en eau douce. En effet, le nombre de papetières dont l'abondance est équivalente dans les zones exposées et de référence ainsi que le Number of mills ayant une richesse supérieure en zone exposée a augmenté au cycle 2. La presque totalité des études qui ont pu comparer leurs résultats d'un cycle à l'autre, montrent des signes de nette amélioration soit par une réduction de l'abondance relative des taxons tolérant l'enrichissement du milieu soit par l'augmentation de la proportion des invertébrés sensibles ou encore par une réduction de l'abondance totale se rapprochant de celle mesurée en zone de référence. En milieu marin, les généralisations sont par contre plus difficiles à formuler en raison des faibles effectifs.

En ce qui concerne les études de poissons, la qualité des études s'est grandement améliorée comparativement au cycle précédent, notamment en raison d'un effort de pêche accru et grâce à l'utilisation d'engins de pêche plus diversifiés. Les résultats montrent que la majorité des populations de poissons analysés présentent des différences statistiques significatives entre les zones exposées et de référence pour au moins une des variables indicatrices mesurées. La tendance générale va vers une augmentation de la condition des poissons, une augmentation du poids relatif du foie et une diminution du poids relatif des gonades en zone d'exposition tout comme ce qui a été observé généralement à travers le pays au cycle 2. Selon les experts, ce patron de réponses serait indicateur d'une eutrophisation du milieu ainsi que d'une perturbation du système endocrinien des poissons. Ces résultats sont cohérents lorsque analysés selon le sexe ou selon que les poissons sont immatures ou adultes. Toutefois, le type et la fréquence des réponses sont très variables selon la famille de poissons considérée. Les résultats indiquent qu'il y a des espèces plus sensibles aux effluents de papetières que d'autres et il faudrait en tenir compte lors du choix des espèces sentinelles des prochains cycles. En milieu marin, les mollusques exposés aux effluents présentent des poids de chair plus élevés que leurs congénères en zone de référence, ce qui suggère aussi un effet d'eutrophisation dans ce milieu.

Il faut souligner que certains facteurs confondants ont pu contribuer aux effets observés sur les populations de poissons au cycle 2. En effet, les résultats obtenus dans les zones d'exposition ont pu être influencés entre autres par des rejets provenant d'autres effluents industriels ou municipaux. Depuis la fin de 1999, une source de pollution non négligeable a été réduite de façon importante grâce à l'installation d'usines d'épuration des eaux usées par plusieurs municipalités qui ne traitaient pas leurs effluents. Pour la majorité des fabriques, les résultats du cycle 2 dans le milieu récepteur ne permettent donc pas d'établir que les effets observés sont uniquement reliés aux effluents papetiers. Les prochains cycles de suivi permettront probablement de discriminer les effets attribuables aux fabriques de ceux qui pourraient être dus à d'autres sources.

Les résultats du cycle 2 ne montrent pas de signes évidents d'amélioration de l'état de santé des poissons par rapport au cycle précédent. En effet, il semble y avoir globalement un accroissement des valeurs supérieures des variables indicatrices en zone exposée par rapport au cycle 1, ce qui pourrait être attribuable à une amélioration des méthodes de pêche et possiblement à une meilleure survie et au retour des espèces sentinelles dans certaines zones d'exposition aux effluents de papetières.

Au cours du cycle 2, des projets de recherche sur le poisson ont été mis sur pied pour vérifier l'utilité d'approches différentes à celle des ESEE ou de certains bioindicateurs. Les résultats concernant l'activité hormonale ou enzymatique des poissons ne semblent pas cohérents entre eux ni avec les résultats de suivi des espèces sentinelles. Il faudrait prévoir d'autres études du genre avant de les incorporer dans les ESEE. Nous croyons que ces outils seraient plus utiles lors de la recherche de causes de certains effets sur le poisson par exemple. L'indice d'évaluation de l'état de santé a démontré une certaine concordance avec les études de suivi, tandis que l'indice d'intégrité biotique peut permettre de constater l'évolution de la diversité de la communauté de poissons. Ce dernier requiert des informations qui ne sont cependant pas disponibles avec une étude d'espèces sentinelles. Ce constat souligne les difficultés d'extrapoler les résultats obtenus sur une ou deux espèces à une communauté complète.

Aucune analyse de traceurs chimiques dans les poissons n'était requise au cycle 2 pour les usines dont les teneurs en acides résiniques dans l'effluent étaient inférieures à 50 µg/L. Les résultats obtenus avec les traceurs chimiques se sont avérés concluants pour 3 fabriques sur 5, où ils ont confirmé l'exposition des poissons à l'effluent. Avec la mise en opération des systèmes de traitement secondaire pour la presque totalité des usines, les teneurs en acides résiniques dans l'effluent et le milieu récepteur sont beaucoup plus faibles, ce qui rend peu probable leur détection chez les poissons.

La modification des procédés et des systèmes de traitement des effluents au cours des années a entraîné une importante diminution des rejets de dioxines et de furannes pour l'ensemble de l'industrie papetière. Une seule fabrique (Emballages Smurfit-Stone à Portage-du-Fort, PP1102) a dû effectuer une analyse de dioxines et furannes chlorés dans les poissons au cycle 2, car des concentrations dans l'effluent ont dépassé les normes de rejet. Les teneurs mesurées dans les poissons de la zone exposée de cette fabrique ne sont pas différentes de celles obtenues en zone de référence. De plus, ces concentrations sont bien en deçà des normes de consommation de poisson de Santé Canada.

Une seule fabrique (Tembec à Témiscaming, PP1094) a été tenue de réaliser une étude organoleptique sur l'altération du goût de la chair des poissons puisque des plaintes avaient été adressées à un bureau régional du ministère de l'Environnement du Québec. Les résultats de cette étude confirment une différence entre la saveur des poissons de la zone exposée et celle des poissons de la zone de référence.

En ce qui concerne la toxicité, les résultats des essais sous-létaux ont montré une diminution importante de la toxicité des effluents entre le cycle 1 et le cycle 2. Cette tendance a été observée également à l'échelle nationale. L'amélioration de la qualité des effluents est attribuable à la mise en place des systèmes de traitement secondaire. D'ailleurs, les usines du Québec ne possédant encore qu'un traitement primaire au deuxième cycle montrent une toxicité plus élevée que celles possédant un système de traitement secondaire.

Néanmoins, les effluents papetiers testés montrent encore, la plupart du temps, des effets sous-létaux, particulièrement pour certains tests. Au cycle 2, *Ceriodaphnia dubia* se présente comme l'organisme d'essai dulcicole le plus sensible alors que pour les tests en milieu marin c'est l'algue *Champia parvula*. Par contre, les essais sur *Menidia beryllina* utilisés par les usines déversant en milieu marin ne montre aucune toxicité depuis les cinq dernières séries.

Grâce à un indice d'intégration, il a été possible de classer les usines selon le niveau de toxicité sous-létale et l'importance des effets des effluents sur le milieu récepteur. Malgré que près d'une dizaine d'études présentaient des effets élevés ou très élevés sur le benthos ou les poissons, la tendance montre que la majorité des fabriques présentaient une toxicité et des effets sur la communauté benthique qualifiés de modérés. Ces résultats viennent confirmer les conclusions de l'évaluation nationale des résultats du cycle 2, du moins concernant l'habitat du poisson, où l'effet général pour l'ensemble des usines au Canada est une eutrophisation modérée du milieu récepteur. En ce qui concerne les études de poisson, les résultats sont beaucoup plus variables et les bénéfices liés à l'amélioration de la qualité des effluents seront probablement plus évidents avec les résultats du cycle 3.

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1 Introduction

1.1 Effluent regulations

The *Pulp and Paper Effluent Regulations* (PPER), aimed primarily at protecting fish and fish habitat pursuant to the *Fisheries Act,* were amended in 1992 to impose more stringent requirements on pulp and paper mills pertaining to their effluent discharges. To comply with the new regulations, most Quebec mills installed a secondary treatment system before September 30, 1995 to reduce their discharge of suspended solids (TSS) and biochemical oxygen demand (BOD_5) in effluents and to eliminate the acute lethality of the effluent to rainbow trout (*Oncorynchus mykiss*) and *Daphnia magna*. Although the new requirements are more likely to protect the environment, they may not guarantee protection of the environment at all sites. Consequently, the amended PPER enacted in 1992 include a requirement that pulp and paper mills carry out environment effects monitoring (EEM).

1.2 Environmental effects monitoring (EEM) studies

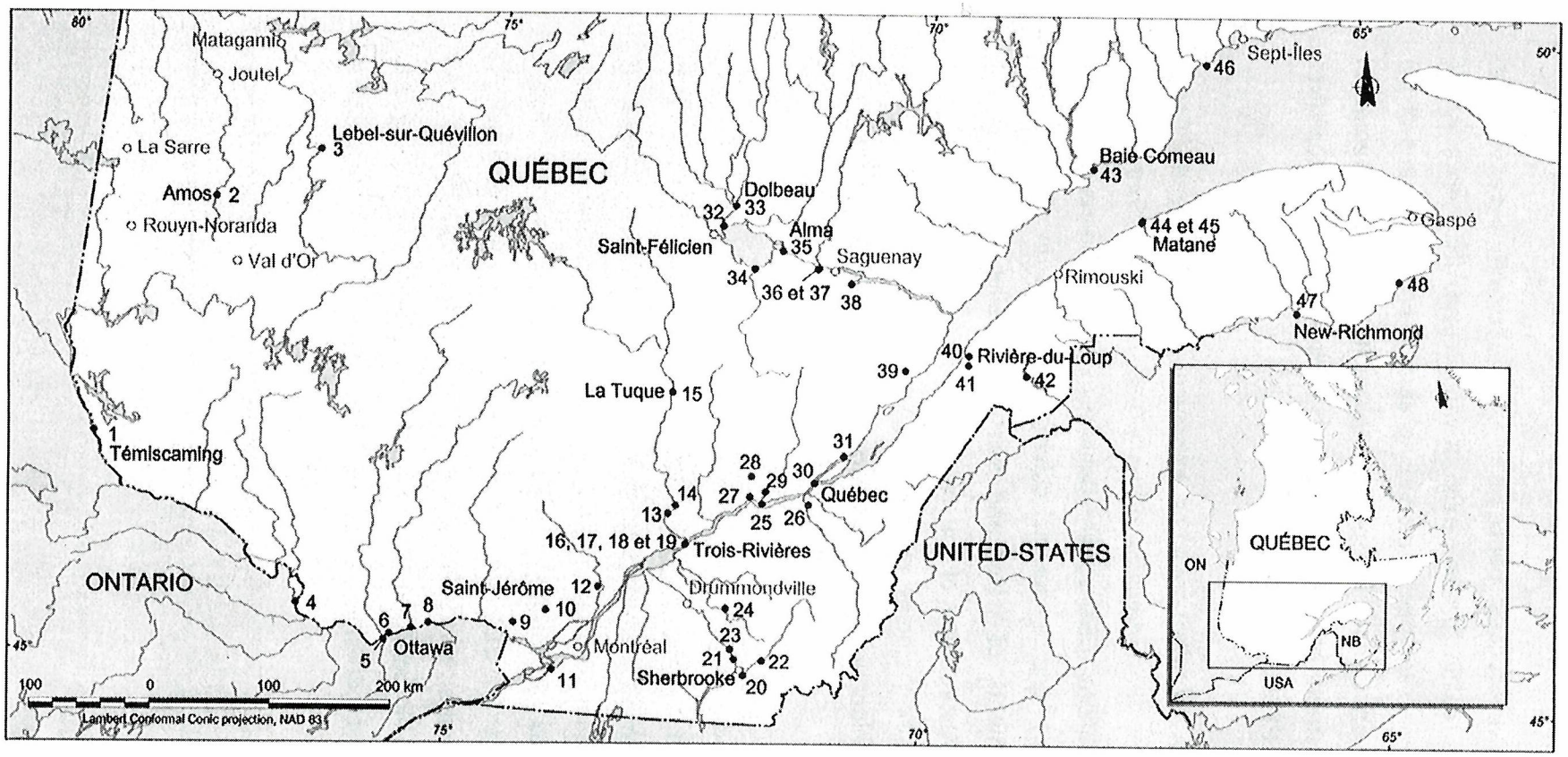
The main objective of the national Environmental Effects Monitoring (EEM) program is to assess the adequacy of the federal regulations protecting fish and fish habitat and the use of fisheries resources. The assessment is based on studies conducted in the receiving environments of pulp and paper mills, where the magnitude of the effects of mill effluents and their spatial extent are measured.

For EEM purposes, an effect is defined as a significant difference measured in an environmental variable between an exposure area and a reference area. Effects may include changes in the health of fish, distortion of fish population structure or the life cycle of fish, deterioration of habitat essential for growth and reproduction, or accumulation of toxic substances in fish to levels prejudicial to human health and/or the marketability of fish. Several successive cycles of EEM will permit the evaluation of temporal variations in the magnitude and the spatial extent of the effects of mill effluents on the receiving environment.

The EEM program entails an iterative process; hence, it is structured with a sequence of monitoring and interpretation phases, called "cycles", each of which spans four years. At the beginning of each cycle, the mills plan site-specific monitoring studies and at the end of the cycle they submit reports to Environment Canada interpreting the results obtained. Environment Canada carries out a regional assessment after each cycle ends in order to set the objectives and requirements for the subsequent EEM cycle.

The EEM program is based on the weight-of-evidence approach wherein several different parameters are reviewed to determine the magnitude of the effects on the environment and, ultimately, the adequacy of the regulations. EEM studies generally include a delineation of the effluent mixing zone, a fish survey and a benthic community survey in the receiving environment, as well as measurements of water and sediment quality in the receiving environment in order to facilitate interpretation of the biomonitoring data and the sublethal toxicity tests of mill effluents. Monitoring studies may also include the analysis of chemical tracers of exposure, the analysis of chlorinated dioxin and furan congeners in fish tissues and a sensory evaluation of fish tainting.

In Quebec, 46 studies (including three joint studies) representing 50 pulp and paper mills were completed in April 2000 for Cycle 2 of the EEM; two other studies were finished in 2002. Seven studies dealt with mills that discharge their effluents to marine or estuarine environments; 41 studies concerned mills that release their effluents into the freshwater environment, specifically lakes and rivers (Figure 1 and Annex 1). This report summarizes the results of the Cycle 2 studies carried out by these mills under the EEM program. The first three chapters deal with the characteristics of the effluents of Quebec mills, including their toxicity, and the following two subsequent chapters synthesize the biomonitoring information derived from fish surveys and benthic community surveys. The last chapter is devoted to integrating the toxicity and biomonitoring results.



• Mill	Location
1- Tembec	Témiscaming
2- Abitibi-Consolidated	Amos
3- Norkraft Quévillon	Lebel-sur-Quévillon
4- Smurfit-Stone Container	Portage-du-Fort
5- Eddy Papers and Scott Papers	Ottawa-Hull
6- Bowater	Gatineau
7- Papiers Masson	Masson-Angers
8- Fraser Papers	Thurso
9- Cascades	Lachute
10- Cascades	Saint-Jérôme
11- Spexel	Beauharnois
12- Scott Papers	Crabtree
13- Abitibi-Consolidated	Shawinigan
14- Abitibi-Consolidated	Grand-Mère
15- Smurfit-Stone Container	La Tuque
16- Kruger Wayagamack	Trois-Rivières

• Mill	Location
17- Kruger	Trois-Rivières
18- Désencrages C.M.D., Cascades Lupel	Cap-de-la-Madeleine
19- Uniforêt Tripap	Trois-Rivières
20- Scott Paper	Lennoxville
21- Kruger	Bromptonville
22- Cascades	East-Angus
23- Domtar	Windsor
24- Cascades	Kingsey Falls
25- Bowater	Donnacona
26- Fibres Breakey	Breakeyville
27- J. Ford	Portneuf
28- Tembec	Saint-Léonard-de-Portneuf
29- EMCO	Pont-Rouge
30- Stadacona Papers	Québec
31- Abitibi-Consolidated	Beaupré
32- SFK Pulp	Saint-Félicien

• Mill	Location
33- Bowater	Dolbeau
34- Produits Desbiens	Desbiens
35- Abitibi-Consolidated	Alma
36- Abitibi-Consolidated	Jonquière
37- Cascades	Jonquière
38- Abitibi-Consolidated	La Baie
39- Abitibi-Consolidated	Clermont
40- F.F. Soucy	Rivière-du-Loup
41- Mohawk Pulp	Saint-Antonin
42- Norampac	Cabano
43- Abitibi-Consolidated	Baie-Comeau
44- Smurfit-Stone Container	Matane
45- Spruce Falls	Matane
46- Uniforêt	Port-Cartier
47- Emballages Smurfit-Stone	New-Richmond
48- Gaspésia	Chandler

Figure 1. Location of the pulp and paper mills in Québec subjected to the Environmental Effects Monitoring (EEM) program.

Environnement Canada Environment Canada

2 The pulp and paper industry in Quebec

The pulp and paper industry is one of the pillars of Quebec's economy. In 2000, the 60 or so Quebec mills produced 11.5 million tonnes of pulp, paper and cardboard, accounting for 33% of Canada's total output. Pulp and paper exports had a value of $7.9 billion dollars, representing 10.7% of the total value of Quebec exports.

Quebec's pulp and paper industry provides employment for more than 35,000 people, with a total payroll of $1.7 billion. The newsprint sector occupies a leading position in the industry. In 2000, Quebec accounted for 42% of Canada's newsprint output and 10% of total newsprint output worldwide. The pulp and paper industry also produces printing and writing papers, tissue papers, board products and commercial pulps (AIFQ, 2002; Ministère de l'Environnement du Québec, 2002).

2.1 Pulp and paper mill manufacturing processes

The 52 mills regulated by the EEM program are identified in Annex 1. They have been grouped in five categories according to the following manufacturing processes: mechanical or thermomechanical; chemical or semi-chemical; kraft, recycled, de-inked pulps; other paper manufacturing processes (purchased pulp etc.). Mills that use multiple processes were grouped on the basis of their dominant process. Annex 2 shows the type of manufacturing process used to classify each mill, and Annex 3 gives the mills' mean annual production, mean effluent flow rate and their discharge of TSS and BOD_5 for 1998 and 1999 when the field studies were conducted for Cycle 2.

Among those mills that discharge their effluent to fresh water (n=45), mean annual production varies widely, ranging from 29 tonnes per day to 1742 tonnes per day. Kraft mills produce the largest tonnage, followed by mills employing mechanical and thermomechanical processes and mills using chemical or semi-chemical processes (Table 1). The lowest output is associated with the recycled or de-inked pulp mills, mills that process purchased pulp and those in the "other" category.

With regard to the 7 mills that discharge their final effluent to the marine environment, mean production per mill varies between 400 and 1500 tonnes/day. The annual output of the chemical and semi-chemical mills is higher than that of the kraft mill (Table 2).

2.2 *Effluent treatment systems*

There are two main methods for treating the process waters of pulp and paper mills. Primary treatment is designed to reduce total suspended solids (TSS) in the effluent by up to 95% using various processes (settling or filtration). Secondary treatment involves the use of microorganisms to break down dissolved organic matter, thereby reducing biochemical oxygen demand (BOD_5) and substances such as resin acids by up to 95%. All Quebec mills regulated by the PPER are equipped with at least one primary treatment unit, and only five mills do not have secondary treatment facilities.

The mills have been grouped according to the following secondary and primary treatment processes: activated sludge; activated sludge with oxygen; sequential biological reactors (SBR); aerated ponds; biological filtration; primary treatment only (includes the following systems: screening, settling, membrane, Poseidon system). Annex 2 indicates the effluent treatment category for each mill.

With respect to mills that release their effluent into fresh water, those that use secondary treatment consisting of activated sludge with oxygen have the highest mean annual production (Table 1), whereas mills that use primary treatment alone have the lowest output values. The other categories include mills that produce an intermediate mean annual tonnage (Table 1). The largest mills discharging to the marine environment use a sequential biological reactor system or activated sludge (Table 2).

Table 1 Mills discharging to fresh water: production, effluent flow rate, TSS and BOD_5 loading of effluent by process type and effluent treatment category

Process Type	Number of Studies	Mean Annual Production tonnes/day (1)	Mean Annual Effluent Flow Rate m^3/day	Mean Annual Effluent TSS Load kg/day	Mean Annual Effluent BOD_5 Load kg/day
Mechanical, thermomechanical	14	697.4	30591.8	749.2	380.0
Chemical, semi-chemical	7	739.9	34581.7	3112.1	1164.5
Kraft	8	869.8	65504.3	2273.7	1312.2
De-inked, recycled pulp	5	250.9	5657.2	303.2	1432.5
Purchased pulp, other	7	283.3	11024.6	378.4	182.1
Effluent treatment method					
Activated sludge	21	599.5	29130.7	1423.6	830.7
Oxygenated activated sludge	3	1334.2	93412.8	1748.4	1103.3
Sequential biological reactor	6	521.6	23465.4	768.2	421.4
Aerated ponds	6	758.6	37193.2	2243.4	1350.3
Biofiltration	1	596.7	29214.8	828.5	467.8
Primary treatment only	4	67.4	3675.2	147.1	138.1
Values for the mills as a whole	41*	613.1	31703.7	1332.4	790.4

(1) These data represent the annual values for 1998 and 1999, the years when the Cycle 2 field studies (fish, benthos) were done (source: INDMONMEF).
Where the studies straddled two or more years, the mean value was calculated for those years.
* The total 41 represents the number of studies conducted by all 45 mills discharging to fresh water.

Table 2 Mills discharging to the marine environment: production, effluent flow rate, TSS and BOD_5 loading of effluent by process type and effluent treatment category

Process Type	Number of Mills	Mean Annual Production tonnes/day	Mean Annual Effluent Flow Rate m^3/day	Mean Annual Effluent TSS Load kg/day	Mean Annual Effluent BOD_5 Load kg/day
Chemical, semi-chemical	6	760.3 (1)	30628.4	1846.8	750.7
Kraft	1	594.7	41994.4	4691.1	933.8
Effluent treatment method					
Activated sludge	4	785.3	35695.3	1749.3	639.2
Aerated ponds	1	594.7	41994.4	4691.1	933.8
Sequential biological reactor	1	1047.9	34493.1	3963.4	1735.4
Primary treatment only	1	372.9	6495.9	120.0	212.4
Values for the mills as a whole	7	737.3	32047.7	2016.0	535.3

(1) These data are the annual values for 1998 and 1999, the years when the Cycle 2 field studies (fish, benthos) were carried out (source: INDMONMEF). Where the studies straddled two or more years, the mean value was calculated for those years.

2.3 *Characterization of effluents (effluent flow rate, TSS, BOD_5)*

The mean annual effluent flow rate of mills that discharge to fresh water is 31,703.7 m^3/day (Table 1). The amount of discharge varies according to the mills' mean production. Kraft mills—the mill category with the highest mean output—have the highest effluent flow rates, whereas mills that use recycled or de-inked pulp and have the lowest mean production have lower effluent flow rates.

For all mills that discharge their final effluent to fresh water, the mean annual TSS loading is 1332. kg/day (Table 1). These final effluents have a mean annual BOD_5 of 790.4 kg/day. The mean flow rate for mills that release their effluent to the marine environment is 32,047.7 m^3/day (Table 2). The mean annual TSS and BOD_5 loading for these mills is 2016 kg/day and 535.3 kg/day.

2.4 *Changes since Cycle 1*

From 1992 to 1995, interim authorizations were granted to companies whose secondary treatment units had not yet reached an adequate operating level. Following the installation and run-in secondary treatment equipment, monitoring studies showed a substantial decline in the suspended solids (decrease of nearly 60% between 1994 and 2001) and the biochemical oxygen demand of the effluents (decrease of over 90% between 1994 and 2001).

This drop in the discharge of TSS and BOD_5 is due to the improvement of existing treatment systems, the installation of new systems, increased efforts to recover residual matter at mills and process modifications (Ministère de l'Environnement du Québec, 2002).

3 Delineation of zone of effluent mixing

3.1 *Objective*

The goal of delineating the effluent mixing zone is to define the boundaries of the effluent plume in the receiving environment. This characterization is used in determining the best locations for benthos and fish sampling stations in the exposure area. It should be noted that an effluent dilution gradient is neither temporally nor spatially static. Changes in the delineation of the zone of mixing may result from variations in the receiving environment or in the effluent itself over time further to climatic variations, modification of the mill's manufacturing processes or displacement of the outfall.

3.2 *Requirements*

The zone of mixing is delineated using a chemical tracer during low water periods or extreme tides. The plume is delineated by a zone where the effluent concentration exceeds 1% (volume/volume) compared with the receiving environment. The main chemical tracer used is Rhodamine WT. Some mills have previously employed other tracers, such as calcium, sodium, levels of certain metals, or conductivity, natural fluorescence or turbidity.

The characteristics of the mixing zone were also been estimated using modelling for 7Q10 low flow conditions, that is, the lowest consecutive seven-day streamflow that is likely to occur once every 10 years. The 7Q10 low flow conditions correspond to a situation where the effluent plume has a maximum extent and therefore minimal dilution. In some cases, the modelling for a given mill was done by taking into account different wind conditions (intensity, direction). When necessary, the effect of tidal cycles was considered in delineating the plume with a tracer or through modelling.

3.3 Methods

The effluent plume is usually characterized by injecting a solution of Rhodamine WT into the effluent upstream from the point of discharge into the receiving environment. Transects perpendicular to the plume axis are established with the help of a DGPS geographic positioning system. Sampling points are positioned on each transect and a water sample is taken, with different depths being sampled if necessary. Other measurements, such as depth and temperature, are also taken. The water samples are then analysed to determine the Rhodamine concentration. The Rhodamine concentration in the receiving environment corresponding to a 1% effluent concentration is likewise determined, allowing all the Rhodamine concentrations to be converted to effluent concentrations. Using the geographic positioning data and the effluent concentration data, the zone of mixing of 1% effluent concentration can be mapped.

Modelling of effluent plume dispersion is customarily done with the CORMIX model (*Cornell Mixing Zone Expert System*), which is recognized by various government agencies including Environment Canada. The Cormix model takes account of the geometry of the outfall in computing near-field dispersion in low flow conditions (typically 7Q10 low flow conditions). This model can provide an overview of the thickness of the plume but, according to Sanexen (1999), no existing model can perfectly predict the behaviour of a floating effluent as a function of wind speed and direction. The wind-induced drift of the plume is estimated by mathematical methods, which involve defining current vectors and wind vectors. The resultant vector represents the axis along which effluent dispersion will occur. The mathematical equation calls for the use of results obtained under windy conditions as well as calm periods. The duration of the Rhodamine test is taken into consideration. After this model calibration phase, modelling can be done based on given wind direction and speed scenarios. The results, particularly the 1% effluent concentration limit, can then be mapped.

3.4 *Results*

In Cycle 2, 70% of the mills carried out a new characterization of their mixing zone. Thirteen of the forty-eight Cycle 2 studies undertook a study using tracers (12 used Rhodamine WT, 1 used conductivity). In all, 26 of the 48 studies carried out modelling (23 with Cormix, 3 with other mathematical models). Only 7 of them applied both approaches (tracer and modelling). The Cycle 2 results (Annex 3) show that the length of the mixing zone varies between a few metres (during high water episodes) and about one hundred kilometres (7Q10 low flow conditions). The mean extent of the mixing zone modelled in Cycle 2 was 9316.5 m in fresh water and 779.3 m in the marine environment.

Most of the tracer and modelling studies conducted in Cycle 2 were initiated further to a change in the location of the mills' outfall or changes in the effluent characteristics (flow rates). As expected, modelling under 7Q10 conditions allowed a much longer mixing zone to be delineated than that suggested by the results of tracer studies. The mixing zone, defined by the 1% effluent concentration limit, was eliminated in one case in Cycle 2, since the effluent concentration was less than 1% right from the point of discharge.

4 Effluent toxicity tests

4.1 *Objectives*

Toxicity tests are aimed at determining the effluent's potential for affecting aquatic organisms and at tracking effluent quality. In these tests, organisms are exposed to various dilutions of effluent. Survival, growth and reproduction are the biological variables which are measured during toxicity testing. The sublethal toxicity of effluent can be expressed by the inhibition concentration (IC_{25}), that is, the concentration in % volume/volume (% v/v) expected to cause a 25% reduction in a biological measure in exposed organisms versus the control group. The more sublethal toxicity a sample exhibits, the more the IC_{25} approaches 0%. Conversely, the less toxic the IC_{25} is, the closer it is to 100%, at least for testing of freshwater organisms. The non-toxicity of a sample is thus represented by an $IC_{25} > 100\%$. For marine test organisms, the

maximum test concentration is 67%, owing to the addition of hypersaline brine during the salinity adjustment phase for effluent samples. In this case, an IC_{25} > 67% implies that there is no sublethal toxicity. Some toxicity tests allow the effect of samples on survival to be determined. In such a case, an LC_{50} is obtained, that is, a concentration that is lethal for 50% of the test organisms. When means are computed, the geometric mean of the IC_{25} or the LC_{50} values is used. These terms are denoted as GM-IC_{25} and GM-LC_{50} respectively.

The organisms used for sublethal toxicity testing in EEM studies of pulp and paper mill effluents represent the different trophic levels of the ecosystem. They include plants, invertebrates and fish. Sublethal toxicity tests are designed to achieve two specific objectives: to support the EEM program by contributing to the weight-of-evidence approach and to measure the variations in toxicity attributable to changes in effluent treatment methods and in industrial processes (Environment Canada, 1997c). The tests selected for EEM studies at pulp and paper mills are listed in the Pulp and Paper Technical Guidance Document for Environmental Effects Monitoring (Environment Canada, 1998).

4.2 Requirements and methods

Every year there are two effluent sampling periods, or series. In Cycle 2, a total of six series of sampling were carried out, compared with four series in Cycle 1. As part of each series, an effluent sample was subjected to three different sublethal toxicity tests (Table 3).

Table 3. Sublethal toxicity tests recommended for the evaluation of pulp and paper mill effluents

Test Description	Receiving Environment	Test Species	Acceptable Method(s)
Fish early life stage development test	Marine/estuarine	Inland silverside *Menidia beryllina*	U.S. EPA 1994 Minimum reporting requirements for Environment Canada
		OR	
		Atherinops affinis	U.S. EPA 1995 Minimum reporting requirements for Environment Canada
	Fresh water	Fathead minnow (*Pimephales promelas*) or salmonid spp.[1]	Environment Canada 1992[e] Changes made to the method in November 1997
Invertebrate reproduction	Marine/estuarine	Echinoids: sea urchins	Environment Canada 1992[c] Changes made to the method in November 1997
Invertebrate survival and reproduction	Fresh water	*Ceriodaphnia dubia*	Environment Canada 1992[d] Changes made to the method in November 1997
Plant toxicity test	Marine/estuarine	*Champia parvula*	U.S. EPA, 1994 Minimum reporting requirements for Environment Canada
	Fresh water	*Selenastrum capricornutum*	Environment Canada 1992[b] Changes made to the method in November 1997

1: For Canadian locations where fathead minnows are not an indigenous species, a salmonid species must be used in accordance with the Environment Canada reference method (1997[c]).

In Cycle 2, sublethal toxicity testing using a plant species involved applying the growth inhibition assay in the alga *Selenastrum capricornutum* for the effluent of mills that discharge to fresh water (Environment Canada, 1992b). In the marine environment, a reproduction test using the alga *Champia parvula* was carried out (U.S. EPA, 1994). It should be noted that in Cycle 1 some mills that discharge their effluent to fresh water used the growth inhibition test with the aquatic vascular plant *Lemna minor*. For the purposes of comparing the results for cycles 1 and 2, only those obtained with *Selenastrum* will be taken into consideration.

Invertebrate toxicity testing was conducted using a survival (lethality) and reproduction (sublethality) test with the cladoceran crustacean *Ceriodaphnia dubia* for mills discharging to fresh water. In the marine environment, invertebrate testing consisted of a fertilization assay using sea urchins, with *Lytechinus pictus* being the specie used most often, although the specie *Arbacia punctulata* was employed occasionally (Environment Canada, 1992d; 1992c).

A larval survival and growth test in fish was conducted using the fathead minnow *Pimephales promelas* for studies in fresh water (Environment Canada, 1992e) and a growth and survival test was done using the inland silverside *Menidia beryllina* for mills discharging to the marine environment (U.S. EPA, 1994).

The sublethal toxicity results were grouped in the following four categories, as in the Cycle 1 synthesis report (Langlois and Dubuc, 1999):

Fresh water:

$IC_{25} < 15\%$ (v/v)

15% (v/v) $\leq IC_{25} < 50\%$ (v/v)

50% (v/v) $\leq IC_{25} < 100\%$ (v/v)

$IC_{25} \geq 100\%$ (v/v)

Marine environment:

$IC_{25} < 15\%$ (v/v)

$15\% \text{ (v/v)} \leq IC_{25} < 50\%$ (v/v)

$50\% \text{ (v/v)} \leq IC_{25} < 67\%$ (v/v)

$IC_{25} \geq 67\%$ (v/v)

4.3 Results

4.3.1 Mean sublethal toxicity observed in Cycle 2

The geometric means for each type of sublethal toxicity test for the individual mills are shown in Annex 4. Table 4 gives the geometric means of the IC_{25} values for the aggregate of sublethal toxicity tests done on the effluents from mills that discharge to fresh water and the marine environment. The tests with *Ceriodaphnia* in fresh water and *Champia* in the marine environment yielded the lowest geometric means for all the Cycle 2 data. There is wide variability associated with mean values. The maximum range of IC_{25} values was obtained in the tests with *Ceriodaphnia* (fresh water) and with the sea urchin (marine environment).

Table 4. Geometric means of the IC_{25} values and range of values for all the sublethal toxicity tests done on mill effluents discharged to fresh water or to the marine environment (Cycle 2)

Test organism	Cycle 2		
	Number of tests	GM-IC_{25} % (v/v)	Range
Fresh water			
Selenastrum	235	65.3	13.7 - >100
Ceriodaphnia	237	35.4	3.6 - >100
Pimephales	237	78.4	20.9 - >100
Marine environment			
Champia	34	13.4	9.7 - 38.3
Sea urchin	34	22.3	2.9 - 58.7
Menidia	34	68.3	66.6 - 69.9

In general, a non-toxic result for marine test organisms is shown as ≥ 67% (v/v), which is the maximum concentration that can be obtained after the salinity of the effluent sample is adjusted in keeping with the current protocol.

The number of studies showing high mean sublethal toxicity (GM-IC_{25} < 15% v/v) varies between 0 and 5 depending on the freshwater and marine test organism used (figures 2 and 3). The number of studies that do not show sublethal toxicity (GM-IC_{25} > 100% v/v) in Cycle 2 ranges from 1 to 13 for tests of freshwater organisms and from 0 to 6 for the marine tests. For freshwater organisms, modal frequency is represented in the sublethal toxicity class between 15% and 50% (*Ceriodaphnia*) or between 50% and 100% (*Selenastrum* and *Pimephales*). In the case of marine species, the small number of studies lessens the significance of modal classes. It is nonetheless interesting to note that only one of the effluents studied in the marine environment displayed sublethal toxicity in the inland silverside (Figure 3).

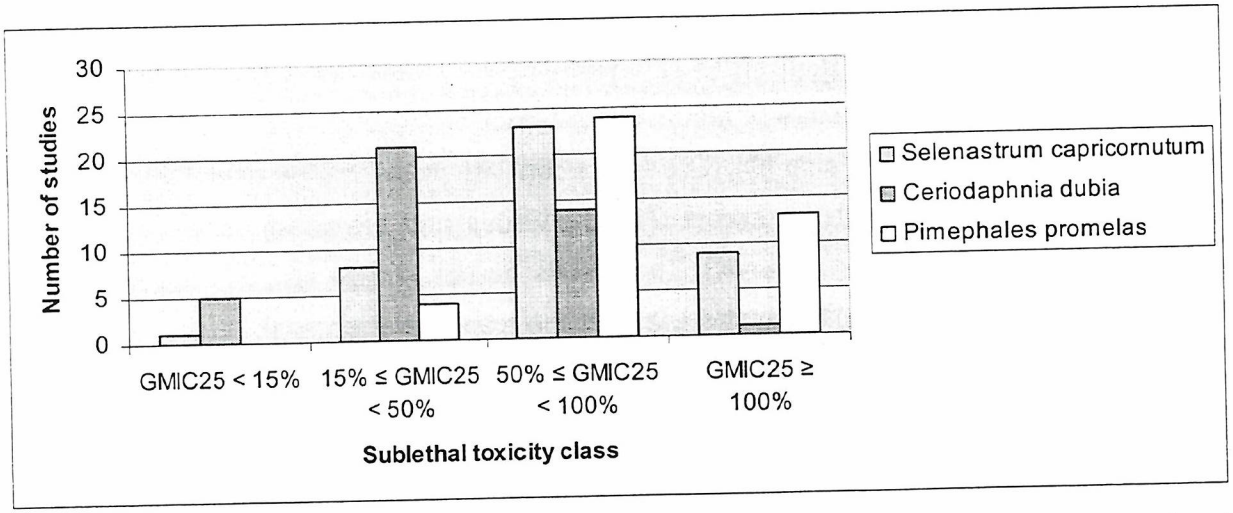


Figure 2 **Frequency of freshwater studies by sublethal toxicity class relative to the test organisms.**

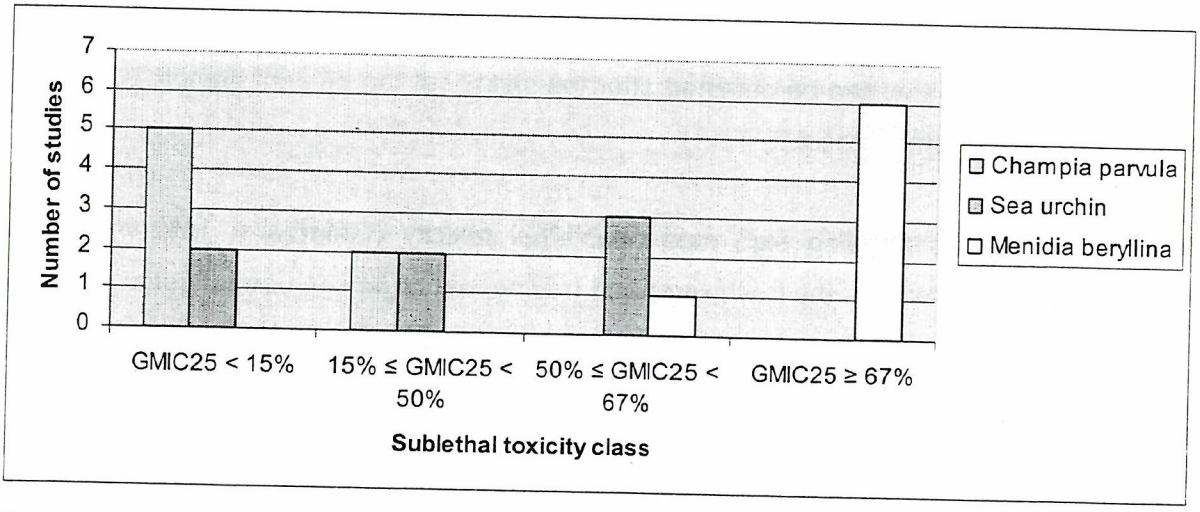


Figure 3 **Frequency of studies in the marine environment by sublethal toxicity class and test organism**

4.3.2 Sublethal toxicity in relation to mill process type

Among mills that discharge to fresh water, the test with the crustacean *Ceriodaphnia* gave the lowest GM-IC_{25} of all the categories of production processes (Table 5). The results indicate that this test provides the most variable IC_{25} values. By contrast, in the marine environment, testing with the alga *Champia* yielded the lowest GM-IC_{25} values and produced values indicative of appreciable toxicity (GM-IC_{25} < 15% v/v). The results do not include any particularly extreme values for a given process type, in the freshwater or the marine environment.

4.3.3 Sublethal toxicity relative to the effluent treatment method

A comparison of sublethal toxicity for mills with secondary treatment and those with only primary treatment shows that the latter induce higher toxicity in *Ceriodaphnia* and *Pimephales* for freshwater studies (Table 6). In contrast, higher sublethal toxicity results are noted for two of the three test organisms (*Champia* and sea urchins) in the case of mills that discharge to the marine environment and have secondary treatment. The sample size for mills discharging to the marine environment is very small and constrains the interpretation of results.

Table 5 **Geometric means of the IC_{25} values from sublethal toxicity tests done in Cycle 2 and range of values, by mill process category**

Test species	Mechanical - Thermomechanical			Chemical – semi-chemical			Kraft			Recycled – de-inked pulp			Other		
	Number of samples	GM-IC_{25} % (v/v)	Range	Number of samples	GM-IC_{25} % (v/v)	Range	Number of samples	GM-IC_{25} % (v/v)	Range	Number of samples	GM-IC_{25} % (v/v)	Range	Number of samples	GM-IC_{25} % (v/v)	Range
Selenastrum	78	76.5	4.2 - 100	39	48.3	3.8 - 100	48	45.3	6.2 - 100	30	72.9	9.4 - 100	40	86.0	8.1 - 100
Ceriodaphnia	80	36.0	0.9 - 100	39	26.6	4.1 - 100	48	37.7	1.9 - 100	30	40.3	5.6 - 100	40	39.4	3.9 - 100
Pimephales	80	87.4	16.6 - 100	39	64.9	4.5 - 100	48	90.9	37.9 - 100	30	66.6	7 - 100	40	73.8	4.1 - 100
Champia				28	13.7	2.7 - 68	6	9.7	0.5 - 68.1						
Sea urchin				28	19.8	1.5 - 69	6	36.5	9.4 - 67						
Menidia				28	68.3	65 - 73	6	68.5	67 - 72						

Table 6 **Geometric means of the IC_{25} values from sublethal toxicity tests done in Cycle 2 and range of values, by effluent treatment method**

Test Organism	Primary Treatment			Secondary Treatment		
	Number of samples	GM-IC_{25} % (v/v)	min - max	Number of samples	GM-IC_{25} % (v/v)	min - max
Selenastrum	21	64,4	25,3 - 100	214	65,4	13,7 - 100
Ceriodaphnia	21	11,4	3,6 – 97,6	216	40,0	9,0 - 100
Pimephales	21	52,7	42,4 – 70,9	216	81,8	20,9 - 100
Champia	6	53,14	38,35 – 68,1	28	11,1	2,7 – 68
Sea urchin	6	60,53	32 – 67,7	28	18,8	2,3 – 69
Menidia	6	66,6	65 – 67,7	28	68,5	67 - 73

Among mills that discharge their final effluent to fresh water (Figure 4), the activated sludge treatment system with oxygen (n = 3) appears to be more effective than that based on activated sludge alone (n = 21) in terms of reducing chronic toxicity of the wastewater. The mean IC_{25} for *Ceriodaphnia*, the most sensitive freshwater species, is of the same order as the IC_{25} for *Selenastrum* in the case of activated sludge treatment with oxygen. In the other cases, the results obtained with the invertebrate test organism show more marked chronic toxicity than in the green alga. It is interesting to note that biofiltration generates two non-toxic results (*Selenastrum* and *Pimephales*) despite the small sample size (n = 1). Overall, chronic toxicity in *Selenastrum* and *Ceriodaphnia* is appreciable in water samples taken from aerated ponds.

In mills that discharge to the marine environment (Figure 5), the results of tests conducted on *Champia*, *Menidia* and sea urchins are similar whether the treatment employed is activated sludge, an aerated pond or a sequential biological reactor. Tests conducted with the alga *Champia* and with sea urchins revealed higher toxicity than was the case with the fish *Menidia*.

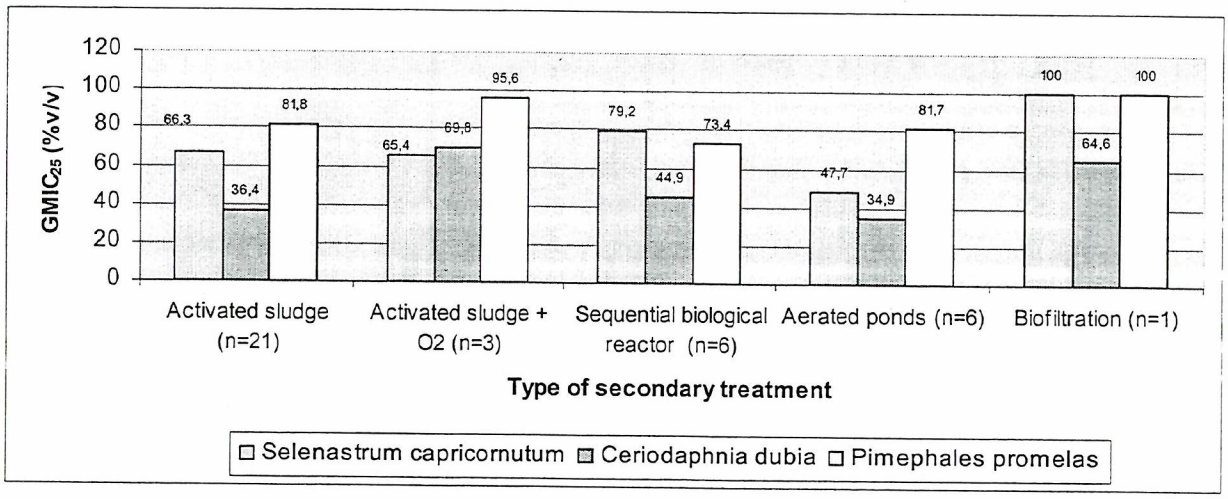


Figure 4 **Mean sublethal toxicity according to the type of secondary treatment applied to the effluent of mills that discharge to fresh water**

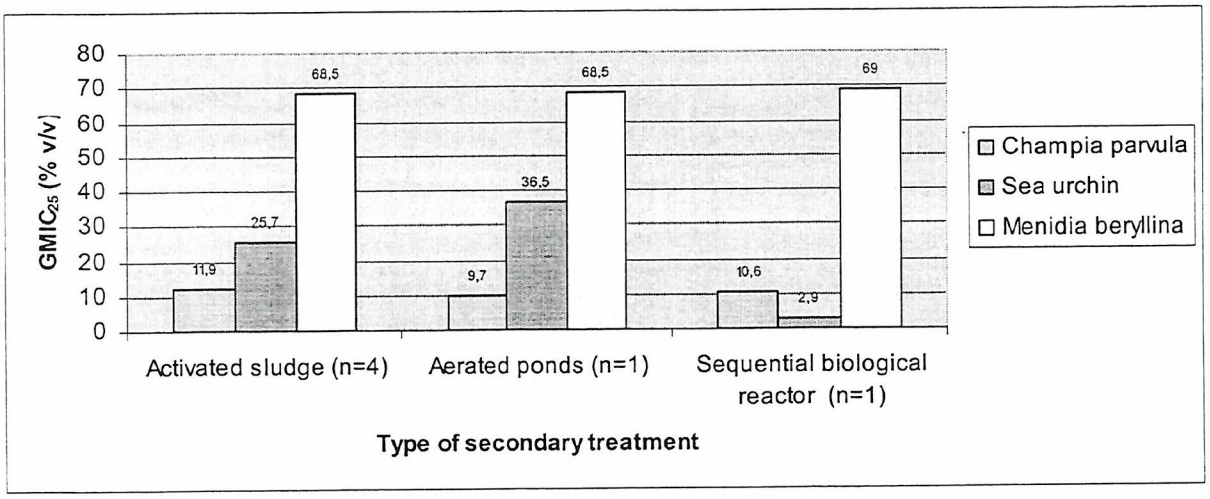


Figure 5 **Mean sublethal toxicity according to the type of secondary treatment applied to the effluent of mills that discharge to the marine environment**

4.3.4 Changes since Cycle 1

In Cycle 2, all the tests show an increase in the geometric mean in comparison with Cycle 1. There is an increase in the minimum sublethal concentrations observed, which is another indication of the reduction in toxicity between the two cycles. In general, the time series (figures 6 and 7) show a change in mean chronic toxicity over time, with GM-IC_{25} values being higher in Cycle 2 versus Cycle 1. *Ceriodaphnia* and *Champia* appear to be the most sensitive test organisms. With regard to mills operating in the marine environment, the inland silverside *Menidia* produced non-toxic results during the last five successive series of Cycle 2 (Figure 7).

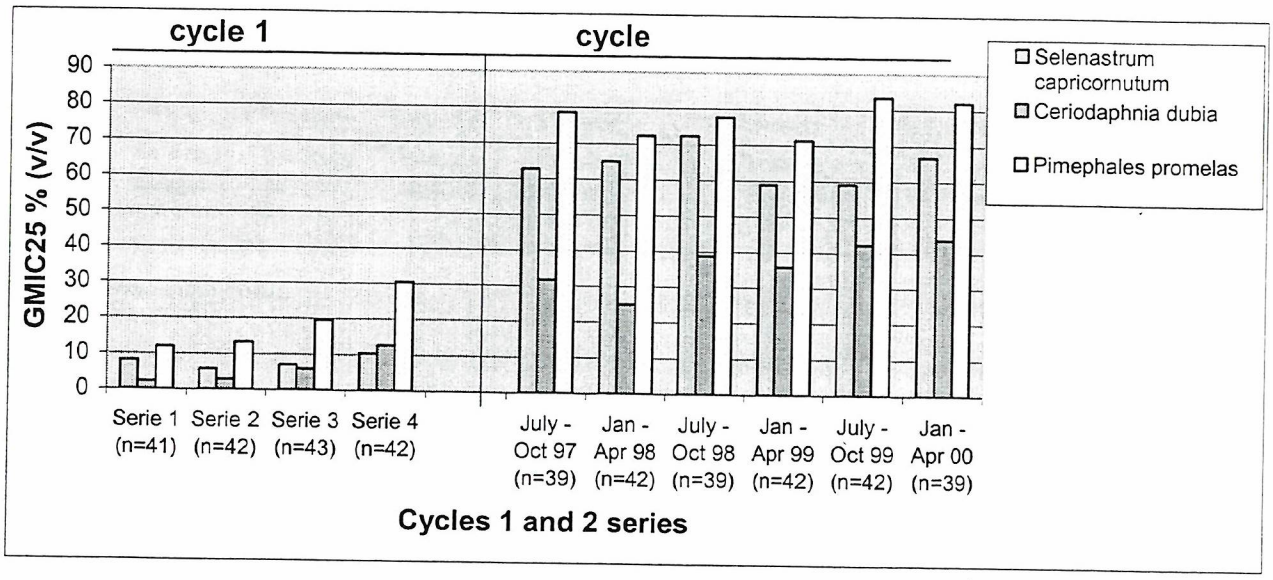


Figure 6 **Geometric mean of sublethal test results in relation to the sampling period (cycles 1 and 2) and the freshwater test organism**

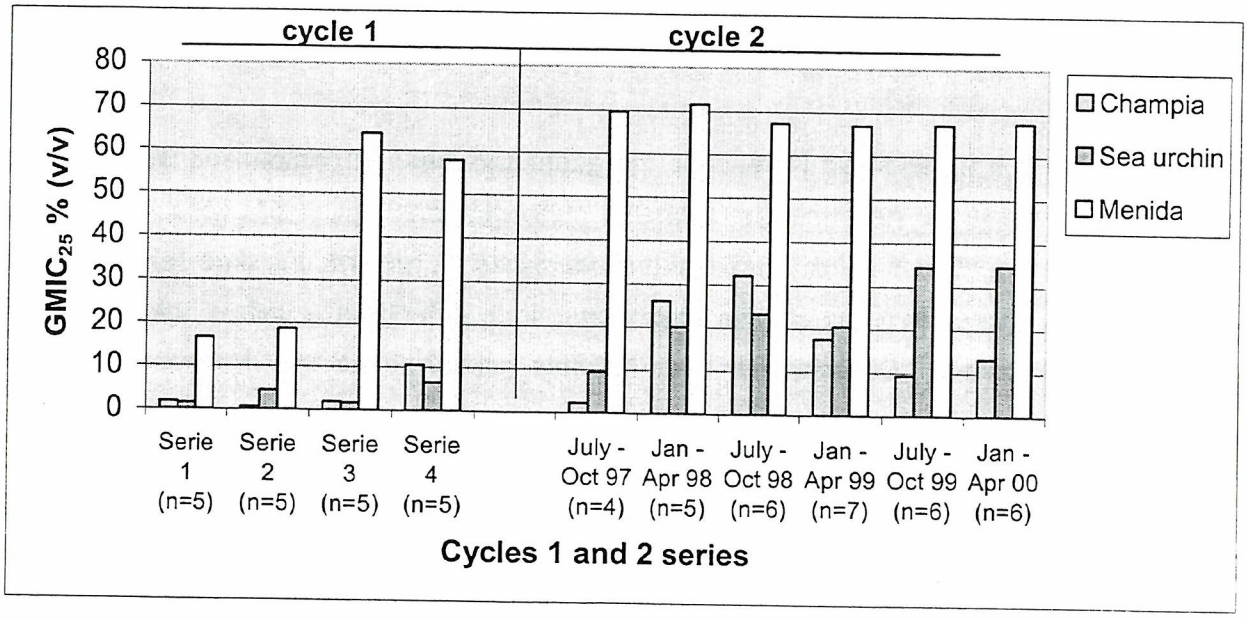


Figure 7 **Geometric mean of sublethal test results in relation to the sampling period (cycles 1 and 2) and the marine test organism**

In Cycle 1, a total of 23 studies involved sublethal toxicity tests on effluents for which the final treatment changed from primary to secondary during the study (22 studies in fresh water, 1 mill in the marine environment). In all, 14 studies included sublethal toxicity testing of effluents that underwent primary treatment only (13 studies in fresh water, 1 mill in the marine environment). Ten studies involved sublethal toxicity testing of effluents that received secondary treatment only (7 in fresh water, 3 in the marine environment).

Subsequently, a large number of mills introduced a secondary treatment system for their process waters. In Cycle 2, five studies had a primary treatment system only (4 in fresh water, 1 in the marine environment), whereas 43 studies had a secondary treatment system (37 in fresh water, 6 in the marine environment).

Mills that discharge effluent to fresh water following primary treatment, whether in Cycle 1 or 2 (Figure 8, categories A and B), show higher GM-IC_{25} values in Cycle 2, particularly for tests with the alga *Selenastrum* and with fathead minnows (*Pimephales*). Mills with secondary treatment in Cycle 2 show higher GM-IC_{25} values than in Cycle 1, even after the reduction in the sublethal toxicity of effluents following the installation of secondary treatment in Cycle 1 (Figure 8, categories C, D and E).

Despite the smaller sample sizes of the tests done for studies in the marine environment, the same pattern is observed for the inland silverside (*Menidia*) test results at mills that installed a secondary treatment system during Cycle 1 (Figure 9, categories C, D and E). There is only one mill with primary treatment that discharged effluent to the marine environment in both cycles. At this site, a considerable improvement in sublethal toxicity occurred in Cycle 2 further to the installation of a process water recirculation system.

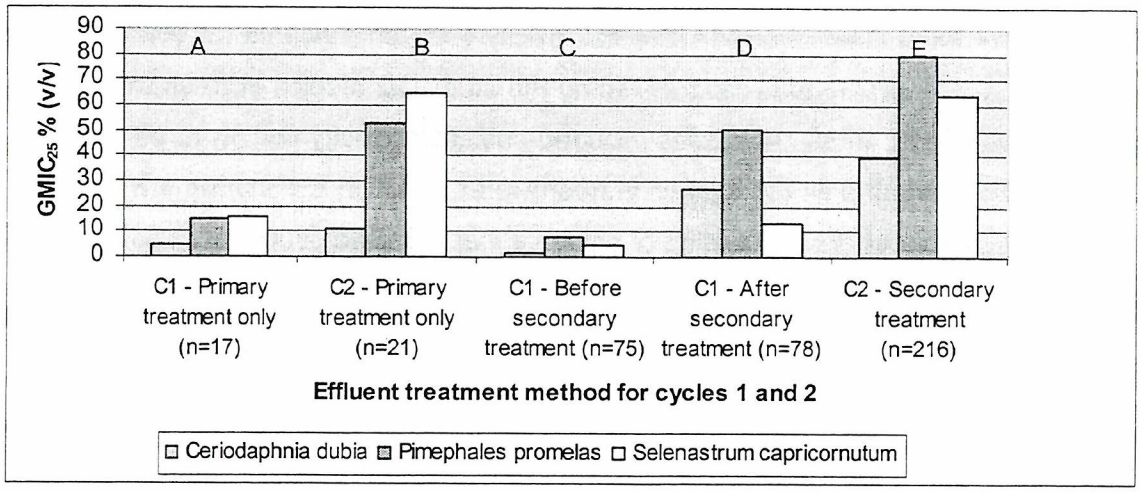


Figure 8 Mean sublethal toxicity for each test organism in relation to the effluent treatment method at mills discharging to fresh water

A and B: mills with primary treatment only during cycles 1 and 2. C and D: cycle 1, before and after secondary treatment was installed, respectively. E: mills with secondary treatment in Cycle 2.

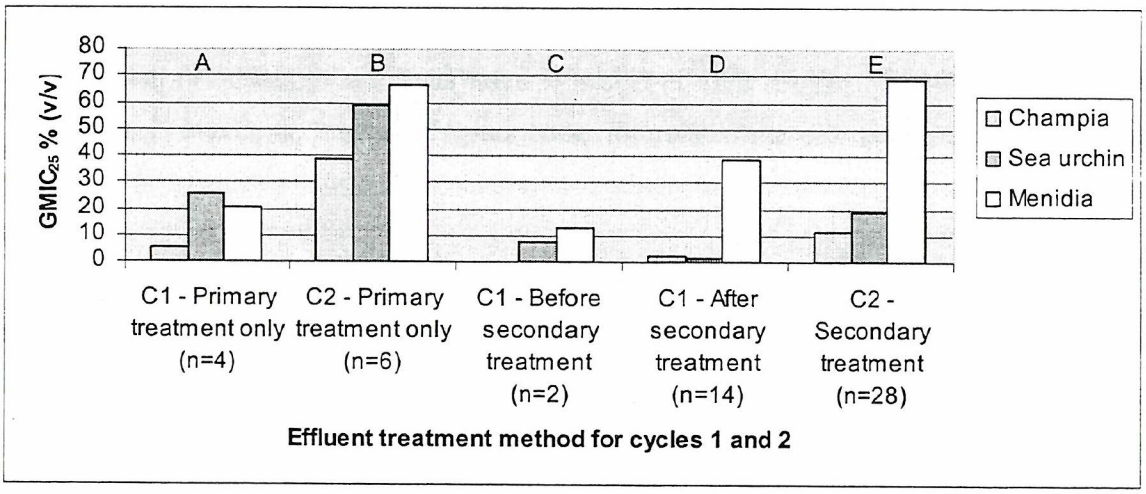


Figure 9 Mean sublethal toxicity for each test organism in relation to the effluent treatment method at mills discharging to the marine environment.

A and B: mills with only primary treatment during cycles 1 and 2. C and D: Cycle 1, before and after secondary treatment was installed. E: mills with secondary treatment in Cycle 2.

5 Fish survey in the receiving environment

5.1 *Objectives*

The main objective of this component of EEM studies is to assess the effects of pulp and paper mill effluents on the survival, growth and reproduction of fish. The effects induced in fish by pulp mill effluents can be of various types. They depend on many factors, including the substances released into the receiving environment, the habitat type, the level of degradation of the receiving environment, the species considered, the degree of statistical precision sought during the observations and the level of biological organization (molecule, tissue, organ, individual or population) of the samples (Carlberg and Stuthridge, 1996; Muir and Servos, 1996; Munkittrick and McMaster, 2000; Munkittrick *et al.*, 2002; Sibley *et al.* 2001; Swanson *et al.*, 1996).

Given the complexity of potential interactions, it is not easy to predict the effects that will occur at a given location. At Jackfish Bay, in Ontario, the kraft process using chlorine bleaching, followed by primary treatment, produced obvious toxic effects in white sucker (Munkittrick *et al.*, 1991). For Canadian mills that use this process but have secondary treatment, the results appear to be more variable (Servos *et al.*, 1992; Swanson *et al.*, 1996). As a result of organic enrichment of the environment, other reactions have been observed in fish species: increased growth (Hodson *et al.*, 1992), liver hypertrophy (Gibbons and Munkittrick 1994; Munkittrick *et al.* 2000) and delayed sexual maturation and/or a decrease in relative gonad size or fecundity (Munkittrick *et al.*, 1994; Gagnon *et al.* 1995; Gibbons and Munkittrick 1994; Munkittrick *et al.* 2000). When the toxic effects combine with those associated with organic enrichment, the response can be highly variable in the populations studied. However, the national assessment of the Cycle 2 EEM data shows that the main trends in the responses observed across Canada are decreased gonad size and increased liver weight along with fish length. This response pattern seems to be indicative of some sort of endocrine disturbance associated with the effects of eutrophication of the receiving environment (Lowell *et al.,* 2003). A descriptive approach has been adopted to describe the variability observed in the responses of the sentinel species used in Quebec.

For EEM purposes, an effect is defined as a significant difference measured in an environmental variable between an exposure area and a reference area. However, the expert working group (Environment Canada, 1997a) considers that a 25% difference in gonad weight relative to body weight between the reference area and the exposure area has ecological significance. Moreover, further to the national analysis of Cycle 2 results, this group of experts has also proposed effect sizes that take account of natural variability and that could represent an ecological significance level for the other parameters, namely a 25% difference in liver weight relative to body weight and for weight at age as well as 10% for the condition factor (weight/length). We will discuss this in greater detail in Chapter 7.

5.2 *Requirements and methods*

As in Cycle 1, the control/impact sampling design was recommended and applied in Cycle 2 in fresh water, with an exposure area located downstream from the effluent and a reference area upstream from the mill's outfall in the same water body. The sectors were to be sampled at the end of summer or in early fall over a short period, i.e. less than two weeks. In estuarine or marine habitats, the reference area was located in a sector adjacent to but beyond the effluent plume.

In keeping with the fish survey requirements, the mills had to take samples of two sentinel species. In most Cycle 2 studies, fish species were used. However, the *Fisheries Act* encompasses other categories of organisms in its definition of fish (eg crustaceans and molluscs) and these were the object of a few studies. Ideally, the species studied by paper mills consisted solely of mature individuals; however, including a certain number of immature specimens is also useful in evaluating the response to effluent. In the freshwater environment, 17 different fish species were used as sentinel species (Table 7). As in Cycle 1, white sucker (*Catostomus commersoni*) was the most commonly used species. The longnose sucker (*Catostomus catostomus*), yellow perch (*Perca flavescens*) and Johnny darter (*Etheostoma nigrum*) are the other sentinel species that were selected most often. Some species (i.e. smallmouth bass *Micropterus dolomieui*, among others) do not meet the criteria set out in Environment Canada's Technical Guidance Document (1998), which stipulates that the species must be abundant, easy to sample, non-migratory, preferably benthivorous and not very mobile. Another important criterion must be added to this list, that of being able to obtain a

sufficient number of individuals in the exposure area. It follows that sentinel species can be considered tolerant or moderately tolerant of pollution. It is interesting to note, in Table 7, that certain taxa which are present at many sites were the object of only a small number of studies (i.e. brown bullhead (*Ameiurus nebulosus*), rock bass (*Ambloplites rupestris*), fallfish (*Semotilus corporalis*) and logperch (*Percina caprodes*). These species have considerable potential for use in upcoming cycles if the mills concerned modify their study designs.

Table 7 Frequency of use and occurrence of the sentinel species selected by mills in Cycle 2

Category of organism	Family or Class (C)	Common Name	Scientific Name	Frequency of use by mills	Frequency of capture
Freshwater fish	Catostomidae	White sucker	*Catostomus commersoni*	22	31
	Catostomidae	Longnose sucker	*Catostomus catostomus*	12	21
	Percidae	Yellow perch	*Perca flavescens*	7	26
	Percidae	Johnny darter*	*Etheostoma nigrum*	4	9
	Cyprinidae	Longnose dace	*Rhinichthys cataractae*	3	9
	Ictaluridae	Brown bullhead	*Ameiurus nebulosus*	2	18
	Ictaluridae	Channel catfish	*Ictalurus punctatus*	2	4
	Catostomidae	Silver redhorse	*Moxostoma anisurum*	2	9
	Centrarchidae	Rock bass	*Ambloplites rupestris*	2	15
	Percidae	Tesselated darter	*Etheostoma olmstedi*	2	4
	Cyprinidae	Fallfish	*Semotilus corporalis*	2	24
	Centrarchidae	Smallmouth bass	*Micropterus dolomieui*	1	14
	Cottidae	Mottled sculpin	*Cottus bairdi*	1	2
	Percidae	Logperch	*Percina caprodes*	1	14
	Cyprinidae	Pearl dace	*Semotilus margarita*	1	2
	Cyprinidae	Blacknose dace	*Rhinichthys atratulus*	1	1
	Percopsidae	Trout-perch	*Percopsis omiscomaycus*	1	2
Marine fish	Cottidae	Shorthorn sculpin	*Myoxocephalus scorpius*	3	3
	Pleuronectidae	Winter flounder	*Pseudopleuronectes americanus*	1	2
Marine invertebrates	Bivalves (C)	Blue mussel	*Mytilus edulis*	2	nc
	Bivalves (C)	Macoma	*Macoma balthica*	1	nc
	Gasteropoda (C)	Waved whelk	*Buccinum undatum*	1	nc

Legend: nc: not calculated, *: may include *Etheostoma olmstedi* in some studies

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In the estuarine or marine environment, two fish species (shorthorn sculpin and winter flounder) and three invertebrate species (blue mussel, *Macoma balthica* and waved whelk) were selected as sentinel species (Table 7). The shorthorn sculpin was selected by three mills, the blue mussel was used in two studies and the other organisms were each used only once.

To obtain results allowing conclusions to be drawn, the mills had to comply with minimal requirements which included sampling two sentinel species by capturing at least 20 to 30 mature individuals of each sex in both the exposure and reference areas (Environment Canada, 1997a). To improve the fishing results, the technical advisory panel, which reviews the mills' study designs and analyses their interpretive reports established a list of recommendations for Cycle 2. They called for fishing to be done between mid-August and early October, with gear to be deployed at a minimum of five stations in each zone over a seven-day period to achieve a fishing effort of at least 70 gear-days. The advisory panel also recommended the simultaneous use of several gear types or several different methods suitable for catching the targeted species.

Fish were harvested in 1997, 1998, 1999 and 2001 primarily during the period from late August to mid-September, but fishing sometimes began in mid-August and was completed at the end of October. The 11 types of gear used by consultants for the sampling were, in decreasing order: gillnets (mono and multifilament, panels with different mesh sizes or one mesh size), hoop net (various models), electrofishing (alternating or direct current, various voltages), fish traps (bait traps), angling, seine (various types), Alaska trap, longline, weir (commercial installation), manual harvesting and manually operated Ponar grab sampler (Annex 5). At times up to five gear types or methods were applied simultaneously in a given study. A greater diversity of methods was recorded in comparison with Cycle 1. In Cycle 2, the gillnet was again the most commonly used gear type and electrofishing was still one of the preferred methods, although hoop nets and fish traps were also employed.

The mean sampling period was 11 days, but a few studies were completed in two days, while in other locations fishing activities were spread over a period of 40 days. Greater effort was expended in Cycle 2 given that the mean sampling period was only seven days in Cycle 1 (Langlois and Dubuc, 1999). Better knowledge of the species present and of the habitats permitted a general improvement in survey quality between the two cycles.

The following variables were measured or estimated in the fish: length, total fresh weight, age, fresh weight of gonads, fecundity of females (absolute number of eggs), fresh weight of the liver, external condition of fish (parasites, lesions and other anomalies) and sex. External condition, fecundity of females and age are the variables that were most often inaccurately reported or not measured. Measurements in the invertebrates used as sentinel species, which differed from those for the fish, included volume measures and ratio type variables. Some mills also reported information for immature individuals, and these data were examined to assess their usefulness.

With regard to statistical processing of the information collected, all the mills followed the prescribed approach involving the comparison of samples from the exposure and reference areas. Initially, the consultants presented descriptive statistics of the biological and morphological parameters (Annex 6). Most mills used one-way analyses of variance (ANOVA) or Student tests to detect significant differences in the means of the exposure area and the reference area, as well as between the sexes. For each area, the biological parameters were subsequently examined in pairs using linear regression analysis (raw or transformed variables) to characterize the following relationships:

- Length at age and body weight at age (describe growth)
- Body weight relative to length (reflects the condition of the fish)
- Liver weight relative to length, body weight (hepatosomatic relationship) or age
- Gonad weight relative to length, body weight (gonado-somatic relationship) or age
- Fecundity of females relative to length, body weight or age

For a given species, the maximum number of comparisons was nine for males and twelve for females. The final step involved performing an analysis of covariance (ANCOVA) for the relationships between the exposure and reference areas. It should be noted that the two regression lines derived through ANCOVA can only be compared when they are parallel and have a slope greater than zero. When the slopes are significantly different, the result is termed an interaction and no comparison can be made. The final diagnostic test that can be used to detect a difference involves comparing the intercepts of the two lines.

Lastly, Kruskal-Wallis tests were applied to compare the two areas in connection with research projects involving *in vivo* or *in vitro* measurements of blood steroids and liver enzymes.

5.3 Results and discussion

5.3.1 Capture results

In Cycle 2, thirty-eight mills (36 studies) conducted a survey of sentinel species, including three mills that discharge to the estuarine or marine environment. In all, 14 mills (12 studies) did not conduct fish surveys in Cycle 2 because the mixing zone was diluted to within 250 metres of the discharge at the surface or because of the impossibility of carrying out fishing in the receiving environment (unfavourable environment or excessive currents). With respect to Environment Canada's minimum requirements, survey quality improved between Cycle 1 and Cycle 2. Nine surveys done in fresh water resulted in the capture of at least 20 males and 20 females of the two sentinel species. Fifteen surveys complied with the minimum requirements for one of the two sentinel species, including three conducted in the marine environment. In six surveys, between 11 and 19 males and females of at least one of the two species were caught, whereas six other studies had major methodology problems or had a very small sample size (fewer than 10 fish in one or two areas for one or both species). It should be noted that 26 studies fell into the last two categories in Cycle 1, and this represents the main source of improvement in the fish survey component of the EEM studies.

Many reasons were put forward to explain the failure to comply with the minimum sampling requirements. The problems encountered included fishing activities carried out too late, capture of only immature specimens, unusual hydrological conditions, unfavourable or degraded habitats and inadequate gear types or fishing methods.

In Cycle 2, the majority of studies (25/36) adopted the control/impact sampling design. However, some mills used designs in which the exposure and reference areas were subdivided (near-field/far-field) (three studies: La Baie (PP1561), New-Richmond (PP1101) and Portage-du-Fort (PP1102)) and some included two rivers serving as receiving environments (three studies: Crabtree (PP1196), Lebel-sur-Quévillon (PP1147) and Lennoxville (PP1188)). A few surveys took place over two years (three studies: Gatineau (PP1118), Masson (PP1153), Thurso (PP1086)) and/or during different seasons (spring and fall, one study: Rivière-du-Loup (PP1138)).

5.3.2 Effects observed in sentinel species

5.3.2.1 Comparison of variables using statistical analyses

Nearly all the fish surveys (33/36) compared the results for the exposure and reference areas by means of statistical analyses (Annex 7). Note that the term "population" denotes a species and a given sex. The aggregate of 134 populations surveyed and analysed includes the information from 29 studies in which ANCOVA analyses were performed for the two sentinel fish species (including both sexes) and 4 studies that did calculations for at least one of the two species, including both sexes where possible. The Cycle 2 results, like those of Cycle 1, indicate that there is no significant difference between the exposure area and the reference area in the majority of comparisons where analyses of covariance were performed. Relative liver weight is the parameter that displays the highest response rate with nearly 50% of differences being significant (Table 8).

Table 8 Summary of the effects on fish (statistically significant differences between the exposure area and the reference area) for all fish populations

Parameter	Number of fish populations (1 or 2 species, 2 sexes, all mills)						
	Length at age	Weight at age	Weight at length	Age	Liver weight at length/ weight	Gonad weight at length/ weight	Fecundity at length/ weight
Significant differences	28	34	36	26	54	38	12
No difference between the 2 areas	51	45	77	70	56	71	31
No statistical analysis	55	55	21	38	24	25	21
Sample size (total number of populations)*	134	134	134	134	134	134	64

* number of populations for the 33 fish surveys in which an ANCOVA was performed

In cases where significant differences were detected between the exposure area and the reference area, it can be seen that for age and the paired variables "length at age", "body weight at age", "body weight at length" and "liver weight at length/body weight", relationships with a higher value in the exposure area account for more than 65% of significant relationships (Figure 10). The gonad weight at length/body weight relationship gives a different picture: lower values in the exposure area are slightly more numerous and make up 61% of the number of significant relationships. Analysis of the results in relation to sex does not change the interpretation, since males and females show similar patterns and fit in with the general pattern already described. With respect to the fecundity at length/body weight relationship, the number of relationships with higher values in the exposure area corresponds to the number of relationships with lower values. No significant relationships were reported in Cycle 2 for the following: liver weight, gonad weight and fecundity at age.

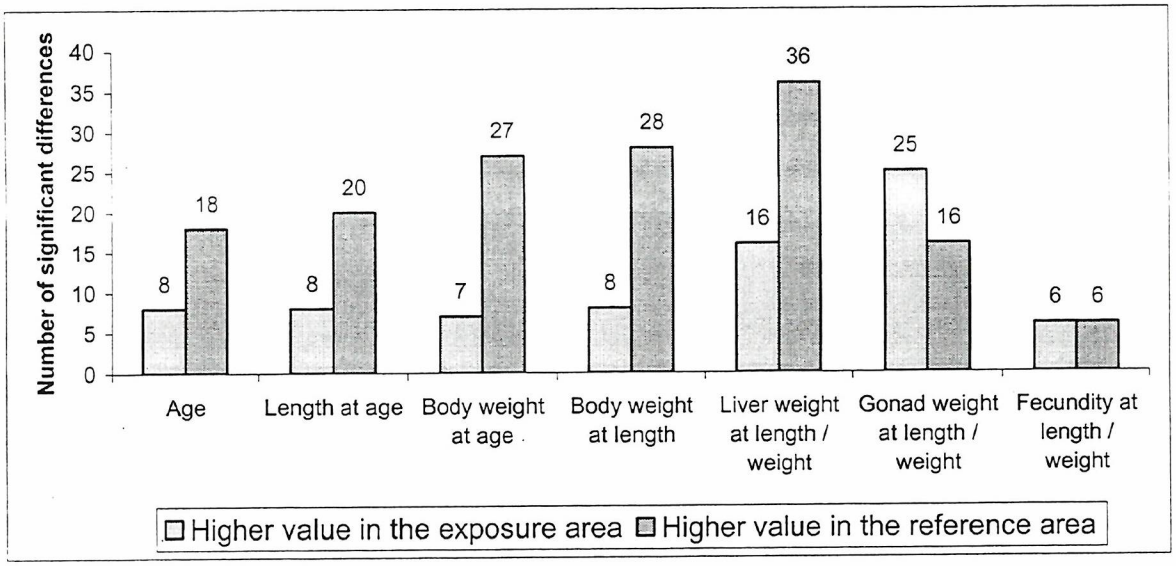


Figure 10 Effects on the parameters measured in fish when significant differences are found between the exposure and reference areas

The analysis of comparisons for immature fish populations yields no additional information. Only the weight at length and liver weight variables show statistically significant differences for 3 of the 7 immature fish populations. Furthermore, the responses of the immature fish are always consistent with those observed in adults of the same species. However, this type of analysis may prove useful in cases where no adult fish were captured.

The general pattern observed in Cycle 2 differs slightly from that in Cycle 1 (Langlois and Dubuc, 1999). The morphological relationships for which higher values were obtained in the exposure area, specifically length at age, body weight at age and body weight at length and age, made up 33 to 58% of the total number of significant comparisons in Cycle 1, in comparison with 70 to 79% in Cycle 2. Furthermore, a larger number of higher values was found for all parameters in the exposure area. The liver weight at length/body weight relationships accounted for about 67% in both cycles. For gonad weight at length/body weight and fecundity at length/body weight, there was an increase in the number of relationships that had higher values in the exposure area in Cycle 2 versus Cycle 1. This general increase in higher values in the exposure area in Cycle 2, which at first glance might seem to suggest a worsening of mill impacts, may merely reflect greater frequentation of the exposure areas by fish in Cycle 2. A number of fish species found to be absent from the exposure area of 7 mills in Cycle 1 were back in these areas in Cycle 2. This phenomenon could also be attributable to increased survival of fish in the exposure area.

The effect that particular sentinel species have on the response pattern can be examined by studying the morphological relationships for each fish family. Table 9 includes data on the most commonly used fish families from studies that featured ANCOVA analyses. For the sake of simplification, the non-significant results and cases of insufficient data were grouped together and assigned a "0". Detailed data for all the species are given in Annex 7. Given the large number of relationships analysed, Castomidae (white sucker and longnose sucker) mark the overall analysis because the pattern they show is consistent with the general pattern.

Table 9 Summary of ANOVA analyses of age and ANCOVA analyses of morphological parameters: number of significant differences between the exposure area and the reference area for the main fish families

Family	Age		Length/ Age		Weight/ Age		Weight/ Length		Liver Weight/ Length		Liver Weight/ Body Weight		Gonad Weight/ Length		Gonad Weight / Body Weight		Fecundity/ Length		Fecundity/ Body Weight		Number of significant	Total number of comparisons	Proportion of significant
(species)	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	comparisons		relationships
Catostomidae (2)	4	12	4	12	3	15	4	16	6	16	6	16	6	4	14	3	4	1	4	2	152	380	40
Percidae (4)	1	2	1	1	1	3	2	4	1	3	2	4	2	3	1	3	1	0	1	0	36	178	20.2
Cyprinidae (4)	0	2	0	3	0	2	0	4	0	4	2	5	2	0	2	0	0	2	0	2	30	87	34.5
Total	5	16	5	16	4	20	6	24	7	23	10	25	10	7	17	6	5	3	5	4	218	645	33.8

Legend: +: Exposure area > Reference area, -: Exposure area < Reference area

Note 1: None of the relationships, ie liver weight at age, gonad weight at age or fecundity at age, were reported to be significant in Cycle 2; these variables have been omitted from the table.

Note 2: For the sake of simplification, the "0" includes "ns" and "na".

When the Catostomidae are excluded, the significant differences (both negative and positive) are reduced or are of the same order of magnitude as for the other families. The Percidae (yellow perch, logperch, tesselated darter and Johnny darter) stand out for having the lowest relative number of significant comparisons, i.e. only 20%. The Cyprinidae show a relative number of significant relationships (34%) that lies between those of the two families mentioned above. The use of a given sentinel species may therefore have an influence on the number of effects observed.

The Abitibi-Consolidated mills in Baie-Comeau (PP1088) and La Baie (PP1561), along with the Spruce Falls mill in Matane (PP1201) (Table 10), also made comparisons for marine invertebrates, encompassing a total of five populations. These data cannot, however, be compared with those for fish populations. For the blue mussel and the bivalve *Macoma balthica*, two of the three organisms studied, shell calcification relative to internal volume appears to be lower in the exposure area. Female waved whelks show a tissue production to shell weight ratio that is higher in the exposure area. This caused an increase in the parameters that assess tissue weight in relation to shell weight or internal volume. Notwithstanding the brevity of the morphological analysis of these organisms, eutrophication effects appear to be present at the two marine sites where invertebrates were studied.

5.3.2.2 Response characterization

In the section above, the signs of significant differences were examined independently for each pair of variables, using an approach that seeks to integrate in a synthetic fashion elements that are considered separately. In the following sections, parameters in the same category have been grouped so that the available data can be analysed from a different angle with a greater degree of integration. The same comparative framework based on ANCOVA was employed to develop the methodology, and data from the same 33 studies were examined.

Table 10 Summary of ANCOVA analyses: morphometric relationships for marine invertebrates (Difference in %: Exposure area – Reference area).

Mill Name	Location	Common Name	Sex	Number Exposure area	Number Reference area	Length/ Age	Weight/ Age	Tissue Weight/ Internal Volume	Tissue Weight/ Shell Weight	Shell Weight/ Internal Volume	Number of significant comparisons	Total number of comparisons
Abitibi-Consolidated Company of Canada (PP1088)	Baie-Comeau	Blue mussel	h	88-90	89-90	ns	ns	12.3	ns	-11.8	2	5
Abitibi-	La Baie	Macoma	h	40-46	73-75	na	na	ns	18.4	-14	2	3
Consolidated Company of		Waved whelk	m	12	17-18	na	na	ns	na	ns	0	2
Canada (PP1561)		Waved whelk	f	28	20	na	na	ns	39.6	ns	1	3
Spruce Falls Inc. (PP1201)	Matane	Blue mussel	h	61	70	na	na	na	na	-17.2	1	1

Legend; f:Female, h: Hermaphrodite, m: Male, na: Not applicable, ns: Not significant, +: Exposure area > Reference area, -: Exposure area < Reference area

To characterize responses, the morphometric relationships were first divided into three groups. The pairs "length at age", "body weight at age" and "body weight at length" were grouped together using the qualifier "somatic (S)". The relationships "liver weight at length" and "liver weight versus body weight" were grouped under "hepatic (H)". The pairs "gonad weight at length", "gonad weight versus body weight", "fecundity at length" and "fecundity at body weight" were grouped under the qualifier "reproductive (R)". The partial redundance of the relationships was used to assess the amount of agreement among the statistical results and to allocate signs to each group. To ensure continuity with the previous section, we considered all the relationships significant regardless of the order of magnitude of differences observed (Table 9).

When in a given group the relationships showed a difference in the same direction, that is, a larger (+) or smaller (-) value in the exposure area or non-significant results (ns; 0) or where the methodology was not applicable (na), the corresponding symbol was assigned to the whole group. When various combinations were present within a group, we denoted them by means of the following signs:

1) A (for antagonistic) in those rare cases where the direction of the different pairs of relationships diverged (" + " and " – " at the same time);
2) + or - as appropriate, including combinations of + or -, accompanied by ns and/or na;
3) 0 when at least one ns occurred in combination with na.

A descriptive approach was adopted to characterize responses for the three groups. In general, the qualifiers "positive" (S^+, H^+, R^+), "negative" (S^-, H^-, R^-) and "no response" (S^0, H^0, R^0) were assigned to responses for groups with signs going in the same direction (" + ", " – ", " 0 ") whether or not accompanied or not by " 0 " or " na ". The qualifier "mixed" was employed when the " + " and " – " signs were parallel in the groups, whether or not accompanied by " 0 " or " na " (i.e. S^+, H^-, R^-). For a mixed response like the trend observed in Cycle 2 Canada-wide, that is, an increase in liver weight and fish size and a decrease in gonad weight, the category used is " mixed $S^+H^+R^-$". The category "indeterminate" was employed when all the groups had the notation "na". The overall responses for each fish population are given in Annex 8.

5.3.2.3 *Responses observed in fish populations in Quebec*

A wide range of responses was observed in the freshwater and marine sentinel species studied. When all the mills that submitted an ANCOVA analysis are taken into consideration, regardless of data quality, the response patterns seen for the 134 populations are as follows: no response for 27% of populations, positive response for 34%, negative response for 19%, mixed response for 12% with 5% being of the type $S^{+}H^{+}R^{-}$, and 8% indeterminate (Table 11). Hence, 65% of the populations showed an effect for at least one of the parameters measured. It should be noted that the vast majority of studies included in the national assessment on the basis of their compliance with the minimum requirements set out by Environment Canada showed effects in fish for at least one of the parameters examined (Munkittrick *et al.* 2002).

Table 11 Overall responses of the main freshwater fish families, separate sexes

Family (species)	No response	Positive	Negative	Mixed	Mixed $S^{+}H^{+}R^{-}$	Indeterminate	Total
Catostomidae (2)	16	18	15	2	5	4	60
Percidae (4)	12	10	2	3	0	3	30
Cyprinidae (4)	4	8	1	2	1	2	18
Other (8)	4	9	7	3	1	2	26
Total	36	45	25	10	7	11	134

In view of the considerable diversity involved, it seems appropriate to examine the degree of variability of the responses in relation to the families of fish and sentinel species selected (Table 11). The frequency with which at least one effect was observed varied according to the fish family, with 67% for the Cyprinidae and the Catostomidae and 50% for the Percidae (Table 11). Many types of responses were observed, reflecting the diversity of sentinel species used, the different industrial processes employed and site-specific characteristics. More characteristic responses were only observed within certain families.

Although the Percidae represent 23% of the populations combined (Table 11), they (yellow perch and Johnny darter primarily) account for nearly half of the zero responses, a little less than one quarter of positive responses and 12% of negative and mixed relationships grouped together. This family seems to respond more quickly to pollution cleanup efforts, or it may be less affected than the others, or the sentinel species selected were inadequate. In Saskatchewan, Swanson *et al.* (1996) were unable to detect any significant difference (gonadosomatic or hepatosomatic indices, growth parameters and enzyme induction) between two populations of walleye (*Stizostedion vitreum*), one of which was exposed to paper mill effluents. In contrast, according to national data from Cycle 2 EEM, yellow perch (*Perca flavescens*) displayed symptoms similar to those observed in fish in a situation of limited food resources (i.e. reduced relative liver weight and gonads). The species within the Percidae group show different reproductive strategies (i.e. yellow perch merely disperse their eggs whereas Johnny darters (*Etheostoma nigrum*) guard the nest) and they occupy different trophic levels (Scott and Crossman 1974). The use of Percidae as sentinel species may thus pose difficulties in interpreting results.

The family Catostomidae (white sucker and longnose sucker) shows similar numbers for each of the response categories, accounting for 44% of the zero responses, 40% of positive responses, 60% of negative responses and 44% of total mixed responses. This corresponds to the percentage (45%) it represents of the total number of subpopulations examined (Table 11). Negative responses of the type S^-, H^-, R^- were observed solely for white suckers (3 subpopulations), whereas the classical response S^+, H^+, R^-, previously found in white suckers (Munkittrick *et al.* 1991; Munkittrick *et al.* 1994), could only be identified in longnose suckers (3 subpopulations). A positive response (S^+, H^+, R^+) was seen in four subpopulations of white suckers, suggesting adaptability to enriched and polluted habitats. The diversity of responses observed in the Catostomidae confirms that these fish, which are widely used as sentinel species, are suitable candidates for studies characterizing the effects of aquatic contamination.

Despite the small number of observations for the family Centrarchidae (smallmouth bass and rock bass) (Annex 8), the frequency of responses is surprising since these fish are not considered suitable sentinels. This group stands out with regard to its reproductive characteristics (nest guarding, large eggs and *K* strategy) and its high trophic level (omnivorous predators with fish as a key dietary item) (Scott and Crossman 1974; Winemiller and Rose 1992). Borton *et al.* (1996) conducted tests in largemouth bass (*Micropterus salmoides*) and bluegill (*Lepomis macrochirus*), exposing them to kraft mill effluents for 263 days. Juveniles of these two species that were maintained in experimental streams exhibited significant differences in growth, morphology and reproduction parameters relative to control groups. Centrarchidae could prove to be useful candidates for studying effluent-induced effects.

Aside from effluent impacts, somatic variables (S) may be influenced by changes in the population size and age structures, environmental conditions, other pollution sources, food resource availability and interactions with other fish species, other organisms or the sampling effort itself (Gagnon *et al.* 1995; Munkittrick and McMaster 2000; Swanson *et al.* 1996). The hepatic variable (H) can be interpreted in various ways. The liver plays several roles simultaneously: it stores glycogen reserves and produces digestive enzymes; it serves as an important organ for detoxifying the body and for synthesizing blood constituents as well as for recycling metabolic wastes. Given its complex functioning, it is difficult to establish links to a single factor (Gibbons and Munkittrick 1994; Munkittrick *et al.* 1994 ; Munkittrick *et al.* 2000). Reproductive parameters (R) can vary with individuals (a better characterization of the maturity stage would be helpful), life cycle, reproductive strategies, sampling period in relation to breeding season and environmental factors (Gagnon *et al.* 1995; Sandström 1996; Munkittrick and McMaster 2000; Munkittrick *et al.* 2000). Annex 8 provides a more detailed description of the types of responses observed. Cycle 3 studies will provide an opportunity to examine the usefulness of this type of response classification and to re-assess temporal variability.

5.3.2.4 *Comparison of responses for the first two cycles*

Cycle 1 focussed on validating the study protocols, determining the variability of the parameters, defining the required sample size and conducting a preliminary assessment of effluent effects on target species (Langlois and Dubuc, 1999). By taking into account the most reliable results—those based on a sample consisting of at least 20 individuals in both areas during both cycles—the responses obtained at 11 mills can be compared (Table 12). Although it is difficult to evaluate the representativeness of the mills selected or the resulting portrait, this preliminary approach could assist in developing the framework to be used in future comparisons. For comparison purposes, we applied the same response classification system to the Cycle 1 data reported by Langlois and Dubuc (1999).

Six of the 11 mills that used the same species in both cycles gave results for both sexes, while five mills provided results for one of the sexes. Only four species underwent monitoring in cycles 1 and 2: white sucker, longnose sucker, brown bullhead and yellow perch (Table 12). The fish studied at the Amos (PP1184), Donnacona (PP1092) and Windsor (PP1148) mills showed no response in Cycle 1 (Langlois and Dubuc, 1999) but they exhibited numerous effects in Cycle 2. In the other cases, the patterns seen were status quo [East-Angus (PP1117) and Shawinigan (PP1135)], new effects [Beaupré (PP1091) and Saint-Félicien (PP1106)], a decrease in or disappearance of effects [Saint-Antonin (PP1182), Saint-Jérôme (PP1198) and Thurso (PP1086)] or an inability to compare findings [Cabano (PP1114)]. The information was insufficient for a comprehensive assessment, with only three mills appearing to show an improvement in conditions between cycles 1 and 2.

Many changes occurred between the cycles that may be a key to interpreting the results. Three studies out of the 11 mills selected took place in Cycle 1 before secondary treatment was operational and so they involved a situation of exposure to effluent that had received only primary treatment. In some cases, study protocols or the reference and exposure areas were changed, and in others sampling was carried out on different dates or the fishing periods were separated by more than three weeks (Table 12). Following the installation of secondary treatment systems designed to improve effluent quality, beneficial effects on sentinel species have yet to be observed. The improvement in the receiving environments is recent and future EEM cycles may shed light on how these changes have affected the health of the fish. For example, the mean age of the white suckers sampled in Cycle 2 is about 6 years; hence the same cohorts are likely to be sampled again in future cycles because this species has a lifespan of more than 20 years.

Table 12 Comparison of the responses seen in sentinel fish species between Cycle 1 and Cycle 2 (sample size ≥ 20).

Mill Name	Location	Sentinel Species	Sex	Response observed in Cycle 1	Response Observed in Cycle 2	Secondary treatment in C1	Changes made To protocols Between cycles	Duration of sampling In Cycle 1 (days)	Duration of sampling In Cycle 2 (days)
Abitibi-Consolidated Company of Canada (PP1184)	Amos	Brown bullhead	m	S^0, H^0, R^0	S^+, H^+, R^+	yes	Reference area	6	6
		Brown bullhead	f	S^0, H^0, R^0	S^0, H^+, R^0		Relocated 11 km upstream		
Abitibi-Consolidated Company of Canada (PP1091)	Beaupré	Longnose sucker	f	S^-, H^0, R^0	S^-, H^-, R^0	yes	None	4	29
Norampac Inc. (PP1114)	Cabano	White sucker	f	S^0, H^+, R^+	S^+, H^{na}, R^0	yes	New exposure area sampled	7	6
Bowater Canadian Forest Products (PP1092)	Donnacona	Longnose sucker	m	S^0, H^0, R^0	S^+, H^+, R^-	yes	Reference area	6	15
		Longnose sucker	f	S^0, H^0, R^0	S^0, H^0, R^-		Relocated 10 km upstream		
Cascades East-Angus Inc., Cartech Division, Paperboard Industries Corp. (PP1117)	East-Angus	White sucker	f	S^+, H^+, R^+	S^+, H^+, R^+	yes	None	5	23
Abitibi-Consolidated Company of Canada (PP1135)	Shawinigan	White sucker	m	S^-, H^0, R^-	S^-, H^+, R^-	no	New reference area sampled	6	8
		White sucker	f	S^-, H^-, R^-	S^-, H^0, R^-				
Mohawk Pulp Ltd (PP1182)	St-Antonin	White sucker	m	S^-, H^-, R^-	S^0, H^0, R^0	na	None	7	5
SFK Pulp (PP1106)	St-Félicien	Brown bullhead	m	S^0, H^{na}, R^{na}	S^-, H^-, R^0	yes	New reference area sampled	9	16
		Brown bullhead	f	S^0, H^{na}, R^{na}	S^{na}, H^-, R^0				
Cascades Fine Papers Group Inc. (PP1198)	St-Jérôme	White sucker	m	S^+, H^+, R^0	S^0, H^0, R^0	no	None	4	4
Fraser Nexfor Papers (PP1086)	Thurso	Yellow perch	m	S^A, H^+, R^0	S^-, H^+, R^0	no	New reference area sampled	3	15
		Yellow perch	f	S^-, H^0, R^0	S^0, H^0, R^0				
Domtar Inc. (PP1148)	Windsor	White sucker	m	S^0, H^0, R^0	S^-, H^0, R^-	yes	None	8	15
		White sucker	f	S^0, H^0, R^0	S^0, H^0, R^0				

Legend: f: Female, m: Male

5.4 *Results of research studies*

Six mills undertook research projects to address specific questions about the suitability of the bioindicators or to compare possible alternatives to the EEM approach. These projects focused on four different species (white sucker, yellow perch, Johnny darter and tesselated darter) in two hydrographic systems (Ottawa and Saint-François rivers). At Gatineau (PP1118), Masson-Angers (PP1153) and Thurso (PP1086), separate studies were carried out and the conclusions were presented separately (McMaster *et al.*, 2000b; McMaster and Munkittrick, 2000; McMaster *et al.*, 2000a). At Bromptonville (PP1131), East-Angus (PP1117) and Windsor (PP1148), separate studies were done but combined analyses and conclusions were presented for the Saint-François River (Kovacs *et al.*, 2001). For the two rivers, the morphological analyses typically done in EEM studies were conducted in conjunction with the measurement of sex hormones and hepatic mixed function oxidase enzymes (MFO). In the Saint-François River, the suitability of a health status indicator was evaluated, and the EEM approach based on the use of sentinel species was compared with the study of fish communities.

With respect to the measurement of biochemical parameters in fish, the research projects provided little information of use for the EEM program (Table 13). Although results were obtained from different locations for a given hormone or enzyme, methodology differences preclude direct comparison. No conclusions can be drawn regarding differences between the sexes or the temporal and spatial variability of all the data, or the general significance of the differences observed. The most surprising finding pertains to hepatic activity as measured in the Saint-François River basin: when a significant difference is observed, the results pointing to enzymatic induction are lower in the exposure area. Between 1994-1995 and 1998, the small number of significant relationships in hepatic activity that had previously been observed were no longer detectable. The information is not consistent with earlier research showing increased hepatic activity in connection with paper mill discharges.

Table 13 Difference (%) between fish species in the exposure area and the reference area with respect to steroid production and hepatic enzyme activity

Mill Name	Location	Year, Study Authors	Sentinel Species	Sex	11 Ketotestosterone	Testosterone	17B Estradiol	Hepatic Activity MFO (EROD)
Kruger Inc. (PP1131)	Bromptonville	1995, Kovacs *et al.* 2001	White sucker	m	not measured	ns	Not measured	-56.1
			White sucker	f	not measured	ns	ns	-60.8
		1998, Kovacs *et al.* 2001	White sucker	m	not measured	ns	Not measured	ns
			White sucker	f	not measured	ns	22.5	ns
Cascades East-Angus Inc., Cartech Division, Paperboard Industries Corp. (PP1117)	East-Angus	1998, Kovacs *et al.* 2001	White sucker	m	not measured	27.9	Not measured	ns
			White sucker	f	not measured	46.3	42.3	ns
Domtar Inc. (PP1148)	Windsor	1994, Kovacs *et al.* 2001	White sucker	m	not measured	ns	Not measured	ns
			White sucker	f	not measured	40.4	37.2	-35.6
		1998, Kovacs *et al.* 2001	White sucker	m	not measured	ns	not measured	ns
			White sucker	f	not measured	ns	ns	ns
Bowater Canadian Forest Products Inc. (PP1118)	Gatineau	1998, McMaster *et al.*, 2000b	Yellow perch	m	ns	ns	Not measured	ns
			Yellow perch	f	not measured	ns	ns	ns
			Johnny darter*	m	-57	ns	Not measured	Not measured
			Johnny darter *	f	not measured	-44	ns	Not measured
Masson Paper Ltd (PP1153)	Masson-Angers	1997, McMaster and Munkittrick, 2000	Yellow perch	m	-54.2	not measured	Not measured	ns
			Yellow perch	f	not measured	not measured	-49.4	-45.6
			Johnny darter*	f	not measured	34.6	53.3	ns
		1998, McMaster and Munkittrick, 2000	Yellow perch	f	not measured	ns	ns	Not measured
Fraser Nexfor Papers (PP1086)	Thurso	1997, McMaster *et al.*, 2000a	Yellow perch	m	ns	ns	Not measured	ns
			Yellow perch	f	not measured	ns	ns	ns
			Johnny darter*	m	ns	-	Not measured	Not measured
			Johnny darter*	f	not measured	ns	ns	Not measured

Legend: ns: not significant, -: lower in the exposure area, +: higher in the exposure area, m: male, f: female, MFO: mixed function oxidase, EROD: ethoxyresorufin-o-deethylase, *: May include *E. olmstedi.*

Note 1: Kruskal-Wallis or Mann-Whitney tests were used to detect significant differences.

Note 2: None of the studies cited above reported the number of male and female specimens used in the tests.

With regard to testosterone and 17ß-estradiol levels in the blood plasma of white suckers, significant differences disappeared at Windsor whereas the opposite pattern is observed at Bromptonville. The steroid results are not always in agreement with the EEM results. For example, female suckers in the exposure area at Bromptonville had reduced gonad and fecundity values relative to the reference area, whereas hormonal activity appeared to be higher there. The hormone and enzyme activity test results for the Ottawa River do not appear to be consistent with the monitoring study results. It therefore appears that these indicators cannot readily be used in the EEM program. Additional pilot studies should be set up during future cycles before these indicators can eventually be integrated with the customary measurement parameters for EEM.

A health assessment index (HAI) was used to compare populations in the exposure area and the reference area of the three mills on the Saint-François River (Kovacs *et al.* 2001). The protocol developed by Adams *et al.* (1993) was employed; however, the external and internal examinations were supplemented with other observations and an analysis of blood parameters, all of which were incorporated into the calculation of metrics. The HAI is defined based on the variation from mean values, with a low index most closely approximating a normal state of health. In 1998, sampling was conducted at the three mills and the data for the two sexes were grouped. White suckers, which were caught at all three sites, showed a significantly higher HAI in the exposure area at East-Angus and at Bromptonville. A comparison of these results with the Cycle 2 EEM results for the same species reveals that at Bromptonville gonad and fecundity values were lower in the exposure area, and at East Angus the liver and body weight values for suckers were higher in the exposure area. Smallmouth bass, which were sampled at Windsor only, exhibited a better health condition than white suckers, but the index values did not differ statistically between the exposure area and the reference area, a finding which is fairly consistent with the EEM results. Surprisingly, in the case of tessellated darters—used as a sentinel species at East-Angus and Bromptonville only—the exposure area stations had a HAI closer to the normal value than did the reference area stations. This finding is in keeping with the EEM results at Bromptonville; however, at East Angus, the gonad, liver and weight values for the darters were higher in the exposure area. A temporal comparison can only be made for white suckers, which were sampled at Bromptonville in 1995 and 1998.

While no significant difference was observed in the exposure area between the two periods, the index decreased at the reference area station. Distinct sensitivity levels among the sentinel species and the smaller number of parameters used in the HAI calculation for tesselated darter may pose interpretation problems. Despite all the differences observed, some links were established with the EEM results and paper mill effluents.

A biotic integrity index (BII) was computed for the Saint-François River from surveys conducted using an electrofishing method standardized in 1998. This approach follows the methodology developed by Karr (1981) for studying fish communities in small rivers and streams of the United States. A temporal comparison was made possible by applying the protocol that Richard (1996) had used in 1991 on this river, with fishing being conducted along two 500 m stretches encompassing both banks at each station. At East-Angus and at Bromptonville, the BII went from "poor" in 1991 to "good" in 1998, whereas at Windsor it went from "moderate" to "good" during the same period. Although these results point to an improvement in community structure at the three sites based on the metrics defined for the index, they could also be linked to the general improvement in water quality in this river basin. The increase observed in community species diversity and in the number of pollution-sensitive species in the receiving environment between 1991 and 1998 are not studied during EEM. The EEM results for white suckers—the sentinel species selected at the three mills—do not indicate an improvement in the environment (see Table 12). This finding, obtained with both approaches, underscores the difficulty of extrapolating morphometric results for one or two species to the entire fish community.

5.5 Chemical tracers of exposure

An exposure tracer is useful when fish can swim freely between the exposure area and the reference area, with no obstacles to block their movement. Confirmation of the exposure of fish to paper mill discharges had to be done through the analysis of resin acids in cases where the concentrations of these acids in the effluent amounted to at least 50 µg/L. Three composite bile samples were used for each area, each consisting of three to nine fish.

Only five mills were required to measure the resin acid concentrations in their effluents, the aquatic receiving environment and the reference area as well as in the bile of a sentinel species (Table 14). The total resin acid concentrations ranged from 50 to 157 µg/l in the effluents studied. Resin acids were not detected in the exposure areas but they were found at a low concentration in the reference area of only one site. These concentrations are probably natural in origin. Decomposing wood can be a major source of resin acids (Plam et al., 1995). The mean concentrations in fish bile from the exposure area were higher at three of the five sites, which had values ranging from 10 to 87 µg/g compared with a range of 0.3 to 1.5 µg/g at the other two locations. These results confirm that fish in the exposure area were indeed exposed to the effluent plume at the three mills. Furthermore, a number of significant differences were detected between the exposure area fish and the reference area fish at those mills.

Despite the much smaller sample sizes in Cycle 2, a substantial decrease can be seen in the mean resin acid levels in effluents, exposure area water and fish bile. In Cycle 1 (n=29), the mean concentrations were 1047 µg/L in effluents, 159 µg/L in the exposure area, 57 µg/g in fish bile from the exposure area and 10 µg/g in fish bile from the reference area (Langlois and Dubuc, 1999). Since the installation of secondary treatment systems has reduced resin acid loading to the effluent, causing a decline in concentrations in the receiving environment and in fish bile, it follows that very few mills can now use these substances as tracers.

Table 14 **Total resin acid concentrations in the effluent, in the water of the reference and exposure areas, and in the bile of sentinel fish species**

Mill Name	Location	Common Name	Water from effluent (µg/L)	Water from Reference area (µg/L)	Water from exposure area (µg/L)	Mean concentration In the bile of fish from the Reference area (µg/g)	Standard deviation reference area (µg/g)	Mean concentration In the bile of fish Exposure area (µg/g)	Standard deviation exposure area (µg/g)
Bowater Canadian Forest Products Inc.	Donnacona	Longnose sucker	50.4	11.3	not detected	0.36	0.22	0.33	0.12
Smurfit-Stone Container (Canada) Inc.	La Tuque	White sucker	66.8	not detected	not detected	2.24	1.54	1.54	1.19
Mohawk Pulp Ltd	St-Antonin	White sucker	112.3	not detected	not detected	6.97	9.56	14.20	4.95
SFK Pulp	St-Félicien	Brown bullhead	109.3	not detected	not detected	16.67	2.52	86.67	83.77
Tembec Inc.	Témiscaming	White sucker	157	not detected	not detected	0.14	0.02	10.37	2.37
		Means	99.16			5.28		22.62	

5.6 *Analysis of chlorinated dioxins and furans and of polychlorinated biphenyls in fish*

Paper mills using elemental chlorine bleaching are required to monitor the levels of dioxins and furans in fish tissues. Standards for human consumption, which are established by Health Canada, correspond to a maximum of 15 pg/g of toxic equivalents of the congener 2,3,7,8-TCDD in fish tissues.

In Cycle 2, the Smurfit-Stone Container mill in Portage-du-Fort (PP1102) is the only facility that had to assess dioxin and furan levels in sport fish (walleye) tissues, whereas in Cycle 1 nine mills were required to do so. Toxic equivalent levels of 0.006 pg/g were found in the six composite samples of female walleyes from the exposure area, compared with TEQ levels of 0.002 and 0.014 pg/g being detected in the 20 samples from the two reference areas (Annex 9). These concentrations fall within the Health Canada guideline of 15 pg/g. In Cycle 1, the 2,3,7,8 TCDD toxic equivalents in channel catfish at Portage-du-Fort were found to be 0.21 pg/g in the reference area and 0.28 pg/g in the exposure area (Langlois and Dubuc, 1999). Changes to mill processes and effluent treatment systems over the years have resulted in a major decrease in releases of dioxins and furans in the pulp and paper industry as a whole (Luthe, 1996).

5.7 *Fish tainting evaluation*

The procedure for evaluating sensory characteristics (odour, flavour or abnormal colour) of fish relates directly to human aspects of the use of fishery resources. It is carried out only when certain conditions are met: a verbal or written complaint has been made to the proper authorities (ministère de l'Environnement du Québec or the federal Department of Fisheries and Oceans), the fish tissues do not contain contaminant levels exceeding the guideline for human consumption and a sensory evaluation if one has been done, has detected a problem.

In Cycle 2, the Tembec mill at Temiscaming was the only Quebec facility that had to conduct a sensory evaluation of tainting (taste) on the flesh of walleye. A 30-minute recruitment session was used to set up an initial panel of 13 taste testers with expertise in foods other than fish.

Three training session of 30 to 40 minutes enabled the tasters to familiarize themselves with the stimuli associated with walleye in a fish shop while also serving to decrease the aroma perception threshold. The four qualification sessions (of 15 minutes) permitted evaluation of the tasters' individual reliability from one session to the next and measurement of variability among the tasters. During the qualification phases, difference from control tests (DFC) were employed by using control samples and samples exposed to different effluent concentrations (E1%, E5% and E20%). Two additional training sessions (30 minutes) were held, identical with the final tests, to allow the tasters to familiarize themselves further with the stimuli associated with walleye.

Analysis of walleye tainting was done in three sessions (15 to 20 minutes) and all the available samples were used. For comparison, an analysis of variance (ANOVA) was performed on the difference between the measured values and the control values (DFC). The tainting results showed a significant difference between the flavour of walleye taken from the mill's exposure area and that of walleye fished in the reference area. The study mentions "an unpleasant off-flavour" for fish caught in the effluent mixing zone. The results of the contrast test (exposure-reference, α=0.05 and p=0.0469) are significant, regardless of whether the seven tasters who performed best during testing are considered or all thirteen tasters on the original panel. (GDG CONSEIL INC., 2000).

6 Benthic community survey

6.1 Objectives

The benthic community survey is aimed at determining the magnitude and extent of fish habitat degradation associated with pulp and paper mill effluents and, where possible, evaluating the impacts on the food resources (or habitat) of the fish chosen as sentinel species in the fish survey (Environment Canada, 1998). Effects are assessed by determining whether structural differences (abundance, number of taxa, diversity and evenness) exist in the benthic communities of the aquatic environment in which pulp and paper mill effluents are discharged.

With Cycle 1 serving as a baseline, the benthic community survey of each subsequent cycle can be used to ascertain whether there has been an improvement or a deterioration in fish habitat by comparing the results between cycles. It is also used in determining whether there is a need to refine the sampling design for following cycles or to adopt an alternative strategy where suitable.

Benthic invertebrates are generally good indicators of the health of fish habitat, and variations in abundance or community structure are often indicative of disturbances caused by contaminants and anthropogenic or environmental stressors. Paper mill effluents can have impacts on the diversity and abundance of benthic invertebrates (Lowell *et al.*, 2003). Potential effects of these effluents on benthic fauna include organic and nutrient enrichment, inhibition due to toxic substances and substrate smothering. At low or moderate levels, organic enrichment and nutrient inputs promote an increase in the abundance of numerous taxa (Pearson and Rosenberg, 1978; Lowell *et al.*, 1996; Culp *et al.*, 2000). Marked organic enrichment may contribute to a reduction in the number of taxa by affecting the organisms that are more sensitive to eutrophication. Some effluent constituents can have an inhibitive effect (Lowell *et al.*, 1996). Organic enrichment and the toxicity of some effluents can have simultaneous effects on the receiving environment, with one effect sometimes masking another (Culp *et al.*, 2000). Toxic effluent reduces the abundance and diversity of benthic organisms (Pearson and Rosenberg, 1978; Hellawell, 1986). The discharge of a large amount of organic matter can lead to substrate smothering and the degradation of this matter can create anoxic conditions which will have effects similar to a toxic effluent (Pearson and Rosenberg, 1978; Bonsor *et al.*, 1988).

6.2 *Requirements and methods*

The basic requirements for designing a benthos survey for EEM are as follows: the area of exposure to mill effluent and the reference area must be located in very similar habitats and the exposure area must be situated in the zone where the effluent mixes with the receiving water, resulting in an effluent concentration greater than 1%.

Of the 48 studies done in Cycle 2, 6 mills did not conduct a benthic community survey. The main reasons given were the very limited extent of the effluent plume and the impossibility of conducting sampling in the receiving environment owing to safety concerns (current too strong, effluent in the St Lawrence Seaway) or because of an incompatibility between the sampling gear and the substrate (absence of sediments and water too deep).

Of the 42 benthic community surveys done in Cycle 2, 37 were done at mills that release their effluent into fresh water; they used a control/impact design (exposure area downstream and reference area upstream). As a rule, the basic protocol consisted in sampling benthic fauna in a reference area, a near-field exposure area and a far-field exposure area. To accurately measure the spatial extent of effluent effects, some mills had to delineate a zone extending over a considerable distance, a far – far field exposure area (5 cases in Cycle 2). When an exposure area contained different types of habitats, the number of reference areas could be increased to permit comparisons between reference and exposure areas with a similar habitat. In Cycle 2, 13 surveys comprised 2 reference areas whereas 2 others comprised 3 areas. At least five stations were established in each area, with two subsamples being collected at each station. Whenever possible, the mills made benthos collections at the stations already sampled in Cycle 1.

Five surveys were carried out by mills that discharge to the marine environment; they used a linear gradient design. Stations were sited along one or two effluent exposure gradients, with additional stations established outside the mixing zone. These gradient studies will be summarized in Section 6.4.

The sampling period in Cycle 2 was similar to that of Cycle 1 on the whole. Benthos sampling was generally carried out in late summer, that is, during the period of maximum biological diversity. The sampling equipment used varied with the substrate type characterizing the targeted areas. A grab sampler was typically used to sample fine sediments (sand, silt and clay), such as in the three studies conducted in the marine environment. Hess or Surber samplers were used for gravel, mixed or rocky substrates. Where the substrate was very heterogeneous and the water depth precluded the use of a Hess or Surber sampler, artificial substrates (Hester-Dendy type) were installed. Two (or three in some cases) artificial substrates were laid out at each station. These substrates were left submerged for about six weeks, then collected and processed in the laboratory.

A standardized sample processing method was applied in the majority of studies, enhancing the comparability of the benthos results. Sieving was done using 0.5 mm mesh for freshwater samples and 1 mm mesh for marine samples. In many cases, sample fractioning was carried out when there was a high abundance of organisms in the sieved samples. The final abundance matrices were drawn up taking into account the different fraction sizes; this caused errors in the calculation of total densities in some studies.

The level of taxonomic precision identification, as specified in the Technical Guidance Document, was respected for the most part. Reference collections of benthic organisms were created in the majority of studies. These collections were sent to known experts for taxonomic verification purposes. Corrections were usually incorporated by the mills in the final version of the abundance matrices. In accordance with the Guidance Document, the unit variables measured were total density (number of benthic organisms per square meter of substrate sampled), taxon richness (number of taxa per sample), the Shannon-Weiner diversity index and Pielou's index of evenness (Zar, 1996). The sampling results are presented in annexes 10 and 11.

The methods used to process the data were primarily statistical tests aimed at determining whether there was a significant difference in the values obtained for each unit variable between the reference area and the corresponding exposure area(s). A significant difference of this type is indicative of an effluent effect on the exposed benthic communities. The other most commonly performed statistical analyses were multivariate analyses of the reduced space ordination type (correspondence analysis, AC, or principal components analysis, PCA).

6.3 Results of the freshwater benthos surveys

In Cycle 2, most of the mills successfully conducted a benthos survey that met all the requirements of the program. Only four mills out of the 41 EEM studies completed in fresh water did not undertake a benthos survey and two others submitted incomplete results (Figure 11). There are also two surveys that were conducted in different habitats. Twenty-two benthos surveys showed statistically significant differences between the reference and exposure areas for at least one of the benthic indicators (abundance, richness, diversity or evenness), whereas no significant differences were found for 11 mills. Among the latter, only one was able to conclude that there were no effects. Eight others identified structural differences in the benthic communities between the exposure and reference areas on the basis of correspondence analysis, suggesting a potential effluent effect. In two studies, no conclusions could be drawn because the entire study area was affected by multiple discharges of municipal effluent.

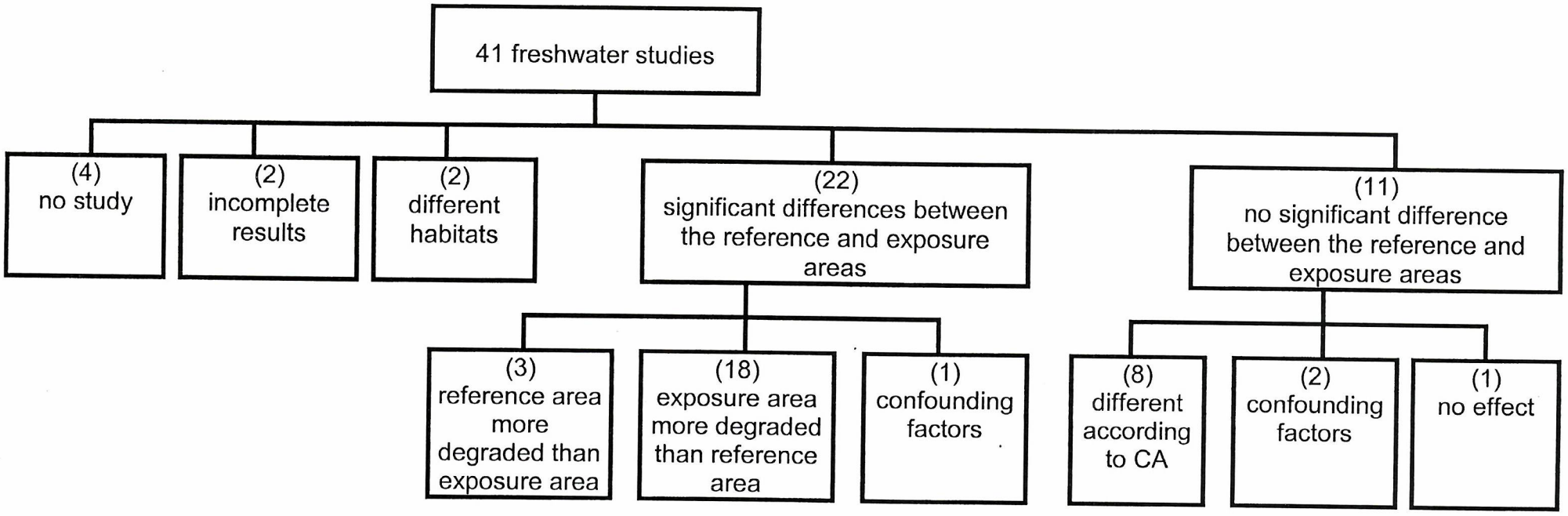


Figure 11 Summary of the results of the Cycle 2 freshwater benthic community surveys in Quebec

Eighteen of the 22 studies that found differences between the areas showed that the benthos in the exposure area was affected to a greater extent than that in the reference area. For the most part, these studies identified differences in abundance which are potentially linked to the paper mill effluents, at least in the near-field area, given the absence of other pollution sources. However, in the far-field area, 7 of 18 studies mentioned the presence of municipal effluents which could mask the potential effects of the paper mill effluents. By contrast, 3 studies showed that the reference area benthos was degraded to a greater degree than the exposure area benthos, while only one study failed to reach a conclusion owing to the existence of confounding factors (i.e. contaminated sediments throughout the study area). As in data analysis for Cycle 1, we wanted to examine the benthic indicator results by considering effect size to determine whether the effect observed for a given variable was ecologically significant. It is necessary to base the effect size on the difference from the normal variability observed in reference areas. The variability measure most widely used in the literature is equal to twice the standard deviation of the mean of a given variable in the reference area (Lowell, 1997). If for a particular variable, the mean for the exposure area is higher or lower by at least twice the standard deviation than that for the reference area, it can be assumed that the measured difference is ecologically significant. Analysis of the Cycle 2 EEM results revealed that this effect size is very useful for distinguishing between major and minor impacts of paper mill effluents on the receiving environment (Lowell *et al.*, 2003).

Most of the 33 studies did not show differences between the areas for the four variables measured in the freshwater benthos surveys. However, nearly 40% of the studies indicated that mean density in the exposure area was higher by at least twice the standard deviation than the mean for the reference area (Figure 12). In terms of taxon richness and diversity, 7 and 6 studies respectively reported a mean for the exposure area that was higher than that for the reference area. With regard to evenness, the number of studies that reported higher values for the exposure area was almost equal to the number showing lower values.

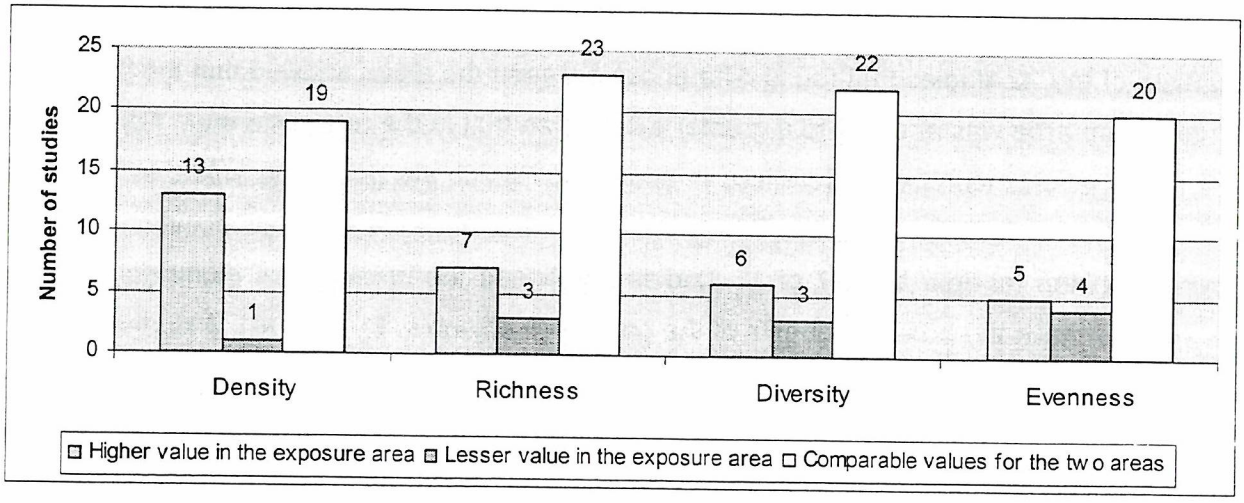


Figure 12 Number of studies reporting differences in benthos density, richness, diversity or evenness equal to at least twice the standard deviation of the mean obtained for the reference area in Cycle 2

The results of the 33 complete benthic community surveys for which the habitats in the exposure and reference areas were comparable were analysed by taking into account the dominant habitat type (sedimentation or erosion) in the receiving environment and the natural variability in the different ecoregions where the mills are located (Langlois and Dubuc, 1999) or the type of effluent treatment. The following sections synthesize these analyses.

6.3.1 Density, taxon richness, diversity and evenness relative to the type of sampling equipment used

Habitat type, characterized mainly by the substrate, current speed, the presence of vegetation, and water depth, plays a prime role in benthic community structure (Davis and Lathrop, 1992). Therefore, it is important to carefully select the reference area during the study design phase. The benthic fauna in fast moving (lotic) waters collected with a Hess sampler will be very different from the community typifying slow moving (lentic) waters sampled with a grab sampler. We wanted to examine the Cycle 2 data from this standpoint. For all areas collectively, mean density of the benthos sampled with a grab sampler was higher than that collected with a Hess or Surber sampler (Figure 13). Regardless of the equipment used, density was found to be of the same order of magnitude in the reference area, except with artificial substrates used in the far-field reference area. In the latter case, density was found to be lower.

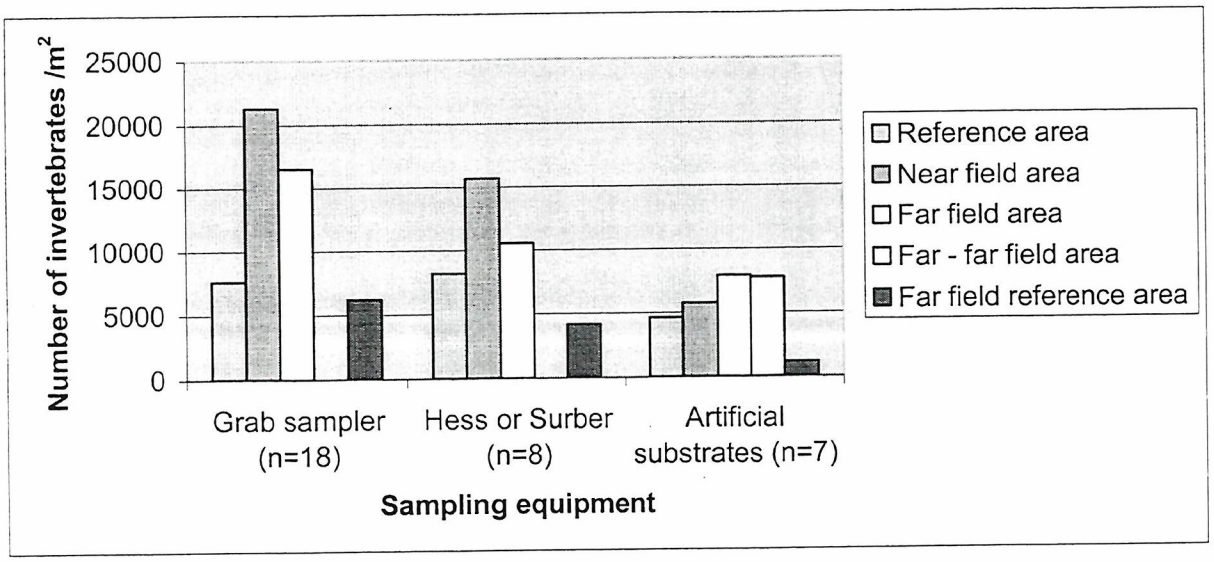


Figure 13 Mean density of benthic invertebrates by equipment type and study area in Cycle 2

It should be noted however that sample size was small in the latter case (n=2). Density tended to be higher in the exposure area than in the reference area particularly for equipment used to sample the natural substrate (grab sampler, Hess and Surber). The difference was less pronounced with artificial substrates. It should be kept in mind that these types of equipment are selective in that they only sample drifting or mobile organisms and not those on or in the sediment. In the case of natural substrates, benthos density appeared to be higher in the near-field exposure area than in the far-field exposure area. These results tend to confirm that fish habitat in the exposure area was more often degraded than that in the reference area.

With regard to taxon richness, benthos sampled with a grab sampler showed a smaller number of taxa than that obtained with other types of equipment (Figure 14). This finding may be explained by the fact that unconsolidated sediments feature less habitat diversity as compared with the lotic environment, which features a variety of microhabitats. In general, small differences were found between the reference and exposure areas. There was a difference, however, in taxon richness between the far-field reference area and the other areas sampled with Hess and Surber samplers. A marked difference in taxon richness can be observed between the far-field exposure area and the other areas in which benthos was sampled using artificial substrates. It is important to note that sample size was very small in the latter two cases.

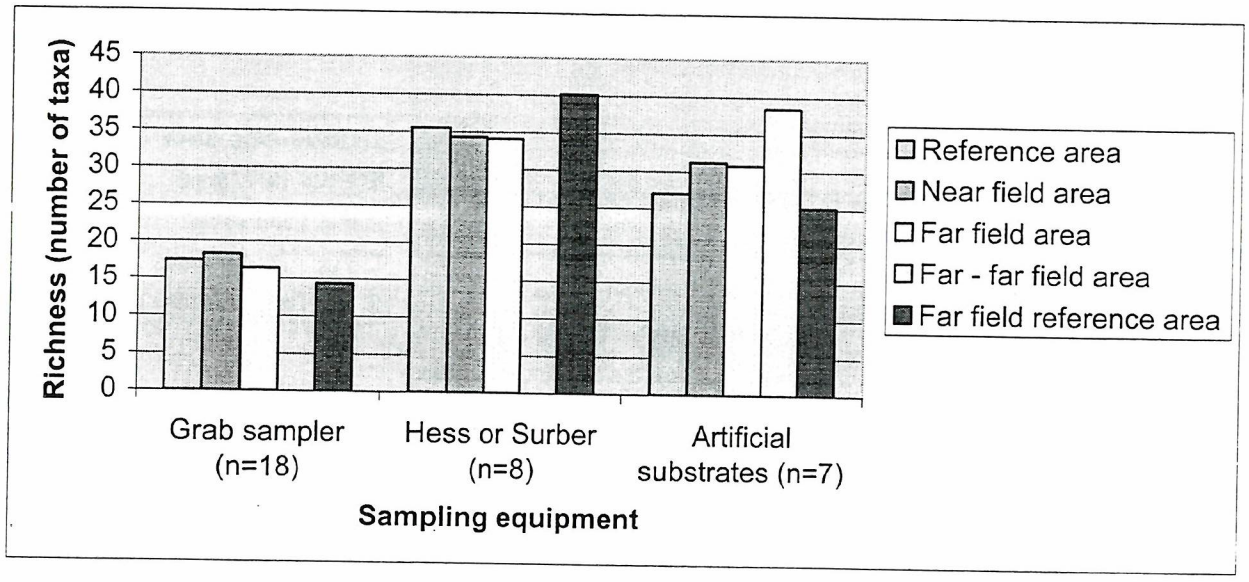


Figure 14 Mean number of benthic invertebrate taxa by equipment type and study area in Cycle 2

Diversity is reflected in the taxon richness results for benthos collected with a grab sampler (Figure 15). Diversity was lower for benthic communities sampled using a grab sampler versus the Hess and Surber samplers or even artificial substrates. No marked differences are seen between the reference areas and the exposure areas, except for data from far-field reference areas, which show slightly lower values than do the other areas (Hess, Surber equipment and artificial substrates). Note that homogeneity was observed for most of the diversity values for benthos colonizing artificial substrates.

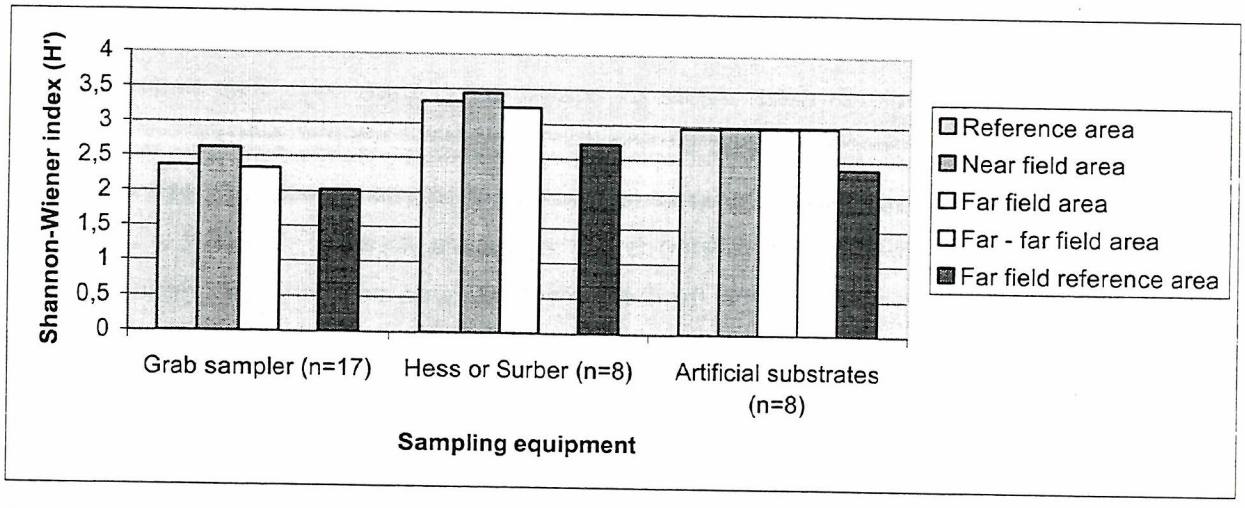


Figure 15 Mean diversity of benthic invertebrates by equipment type and study area in Cycle 2

There were no appreciable differences in the mean evenness values for benthic communities from one equipment type to another or from one area to another (Figure 16), with the exception of the slightly lower values recorded for benthos sampled with a grab sampler. Because of the slight variations in diversity and evenness values and the limited additional information, the following sections will focus solely on density and taxon richness.

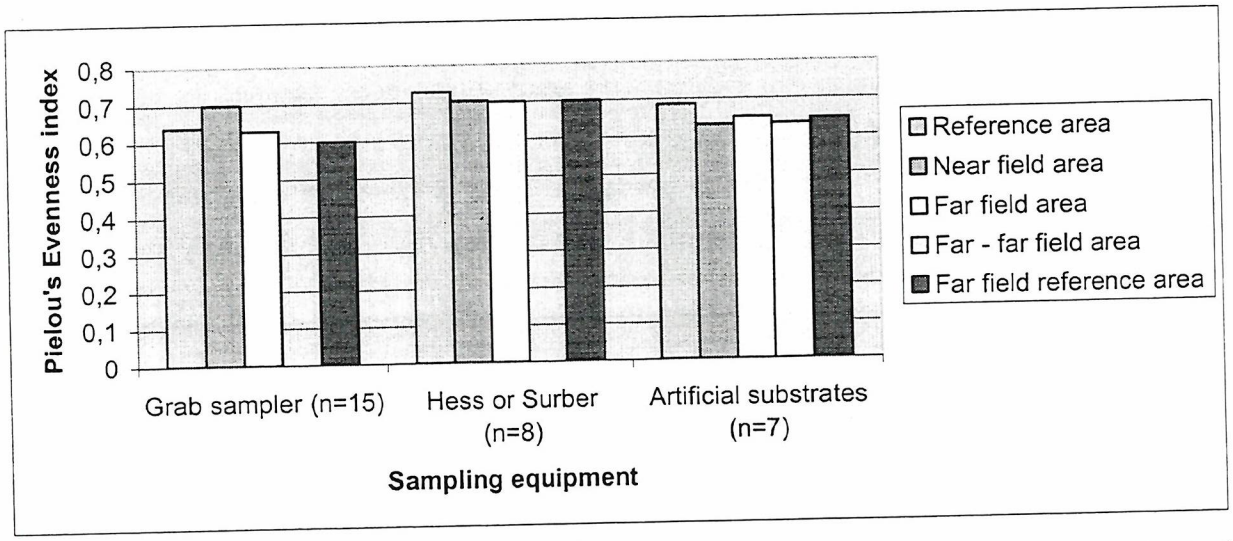


Figure 16 Mean evenness of benthic invertebrates by equipment type and study area in Cycle 2

6.3.2 *Density and taxon richness of the benthos in relation to ecoregions*

One of the recommendations that emerged from the assessment of Cycle 1 results was that ecozones and ecoregions should be taken into consideration in developing a benthos sampling strategy (Environment Canada, 1997d). Ecoregions are geographic subdivisions of ecozones—ecosystems that cover extensive areas and that can be differentiated on the basis of characteristics such as climate, relief, soils, vegetation, fauna and human activities. An ecoregion is characterized by distinct assemblages of multispecies communities. In light of the considerable variability in benthos habitats seen across the studies, it was deemed appropriate to analyse the benthos survey results in relation to their geographic distribution. In Quebec, the paper mills that discharge their effluent to fresh water are located in five ecoregions: Abitibi Plains, Southern and Central Laurentians, Appalachians and St Lawrence Lowlands. The Cycle 1 synthesis also examined the results of benthos surveys in relation to the distribution of the mills in these same ecoregions (Langlois and Dubuc, 1999).

A brief analysis of the results (figures 17 and 18) shows that there were appreciable variations in mean density and taxon richness in Cycle 2 from one ecoregion to the next. The general pattern observed, excluding the St Lawrence Lowlands, is a sharp increase in mean density in the exposure area relative to the reference area (Figure 17).

As in Cycle 1, mean taxon richness increased in Cycle 2 in an order corresponding to the following ecoregions: Abitibi Plains, Southern Laurentians, Central Laurentians, St Lawrence Lowlands, Appalachians (Figure 18). Richness in each region even seemed to be higher in Cycle 2. This finding can be explained by environmental variations as well as methodology differences, with methodology being better overall in Cycle 2. Mean richness was appreciably higher in the exposure area than in the reference area in a few regions, particularly in the Abitibi.

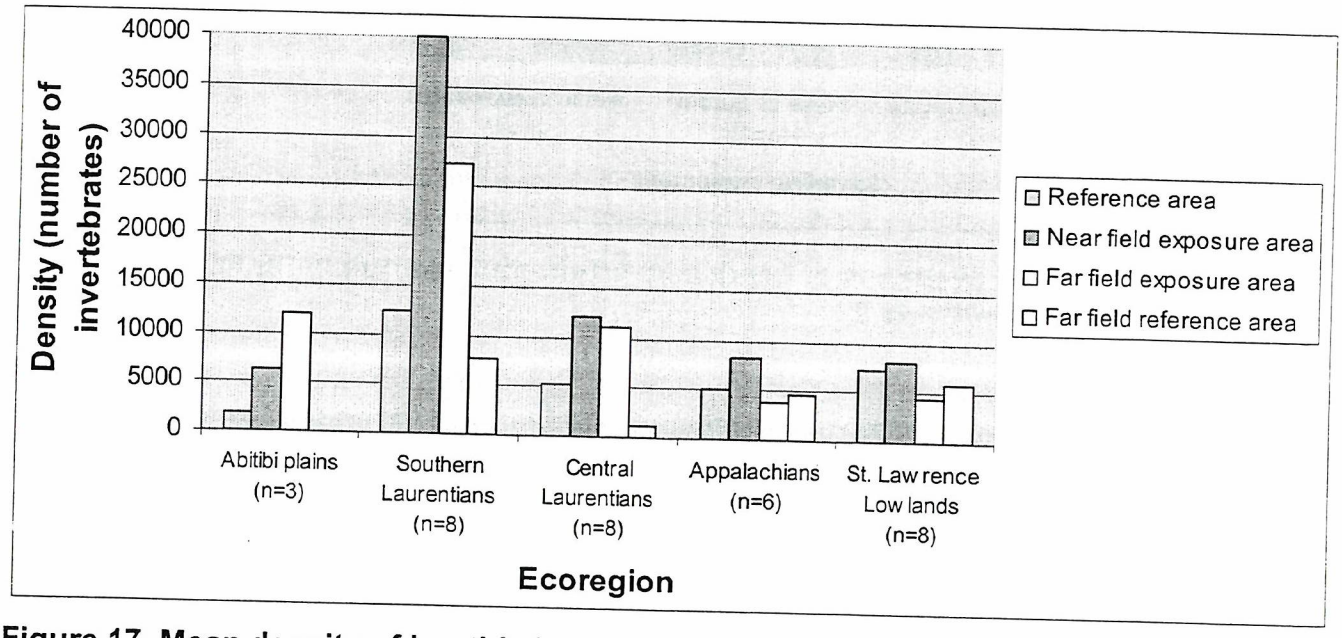


Figure 17 Mean density of benthic invertebrates by ecoregion

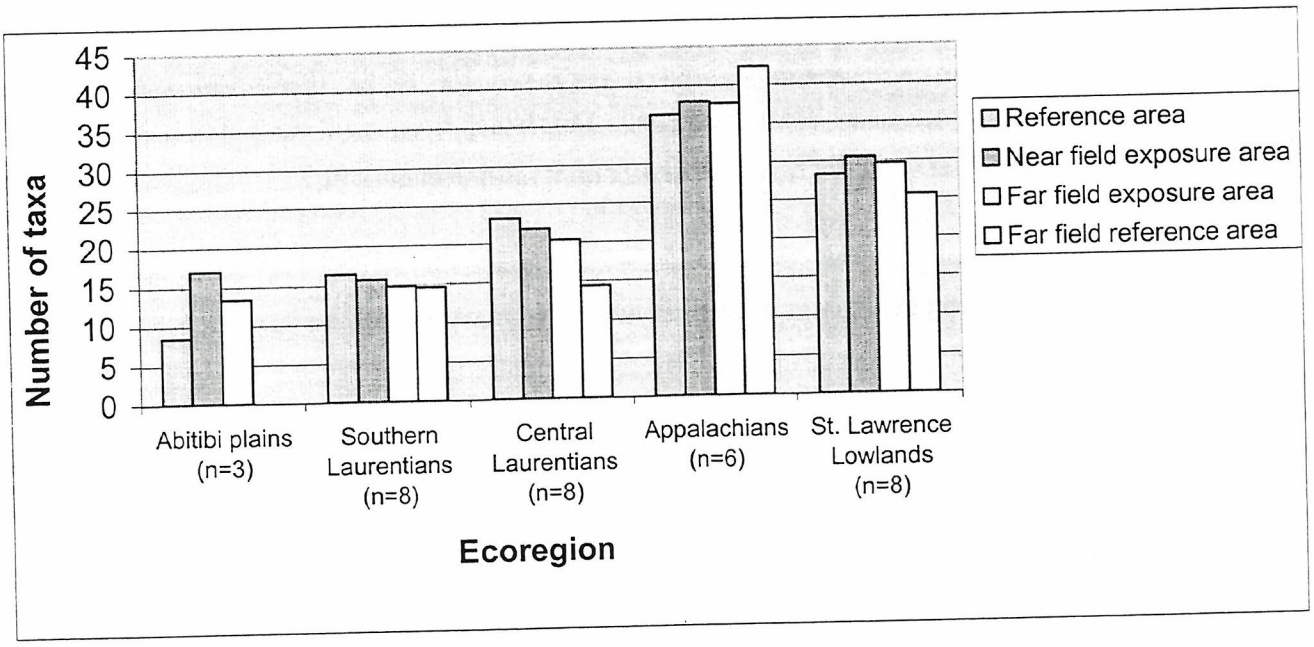


Figure 18 Mean taxon richness of benthic invertebrates by ecoregion

In this region where the waters can be described as oligotrophic, mill effluents can represent an important source of nutrients which appear to have a eutrophication effect on the aquatic environment, resulting in an increase in the density and number of taxa. A decrease in mean richness in the exposure area versus the reference area was noted in the far-field areas of the Appalachians, with a less noticeable decrease in the near-field areas of the Southern and Central Laurentians (Figure 18). This analysis by ecoregion was also performed by considering only those surveys in which the grab sampler was used, ie the most widely employed equipment. The results are given in Annex 12. Overall, the trends are essentially the same: richness increasing from the Abitibi to the Appalachians and the strongest within-ecoregion variations consisted of differences in abundance between the exposure and reference areas.

6.3.3 *Effect of the effluent treatment method used by mills discharging to fresh water on the benthic communities studied*

When the results of the benthos surveys are considered in relation to the effluent treatment method, invertebrate density is found to be higher in the exposure areas relative to the reference areas, with two exceptions (Figure 19). The most noteworthy difference relates to mills using a sequential biological reactor. The differences in taxon richness between the reference and exposure areas were not very pronounced overall.

Note however the appreciable difference in mean taxon richness between far-field reference and exposure areas for mills using aerated ponds (Figure 20). The study results for mills with only primary treatment did not differ from those with secondary treatment, except for the drop in taxon richness in the near-field exposure area versus the reference area.

Ecoregion-associated effects may mask more explicit patterns of variation. We looked at the density and taxon richness trends for mills with the most widely used treatment method (activated sludge), within the ecoregions. The pattern illustrated in figures 19 and 20 for this treatment type was essentially the same in all the different ecoregions. Detailed results are given in Annex 13.

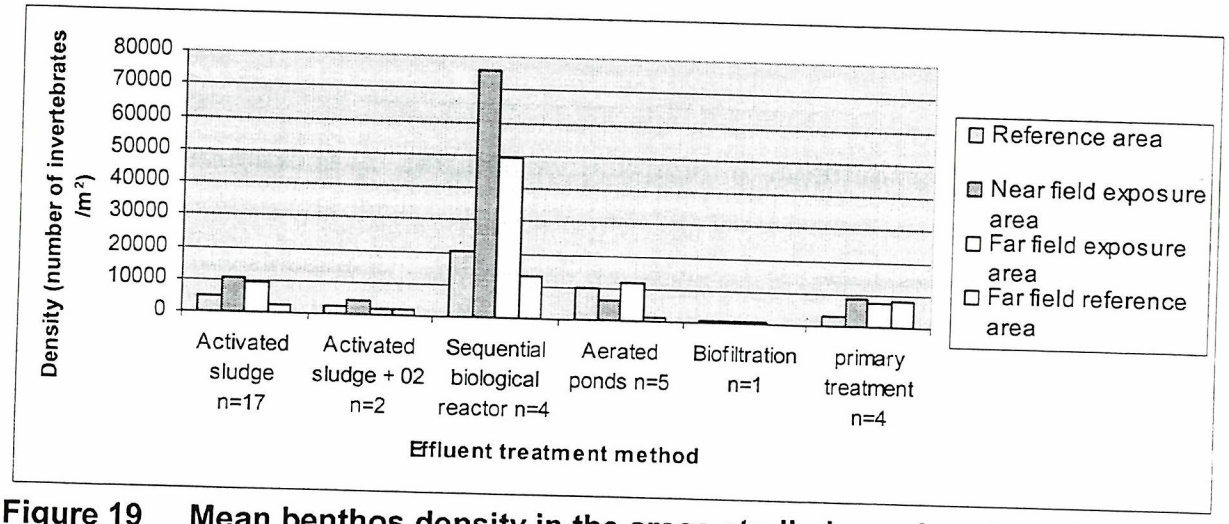


Figure 19 **Mean benthos density in the areas studied as a function of effluent treatment method**

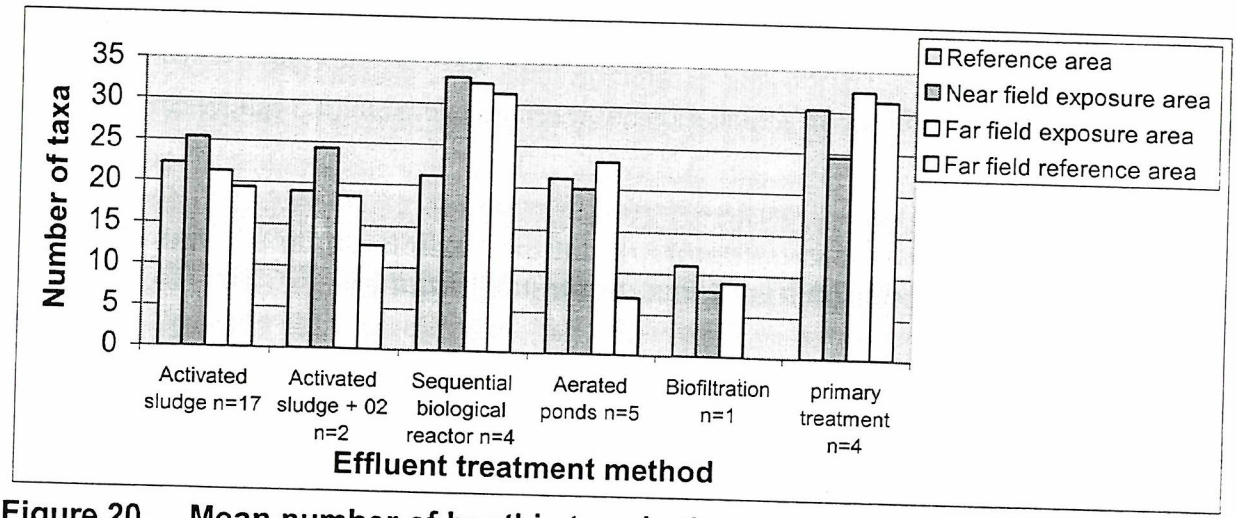


Figure 20 **Mean number of benthic taxa in the areas studied as a function of effluent treatment method**

6.4 Results of the benthos surveys in the marine environment

Five out of seven mills that discharge to the marine environment completed a benthos survey in Cycle 2. One of the mills that did not do a benthos survey had been shut down and in the other case the 1% effluent mixing zone was located within 50 m of the outfall and the effluent consisted primarily of cooling water.

The five mills that conducted a benthic community survey employed a linear gradient sampling design. This approach involves siting a number of stations along the axis of the effluent plume in order to obtain samples at stations along a gradient of decreasing effluent concentration; samples are collected within the 1% effluent concentration limit and at reference stations farther along the transect outside the 1% concentration limit. Two studies used this study design. Three others had a more complete sampling design with two gradients designed to evaluate the effect of the plume during a full tidal cycle.

The same four biotic variables as those used in the freshwater surveys were computed for the marine environment (density, taxon richness, diversity, evenness) from data obtained at each station. In four studies, total biomass (expressed in g/m^2) per station was also calculated. An analysis of correspondence (CA) was performed on the abundance matrices obtained, permitting the identification of subgroups of stations with a similar benthic community structure. Regression analyses were also performed using methods recommended in the Guidance Document (Environment Canada, 1998) to detect effects on the biotic variables that are influenced by distance from the outfall.

6.4.1 Results

In the five studies conducted in the marine environment, no significant linear relationships were found between the biotic variables and distance from the outfall. However, analyses of correspondence differentiated groups of stations according to their community structure (Annex 14). In two of three studies, the groups created revealed a clear separation between stations near the outfall and those farther along the gradient.

The benthic communities of these groups of stations differed not only in terms of the species' tolerance for organic enrichment but also in terms of density, richness and biomass. In these two studies, the near-field stations—those most likely to be affected by the effluent—had lower densities than stations farther away and they had a higher proportion of organisms that are indicators of an environment enriched with organic matter. In one case, biomass was smaller at the near-field stations; in the other case richness was lower at those stations (figures 21 and 22). These results are supported by the higher TOC and/or sulphur values at the near-field stations. The effluent from these two mills seems to have had an inhibitive effect on the benthic fauna in the vicinity of the outfall. A similar effect was observed across Canada in Cycle 2 studies for a large number of mills that discharge to the marine environment (Lowell *et al.*, 2003).

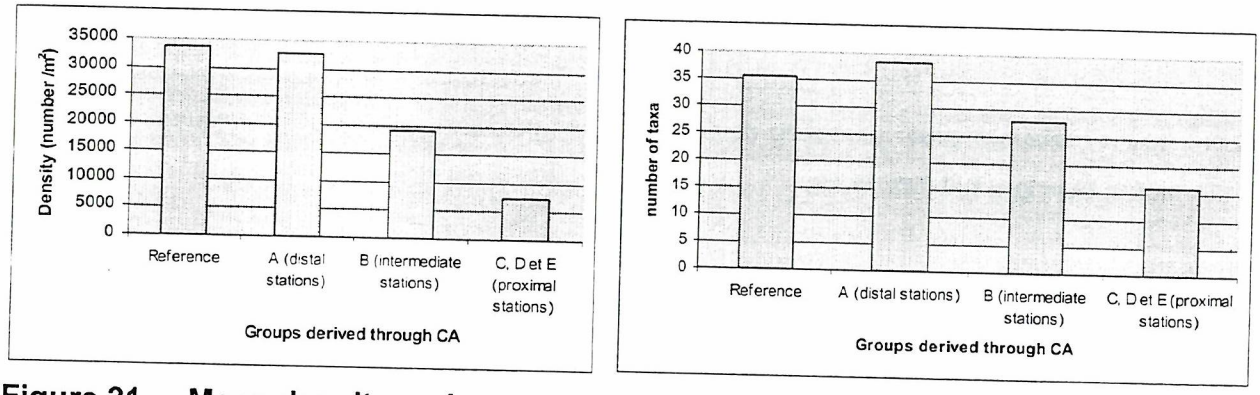


Figure 21 **Mean density and mean number of taxa at the reference stations and those making up the groups derived through CA, at the New-Richmond mill.**

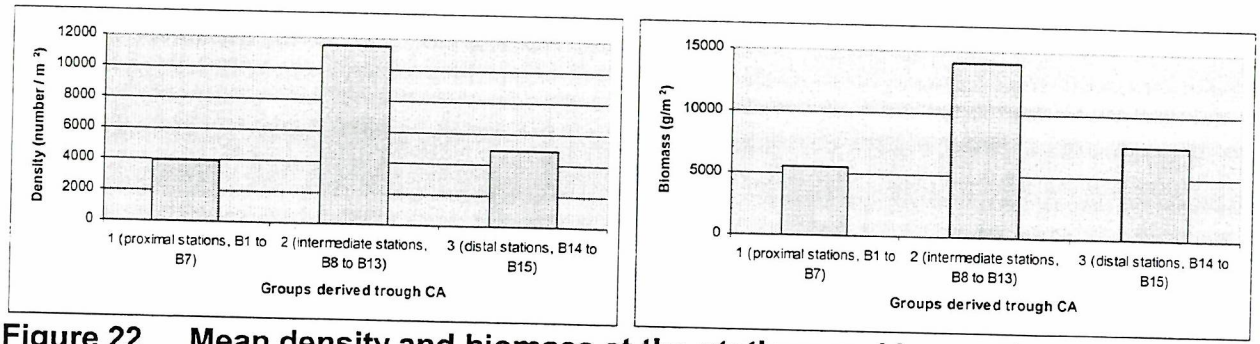


Figure 22 **Mean density and biomass at the stations making up the groups derived through CA, at the Baie-Comeau mill.**

In another study (La Baie, PP1561), two groups made up of nearly all the stations contained stations both close to and far from the outfall. The structure of one group seemed to be influenced to a greater extent by freshwater inputs, judging from the benthic fauna composition dominated by oligochaetes and chironomids. The results for the other group of stations contradicted the trends observed in the two previous studies, with density, biomass and richness values being higher near the outfall (Figure 23). The benthic fauna consisted primarily of two pioneer species of polychaetes that are characteristic of marine environments affected by organic enrichment.

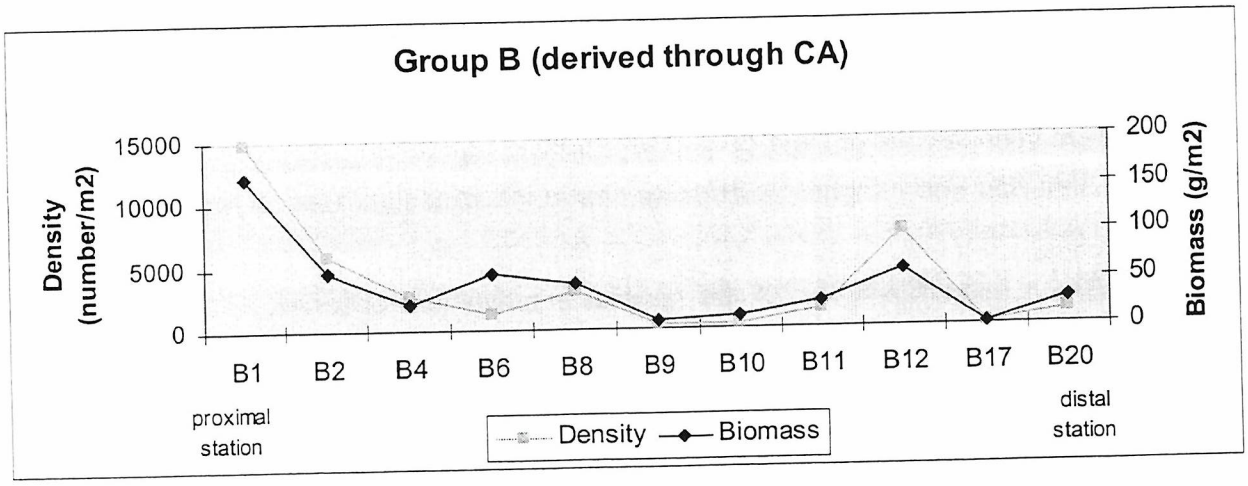


Figure 23 Density and biomass at the stations in group B derived through CA, at the La Baie mill.

For the Spruce Falls mill in Matane (PP1201), correspondence analysis did not allow groups of stations to be differentiated as a function of distance to the outfall. Only two of the nearest stations along the two gradients showed signs of organic enrichment as evidenced by their higher density and their lower diversity and evenness compared with the other stations located farther from the outfall. Lastly, the Port-Cartier mill (PP1202) effluents appeared to have no effect on the benthic fauna since no relationship was found between the biotic variables (including benthic community structure) and distance from the outfall.

6.5 Comparison of Cycle 1 and Cycle 2 results

6.5.1 Freshwater studies

The results of all the benthic surveys conducted in cycles 1 and 2 were compared in terms of the differences in density and richness between the exposure and reference areas. These two variables were the only ones measured in all studies during both EEM cycles. The number of paper mills with mean density values that were the same in the exposure and reference areas increased slightly in Cycle 2, whereas an opposite trend was found in studies with a density higher than twice the standard deviation of the mean of the reference area (Figure 24). With regard to taxon richness, the number of studies reporting equivalent values was still higher than the number that had either higher or lower values in the exposure area. However, in Cycle 2 there was a larger number of studies with higher richness values in the exposure area. These results provide a good illustration of the general improvement observed in the condition of benthic communities exposed to pulp and paper mill effluents in Quebec.

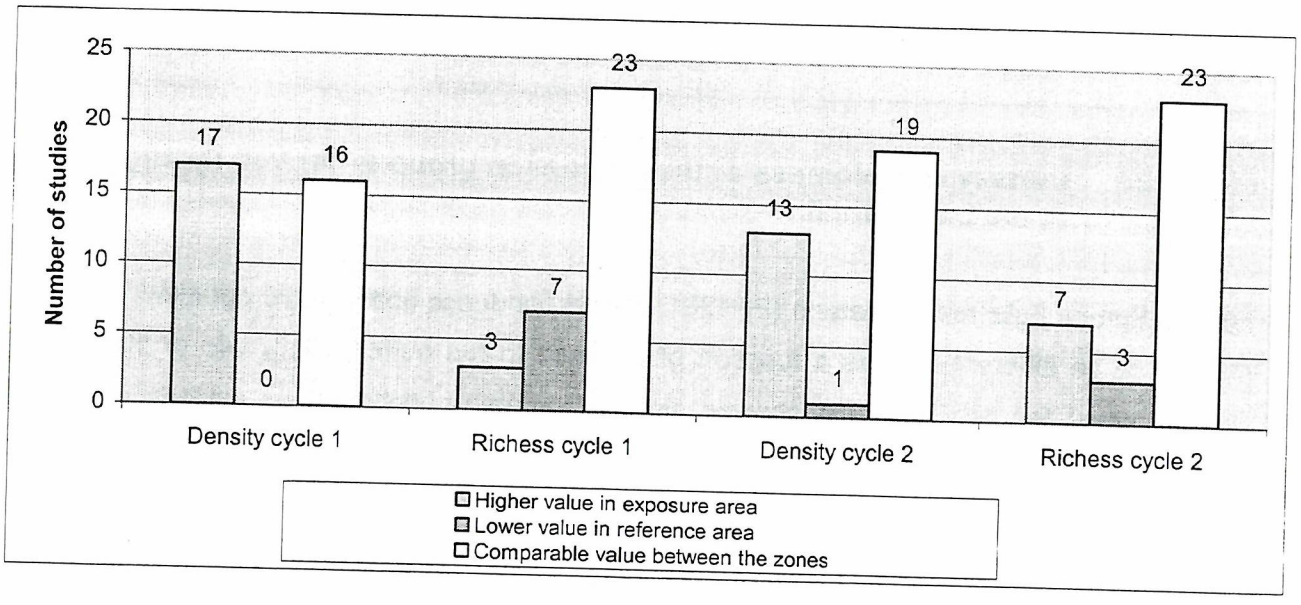


Figure 24 Comparison of the number of studies in which the differences in density and taxon richness are approximately twice the standard deviation of the mean calculated in the reference area between cycles 1 and 2.

A temporal comparison was made of the results reported by the paper mills. Here again, only density and taxon richness could be compared between the cycles. In 18 of the 37 studies done in Cycle 2, this type of between-cycle comparison could not be made, either because of a change in the sampling equipment used or because of a change in the location of stations or areas between the two cycles.

With regard to the 19 studies that could be compared, the majority showed an improvement in benthic community condition in the exposure area in Cycle 2 relative to Cycle 1 (Table 15). These improvements were evidenced chiefly by the reduction in the relative abundance of organisms that are tolerant of organic enrichment (oligochaetes or chironomids) and/or the increase in the proportion of taxa that are sensitive to eutrophication (Ephemeroptera, Plecoptera, Tricoptera).

Table 15 Comparison of benthic community responses between Cycle 1 and Cycle 2

Mill	City	Change in Abundance in the exposure area	Change in Richness in the exposure area	Change in the abundance of indicator taxa	Change in the condition of benthc communities
Abitibi-Consolidated Company of Canada (PP1184)	Amos	ND	+	Decline in oligochaetes and TOC	Improvement
Norkraft Quévillon Inc. (PP1147)	Lebel-sur-Quévillon	+*	++**	Increase in diversity and evenness	Improvement
Masson Paper Ltd (PP1153)	Masson-Angers	-	+	Decline in oligochaetes and TOC	Improvement
Bowater Canadian Forest Products Inc. (PP1118)	Gatineau	-	ND	Decline in oligochaetes, increase in intolerant taxa	Improvement
Cascades Fine Papers Group Inc. (PP1198)	St-Jérôme	-	ND	Decline in oligochaetes	Improvement
Smurfit-Stone Container (Canada) Inc. (PP1102)	Portage-du-Fort	ND	0	Status quo	Status quo
Norampac Inc. (PP1114)	Cabano	ND	ND	Decline in oligochaetes	Improvement
Scott Paper Ltd (PP1188)	Lennoxville	+	ND	Decline in oligochaetes	Improvement
Bowater Canadian Forest Products Inc. (PP1092)	Donnacona	0	+	Decline in oligochaetes, increase in diversity	Improvement
Désencrage C.M.D. Inc., Cascades Lupel Inc. (PP1179 & PP1183)	Cap-de-la-Madeleine	+	-	Increase in oligochaetes	Deterioration
Abitibi-Consolidated Company of Canada (PP1091)	Beaupré	-	-	Decline in oligochaetes and TOC	Improvement
Spexel Inc. (PP1193)	Beauharnois	ND	ND	Increase in oligochaetes in exposure area and reference area	Deterioration
Abitibi-Consolidated Company of Canada (PP1104)	Clermont	ND	0	Increase in EPT	Improvement
J. Ford Ltd (PP1187)	Portneuf	ND	ND	Increase in EPT, exposure area and reference area	Status quo
F.F. Soucy Inc. (PP1138)	Rivière-du-Loup	ND	ND	Decline in chironomids, increase intolerant taxa	Improvement
Tembec Inc. (PP1094)	Témiscaming	-	+	Status quo	Improvement
Domtar Inc. (PP1148)	Windsor	ND	ND	Decline in oligochaetes, increase in arthropods	Improvement
Kruger Inc. (PP1131)	Bromptonville	ND	0	Decrease in chironomids, increase in EPT	Improvement
Cascades Inc. (PP1208)	Kingsey Falls	-	++	Decrease in oligochaetes, increase in intolerant taxa	Improvement

+ increase, - decrease, ND : Variation similar in reference area
*beneficial increase in density since Cycle 1 abundance was almost nil in the exposure area
++** : increase greater than 10 taxa

These trends may also be reflected in changes in density and taxon richness. Indeed, five studies showed a density reduction in the exposure area and a decrease in the difference between the reference and exposure areas in Cycle 2. A total of 6 studies showed an increase in the number of taxa only in the exposure area in Cycle 2.

By contrast, only a small number of studies reported a deterioration in the benthic community of the exposure area in Cycle 2 versus Cycle 1 (Table 15). With regard to impacts on benthos structure, the most frequent sign is an increase in the abundance and taxon richness of tolerant organisms (Oligochaeta or Chironomidae).

In two other studies, the qualifier *status quo* was assigned to benthos structure in the corresponding exposure areas on the basis of a condition measured in Cycle 1 that was still observable and unchanged in Cycle 2.

6.5.2 *Marine environment studies*

Since not enough benthos surveys were done in the marine environment, no general trend could be identified as was done for mills discharging to fresh water. Furthermore, the sampling design had changed since Cycle 1, making quantitative comparisons more difficult. At the New-Richmond mill (PP1101), the benthic survey results revealed a general increase in abundance at reference stations and exposure stations alike in Cycle 2. It is difficult to identify other trends for the results from exposure stations, since their location changed between the two cycles.

At the La Baie mill (PP1561), a general improvement can be seen in the exposure area relative to Cycle 1 given the increase in taxon richness associated with a decline in density. If this is in fact indicative of an improvement, the actual reason may be the effluent treatment system introduced in 1995. Alternatively, the benthos structure observed in Cycle 2 may reflect the effect of recolonization of the substrate following the 1996 floods.

The study at the Baie-Comeau mill (PP1088) in Cycle 1 indicated that benthos density and taxon richness at stations near the effluent were lower than at more distant stations, a situation that was attributed to an effluent effect on benthos in this sector. A similar response pattern was seen in Cycle 2. In the studies at the Uniforêt mill in Port-Cartier (PP1202) and Spruce Falls in Matane (PP1201) major differences in methodology preclude comparison of the two cycles.

7 Evaluation of the overall effect of individual mills in Quebec

7.1 Introduction

The approach described and applied in this section is based on the weight-of-evidence concept (Environment Canada, 1997c), which denotes an approach used to examine all the monitoring results and determine the adequacy of the existing regulations in protecting fish, fish habitat and the use of fisheries resources. At a workshop on integrating EEM data (Environment Canada, 1999), participants agreed on the need to develop a method for applying the weight-of-evidence approach to the data derived from EEM cycles (see also Walker *et al.*, 2002). This approach aids in considering all the results, using professional judgement to ascertain whether the results are ecologically significant and assessing the strengths and limitations of the data accumulated. This chapter presents an integration approach along those lines.

In view of the large quantity of results obtained from the 48 EEM studies done in Quebec, it is essential to create a data management tool that can be used to integrate all of the information obtained for the three study components (toxicity, benthos and fish). The advantages of integration are numerous:

- permits synthesis of information without the need for complex statistical analyses and facilitates its use for dissemination or environmental risk management purposes;
- allows each mill to be characterized;
- provides a basis of comparison for all mills;
- can serve as a temporal monitoring tool (between cycle comparison);
- numerical representation of a particular state;
- graphical representation of the values of unit variables (pie chart, histogram).

7.2 *Design of the composite index: EEM Triad index*

The design of the EEM Triad index draws on an index developed by Chapman (1986, in Chapman, 1992) for evaluating sediment quality (Sediment Quality Triad, or SQT). Parker and Dumaresq (2002) advocate the use of the SQT in EEM studies on metal mining effluents. Other composite indices integrate biological variables only (Invertebrate Composite Index, or ICI: Willsie 1993, in Bombardier and Blaise, 2000). The SQT index incorporates measurements of contaminant levels in sediments, toxicity results from measurements of the sediments and data on the structure of the benthic communities associated with the sediments. The three components provide complementary chemical and biological data. The weight of evidence concept is therefore central to this approach.

Whereas the SQT is made up of variables measured in samples from the receiving environment alone, the EEM Triad index incorporates a measure of sublethal toxicity in a sample of final effluent and data reflecting the effect of this effluent on biological components of the receiving environment. For both the SQT and the EEM Triad index, an equal weight is assigned to each variable that makes up the index. This characteristic may be changed at some point in the future, if new information indicates that this weighting is inappropriate.

The three components of the EEM Triad index are the same as those used in the LTF (lab to field) approach in Ontario. In this approach developed by Moody (2002), the toxicity results (toxicity rating) were compared with the transformed results from fish and benthos surveys (ratio of statistically significant comparisons). The main difference between the two approaches is that the EEM Triad index uses all three components, combining them in an integrated index.

Instead of assessing the magnitude of effects on fish and benthos based solely on the statistical differences between the exposure and reference areas, we wanted to compare the variables using an index that takes account of natural variability. To this end, we used the effect sizes of the magnitude that EEM should be able to detect and that was measured in the majority of Cycle 2 studies in Canada (Lowell et al., 2003). In EEM, an effect is defined as: "a change in the measured variable which is outside the range of the natural variation observed at reference areas, unless there is an effect size defined for that variable. Effect size is the change in a variable that is considered ecologically significant." (Environment Canada, 1997b).

Computing the EEM Triad index involves the following steps:

- classification of sublethal toxicity results (IC_{25});
- identification of the significant differences observed in benthic or fish variables between the reference area and the exposure area as well as other results revealing differences between the two areas;
- transformation of the above data (sublethal toxicity, benthos, fish) into an EEM Triad rating;
- establishment of combined ratings and the EEM Triad index.

7.3 Development of the EEM Triad index

7.3.1 Steps involved in transforming the results into EEM Triad ratings

With respect to sublethal toxicity data, each GM-IC_{25} value obtained at the end of Cycle 2 was converted to a sublethal test score, using a pre-defined scale (Table 16). This scale is divided into five intervals for which threshold values were determined during the preparation of the Cycle 1 synthesis report (Langlois and Dubuc, 1999).

Table 16 Transforming and combining the sublethal toxicity testing results into an EEM Triad rating

Fresh water Scale (GM-IC_{25})	GM < 15% v/v	15% ≤ GM < 50% v/v	50% ≤ GM < 100% v/v	GM ≥ 100% v/v
Sublethal test score	4	3	2	1

Marine environment Scale (GM-IC_{25})	GM < 15% v/v	15% ≤ GM < 50% v/v	50% ≤ GM < 67% v/v	GM ≥ 67% v/v
Sublethal test score	4	3	2	1

Combination	Sublethal toxicity class	EEM Triad Rating
4.4.4 4.4.3 4.4.2 4.4.1	Very High Toxicity	5
4.3.3 4.3.2 4.3.1 4.2.2 4.2.1 4.1.1	Moderate to high toxicity	4
3.3.3 3.3.2 3.3.1 3.2.2 3.2.1 3.1.1	Low to moderate Toxicity	3
2.2.2 2.2.1 2.1.1	Low toxicity	2
1.1.1	Non toxic	1

For the transformation of benthos results from control/impact design studies (exposure area vs reference area), we considered the statistically significant differences among the four measured variables that were greater than natural variations in the environment. This involved calculating the relative frequency (%) of effects by dividing the number of cases in which significant differences greater than twice the standard deviation of the reference area were found by the total number of possible comparisons. Depending on the value of the relative frequency of the differences, an EEM Triad rating that lies between 1 and 5 (Table 17) is obtained. To refine the classification, the results of multivariate analyses (analysis of correspondence) were also taken into account when available. Where no benthos survey was carried out owing to the small extent of the plume (e.g. less than 100 m long), a rating of 1 (no effect) was assigned.

The results of the benthic community surveys using a gradient design were interpreted based on a significance test of the relationship (linear) between the values of a given benthic variable and distance from the outfall. The existence of a significant relationship is taken into account to determine a benthos rating. We calculated the relative frequency (%) of effects by dividing the number of variables that yielded significant relationships by the total number of variables measured. Depending on the relative frequency value, an EEM Triad rating ranging from 1 to 5 is obtained (Table 17).

We applied a similar approach to the fish survey results. All of the comparisons derived through ANCOVA analyses were subdivided into three groups of variables: somatic variables (S), hepatic variables (H) and reproductive variables (R). When significant differences were found we examined the cases where the deviation exceeded known values for natural variability, as discussed in section 4.1. When no fish survey was done because the plume was less than 250 m long, a rating of 1 (no effect) was assigned. Depending on the relative frequency of the significant differences for the groups of variables, an EEM Triad rating varying between 1 and 5 was derived (Table 17).

Table 17 EEM Triad rating for the three components of monitoring studies.

Benthos survey results Relative frequency of effects	Fish survey results Relative frequency of effects	Sublethal toxicity Combined ratings	EEM Triad rating	Effect class
0,75 to 1	0,75 to 1	4.4.1 to 4.4.4	5	Very high
0,50 to 0,74	0,50 to 0,74	4.1.1 to 4.3.3	4	High
0,25 to 0,49	0,25 to 0,49	3.1.1 to 3.3.3	3	Moderate
0,01 to 0,24	0,01 to 0,24	2.1.1 to 2.2.2	2	Low
0	0	1.1.1	1	Nil

Benthos and fish: ratio of the number of significant differences exceeding the effect size thresholds/number of comparisons
Toxicity: 3 tests = 3 ratings = 1 combined rating

7.3.2 *Combined ratings*

For each of the three components of the EEM Triad index, we obtained a rating ranging from 1 to 5 (Table 17). To proceed to the final transformation step, the same approach is used as for the sublethal toxicity data. In other words, the three EEM Triad ratings obtained are classified from the largest to the smallest value. This yields a combined rating varying between 1.1.1 and 5.5.5 which constitutes the EEM Triad index. The combined ratings are then ordered according to effect classes ranging from very high to nil (Table 18).

Where the fish or benthos survey results did not meet all the basic quality criteria and therefore could not be taken into consideration (too few unit samples, appreciable influence of confounding factors, etc.), the data could not be transformed into an EEM Triad rating. In these cases, the missing rating was replaced with a rating of 1 and the index value thus obtained was then grouped with the others. Hence, mills with no rating could be assessed and compared according to a conservative scenario.

Table 18 EEM Triad index based on the combined ratings for the three components of EEM

EEM Triad index (Combined ratings)	Effect class	EEM Triad index (Combined ratings)	Effect class
5.5.5			
5.5.4		4.3.3	
5.5.3		4.3.2	
5.5.2		4.3.1	
5.5.1	Very high	4.2.2	
5.4.4		4.2.1	Moderate
5.4.3		4.1.1	
5.4.2		3.3.3	
5.4.1		3.3.2	
5.3.3		3.3.1	
5.3.2		3.2.2	
5.3.1		3.2.1	
5.2.2		3.1.1	Low
5.2.1	High	2.2.2	
5.1.1		2.2.1	
4.4.4		2.1.1	
4.4.3		1.1.1	Nil
4.4.2			
4.4.1			

7.4 Results

Table 19 shows the values of the EEM ratings for the three components of the EEM Triad index and the index value. To facilitate interpretation of the index, the ratings are always presented in the following order: benthos-fish-toxicity. The index values range from 5.4.3 (Tembec mill in Témiscaming, PP1094) to 1.1.2. [Stadacona Paper Ltd in Quebec City (PP1093) and Eddy Speciality Papers Ltd, Scott Papers Ltd in Ottawa-Hull (PP1186)]. An index of 1.1.1 indicates that the mill has no effect and no toxicity. One third of the studies (16/48) have a rating higher than 3, indicating that the toxicity or an environmental effect is high or very high. The Tembec mill in Témiscaming (PP1094) exhibits the strongest effects on the receiving environment despite moderate sublethal toxicity. This is the only mill that has high or very high effects for two components simultaneously. Note also that two of the mills among the first five freshwater studies listed in Table 19 [J. Ford Ltd in Portneuf (PP1187) and Mohawk Pulp Ltd in St-Antonin (PP 1182)] have only primary treatment for their effluent. By contrast, about one quarter (13) of the mills have a low effect or no effect on the receiving environment.

The integration index shows that the environmental studies are fairly cohesive since more than half of them yield benthos and fish ratings that are equal or differ in rating by only 1. It is when the toxicity ratings are compared with those for the environmental studies that the largest differences are seen, particularly in comparisons related to fish. The benthos results appear to agree to a greater extent with the toxicity results.

Table 19 Ratings and EEM Triad index for all of the Cycle 2 studies conducted in Quebec

National project No.	Mill name (location)	Benthos rating	Fish rating	Sublethal toxicity rating	EEM Triad index (benthos-fish-toxicity)	Effect class
Fresh Water						
PP1094	Tembec Inc. (Témiscaming)	5	4	3	5,4,3	Very high
PP1191	Tembec, Papers Group, St-Raymond Mill (St-Léonard-de-Portneuf)	2	3	5	2,3,5	
PP1177	Abitibi-Consolidated Company of Canada (Alma)	3	5	2	3,5,2	High
PP1187	J. Ford Ltd (Portneuf)	3	4	4	3,4,4	
PP1182	Mohawk Pulp Ltd (St-Antonin)	4	2	4	4,2,4	
PP1145	Cascades Inc., Boxboard Group (Jonquière)	3	4	2	3,4,2	
PP1138	F.F. Soucy inc. (Rivière-du-Loup)	2	4	2	2,4,2	
PP1132	Abitibi-Consolidated Company of Canada (Jonquière)	2	4	2	2,4,2	
PP1091	Abitibi-Consolidated Company of Canada (Beaupré)	2	1	4	2,1,4	
PP1098	Smurfit-Stone Container (Canada) Inc. (La Tuque)	3	3	3	3,3,3	Moderate
PP1102	Smurfit-Stone Container (Canada) Inc. (Portage-du-Fort)	3	3	3	3,3,3	
PP1104	Abitibi-Consolidated Company of Canada (Clermont)	3	3	3	3,3,3	
PP1184	Abitibi-Consolidated Company of Canada (Amos)	3	2	3	3,2,3	
PP1148	Domtar Inc. (Windsor)	3	2	3	3,2,3	
PP1092	Bowater Canadian Forest Products Inc. (Donnacona)	3	2	3	3,2,3	
PP1188	Scott Paper Ltd (Lennoxville)	3	ND	4	3,1,4	
PP1117	Cascades East-Angus Inc., Division Cartech, Paperboard Industries Corp. (East-Angus)	ND	4	3	1,4,3	
PP1153	Masson Papers Ltd (Masson-Angers)	3	ND	3	3,1,3	Moderate
PP1147	Nortkraft Quévillon inc. (Lebel-sur-Quévillon)	3	ND	3	3,1,3	
PP1086	Fraser Nexfor Papers (Thurso)	3	ND	3	3,1,3	
PP1179 & PP1183	Désencrages C.M.D. inc., Cascades Lupel inc. (Cap-de-la-Madeleine)	3	ND	3	3,1,3	
PP1135	Abitibi-Consolidated Company of Canada (Shawinigan)	3	2	2	3,2,2	
PP1106	SFK Pulp (St-Félicien)	2	1	3	2,1,3	
PP1087	Kruger Inc. (Trois-Rivières)	1*	1**	3	1,1,3	Low
PP1136	Abitibi-Consolidated Company of Canada (Grand-Mère)	1*	1**	3	1,1,3	
PP1178	EMCO Ltd (Pont-Rouge)	1*	1**	3	1,1,3	
PP1114	Norampac Inc. (Cabano)	2	2	2	2,2,2	

Mills	Mill name (location)	Benthos rating	Fish rating	Sublethal toxicity rating	EEM Triad index (benthos-fish-toxicity)	Effect Class
Fresh water (cont'd)						
PP1131	Kruger Inc. (Bromptonville)	2	1	2	2,1,2	
PP1133	Bowater Canadian Forest Products Inc. (Dolbeau)	2	1**	2	2,1,2	
PP1197	Produits Desbiens inc. (Desbiens)	2	1**	2	2,1,2	Low
PP1093	Stadacona Paper Ltd (Quebec City)	1*	1**	2	1,1,2	
PP1186	Eddy Speciality Papers Ltd, Scott Paper Ltd (Ottawa-Hull)	1	1**	2	1,1,2	
PP1194	Cascades Inc. Tissue Group (Lachute)	2	ND	3	2,1,3	
PP1208	Cascades Inc. (Kingsey Falls)	2	ND	3	2,1,3	
PP1196	Scott Paper Ltd (Crabtree)	2	ND	2	2,1,3	
PP1181	Breakey Fibres (Breakeyville)	ND	2	3	1,2,3	
PP1137	Kruger Wayagamack Inc. (Trois-Rivières)	ND	1**	3	1,1,3	Low
PP1193	Spexel Inc. (Beauharnois)	ND	1**	3	1,1,3	
PP1100	Uniforêt Tripap Inc. (Trois-Rivières)	ND	1**	3	1,1,3	
PP1198	Cascades Fine Papers Group Inc. (St-Jérôme)	ND	ND	3	1,1,3	
PP1118	Bowater Canadian Forest Products Inc. (Gatineau)	ND	ND	2	1,1,2	
Marine						
PP1561	Abitibi-Consolidated Company of Canada (La Baie)	4	ND	5	4,1,5	Very high
PP1157	Gaspésia Ltd (Chandler)	ND	ND	5	1,1,5	High
PP1088	Abitibi-Consolidated Company of Canada (Baie-Comeau)	3	3	4	3,3,4	
PP1201	Spruce Falls Inc. (Matane)	3	2	4	3,2,4	Moderate
PP1101	Smurfit-Stone Container (Canada) Inc. (New-Richmond)	3	1	4	3,1,4	
PP1099	Smurfit-Stone Container (Canada) Inc. (Matane)	1*	1**	3	1,1,3	Low
PP1202	Uniforêt Scierie Pâte Inc. (Port-Cartier)	1	1**	3	1,1,3	

The shaded results identify mills for which 1 or 2 ratings are missing. A rating of 1 has been assigned in these cases

*Mills that did not conduct a benthos survey owing to the plume's limited extent or the impossibility of carrying out sampling

**Mills that did not conduct a fish survey because the mixing zone was less than 250 m long

We examined the distribution of ratings in each study. When the results are considered based on the three ratings taken separately, the majority of mills show moderate effects for toxicity and for the benthic community (Figure 25). With regard to fish surveys, aside from the 12 studies that were not done because the effluent plume was less than 250 m long and that were assigned a rating of 1, the results are much more variable, with the effects ranging mainly from high (rating of 4) to nil (rating of 1). These findings confirm the conclusion drawn in the national assessment of Cycle 2 results, at least for fish habitat, that the predominant effect for all mills in Canada is moderate eutrophication of the receiving environment caused by nutrient inputs (Lowell et al., 2003).

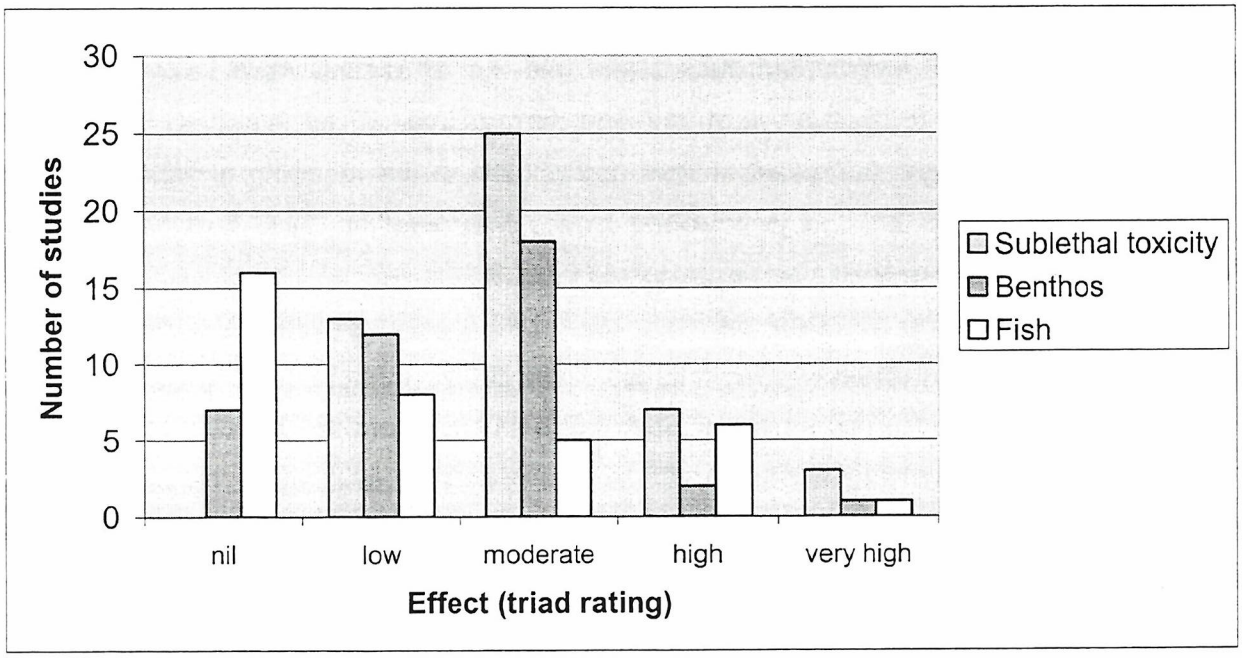


Figure 25 Frequency distribution of the EEM-Triad ratings for the different study components (sublethal toxicity, benthos and fish).

8 Conclusion

After two EEM cycles, it can be concluded that there has been an across-the-board decline in the aquatic pollution caused by pulp and paper mill effluents further to the installation of secondary treatment systems at nearly all the mills in Quebec. This reduction in the effluent pollution load has given rise to an improvement in the affected environments, which is particularly noticeable in benthic communities. Few changes have been observed in fish populations to date because the improvement in the receiving waters is still too recent. Upcoming EEM cycles should provide more conclusive evidence of positive effects.

The EEM Cycle 2 results for Quebec and the rest of Canada nonetheless show that adverse effects on the receiving environment subsist and that not all aspects have been elucidated sufficiently with respect to the short term and long term outlook. Given that there is always a time lag between changes introduced at mills and effects on the receiving environment, it is appropriate to track these changes over several cycles of observation. Cycle 3, which is already under way, will provide a new data series beginning in 2004.

In contrast with Cycle 2 which saw many changes in the EEM requirements aimed at improving the program in response to recommendations from the industry and the expert working group, Cycle 3 entails only slight modifications that are very specific, including some pertaining to quality control and supporting variables. These changes and the recommendations put forth by the scientific committee are presented in detail on the Web site of the National Office (www.ec.gc.ca/eem/). For the most part, Cycle 3 involves the same study requirements as Cycle 2.

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Annex 1 List of mills that completed a Cycle 2 EEM study

National Project No.	Mill Name	Mill Name Cycle 1	Division	Location
PP1086	Fraser Papers	James MacLaren Industries Inc	Kraft Pulp Division	Thurso
PP1087	Kruger Inc.	Kruger Inc		Trois-Rivières
PP1088	Abitibi-Consolidated Inc.	QUNO	Baie-Comeau Division	Baie-Comeau
PP1091	Abitibi-Consolidated Inc.	Abitibi-Price Inc		Beaupré
PP1092	Bowater Inc.	Alliance Forest Products Inc		Donnacona
PP1093	Stadacona Papers	Daishowa Inc		Quebec City
PP1094	Tembec Inc.	Tembec Inc		Témiscaming
PP1098	Smurfit-Stone Container Corporation	St Laurent Paperboard Inc		La Tuque
PP1099	Smurfit-Stone Container Corporation	St Laurent Paperboard Inc		Matane
PP1100	Uniforêt Tripap Inc.	Tripap Inc		Trois-Rivières
PP1101	Smurfit-Stone Container Corporation	Stone Packaging Inc	Chaleur Division	New-Richmond
PP1102	Smurfit-Stone Container Corporation	Stone Packaging Inc	Pontiac Division	Portage-du-Fort

Annex 1 List of mills that completed a Cycle 2 EEM study

National Project No.	Mill Name	Mill Name Cycle 1	Division	Location
PP1104	Abitibi-Consolidated Inc.	Donohue Forest Products Inc	Clermont Division	Clermont
PP1106	SFK Pulp	Donohue Forest Products Inc	St-Félicien Division	St-Félicien
PP1114	Norampac Inc.	Cascades Inc	Cabano Division	Cabano
PP1117	Cascades East-Angus Inc	Cascades East-Angus Inc, Cascades Cartech	Cartech	East-Angus
PP1118	Bowater Inc.	Avenor		Gatineau
PP1131	Kruger Inc.	Kruger Inc		Bromptonville
PP1132	Abitibi-Consolidated Inc.	Abitibi-Price Inc	Kénogami	Jonquière
PP1133	Bowater Inc.	Alliance Forest Products Inc		Dolbeau
PP1135	Abitibi-Consolidated Inc.	Stone-Consolidated	Belgo	Shawinigan
PP1136	Abitibi-Consolidated Inc.	Stone-Consolidated	Laurentide	Grand-Mère
PP1137	Kruger Wayagamack Inc.	Stone-Consolidated	Wayagamack	Trois-Rivières
PP1138	F.F. Soucy Inc.	F.F. Soucy Inc		Rivière-du-Loup

Annex 1 List of mills that completed a Cycle 2 EEM study

National Project No.	Mill Name	Mill Name Cycle 1	Division	Location
PP1145	Cascades Plat Inc.	Cascades Inc	Paperboard Division Jonquière	Jonquière
PP1147	Nortkraft Quévillon Inc.	Domtar		Lebel-sur-Quévillon
PP1148	Domtar Inc.	Domtar	Domtar Communication Papers, Windsor Business Centre	Windsor
PP1153	Masson Ltd	James MacLaren Industries nc	Newsprint Division	Masson-Angers
PP1157	Gaspesia Ltd	Gaspesia Co.	A subsidiary of Abitibi-Consolidated Inc	Chandler
PP1177	Abitibi-Consolidated Inc.	Abitibi-Price Inc		Alma
PP1178	EMCO Ltd	BPCO		Pont-Rouge
PP1183 PP1179	Désencrages C.M.D. Inc., Cascades Lupel Inc.	Désencrages C.M.D., Cascades Lupel Inc		Cap-de-la-Madeleine
PP1181	Cascades Inc.	Cascades Inc		Breakeyville
PP1182	Mohawk Pulp Ltd	Mohawk Pulp Ltd		St-Antonin
PP1184	Abitibi-Consolidated Inc.	Donohue Inc	Amos Division	Amos
PP1186	Eddy Paper Ltd, Scott Paper Ltd	E.B.Eddy Ltd, Scott Paper Ltd	Domtar Division	Ottawa-Hull
PP1187	J. Ford Ltd	J.Ford Ltd		Portneuf

Annex 1 List of mills that completed a Cycle 2 EEM study

National Project No.	Mill Name	Mill Name Cycle 1	Division	Location
PP1188	Scott Papers Ltd	Scott Ltd		Lennoxville
PP1191	Tembec, St-Raymond Mill	Mallette Québec Inc	Mallette Québec Inc Division	St-Léonard-de-Portneuf
PP1193	Spexel Inc.	Domtar Inc		Beauharnois
PP1194	Cascades Inc.	Perkins Ltd	Lachute Division	Lachute
PP1196	Scott Paper Ltd	Scott Paper Ltd		Crabtree
PP1197	Produits Desbiens Inc.	Produits Desbiens Inc		Desbiens
PP1198	Cascades Inc.	Cascades Rolland Inc		St-Jérome
PP1201	Spruce Falls Inc.	Donohue Inc		Matane
PP1202	Uniforêt Sawmill Pulp Inc.	Uniforêt Sawmill Pulp Inc.		Port-Cartier
PP1208	Cascades Inc.	Cascades Inc	Research and Development	Kingsey Falls
PP1561	Abitibi-Consolidated Inc.	Stone-Consolidated	Port Alfred	La Baie

Annex 2 Characteristics of pulp and paper mills in Quebec

National Project No.	Mill Name	Location	Product	Process Type	Bleaching Process	Effluent Treatment Method	Secondary Treatment (Start-up)
PP1086	Fraser Papers	Thurso	Kraft	Kraft	Chlorine, Chlorine dioxide	Activated sludge	June 15, 95
PP1087	Kruger Inc.	Trois-Rivières	Newsprint, Coated papers, Specialty papers	**Mechanical, thermomechanical**, kraft, de-inked pulp	none	Activated sludge	Sept. 95
PP1088	Abitibi-Consolidated Inc.	Baie-Comeau	Newsprint	**Chemithermomechanical pulp**, Thermomechanical, recycled pulp	nd	Activated sludge	Sept. 95
PP1091	Abitibi-Consolidated Inc.	Beaupré	Specialty papers	**Thermomechanical pulp**, kraft, recycled pulp	Sodium hydrosulphite, Peroxide	Activated sludge	June 95
PP1092	Bowater Inc.	Donnacona	Specialty papers	Chemithermomechanical pulp	Peroxide, Sodium hydrosulphite	Activated sludge	July 95
PP1093	Stadacona Papers	Quebec City	Paperboard, Newsprint, Specialty papers	**Thermomechanical pulp**, Recycled and de-inked pulp	nd	Activated sludge + oxygen	Sept. 95
PP1094	Tembec Inc.	Témiscaming	Special use cellulose, Alcohol	High-yield sulphite pulp, **chemithermomechanical pulp**	nd	Activated sludge	July 95
PP1098	Smurfit-Stone Container Corporation	La Tuque	Paperboard	Kraft	Chlorine dioxide	Activated sludge + oxygen	Sept. 95

Bold: Dominant process type used in the study
na: not applicable
nd: not determined

Annex 2 Characteristics of pulp and paper mills in Quebec

National Project No.	Mill Name	Location	Product	Process Type	Bleaching Process	Effluent Treatment Method	Secondary Treatment (Start-up)
PP1099	Smurfit-Stone Container Corporation	Matane	Paperboard	Semi-chemical pulp	nd	Primary treatment	na
PP1100	Uniforêt Tripap Inc.	Trois-Rivières	Specialty papers	nd	Peroxide	Activated sludge	August 95
PP1101	Smurfit-Stone Container Corporation	New-Richmond	Paperboard	Kraft	none	Aerated ponds	Sept. 27, 95
PP1102	Smurfit-Stone Container Corporation	Portage- du-Fort	Kraft	Kraft	Chlorine, Chlorine dioxide, Sodium hypochlorite, Peroxide	Aerated ponds	1967
PP1104	Abitibi-Consolidated Inc.	Clermont	Specialty papers	**Thermomechanical** and de-inked pulp	nd	Activated sludge	August 95
PP1106	SFK Pulp	St-Félicien	Kraft	Kraft	Chlorine dioxide	Aerated ponds	Sept. 15, 95
PP1114	Norampac Inc.	Cabano	Corrugated paper	Semi-chemical without sulphur	none	Aerated ponds	1976
PP1117	Cascades East-Angus Inc.	East-Angus	Specialty papers, Paperboard	**Kraft**, recycled	Recycled pulp bleached with peroxide and/or sodium hydrosulphite	Aerated pond	August 95
PP1118	Bowater Inc.	Gatineau	Newsprint	**Thermomechanical pulp**, Recycled	nd	Activated sludge + Oxygen	July 95
PP1131	Kruger Inc.	Bromptonville	Newsprint	**Thermomechanical pulp**, Recycled and de-inked	Sodium hydrosulphite	Sequential biological reactor	August 95
PP1132	Abitibi-Consolidated Inc.	Jonquière	Moulded pulp, Thermomechanical pulp	Mechanical pulp, Thermomechanical pulp	Sodium hydrosulphite	Activated sludge	July 95

Bold: Dominant process type used in the study
na: not applicable
nd: not determined

Annex 2 Characteristics of pulp and paper mills in Quebec

National Project No.	Mill Name	Location	Product	Process Type	Bleaching Process	Effluent Treatment Method	Secondary Treatment (Start-up)
PP1133	Bowater Inc.	Dolbeau	Newsprint, Specialty papers	Chemithermomechanical pulp	Peroxide, Sodium hydrosulphite	Activated sludge	Oct. 95
PP1135	Abitibi-Consolidated Inc.	Shawinigan	Newsprint	Thermomechanical pulp, **Chemithermomechanical pulp**, De-inked pulp	Sodium hydrosulphite	Sequential biological reactor	Sept. 22, 95
PP1136	Abitibi-Consolidated Inc.	Grand-Mère	Specialty papers	Mechanical pulp, High yield **chemical pulp**, Kraft pulp	Sodium hydrosulphite	Sequential biological reactor	July 95
PP1137	Kruger Wayagamack Inc.	Trois-Rivières	Specialty papers	Mechanical pulp, **Kraft**	Chlorine dioxide, Sodium hydroxide and peroxide	Sequential biological reactor	Sept. 95
PP1138	F.F. Soucy Inc.	Rivière-du-Loup	Newsprint	Thermomechanical pulp	Sodium hydrosulphite, Peroxide	Activated sludge	July 95
PP1145	Cascades Inc.	Jonquière	Paperboard	**Thermomechanical pulp**, Recycled	none	Activated sludge	Sept. 95
PP1147	Norkraft Quévillon Inc.	Lebel-sur-Quévillon	Kraft	Kraft	Chlorine dioxide, Chlorine	Activated sludge	Sept. 95
PP1148	Domtar Inc.	Windsor	Kraft, Specialty papers	Kraft	Chlorine dioxide	Aerated ponds	1987
PP1153	Papier Masson ltée	Masson-Angers	Newsprint	Mechanical pulp, **High-yield sulphite pulp**	Sodium hydroxide	Activated sludge	June 95
PP1157	Gaspesia Ltd	Chandler	Newsprint	Mechanical pulp, **High-yield sulphite pulp**, kraft, de-inked	nd	Activated sludge	August 95

Bold: Dominant process type used in the study
na: not applicable
nd: not determined

Annex 2 Characteristics of pulp and paper mills in Quebec

National Project <No.	Mill Name	Location	Product	Process Type	Bleaching Process	Effluent Treatment Method	Secondary Treatment (Start-up)
PP1177	Abitibi-Consolidated Inc.	Alma	Specialty papers, Newsprint	**Thermomechanical**, de-inked, kraft	nd	Activated sludge	July 95
PP1178	EMCO Ltd	Pont-Rouge	Specialty papers, fibreboard	**Thermomechanical pulp**, Recycled	nd	Activated sludge	July 95
PP1183 PP1179	Papier Cascade Lupel Inc. et Désencrage CMD Inc.	Cap-de-la-Madeleine	Specialty papers, de-inked pulp	Recycled	none	none (Lupel), Activated sludge (CMD)	1994
PP1181	Cascades Inc.	Breakeyville	Kraft	De-inked	Hydrogen peroxide, Sodium hydrosulphite	Activated sludge	Oct. 94
PP1182	Mohawk Pulp Ltd	St-Antonin	Moulded pulp	Mechanical pulp	nd	Primary treatment (membrane)	Sept./Oct. 95
PP1184	Abitibi-Consolidated Inc.	Amos	Newsprint	Thermomechanical pulp	Sodium hydrosulphite	Activated sludge	August 93
PP1186	Eddy Paper ltée, Scott Paper Ltd	Ottawa-Hull	Fine paper, Tissue paper	nd	nd	Biofiltration	Oct. 95
PP1187	J. Ford Ltd	Portneuf	Specialty papers, Paperboard	Mechanical, Thermomechanical	nd	Primary treatment (screening)	na
PP1188	Scott Paper Ltd	Lennoxville	Bathroom tissue	Kraft and de-inked	nd	Primary treatment (settling)	na
PP1191	Tembec, St-Raymond Mill	St-Léonard, Cté Portneuf	Specialty papers	Alkaline Peroxide Mechanical Pulp	Sodium hydrosulphite	Activated sludge	1991

Bold: Dominant process type used in the study
na: not applicable
nd: not determined

Annex 2 Characteristics of pulp and paper mills in Quebec

National Project No.	Mill Name	Location	Product	Process Type	Bleaching Process	Effluent Treatment Method	Secondary Treatment (Start-up)
PP1193	Spexel Inc.	Beauharnois	Specialty and security papers	nd	nd	Sequential biological reactor	August 95
PP1194	Cascades Inc.	Lachute	Tissue paper	Recycled pulp	none	Sequential biological reactor (Activated sludge since Feb 99)	Sept. 95
PP1196	Scott Paper Ltd	Crabtree	Recycled pulp, Bathroom tissue	Recycled	nd	Activated sludge	1991
PP1197	Produits Desbiens Inc.	Desbiens	Paperboard	na	na	Primary treatment (Poseidon)	nNa
PP1198	Cascades Groupe Papiers Fins Inc.	St-Jérôme	Fine papers	na	na	Aerated ponds	Sept. 95
PP1201	Spruce Falls Inc.	Matane	Pulp	Chemithermomechanical pulp	Peroxide	Activated sludge	June 95
PP1202	Uniforêt Sawmill Pulp Inc.	Port-Cartier	Pulp	Chemithermomechanical pulp	Peroxide	Activated sludge	Nov 96
PP1208	Cascades Inc.	Kingsey Falls	Moulded pulp, Paperboard, Tissue papers	Recycled, de-inked pulp	Hydrogen peroxide and/or sodium hydrosulphite (only part of the pulp used for tissue paper is bleached)	Activated sludge	Sept. 95
PP1561	Abitibi-Consolidated Inc.	La Baie	Newsprint	Mechanical pulp, Thermomechanical pulp, **High-yield sulphite pulp**	none	Sequential biological reactor	Sept. 95

Bold: Dominant process type used in the study
na: not applicable
nd: not determined

Annex 3 Receiving environment and main characteristics related to the extent of the effluent mixing zone

National Project No.	Mill Name (Location)	Receiving environment	Mean annual flow of receiving environment (m^3/s)	Mean 7Q10 flow (m^3/s)	Mean annual effluent flow (m^3/d)	Plume study or modelling in Cycle 2	Date of plume study or modelling	Measured plume length (m)	Modelled plume length (m)	Mean TSS (kg/d)	Mean BOD_5 (kg/d)	Mean output (t/d)
PP1086	Fraser Papers (Thurso)	Ottawa River	900	681	61775	Cx	1999	950	1520 (7Q10)	494	370	677
PP1087	Kruger Inc. (Trois-Rivières)	St Lawrence River	11000	8822	57840	Cx	1999	225	250 (7Q10)	1227	310	1742
PP1088	Abitibi-Consolidated Inc. (Baie-Comeau)	St Lawrence River	na	na	89347	Rwt	August 5, 1998	1015 (rising) 629 (falling)	1000	1563	945	1500
PP1091	Abitibi-Consolidated Inc. (Beaupré)	Rivière des Vases	11,3	nd	19787	Cx	January 1997	700 (rising) 800 (falling)	850 (rising) 1000 (falling)	406	193	520
PP1092	Bowater Inc. (Donnacona)	St Lawrence River	12050	nd	33876	none		693 (rising) 750 (falling)	487 (rising) 543 (falling)	965	311	500
PP1093	Stadacona Papers (Québec)	St Lawrence River	12600	nd	81429	Calculation		66 (rising) 53 (falling)		2907	2256	1400
PP1094	Tembec Inc. (Témiscaming) (effluent TDE)	Ottawa River	683	229	85795	Cx	1999	500	34000 (low flow) 7300 (mean flow)	16415	5369.9	1602.7
PP1098	Smurfit-Stone Container Corporation (La Tuque)	Saint-Maurice River	516,1	261,7	132021	Rwt, Cx	June 1998	345	950 (7Q10)	1116	719	1300
PP1099	Smurfit-Stone Container Corporation (Matane)	St Lawrence River	na	na	6543	none		50	0.21% at 200 m	103	446	400
PP1100	Uniforêt Tripap Inc. (Trois-Rivières)	St Lawrence River	733 (St-Maurice), 11598 (St Lawrence)	7224	21585	Rwt	July 27, 1999	175 (rising) 340 (falling)		472	516	530

Cx: Cormix model; Rwt: Rhodamine WT
nd: not determined
Shaded cells: effluent discharged to tide-affected areas

Annex 3 Receiving environment and main characteristics related to the extent of the effluent mixing zone

National Project No.	Mill Name (Location)	Receiving environment	Mean annual flow of receiving environment (m^3/s)	Mean 7Q10 flow (m^3/s)	Mean annual effluent flow (m^3/d)	Plume study or modelling in Cycle 2	Date of plume study or modelling	Measured plume length (m)	Modelled plume length (m)	Mean TSS (kg/d)	Mean BOD_5 (kg/d)	Mean output (t/d)
PP1101	Smurfit-Stone Container Corporation (New-Richmond)	Chaleur Bay	na	na	41898	Cx	1999	1060 (rising)	680 (rising) 956 (falling)	4682	931	578
PP1102	Smurfit-Stone Container Corporation (Portage-du-Fort)	Ottawa River	1164	293,5	71281	Cx	08-99 and 09-99	800	570 (7Q10)	3353	1360.9	604
PP1104	Abitibi-Consolidated Inc. (Clermont)	Malbaie River	26,5	6.1	29193	none		10000		532	236	900
PP1106	SFK Pulp (St-Félicien)	Mistassini River	461	138	52329	Rwt	August 16, 1994	4100		2900	3464	822
		Ashuap-mushuan River	303	nd		Rwt	August 10 and 11, 1998	260				
PP1114	Norampac Inc. (Cabano)	Cabano River	2,56	0,276	10230	Cx	1999	1400	5% at 650 m (summer low flow)	243	65	450
PP1117	Cascades East-Angus Inc. (East-Angus)	St-François River	78,6	10,3	3782	Cx	1998	160 (main effluent) 60 (effluent	10000 (7Q10)	1147	2400.7	429
PP1118	Bowater Inc. (Gatineau)	Ottawa River	1200 (rdo), 125 (kettl)	400(rdo) 41.7(kett)	71679	Rwt	July 8, 1998	2500	The Cormix model does not simulate the 1% plume adequately	1200	400	1122
PP1131	Kruger Inc. (Bromptonville)	St-François River	165	35	32983	Rwt, Calculation	August 1998	1950	22000 (7Q10)	1036	497.4	703
PP1132	Abitibi-Consolidated Inc. (Jonquière)	Saguenay River	136,3	12,6	43020	Rwt	August 3, 1999	180	1500 (low flow)	674	205	658.9
PP1133	Bowater Inc. (Dolbeau)	Mistassini River	440	78,8	24240	Rwt, Cx	July 7, 1998	140	85 (7Q10)	620	484.7	550

Cx: Cormix model; Rwt: Rhodamine WT
nd: not determined
Shaded cells: effluent discharged to tide-affected areas

Annex 3 Receiving environment and main characteristics related to the extent of the effluent mixing zone

National Project No.	Mill Name (Location)	Receiving environment	Mean annual flow of receiving environment (m^3/s)	Mean 7Q10 flow (m^3/s)	Mean annual effluent flow (m^3/d)	Plume study or modelling in Cycle 2	Date of plume study or modelling	Measured plume length (m)	Modelled plume length (m)	Mean TSS (kg/d)	Mean BOD_5 (kg/d)	Mean output (t/d)
PP1135	Abitibi-Consolidated Inc. (Shawinigan)	Shawinigan River	9	nd	32747	Calculation	1999	800	1300	1000	731	1034
PP1136	Abitibi-Consolidated Inc. (Grand-Mère)	St-Maurice River	700	300	24007	none		50	70 (7Q10)	1008	672	970
PP1137	Kruger Wayagamack Inc. (Trois-Rivières)	St Lawrence River	733 (St-Maurice), 11598 (St Lawrence)	7224	70630	Cx	1998	200	230 (7Q10)	599	989	600
PP1138	F.F. Soucy Inc. (Rivière-du-Loup)	Rivière du Loup	19,49	1,3	13900	Cx, Conductivity	12-10-99	800	6500	629	313	650
PP1145	Cascades Inc. (Jonquière)	Rivière aux Sables	23,2	12,6	6149	Rwt, Cx	August 18, 1998	175	250	755	218	391
PP1147	Nortkraft Quévillon Inc. (Lebel-sur-Quévillon)	Quévillon River (nd), Bell	266	132	79328	none		3300 (conductivity)	35000 (7Q10)	895	344	900
PP1148	Domtar Inc. (Windsor)	St-François River	202	15	67836	Cx	1999	2400	80000 (7Q10)	5267	2154	1800
PP1153	Papier Masson ltée (Masson-Angers)	Rivière du Lièvre	165	85	36313	Rwt, Cx	August 29, 1996	1400	1650 (7Q10)	1198	654	600
PP1157	Gaspesia Ltd (Chandler)	Chaleur Bay	na	na	13493	Cx	September 1996	250 (rising) 800 (falling)	600 (rising) 1500 (falling)	303	191.4	700
PP1177	Abitibi-Consolidated Inc. (Alma)	Petite Décharge River	123	10	45645	Cx	August 1999	1000	3200	500	439	752
PP1178	EMCO Ltd (Pont-Rouge)	Jacques-Cartier River	61,3	21,8	2563	none		40		150	55.8	223.2
PP1183 PP1179	Papier Cascade Lupel Inc. et Désencrage CMD Inc. (Cap-de-la-Madeleine)	St Lawrence River	11871	nd	5378	none		825		633	237	137.4

Cx: Cormix model; Rwt : Rhodamine WT
nd: not determined
Shaded cells: effluent discharged to tide-affected areas

Annex 3 Receiving environment and main characteristics related to the extent of the effluent mixing zone

National Project No.	Mill Name (Location)	Receiving environment	Mean annual flow of receiving environment (m^3/s)	Mean 7Q10 flow (m^3/s)	Mean annual effluent flow (m^3/d)	Plume study or modelling in Cycle 2	Date of plume study or modelling	Measured plume length (m)	Modelled plume length (m)	Mean TSS (kg/d)	Mean BOD_5 (kg/d)	Mean output (t/d)
PP1181	Cascades Inc. (Breakeyville)	Chaudière River	116,04	6,9	970	Rwt, Cx	July 27, 1999	165	3500 (7Q10)	36	10.7	125
PP1182	Mohawk Pulp Ltd (St-Antonin)	Rivière du Loup	18,63	1,017	3049	none		540	100 (7Q10)	116	76.2	29
PP1184	Abitibi-Consolidated Inc. (Amos)	Harricana River	59.3	14.3	21680	none		700	82000 (7Q10)	422	125.6	500
PP1186	Eddy Paper ltée, Scott Paper Ltd (Ottawa-Hull)	Ottawa River	898	290	27000	Rwt	1997 and 1998	0.83% at 55 m	363 (7Q10)	850	600	636.4
PP1187	J. Ford Ltd (Portneuf)	Portneuf River	10,9	1,37	4681	none		90	3000 (7Q10)	194	357.4	158
PP1188	Scott Paper Ltd (Lennoxville)	St-François and Massawippi rivers	90(st-fr), 30(massa)	14.8 (st-fr), 1.2 (massa)	3361	none		500	3500 (7Q10)	156	53.7	50
PP1191	Tembec, St-Raymond Mill (St-Léonard-de-Portneuf)	Ste-Anne River	48,9	7,6	11521	none		350	100 000 (7Q10)	199	197	164
PP1193	Spexel Inc. (Beauharnois)	St Lawrence River	8263	4223	4142	Cx	1999	465	450	58	33.14	60.5
PP1194	Cascades Inc. (Lachute)	Rivière du Nord	25	7,06	1041	Cx	1996	95	205 (7Q10)	80	64.54	48
PP1196	Scott Paper Ltd (Crabtree)	Ouareau River	13,9	2,7	21492	none		6000	8000 (7Q10)	213	72	445
PP1197	Produits Desbiens Inc. (Desbiens)	Métabetchouane River	48,8	12,9	2440	Cx	August 1999	60	100 (7Q10)	93	39	30
PP1198	Cascades Groupe Papier Fins Inc. (St-Jérôme)	Rivière du Nord	23,46	4,38	6793	Cx	1998 and 1999		6500 (summer low flow)	590	282	460

Cx: Cormix model; Rwt: Rhodamine WT
nd: not determined
Shaded cells: effluent discharged to tide-affected areas

Annex 3 Receiving environment and main characteristics related to the extent of the effluent mixing zone

National Project No.	Mill Name (Location)	Receiving environment	Mean annual flow of receiving environment (m^3/s)	Mean 7Q10 flow (m^3/s)	Mean annual effluent flow (m^3/d)	Plume study or modelling in Cycle 2	Date of plume study or modelling	Measured plume length (m)	Modelled plume length (m)	Mean TSS (kg/d)	Mean BOD_5 (kg/d)	Mean output (t/d)
PP1201	Spruce Falls Inc. (Matane)	St Lawrence River	na	na	16730	none		700 (rising) 600 (falling)	1000 (rising) 720 (falling)	971	502	477
PP1202	Uniforêt Sawmill Pulp Inc. (Port-Cartier)	St Lawrence River	na	na	16719	none		110	214	1386	535	499
PP1208	Cascades Inc. (Kingsey Falls)	Rivière Nicolet Sud-Ouest	27,8	0,315	6160	Cx	1998	30	6000-6500 (summer low flow)	536	160.2	600
PP1561	Abitibi-Consolidated Inc. (La Baie)	Saguenay River(Ha! Ha! Bay)	na	na	43085	none		100 (rising) 720 (falling)	1000 (extreme tides)	4356	2467	1031.15

Cx: Cormix model; Rwt: Rhodamine WT
nd: not determined
Shaded cells: effluent discharged to tide-affected areas

Annex 4 Results of sublethal (GM-IC25) and lethal (GM-LC50) toxicity tests, Cycle 1 vs Cycle 2

National Project No.	Mill Name (Location)	Cycle 1			Cycle 2				
		Selenastrum capricornutum GM-IC25	*Ceriodaphnia dubia* GM-IC25	*Pimephales promelas* GM-IC25	*Selenastrum capricornutum* GM-IC25	*Ceriodaphnia dubia* GM-IC25	*Pimephales promelas* GM-IC25	*Ceriodaphnia dubia* GM-LC50	*Pimephales promelas* GM-LC50
	FRESH WATER								
PP1086	Fraser Papers (Thurso)	3,0	7.6	8.0	58.8	43.3	100.0	100	100
PP1087	Kruger Inc. (Trois-Rivières)	3.7	1.3	17.2	100.0	38.2	100.0	100	100
PP1091	Abitibi-Consolidated Inc. (Beaupré)	ND	0.2	2.1	46.7	9.0	96.0	79.7	100
PP1092	Bowater Inc. (Donnacona)	1.9	1.7	10.5	72.8	19.1	83.0	100	100
PP1093	Stadacona Papers (Québec)	39.7	5.0	19.7	100.0	100.0	90.2	100	100
PP1094	Tembec Inc. (Témiscaming) (effluent TDE)	5.5	22.5	19.9	18.0	22.0	20.9	59.8	46.4
PP1098	Smurfit-Stone Container Corporation (La Tuque)	nd	12.6	17.2	30.2	59.2	97.0	100	100
PP1100	Uniforêt Tripap Inc. (Trois-Rivières)	2.8	5.0	27.1	100.0	48.5	100.0	100	100
PP1102	Smurfit-Stone Container Corporation (Portage-du-Fort)	21.4	44.3	96.0	37.8	52.8	100.0	92.4	100
PP1104	Abitibi-Consolidated Inc. (Clermont)	4.4	1.8	18.3	100.0	28.2	100.0	90.6	100
PP1106	SFK Pulp (St-Félicien)	16.2	15.6	53.2	20.9	20.1	68.6	95.6	100
PP1114	Norampac Inc. (Cabano)	61.2	39.8	99.2	100.0	66.1	83.7	100	100
PP1117	Cascades East-Angus Inc.. Divison Cartech. Paperboard Industries Corp. (East-Angus)	4.8	4.4	17.3	40.7	49.9	100.0	100	100
PP1118	Bowater Inc. (Gatineau)	ND	3.0	16.0	92.8	57.5	100.0	100	100
PP1131	Kruger Inc. (Bromptonvile)	12.0	1.4	12.1	66.6	83.8	100.0	100	100
PP1132	Abitibi-Consolidated Inc. (Jonquière)	7.5	0.8	5.2	92.8	69.0	95.5	100	100
PP1133	Bowater Inc. (Dolbeau)	6.0	1.3	3.1	88.5	54.6	94.5	100	100
PP1135	Abitibi-Consolidated Inc. (Shawinigan)	6.3	2.5	20.9	91.9	59.2	77.7	100	100
PP1136	Abitibi-Consolidated Inc. (Grand-Mère)	9.5	10.2	35.8	82.0	40.3	61.7	100	100

ND: not determined

Annex 4 Results of sublethal (GM-IC25) and lethal (GM-LC50) toxicity tests, Cycle 1 vs Cycle 2

National Project No.	Mill Name (Location)	Cycle 1			Cycle 2				
		Selenastrum capricornutum GM-IC25	*Ceriodaphnia dubia* GM-IC25	*Pimephales promelas* GM-IC25	*Selenastrum capricornutum* GM-IC25	*Ceriodaphnia dubia* GM-IC25	*Pimephales promelas* GM-IC25	*Ceriodaphnia dubia* GM-LC50	*Pimephales promelas* GM-LC50
	FRESH WATER								
PP1137	Kruger Wayagamack Inc. (Trois-Rivières)	18.0	11.0	52.5	81.1	33.7	84.7	100	100
PP1138	F.F. Soucy Inc. (Rivière-du-Loup)	ND	2.5	8.9	84.2	65.2	86.2	100	100
PP1145	Cascades Inc. (Jonquière)	14.0	5.3	18.1	95.7	85.3	100.0	100	100
PP1147	Nortkraft Quévillon Inc. (Lebel-sur-Quévillon)	5.2	8.0	16.9	60.4	43.7	100.0	100	100
PP1148	Domtar Inc. (Windsor)	9.8	23.7	75.6	64.0	20.4	82.4	100	100
PP1153	Papier Masson ltée (Masson-Angers)	2.4	0.8	4.3	78.9	21.7	87.5	100	100
PP1177	Abitibi-Consolidated Inc. (Alma)	ND	3.5	7.4	100.0	57.8	100.0	100	100
PP1178	EMCO Ltd (Pont-Rouge)	1.6	1.1	8.9	56.7	42.1	80.7	95.5	86.2
PP1183 PP1179	Papier Cascade Lupel Inc. et Désencrage CMD Inc. (Cap-de-la-Madeleine)	29.0	4.9	45.2	96.4	40.7	95.3	100	100
PP1181	Cascades Inc. (Breakeyville)	20.7	11.2	24.7	40.7	37.0	35.5	80.6	47.6
PP1182	Mohawk Pulp Ltd (St-Antonin)	4.0	0.7	29.7	100.0	3.6	48.7	87.8	47.3
PP1184	Abitibi-Consolidated Inc. (Amos)	54.8	100.0	95.7	66.1	30.3	100.0	79.4	100
PP1186	Eddy Paper ltée. Scott Paper Ltd (Ottawa-Hull)	ND	44.3	85.2	100.0	64.6	100.0	100	100
PP1187	J. Ford Ltd (Portneuf)	ND	2.1	2.1	25.3	6.3	42.4	57.3	42.5
PP1188	Scott Paper Ltd (Lennoxville)	ND	9.6	55.4	68.2	7.5	70.9	59.4	93.3
PP1191	Tembec. St-Raymond Mill (St-Léonard-de-Portneuf)	0.9	3.4	20.4	13.7	11.2	86.4	59.3	100
PP1193	Spexel Inc. (Beauharnois)	17.2	32.0	33.0	90.1	48.6	54.2	48.6	54.2
PP1194	Cascades Inc. (Lachute)	ND	1.6	8.1	67.4	24.9	70.8	84.1	91.8
PP1196	Scott Paper Ltd (Crabtree)	ND	32.2	96.0	96.8	69.4	84.9	100	94.0
PP1197	Produits Desbiens Inc. (Desbiens)	100.0	63.9	ND	100.0	97.6	52.8	100	90.4
PP1198	Cascades Inc. (St-Jérôme)	3.5	3.4	8.1	57.7	25.5	62.9	100	92.6
PP1208	Cascades Inc. (Kingsey Falls)	0.6	0.5	3.1	80.7	40.8	64.2	100	92.6

ND: not determined

Annex 4 Results of sublethal (GM-IC25) and lethal (GM-LC50) toxicity tests, Cycle 1 vs Cycle 2

National Project No.	Mill Name (Location)	Cycle 1			Cycle 2			
		Echinoderms	*Menidia beryllina*	*Champia parvula*	*Echinodermes*	*Menidia beryllina*	*Champia parvula*	*Menidia beryllina*
		GM-IC25	GM-IC25	GM-IC25	GM-IC25	GM-IC25	GM-IC25	GM-LC50
	MARINE ENVIRONMENT							
PP1088	Abitibi-Consolidated Inc. (Baie-Comeau)	5.9	12.9	5.2	21.1	68.8	11.3	68.8
PP1099	Smurfit-Stone Container Corporation (Matane)	25.4	20.1	5.4	58.7	66.7	38.3	66.7
PP1101	Smurfit-Stone Container Corporation (New-Richmond)	5.2	75.8	2.5	36.5	68.5	9.7	68.5
PP1157	Gaspesia Ltd (Chandler)	4.5	36.0	0.9	7.5	69.9	10.9	69.9
PP1201	Spruce Falls Inc. (Matane)	ND	ND	ND	52.6	67.7	15.5	67.8
PP1202	Uniforêt Sawmill Pulp Inc. (Port-Cartier)	ND	ND	ND	52.6	67.5	10.4	67.3
PP1561	Abitibi-Consolidated Inc. (La Baie)	0.1	22.5	0.8	2.9	69.0	10.6	69.0

ND: not determined

Annex 5 Fishing methods and sampling period in Cycle 2

National Project No.	Mill Name	Location	Receiving Environment	Exposure Area Gear Types (Effort) (Gear/day) or (hr/pers.)*	Reference Area Gear Types (Effort) (Gear/day) or (hr/pers.)*	Sampling Period in Cycle 2
PP1086	Fraser Papers	Thurso	Ottawa River	Electrofishing + Angling+ Hoop net+ Alaska trap (not determined)	Electrofishing + Angling+ Hoop net+ Alaska trap (not determined)	19-24/4/1997, 26/9/1997 to 10/10/1997, 14-16/10/1998
PP1087	Kruger Inc.	Trois-Rivières	St Lawrence River	No fish survey		
PP1088	Abitibi-Consolidated Inc.	Baie-Comeau	St Lawrence River	Gillnet (35), Hoop net (10), Longline (2), Angling (10)*	Gillnet (28), Hoop net (10), Angling (5)*	26/8/1999 to 2/9/1999
PP1091	Abitibi-Consolidated Inc.	Beaupré	Rivière des Vases	Gillnet (25), Fish trap (7), Seine (1), Electrofishing (32.4)	Gillnet (22), Alaska trap (1), Seine (3), Electrofishing (37.2)	14/8/1999 to 11 /09/1999
PP1092	Bowater Inc.	Donnacona	St Lawrence River	Gillnet (59), Seine (3)	Gillnet (52), Weir(30)	21/9/1999 to 7/10/1999
PP1093	Stadacona Papers	Quebec City	St Lawrence River	No fish survey		
PP1094	Tembec Inc.	Témiscaming	Ottawa River	Gillnet (30), Fish trap (8), Hoop net (5)	Gillnet (48), Fish trap (3)	14-20/8/1999
PP1098	Smurfit-Stone Container Corporation	La Tuque	Saint-Maurice River	Gillnet (36), Hoop net (11), Fish trap (4), Angling(1)	Gillnet (46), Hoop net (9)	1-10/9/1999
PP1099	Smurfit-Stone Container Corporation	Matane	St Lawrence River	No fish survey		
PP1100	Uniforêt Tripap Inc.	Trois-Rivières	St Lawrence River	No fish survey		
PP1101	Smurfit-Stone Container Corporation	New-Richmond	Chaleur Bay	Gillnet (30)	Gillnet (east: 19, west: 20)	13-21/9/1999
PP1102	Smurfit-Stone Container Corporation	Portage- du-Fort	Ottawa River	Gillnet (70)	Gillnet (east: 44, west: 55)	6-15/10/1999
PP1104	Abitibi-Consolidated Inc.	Clermont	Malbaie River	Hoop net (5), Fish trap (21), Electrofishing (14.6)	Hoop net (10), Fish trap (20), Electrofishing (9.2)	25/8/1999 to 1/9/1999
PP1106	SFK Pulp	St-Félicien	Mistassini River	Gillnet (32), Hoop net (14), Fish trap (29),Seine (7)	Gillnet (24), Hoop net (45)	30/9/1998 to 15/10/1998
PP1114	Norampac Inc.	Cabano	Cabano River	Electrofishing (57), Gillnet (6)	Gillnet (17), Hoop net (2)	7-12/9/1998
PP1117	Cascades East-Angus Inc. Division Cartech, Paperboard Industries Corp.	East-Angus	St-François River	Hoop net (22), Electrofishing (402.7)	Hoop net (14), Electrofishing (123.0)	28/9/1998 to 19/10/1998

Annex 5 Fishing methods and sampling period in Cycle 2

National Project No.	Mill Name	Location	Receiving environment	Exposure Area Gear Types (Effort) (gear/day) or (hr/pers.)*	Reference Area Gear Types (Effort) (gear/day) or (hr/pers.)*	Sampling Period in Cycle 2
PP1118	Bowater Inc.	Gatineau	Ottawa River	Angling+ Hoop net+ Electrofishing (not determined)	Angling+ Hoop net + Electrofishing (not determined)	4-16/10/1998 and 2-6/10/1999
PP1131	Kruger Inc.	Bromptonville	St-François River	Hoop net(19), Electrofishing (541.9)	Hoop net (20), Electrofishing (142.8)	14/9/1998 to 23/10/1998
PP1132	Abitibi-Consolidated Inc.	Jonquière	Saguenay River and Riv. aux Sables	Gillnet(35)	Gillnet (20)	30/8/1999 to 6/9/1999
PP1133	Bowater Inc.	Dolbeau	Mistassini River	Gillnet+ Hoop net+ Fish trap (33)	No fishing	30/9/1998 to 8/10/1998
PP1135	Abitibi-Consolidated Inc.	Shawinigan	Shawinigan River	Gillnet (18), Hoop net(4), Fish trap (13), Longline (21)	Gillnet(10), Hoop net(10), Fish trap (12), Longline(19), Seine (3)	13-20/8/1999
PP1136	Abitibi-Consolidated Inc.	Grand-Mère	St-Maurice River	No fish survey		
PP1137	Kruger Wayagamack Inc.	Trois-Rivières	St Lawrence River	No fish survey		
PP1138	F.F. Soucy Inc.	Rivière-du-Loup	Rivière du Loup	Electrofishing (216 fall + not determined spring), Seine (not determined)	Electrofishing (426 fall + not determined spring), Seine (not determined)	14-22/5/1999 and 4-11/10/1999
PP1145	Cascades Goupe Carton Plat Inc.	Jonquière	Rivière aux Sables	Gillnet (5), Hoop net+ Alaska trap (12)	Gillnet(20)	28/8 to 6/9 and 28/9 to 2/10/1999
PP1147	Nortkraft Quévillon Inc.	Lebel-sur-Quévillon	Quévillon River	Gillnet (8), Alaska trap (17), Electrofishing (45)	Hoop net(22)	2-12/9/1998
			Bell River	Gillnet(35)	Gillnet (20)	2-12/9/1998
PP1148	Domtar Inc.	Windsor	St-François River	Hoop net (39), Electrofishing (360)	Hoop net (16)	21/9/1998 to 7/10/1998
PP1153	Papier Masson ltée	Masson-Angers	Rivière du Lièvre	Angling+ Electrofishing (not determined)	Angling+ Electrofishing (not determined)	19-24/4/1997 and 26/9/1997 to 10/10/1997 and ? 1998
PP1157	Gaspesia Ltd	Chandler	Chaleur Bay	No fish survey		
PP1177	Abitibi-Consolidated Inc.	Alma	Petite Décharge River	Fish trap (24), Longline(30), Hoop net (8), Gillnet (4)	Hoop net (20), Gillnet (12)	15-20/9/1999
PP1178	EMCO Ltd	Pont-Rouge	Jacques-Cartier River	No fish survey		

Annex 5 Fishing methods and sampling period in Cycle 2

National Project No.	Mill Name	Location	Receiving environment	Exposure Area Gear Types (Effort) (gear/day) or (hr/pers.)*	Reference Area Gear Types (Effort) (gear/day) or (hr/pers.)*	Sampling Period in Cycle 2
PP1183 PP1179	Papier Cascade Lupel Inc. et Désencrage CMD Inc.	Cap-de-la-Madeleine	St Lawrence River	Seine (10)	Seine (11)	2-3/9/1999
PP1181	Cascades Inc.	Breakeyville	Chaudière River	Electrofishing (182)	Electrofishing (205)	8-9/9/1999
PP1182	Mohawk Pulp Ltd	St-Antonin	Rivière du Loup	Hoop net (4), Gillnet (2), Angling (2.58)*, Alaska trap (2)	Hoop net (2), Gillnet (7), Angling (1.33)*, Alaska trap(1)	13-17/9/1999
PP1184	Abitibi-Consolidated Inc.	Amos	Harricana River	Gillnet (6), Hoop net(7)	Gillnet (22), Hoop net (10)	16-21/9/1998
PP1186	Papiers de spécialité Eddy ltée, Scott Paper Ltd	Ottawa-Hull	Ottawa River	No fish survey		
PP1187	J. Ford Ltd	Portneuf	Portneuf River	Gillnet (near-field: 44), Hoop net (far-field: 14), Electrofishing (75)	Gillnet(145)	25/9/1999 to 3/10/1999
PP1188	Scott Paper Ltd	Lennoxville	Massawippi and St-François rivers	Gillnet (Massawipi:34), Seine (Massawipi:4)	Gillnet (Massawipi: 48., St-François: 37), Seine (St-François: 3)	1-13/10/1998
PP1191	Tembec, St-Raymond Mill	St-Léonard-de-Portneuf	Ste-Anne River	Gillnet (18), Hoop net (9), Fish trap (4)	Gillnet (21), Hoop net(11), Fish trap (2)	29/8/1999 to 6/9/1999
PP1193	Spexel Inc.	Beauharnois	St Lawrence River	No fish survey		
PP1194	Cascades Inc.	Lachute	Rivière du Nord	Electrofishing (63.3)	Electrofishing (39.6)	24-30/8/1999
PP1196	Scott Paper Ltd	Crabtree	Ouareau River	Gillnet (6), Hoop net (18), Electrofishing (490)	Gillnet (Ouareau: 28, Rouge: 12)	14-21/9/1999
PP1197	Produits Desbiens Inc.	Desbiens	Métabetchouane River	No fish survey		
PP1198	Cascades Inc.	St-Jérôme	Rivière du Nord	Electrofishing (117), Gillnet (1), Hoop net (1)	Electrofishing (54), Gillnet (2), Hoop net (1)	1-4/9/1998
PP1201	Spruce Falls Inc.	Matane	St Lawrence River	Gillnet (36), Night line (1), Angling(1)	Gillnet (51)	24/9/2001-2/10/2001
PP1202	Uniforêt Sawmill Pulp Inc.	Port-Cartier	St Lawrence River	No fish survey		
PP1208	Cascades Inc.	Kingsey Falls	Rivière Nicolet Sud-Ouest	Electrofishing (280), Hoop net (5)	Electrofishing (172), Gillnet (26)	24-31/8/1998
PP1561	Abitibi-Consolidated Inc.	La Baie	Saguenay River	Ponar grab sampler (30), Hoop net (16), Fish trap (40), Gillnet (77), Angling (2)	Ponar grab sampler (3), Manual harvesting by divers (2), Gillnet (19)	2-14/10/1999

Annex 6 Capture results and means of the morphological parameters for the exposure and reference area populations

National Project No.	Mill Name (Location)	Area fished	Common Name	Sex	n caught (m+f)	n measured	Mean total length (mm)	Mean fork length (mm)	Mean body weight (g)	Mean age (yrs)	Mean liver weight (g)	Mean gonad weight (g)	Mean fecundity (n eggs)
PP1086	Fraser Papers	E	Yellow perch	m	143	44	Nd	na	nd	nd	nd	nd	na
	(Thurso)	E	Yellow perch	f		60	Nd	na	nd	nd	nd	nd	nd
	1997	E	Yellow perch	i		39	Nd	na	nd	nd	nd	nd	na
		E	Johnny darter	m	59	21	Nd	na	nd	nd	nd	nd	na
		E	Johnny darter	f		27	Nd	na	nd	nd	nd	nd	nd
		R	Yellow perch	m	108	25	Nd	na	nd	nd	nd	nd	na
		R	Yellow perch	f		53	Nd	na	nd	nd	nd	nd	nd
		R	Yellow perch	i		30	Nd	na	nd	nd	nd	nd	na
		R	Johnny darter	m	58	20	Nd	na	nd	nd	nd	nd	na
		R	Johnny darter	f		24	Nd	na	nd	nd	nd	nd	nd
	1998	**E**	**Yellow perch**	**m**	**nd**	**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**na**
		E	**Yellow perch**	**f**		**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**nd**
		E	**Johnny darter**	**m**	**nd**	**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**na**
		E	**Johnny darter**	**f**		**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**nd**

Legend: i: Immature, f: Female, m: Male, na: not applicable, nd: not determined, E: Exposure area, R: Reference area
Italics: Data not considered as no statistical analysis was performed
Bold: Data not considered as there were two data series for the same mill

Annex 6 Capture results and means of the morphological parameters for the exposure and reference area populations

National Project No.	Mill Name (Location)	Area fished	Common Name	Sex	n caught (m+f)	n measured	Mean total length (mm)	Mean fork length (mm)	Mean body weight (g)	Mean age (yrs)	Mean liver weight (g)	Mean gonad weight (g)	Mean fecundity (n eggs)
PP1086 (cont'd)		**R**	**Yellow perch**	**m**	**nd**	**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**na**
		R	**Yellow perch**	**f**		**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**nd**
		R	**Johnny darter**	**m**	**nd**	**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**na**
		R	**Johnny darter**	**f**		**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**nd**
PP1088	Abitibi-Consolidated Inc. (Baie-Comeau)	E	Shorthorn sculpin	m	101	18	196	na	116	4,0	4,77	0,34	na
		E	Shorthorn sculpin	f		20	216	na	159	4,0	5,76	0,74	nd
		R	Shorthorn sculpin	m	89	20	172	na	77	3,0	2,37	0,11	na
		R	Shorthorn sculpin	f		39	240	na	249	4,0	10,67	3,43	nd
PP1091	Abitibi-Consolidated Inc. (Beaupré)	E	Longnose sucker	m	109	18	na	362	678	8,0	21,73	36,36	na
		E	Longnose sucker	f		77	Na	409	942	9,0	24,32	51,05	49272
		E	Mottled sculpin	m	114	25	na	60	2,84	5,0	0,06	0,01	na
		E	Mottled sculpin	f		19	na	66	3,65	6,0	0,08	0,02	nd
		E	Mottled sculpin	i		61	na	50	1,42	4,0	0,05	nd	na

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Annex 6 Capture results and means of the morphological parameters for the exposure and reference area populations

National Project No.	Mill Name (Location)	Area fished	Common Name	Sex	n caught (m+f)	n measured	Mean total length (mm)	Mean fork length (mm)	Mean body weight (g)	Mean age (yrs)	Mean liver weight (g)	Mean gonad weight (g)	Mean fecundity (n eggs)
PP1091 (cont'd)		R	Longnose sucker	m	138	52	na	364	665	8,0	21,90	44,60	na
		R	Longnose sucker	f		68	na	391	845	7,0	26,64	50,80	43604
		R	Mottled sculpin	m	127	13	na	57	2,38	4,0	0,07	0,01	na
		R	Mottled sculpin	f		8	na	95	10,2	8,0	0,25	0,10	nd
		R	Mottled sculpin	i		42	na	55	1,98	5,0	0,07	nd	na
PP1092	Bowater Inc. (Donnacona)	E	Longnose sucker	m	413	34	na	356	653	8,0	17,08	44,20	na
		E	Longnose sucker	f		57	na	390	844	8,0	23,25	53,36	37895
		E	White sucker	m	65	24	na	347	633	5,0	11,41	49,22	na
		E	White sucker	f		12	na	385	891	6,0	18,25	53,56	27215
		R	Longnose sucker	m	101	33	na	350	605	8,0	12,69	48,31	na
		R	Longnose sucker	f		54	na	383	802	8,0	21,14	66,47	39631
		R	White sucker	m	86	20	na	332	589	5,0	8,00	45,07	na
		R	White sucker	f		31	na	366	785	5,0	14,51	42,58	27752

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Annex 6 Capture results and means of the morphological parameters for the exposure and reference area populations

National Project No.	Mill Name (Location)	Area fished	Common Name	Sex	n caught (m+f)	n measured	Mean total length (mm)	Mean fork length (mm)	Mean body weight (g)	Mean age (yrs)	Mean liver weight (g)	Mean gonad weight (g)	Mean fecundity (n eggs)
PP1094	Tembec Inc. (Témiscaming)	E	White sucker	m	52	20	na	370	912	8,0	12,42	16,22	na
		E	White sucker	f		26	na	409	1176	8,0	17,48	29,99	59745
		E	Fallfish	m	41	16	na	286	514	5,0	10,13	1,45	na
		E	Fallfish	f		7	na	349	714	6,0	17,37	4,24	nd
		R	White sucker	m	70	33	na	331	557	6,0	4,87	8,34	na
		R	White sucker	f		43	na	392	778	7,0	8,59	17,67	41568
		R	Fallfish	m	13	7	na	218	158	4,0	2,02	1,14	na
		R	Fallfish	f		2	na	252	240	nd	2,63	2,01	nd
PP1098	Smurfit-Stone Container Corporation (La Tuque)	E	White sucker	m	44	24	na	372	737	7,0	5,42	39,96	na
		E	White sucker	f		14	na	424	918	7,0	9,95	30,89	27699
		E	Rock bass	m	94	35	na	189	178	8,0	1,28	0,78	na
		E	Rock bass	f		22	na	183	163	7,0	1,46	2,96	nd
		R	White sucker	m	43	16	na	404	1125	6,0	16,81	67,32	na
		R	White sucker	f		24	na	442	1423	7,0	17,96	52,14	61797
		R	Rock bass	m	50	31	na	233	274	8,0	2,31	1,85	na
		R	Rock bass	f		17	na	192	163	7,0	1,75	2,19	nd

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Annex 6 Capture results and means of the morphological parameters for the exposure and reference area populations

National Project No.	Mill Name (Location)	Area fished	Common Name	Sex	n caught (m+f)	n measured	Mean total length (mm)	Mean fork length (mm)	Mean body weight (g)	Mean age (yrs)	Mean liver weight (g)	Mean gonad weight (g)	Mean fecundity (n eggs)
PP1101	Smurfit-Stone Container Corporation (New-Richmond)	E	Winter flounder	m	225	55	293	na	382.8	9.2	5.70	22.40	na
		E	Winter flounder	f		59	315	na	496.9	9.8	11.70	28.30	1420075
		E	Shorthorn sculpin	m	18	0	nd	na	nd	nd	nd	nd	na
		E	Shorthorn sculpin	f		17	351	na	779.1	4.5	34.90	25.90	59454
	east	R	Winter flounder	m	230	10	293	na	412.8	9.6	6.40	19.90	na
		R	Winter flounder	f		1	255	na	245	10.0	3.01	5.47	nd
		R	Shorthorn sculpin	m	26	2	302	na	482.5	4.5	22.00	12.10	na
		R	Shorthorn sculpin	f		24	354	na	868.3	4.4	39.60	25.30	80084
	west	R	Winter flounder	m	250	31	294	na	384.7	9.8	5.90	20.10	na
		R	Winter flounder	f		32	323	na	522	9.9	13.40	30.90	1450375
		R	Shorthorn sculpin	m	26	0	nd	na	nd	nd	nd	nd	na
		R	Shorthorn sculpin	f		26	355	na	825.2	4.3	35.70	23.50	72542

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Annex 6 Capture results and means of the morphological parameters for the exposure and reference area populations

National Project No.	Mill Name (Location)	Area fished	Common Name	Sex	n caught (m+f)	n measured	Mean total length (mm)	Mean fork length (mm)	Mean body weight (g)	Mean age (yrs)	Mean liver weight (g)	Mean gonad weight (g)	Mean fecundity (n eggs)
PP1102	Emballages Smurfit-	E	White sucker	m	49	20	na	390	884.3	5.0	8.80	60.10	na
	Stone Canada Inc.	E	White sucker	f		29	na	378	823.3	4.5	11.00	50.70	50081
	(Portage- du-Fort)	E	Channel catfish	m	50	23	na	391	857.6	11.9	13.60	3.80	na
		E	Channel catfish	f		16	na	352	621.3	10.8	10.20	24.40	7066
	east	R	White sucker	m	47	15	na	380	814.7	6.2	9.20	53.80	na
		R	White sucker	f		30	na	406	998.5	5.5	14.60	58.60	58365
		R	Channel catfish	m	11	4	na	469	1922.5	9.8	38.80	15.80	na
		R	Channel catfish	f		5	na	623	3975	19.2	82.70	143.80	48285
	west	**R**	**White sucker**	**m**	**22**	**7**	**na**	**367**	**695.7**	**4.7**	**5.70**	**36.00**	**na**
		R	**White sucker**	**f**		**15**	**na**	**373**	**809.3**	**4.7**	**9.40**	**49.60**	**48728**
		R	**Channel catfish**	**m**	**28**	**6**	**na**	**479**	**1634.2**	**16.0**	**22.10**	**5.90**	**na**
		R	**Channel catfish**	**f**		**15**	**na**	**420**	**1447.3**	**13.0**	**25.70**	**58.10**	**11868**

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Annex 6 Capture results and means of the morphological parameters for the exposure and reference area populations

National Project No.	Mill Name (Location)	Area fished	Common Name	Sex	n caught (m+f)	n measured	Mean total length (mm)	Mean fork length (mm)	Mean body weight (g)	Mean age (yrs)	Mean liver weight (g)	Mean gonad weight (g)	Mean fecundity (n eggs)
PP1104	Compagnie Abitibi-Consolidated du Canada (Clermont)	E	Longnose sucker	m	828	31	na	242	159	3.0	2.180	8.35	na
		E	Longnose sucker	f		38	na	373	225	3.0	3.410	8.46	9401
		E	Longnose dace	m	112	31	na	69	3.9	3.0	0.098	0.02	na
		E	Longnose dace	f		35	na	80	6.1	4.0	0.151	0.21	1288
		R	Longnose sucker	m	275	33	na	162	46	4.0	0.690	2.06	na
		R	Longnose sucker	f		37	na	182	68	4.0	1.100	2.66	2994
		R	Longnose dace	m	92	10	na	52	1.4	2.0	0.018	0.01	na
		R	Longnose dace	f		35	na	57	2.1	2.0	0.031	0.05	324
PP1106	SFK Pulp (St-Félicien)	E	Brown bullhead	m	107	31	na	219	134	5.0	3.11	0.19	na
		E	Brown bullhead	f		31	na	220	133	5.0	3.34	1.69	4704
		E	White sucker	m	27	3	na	441	975	10.0	13.48	76.17	na
		E	White sucker	f		5	na	474	1565	10.0	28.13	95.37	44433
		R	Brown bullhead	m	67	32	na	237	187	5.0	4.96	0.24	na
		R	Brown bullhead	f		21	na	229	159	5.0	4.40	2.02	5288
		R	White sucker	m	17	6	na	455	1425	10.0	16.52	78.27	na
		R	White sucker	f		10	na	504	1840	11.0	32.25	96.92	57200

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PP1114	Norampac Inc. (Cabano)	E	White sucker	m	177	32	354	na	481	7.1	4.400	28.20	na
		E	White sucker	f		25	368	na	501	6.8	5.800	14.00	11361
		E	Yellow perch	m	92	24	151	na	49	4.6	0.500	2.90	na
		E	Yellow perch	f		28	194	na	106	4.3	1.600	2.10	9039
		R	White sucker	m	138	31	352	na	441	7.1	3.400	26.00	na
		R	White sucker	f		29	362	na	459	7.0	4.300	11.90	9521
		R	Yellow perch	m	60	12	116	na	20	2.9	0.200	1.10	na
		R	Yellow perch	f		15	182	na	81	4.8	0.900	1.50	5409
PP1117	Cascades East-Angus Inc,. Division Cartech. Paperboard Industries Corp. (East-Angus)	E	White sucker	m	88	33	399	na	721.3	6.0	11.27	50.18	na
		E	White sucker	f		35	430	na	940.9	6.5	18.38	60.58	28596
		E	Tesselated darter	m	60	29	61	na	1.94	2.6	0.026	0.02	na
		E	Tesselated darter	f		31	54	na	1.39	1.9	0.017	0.03	nd
		R	White sucker	m	64	31	376	na	570.1	5.5	3.960	38.36	na
		R	White sucker	f		33	414	na	714.5	5.7	6.310	36.04	19726
		R	Tesselated darter	m	61	31	64	na	2.11	2.8	0.026	0.02	na
		R	Tesselated darter	f		30	55	na	1.37	2.0	0.021	0.03	nd

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PP1118	Bowater Inc. (Gatineau) (1998)	E	Yellow perch	m	36	1	129	na	26	nd	nd	nd	na
		E	Yellow perch	f		19	180	na	71.4	nd	nd	nd	nd
		E	Yellow perch	i		16	153	na	42.9	nd	nd	nd	na
		E	Johnny darter	m	113	29	60	na	1.74	nd	nd	nd	na
		E	Johnny darter	f		28	53	na	1.18	nd	nd	nd	nd
		R	Yellow perch	m	69	21	147	na	41.2	nd	nd	nd	na
		R	Yellow perch	f		25	177	na	69.1	nd	nd	nd	nd
		R	Yellow perch	i		23	144	na	35.9	nd	nd	nd	na
		R	Johnny darter	m	116	22	60	na	1.68	nd	nd	nd	na
		R	Johnny darter	f		26	56	na	1.41	nd	nd	nd	nd
		E	Yellow perch	mf	nd	nd	nd	na	nd	nd	nd	nd	nd
		R	Yellow perch	mf		nd	nd	na	nd	nd	nd	nd	nd
PP1118 (cont'd)	**Bowater Produits forestiers du Canada Inc. (Gatineau) (1999)**	**E**	**Yellow perch**	**m**	**21**	**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**na**
		E	**Yellow perch**	**f**	**20**	**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**na**
		E	**Yellow perch**	**i**	**19**	**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**na**
		R	**Yellow perch**	**m**	**21**	**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**na**
		R	**Yellow perch**	**f**	**20**	**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**na**
		R	**Yellow perch**	**i**	**23**	**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**na**

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PP1131	Kruger Inc. (Bromptonville)	E	White sucker	m	73	nd	392	na	704.3	6.1	4.320	57.33	na
		E	White sucker	f		nd	443	na	940.5	7.1	9.200	43.39	29751
		E	Tesselated darter	m	64	nd	63	na	2.29	2.8	0.028	0.04	na
		E	Tesselated darter	f		nd	59	na	1.52	2.3	0.040	0.05	nd
		R	White sucker	m	76	nd	383	na	642.3	4.4	4.970	56.60	na
		R	White sucker	f		nd	418	na	854.7	5.5	8.620	45.23	30432
		R	Tesselated darter	m	64	nd	67	na	2.58	2.8	0.050	0.03	na
		R	Tesselated darter	f		nd	55	na	1.34	1.9	0.035	0.04	nd
PP1132	Abitibi-Consolidated Inc. (Jonquière)	E	Longnose sucker	m	400	34	na	300	361	7.0	5.19	16.12	na
		E	Longnose sucker	f		42	na	314	414	7.0	7.29	13.44	17356
		E	**White sucker**	**mf**	**7**	**7**	**na**	**325**	**545**	**nd**	**nd**	**nd**	**na**
		R	Longnose sucker	m	328	38	na	260	246	7.0	2.78	13.16	na
		R	Longnose sucker	f		82	na	293	352	7.0	3.43	11.39	15964
		R	**White sucker**	**mf**	**160**	**132**	**na**	**285**	**348**	**nd**	**nd**	**nd**	**na**

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PP1133	*Bowater Inc.*	*E*	*Longnose sucker*	*m*	*8*	*4*	*na*	*395*	*821*	*nd*	*12.19*	*33.35*	*na*
	(Dolbeau)	*E*	*Longnose sucker*	*f*		*1*	*na*	*410*	*900*	*nd*	*11.21*	*64.96*	*nd*
		E	*White sucker*	*m*	*6*	*2*	*na*	*430*	*1225*	*nd*	*20.94*	*59.58*	*na*
		E	*White sucker*	*f*		*3*	*na*	*477*	*1592*	*nd*	*26.81*	*82.81*	*nd*
		R	*Longnose sucker*	*m*	*0*	*0*	*na*	*nd*	*nd*	*nd*	*nd*	*nd*	*na*
		R	*Longnose sucker*	*f*		*0*	*na*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*
		R	*White sucker*	*m*	*0*	*0*	*na*	*nd*	*nd*	*nd*	*nd*	*nd*	*na*
		R	*White sucker*	*f*		*0*	*na*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*
PP1135	Abitibi-Consolidated Inc.	E	White sucker	m	298	71	na	365	744	6.0	11.72	9.75	na
	(Shawinigan)	E	White sucker	f		52	na	387	871	6.0	15.87	19.85	34938
		E	Rock bass	m	21	4	na	181	141	nd	1.41	0.55	na
		E	Rock bass	f		12	na	169	111	5.0	1.36	0.82	nd
		R	White sucker	m	427	49	na	349	667	4.0	9.65	14.20	na
		R	White sucker	f		50	na	393	929	5.0	16.10	24.02	51614
		R	Rock bass	m	89	40	na	166	97	nd	1.31	0.38	na
		R	Rock bass	f		29	na	153	82	6.0	1.24	1.05	nd

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PP1138	F.F. Soucy Inc. (Rivière-du-Loup) Spring	**E**	**Blacknose dace**	**m**	**446**	**59**	**71**	**na**	**nd**	**nd**	**nd**	**0,03**	**na**
		E	**Blacknose dace**	**f**		**66**	**75**	**na**	**nd**	**nd**	**0.11**	**0.59**	**nd**
		E	**Pearl dace**	**m**	**191**	**0**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**na**
		E	**Pearl dace**	**f**		**37**	**107**	**na**	**10.71**	**nd**	**nd**	**nd**	**nd**
		R	**Blacknose dace**	**m**	**653**	**37**	**67**	**na**	**nd**	**nd**	**0.05**	**0.02**	**na**
		R	**Blacknose dace**	**f**		**22**	**69**	**na**	**3.1**	**nd**	**0.09**	**0.41**	**nd**
		R	**Pearl dace**	**m**	**178**	**0**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**na**
		R	**Pearl dace**	**f**		**17**	**106**	**na**	**10.0**	**nd**	**nd**	**nd**	**nd**
	Fall	E	Blacknose dace	m	382	66	73	na	3.8	nd	nd	nd	na
		E	Blacknose dace	f		43	74	na	nd	nd	0.10	0.29	899
		E	Pearl dace	m	197	55	101	na	nd	nd	0.24	nd	na
		E	Pearl dace	f		56	113	na	nd	nd	0.32	1.34	2307
		R	Blacknose dace	m	191	41	71	na	3.26	nd	nd	nd	na
		R	Blacknose dace	f		44	71	na	nd	nd	0.07	0.24	704
		R	Pearl dace	m	297	60	101	na	nd	nd	0.14	nd	na
		R	Pearl dace	f		47	104	na	nd	nd	0.19	0.75	1873

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Annex 6 Capture results and means of the morphological parameters for the exposure and reference area populations

National Project No.	Mill Name (Location)	Zone fished	Common Name	Sex	n caught (m+f)	n measured	Mean total length (mm)	Mean fork length (mm)	Mean body weight (g)	Mean age (yrs)	Mean liver weight (g)	Mean gonad weight (g)	Mean fecundity (n eggs)
PP1145	Cascades Inc. (Jonquière)	E	Longnose sucker	m	353	33	na	283	330	7.0	5.21	17.50	na
		E	Longnose sucker	f		83	na	315	447	7.0	8.38	28.72	14957
		E	White sucker	m	154	30	na	281	369	5.0	3.96	19.75	na
		E	White sucker	f		36	na	334	561	7.0	8.43	25.72	12990
		R	Longnose sucker	m	328	38	na	260	246	7.0	2.78	13.16	na
		R	Longnose sucker	f		82	na	293	352	7.0	3.43	11.39	15964
		R	White sucker	m	160	54	na	286	337	7.0	2.51	15.68	na
		R	White sucker	f		40	na	311	434	8.0	5.74	14.45	15246
PP1147	Nortkraft Quévillon Inc. (Lebel-sur-Quévillon) (Quévillon River)	E	Longnose sucker	m	49	23	na	349	627	9.0	9.94	28.87	na
		E	Longnose sucker	f		22	na	371	738	9.0	11.21	37.21	19068
		E	White sucker	m	32	16	na	363	742	7.0	9.01	46.35	na
		E	White sucker	f		13	na	406	1058	8.0	15.40	37.85	27620
		R	Longnose sucker	m	49	9	na	335	536	8.0	9.10	24.40	na
		R	Longnose sucker	f		32	na	380	772	9.0	12.64	42.26	21567
		R	White sucker	m	13	7	na	366	756	7.0	8.23	46.52	na
		R	White sucker	f		4	na	364	715	5.0	9.56	18.13	24993

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Annex 6 Capture results and means of the morphological parameters for the exposure and reference area populations

National Project No.	Mill Name (Location)	Area fished	Common Name	Sex	n caught (m+f)	n measured	Mean total length (mm)	Mean fork length (mm)	Mean body weight (g)	Mean age (yrs)	Mean liver weight (g)	Mean gonad weight (g)	Mean fecundity (n eggs)
PP1147 (cont'd)	Nortkraft Quévillon Inc. (Lebel-sur-Quévillon) (Bell River)	E	Longnose sucker	m	20	12	na	338	569	9.0	6.83	26.25	na
		E	Longnose sucker	f		6	na	342	558	9.0	7.51	28.52	13421
		E	White sucker	m	35	11	na	358	730	8.0	6.40	33.39	na
		E	White sucker	f		15	na	346	607	7.0	8.04	19.42	17291
		R	Longnose sucker	m	19	7	na	339	547	8.0	7.98	24.49	na
		R	Longnose sucker	f		7	na	364	725	9.0	11.33	45.71	20317
		R	White sucker	m	38	11	na	341	615	7.0	6.52	35.69	na
		R	White sucker	f		11	na	356	663	7.0	8.06	25.65	17682
PP1148	Domtar Inc. (Windsor)	E	White sucker	m	22	22	395	na	654.9	6.5	4.05	46.79	na
		E	White sucker	f	33	33	433	na	864.7	7.6	8.11	42.87	26906
		E	Smallmouth bass	m	29	29	333	na	536.9	3.5	5.24	2.73	na
		E	Smallmouth bass	f	26	26	358	na	760.8	4.7	10.37	18.32	13680
		R	White sucker	m	29	29	387	na	655.6	6.0	3.87	58.32	na
		R	White sucker	f	31	31	417	na	796.1	6.2	6.23	43.82	26621
		R	Smallmouth bass	m	31	31	321	na	510	4.2	5.67	3.01	na
		R	Smallmouth bass	f	30	30	352	na	683	4.6	8.47	18.23	14052

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Annex 6 Capture results and means of the morphological parameters for the exposure and reference areas

National Project No.	Mill Name (Location)	Area fished	Common Name	Sex	n caught (m+f)	n measured	Mean total length (mm)	Mean fork length (mm)	Mean body weight (g)	Mean age (yrs)	Mean liver weight (g)	Mean gonad weight (g)	Mean fecundity (n eggs)
PP1153	Masson Ltd (Masson-Angers) (1997)	E	Yellow perch	m	98	12	nd	na	nd	nd	nd	nd	na
		E	Yellow perch	f		48	nd	na	nd	nd	nd	nd	nd
		E	Johnny darter	m	61	20	nd	na	nd	nd	nd	nd	na
		E	Johnny darter	f		36	nd	na	nd	nd	nd	nd	nd
		R	Yellow perch	m	82	16	nd	na	nd	nd	nd	nd	na
		R	Yellow perch	f		36	nd	na	nd	nd	nd	nd	nd
		R	Johnny darter	m	77	23	nd	na	nd	nd	nd	nd	na
		R	Johnny darter	f		35	nd	na	nd	nd	nd	nd	nd
PP1153 (cont'd)	**Masson Ltd (Masson-Angers) (1998)**	**E**	**Yellow perch**	**m**	**45**	**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**na**
		E	**Yellow perch**	**f**		**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**nd**
		E	**Johnny darter**	**m**		**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**na**
		E	**Johnny darter**	**f**		**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**nd**
		R	**Yellow perch**	**m**	**82**	**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**na**
		R	**Yellow perch**	**f**		**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**nd**
		R	**Johnny darter**	**m**		**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**na**
		R	**Johnny darter**	**f**		**nd**	**nd**	**na**	**nd**	**nd**	**nd**	**nd**	**nd**

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Annex 6 Capture results and means of the morphological parameters for the exposure and reference areas

National Project No.	Mill Name (Location)	Area fished	Common Name	Sex	n caught (m+f)	n measured	Mean total length (mm)	Mean fork length (mm)	Mean body weight (g)	Mean age (yrs)	Mean liver weight (g)	Mean gonad weight (g)	Mean fecundity (n eggs)
PP1177	Abitibi-Consolidated Inc. (Alma)	E	Brown bullhead	m	58	37	na	221	161	4.0	2.97	0.38	na
		E	Brown bullhead	f		18	na	213	143	4.0	2.76	1.36	2127
		E	Longnose sucker	m	122	27	na	295	354	6.0	4.73	18.09	na
		E	Longnose sucker	f		37	na	304	390	5.0	5.78	390	16386
		R	Brown bullhead	m	154	43	na	196	107	4.0	1.67	0.22	na
		R	Brown bullhead	f		34	na	179	83	4.0	1.15	0.71	1199
		R	Longnose sucker	m	9	4	na	320	454	8.0	5.41	16.90	na
		R	Longnose sucker	f		3	na	324	510	6.0	6.25	24.93	23667
PP1183 PP1179	Papier Cascade Lupel Inc. et Désencrage CMD Inc. (Cap-de-la-Madeleine)	E	Yellow perch	m	912	28	151	na	47.3	3.8	0.575	0.29	na
		E	Yellow perch	f		28	181	na	83.01	4.3	0.948	0.86	9015
		E	Trout-perch	m	367	31	66	na	2.67	2.9	0.032	0.00	na
		E	Trout-perch	f		28	68	na	3.13	2.9	0.034	0.04	nd
		R	Yellow perch	m	242	29	141	na	40.2	3.2	0.494	0.25	na
		R	Yellow perch	f		30	182	na	86.56	4.1	1.108	0.94	12220
		R	Trout-perch	m	299	36	69	na	3.03	2.8	0.036	0.01	na
		R	Trout-perch	f		33	70	na	3.65	2.8	0.036	0.03	nd

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Annex 6 Capture results and means of the morphological parameters for the exposure and reference areas

National Project No.	Mill Name (Location)	Area fished	Common Name	Sex	n caught (m+f)	n measured	Mean total length (mm)	Mean fork length (mm)	Mean body weight (g)	Mean age (yrs)	Mean liver weight (g)	Mean gonad weight (g)	Mean fecundity (n eggs)
PP1181	Cascades Inc. (Breakeyville)	E	Longnose dace	m	273	31	75	na	3.91	3.7	0.068	0.03	na
		E	Longnose dace	f		32	80	na	5.05	4.0	0.087	0.21	493
		E	Johnny darter	m	312	30	64	na	2.61	3.4	0.016	0.00	na
		E	Johnny darter	f		33	69	na	3.23	3.5	0.021	0.01	nd
		R	Longnose dace	m	217	31	74	na	3.68	3.5	0.070	0.03	na
		R	Longnose dace	f		25	86	na	5.83	3.6	0.124	0.28	553
		R	Johnny darter	m	197	31	66	na	2.58	3.3	0.019	0.00	na
		R	Johnny darter	f		32	70	na	3.15	3.4	0.025	0.02	nd
PP1182	Mohawk Pulp Ltd (St-Antonin)	E	White sucker	m	243	37	na	284	309	7.0	2.82	17.48	na
		E	White sucker	f		27	na	308	370	8.0	4.20	13.79	10387
		E	Yellow perch	m	73	37	na	122	26	4.0	0.22	2.31	na
		E	Yellow perch	f		27	na	211	146	6.0	2.10	4.65	15016
		R	White sucker	m	87	35	na	289	318	7.0	2.98	18.17	na
		R	White sucker	f		30	na	314	407	6.0	5.32	17.54	12786
		R	Yellow perch	m	88	35	na	131	33	4.0	0.26	3.00	na
		R	Yellow perch	f		30	na	192	112	6.0	1.50	4.01	12985

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Annex 6 Capture results and means of the morphological parameters for the exposure and reference areas

National Project No.	Mill Name (Location)	Area fished	Common Name	Sex	n caught (m+f)	n measured	Mean total length (mm)	Mean fork length (mm)	Mean body weight (g)	Mean age (yrs)	Mean liver weight (g)	Mean gonad weight (g)	Mean fecundity (n eggs)
PP1184	Abitibi-Consolidated Inc. (Amos)	E	Brown bullhead	m	780	63	291	na	336	9.0	7.22	0.59	na
		E	Brown bullhead	f		30	291	na	320	8.0	8.29	3.22	6838
		E	Longnose sucker	m	129	30	na	347	559	8.0	7.14	23.88	na
		E	Longnose sucker	f		41	na	379	732	8.0	11.60	31.11	20586
		R	Brown bullhead	m	260	52	281	na	295	8.0	5.35	0.45	na
		R	Brown bullhead	f		30	281	na	288	9.0	6.63	3.02	6081
		R	Longnose sucker	m	60	30	na	331	484	7.0	5.37	20	na
		R	Longnose sucker	f		17	na	364	620	8.0	8.33	34.87	15006
PP1187	J. Ford Ltd (Portneuf)	E	White sucker	m	42	16	na	224	151.3	2.8	1.80	10.00	na
		E	White sucker	f		21	na	235	182	2.8	2.20	9.80	17672
		E	White sucker	i		5	na	113	17.2	0.8	0.20	nd	na
		E	**Longnose sucker**	**mf**	**4**	**0**	**na**	**nd**	**nd**	**nd**	**nd**	**nd**	**na**
		R	White sucker	m	184	28	na	190	82.9	3.2	0.70	4.40	na
		R	White sucker	f		114	na	185	100.4	3.1	1.20	6.80	11449
		R	White sucker	i		42	na	123	22.2	1.5	0.20	nd	na
		R	**Longnose sucker**	**mf**	**67**	**0**	**na**	**nd**	**nd**	**nd**	**nd**	**nd**	**na**

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Annex 6 Capture results and means of the morphological parameters for the exposure and reference areas

National Project No.	Mill Name (Location)	Area fished	Common Name	Sex	n caught (m+f)	n measured	Mean total length (mm)	Mean fork length (mm)	Mean body weight (g)	Mean age (yrs)	Mean liver weight (g)	Mean gonad weight (g)	Mean fecundity (n eggs)
PP1188	Scott Paper Ltd (Lennoxville) (Massawippi River)	E	White sucker	m	50	7	na	329	527.9	3.7	10.90	33.60	na
		E	White sucker	f		23	na	368	783.5	4.1	11.60	48.60	29023
		E	White sucker	i		15	na	223	202	1.5	2.70	nd	na
		E	Fallfish	m	296	4	na	172	71	2.0	1.00	1.00	na
		E	Fallfish	f		14	na	160	55.5	1.9	0.800	1.40	4298
		E	Fallfish	i		5	na	138	38.9	1.5	0.600	nd	na
		R	White sucker	m	39	12	na	322	538.1	3.3	4.70	37.00	na
		R	White sucker	f		19	na	327	492.6	3.2	5.70	21.70	21942
		R	White sucker	i		7	na	212	129.6	1.3	1.30	nd	na
		R	Fallfish	m	56	nd	na	nd	nd	nd	nd	nd	na
		R	Fallfish	f		nd	na	nd	nd	nd	nd	nd	nd
		R	Fallfish	i		nd	na	nd	nd	nd	nd	nd	na

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Annex 6 Capture results and means of the morphological parameters for the exposure and reference areas

National Project No.	Mill Name (Location)	Area fished	Common Name	Sex	n caught (m+f)	n measured	Mean total length (mm)	Mean fork length (mm)	Mean body weight (g)	Mean age (yrs)	Mean liver weight (g)	Mean gonad weight (g)	Mean fecundity (n eggs)
PP1188 (cont'd)	(St-François River)	R	White sucker	m	26	8	na	350	643.1	4.0	9.60	53.00	na
		R	White sucker	f		13	na	382	850.4	4.4	14.60	54.70	28533
		R	White sucker	i		5	na	155	84.6	1.0	nd	nd	na
		R	Fallfish	m	387	8	na	224	192.4	3.4	2.10	2.00	na
		R	Fallfish	f		13	na	144	47.7	1.5	0.70	1.10	6463
		R	Fallfish	i		21	na	130	32.1	1.2	0.30	nd	na
PP1191	Tembec, Groupe Papiers, Usine St-Raymond (St-Léonard-de-Portneuf)	E	Longnose sucker	m	120	38	na	165	62	5.0	0.71	4.17	na
		E	Longnose sucker	f		56	na	190	82	5.0	1.05	4.53	4959
		E	White sucker	m	144	41	na	359	574	6.0	4.59	27.16	na
		E	White sucker	f		15	na	370	621	7.0	6.44	16.31	14074
		R	Longnose sucker	m	127	17	na	159	53	5.0	0.41	3.23	na
		R	Longnose sucker	f		63	na	163	55	5.0	0.57	2.87	2748
		R	White sucker	m	215	15	na	316	394	7.0	4.39	12.02	na
		R	White sucker	f		11	na	330	444	8.0	4.83	13.35	11481

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Annex 6 Capture results and means of the morphological parameters for the exposure and reference areas

National Project No.	Mill Name (Location)	Area fished	Common Name	Sex	n caught (m+f)	n measured	Mean total length (mm)	Mean fork length (mm)	Mean body weight (g)	Mean age (yrs)	Mean liver weight (g)	Mean gonad weight (g)	Mean fecundity (n eggs)
PP1194	Cascades Inc.	E	Longnose dace	m	312	33	89	na	7.45	4.6	0.120	0.03	na
	(Lachute)	E	Longnose dace	f		34	100	na	10.88	5.5	0.189	0.21	753
		E	Logperch	m	72	19	119	na	18.13	5.9	0.214	0.05	na
		E	Logperch	f		6	123	na	19.77	6.0	0.139	0.10	391
		R	Longnose dace	m	236	32	91	na	7.88	4.8	0.126	0.03	na
		R	Longnose dace	f		31	99	na	10.65	5.5	0.186	0.22	769
		R	Logperch	m	53	19	117	na	17.18	6.1	0.171	0.04	na
		R	Logperch	f		4	118	na	17.82	6.2	0.169	0.09	359
PP1196	*Scott Paper Ltd*	*E*	*White sucker*	*m*	*8*	*0*	*na*	*nd*	*nd*	*nd*	*nd*	*nd*	*na*
	(Crabtree)	*E*	*White sucker*	*f*		*2*	*na*	*332*	*492.5*	*5.5*	*4.70*	*16.70*	*26496*
		E	*Silver redfish*	*m*	*1*	*1*	*na*	*436*	*1200*	*9.0*	*8.90*	*43.60*	*na*
		E	*Silver redfish*	*f*		*0*	*na*	*nd*	*nd*	*nd*	*nd*	*nd*	*nd*
	Ouareau River	*R*	*White sucker*	*m*	*85*	*33*	*na*	*319*	*418.8*	*4.9*	*2.50*	*25.80*	*na*
		R	*White sucker*	*f*		*43*	*na*	*327*	*440.7*	*5.0*	*3.30*	*12.60*	*20759*
		R	*Silver redfish*	*m*	*76*	*37*	*na*	*382*	*865.1*	*8.7*	*5.90*	*37.70*	*na*
		R	*Silver redfish*	*f*		*22*	*na*	*406*	*1062.5*	*9.5*	*8.60*	*35.90*	*19554*

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Annex 6 Capture results and means of the morphological parameters for the exposure and reference areas

National Project No.	Mill Name (Location)	Area fished	Common Name	Sex	n caught (m+f)	n measured	Mean total length (mm)	Mean fork length (mm)	Mean body weight (g)	Mean age (yrs)	Mean liver weight (g)	Mean gonad weight (g)	Mean fecundity (n eggs)
PP1196 (cont'd)	*Rouge River*	*R*	*White sucker*	*m*	*95*	*19*	*na*	*315*	*405.8*	*4.7*	*2.50*	*24.30*	*na*
		R	*White sucker*	*f*		*55*	*na*	*327*	*449.2*	*5.2*	*3.60*	*16.30*	*23759*
		R	*Silver redfish*	*m*	*18*	*7*	*na*	*339*	*630*	*6.1*	*4.10*	*24.80*	*na*
		R	*Silver redfish*	*f*		*10*	*na*	*339*	*666*	*6.8*	*4.80*	*24.30*	*24131*
PP1198	Cascades Inc.	E	White sucker	m	172	31	345	na	502	5.4	5.70	27.40	na
	(St-Jérôme)	E	White sucker	f		31	365	na	597	5.2	8.20	19.00	22125
		E	Yellow perch	m	9	0	nd	na	nd	nd	nd	nd	na
		E	Yellow perch	f		0	nd	na	nd	nd	nd	nd	nd
		R	White sucker	m	117	31	337	na	453	4.9	5.00	23.70	na
		R	White sucker	f		31	368	na	575	5.2	7.80	19.90	19413
		R	Yellow perch	m	0	0	nd	na	nd	nd	nd	nd	na
		R	Yellow perch	f		0	nd	na	nd	nd	nd	nd	nd

Legend: i: Immature, f: Female, m: Mâle, na: Not applicable, nd: not determined, E: Exposure area, R: Reference area
Italics: Data not considered as no statistical analysis was performed
Bold: Data not considered as there were two data series for the same mill

Annex 6 Capture results and means of the morphological parameters for the exposure and reference areas

National Project No.	Mill Name (Location)	Area fished	Common Name	Sex	n caught (m+f)	n measured	Mean total length (mm)	Mean fork length (mm)	Mean body weight (g)	Mean age (yrs)	Mean liver weight (g)	Mean gonad weight (g)	Mean fecundity (n eggs)
PP1201	Spruce Falls Inc. (Matane)	E	Shorthorn sculpin	f	48	30	351	nd	763	5.7	35.8	43.1	26265
		R	Shorthorn sculpin	f	45	28	314	nd	542	4.7	24	38.3	26157
PP1208	*Cascades Inc.*	*E*	*White sucker*	*m*	*10*	*5*	*377*	*na*	*524*	*5.6*	*5.60*	*18.80*	*na*
	(Kingsey Falls)	*E*	*White sucker*	*f*		*5*	*402*	*na*	*624*	*6.2*	*6.90*	*17.80*	*23243*
		E	*Silver redfish*	*m*	*23*	*13*	*480*	*na*	*1173*	*11.9*	*10.30*	*17.40*	*na*
		E	*Silver redfish*	*f*		*7*	*484*	*na*	*1282*	*11.3*	*14.00*	*22.50*	*12423*
		R	*White sucker*	*m*	*47*	*9*	*357*	*na*	*527*	*4.2*	*5.40*	*26.10*	*na*
		R	*White sucker*	*f*		*28*	*399*	*na*	*799*	*5.5*	*6.80*	*24.50*	*24492*
		R	*Silver redfish*	*m*	*40*	*19*	*497*	*na*	*1580*	*11.3*	*14.10*	*58.30*	*na*
		R	*Silver redfish*	*f*		*18*	*530*	*na*	*1828*	*11.7*	*19.80*	*58.30*	*26697*

Legend: i: Immature, f: Female, m: Male, na: Not applicable, nd: not determined, E: Exposure area, R: Reference area
Italics: Data not considered as no statistical analysis was performed
Bold: Data not considered as there were two data series for the same mill

Annex 7 ANOVA age comparisons and ANCOVA comparisons of morphometric relationships between the exposure area and the reference area – Cycle 2

National Project No.	Mill Name (Location)	Common Name	Sex	Difference (%) between Exposure Area and Reference Area										Significant differences/ Number of comparisons
				Age	Length/ Age	Weight/ Age	Weight/ Length	Liver weight/ Length	Liver weight/ Body weight	Gonad weight/ Length	Gonad weight/ Body weight	Fecundity/ Length	Fecundity/ Body weight	
PP1086	Papiers Fraser Nexfor (Thurso)	Yellow perch	m	-	-	-	-	x	+	ns	ns	X	x	5/7
		Yellow perch	f	ns	ns	ns	ns	x	ns	ns	ns	Ns	ns	0/9
		Yellow perch	i	x	x	x	-	x	+	ns	ns	X	x	2/4
		Johnny darter	m	x	x	x	ns	x	ns	ns	ns	X	x	0/4
		Johnny darter	f	x	x	x	+	x	ns	ns	ns	X	x	1/4
PP1088	Abitibi-Consolidated Inc. (Baie-Comeau)	Shorthorn sculpin	m	ns	x	x	ns	+40.7	ns	ns	ns	X	x	1/6
		Shorthorn sculpin	f	ns	ns	-39.9	ns	ns	ns	ns	ns	X	x	1/8
PP1091	Compagnie Abitibi-Consolidated du Canada (Beaupré)	Longnose sucker	m	ns	ns	ns	ns	ns	ns	ns	ns	X	x	0/8
		Longnose sucker	f	+	ns	ns	-5.6	ns	-13.3	ns	ns	Ns	ns	3/10
		Mottled sculpin	m	ns	ns	ns	-8	-13.8	-20.6	ns	ns	X	x	3/8
		Mottled sculpin	f	-	ns	ns	ns	ns	ns	ns	ns	Ns	ns	1/10
		Mottled sculpin	i	-	ns	ns	-4.2	-12	ns	ns	ns	x	x	3/8
PP1092	Bowater Produits forestiers du Canada Inc. (Donnacona)	Longnose sucker	m	ns	ns	ns	+5	+21.3	+16.9	-12.8	-14.1	x	x	5/8
		Longnose sucker	f	+	ns	ns	ns	ns	ns	-20.2	-26.3	ns	ns	3/10
		White sucker	m	ns	ns	x	ns	+26.6	+20.3	x	ns	x	x	2/6
		White sucker	f	ns	ns	ns	ns	ns	ns	ns	ns	x	ns	0/9
PP1094	Tembec Inc. (Témiscaming)	White sucker	m	+	x	+48.8	+17.9	+73.2	+42	ns	ns	x	x	5/7
		White sucker	f	ns	+9.9	+49.2	+20.6	+50.9	+36.4	ns	ns	ns	ns	5/10
		Fallfish	m	ns	+11.8	+64	ns	ns	ns	-43.7	-50.5	x	x	4/8
		Fallfish	f	x	x	x	x	x	x	x	x	x	x	x

Legend: i: Immature, f: Female, m: Male, ns: Not significant, x: Not applicable (insufficient data or unequal slopes), +: Higher value in exposure area, -: Lower value in exposure area

Annex 7 ANOVA age comparisons and ANCOVA comparisons of morphometric relationships between the exposure area and the reference area – Cycle 2

National Project No.	Mill Name (Location)	Common Name	Sex	Difference (%) between Exposure Area and Reference Area										Significant differences/ Number of comparisons
				Age	Length/ Age	Weight/ Age	Weight/ Length	Liver weight/ Length	Liver weight/ Body weight	Gonad weight/ Length	Gonad weight/ Body weight	Fecundity/ Length	Fecundity/ Body weight	
PP1098	Emballages Smurfit- Stone Canada Inc. (La Tuque)	White sucker	m	+	x	x	-18.4	-24	ns	x	-27	x	x	4/5
		White sucker	f	ns	-9.8	-37.2	-17.4	-21.4	ns	-23.3	ns	x	x	5/8
		Rock bass	m	ns	-9	-29.5	ns	ns	ns	x	x	x	x	2/6
		Rock bass	f	ns	-8.7	ns	ns	ns	ns	+15.9	ns	x	x	2/8
PP1101	Emballages Smurfit-Stone Canada Inc. (New-Richmond)	Winter flounder	m	x	ns	ns	ns	ns	ns	x	+	x	x	1/6
		Winter flounder	f	x	ns	ns	ns	ns	ns	x	ns	ns	ns	0/8
		Shorthorn sculpin	m	x	x	x	x	x	x	x	x	x	x	x
		Shorthorn sculpin	f	x	ns	ns	ns	ns	ns	x	+	x	x	1/6
PP1102	Smurfit-Stone Container Corporation (Portage- du-Fort) (est)	White sucker	m	x	-	ns	ns	x	ns	x	ns	x	x	1/5
		White sucker	f	x	ns	ns	ns	x	ns	x	ns	ns	ns	0/7
		Channel catfish	m	x	+	+	+	x	+	x	ns	x	x	4/5
		Channel catfish	f	x	+	+	ns	x	ns	x	ns	ns	ns	2/7
PP1104	Compagnie Abitibi-Consolidated du Canada (Clermont)	Longnose sucker	m	-	+154.1	+383.3	ns	ns	ns	ns	-24.9	x	x	4/8
		Longnose sucker	f	-	x	x	ns	ns	ns	x	-29	ns	ns	2/7
		Longnose dace	m	+	+6.5	x	ns	x	x	ns	x	x	x	2/4
		Longnose dace	f	+	+6	x	ns	+66.7	+60.9	ns	ns	+44.2	+45.4	6/9

Legend: i: Immature, f: Female, m: Male, ns: Not significant, x: Not applicable (insufficient data or unequal slopes), +: Higher value in exposure area, -: Lower value in exposure area

Annex 7 ANOVA age comparisons and ANCOVA comparisons of morphometric relationships between the exposure area and the reference area – Cycle 2

National Project No.	Mill Name (Location)	Common Name	Sex	Difference (%) between Exposure Area and Reference Area										Significant differences/ Number of comparisons
				Age	Length/ Age	Weight/ Age	Weight/ Length	Liver weight/ Length	Liver weight/ Body weight	Gonad weight/ Length	Gonad weight/ Body weight	Fecundity/ Length	Fecundity/ Body weight	
PP1106	SFK Pulp (St-Félicien)	Brown bullhead	m	ns	-6.4	-23.1	x	-15.3	-13.7	ns	ns	x	x	4/7
		Brown bullhead	f	ns	ns	x	x	-12.7	-8.7	x	ns	ns	ns	2/7
		White sucker	m	ns	x	x	x	x	x	x	x	x	x	0/1
		White sucker	f	ns	x	x	ns	x	x	ns	ns	x	x	0/4
PP1114	Norampac Inc. (Cabano)	White sucker	m	ns	x	x	+5.6	x	x	ns	ns	x	x	1/4
		White sucker	f	ns	x	x	+5	x	x	ns	ns	x	x	1/4
		Yellow perch	m	+	ns	ns	ns	x	x	x	+8	x	x	2/5
		Yellow perch	f	ns	ns	ns	ns	+26.4	ns	ns	ns	ns	ns	1/10
PP1117	Cascades East-Angus Inc., Division Cartech, Paperboard Industries Corp. (East-Angus)	White sucker	m	+	+3.6	+21	+12	+156	x	+17	ns	x	x	6/7
		White sucker	f	+	+2.5	+23	+16	+136	x	+35	ns	x	+21	7/8
		Tesselated darter	m	ns	ns	ns	+6.7	ns	ns	+38	+28	x	x	3/8
		Tesselated darter	f	ns	ns	ns	ns	+35	+32	x	x	ns	ns	2/8
PP1118	Bowater Produits forestiers du Canada Inc. (1998) (Gatineau)	Yellow perch	m	ns	ns	ns	ns	x	ns	ns	ns	x	x	0/7
		Yellow perch	f	ns	ns	ns	ns	x	ns	ns	ns	ns	ns	0/9
		Yellow perch	i	x	ns	ns	ns	x	ns	ns	ns	x	x	0/6
		Johnny darter	m	ns	ns	ns	ns	x	ns	ns	ns	x	x	0/7
		Johnny darter	f	ns	x	x	ns	x	ns	-	+14	x	x	2/5

Legend: i: Immature, f: Female, m: Male, ns: Not significant, x: Not applicable (insufficient data or unequal slopes), +: Higher value in exposure area, -: Lower value in exposure area

Annex 7 ANOVA age comparisons and ANCOVA comparisons of morphometric relationships between the exposure area and the reference area – Cycle 2

National Project No.	Mill Name (Location)	Common Name	Sex	Difference (%) between Exposure Area and Reference Area										Significant differences/ Number of comparisons
				Age	Length/ Age	Weight/ Age	Weight/ Length	Liver weight/ Length	Liver weight/ Body weight	Gonad weight/ Length	Gonad weight/ Body weight	Fecundity/ Length	Fecundity/ Body weight	
PP1131	Kruger Inc. (Bromptonville)	White sucker	m	+	ns	ns	ns	ns	-17	ns	-11	x	x	3/8
		White sucker	f	+	ns	ns	ns	ns	ns	x	-13	-15	-12	4/9
		Tesselated darter	m	ns	x	x	ns	ns	ns	x	ns	x	x	0/5
		Tesselated darter	f	ns	x	ns	ns	ns	ns	+12	x	ns	ns	1/8
PP1132	Abitibi-Consolidated Inc. (Jonquière)	Longnose sucker	m	ns	+13	+43.2	+6.2	+25.4	+20.3	-15.2	-22	x	x	7/8
		Longnose sucker	f	ns	na	na	na	na	na	-19	-14.2	ns	ns	2/5
PP1135	Compagnie Abitibi-Consolidated du Canada (Shawinigan)	White sucker	m	+	-4.6	x	ns	x	+21.1	x	-47.4	x	x	4/5
		White sucker	f	+	x	-22.7	x	x	ns	ns	ns	-29.5	-29.9	4/7
		Rock bass	m	ns	x	x	x	x	x	x	x	x	x	0/1
		Rock bass	f	ns	x	x	ns	ns	-23.2	-28	-25	x	x	3/6
PP1138	F.F. Soucy Inc. (Rivière-du-Loup)	Blacknose dace	m	x	x	x	x	x	x	x	x	x	x	x
		Blacknose dace	f	x	x	x	x	x	+20	x	ns	x	ns	1/3
		Pearl dace	m	x	x	x	x	x	+59.7	x	x	x	x	1/1
		Pearl dace	f	x	x	x	x	x	+29.3	x	x	x	ns	1/2
PP1145	Cascades Inc. (Jonquière)	Longnose sucker	m	ns	x	+24.6	+7	+40.5	+27.7	ns	ns	x	x	4/7
		Longnose sucker	f	+	+10.1	+28.9	x	+75.6	+69.7	+79.1	+71.1	-26.8	-30.8	9/9
		White sucker	m	-	+13.8	+47.9	+8.7	+41.6	+33.9	ns	x	x	x	6/7
		White sucker	f	-	+9.4	+42.6	+5.5	+24.4	+17.6	+52.6	+43.6	x	x	8/8

Legend: i: Immature, f: Female, m: Male, ns: Not significant, x: Not applicable (insufficient data or unequal slopes), +: Higher value in exposure area, -: Lower value in exposure area

Annex 7 ANOVA age comparisons and ANCOVA comparisons of morphometric relationships between the exposure area and the reference area – Cycle 2

National Project No.	Mill Name (Location)	Common Name	Sex	Difference (%) between Exposure Area and Reference Area										Significant differences/ Number of comparisons
				Age	Length/ Age	Weight/ Age	Weight/ Length	Liver weight/ Length	Liver weight/ Body weight	Gonad weight/ Length	Gonad weight/ Body weight	Fecundity/ Length	Fecundity/ Body weight	
PP1147	Nortkraft Quévillon Inc. (Lebel-sur-Quévillon) (rivière Quévillon) (rivière Bell)	Longnose sucker	m	ns	x	x	ns	x	ns	ns	ns	x	x	0/5
		Longnose sucker	f	ns	x	x	ns	x	ns	ns	ns	x	ns	0/6
		White sucker	m	ns	x	x	ns	x	x	ns	ns	x	x	0/4
		White sucker	f	x	x	x	x	x	x	x	x	x	x	x
		Longnose sucker	m	ns	x	x	ns	x	x	x	x	x	x	0/2
		Longnose sucker	f	ns	x	x	ns	x	x	x	ns	x	x	0/3
		White sucker	m	ns	ns	ns	ns	-22.3	-23.1	ns	x	x	x	2/7
		White sucker	f	ns	ns	ns	ns	x	ns	ns	ns	x	ns	0/8
PP1148	Domtar Inc. (Windsor)	White sucker	m	ns	ns	ns	-5	x	ns	-21	-18	x	x	3/7
		White sucker	f	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	0/10
		Smallmouth bass	m	ns	+9.3	+41	+5.2	ns	-12	ns	-15	x	x	5/8
		Smallmouth bass	f	ns	ns	+12	+4	ns	ns	ns	-18	ns	-21	4/10
PP1153	Masson Ltd (Masson-Anger) (1997)	Yellow perch	m	ns	ns	ns	ns	ns	x	ns	ns	x	x	0/6
		Yellow perch	f	ns	ns	+3.3	ns	ns	ns	ns	ns	ns	ns	1/9
		Johnny darter	m	x	x	x	ns	x	ns	ns	ns	x	x	0/4
		Johnny darter	f	x	x	x	ns	x	ns	-	ns	x	x	1/4
PP1177	Compagnie Abitibi-Consolidated du Canada (Alma)	Brown bullhead	m	ns	x	+42.9	x	x	+23.3	+36.8	ns	x	x	3/5
		Brown bullhead	f	ns	x	x	+17	+47.2	+27.9	+31.5	ns	+31.2	ns	5/8
		Longnose sucker	m	x	x	x	x	x	x	x	x	x	x	x
		Longnose sucker	f	x	x	x	x	x	x	x	x	x	x	x

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Annex 7 ANOVA age comparisons and ANCOVA comparisons of morphometric relationships between the exposure area and the reference area – Cycle 2

National Project No.	Mill Name (Location)	Common Name	Sex	Difference (%) between Exposure Area and Reference Area										Significant differences/ Number of comparisons
				Age	Length/ Age	Weight/ Age	Weight/ Length	Liver weight/ Length	Liver weight/ Body weight	Gonad weight/ Length	Gonad weight/ Body weight	Fecundity/ Length	Fecundity/ Body weight	
PP1183 PP1179	Papier Cascade Lupel Inc. et Désencrage CMD Inc. (Cap-de-la-Madeleine)	Yellow perch	m	+	ns	+13,6	ns	ns	ns	ns	ns	x	x	2/8
		Yellow perch	f	ns	ns	ns	ns	-14.4	-14.4	ns	ns	-26.2	-26.2	4/10
		Trout-perch	m	ns	x	x	ns	ns	ns	ns	ns	x	x	0/6
		Trout-perch	f	ns	x	x	ns	x	ns	x	x	x	x	0/3
PP1181	Cascades Inc. (Breakeyville)	Longnose dace	m	ns	ns	ns	+3.6	ns	-4.3	-6.9	ns	x	x	3/8
		Longnose dace	f	ns	ns	+9.3	+7.3	+88.7	-29.8	ns	ns	+15.9	ns	5/10
		Johnny darter	m	ns	x	x	+9.9	ns	-16.8	+7.7	-3.9	x	x	4/6
		Johnny darter	f	ns	ns	ns	+5.2	x	x	x	x	x	x	1/4
PP1182	Pâte Mohawk Itée (St-Antonin)	White sucker	m	ns	ns	ns	ns	ns	ns	ns	ns	x	x	0/8
		White sucker	f	+	-12.3	-37.9	ns	-13.6	-12.7	x	-14.1	-13	-14.2	8/9
		Yellow perch	m	ns	x	x	ns	ns	ns	ns	ns	x	x	0/6
		Yellow perch	f	ns	+13.2	+34	ns	+17.6	+15	ns	ns	ns	ns	4/10
PP1184	**Compagnie Abitibi-Consolidated du Canada (Amos)**	**Brown bullhead**	**m**	**+**	**x**	**+14**	**ns**	**x**	**+14.2**	**x**	**+17.4**	**x**	**x**	**4/5**
		Brown bullhead	**f**	**-**	**x**	**x**	**ns**	**+17**	**x**	**ns**	**ns**	**ns**	**x**	**1/5**
		Longnose sucker	**m**	**ns**	**ns**	**+12**	**ns**	**+22.1**	**+17.2**	**ns**	**ns**	**x**	**x**	**3/8**
		Longnose sucker	**f**	**ns**	**+4.7**	**+13.2**	**ns**	**+27.9**	**+19.9**	**ns**	**-54.1**	**ns**	**ns**	**5/10**

Legend: i: Immature, f: Female, m: Male, ns: Not significant, x: Not applicable (insufficient data or unequal slopes), +: Higher value in exposure area, -: Lower value in exposure area

Annex 7 ANOVA age comparisons and ANCOVA comparisons of morphometric relationships between the exposure area and the reference area – Cycle 2

National Project No.	Mill Name (Location)	Common Name	Sex	Difference (%) between Exposure Area and Reference Area										Significant differences/ Number of comparisons
				Age	Length/ Age	Weight/ Age	Weight/ Length	Liver weight/ Length	Liver weight/ Body weight	Gonad weight/ Length	Gonad weight/ Body weight	Fecundity/ Length	Fecundity/ Body weight	
PP1187	J. Ford Ltd (Portneuf)	White sucker	m	x	+	+	+	+	+	x	+	x	x	6/6
		White sucker	f	x	+	+	+	ns	ns	x	ns	+	+	5/8
PP1188	Papiers Scott Itée (Lennoxville) (Massawippi River) (St-François River)	White sucker	m	x	x	ns	ns	x	-	x	ns	x	x	1/4
		White sucker	f	x	ns	ns	+	-	-	x	ns	ns	ns	3/8
		White sucker	i	x	ns	ns	ns	ns	ns	x	x	x	x	0/5
		Fallfish	m	x	x	x	ns	ns	ns	x	ns	x	x	0/4
		Fallfish	f	x	x	x	+	ns	ns	x	x	x	+	2/4
		Fallfish	i	x	ns	ns	+	+	x	x	x	x	x	2/4
		White sucker	m	x	ns	ns	ns	-	x	x	x	x	x	1/4
		White sucker	f	x	ns	ns	ns	+	+	x	ns	ns	ns	2/8
		White sucker	i	x	ns	x	ns	x	x	x	x	x	x	0/2
		Fallfish	m	x	x	x	ns	ns	ns	x	ns	x	x	0/4
		Fallfish	f	x	ns	ns	ns	ns	ns	x	-	ns	ns	1/8
		Fallfish	i	x	ns	ns	ns	ns	ns	x	x	x	x	0/5
PP1191	Tembec, Groupe papiers, Usine St-Raymond (St-Léonard-de-Portneuf)	Longnose sucker	m	ns	x	x	+7.4	x	+25.9	ns	ns	x	x	2/5
		Longnose sucker	f	ns	x	x	x	+40.4	+36	x	ns	ns	ns	2/6
		White sucker	m	ns	+14.5	+57.2	ns	ns	ns	ns	ns	x	x	2/8
		White sucker	f	ns	x	x	ns	ns	x	x	ns	x	x	0/4

Legend: i: Immature, f: Female, m: Male, ns: Not significant, x: Not applicable (insufficient data or unequal slopes), +: Higher value in exposure area, -: Lower value in exposure area

Annex 7 ANOVA age comparisons and ANCOVA comparisons of morphometric relationships between the exposure area and the reference area – Cycle 2

National Project No.	Mill Name (Location)	Common Name	Sex	Difference (%) between Exposure Area and Reference Area										Significant differences/ Number of comparisons
				Age	Length/ Age	Weight/ Age	Weight/ Length	Liver weight/ Length	Liver weight/ Body weight	Gonad weight/ Length	Gonad weight/ Body weight	Fecundity/ Length	Fecundity/ Body weight	
PP1194	Cascades Inc. (Lachute)	Longnose dace	m	ns	ns	x	ns	ns	ns	x	x	x	x	0/5
		Longnose dace	f	ns	x	x	ns	+4.6	+4.6	ns	ns	ns	ns	2/8
		Logperch	m	ns	x	x	ns	x	x	x	x	x	x	0/2
		Logperch	f	ns	x	x	x	x	x	x	x	x	x	0/1
PP1198	Cascades Groupe Papiers Fins Inc. (St-Jérôme)	White sucker	m	ns	ns	ns	ns	ns	ns	ns	ns	x	x	0/8
		White sucker	f	ns	ns	ns	+4.2	ns	ns	ns	-9.7	x	x	2/8
		Yellow perch	m	x	x	x	x	x	x	x	x	x	x	x
		Yellow perch	f	x	x	x	x	x	x	x	x	x	x	x
PP1201	Spruce Falls Inc. (Matane)	Shorthorn sculpin	f	+	+	+	ns	ns	ns	-31.1	-26.5	ns	ns	5/10

Legend: i: Immature, f: Female, m: Male, ns: Not significant, x: Not applicable (insufficient data or unequal slopes), +: Higher value in exposure area, -: Lower value in exposure area

Annex 8 Synopsis of the ANCOVA analyses of morphometric relationships between the exposure and reference areas - Cycle 1 and Cycle 2.

National Project No.	Mill Name	Location	Sentinel Species	Sex	Response	
					Cycle 1	Cycle 2
PP1086	Fraser Papers	Thurso	Yellow perch	m	S^{A}, H^{+}, R^{0}	S^{-}, H^{+}, R^{0}
			Yellow perch	f	S^{-}, H^{0}, R^{0}	S^{0}, H^{0}, R^{0}
			Yellow perch	i	na	S^{-}, H^{+}, R^{0}
			Johnny darter	m	na	S^{0}, H^{0}, R^{0}
			Johnny darter	f	na	S^{+}, H^{0}, R^{0}
			Yellow perch	m	S^{A}, H^{+}, R^{0}	S^{0}, H^{0}, R^{+}
			Yellow perch	f	S^{-}, H^{0}, R^{0}	S^{0}, H^{0}, R^{0}
			Etheostoma nigrum	m	na	S^{0}, H^{0}, R^{0}
			Etheostoma nigrum	f	na	S^{0}, H^{0}, R^{0}
PP1088	Abitibi-Consolidated Inc.	Baie-Comeau	Shorthorn sculpin	m	na	S^{0}, H^{+}, R^{0}
			Shorthorn sculpin	f	na	S^{-}, H^{0}, R^{0}
PP1091	Abitibi-Consolidated Inc.	Beaupré	Longnose sucker	m	S^{0}, H^{0}, R^{0}	S^{0}, H^{0}, R^{0}
			Longnose sucker	f	S^{-}, H^{0}, R^{0}	S^{-}, H^{-}, R^{0}
			Mottled sculpin	m	na	S^{-}, H^{-}, R^{0}
			Mottled sculpin	f	na	S^{0}, H^{0}, R^{0}
			Mottled sculpin	i	na	S^{-}, H^{-}, R^{0}
PP1092	Bowater Inc.	Donnacona	Longnose sucker	m	S^{0}, H^{0}, R^{0}	S^{+}, H^{+}, R^{-}
			Longnose sucker	f	S^{0}, H^{0}, R^{0}	S^{0}, H^{0}, R^{-}
			White sucker	m	na	S^{0}, H^{+}, R^{0}
			White sucker	f	na	S^{0}, H^{0}, R^{0}
PP1094	Tembec Inc.	Témiscaming	White sucker	m	na	S^{+}, H^{+}, R^{0}
			White sucker	f	na	S^{+}, H^{+}, R^{0}
			Fallfish	m	na	S^{+}, H^{0}, R^{-}
			Fallfish	f	na	na
PP1098	Smurfit-Stone Container Corporation	La Tuque	White sucker	m	S^{-}, H^{+}, R^{-}	S^{-}, H^{-}, R^{-}
			White sucker	f	S^{-}, H^{+}, R^{-}	S^{-}, H^{-}, R^{-}
			Rock bass	m	na	S^{-}, H^{0}, R^{na}
			Rock bass	f	na	S^{-}, H^{0}, R^{+}
PP1101	Smurfit-Stone Container Corporation	New-Richmond	Winter flounder	m	S^{0}, H^{0}, R^{0}	S^{0}, H^{0}, R^{+}
			Winter flounder	f	S^{0}, H^{0}, R^{0}	S^{0}, H^{0}, R^{0}
			Shorthorn sculpin	m	na	na
			Shorthorn sculpin	f	na	S^{0}, H^{0}, R^{+}

Legend: i: Immature, f: Female, m: Male

Response: + : higher value in exposure area, - : lower value in exposure area, 0: no significant differences, A: direction of significant differences diverges within group (ex. : S^{A}), na: not applicable (insufficient data or unequal slopes)

Annex 8 Synopsis of the ANCOVA analyses of morphometric relationships between the exposure and reference areas - Cycle 1 and Cycle 2.

National Project No.	Mill Name	Location	Sentinel Species	Sex	Response	
					Cycle 1	Cycle 2
PP1102	Smurfit-Stone Container Corporation	Portage- du-Fort	White sucker	m	S^-, H^0, R^0	S^-, H^0, R^0
			White sucker	f	S^0, H^0, R^0	S^0, H^0, R^0
			Channel catfish	m	S^0, H^0, R^0	S^+, H^+, R^0
			Channel catfish	f	S^0, H^0, R^0	S^+, H^0, R^0
			White sucker	m	S^-, H^0, R^0	S^0, H^-, R^0
			White sucker	f	S^0, H^0, R^0	S^0, H^{na}, R^0
			Channel catfish	m	S^0, H^0, R^0	S^0, H^0, R^0
			Channel catfish	f	S^0, H^0, R^0	S^0, H^0, R^0
PP1104	Abitibi-Consolidated Inc.	Clermont	Longnose sucker	m	na	S^+, H^0, R^-
			Longnose sucker	f	na	S^0, H^0, R^-
			Longnose dace	m	na	S^+, H^{na}, R^{na}
			Longnose dace	f	na	S^+, H^+, R^+
PP1106	SFK Pulp	St-Félicien	Brown bullhead	m	S^0, H^{na}, R^{na}	S^-, H^-, R^0
			Brown bullhead	f	S^0, H^{na}, R^{na}	S^{na}, H^-, R^0
			White sucker	m	na	na
			White sucker	f	S^0, H^0, R^0	S^0, H^{na}, R^0
PP1114	Norampac Inc.	Cabano	White sucker	m	S^0, H^0, R^0	S^+, H^{na}, R^0
			White sucker	f	S^0, H^+, R^+	S^+, H^{na}, R^0
			Yellow perch	m	na	S^0, H^{na}, R^+
			Yellow perch	f	na	S^0, H^+, R^0
PP1117	Cascades East-Angus Inc.	East-Angus	White sucker	m	S^+, H^+, R^0	S^+, H^+, R^+
			White sucker	f	S^+, H^+, R^+	S^+, H^+, R^+
			Tesselated darter	m	na	S^+, H^0, R^+
			Tesselated darter	f	na	S^0, H^+, R^0
PP1118	Bowater Inc.	Gatineau	Yellow perch	m	na	S^0, H^0, R^0
			Yellow perch	f	na	S^0, H^0, R^0
			Yellow perch	i	na	S^0, H^0, R^0
			Johnny darter	m	na	S^0, H^0, R^0
			Johnny darter	f	na	S^0, H^0, R^A
			Yellow perch	m	na	S^0, H^0, R^0
			Yellow perch	f	na	S^0, H^0, R^0
			Yellow perch	i	na	S^0, H^0, R^0

Legend: i: Immature, f: Female, m: Male
Response: + : higher value in exposure area, - : lower value in exposure area, 0: no significant differences, A: direction of significant differences diverges within group (ex. : S^A), na: not applicable (insufficient data or unequal slopes)

Annex 8 Synopsis of the ANCOVA analyses of morphometric relationships between the exposure and reference areas - Cycle 1 and Cycle 2.

National Project No.	Mill Name	Location	Sentinel Species	Sex	Response	
					Cycle 1	Cycle 2
PP1131	Kruger Inc.	Bromptonville	White sucker	m	S^0, H^0, R^0	S^0, H^-, R^-
			White sucker	f	S^0, H^0, R^0	S^0, H^0, R^-
			Tesselated darter	m	na	S^0, H^0, R^0
			Tesselated darter	f	na	S^0, H^0, R^+
PP1132	Abitibi-Consolidated Inc.	Jonquière	Longnose sucker	m	na	S^+, H^+, R^-
			Longnose sucker	f	na	S^{na}, H^{na}, R^-
			White sucker	mf	na	na
PP1133	Bowater Inc.	Dolbeau	Longnose sucker	m	na	na
			Longnose sucker	f	na	na
			White sucker	m	na	na
			White sucker	f	na	na
PP1135	Abitibi-Consolidated Inc.	Shawinigan	White sucker	m	S^-, H^0, R^-	S^-, H^+, R^-
			White sucker	f	S^-, H^-, R^-	S^-, H^0, R^-
			Rock bass	m	na	na
			Rock bass	f	na	S^0, H^-, R^-
PP1138	F.F. Soucy Inc.	Rivière-du-Loup	Blacknose dace	m	na	S^-, H^0, R^0
			Blacknose dace	f	na	S^0, H^0, R^0
			Pearl dace	m	na	na
			Pearl dace	f	na	S^0, H^{na}, R^{na}
			Blacknose dace	m	na	na
			Blacknose dace	f	na	S^{na}, H^+, R^0
			Pearl dace	m	na	S^{na}, H^+, R^{na}
			Pearl dace	f	na	S^{na}, H^+, R^{na}
			Blacknose dace	m	na	S^-, H^+, R^{na}
			Blacknose dace	f	na	S^-, H^+, R^0
PP1145	Cascades Inc.	Jonquière	Longnose sucker	m	na	S^+, H^+, R^0
			Longnose sucker	f	na	S^+, H^+, R^A
			White sucker	m	na	S^+, H^+, R^{na}
			White sucker	f	na	S^+, H^+, R^+

Legend: i: Immature, f: Female, m: Male

Response: + : higher value in exposure area, - : lower value in exposure area, 0: no significant differences, A: direction of significant differences diverges within group (ex. : S^A), na: not applicable (insufficient data or unequal slopes)

Annex 8 Synopsis of the ANCOVA analyses of morphometric relationships between the exposure and reference areas - Cycle 1 and Cycle 2.

National Project No.	Mill Name	Location	Sentinel Species	Sex	Response	
					Cycle 1	Cycle 2
PP1147	Nortkraft Quévillon Inc.	Lebel-sur-Quévillon	Longnose sucker	m	na	S^0, H^0, R^0
			Longnose sucker	f	na	S^0, H^0, R^0
			White sucker	m	na	S^0, H^{na}, R^0
			White sucker	f	na	na
			Longnose sucker	m	S^0, H^0, R^0	S^0, H^{na}, R^{na}
			Longnose sucker	f	S^0, H^0, R^-	S^0, H^{na}, R^0
			White sucker	m	S^+, H^+, R^-	S^0, H^-, R^{na}
			White sucker	f	na	S^0, H^0, R^0
PP1148	Domtar Inc.	Windsor	White sucker	m	S^0, H^0, R^0	S^-, H^0, R^-
			White sucker	f	S^0, H^0, R^0	S^0, H^0, R^0
			Smallmouth bass	m	na	S^+, H^-, R^-
			Smallmouth bass	f	na	S^+, H^0, R^-
PP1153	Papier Masson ltée	Masson-Angers	Yellow perch	m	S^+, H^+, R^-	S^0, H^0, R^0
			Yellow perch	f	S^+, H^0, R^+	S^+, H^0, R^0
			Johnny darter	m	na	S^0, H^0, R^0
			Johnny darter	f	na	S^0, H^0, R^-
			Yellow perch	m	S^+, H^+, R^-	na
			Yellow perch	f	S^+, H^0, R^+	S^0, H^{na}, R^0
			Johnny darter	m	na	S^+, H^0, R^0
			Johnny darter	f	na	S^+, H^0, R^+
PP1177	Abitibi-Consolidated Inc.	Alma	Brown bullhead	m	na	S^+, H^+, R^+
			Brown bullhead	f	na	S^+, H^+, R^+
			Longnose sucker	m	na	na
			Longnose sucker	f	na	na
PP1183 & PP1179	Papier Cascade Lupel Inc. et Désencrage CMD Inc.	Cap-de-la-Madeleine	Yellow perch	m	na	S^+, H^0, R^0
			Yellow perch	f	na	S^0, H^-, R^-
			Trout-perch	m	na	S^0, H^0, R^0
			Trout-perch	f	na	S^0, H^0, R^{na}
PP1181	Cascades Inc.	Breakeyville	Longnose dace	m	na	S^+, H^-, R^-
			Longnose dace	f	na	S^+, H^A, R^+
			Johnny darter	m	na	S^+, H^-, R^A
			Johnny darter	f	na	S^+, H^{na}, R^{na}

Legend: i: Immature, f: Female, m: Male
Response: + : higher value in exposure area, - : lower value in exposure area, 0: no significant differences, A: direction of significant differences diverges within group (ex. : S^A), na: not applicable (insufficient data or unequal slopes)

Annex 8 Synopsis of the ANCOVA analyses of morphometric relationships between the exposure and reference areas - Cycle 1 and Cycle 2.

National Project No.	Mill Name	Location	Sentinel Species	Sex	Response	
					Cycle 1	Cycle 2
PP1182	Mohawk Pulp Ltd	St-Antonin	White sucker	m	S^-, H^-, R^-	S^0, H^0, R^0
			White sucker	f	S^-, H^-, R^-	S^-, H^-, R^-
			Yellow perch	m	na	S^0, H^0, R^0
			Yellow perch	f	S^A, H^-, R^-	S^+, H^+, R^0
PP1184	Abitibi-Consolidated Inc.	Amos	Brown bullhead	m	S^0, H^0, R^0	S^+, H^+, R^+
			Brown bullhead	f	S^0, H^0, R^0	S^0, H^+, R^0
			Longnose sucker	m	na	S^+, H^+, R^0
			Longnose sucker	f	na	S^+, H^+, R^-
PP1187	J. Ford Ltd	Portneuf	White sucker	m	S^+, H^+, R^+	S^+, H^+, R^+
			White sucker	f	S^+, H^+, R^-	S^+, H^0, R^+
			Longnose sucker	mf	na	na
PP1188	Scott Paper Ltd	Lennoxville	White sucker	m	S^+, H^+, R^+	S^0, H^-, R^0
			White sucker	f	S^0, H^+, R^+	S^+, H^-, R^0
			White sucker	i	na	S^0, H^0, R^0
			Fallfish	m	na	S^0, H^0, R^0
			Fallfish	f	na	S^+, H^0, R^+
			Fallfish	i	na	S^+, H^+, R^{na}
			White sucker	m	S^+, H^+, R^+	S^0, H^-, R^{na}
			White sucker	f	S^0, H^+, R^+	S^0, H^+, R^0
			White sucker	i	na	S^0, H^{na}, R^{na}
			Fallfish	m	na	S^0, H^0, R^0
			Fallfish	f	na	S^0, H^0, R^-
			Fallfish	i	na	S^0, H^0, R^{na}
PP1191	Tembec, St-Raymond Mill	St-Léonard-de-Portneuf	Longnose sucker	m	na	S^+, H^+, R^0
			Longnose sucker	f	S^0, H^0, R^-	S^{na}, H^+, R^0
			White sucker	m	S^0, H^+, R^0	S^+, H^0, R^0
			White sucker	f	na	S^0, H^0, R^0
PP1194	Cascades Inc.	Lachute	Longnose dace	m	na	S^0, H^0, R^{na}
			Longnose dace	f	na	S^0, H^+, R^0
			Logperch	m	na	S^0, H^{na}, R^{na}
			Logperch	f	na	na
PP1196	Les Scott Paper Ltd	Crabtree	White sucker	m	S^+, H^+, R^+	na
			White sucker	f	S^+, H^+, R^A	na
			Silver redfish	m	S^+, H^+, R^+	na
			Silver redfish	f	S^+, H^+, R^+	na

Legend: i: Immature, f: Female, m: Male

Response: + : higher value in exposure area, - : lower value in exposure area, 0: no significant differences, A: direction of significant differences diverges within group (ex. : S^A), na: not applicable (insufficient data or unequal slopes)

Annex 8 Synopsis of the ANCOVA analyses of morphometric relationships between the exposure and reference areas - Cycle 1 and Cycle 2.

National Project No.	Mill Name	Location	Sentinel Species	Sex	Response	
					Cycle 1	Cycle 2
PP1198	Cascades Inc.	St-Jérôme	White sucker	m	S^{+}, H^{+}, R^{0}	S^{0}, H^{0}, R^{0}
			White sucker	f	S^{+}, H^{0}, R^{-}	S^{+}, H^{0}, R^{-}
			Yellow perch	m	na	na
			Yellow perch	f	na	na
PP1201	Spruce Falls Inc.	Matane	Shorthorn sculpin	f	S^{0}, H^{0}, R^{0}	S^{+}, H^{0}, R^{-}
PP1208	Cascades Inc.	Kingsey Falls	White sucker	m	S^{+}, H^{+}, R^{0}	na
			White sucker	f	S^{+}, H^{+}, R^{0}	na
			Silver redfish	m	S^{A}, H^{+}, R^{0}	na
			Silver redfish	f	S^{A}, H^{+}, R^{0}	na

Legend: i: Immature, f: Female, m: Male
Response: + : higher value in exposure area, - : lower value in exposure area, 0: no significant differences, A: direction of significant differences diverges within group (ex. : S^{A}), na: not applicable (insufficient data or unequal slopes)

Annex 9 Chlorinated dioxin and furan levels in the tissues of female walleye from sites at the Smurfit-Stone Container (Canada) Inc mill in Portage-du-Fort

Congener Name	Exposure Area (pg/g)	Reference Area - East (pg/g)	Reference Area - West (pg/g)
Furans:			
T4CDF	< 4.3	< 0.82	< 4.3
T5CDF	0,67	< 0.47	0,47
T6CDF	< 3.7	< 0.39	< 2.4
T7CDF	< 0.94	< 0.37	< 0.42
OCDF	< 0.30	0,5	< 0.25
Dioxins:			
T4CDD	< 0.23	< 0.18	< 0.19
T4CDD	< 0.18	< 0.23	< 0.19
T4CDD	< 0.25	< 0.23	< 0.19
T4CDD	0,46	0,74	0,33
OCDD	1,8	5,8	2,1
Toxic equivalent factor (TEF)	0,006	0,014	0,002
Maximum toxic equivalent factor	< 0.70	< 0.63	< 0.63

Legend: < below detection level.

Note: The analysis involved six composite samples from the exposure area and ten from each reference area.

Annex 10 Sampling results for freshwater benthic communities, mean density and richness values and summary of the differences observed between the reference and exposure areas

National Project No.	Mill Name (Location)	Sampling Period	Équipment (number of reference areas)	Reference area 1		Near-field exposure area		Far-field exposure area		Reference area 2 or other area		CA (1)
				Density (no./m^2) (standard deviation)	Richness (no. species) (standard deviation)	Density* (no./m^2) (standard deviation)	Richness* (no. species)(standard deviation)	Density* (no./m2) (standard deviation)	Richness (no. species) (standard deviation)	Density (no./m2) (standard deviation)	Richness (no. species) (standard deviation)	
Central Laurentians Ecoregion (101)												
PP1098	Smurfit-Stone Container Corporation (La Tuque)	9 to 10-09-99	Hester-Dendy (2)	2357.4 (500.7)	30 (7)	7774.2 (2764.7) +	40.4 (4.2)	2680.8 (985.4)	27 (1.4)	1833.4 (807.1)	14.2 (2.2)	Y
PP1104	Abitibi-Consolidated Inc. (Clermont)	31-08 to 1-09-99	Hess (1)	4375 (1407)	27 (2)	30833 (6080) +	27 (2)	22184 (8527) +	31 (3)			P
PP1106	SFK Pulp (Saint-Félicien)	Mistassini River: 12 to 16-10-98	Ponar (1)	4235 (3327)	15 (11)	1758 (943)	10 (2)	12050 (12042) +	18 (2)			P
		Ashuapmushuan River: 11 to 12-09-99	Ponar (1)	835 (632)	7 (3)	1492 (379)	9 (3)					P
PP1132	Abitibi-Consolidated Inc. (Jonquière)	3-08 to 3-09-99	Hester-Dendy (1)	7193.6 (1882.5)	26 (2)	11132 (5806.5) +	23 (2)	16101.8 (2726.1) +	25.8 (1.8)	FFEA= 9654,8 (719.3)	26.5 (3.1)	Y
PP1133	Bowater Inc. (Dolbeau)	4 to 9-10-98	Ponar (2)	827 (1297)	14 (10)	3258 (1547)	25 (9)	388 (191)	5 (3)	425 (191)	6 (5)	P
PP1145	Cascades Inc. (Jonquière)	1 to 3-10-99	Ponar (1)	12762 (5928)	18 (2)	2960 (2432)	6 (2) -	30940 (21004) +	21 (2)			P
PP1177	Abitibi-Consolidated Inc. (Alma)	15 to 20-09-99	Hess (2)	7553 (2720.9)	34.6 (3.2)	36358.8 (17827.5) +	28.4 (6.1)	3456.8 (5495.1)	12.8 (5.8)	1437.4 (1268.3)	18.4 (7.8)	Y
PP1197	Produits Desbiens Inc. (Desbiens)	7 to 9-10-99	Ponar (2)	2273 (1161)	21 (8)	2846 (897)	15 (4)	1327 (1002)	22 (9)	1022 (786)	19 (7)	NA

(1) = Results of the correspondence analyses: presence of statistically different groups between the exposure area and the reference area
Y: Yes, N: No, P: Partially, NA: Not applicable
* Lower (-) or higher (+) value in the exposure area relative to the reference area. The exposure area and the reference area must differ by at least two standard deviations from the mean of the reference area in order for a sign to be allocated.
FFEA: Far far-field exposure area

Annex 10 Sampling results for freshwater benthic communities, mean density and richness values and summary of the differences observed between the reference and exposure areas

National Project No.	Mill Name (Location)	Sampling Period	Équipment (number of reference areas)	Reference Area 1		Near-field exposure area		Far-field exposure area		Reference area 2 or other area		DIFF. REGR. (1)
				Density (no./m2) (standard deviation)	Richness (no. species) (standard deviation)	Density* (no./m2) (standard deviation)	Richness* (no. species) (standard deviation)	Density* (no./m^2) (standard deviation)	Richness (no. species) (standard deviation)	Density (no./m^2) (standard deviation)	Richness (no. species) (standard deviation)	
Southern Laurentians Ecoregion (99)												
PP1086	Fraser Papers (Thurso)	26 to 29 -10-98	Ponar (2)	4360 (3281)	16 (6)	17540 (3970) +	19 (4)	8420 (15801) +	11 (8)	3060 (445)	14 (2)	NA
PP1102	Smurfit-Stone Container Corporation (Portage-du-Fort)	11 to 15-10-99	Ponar and Standard Ponar (3)	1300.4 (245)	8.2 (1.9)	512.4 (289.75) -	6.8 (2.6)	490.4 (143.32) -	8.2 (2.9)	Ref. downstream 2=1237,2 (745.4) and Ref. upstream=1300, 4 (245)	Ref downstream 2 = 9,6 (2.9) and Ref upstream = 8,2 (1.9)	P
PP1118	Bowater Inc. (Gatineau)	6 to 8 -10-99	Ponar (2)	2210 (706)	8 (1)	1232 (627)	8 (4)	1192 (833)	10 (3)	1602 (1067)	11 (1)	Y
PP1135	Abitibi-Consolidated Inc. (Shawinigan)	20 to 23-09-99	Ponar (2)	24994 (18485.8)	17 (3.1)	268138.4 (73127.1) +	12.6 (2.4)	165053.8 (47034) +	19.4 (2.1)	25038.4 (12743)	26.6 (6.7)	Y
PP1153	Masson Ltd (Masson-Angers)	27 to 29-08-96	Ponar (2)	8491 (3647)	15 (2)	3887 (4248)	19 (5) +	12509 (10490)	16 (7)	Ref. 2 (Riv. Blanche and Ottawa R.)= 9984,67 (11571.51) and Exp. area Ile à Cruchet = 18677 (10159)	Ref. 2 (Riv. Blanche and Ottawa R.)= 23,67 (3.21) and Exp. area Ile à Cruchet = 16 (4)	NA
PP1186	Papiers de spécialité Eddy Ltée, Scott Paper Ltd (Hull-Ottawa)	26-08 to 20-10-99	Hester-Dendy (1)	504 (153)	11 (2)	378 (116)	8 (1)	505 (475)	9 (4)			NA
PP1194	Cascades Groupe tissus Inc. (Lachute)	24-08-99	Surber (1)	35827 (19383)	44 (5)	18008 (8113)	41 (6)	26888 (9513)	36 (5)			Y
PP1198	Cascades Inc. (St-Jérôme)	2 to 4-09-98	Ponar (1)	21085 (17213)	12 (7)	10009 (8426)	11 (4)	2744 (1470)	9 (2)			N

(1) = Results of the correspondence analyses: presence of statistically different groups between the exposure area and the reference area
Y: Yes, N: No, P: Partially, NA: Not applicable
* Lower (-) or higher (+) value in the exposure area relative to the reference area. The exposure area and the reference area must differ by at least two standard deviations from the mean of the reference area in order for a sign to be allocated.
FFEA: Far far-field exposure area

Annex 10 Sampling results for freshwater benthic communities, mean density and richness values and summary of the differences observed between the reference and exposure areas

National Project No.	Mill Name (Location)	Sampling Period	Équipment (number of reference areas)	Reference area 1		Near-field exposure area		Far-field exposure area		Reference area 2 or other area		DIFF. REGR. (1)
				Density (no./m^2) (standard deviation)	Richness (no. species) (standard deviation)	Density* (no./m^2) (standard deviation)	Richness* (no. species) (standard deviation)	Density* (no./m^2) (standard deviation)	Richness* (no. species) (standard deviation)	Density (no./m^2) (standard deviation)	Richness (no. species) (standard deviation)	
Appalachians Ecoregion (117)												
PP1114	Norampac Inc. (Cabano)	8 to 11-9-98	Ponar (1)	6913 (4333)	33 (12)	9832 (5757)	41 (8)	16683 (4153) +	40 (7)			Y
PP1117	Cascades East Angus Inc. (East Angus)	29 to 30-09-99	Hester-Dendy (1)	1578 (474)	26 (1)	2324 (643)	38 (7) +	1114 (80)	27 (5)			NA
PP1138	F.F. Soucy Inc. (Rivière-du-Loup)	9 to 14-10-99	Surber (3)	Réf: 1 = 441 (331) Réf1A= 176 (95)	1=45 (10) 1A=36 (5)	1004 (738) +	58 (8)	361 (60)	43 (5)	421 (113)	59 (4)	Y
PP1148	Domtar Inc. (Windsor)	15 to 16-09-99	Hester-Dendy (1)	15809.5 (12621.1)	38 (5.8)	7660.4 (1950.1)	35.4 (4)	27021.6 (36410)	41.4 (2.9)	FFEA= 18439.4 (20197.2)	43.2 (9.3)	Y
PP1181	Cascades Inc. (Breakeyville)	31-08 to 1-09-99	Surber (1)	5853.3 (3120.99)	57 (9)	7311 (6079.09)	48 (5)	5121.1 (3278.7)	44 (8)			NA
PP1182	Pâtes Mohawk Ltée (St-Antonin)	17-09-99	Hess (1)	3153 (1637)	37 (6)	24267 (9787) +	29 (4)	10497 (6216) +	38 (3)			Y
PP1188	Scott Paper Ltd (Lennoxville)	3 to 13-10-98	Ponar (2)	3872 (3009)	30 (8)	6583 (2043)	27 (5)	4211 (2728)	28 (5) -	12960 (6120)	32 (2)	Y
St Lawrence Lowlands Ecoregion (132)												
PP1091	Abitibi-Consolidated Inc. (Beaupré)	26 to 28-08-99	Ponar (2)	2546 (959)	12 (1)	1658 (856)	8 (2) -	787 (142)	8 (1)	1213 (808)	8 (1)	P
PP1092	Bowater Inc. (Donnacona)	24 to 26-09-99	Ponar (1)	14992 (7841)	24 (5)	6846 (1881)	27 (2)	3432 (484)	15 (2)			Y

(1) = Results of the correspondence analyses: presence of statistically different groups between the exposure area and the reference area
Y: Yes, N: No, P: Partially, NA: Not applicable
* Lower (-) or higher (+) value in the exposure area relative to the reference area. The exposure area and the reference area must differ by at least two standard deviations from the mean of the reference area in order for a sign to be allocated.
FFEA: Far far-field exposure area

Annex 10 Sampling results for freshwater benthic communities, mean density and richness values and summary of the differences observed between the reference and exposure areas

National Project No.	Mill Name (Location)	Sampling Period	Equipment (number of reference areas)	Reference area 1		Near-field exposure area		Far-field exposure area		Reference area 2 or other area		DIFF. REGR. (1)
				Density (no./m2) (standard deviation)	Richness (no. species) (standard deviation)	Density* (no./m2) (standard deviation)	Richness* (no. species) (standard deviation)	Density* (no./m2) (standard deviation)	Richness* (no. species) (standard deviation)	Density (no./m2) (standard deviation)	Richness (no. species) (standard deviation)	
St Lawrence Lowlands Ecoregion (132)												
PP1100	Uniforêt Tripap Inc. (Trois-Rivières)	8 to 9-09-99	Ponar (1)	31704 (42138)	29 (3)	3423 (1363)	32 (5)	5731 (1960)	31 (3)			NA
PP1131	Kruger Inc. (Bromptonville)	8-07 to 9-09-99	Hester-Dendy (2)	357 (170.6)	34.4 (14.1)	321.6 (64.7)	37 (4.5)	367.4 (190.9)	35.4 (10.1)	Far-field ref. = 457,3 (36) FFEA= 586,2 (60)	Far-field ref. = 36 (2) FFEA= 60 (5.4)	P
PP1137	Kruger Wayagamack Inc. (Trois-Rivières)	27-08 au28-08-99	Ponar									NA
PP1183 PP1179	Désencrage C.M.D. Inc., Cascades Lupel Inc. (Cap-de-la-Madeleine)	8-9-99	Ponar (1)	1676 (791)	14 (3)	15782 (8508) +	22 (5) +	861 (421)	9 (3)			Y
PP1187	J. Ford Ltd (Portneuf)	29-09 to 3-10-99	Hess (2)	1992.8 (1876.1)	33 (9)	210.4 (172)	27 (8)	5139.6 (1910.9)	42 (7)	10529.2 (7537.1)	43 (6)	P
PP1191	Tembec, St-Raymond Mill (St-Léonard-de-Portneuf)	5 to 9-09-99	Hess (1)	11489 (5099)	41 (2)	13477 (2838)	35 (5) -	14987 (6275)	40 (3)			Y
PP1193	Spexel Inc. (Beauharnois)	14-15-9-99	Ponar (1)	19643 (4790)	37 (3)	15992 (7123)	42 (2)	4031 (798) -	39 (4)			Y
PP1196	Scott Paper Ltd (Crabtree)	21 to 22-09-99	Hess (1)	468 (208)	22 (6)	1581 (660) +	29 (3)	812 (236)	30 (6)	1042 (639)	28 (5)	P
PP1208	Cascades Inc. (Kingsey Falls)	24-08 to 8-10-98	Hester-Dendy (1)	5948.9 (2735.48)	43 (3)	9230.7 (1850.28)	54 (2) +	5708 (2070.2)	54 (6) +			P

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Y: Yes, N: No, P: Partially, NA: Not applicable
* Lower (-) or higher (+) value in the exposure area relative to the reference area. The exposure area and the reference area must differ by at least two standard deviations from the mean of the reference area in order for a sign to be allocated.
FFEA: Far far-field exposure area

Annex 10 Sampling results for freshwater benthic communities, mean density and richness values and summary of the differences observed between the reference and exposure areas

National Project No.	Mill Name (Location)	Sampling Period	Équipment (number of reference areas)	Reference area 1		Near-field exposure area		Far-field exposure area		Reference area 2 or other area		DIFF. REGR. (1)
				Density ($no./m^2$) (standard deviation)	Richness (no. species) (standard deviation)	Density* ($no./m^2$) (standard deviation)	Richness* (no. species) (standard deviation)	Density* ($no./m^2$) (standard deviation)	Richness* (no. species) (standard deviation)	Density* ($no./m^2$) (standard deviation)	Richness* (no. species) (standard deviation)	
Abitibi Plains Ecoregion (96)												
PP1094	Tembec Inc. (Témiscaming)	1 to 2-11-99	Hester-Dendy (1)	186.8 (40.1)	6.6 (4.2)	3820.6 (712.4) +	21 (3.7) +	2637.8 (444.8) +	23.2 (4) +	FFEA: 2173,0 (650.9) +	24.2 (3.1) +	Y
PP1147	Norkraft Quévillon Inc. (Lebel-sur-Quévillon)	13 to 14-09-98	Ponar (2)	4558 (3067)	11 (3)	12546 (16175) +	17 (7) +	Bell= 9015 (3184)	7 (1)	Bell= 9385 (3533)	11 (4)	P
PP1184	Abitibi-Consolidated Inc. (Amos)	20 to 21-09-98	Ponar (1)	408 (34)	8 (2)	2181 (966) +	13 (3) +	24239 (11035) +	10 (2)			Y

(1) = Results of the correspondence analyses: presence of statistically different groups between the exposure area and the reference area
Y: Yes, N: No, P: Partially, NA: Not applicable
* Lower (-) or higher (+) value in the exposure area relative to the reference area. The exposure area and the reference area must differ by at least two standard deviations from the mean of the reference area in order for a sign to be allocated.
FFEA: Far far-field exposure area

Annex 11 Mean diversity and evenness values for freshwater benthic communities, % of oligochaetes in each area and summary of the differences observed between the reference and exposure areas

National Project No.	Mill Name (Location)	Reference area 1			Near-field exposure area			Far-field exposure area			Reference area 2 or other area		
		Diversity (standard deviation)	Evenness (standard deviation)	% oligo-chaetes	Diversity* (standard deviation)	Evenness* (standard deviation)	% oligo-chaetes	Diversity* (standard deviation)	Evenness* (standard deviation)	% oligochaetes	Diversity (standard deviation)	Evenness (standard deviation)	% oligochaetes
Central Laurentians Ecoregion (101)													
PP1098	Smurfit-Stone Container Corporation (La Tuque)	3.13 (0.53)	0.64 (0.07)	8	3.86 (0.16)	0.72 (0.04)	36,3	3.33 (0.48)	0.7 (0.1)	76,6	1.95 (0.48)	0.51 (0.1)	72,7
PP1104	Abitibi-Consolidated Inc. (Clermont)	3.11 (0.18)	0.65 (0.03)	2,4	3.1 (0.15)	0.65 (0.03)	3,5	3.67 (0.32) +	0.74 (0.05) +	1,6			
PP1106	SFK Pulp (Saint-Félicien) (Mistassini River)	2,65 (0.83)	0,68 (0.11)	31	2,868 (0.26)	0,87 (0.05)	1,3	Mista= 2,736 (0.79)	0,67 (0.2)	56,9			
	(Ashuapmushuan River)	2,012 (0.63)	0,76 (0.08)	7,7	2,3 (0.71)	0,73 (0.18)	6,8						
PP1132	Abitibi-Consolidated Inc. (Jonquière)	2.45 (0.49)	0.52 (0.1)	74,5	1.84 (0.51)	0.41 (0.12)	86,9	1.6 (0.19)	0.34 (0.04)	91,6	2.43 (0.22)	0.51 (0.04)	78,4
PP1133	Bowater Inc. (Dolbeau)	3.008 (0.48)	0.86 (0.08)	10,2	3.828 (0.42)	0.84 (0.04)	9,9	1.675 (0.82)	0.7 (0.05)	2,5	1.802 (0.99)	0.78 (0.16)	Far-field ref. area= 16,3
PP1145	Cascades Inc. (Jonquière)	2.62 (0.43)	0.63 (0.08)	82	1.55 (0.41) -	0.67 (0.13)	92,5	2.72 (0.55)	0.62 (0.11)	86,4			
PP1177	Abitibi-Consolidated Inc. (Alma)	2.46 (0.45)	0.76 (0.05)	1,7	3.87 (0.25) +	0.51 (0.07) -	52,8	2.17 (0.59)	0.61 (0.08)	78,6	2.8 (0.54)	0.7 (0.16)	50,2
PP1197	Produits Desbiens Inc. (Desbiens)			4			14						

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Annex 11 Mean diversity and evenness values for freshwater benthic communities, % of oligochaetes in each area and summary of the differences observed between the reference and exposure areas

National Project No.	Mill Name (Location)	Reference area 1			Near-field exposure area			Far-field exposure area			Reference area 2 or other area		
		Diversity (standard deviation)	Evenness (standard deviation)	% oligo-chaetes	Diversity* (standard deviation)	Evenness* (standard deviation)	% oligochaetes	Diversity (standard deviation)	Evenness (standard deviation)	% oligo-chaetes	Diversity (standard deviation)	Evenness (standard deviation)	% oligochaetes
Southern Laurentians Ecoregion (99)													
PP1086	Fraser Papers (Thurso)	2.96 (0.44)		25	2.94 (0.11)		14	2.56 (0.54)		25	3.05 (0.34)		
PP1102	Smurfit-Stone Container Corporation (Portage-du-Fort)	1.37 (0.26)	0.66 (0.06)	22,9	1.3 (0.29)	0.7 (0.08)	1,6	1.42 (0.43)	0.69 (0.1)	5,3	Ref. downstream 2=1,33 (0.34) and ref upstream=1,37 (0.26)	Réf aval 2=0,60 (0.11) et réf amont=0,66 (0.06)	Réf aval 2= 7,7 et réf amont= 22,9
PP1118	Bowater Inc. (Gatineau)	1.34 (0.18)	0.45 (0.07)	3,2	2.1 (0.93) +	0.68 (0.16) +	8,5	2.15 (0.69)	0.63 (0.14)	1,1	2.36 (0.22)	0.68 (0.06)	25,7
PP1135	Abitibi-Consolidated Inc. (Shawinigan)	2.252 (0.29)	0.54 (0.06)	60,7	2.192 (0.6)	0.6 (0.14)	98	2.3 (0.17)	0.53 (0.01)		2.67 (0.64)	0.57 (0.14)	
PP1153	Masson Ltd (Masson-Angers)	2.52 (0.18)		42	2.62 (0.49)		17	2.57 (0.33)		12	Ref. 2 (Riv. Blanche and Ottawa R.=3,07 (0.26) and Exp. area. Ile à Cruchet = 2,32 (0.24)		Ref. 2 (Riv. Blanche and Ottawa R.= 39 and Exp. area Ile à Cruchet = 33
PP1186	Papiers de spécialité Eddy Ltée, Scott Paper Ltd (Hull-Ottawa)	2.25 (0.5)	6.25 (0.87)	0	2.04 (0.34)	4.8 (0.84)	0	2.17 (0.35)	4.7 (1.44)	0,9			
PP1194	Cascades Groupe tissus Inc. (Lachute)	3.52 (0.42)	0.64 (0.07)	1,4	3.97 (0.1)	0.74 (0.03)	19,6	3.37 (0.4)	0.65 (0.06)	6,2			
PP1198	Cascades Inc. (St-Jérôme)	1.67 (0.22)	0.47 (0.07)	88,6	1.95 (0.42)	0.57 (0.1)	75,4	2.02 (0.49)	0.6 (0.11)	48,1			

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National Project No.	Mill Name (Location)	Reference area 1			Near-field exposure area			Far-field exposure area			Reference area 2 or other area		
		Diversity (standard deviation)	Evenness (standard deviation)	% oligo-chaetes	Diversity* (standard deviation)	Evenness* (standard deviation)	% oligo-chaetes	Diversity* (standard deviation)	Evenness* (standard deviation)	% oligo-chaetes	Diversity (standard deviation)	Evenness (standard deviation)	% oligochaetes
Appalachians Ecoregion (117)													
PP1114	Norampac Inc. (Cabano)	3.26 (0.61)	0.77 (0.1)	15	3.63 (0.32)	0.74 (0.04)	13,2	3.67 (0.34)	0.74 (0.07)	29,2			
PP1117	Cascades East Angus Inc. (East Angus)	4.3 (0.4)	0.79 (0.02)	1,4	4.1 (0.3)	0.73 (0.02) -	1,7	3.7 (0.6)	0.78 (0.07)				
PP1138	F.F. Soucy Inc. (Rivière-du-Loup)			1=9,93 1A=6,86			13,24			10,11			1,34
PP1148	Domtar Inc. (Windsor)	3.54 (0.35)	0.68 (0.05)	70	2.64 (0.41) -	0.51 (0.09) -	84,5	3.12 (0.36)	0.58 (0.06) -	52,5	3.91 (0.18)	0.73 (0.03)	69,7
PP1181	Cascades Inc. (Breakeyville)	4.32 (0.29)	0.76 (0.07)	37	4.08 (0.31)	0.75 (0.05)	3,5	3.5 (0.52) -	0.65 (0.07)	2,4			
PP1182	Pâtes Mohawk Ltée (St-Antonin)	4.23 (0.23)	0.82 (0.05)	2,9	3.61 (0.34) -	0.72 (0.04) -	62	3.99 (0.39)	0.76 (0.06)	25,2			
PP1188	Scott Paper Ltd (Lennoxville)	2.52 (0.16)	0.77 (0.05)	2,6	2.32 (0.31)	0.72 (0.09)	15	2.64 (0.29)	0.81 (0.06) +	20,1	2.41 (0.14)	0.71 (0.03)	Ref. area St-François= 22,3
St Lawrence Lowlands Ecoregion (132)													
PP1091	Abitibi-Consolidated Inc. (Beaupré)	2.72 (0.36)	0.75 (0.1)	20,3	2.04 (0.61)	0.69 (0.19)	41,6	1.23 (0.12)	0.41 (0.03)	87	1.31 (0.18)	0.43 (0.07)	93,1
PP1092	Bowater Inc. (Donnacona)	2.01 (0.32)	0.44 (0.07)	84,8	3.12 (0.24) +	0.66 (0.04) +	35,2	2.14 (0.29)	0.55 (0.06)				

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Annex 11 Mean diversity and evenness values for freshwater benthic communities, % of oligochaetes in each area and summary of the differences observed between the reference and exposure areas

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St Lawrence Lowlands Ecoregion (132)													
PP1100	Uniforêt Tripap Inc. (Trois-Rivières)	2.83 (0.56)	0.58 (0.11)	83,3	3.69 (0.31)	0.74 (0.04)	63,3	3.62 (0.25)	0.73 (0.04)	48,8			
PP1131	Kruger Inc. (Bromptonville)	2.64 (0.55)	0.77 (0.04)	3,4	2.9 (0.12)	0.8 (0.04)	1,2	2.72 (0.27)	0.77 (0.04)	6,1	Far-field ref.= 2,81 (0.16) FFEA= 3,02 (0.17)	Far-field ref. = 0,78 (0.03) FFEA= 0,74 (0.05)	Far-field ref.= 1,1 FFEA= 1,9
PP1137	Kruger Wayagamack Inc. (Trois-Rivières)												
PP1183 PP1179	Désencrage C.M.D. Inc., Cascades Lupel Inc. (Cap-de-la-Madeleine)	2.44 (0.58)	0.61 (0.12)	15,8	2.8 (0.64)	0.61 (0.12)	41,6	2.46 (0.53)	0.73 (0.08)	34,6			
PP1187	J. Ford Ltd (Portneuf)	2.69 (0.21)	0.77 (0.03)	7,6	2.75 (0.26)	0.84 (0.06) +	9,9	2.42 (0.4)	0.65 (0.09)	2,5	2.63 (0.32)	0.7 (0.06)	0,8
PP1191	Tembec, St-Raymond Mill (St-Léonard-de-Portneuf)	4.23 (0.16)	0.79 (0.02)	5	3.93 (0.24)	0.77 (0.03)	7,4	4.16 (0.32)	0.78 (0.06)	3,6			
PP1193	Spexel Inc. (Beauharnois)	3.95 (0.13)	0.76 (0.02)	31,1	4.26 (0.29) +	0.79 (0.05)	27,3	4.15 (0.13)	0.79 (0.02)	12,5			
PP1196	Scott Paper Ltd (Crabtree)	1.97 (0.57)	0.64 (0.17)		2.18 (0.35)	0.65 (0.09)		2.59 (0.19)	0.76 (0.04)		2.2 (0.23)	0.67 (0.06)	
PP1208	Cascades Inc. (Kingsey Falls)	3.48 (0.13)	0.64 (0.03)	2,5	4.2 (0.14) +	0.74 (0.02) +	3,5	4.28 (0.2) +	0.75 (0.02) +	2			

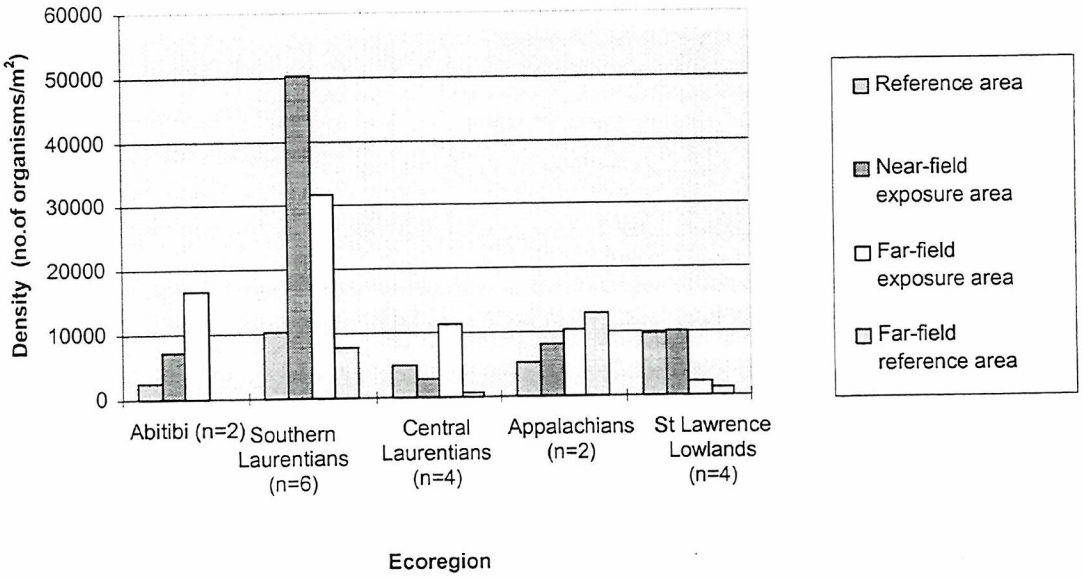
* Lower (-) or higher (+) value in the exposure area relative to the reference area. The exposure area and the reference area must differ by at least two standard deviations from the mean of the reference area in order for a sign to be allocated.

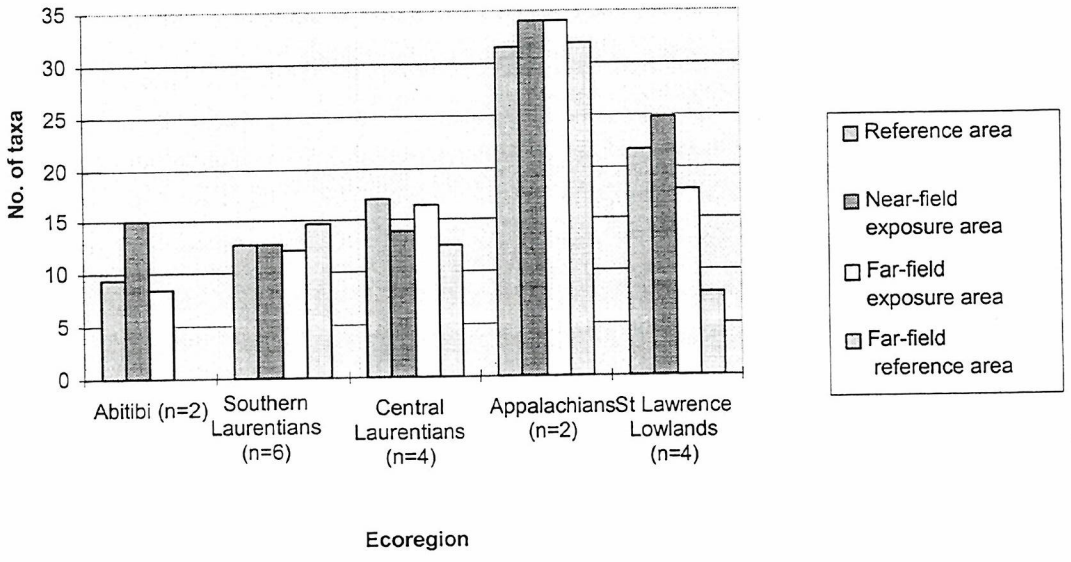
Annex 11 Mean diversity and evenness values for freshwater benthic communities, % of oligochaetes in each area and summary of the differences observed between the reference and exposure areas

National Project No.	Mill Name (Location)	Reference area 1			Near-field exposure area			Far-field exposure area			Reference area 2 or other area		
		Diversity (standard deviation)	Evenness (standard deviation)	% oligo-chaetes	Diversity* (standard deviation)	Evenness* (standard deviation)	% oligo-chaetes	Diversity (standard deviation)	Evenness* (standard deviation)	% oligo-chaetes	Diversity* (standard deviation)	Evenness* (standard deviation)	% oligo-chaetes
Abitibi Plains Ecoregion (96)													
PP1094	Tembec Inc. (Témiscaming)	1.88 (0.66)	0.76 (0.04)	7,8	2.19 (0.41)	0.5 (0.1) -	58,3	2.83 (0.32)	0.63 (0.07) -	70,3	2.52 (2.13)	0.55 (0.07) -	73
PP1147	Norkraft Quévillon Inc. (Lebel-sur-Quévillon)	0.754 (0.46)	0.52 (0.12)	Quév. Riv.= 8,3	2.936 (0.54) +	0.76 (0.17) +	Quév. Riv.= 20,1 Bell Riv. = 90,4	0.784 (0.26)	0.28 (0.1) -		1.506 (0.36) -	0.46 (0.12)	Bell Riv. = 85
PP1184	Abitibi-Consolidated Inc. (Amos)	2.056 (0.5)	0.68 (0.11)	9,9	2.166 (0.6)	0.58 (0.13)	25,3	2.318 (0.09)	0.7 (0.05)	86			

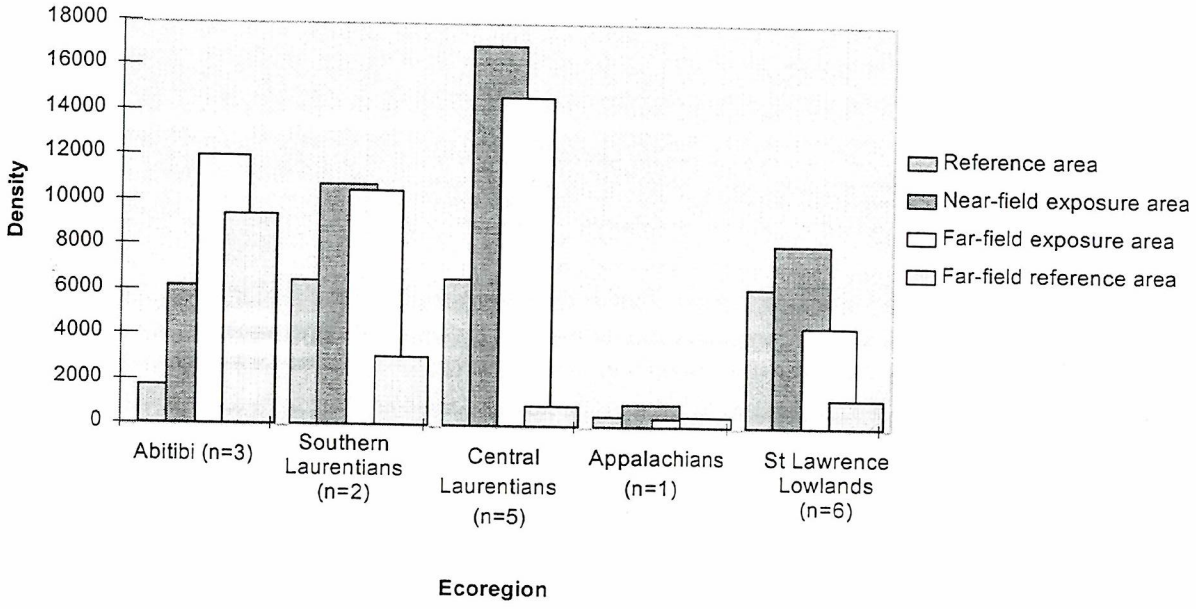
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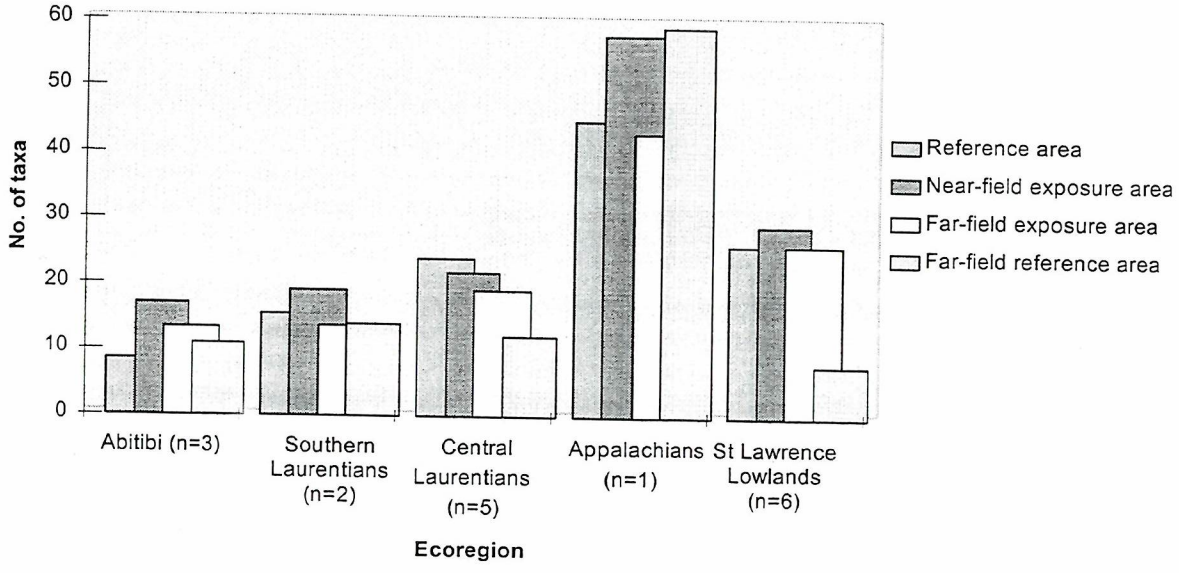
Annex 12 Variation in density and mean taxonomic richness of benthos in freshwater samples obtained by grab sampler in the different study areas, in relation to Quebec ecoregions





Annex 13 Variation in density and mean taxonomic richness of benthos in freshwater study areas at mills employing activated sludge treatment, in relation to ecoregions





Annex 14 Sampling results for benthic communities in the marine environment and mean values of the variables measured by groups of stations

Mill Name (Location)	Sampling Period	Sampling Gear	Number of stations in the 1% mixing zone	Total number of stations	Gradient length (m)	Groups formed through CA	Mean distance to outfall (m)	Number of stations per group	Mean density (standard deviation) (no./m^2)	Mean number of taxa (standard deviation)	Mean diversity (standard deviation) (H')	Mean evenness (standard deviation) (J')	Mean biomass (standard deviation) (g/m^2)
Smurfit-Stone Container Corporation Division Chaleurs (New-Richmond)	September 16 to 22 1999	Standard Ponar grab sampler	8*	12**	2148	Ref	4226	5	33797.6 (13897.6)	35.4 (9.3)	2.13 (0.7)	0.6 (0.16)	—
						A	1644	6	32608 (9694.5)	38.3 (7.7)	2.05 (0.16)	0.57 (0.02)	—
						B	795	3	19165.3 (9949.7)	28 (7.2)	2.17 (0.14)	0.66 (0.07)	—
						C, D et E	228	3	7413.3 (6201.3)	16 (5.6)	1.9 (0.4)	0.7 (0.07)	—
Abitibi-Consolidated Inc. Division Port Alfred (La Baie)	October 8 and 11, 1999	Standard Ponar grab sampler	12	20	1500	A	948	6	884.5 (603.9)	11.2 (1.9)	0.82 (0.1)	0.8 (0.1)	18.6 (18.1)
						B	649.9	11	3479 (4438.1)	11.2 (3.9)	0.69 (0.1)	0.68 (0.1)	45.3 (44.1)
						C	196	1	260 (nd)	5 (nd)	0.6 (nd)	0.86 (nd)	3 (nd)
						D	1065	2	327 (108.9)	8 (0)	0.74 (0.1)	0.82 (0.1)	2.5 (2.3)
Compagnie Abitibi-Consolidated du Canada (Baie-Comeau)	September 1, 1999	Standard Ponar grab sampler	11	15	825	1	265.7	7	3910.7 (1288.5)	23.1 (3.4)	0.85 (0.1)	0.69 (0.05)	5514.3 (1886.3)
						2	477.8	6	11514.4 (4008.5)	24.7 (5.4)	0.74 (0.15)	0.58 (0.09)	14108.3 (7279.0)
						3	757	2	4879.8 (428.9)	21.0 (0)	0.83 (0.01)	0.69 (0.01)	7550.0 (70.7)

* 2 gradients X 4 stations in the 1% zone = 8 stations

** 2 gradients X 6 stations = 12 stations

Annex 14 Sampling results for benthic communities in the marine environment and mean values of the variables measured by groups of stations

Mill Name (Location)	Sampling Period	Sampling Gear	Number of stations in the 1% mixing zone	Total number of stations	Gradient length (m)	Groups formed through CA	Mean distance to outfall (m)	Number of stations per group	Mean density (standard deviation) (no./m^2)	Mean number of taxa (standard deviation)	Mean diversity (standard deviation) (H')	Mean evenness (standard deviation) (J')	Mean biomass (standard deviation) (g/m^2)
Spruce Falls Inc. (Matane)	September 28 and 29, 2001	Standard Ponar grab sampler	transect 1:5 transect 2:5	17*	transect 1:1240 transect 2:1820	A	410	3	10820.3 (7768.8)	15.3 (1.5)	2.00 (0.17)	0.51 (0.06)	1135.3 (1622.9)
						B	520	1	4635 (nd)	11 (nd)	2.31 (nd)	0.67 (nd)	209 (nd)
						C	1135	2	24581.5 (9634.3)	30 (4.2)	2.08 (0.01)	0.42 (0.01)	819.5 (367.0)
						D	840	1	3298 (nd)	17 (nd)	2.3 (nd)	0.56 (nd)	483 (nd)
						AA	160	1	19135 (nd)	16 (nd)	1.44 (nd)	0.36 (nd)	86 (nd)
						BB	730	1	2452 (nd)	10 (nd)	1.96 (nd)	0.59 (nd)	27 (nd)
						CC	1283	4	7591.3 (2842.6)	9.8 (1.7)	1.37 (0.14)	0.42 (0.07)	21.5 (4.1)
						DD	560	1	2587 (nd)	12 (nd)	1.59 (nd)	0.44 (nd)	10 (nd)
						EE	1163	3	6500 (2095.8)	9.7 (2.5)	1.68 (0.10)	0.53 (0.08)	36 (nd)
Uniforêt Sawmill Pulp Inc. (Port-Cartier)	September 13, 14 and 29, 2000 October 1 and 2, 2000	Van Veen grab sampler	4	20	554	A	77	4	2095.0 (613.7)	29.8 (3.5)	1.01 (0.14)	0.68 (0.09)	16.6 (15.6)
						B	126	6	1745.5 (1054.1)	28.5 (5.7)	1.12 (0.16)	0.78 (0.12)	21.5 (18.4)
						C	99	7	3292.4 (2210.8)	35.0 (5.2)	1.09 (0.17)	0.74 (0.03)	25.3 (22.4)
						D	119	1	2914 (nd)	29 (nd)	0.86 (nd)	0.59 (nd)	49.37 (nd)
						E	30	1	1752 (nd)	26 (nd)	0.76 (nd)	0.54 (nd)	7.72 (nd)
						F	320	1	819 (nd)	18 (nd)	0.82 (nd)	0.65 (nd)	4.59 (nd)

* transect 1 = 10 stations, transect 2 = 7 stations